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Clipcode Source Tour For Angular 5.2

(with new draft appendix: Render3 in Angular 6)

A detailed guided tour to the source trees of Angular and related projects

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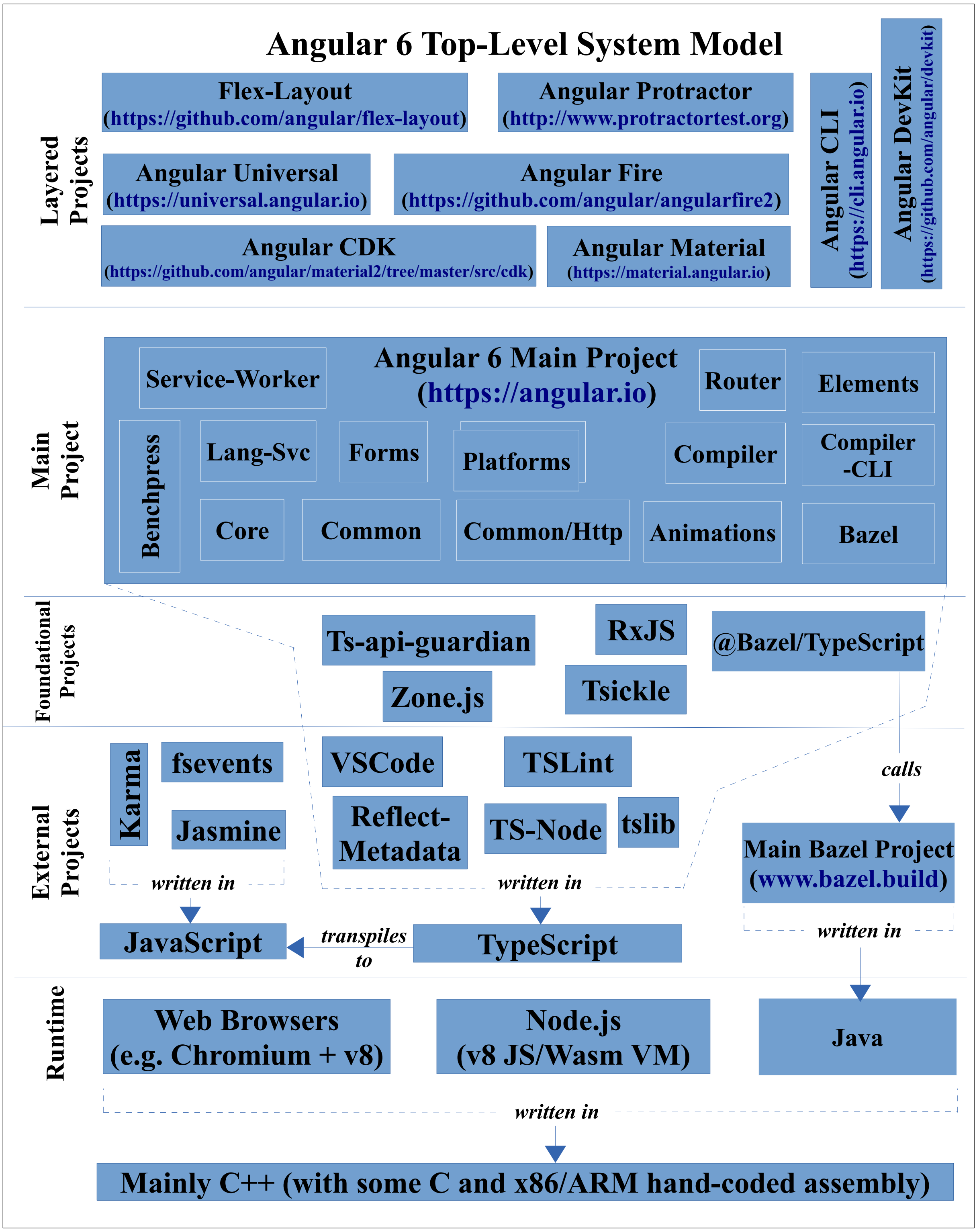
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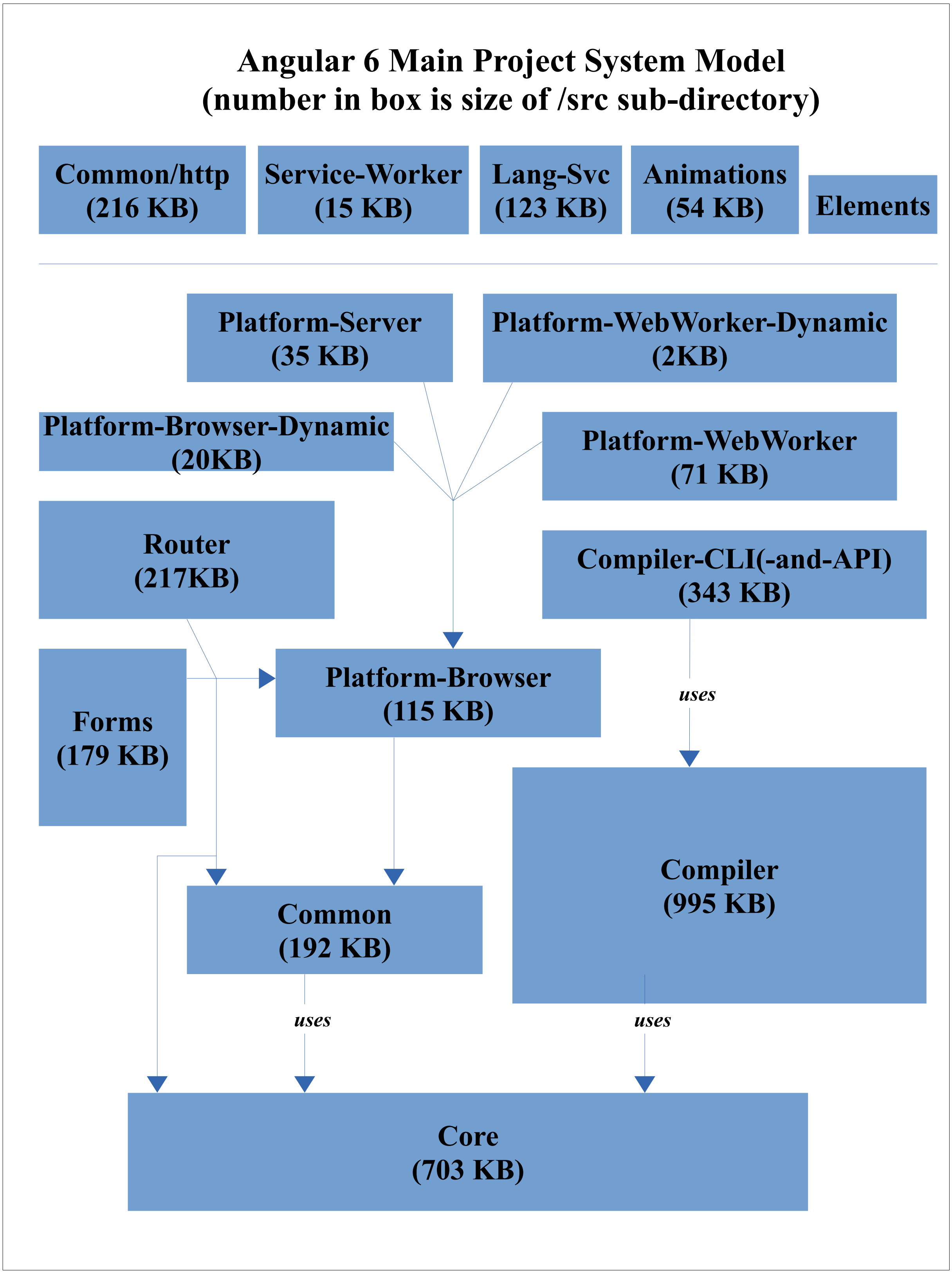
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An Ecosystem for Modern Web Applications

The Angular ecosystem consists of multiple projects that work together to provide a comprehensive foundation for developing modern web applications.

With a few exceptions, all of these projects are written with TypeScript (even the TypeScript compiler is itself written in TypeScript). The exceptions are the Bazel main project (which uses Java), fsevents for native access to macOS FSEvents along with the Jasmine unit test framework and Karma test runner (all these use JavaScript). The dependency on other projects varies.

Note that the Java-based Bazel main project is used to build Angular itself. Bazel and Java are not needed to build regular Angular applications. Bazel is great for incremental and multi-core builds so it has advantages when used with large codebases (such as Angular itself). In future Bazel is likely to become a sensible build option for larger Angular applications.

None of these projects are dependent on Visual Studio Code. These projects only need a code editor that can work with the TypeScript tsc compiler – and there are many - see middle of main page at:

- http://typescriptlang.org

Visual Studio Code is one such editor, that is particularly good, open source, freely available for macOS, Linux and Windows, and it too is written in TypeScript.

- https://code.visualstudio.com

Of choose you can use any editor to investigate the source trees of these projects.

Viewing Markdown Files

In addition to source in TypeScript, all these projects also contain documentation files in markdown format (*.md). Markdown is a domain specific language (DSL) for represent HTML documents. It is easier / quicker to manually author compared to HTML. When transformed to HTML it provides professional documentation. One question you might have is how to view them (as HTML, rather that as .md text). One easy way to see them as html is just to view the .md files on Github, e.g.:

- https://github.com/angular/angular

Alternatively, on your own machine, most text editors have either direct markdown support or it is available through extensions. When examining a source tree with .md files, it is often useful when your code editor can also open markdown files and transform them to HTML when requested. StackOverflow covers this issue here:

- http://stackoverflow.com/questions/9843609/view-markdown-files-offline

For example, Visual Studio Code supports Markdown natively and if you open a .md file and select CTRL+SHIFT+V, you get to see nice HTML:

- https://code.visualstudio.com/docs/languages/markdown

Finally, if you want to learn markdown, try here:

- http://www.markdowntutorial.com

Target Audience

This guided tour of the Angular source tree is aimed at intermediate to advanced application developers who wish to develop a deeper understanding of how Angular actually works. To really appreciate the functioning of Angular, an application developer should read the source. Yes, Angular come with developer documentation at https://angular.io/docs (which is mostly quite good) but it is best studied in conjunction with the source code.

Benefits of Understanding The Source

There are many good reasons for intermediate- to advanced-developers to become familiar with the source trees of the projects that provide the foundation for their daily application development.

Enhanced Understanding - As in common with many software packages, descriptions of software concepts and API documentation may or may not be present, and if present may not be as comprehensive as required, and what is present may or may not accurately reflect what the code currently does - the doc for a particular concept may well once have been up-to-date, but code changes, the doc not necessarily so, and certainly not in lock-step, and this applies to any fast evolving framework.

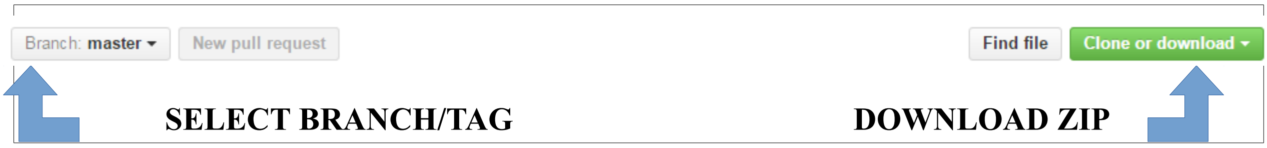
Advanced Debugging – When things go wrong, as they must assuredly will (and usually just become an important presentation to potential customers), application developers scrambling to fix problems will be much quicker when they have better insight via knowing the source.

Optimization – for large-scale production applications with high data throughput, knowing how your application's substrate actually works can be really useful in deciding how / what to optimize (for example, when application developers really understand how Angular's `NgZone` works and is intertwined with Angular's change detection, then they can place CPU-intensive but non-UI code in a different zone within the same thread, and this can result in much better performance).

Productivity - Familiarity with the source is important for maximum productivity with any framework and is one part of a developer accumulating a broader understanding of the substrate upon which their applications execute.

Good practices – Studying large codebases that are well tested and subjected to detailed code reviews is a great way for "regular" developers to pick up good coding habits and use in their own application source trees.

Accessing the Source



To study the source, you can browse it online, get a copy of the repo via git (usual) or download a zip. Some packages may provide extra detail about getting the source –

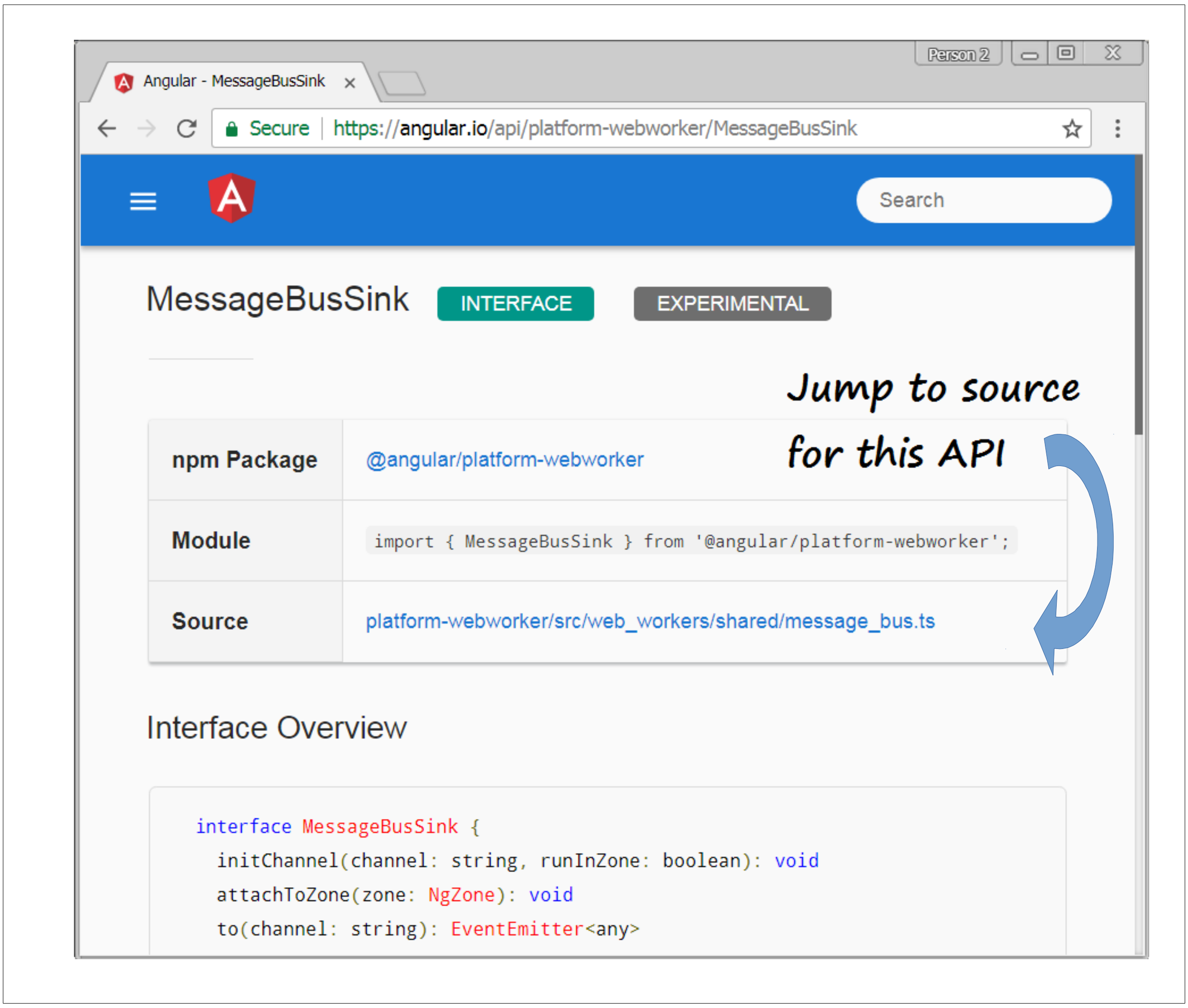
for example, for the Angular project, read “Getting the Sources” here:

- https://github.com/angular/angular/blob/master/docs/DEVELOPER.md

We first need to decide which branch to use. For master, we use this:

- https://github.com/angular/angular/tree/master

Specifically for the Angular main project, an additional way to access the source is in the Angular API Reference (https://angular.io/api), the API page for each Angular type has a hyperlink at the top of the page to the relevant source file (this resolves to the latest stable version, which may or may not be the same source as master).



MessageBusSink

Jump to source for this API

npm Package	@angular/platform-webworker
Module	`import { MessageBusSink } from '@angular/platform-webworker';`
Source	platform-webworker/src/web_workers/shared/message_bus.ts

Interface Overview

```
interface MessageBusSink {
  initChannel(channel: string, runInZone: boolean): void
  attachToZone(zone: NgZone): void
  to(channel: string): EventEmitter<any>
```

Keeping up to date

Angular is a fast evolving project. To keep up to date, read the development team’s weekly meeting notes, which are available here:

- http://g.co/ng/weekly-notes

The Changelog in Github lists features of new releases:

- https://github.com/angular/angular/blob/master/CHANGELOG.md

1: Zone.js

Overview

The Zone.js project provides multiple asynchronous execution contexts running within a single JavaScript thread (i.e. within the main browser UI thread or within a single web worker). Zones are a way of sub-dividing a single thread using the JavaScript event loop. A single zone does not cross thread boundaries. A nice way to think about zones is that they sub-divide the stack within a JavaScript thread into multiple mini-stacks, and sub-divide the JavaScript event loop into multiple mini event loops that seemingly run concurrently (but really share the same VM event loop).

When your app loads Zone.js, it monkey-patches certain asynchronous calls (e.g. `setTimer`, `addEventListener`) to implement zone functionality. Zone.js adds wrappers to the callbacks the application supplies, and when a timeout occurs or an event is detected, it runs the wrapper first and then the application callback. Chunks of executing application code form tasks and each task executes in the context of a zone.

Zones are arranged in a hierarchy and provide useful features in areas such as error handling, performance measuring and executing configured work items upon entering and leaving a zone (all of which might be of great interest to implementors of change detection in a modern web UI framework, like Angular).

Zone.js is mostly transparent to application code. Zone.js runs in the background and for the most part "just works". Application code can make zone calls if needed and become more actively involved in zone management. Angular uses Zone.js and Angular application code usually runs inside a zone (although advanced application developers can take certain steps to move some code outside of the Angular zone – using the `NgZone` class).

Project Information

The homepage and root of the source tree for Zone.js is at:

- https://github.com/angular/zone.js

Below we assume you have got the Zone.js source tree downloaded locally under a directory we will call <ZONE-MASTER> and any pathnames we use will be relative to that.

Zone.js is written in TypeScript. It has no package dependencies (its package.json has this entry: `"dependencies": {}`), though it has many `devDependencies`. It is quite a small source tree, whose size (uncompressed) is about 2 MB.

Loading Zone.js

To use Zone.js in your applications, you need to load it. Your package.json file will need (if creating a project using Angular CLI, this is added automatically for you):

```
"dependencies": {
    ..
    "zone.js": "<version>"
  },
```

You should load Zone.js after loading core.js (if using that). For example, if using an Angular application generated via Angular CLI (as most production apps will be), Angular CLI will generate a file called <project-name>/src/polyfills.ts and it will contain:

```
/***************************************************************************
 * Zone JS is required by Angular itself.
 */
import 'zone.js/dist/zone';  // Included with Angular CLI.
```

Angular CLI also generates an angular-cli.json configuration file, with this line that sets up polyfills:

```
 "apps": [
    {
      ..
      "index": "index.html",
      "main": "main.ts",
      "polyfills": "polyfills.ts",
      ..
```

If writing your application in TypeScript (recommended), you also need to get access to the ambient declarations. These define the Zone.js API and are supplied in:

- <ZONE-MASTER>/dist/zone.js.d.ts

(IMPORTANT: This file is particularly well documented and well worth some careful study by those learning Zone.js). Unlike declarations for most other libraries, zone.js.d.ts does not use `import` or `export` at all (those constructs do not appear even once in that file). That means application code wishing to use zones cannot simply import its .d.ts file, as is normally the case. Instead, the `///reference` construct needs to be used. This includes the referenced file at the site of the `///reference` in the containing file. The benefit of this approach is that the containing file itself does not have to (but may) use `import`, and thus may be a script, rather than having to be a module. The use of zones is not forcing the application to use modules (however, most larger applications, including all Angular applications - will). How this works is best examined with an example, so lets look at how Angular includes zone.d.ts. Angular contains a file, types.d.ts under its packages directory (and a similar one under its modules directory and tools directory):

- <ANGULAR-MASTER>/packages/types.d.ts

and it has the following contents:

```
/// <reference path="../node_modules/zone.js/dist/zone.js.d.ts" />
/// <reference path="../node_modules/@types/hammerjs/index.d.ts" />
/// <reference path="../node_modules/@types/jasmine/index.d.ts" />
/// <reference path="../node_modules/@types/node/index.d.ts" />
/// <reference path="../node_modules/@types/selenium-webdriver/index.d.ts" />
/// <reference path="./es6-subset.d.ts" />
/// <reference path="./system.d.ts" />
/// <reference path="./goog.d.ts" />
```

When building each Angular component, the tsconfig-build.json file, located in:

- <ANGULAR-MASTER>/packages

contains:

```
"files": [
    "public_api.ts",
    "../../node_modules/zone.js/dist/zone.js.d.ts"
  ],
```

Use Within Angular

When writing Angular applications, all your application code runs within a zone, unless you take specific steps to ensure some of it does not. Also, most of the Angular framework code itself runs in a zone. When beginning Angular application development, you can get by simply ignoring zones, since they are set up correctly by default for you and applications do not have to do anything in particular to take advantage of them. The end of the file <ZONE-MASTER>/blob/master/MODULE.md explains where Angular uses zones:

"Angular uses zone.js to manage async operations and decide when to perform change detection. Thus, in Angular, the following APIs should be patched, otherwise Angular may not work as expected.

- *ZoneAwarePromise*
- *timer*
- *on_property*
- *EventTarget*
- *XHR"*

Zones are how Angular initiates change detection – when the zone's mini-stack is empty, change detection occurs. Also, zones are how Angular configures global exception handlers. When an error occurs in a task, its zone's configured error handler is called. A default implementation is provided and applications can supply a custom implementation via dependency injection. For details, see here:

- https://angular.io/api/core/ErrorHandler

On that page note the code sample about setting up your own error handler:

```
class MyErrorHandler implements ErrorHandler {
  handleError(error) {
    // do something with the exception
  }
}
@NgModule({
  providers: [{provide: ErrorHandler, useClass: MyErrorHandler}]
})
class MyModule {}
```

Angular provide a class, `NgZone`, which builds on zones:

- https://angular.io/api/core/NgZone

As you begin to create more advanced Angular applications, specifically those involving computationally intensive code that does not change the UI midway through the computation (but may at the end), you will see it is desirable to place such CPU-intensive work in a separate zone, and you would use a custom NgZone for that.

We will be looking in detail at NgZone and the use of zones within Angular in general when we explore the source tree for the main Angular project later, but for now, note the source for NgZone is in:

- <ANGULAR-MASTER>/packages/core/src/zone

and the zone setup during bootstrap for an application is in:

- <ANGULAR-MASTER>/packages/core/src/application_ref.ts

When we bootstrap our Angular applications, we either use bootstrapModule<M> (using the dynamic compiler) or bootstrapModuleFactory<M> (using the offline compiler). Both these functions are in application_ref.ts. bootstrapModule<M> calls the Angular compiler and then calls bootstrapModuleFactory<M>. It is in bootstrapModuleFactory we see how zones are initialized for Angular:

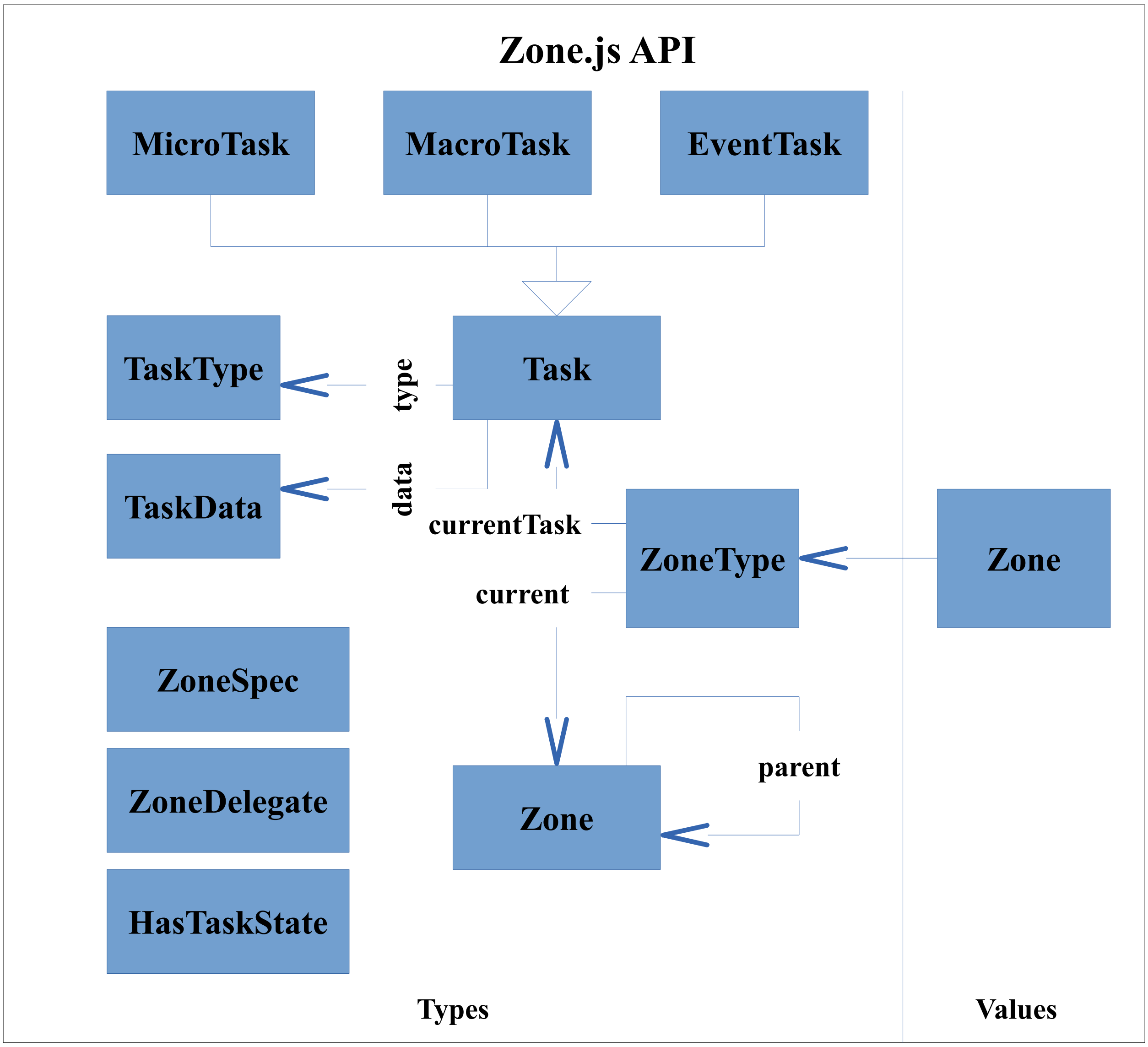
```
bootstrapModuleFactory<M>(moduleFactory: NgModuleFactory<M>,
       options?: BootstrapOptions): Promise<NgModuleRef<M>> {
  // Note: We need to create the NgZone _before_ we instantiate the module,
  // as instantiating the module creates some providers eagerly.
  // So we create a mini parent injector that just contains the new NgZone
  // and pass that as parent to the NgModuleFactory.
  const ngZoneOption = options ? options.ngZone : undefined;
  1 const ngZone = getNgZone(ngZoneOption);
  // Attention: Don't use ApplicationRef.run here,
  // as we want to be sure that all possible constructor calls are
  // inside `ngZone.run`!
  2 return ngZone.run(() => {
    const ngZoneInjector = Injector.create(
             [{provide: NgZone, useValue: ngZone}], this.injector);
    const moduleRef =
             <InternalNgModuleRef<M>>moduleFactory.create(ngZoneInjector);
    const exceptionHandler: ErrorHandler =
  3           moduleRef.injector.get(ErrorHandler, null);
    if (!exceptionHandler) {
      throw new Error(
        'No ErrorHandler. Is platform module (BrowserModule) included?');
    }
    moduleRef.onDestroy(() => remove(this._modules, moduleRef));
    ngZone !.runOutsideAngular(
    4   () => ngZone !.onError.subscribe(
            {next: (error: any) =>
                     { exceptionHandler.handleError(error); }}));
    return _callAndReportToErrorHandler(exceptionHandler, ngZone !, () => {
      const initStatus: ApplicationInitStatus =
             moduleRef.injector.get(ApplicationInitStatus);
      initStatus.runInitializers();

      return initStatus.donePromise.then(() => {
  5     this._moduleDoBootstrap(moduleRef);
        return moduleRef; });
    });
  });
}
```

At 1 we see a new NgZone being created and at 2 its run() method being called, at 3 we see an error handler implementation being requested from dependency injection (a default implementation will be returned unless the application supplies a custom one) and at 4, we see that error handler being used to configure error handling for the newly created `NgZone`. Finally at 5, we see the call to the actual bootstrapping.

So in summary, as Angular application developers, we should clearly learn about zones, since that is the execution context within which our application code will run.

API Model

Zone.js exposes an API for applications to use in the <ZONE-MASTER>/dist/zone.js.d.ts file.



The two main types it offers are for tasks and zones, along with some helper types. A zone is a (usually named) asynchronous execution context; a task is a block of functionality (may also be named). Tasks run in the context of a zone.

Zone.js also supplies a const value, also called `Zone`, of type `ZoneType`:

```
interface ZoneType {
    current: Zone;
    currentTask: Task;
    assertZonePatched(): void;
    root: Zone;
}
declare const Zone: ZoneType;
```

Recall that TypeScript has distinct declaration spaces for values and types, so the `Zone` value is distinct from the `Zone` type. For further details, see the TypeScript Language Specification – Section 2.3 – Declarations:

- https://github.com/Microsoft/TypeScript/blob/master/doc/spec.md#2.3

Apart from being used to define the `Zone` value, `ZoneType` is not used further.

When your application code wishes to find out the current zone it simply uses `Zone.current`, and when it wants to discover the current task within that zone, it uses `Zone.currentTask`. If you need to figure out whether Zone.js is available to your application (it will be for Angular applications), then just make sure `Zone` is not undefined. If we examine:

- <ANGULAR-MASTER>/packages/core/src/zone/ng_zone.ts

– we see that is exactly what Angular's NgZone.ts does:

```
constructor({enableLongStackTrace = false}) {
    if (typeof Zone == 'undefined') {
      throw new Error('Angular requires Zone.js polyfill.');
    }
```

Two simple helper types used to define tasks are `TaskType` and `TaskData`. `TaskType` is just a human-friendly string to associate with a task. It is usually set to one of the three task types as noted in the comment:

```
declare type TaskType = 'microTask' | 'macroTask' | 'eventTask';
```

`TaskData` contains a boolean (is this task periodic, i.e. is to be repeated) and two numbers - delay before executing this task and a handler id from `setTimout`.

```
interface TaskData {
    /**
     * A periodic [MacroTask] is such which get
     * automatically rescheduled after it is executed.
     */
    isPeriodic?: boolean;
    /**
     * Delay in milliseconds when the Task will run.
     */
    delay?: number;
    /**
     * identifier returned by the native setTimeout.
     */
    handleId?: number;
}
```

A task is an interface declared as:

```
interface Task {
    type: TaskType;  // one of `microTask`, `macroTask`, `eventTask`
    state: TaskState;// one of `notScheduled`, `scheduling`,
                     // `scheduled`, `running`, `canceling`, `unknown`
    source: string;  // debug string
    invoke: Function;// VM calls this when it enters a task
    callback: Function; // tasks call this when Zone.currentTask has been set
    data: TaskData;  // data passed to scheduleFn
    scheduleFn: (task: Task) => void;
                     // work which needs to be done to schedule the Task
    cancelFn: (task: Task) => void;
                     // work which needs to be done to un-schedule the Task
    readonly zone: Zone;
                     // The zone which will be used to invoke the `callback`
    runCount: number;// Number of times the task has been executed
    cancelScheduleRequest(): void; // Cancel the scheduling request
}
```

There are three marker interfaces derived from `Task`:

```
interface MicroTask extends Task { type: 'microTask'; }
interface MacroTask extends Task { type: 'macroTask'; }
interface EventTask extends Task { type: 'eventTask'; }
```

There are three helper types used to define `Zone`. `HasTaskState` just contains booleans for each of the task types and a string:

```
declare type HasTaskState = {
    microTask: boolean;
    macroTask: boolean;
    eventTask: boolean;
    change: TaskType;
};
```

`ZoneDelegate` is used when one zone wishes to delegate to another how certain operations should be performed. So for forcking (creating new tasks), scheduling, intercepting, invoking and error handling, the delegate may be called upon to carry out the action.

```
interface ZoneDelegate {
    zone: Zone;
    fork(targetZone: Zone, zoneSpec: ZoneSpec): Zone;
    intercept(targetZone: Zone, callback: Function,
       source: string): Function;
    invoke(targetZone: Zone, callback: Function, applyThis: any,
       applyArgs: any[], source: string): any;
    handleError(targetZone: Zone, error: any): boolean;
    scheduleTask(targetZone: Zone, task: Task): Task;
    invokeTask(targetZone: Zone, task: Task, applyThis: any,
       applyArgs: any): any;
    cancelTask(targetZone: Zone, task: Task): any;
    hasTask(targetZone: Zone, isEmpty: HasTaskState): void;
}
```

`ZoneSpec` is an interface that allows implementations to state what should have when certain actions are needed. It uses `ZoneDelegate` and the current zone:

```
interface ZoneSpec {
    name: string;
    properties?: { [key: string]: any; };
    onFork?: (parentZoneDelegate: ZoneDelegate, currentZone: Zone,
      targetZone: Zone, zoneSpec: ZoneSpec) => Zone;
    onIntercept?: (parentZoneDelegate: ZoneDelegate, currentZone: Zone,
      targetZone: Zone, delegate: Function, source: string) => Function
    onInvoke?: (parentZoneDelegate: ZoneDelegate, currentZone: Zone,
      targetZone: Zone, delegate: Function, applyThis: any, applyArgs: any[],
      source: string) => any;
    onHandleError?: (parentZoneDelegate: ZoneDelegate,
     currentZone: Zone, targetZone: Zone, error: any) => boolean;
    onScheduleTask?: (parentZoneDelegate: ZoneDelegate,
     currentZone: Zone, targetZone: Zone, task: Task) => Task;
    onInvokeTask?: (parentZoneDelegate: ZoneDelegate, currentZone: Zone,
     targetZone: Zone, task: Task, applyThis: any, applyArgs: any) => any;
    onCancelTask?: (parentZoneDelegate: ZoneDelegate,
     currentZone: Zone, targetZone: Zone, task: Task) => any;
    onHasTask?: (parentZoneDelegate: ZoneDelegate, currentZone: Zone,
      targetZone: Zone, hasTaskState: HasTaskState) => void;
}
```

The definition of the `Zone` type is:

```
interface Zone {
    parent: Zone;
    name: string;
    get(key: string): any;
    getZoneWith(key: string): Zone;
    fork(zoneSpec: ZoneSpec): Zone;
    wrap<F extends Function>(callback: F, source: string): F;
    run<T>(callback: Function, applyThis?: any, applyArgs?: any[],
            source?: string): T;
    runGuarded<T>(callback: Function, applyThis?: any, applyArgs?: any[],
            source?: string): T;
    runTask(task: Task, applyThis?: any, applyArgs?: any): any;
    scheduleMicroTask(source: string, callback: Function, data?: TaskData,
            customSchedule?: (task: Task) => void): MicroTask;
    scheduleMacroTask(source: string, callback: Function, data: TaskData,
            customSchedule: (task: Task) => void, customCancel:
            (task: Task) => void): MacroTask;
    scheduleEventTask(source: string, callback: Function, data: TaskData,
            customSchedule: (task: Task) => void,
            customCancel: (task: Task) => void): EventTask;
    scheduleTask<T extends Task>(task: T): T;
    cancelTask(task: Task): any;
}
```

Relationship between Zone/ZoneSpec/ZoneDelegate interfaces

Think of `ZoneSpec` as the processing engine that controls how a zone works. It is a required parameter to the `Zone.fork()` method:

```
// Used to create a child zone.
// @param zoneSpec A set of rules which the child zone should follow.
// @returns {Zone} A new child zone.
fork(zoneSpec: ZoneSpec): Zone;
```

Often when a zone needs to perform an action, it uses the supplied `ZoneSpec`. Do you want to record a long stack trace, keep track of tasks, work with WTF (discussed later) or run async test well? For each a these a different `ZoneSpec` is supplied, and each offers different features and comes with different processing costs. Zone.js supplies one implementation of the `Zone` interface, and multiple implementations of the `ZoneSpec` interface (in <ZONE-MASTER>/lib/zone-spec). Application code with specialist needs could create a custom `ZoneSpec`.

An application can build up a hierarchy of zones and sometimes a zone needs to make a call into another zone further up the hierarchy, and for this a `ZoneDelegate` is used.

Source Tree Layout

The Zone.js source tree consists of a root directory with a number of files and the following immediate sub-directories:

- dist
- doc
- example
- scripts
- tests

The main source is in lib:

- lib

During compilation the source gets built into a newly created build directory.

Root directory

The root directory contains these markdown documentation files:

- CHANGELOG.md
- DEVELOPER.md
- MODULE.md
- NON-STANDARD-APIS.md
- README.md
- STANDARD-APIS.md

When we examine <ZONE-MASTER>/dist/zone.js.d.ts we see it is actually very well documented and contains plenty of detail to get us up and running writing applications that use Zone.js. From the DEVELOPER.md document we see the contents of dist is auto-generated (we need to explore how).

The root directory contains these JSON files:

- tslint.json
- tsconfig[-node|-esm-node|esm|].json
- package.json

There are multiple files starting with tsconfig – here is the main one:

```
{
  "compilerOptions": {
    "module": "commonjs",
    "target": "es5",
    "noImplicitAny": true,
    "noImplicitReturns": false,
    "noImplicitThis": false,
    "outDir": "build",
    "inlineSourceMap": true,
    "inlineSources": true,
    "declaration": false,
    "noEmitOnError": false,
    "stripInternal": false,
    "lib": ["es5", "dom", "es2015.promise"]
  },
  "exclude": [
    "node_modules",
    "build",
    "build-esm",
    "dist",
    "lib/closure"
  ]
}
```

The package.json file contains metadata (including main and browser, which provide alternative entry points depending on whether this package 1 is loaded into a server [node] or a 2 browser app):

```
{
  "name": "zone.js",
  "version": "0.8.18",
  "description": "Zones for JavaScript",
1 "main": "dist/zone-node.js",
2 "browser": "dist/zone.js",
  "typings": "dist/zone.js.d.ts",
  "files": [
    "lib",
    "dist"
  ],
  "directories": {
    "lib": "lib",
    "test": "test"
  },
```

and a list of scripts:

```
   "scripts": {
    "changelog": "gulp changelog",
    "ci": "npm run lint && npm run format && npm run promisetest && npm run
test:single && npm run test-node",
    "closure:test": "scripts/closure/closure_compiler.sh",
    "format": "gulp format:enforce",
    "karma-jasmine": "karma start karma-build-jasmine.conf.js",
    "karma-jasmine:phantomjs": "karma start karma-build-jasmine-
phantomjs.conf.js --single-run",
    "karma-jasmine:single": "karma start karma-build-jasmine.conf.js
--single-run",
    "karma-jasmine:autoclose": "npm run karma-jasmine:single && npm run ws-
client",
    "karma-jasmine-phantomjs:autoclose": "npm run karma-jasmine:phantomjs &&
npm run ws-client",
    "lint": "gulp lint",
    "prepublish": "tsc && gulp build",
    "promisetest": "gulp promisetest",
    "webdriver-start": "webdriver-manager update && webdriver-manager start",
    "webdriver-http": "node simple-server.js",
    "webdriver-test": "node test/webdriver/test.js",
    "webdriver-sauce-test": "node test/webdriver/test.sauce.js",
    "ws-client": "node ./test/ws-client.js",
    "ws-server": "node ./test/ws-server.js",
    "tsc": "tsc -p .",
    "tsc:w": "tsc -w -p .",
    "test": "npm run tsc && concurrently \"npm run tsc:w\"
          \"npm run ws-server\" \"npm run karma-jasmine\"",
    "test:phantomjs": "npm run tsc && concurrently \"npm run tsc:w\"
          \"npm run ws-server\" \"npm run karma-jasmine:phantomjs\"",
    "test:phantomjs-single": "npm run tsc && concurrently \"npm run
            ws-server\" \"npm run karma-jasmine-phantomjs:autoclose\"",
    "test:single": "npm run tsc && concurrently \"npm run ws-server\"
            \"npm run karma-jasmine:autoclose\"",
    "test-dist": "concurrently \"npm run tsc:w\" \"npm run
             ws-server\" \"karma start karma-dist-jasmine.conf.js\"",
    "test-node": "gulp test/node",
    "test-mocha": "npm run tsc && concurrently \"npm run tsc:w\"
               \"npm run ws-server\" \"karma start
               karma-build-mocha.conf.js\"",
    "serve": "python -m SimpleHTTPServer 8000"
  },
```

It has no dependencies:

```
    "dependencies": {},
```

It has many devDependencies.

The root directory also contains the MIT license in a file called LICENSE, along with the same within a comment in a file called LICENSE.wrapped.

It contains this file concerning bundling:

- webpack.config.js

This has the following content:

```
  module.exports = {
    entry: './test/source_map_test.ts',
    output: {
      path: __dirname + '/build',
      filename: 'source_map_test_webpack.js'
    },
    devtool: 'inline-source-map',
    module: {
      loaders: [
        {test: /\.ts/, loaders: ['ts-loader'], exclude: /node_modules/}
      ]
    },
    resolve: {
      extensions: ["", ".js", ".ts"]
    }
  }
```

Webpack is quite a popular bundler and ts-loader is a TypeScript loader for webpack. Details on both projects can be found here:

```
https://webpack.github.io/
https://github.com/TypeStrong/ts-loader
```

The root directory contains this file related to GIT:

- .gitignore

It contains this task runner configuration:

- gulpfile.js

It supplies a gulp task called "test/node" to run tests against the node version of Zone.js, and a gulp task "compile" which runs the TypeScript tsc compiler in a child process. It supplies many gulp tasks to build individual components and run tests.

All of these tasks result in a call to a local method `generateScript` which minifies (if required) and calls webpack and places the result in the dist sub-directory.

dist

This single directory contains all the output from the build tasks. The zone.d.ts file is the ambient declarations, which TypeScript application developers will want to use. This is surprisingly well documented, so a new application developer getting up to speed with zone.js should give it a careful read. Three implementations of Zone are provided, for the browser, for the server and for Jasmine testing:

- zone.js / zone.min.js
- zone-node.js
- jasmine-patch.js / jasmine-patch.min.js

Minified versions are supplied for the browser and jasmine builds, but not node. If you are using Angular in the web browser, then zone.js (or zone.min.js) is all you need.

The remaining files in the dist directory are builds of different zone specs, which for specialist reasons you may wish to include – for example:

- async-test.js
- fake-async-test.js
- long-stack-trace-zone.js / long-stack-trace-zone.min.js
- proxy.js / proxy.min.js
- task-tracking.js / task-tracking.min.js
- wtf.js / wtf.min.js

We will look in detail at what each of these does later when examining the <ZONE-MASTER>/lib/zone-spec source directory.

example

The example directory contains a range of simple examples showing how to use Zone.js.

scripts

The script directory (and its sub-directories) contains these scripts:

- grab-blink-idl.sh
- closure/clousure_compiler.sh
- closure/closure_flagfile
- sauce/sauce_connect_setup.sh
- sauce/sauce_connect_block.sh

Source Model

The main source for Zone.js is in:

- <ZONE-MASTER>/lib

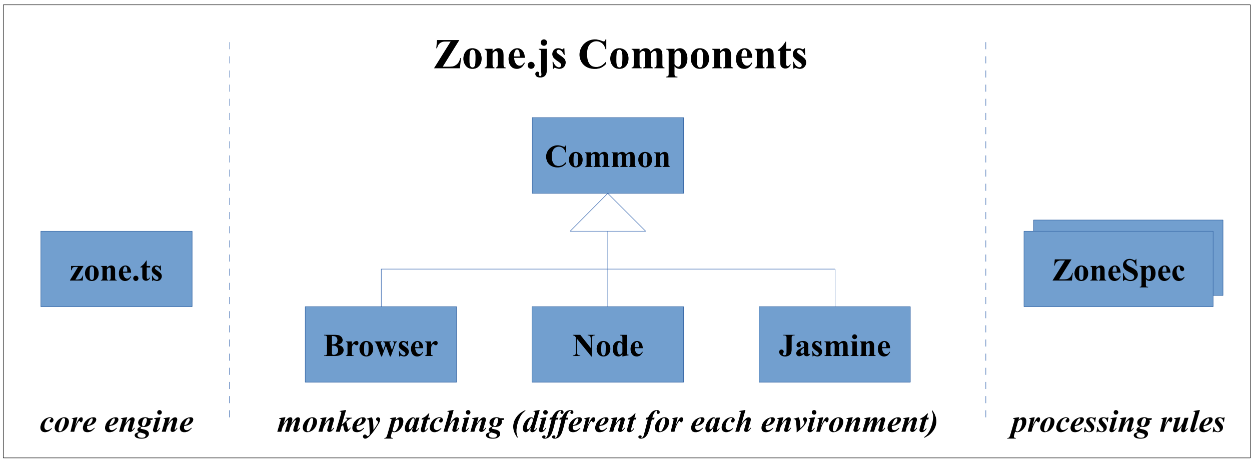
It contains five directories:

- browser
- closure
- common
- extra
- jasmine
- mix (a mix of browser and node)
- mocha
- node
- rxjs
- zone-spec

along with one source file:

- zone.ts

It is best to think of them arranged as follows:



To enable Zone.js to function, any JavaScript APIs related to asynchronous code execution must be patched – a Zone.js specific implementation of the API is needed. So for calls such as `setTimeout` or `addEventListener` and similar, Zone.js needs its own handling, so that when timeouts and events and promises get triggered, zone code runs first.

There are a number of environments supported by Zone.js that need monkey patching, such as the browser, the server (node) and Jasmine and each of these has a sub-direcory with patching code. The common patching code reside in the common directory. The core implementation of the Zone.js API (excluding `ZoneSpec`) is in zone.ts file. The additional directory is for zone specs, which are the configurable logic one can add to a zone to change its behavior. There are multiple implementations of these, and applications could create their own.

zone.ts

The first six hundred lines of the zone.ts file is the well-commented definition of the Zone.js API, that will end up in zone.d.ts. The slightly larger remainder of the file is an implementation of the `Zone` const:

```
const Zone: ZoneType = (function(global: any) {
...
  return global['Zone'] = Zone;
})(typeof window !== 'undefined' && window
    || typeof self !== 'undefined' && self || global);
```

The `_ZonePrivate` interface defines private information that is managed per zone:

```
interface _ZonePrivate {
  currentZoneFrame: () => _ZoneFrame;
  symbol: (name: string) => string;
  scheduleMicroTask: (task?: MicroTask) => void;
  onUnhandledError: (error: Error) => void;
  microtaskDrainDone: () => void;
  showUncaughtError: () => boolean;
  patchEventTarget: (global: any, apis: any[], options?: any) => boolean[];
  patchOnProperties: (obj: any, properties: string[]) => void;
  setNativePromise: (nativePromise: any) => void;
  patchMethod:
      (target: any, name: string,
       patchFn: (delegate: Function, delegateName: string, name: string) =>
           (self: any, args: any[]) => any) => Function;
}
```

When using the client API you will not see this, but when debugging through the Zone.js implementation, it will crop up from time to time.

A microtask queue is managed, which requries these variables:

```
  let _microTaskQueue: Task[] = [];
  let _isDrainingMicrotaskQueue: boolean = false;
  let nativeMicroTaskQueuePromise: any;
```

`_microTaskQueue` is an array of microtasks, that must be executed before we give up our VM turn. `_isDrainingMicrotaskQueue` is a boolean that tracks if we are in the process of emptying the microtask queue. When a task is run within an existing task, they are nested and `_nativeMicroTaskQueuePromise` is used to access a native microtask queue. Which is stored as a global is not set. Two functions manage a microtask queue:

- scheduleMicroTask
- drainMicroTaskQueue

It also implements three classes:

- Zone
- ZoneDelegate
- ZoneTask

There are no implementations of `ZoneSpec` in this file. They are in the separate zone-spec sub-directory.

ZoneTask is the simplest of these classes:

```
class ZoneTask<T extends TaskType> implements Task {
    public type: T;
    public source: string;
    public invoke: Function;
    public callback: Function;
    public data: TaskData;
    public scheduleFn: (task: Task) => void;
    public cancelFn: (task: Task) => void;
    _zone: Zone = null;
    public runCount: number = 0;
    _zoneDelegates: ZoneDelegate[] = null;
    _state: TaskState = 'notScheduled';
```

The constructor just records the supplied parameters and sets up invoke:

```
    constructor(
        type: T, source: string, callback: Function, options: TaskData,
        scheduleFn: (task: Task) => void, cancelFn: (task: Task) => void) {
      this.type = type;
      this.source = source;
      this.data = options;
      this.scheduleFn = scheduleFn;
      this.cancelFn = cancelFn;
      this.callback = callback;
      const self = this;
      if (type === eventTask && options
              && (options as any).isUsingGlobalCallback) {
        this.invoke = ZoneTask.invokeTask;
      } else {
        this.invoke = function() {
          return ZoneTask.invokeTask.apply(global,
                            [self, this, <any>arguments]);
        };
      }
    }
```

The interesting activity in here is setting up the invoke function. It increments the _numberOfNestedTaskFrames counter, calls zone.runTask(), and in a finally block, checks if _numberOfNestedTaskFrames is 1, and if so, calls the standalone function drainMicroTaskQueue(), and then decrements _numberOfNestedTaskFrames.

```
static invokeTask(task: any, target: any, args: any): any {
      if (!task) {
        task = this;
      }
      _numberOfNestedTaskFrames++;
      try {
        task.runCount++;
        return task.zone.runTask(task, target, args);
      } finally {
        if (_numberOfNestedTaskFrames == 1) {
          drainMicroTaskQueue();
        }
        _numberOfNestedTaskFrames--;
      }
    }
```

A custom toString() implementation returns data.handleId (if available) or else the object’s `toString()` result:

```
public toString() {
      if (this.data && typeof this.data.handleId !== 'undefined') {
        return this.data.handleId;
      } else {
        return Object.prototype.toString.call(this);
      }
    }
```

If we exclude error handling, `drainMicroTaskQueue()` is defined as:

```
function drainMicroTaskQueue() {
    if (!_isDrainingMicrotaskQueue) {
      _isDrainingMicrotaskQueue = true;
      while (_microTaskQueue.length) {
        const queue = _microTaskQueue;
        _microTaskQueue = [];
        for (let i = 0; i < queue.length; i++) {
          const task = queue[i];
          try {
            task.zone.runTask(task, null, null);
          } catch (error) {
            ..
          }
        }
      }
      ..
    }
  }
```

The `_microTaskQueue` gets populated via a call to `scheduleMicroTask`:

```
function scheduleMicroTask(task?: MicroTask) {
     // if we are not running in any task, and there has not been
     // anything scheduled we must bootstrap the initial task creation
     // by manually scheduling the drain
    if (_numberOfNestedTaskFrames === 0 && _microTaskQueue.length === 0) {
       // We are not running in Task, so we need to
       // kickstart the microtask queue.
      if (!nativeMicroTaskQueuePromise) {
        if (global[symbolPromise]) {
          nativeMicroTaskQueuePromise = global[symbolPromise].resolve(0);
        }
      }
      if (nativeMicroTaskQueuePromise) {
        nativeMicroTaskQueuePromise[symbolThen](drainMicroTaskQueue);
      } else {
        global[symbolSetTimeout](drainMicroTaskQueue, 0);
      }
    }
    task && _microTaskQueue.push(task);
  }
```

If needed (not running in a task), this calls `setTimeout` with timeout set to 0, to enqueue a request to drain the microtask queue. Even though the timeout is 0, this does not mean that the `drainMicroTaskQueue()` call will execute immediately. Instead, this puts an event in the JavaScript’s event queue, which after the already scheduled events have been handled (there may be one or move already in the queue), will itself be handled. The currently executing function will first run to completion before any event is removed from the event queue. Hence in the above code, where `scheduleQueueDrain()` is called before `_microTaskQueue.push()`, is not a problem. `_microTaskQueue.push()` will execute first, and then sometime in future, the `drainMicroTaskQueue()`function will be called via the timeout.

The `ZoneDelegate` class has to handle eight scenarios:

- fork
- intercept
- invoke
- handleError
- scheduleTask
- invokeTask
- cancelTask
- hasTask

It defines variables to store values for a `ZoneDelegate` and `ZoneSpec` for each of these, which are initialized in the constructor.

```
private _interceptDlgt: ZoneDelegate;
private _interceptZS: ZoneSpec;
private _interceptCurrZone: Zone;
```

`ZoneDelegate` also declares three variables, to store the delegates zone and parent delegate, and to represent task counts (for each kind of task):

```
public zone: Zone;

private _taskCounts: {microTask: number,
                      macroTask: number,
                      eventTask: number} =
                      {'microTask': 0, 'macroTask': 0, 'eventTask': 0};

private _parentDelegate: ZoneDelegate;
```

In `ZoneDelegate`'s constructor, the `zone` and `parentDelegate` fields are initialized to the supplied parameters, and the `ZoneDelegate` and `ZoneSpec` fields for the eight scenarios are set (using TypeScript type guards), either to the supplied `ZoneSpec` (if not null), or the parent delegate's:

```
   constructor(zone: Zone, parentDelegate: ZoneDelegate, zoneSpec: ZoneSpec) {
        this.zone = zone;
        this._parentDelegate = parentDelegate;
 …
       this._scheduleTaskZS = zoneSpec &&
         (zoneSpec.onScheduleTask ? zoneSpec : parentDelegate._scheduleTaskZS);
        this._scheduleTaskDlgt =
            zoneSpec && (zoneSpec.onScheduleTask ?
              parentDelegate : parentDelegate._scheduleTaskDlgt);
        this._scheduleTaskCurrZone =
            zoneSpec && (zoneSpec.onScheduleTask ?
              this.zone : parentDelegate.zone);
```

The `ZoneDelegate` methods for the eight scenarios just forward the calls to the selected `ZoneSpec` (pr parent delegate) and does some house keeping. For example, the invoke method checks if `_invokeZS` is defined, and if so, calls its `onInvoke`, otherwise it calls the supplied callback directly:

```
   invoke(targetZone: Zone, callback: Function,
     applyThis: any, applyArgs: any[], source: string): any {
      return this._invokeZS ?
          this._invokeZS.onInvoke(
              this._invokeDlgt, this._invokeCurrZone,
              targetZone, callback, applyThis, applyArgs,
              source) :
          callback.apply(applyThis, applyArgs);
    }
```

The `scheduleTask` method is a bit different, in that it first 1 tries to use the `_scheduleTaskZS` (if defined), otherwise 2 tries to use the supplied task's `scheduleFn` (if defined), otherwise 3 if a microtask calls `scheduleMicroTask()`, otherwise 4 it is an error:

```
scheduleTask(targetZone: Zone, task: Task): Task {
      let returnTask: ZoneTask<any> = task as ZoneTask<any>;
      if (this._scheduleTaskZS) {
   1    if (this._hasTaskZS) {
          returnTask._zoneDelegates.push(this._hasTaskDlgtOwner);
        }
        returnTask = this._scheduleTaskZS.onScheduleTask(
            this._scheduleTaskDlgt, this._scheduleTaskCurrZone,
            targetZone, task) as ZoneTask<any>;
        if (!returnTask) returnTask = task as ZoneTask<any>;
      } else {
   2    if (task.scheduleFn) {
          task.scheduleFn(task);
   3    } else if (task.type == microTask) {
          scheduleMicroTask(<MicroTask>task);
   4    } else {
          throw new Error('Task is missing scheduleFn.');
        }
      }
      return returnTask;
    }
```

The fork method is where new zones get created. If `_forkZS` is defined, it is used, otherwise a new zone is created with the supplied `targetZone` and `zoneSpec`:

```
    fork(targetZone: Zone, zoneSpec: ZoneSpec): AmbientZone {
      return this._forkZS ? this._forkZS.onFork(this._forkDlgt, this.zone,
targetZone, zoneSpec) :
                            new Zone(targetZone, zoneSpec);
    }
```

The internal variable `_currentZoneFrame` is initialized to the root zone and `_currentTask` to null:

```
  let _currentZoneFrame: _ZoneFrame =
       {parent: null, zone: new Zone(null, null)};
  let _currentTask: Task = null;
  let _numberOfNestedTaskFrames = 0;
```

2: Tsickle

Overview

Tsickle is a small utility that carries out transformations on TypeScript code to make it suitable as input for the Closure Compiler, which in turn is used to generate highly optimized JavaScript code.

The home for the Tsickle project is:

- https://github.com/angular/tsickle

which introduces Tsickle as:

> *"Tsickle converts TypeScript code into a form acceptable to the Closure Compiler. This allows using TypeScript to transpile your sources, and then using Closure Compiler to bundle and optimize them, while taking advantage of type information in Closure Compiler."*

To learn more about Closure, visit:

- https://github.com/google/closure-compiler

Tsickle is used Angular but can also be used by non-Angular projects.

Source Tree Layout

The Tsickle source tree has these sub-directories:

- src
- test
- test_files
- third_party

The main directory has these important files:

- readme.md
- package.json
- gulpfile.js
- tsconfig.json

The readme.md contains useful information about the project, including this important guidance about the use of tsconfig.json:

> *Project Setup*
>
> *Tsickle works by wrapping tsc. To use it, you must set up your project such that it builds correctly when you run tsc from the command line, by configuring the settings in tsconfig.json.*
>
> *If you have complicated tsc command lines and flags in a build file (like a gulpfile etc.) Tsickle won't know about it. Another reason it's nice to put*

everything in tsconfig.json is so your editor inherits all these settings as well.

The package.json file contains:

```
"main": "built/src/tsickle.js",
"bin":  "built/src/main.js",
```

The gulpfile.js file contains the following Gulp tasks:

- gulp format
- gulp test.check-format (formatting tests)
- gulp test.check-lint (run tslint)

The src Sub-Directory

The src sub-directory contains the following source files:

- class_decorator_downlevel_transformer.ts
- cli_support.ts
- closure_externs.js
- decorator-annotator.ts
- decorators.ts
- es5processor.ts
- fileoverview_comment_transformer.ts
- jsdoc.ts
- main.ts
- modules_manifest.ts
- rewriter.ts
- source_map_utils.ts
- transformer_sourcemap.ts
- transformer_util.ts
- tsickle.ts
- type-translator.ts
- util.ts

main.ts is where the call to tsickle starts executing and tsickle.ts is where the core logic is – the other files are helpers.

The entry point at the bottom of main.ts calls the main function passing in the argument list as an array of strings.

```
function main(args: string[]): number {
1 const {settings, tscArgs} = loadSettingsFromArgs(args);
2 const config = loadTscConfig(tscArgs);
  if (config.errors.length) {
    console.error(tsickle.formatDiagnostics(config.errors));
    return 1;
  }

  if (config.options.module !== ts.ModuleKind.CommonJS) {
    // This is not an upstream TypeScript diagnostic, therefore it does not
    // go through the diagnostics array mechanism.
    console.error(
    'tsickle converts TypeScript modules to Closure modules via
        'CommonJS internally. Set tsconfig.js "module": "commonjs"');
    return 1;
  }

  // Run tsickle+TSC to convert inputs to Closure JS files.
3 const result = toClosureJS(
      config.options, config.fileNames, settings,
      (filePath: string, contents: string) => {
        mkdirp.sync(path.dirname(filePath));
4       fs.writeFileSync(filePath, contents, {encoding: 'utf-8'});
      });
  if (result.diagnostics.length) {
    console.error(tsickle.formatDiagnostics(result.diagnostics));
    return 1;
  }

5 if (settings.externsPath) {
    mkdirp.sync(path.dirname(settings.externsPath));
    fs.writeFileSync(settings.externsPath,
        tsickle.getGeneratedExterns(result.externs));
  }
  return 0;
}

// CLI entry point
if (require.main === module) {
  process.exit(main(process.argv.splice(2)));
}
```

The main function first loads the settings 1 from the args and 2 the tsc config. Then it calls the `toClosureJs()` function 3, and outputs to a file 4 each resulting JavaScript file. If `externsPath` is set in settings, they too are written out to files 5.

The `loadSettingsfromArgs()` function handles the command-line arguments, which can be a mix of tsickle-specific arguments and regular tsc arguments. The tsickle-specific arguments are –externs (generate externs file) and –untyped (every TypeScript type becomes a Closure {?} type).

The `toClosureJs()` function is where the transformation occurs. It returns 1 a map of transformed file contents, optionally with externs information, it so configured.

```
export function toClosureJS(
    options: ts.CompilerOptions, fileNames: string[], settings: Settings,
    writeFile?: ts.WriteFileCallback): tsickle.EmitResult {
1 const compilerHost = ts.createCompilerHost(options);
2 const program = ts.createProgram(fileNames, options, compilerHost);

3 const transformerHost: tsickle.TsickleHost = {
    shouldSkipTsickleProcessing: (fileName: string) => {
      return fileNames.indexOf(fileName) === -1;
    },
    shouldIgnoreWarningsForPath: (fileName: string) => false,
    pathToModuleName: cliSupport.pathToModuleName,
    fileNameToModuleId: (fileName) => fileName,
    es5Mode: true, googmodule: true, prelude: '',
    transformDecorators: true, transformTypesToClosure: true,
    typeBlackListPaths: new Set(), untyped: false,
    logWarning: (warning) =>
       console.error(tsickle.formatDiagnostics([warning])),
  };
  const diagnostics = ts.getPreEmitDiagnostics(program);
  if (diagnostics.length > 0) {
    return {
      diagnostics,
      modulesManifest: new ModulesManifest(),
      externs: {},
      emitSkipped: true,
      emittedFiles: [],
    };
  }
4  return tsickle.emitWithTsickle(
      program, transformerHost, compilerHost, options, undefined, writeFile);
}
```

It first creates 1 a compiler host based on the supplied options, then 2 it uses TypeScript's `createProgram` method with the original program source to ensure it is syntatically correct and any error messages refer the original source, not the modified source. Then it creates 3 a `tsickle.TsickleHost` instance which it passes 4 to `tsickle.emitWithTsickle()`.

The `annotate` function is a simple function:

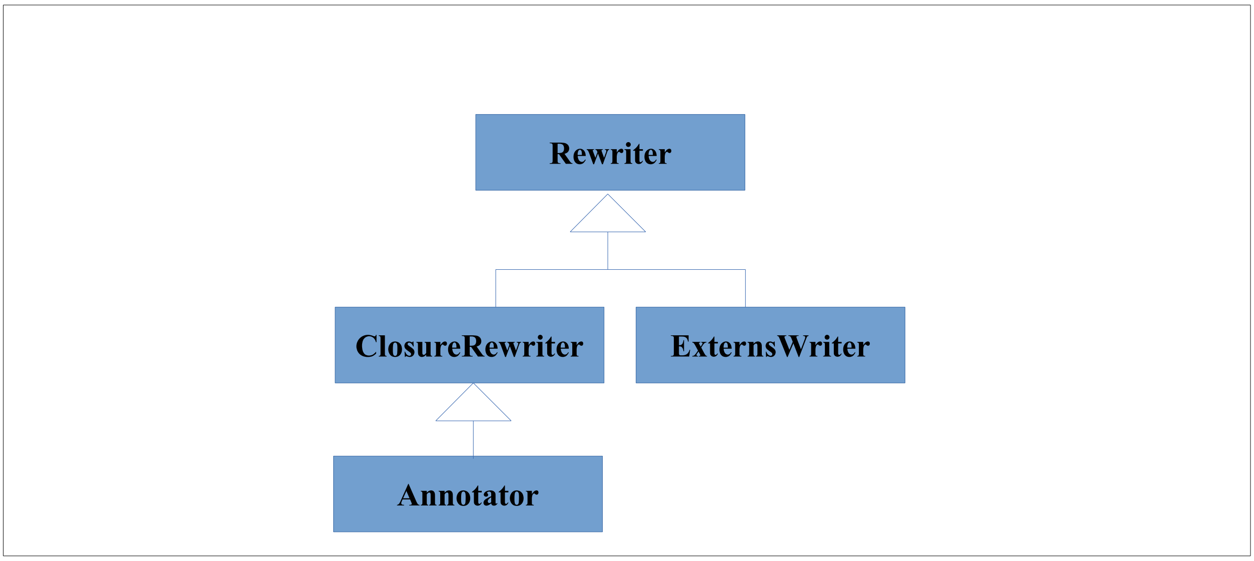
```
export function annotate(
    typeChecker: ts.TypeChecker, file: ts.SourceFile, host: AnnotatorHost,
    tsHost?: ts.ModuleResolutionHost, tsOpts?: ts.CompilerOptions,
    sourceMapper?: SourceMapper): {output: string, diagnostics:
ts.Diagnostic[]} {
  return new Annotator(typeChecker, file, host, tsHost, tsOpts,
sourceMapper).annotate();
}
```

Classes called rewriters are used to rewrite the source. The rewriter.ts file has the `Rewriter` abstract class. An important method is `maybeProcess()`.

```
/**
 * A Rewriter manages iterating through a ts.SourceFile, copying input
 * to output while letting the subclass potentially alter some nodes
 * along the way by implementing maybeProcess().
 */
export abstract class Rewriter {
  private output: string[] = [];
  /** Errors found while examining the code. */
  protected diagnostics: ts.Diagnostic[] = [];
  /** Current position in the output. */
  private position: SourcePosition = {line: 0, column: 0, position: 0};
  /**
   * The current level of recursion through TypeScript Nodes.  Used in
formatting internal debug
   * print statements.
   */
  private indent = 0;
  /**
   * Skip emitting any code before the given offset.
   * E.g. used to avoid emitting @fileoverview
   * comments twice.
   */
  private skipCommentsUpToOffset = -1;
```

```
    constructor(public file: ts.SourceFile,
                private sourceMapper: SourceMapper = NOOP_SOURCE_MAPPER) {   }
```

tsickle.ts has some classes that derive from `Rewriter`, according to this hierarchy:



`Annotator.maybeProcess()` is where the actual rewriting occurs.

3: TS-API-Guardian

Overview

Ts-api-guardian is a small tool that tracks a package's public API.

Usage

It is used in the Angular build to check for changes to the Angular public API and to ensure that inadvertent changes to the public API are detected. Specifically, it you examine gulpfile.ts in the main Angular project:

- <ANGULAR-MASTER>/gulpfile.js

you will see it has these two lines:

```
gulp.task('public-api:enforce', loadTask('public-api', 'enforce'));
gulp.task('public-api:update', ['build.sh'],
    loadTask('public-api', 'update'));
```

and when we look at:

- <ANGULAR-MASTER>/tools/gulp-tasks/public-api.js

we see two tasks named 'public-api:enforce' and 'public-api:update' and In here we see how ts-api-guardian is used, to 1 ensure it has not been unexpectedly changed and to 2 generate a "golden file" representing the API:

```
// Enforce that the public API matches the golden files
// Note that these two commands work on built d.ts files
// instead of the source
1 enforce: (gulp) => (done) => {
  const platformScriptPath = require('./platform-script-path');
  const childProcess = require('child_process');
  const path = require('path');

  childProcess
      .spawn(path.join(__dirname,
         platformScriptPath(`../../node_modules/.bin/ts-api-guardian`)),
          ['--verifyDir', path.normalize(publicApiDir)]
            .concat(publicApiArgs), {stdio: 'inherit'})
      .on('close', (errorCode) => {
        if (errorCode !== 0) {
          done(new Error(
            'Public API differs from golden file. ' +
            'Please run `gulp public-api:update`.'));
        } else {
          done();
        }
      });
},

// Generate the public API golden files
2 update: (gulp) => (done) => {
  const platformScriptPath = require('./platform-script-path');
```

```
      const childProcess = require('child_process');
      const path = require('path');

      childProcess
          .spawn(
              path.join(__dirname, platformScriptPath(
                 `../../node_modules/.bin/ts-api-guardian`)),
              ['--outDir', path.normalize(publicApiDir)].concat(publicApiArgs),
               {stdio: 'inherit'})
          .on('close', done);
    }
```

Source Tree

The root directory contains these files:

- gulpfile.js
- package.json
- tsconfig.json
- tsd.json

and these top-level directories:

- bin
- lib
- test

The primary tasks in the gulpfile are:

- compile
- test.compile
- test.unit
- watch

The unit tests are based on mocha (unlike most of the rest of Angular, which uses jasmine).

The package.json has the following dependencies:

```
  "dependencies": {
      "chalk": "^1.1.3",
      "diff": "^2.2.3",
      "minimist": "^1.2.0",
      "typescript": "2.0.10"
    },
```

The most important of these is the diff package, which is used to determine differences between blocks of text (https://www.npmjs.com/package/diff).

Package.json also list the single callable program inside ts-api-guardian:

```
  "bin": {
      "ts-api-guardian": "./bin/ts-api-guardian"
    },
```

bin

The bin directory has one file, ts-api-guardian, which just has these lines:

```
#!/usr/bin/env node
require('../build/lib/cli').startCli();
```

lib

The lib sub-directory contains these files:

- cli.ts – command-line interface, processes argument list and invokes commands
- main.ts – main logic for generating and verifying golden files
- serializer.ts – code to serialize an API (to create the contents of a golden file)

A golden file is a textual representation of an API and the two key tasks of ts-api-guardian is to either create or verify golden files based on supplied command line arguments.

Cli.ts starts with some useful comments about how to call ts-api-guardian:

```
// # Generate one declaration file
// ts-api-guardian --out api_guard.d.ts index.d.ts
//
// # Generate multiple declaration files //#(output location like typescript)
// ts-api-guardian --outDir api_guard [--rootDir .] core/index.d.ts
core/testing.d.ts
//
// # Print usage
// ts-api-guardian --help
//
// # Check against one declaration file
// ts-api-guardian --verify api_guard.d.ts index.d.ts
//
// # Check against multiple declaration files
// ts-api-guardian --verifyDir api_guard [--rootDir .] core/index.d.ts
core/testing.d.ts
```

cli.ts accepts the following command line options:

```
--help                          Show this usage message
        --out <file>            Write golden output to file
        --outDir <dir>          Write golden file structure to directory
        --verify <file>         Read golden input from file
        --verifyDir <dir>       Read golden file structure from directory
        --rootDir <dir>         Specify the root directory of input files
        --stripExportPattern <regexp>
                                 Do not output exports matching the pattern
        --allowModuleIdentifiers <identifier>
                                 Whitelist identifier for "* as foo" imports
        --onStabilityMissing <warn|error|none>
                     Warn or error if an export has no stability annotation`);
```

The Angular API allows annotations to be attached to each API indicating whether it is stable, deprecated or experiemental. The `onStabilityMissing` option indicates what action is required if such an annotation is missing. The `startCli()` function parses the command line and initializes an instance of `SerializationOptions`, and then for generation mode calls `generateGoldenFile()` or for verification mode calls `verifyAgainstGoldenFile()` - both are in main.ts and are actually quite short functions:

```
export function generateGoldenFile(
    entrypoint: string, outFile: string,
    options: SerializationOptions = {}): void {
  const output = publicApi(entrypoint, options);
  ensureDirectory(path.dirname(outFile));
  fs.writeFileSync(outFile, output);
}
```

generateGoldenFile calls publicApi (from Serializer.ts) to generate the contents of the golden file and then writes it to a file. VerifyAgainstGoldenFile() also calls publicApi and saves the result in a string called actual, and then loads the existing golden file data into a string called expected, and then compares then. If then are different, it calls createPatch (from the diff package), to create a representation of the differences between the actual and expected golden files.

```
export function verifyAgainstGoldenFile(
    entrypoint: string, goldenFile: string, options: SerializationOptions =
{}): string {
  const actual = publicApi(entrypoint, options);
  const expected = fs.readFileSync(goldenFile).toString();

  if (actual === expected) {
    return '';
  } else {
    const patch = createPatch(goldenFile, expected, actual, 'Golden file',
'Generated API');

    // Remove the header of the patch
    const start = patch.indexOf('\n', patch.indexOf('\n') + 1) + 1;

    return patch.substring(start);
  }
}
```

serializer.ts defines `SerializationOptions` which has three optional properties:

```
export interface SerializationOptions {
  /**
   * Removes all exports matching the regular expression.
   */
  stripExportPattern?: RegExp;
  /**
   * Whitelists these identifiers as modules in the output. For example,
   * ```
   * import * as angular from './angularjs';
   *
   * export class Foo extends angular.Bar {}
   * ```
   * will produce `export class Foo extends angular.Bar {}` and requires
   * whitelisting angular.
   */
  allowModuleIdentifiers?: string[];
  /**
   * Warns or errors if stability annotations are missing on an export.
   * Supports experimental, stable and deprecated.
   */
  onStabilityMissing?: string;  // 'warn' | 'error' | 'none'
}
```

Serializer.ts defines a public API function which just calls `publicApiInternal()`, which in turn calls `ResolvedDeclarationEmitter()`, which is a 200-line class where the actual work is performed. It has three methods which perform the serialization:

- emit(): string
- private getResolvedSymbols(sourceFile: ts.SourceFile): ts.Symbol[]
- emitNode(node: ts.Node)

4: The Core Package

Overview

Core is the foundational Angular package upon which all other packages are based. It supplies a wide range of functionality, in areas such as metadata, the template linker, the Ng module system, application initialization, dependency injection, i18n, animation, WTF, and foundational types such as `NgZone`, `Sanitizer` and `SecurityContext`.

Core Public API

The index.ts file in Core's root directory just exports the contents of the public-api file, which in turn exports the contents of src/core.ts:

- <ANGULAR-MASTER>/packages/core/src/core.ts

which is where Core's exported API is defined:

```
export * from './metadata';
export * from './version';
export {TypeDecorator} from './util/decorators';
export * from './di';
export {createPlatform, assertPlatform, destroyPlatform, getPlatform,
  PlatformRef, ApplicationRef, enableProdMode, isDevMode,
createPlatformFactory, NgProbeToken} from './application_ref';
export {APP_ID, PACKAGE_ROOT_URL, PLATFORM_INITIALIZER, PLATFORM_ID,
  APP_BOOTSTRAP_LISTENER} from './application_tokens';
export {APP_INITIALIZER, ApplicationInitStatus} from './application_init';
export * from './zone';
export * from './render';
export * from './linker';
export {DebugElement, DebugNode, asNativeElements,
  getDebugNode, Predicate} from './debug/debug_node';
export {GetTestability, Testability, TestabilityRegistry,
   setTestabilityGetter} from './testability/testability';
export * from './change_detection';
export * from './platform_core_providers';
export {TRANSLATIONS, TRANSLATIONS_FORMAT, LOCALE_ID,
  MissingTranslationStrategy} from './i18n/tokens';
export {ApplicationModule} from './application_module';
export {wtfCreateScope, wtfLeave, wtfStartTimeRange,
  wtfEndTimeRange, WtfScopeFn} from './profile/profile';
export {Type} from './type';
export {EventEmitter} from './event_emitter';
export {ErrorHandler} from './error_handler';
export * from './core_private_export';
export {Sanitizer, SecurityContext} from './security';
export * from './codegen_private_exports';
export * from './animation/animation_metadata_wrapped';
import {AnimationTriggerMetadata}
  from './animation/animation_metadata_wrapped';
```

If you are writing a normal Angular application, to use the Core package you will import Core’s index.ts. There are two additional files with exports, which are used internally within Angular, to allow other Angular packages import additional types from the Core package (that are not in the normal index.ts). These two files are named private_exports and are located in Core’s src directory (whereas index.ts is located in Core’s root directory).

The first of these is:

- <ANGULAR-MASTER>/packages/core/src/core_private_export.ts

and has these exports:

```
export {ALLOW_MULTIPLE_PLATFORMS as ɵALLOW_MULTIPLE_PLATFORMS} from
'./application_ref';
export {APP_ID_RANDOM_PROVIDER as ɵAPP_ID_RANDOM_PROVIDER} from
'./application_tokens';
export {ValueUnwrapper as ɵValueUnwrapper, devModeEqual as ɵdevModeEqual}
from './change_detection/change_detection_util';
export {isListLikeIterable as ɵisListLikeIterable} from
'./change_detection/change_detection_util';
export {ChangeDetectorStatus as ɵChangeDetectorStatus,
isDefaultChangeDetectionStrategy as ɵisDefaultChangeDetectionStrategy} from
'./change_detection/constants';
export {Console as ɵConsole} from './console';
export {ComponentFactory as ɵComponentFactory} from
'./linker/component_factory';
export {CodegenComponentFactoryResolver as ɵCodegenComponentFactoryResolver}
from './linker/component_factory_resolver';
export {ReflectionCapabilities as ɵReflectionCapabilities} from
'./reflection/reflection_capabilities';
export {GetterFn as ɵGetterFn, MethodFn as ɵMethodFn, SetterFn as ɵSetterFn}
from './reflection/types';
export {DirectRenderer as ɵDirectRenderer, RenderDebugInfo as
ɵRenderDebugInfo} from './render/api';
export {global as ɵglobal, looseIdentical as ɵlooseIdentical, stringify as
ɵstringify} from './util';
export {makeDecorator as ɵmakeDecorator} from './util/decorators';
export {isObservable as ɵisObservable, isPromise as ɵisPromise} from
'./util/lang';
export {clearOverrides as ɵclearOverrides, overrideComponentView as
ɵoverrideComponentView, overrideProvider as ɵoverrideProvider} from
'./view/index';
export {NOT_FOUND_CHECK_ONLY_ELEMENT_INJECTOR as
ɵNOT_FOUND_CHECK_ONLY_ELEMENT_INJECTOR} from './view/provider';
```

We observe that the exports are being renamed with the Greek Theta symbol (looks like a ‘o’ with a horizontal line through it) – all are exported as:

```
export X as ɵX;
```

For an explanation see here - https://stackoverflow.com/questions/45466017/%C9%B5-theta-like-symbol-in-angular-2-source-code

> *“The letter ɵ is used by the Angular team to indicate that some method is private to the framework and must not be called directly by the user, as the API for these method is not guaranteed to stay stable between Angular versions (in fact, I would say it’s almost guaranteed to break).”*

The second private exports file is:

- <ANGULAR-MASTER>/packages/core/src/codegen_private_exports.ts

and has these exports:

```
export {CodegenComponentFactoryResolver as ɵCodegenComponentFactoryResolver}
from './linker/component_factory_resolver';
export {registerModuleFactory as ɵregisterModuleFactory} from
'./linker/ng_module_factory_loader';
export {ArgumentType as ɵArgumentType, BindingFlags as ɵBindingFlags,
DepFlags as ɵDepFlags, EMPTY_ARRAY as ɵEMPTY_ARRAY, EMPTY_MAP as ɵEMPTY_MAP,
NodeFlags as ɵNodeFlags, QueryBindingType as ɵQueryBindingType,
QueryValueType as ɵQueryValueType, ViewDefinition as ɵViewDefinition,
ViewFlags as ɵViewFlags, anchorDef as ɵand, createComponentFactory as ɵccf,
createNgModuleFactory as ɵcmf, createRendererType2 as ɵcrt, directiveDef as
ɵdid, elementDef as ɵeld, elementEventFullName as ɵelementEventFullName,
getComponentViewDefinitionFactory as ɵgetComponentViewDefinitionFactory,
inlineInterpolate as ɵinlineInterpolate, interpolate as ɵinterpolate,
moduleDef as ɵmod, moduleProvideDef as ɵmpd, ngContentDef as ɵncd, nodeValue
as ɵnov, pipeDef as ɵpid, providerDef as ɵprd, pureArrayDef as ɵpad,
pureObjectDef as ɵpod, purePipeDef as ɵppd, queryDef as ɵqud,
textDef as ɵted, unwrapValue as ɵunv, viewDef as ɵvid} from './view/index';
```

Source Tree Layout

The Core source tree is at:

- <ANGULAR-MASTER>/packages/core

The source tree for the Core package contains these directories:

- src
- test (unit tests in Jasmine)
- testing (test tooling)

and these files:

- BUILD.bazel
- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

Source

core/src

The core/src directory directly contains many files, which we will group into three categories. Firstly, a number of files just export types from equivalently named sub-directories. Files that fall into this category include:

- change_detection.ts
- core.ts
- di.ts
- metadata.ts
- linker.ts
- render.ts

- zone.ts

For example, the renderer.ts file is a one-liner that just exports from renderer/api.ts:

```
export {RenderComponentType, Renderer, Renderer2, RendererFactory2,
      RendererStyleFlags2, RendererType2, RootRenderer} from './render/api';
```

and zone.ts file is a one-liner that just exports from zone/ng_zone.ts:

```
export {NgZone} from './zone/ng_zone';
```

Secondly, are files containing what we might call utility functionality:

- console.ts
- error_handler.ts
- platform_core_providers.ts
- security.ts
- types.ts
- util.ts
- version.ts

console.ts contains an injectable service used to write to the console:

```
@Injectable()
export class Console {
  log(message: string): void {
    // tslint:disable-next-line:no-console
    console.log(message);
  }
  // Note: for reporting errors use `DOM.logError()`
  // as it is platform specific
  warn(message: string): void {
    // tslint:disable-next-line:no-console
    console.warn(message);
  }
}
```

It is listed as an entry in `_CORE_PLATFORM_PROVIDERS` in platform_core_providers.ts, which is used to create platforms.

error_handler.ts defines he default error handler and also, in comments, describes how you could implement your own.

platform_core_providers.ts defines `_CORE_PLATFORM_PROVIDERS` which lists the core providers for dependency injection:

```
const _CORE_PLATFORM_PROVIDERS: StaticProvider[] = [
  // Set a default platform name for platforms that don't set it explicitly.
  {provide: PLATFORM_ID, useValue: 'unknown'},
  {provide: PlatformRef, deps: [Injector]},
  {provide: TestabilityRegistry, deps: []},
  {provide: Console, deps: []},
];
```

It also defines the `platformCore` const, used when creating platforms:

```
export const platformCore = createPlatformFactory(null, 'core',
                                                 _CORE_PLATFORM_PROVIDERS);
```

security.ts defines the `SecurityContext` enum:

```
export enum SecurityContext {
  NONE = 0,
  HTML = 1,
  STYLE = 2,
  SCRIPT = 3,
  URL = 4,
  RESOURCE_URL = 5,
}
```

and the `Sanitizer` abstract class:

```
/**
 * Sanitizer is used by the views to sanitize potentially dangerous values.
 *
 * @stable
 */
export abstract class Sanitizer {
  abstract sanitize(context: SecurityContext,
                    value: {}|string|null) : string|null;
}
```

They are used in <ANGULAR-MASTER>/packages/compiler/src/schema and <ANGULAR-MASTER>/packages/platform-browser/src/security to enfore security restrictions on potentially dangerous constructs.

The third category of source files directly in the src directory are files related to platform- and application-initialization. These include:

- application_init.ts
- application_module.ts
- application_tokens.ts
- application_ref.ts

The first three of these are small (50-70 lines of code), whereas application_ref.ts is larger at over 500 lines.

Let's start with application_tokens.ts. It contains one provider definition and a set of opaque tokens for various uses. `PLATFORM_INITIALIZER` is an opaque token that Angular itself and application code can use to register supplied functions that will be executed when a platform is initialized:

```
// A function that will be executed when a platform is initialized.
export const PLATFORM_INITIALIZER =
       new InjectionToken<Array<() => void>>('Platform Initializer');
```

An example usage within Angular is in platform-browser:

- <ANGULAR-MASTER>/packages/platform-browser/src/browser.ts

where it is used to have `initDomAdapter` function called upon platform initialization (note use of `multi` – which means multiple such initializer functions can be registered):

```
export const INTERNAL_BROWSER_PLATFORM_PROVIDERS: StaticProvider[] = [
  {provide: PLATFORM_ID, useValue: PLATFORM_BROWSER_ID},
  {provide: PLATFORM_INITIALIZER, useValue: initDomAdapter, multi: true},
  {provide: PlatformLocation, useClass: BrowserPlatformLocation,
                                                      deps: [DOCUMENT]},
  {provide: DOCUMENT, useFactory: _document, deps: []},
];
```

INTERNAL_BROWSER_PLATFORM_PROVIDERS is used a few lines later in browser.ts to create the browser platform (and so is used by most Angular applications):

```
  export const platformBrowser: (extraProviders?: StaticProvider[]) =>
    PlatformRef = createPlatformFactory(platformCore, 'browser',
    INTERNAL_BROWSER_PLATFORM_PROVIDERS);
```

Another opaque token in application_tokens.ts is PACKAGE_ROOT_URL - used to discover the application’s root directory.

The provider definition identified by APP_ID supplies a function that generates a unique string that can be used as an application identifier.

```
  export const APP_ID = new InjectionToken<string>('AppId');
```

A default implementation is supplied, that uses Math.random and this is then used to create an APP_ID_RANDOM_PROVIDER:

```
  function _randomChar(): string {
    return String.fromCharCode(97 + Math.floor(Math.random() * 25));
  }

  export function _appIdRandomProviderFactory() {
    return `${_randomChar()}${_randomChar()}${_randomChar()}`;
  }

  export const APP_ID_RANDOM_PROVIDER = {
    provide: APP_ID,
    useFactory: _appIdRandomProviderFactory,
    deps: <any[]>[],
  };
```

application_init.ts defines one opaque token and one injectable service. The opaque token is:

```
  // A function that will be executed when an application is initialized.
  export const APP_INITIALIZER =
             new InjectionToken<Array<() => void>>('Application Initializer');
```

APP_INITIALIZER Its role is similar to PLATFORM_INITIALIZER, except it is called when an application is initialized. The injectable service is ApplicationInitStatus, which returns the status of executing app initializers:

```
  // A class that reflects the state of running {@link APP_INITIALIZER}s.
  @Injectable()
  export class ApplicationInitStatus {
    private resolve: Function;
    private reject: Function;
    private initialized = false;
    public readonly donePromise: Promise<any>;
    public readonly done = false;

    constructor(@Inject(APP_INITIALIZER)
  @Optional() private appInits: (() => any)[]) {
      this.donePromise = new Promise((res, rej) => {
        this.resolve = res;
        this.reject = rej;
      });
    }
```

We will soon see how it is used in application_ref.ts.

application_module.ts defines the `ApplicationModule` class:

```
/**
 * This module includes the providers of @angular/core that are needed
 * to bootstrap components via `ApplicationRef`.
 */
@NgModule({
  providers: [
    ApplicationRef,
    ApplicationInitStatus,
    Compiler,
    APP_ID_RANDOM_PROVIDER,
    {provide: IterableDiffers, useFactory: _iterableDiffersFactory},
    {provide: KeyValueDiffers, useFactory: _keyValueDiffersFactory},
    {
      provide: LOCALE_ID,
      useFactory: _localeFactory,
      deps: [[new Inject(LOCALE_ID), new Optional(), new SkipSelf()]]
    },
  ]
})
export class ApplicationModule {
  // Inject ApplicationRef to make it eager...
  constructor(appRef: ApplicationRef) {}
}
```

Providers are supplied to Angular's dependency injection system. The `IterableDiffers` and `KeyValueDiffers` provides related to change detection. `ViewUtils` is defined in the src/linker sub-directory and contains utility-style code related to rendering.

The types in application_ref.ts plays a pivotal role in how the entire Angular infrastructure works. Application developers wishing to learn how Angular really works are strongly encouraged to carefully study the code in application_ref.ts. Let's start our examination by looking at the `createPlatformFactory()` function:

```
export function createPlatformFactory(
1   parentPlatformFactory:
       ((extraProviders?: StaticProvider[]) => PlatformRef) | null,
2   name: string,
3   providers: StaticProvider[] = [])
4       : (extraProviders?: StaticProvider[]) => PlatformRef {
  const marker = new InjectionToken(`Platform: ${name}`);
5 return (extraProviders: StaticProvider[] = []) => {
    let platform = getPlatform();
    if (!platform || platform.injector.get(ALLOW_MULTIPLE_PLATFORMS, false)) {
      if (parentPlatformFactory) {
        parentPlatformFactory(
            providers.concat(extraProviders).concat(
                           {provide: marker, useValue: true}));
      } else {
6       createPlatform(Injector.create(
            providers.concat(extraProviders).concat(
                            {provide: marker, useValue: true})));
      }
    }
7   return assertPlatform(marker);
  };
}
```

It takes three parameters – 1 `parentPlatformFactory`, 2 `name` and an 3 array of providers. It returns 4 a factory function, that when called, will return a `PlatformRef`.

This factory function first creates an opaque token 5 to use for DI lookup based on the supplied name; then it calls `getPlatform()` to see if a platform already exists (only one is permitted at any one time), and if false is returned, it calls 6 `createPlatform()`, passing in the result of a call to `ReflectiveInjector`’s `resolveAndCreate` (supplied with the providers parameter). Then 7 `assertPlatform` is called with the marker and the result of that call becomes the result of the factory function.

`PlatformRef` is defined as:

```
  @Injectable()
  export class PlatformRef {
    private _modules: NgModuleRef<any>[] = [];
    private _destroyListeners: Function[] = [];
    private _destroyed: boolean = false;

    /** @internal */
    constructor(private _injector: Injector) {}

    bootstrapModuleFactory<M>(
       moduleFactory: NgModuleFactory<M>,
       options?: BootstrapOptions): Promise<NgModuleRef<M>> {    }


    bootstrapModule<M>(
         moduleType: Type<M>,
     compilerOptions: (CompilerOptions&BootstrapOptions)|Array<CompilerOptions&BootstrapOptions>=[]
    ) : Promise<NgModuleRef<M>> {   }

    private _moduleDoBootstrap(moduleRef: InternalNgModuleRef<any>): void {   }

    onDestroy(callback: () => void): void {   }

    get injector(): Injector { return this._injector; }

    destroy() {   }

    get destroyed() { return this._destroyed; }
  }
```

A platform represents the hosting environment within which one or more applications execute. Different platforms are supported (e.g. browser UI, web worker, server and you can create your own). For a web page, it is how application code interacts with the page (e.g. sets URL). `PlatformRef` represents the platform, and we see its two main features are supplying the root injector and module bootstrapping. The other members are to do with destroying resources when no longer needed.

The supplied implementation of PlatformRef manages the root injector passed in to the constructor, an array of `NgModuleRef`s and an array of destroy listeners. In the constructor, it takes in an injector. Note that calling the platform's `destroy()` method will result in all applications that use that platform having their `destroy()` methods called.

The two bootstrapping methods are `bootstrapModule` and `bootstrapModuleFactory`. An important decision for any Angular application team is to decide when to use the runtime compilation and when to use offline compilation. Runtime compilation is simpler to use and is demonstrated in the Quickstart on Angular.io. Runtime compilation makes the application bigger (the template compiler needs to run in the browser) and is slower (template compilation is required before the template can be used). Applications that use runtime compilation need to call `bootstrapModule`. Offline compilation involves extra build time configuration and so is a little more complex to set up, but due to its performance advantages is likely to be used for large production applications. Applications that use offline compilation need to call `bootstrapModuleFactory()`.

```
bootstrapModule<M>(
     moduleType: Type<M>,
     compilerOptions: (CompilerOptions&BootstrapOptions)|
     Array<CompilerOptions&BootstrapOptions> = []): Promise<NgModuleRef<M>> {

const compilerFactory: CompilerFactory = this.injector.get(CompilerFactory);
const options = optionsReducer({}, compilerOptions);
const compiler = compilerFactory.createCompiler([options]);

1 return compiler.compileModuleAsync(moduleType)
2 .then((moduleFactory)=>this.bootstrapModuleFactory(moduleFactory,
options));
}
```

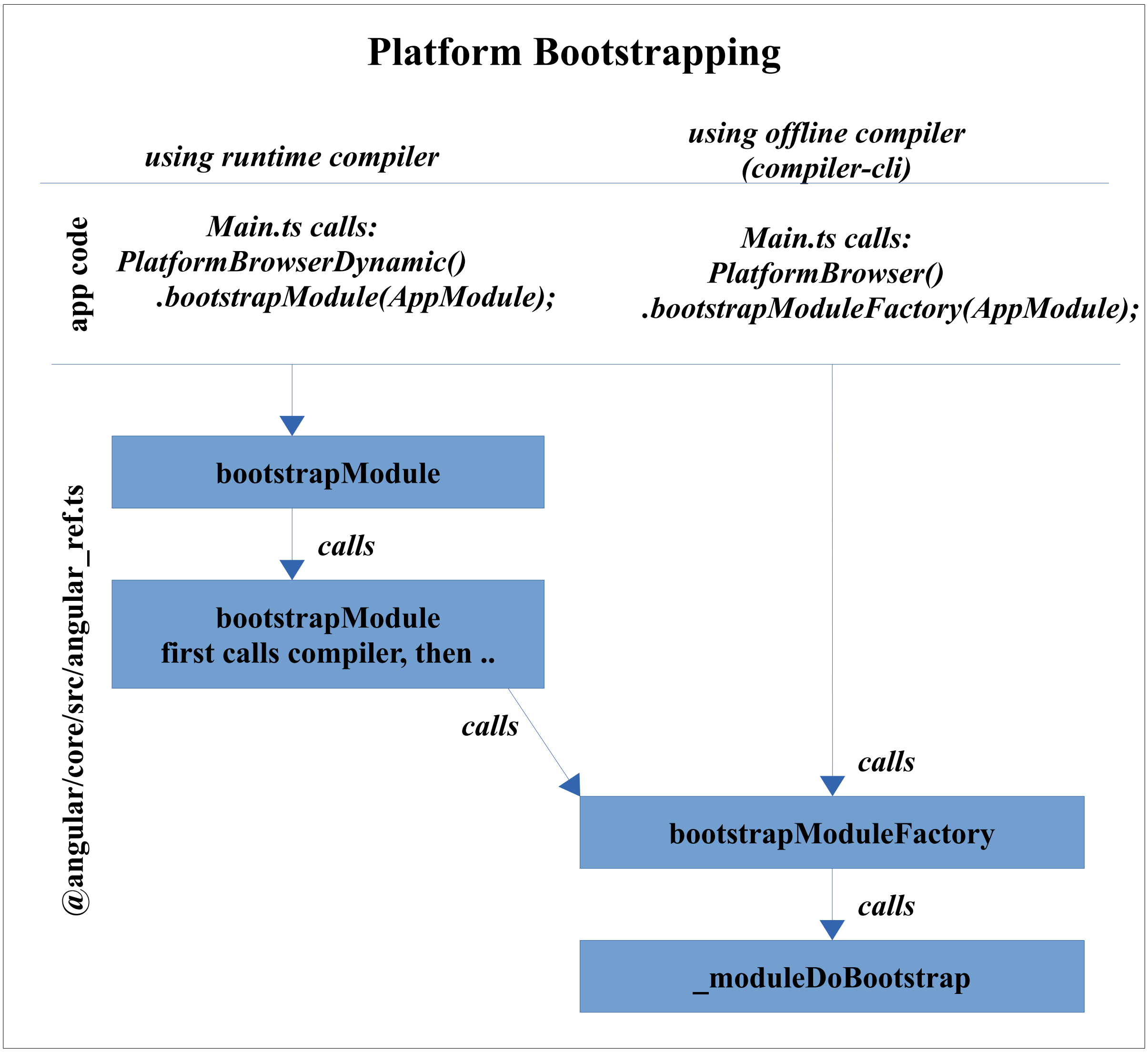
`bootstrapModule` first calls 1 the template compiler and then 2 calls `bootstrapModuleFactory`, so after the extra runtime compilation step, both bootstrapping approaches follow the same code path.

When examining zones we already looked at the use of zones within `bootstrapModuleFactory` d- other important code there includes the construction of `moduleRef` 1 and the call to 2 `_moduleDoBootstrap(moduleRef)`:

```
1 const moduleRef =
<InternalNgModuleRef<M>>moduleFactory.create(ngZoneInjector);

return _callAndReportToErrorHandler(exceptionHandler, ngZone !, () => {
  const initStatus: ApplicationInitStatus =
moduleRef.injector.get(ApplicationInitStatus);
  initStatus.runInitializers();
  return initStatus.donePromise.then(() => {
2   this._moduleDoBootstrap(moduleRef);
    return moduleRef;
  });
```

It is in `_moduleDoBootstrap` that we see the actual bootstrapping taking place:

```
private _moduleDoBootstrap(moduleRef: InternalNgModuleRef<any>): void {
      const appRef = moduleRef.injector.get(ApplicationRef) as ApplicationRef;
      if (moduleRef._bootstrapComponents.length > 0) {
        moduleRef._bootstrapComponents.forEach(f => appRef.bootstrap(f));
      } else if (moduleRef.instance.ngDoBootstrap) {
        moduleRef.instance.ngDoBootstrap(appRef);
      } else {
        throw new Error(
            `The module ${stringify(moduleRef.instance.constructor)} was
            bootstrapped, but it does not declare "@NgModule.bootstrap"
            components nor a "ngDoBootstrap" method. ` +
            `Please define one of these.`);
      }
      this._modules.push(moduleRef);
    }
```


Platform Bootstrapping
using runtime compiler
using offline compiler (compiler-cli)
app code
Main.ts calls: PlatformBrowserDynamic() .bootstrapModule(AppModule);
Main.ts calls: PlatformBrowser() .bootstrapModuleFactory(AppModule);
@angular/core/src/angular_ref.ts
bootstrapModule
calls
bootstrapModule first calls compiler, then ..
calls
calls
bootstrapModuleFactory
calls
_moduleDoBootstrap

In addition to bootstrapping functionality, there are a few simple platform-related functions in core/src/application_ref.ts. `createPlatform()` creates a platform ref instance, or more accurately, as highlighted in the code, asks the injector for a platform ref and then calls the initializers:

```
  /**
   * Creates a platform.
   * Platforms have to be eagerly created via this function.
```

```
 */
export function createPlatform(injector: Injector): PlatformRef {
  if (_platform && !_platform.destroyed &&
      !_platform.injector.get(ALLOW_MULTIPLE_PLATFORMS, false)) {
    throw new Error(
        'There can be only one platform.
         Destroy the previous one to create a new one.');
  }
  _platform = injector.get(PlatformRef);
  const inits = injector.get(PLATFORM_INITIALIZER, null);
  if (inits) inits.forEach((init: any) => init());
  return _platform;
}
```

Only a single platform may be active at any one time. `_platform` is defined as:

```
let _platform: PlatformRef;;
```

The `getPlatform()` function is simply defined as:

```
export function getPlatform(): PlatformRef|null {
  return _platform && !_platform.destroyed ? _platform : null;
}
```

The `assertPlatform()` function ensures two things, and if either false, throws an error. Firstly it ensures that a platform exists, and secondly that its injector has a provider for the token specified as a parameter.

```
/**
 * Checks that there currently is a platform which contains the
 * given token as a provider.
 */
export function assertPlatform(requiredToken: any): PlatformRef {
  const platform = getPlatform();
  if (!platform) { throw new Error('No platform exists!'); }
  if (!platform.injector.get(requiredToken, null)) {
    throw new Error(
        'A platform with a different configuration has been created.
         Please destroy it first.');
  }
  return platform;
}
```

The `destroyPlatform()` function calls the `destroy` method for the platform:

```
export function destroyPlatform(): void {
  if (_platform && !_platform.destroyed) {
    _platform.destroy();
  }
}
```

The run mode specifies whether the platform is is production mode or developer mode. By default, it is in developer mode:

```
let _devMode: boolean = true;
let _runModeLocked: boolean = false;
```

This can be set by calling `enableProdMode()`:

```
export function enableProdMode(): void {
  if (_runModeLocked) {
    throw new Error('Cannot enable prod mode after platform setup.');
  }
  _devMode = false;
}
```

To determine which mode is active, call `isDevMode()`. This always returns the same value. In other words, whatever mode is active when this is first call, that is the mode that is always active.

```
  export function isDevMode(): boolean {
    _runModeLocked = true;
    return _devMode;
  }
```

`ApplicationRef` is defined as:

```
  @Injectable()
  export class ApplicationRef {
    public readonly componentTypes: Type<any>[] = [];
    public readonly components: ComponentRef<any>[] = [];
    public readonly isStable: Observable<boolean>;
    bootstrap<C>(componentOrFactory: ComponentFactory<C>|Type<C>,
                                 rootSelectorOrNode?: string|any): {}
    tick(): void { }
    attachView(viewRef: ViewRef): void { }
    detachView(viewRef: ViewRef): void { }
    get viewCount() { return this._views.length; }
  }
```

It main method is `bootstrap()`, which is a generic method with a type parameter - which attaches the component to DOM elements and sets up the application for execution. Note that bootstrap's parameter is a union type, it represents either a `ComponentFactory` or a `Type`, both of which take C as a type parameter.

One implementation of `ApplicationRef` is supplied, called `ApplicationRef_`. This is marked as `Injectable()`. It maintains the following fields:

```
    static _tickScope: WtfScopeFn = wtfCreateScope('ApplicationRef#tick()');
    private _bootstrapListeners: ((compRef: ComponentRef<any>) => void)[] = [];
    private _views: InternalViewRef[] = [];
    private _runningTick: boolean = false;
    private _enforceNoNewChanges: boolean = false;
    private _stable = true;
```

Its constructor shows what it needs from an injector and sets up the observables (code here is abbreviated):

```
     constructor(
         private _zone: NgZone,
         private _console: Console,
         private _injector: Injector,
         private _exceptionHandler: ErrorHandler,
         private _componentFactoryResolver: ComponentFactoryResolver,
         private _initStatus: ApplicationInitStatus) {

      this._enforceNoNewChanges = isDevMode();

     this._zone.onMicrotaskEmpty.subscribe(
         {next: () => { this._zone.run(() => { this.tick(); }); }});

     const isCurrentlyStable =
         new Observable<boolean>((observer: Observer<boolean>) => {
        });

        const isStable = new Observable<boolean>((observer: Observer<boolean>)=>{
          // Create the subscription to onStable outside the Angular Zone so that
          // the callback is run outside the Angular Zone.
          let stableSub: Subscription;
          this._zone.runOutsideAngular(()
          });

          const unstableSub: Subscription = this._zone.onUnstable.subscribe();
        });

          return () => {
            stableSub.unsubscribe();
            unstableSub.unsubscribe();
          };
        });

        (this as{isStable: Observable<boolean>}).isStable =
            merge(isCurrentlyStable, share.call(isStable));
```

Its `bootstrap()` implementation passes some code to the run function (to run in the zone) and this code calls `componentFactory.create()` to create the component and then `_loadComponent()`.

```
    bootstrap<C>(componentOrFactory: ComponentFactory<C>|Type<C>,
    rootSelectorOrNode?: string|any):
          ComponentRef<C> {

        let componentFactory: ComponentFactory<C>;
        if (componentOrFactory instanceof ComponentFactory) {
          componentFactory = componentOrFactory;
        } else {
          componentFactory = this._componentFactoryResolver
                               .resolveComponentFactory(componentOrFactory) !;
        }
        this.componentTypes.push(componentFactory.componentType);

         // Create a factory associated with the current module if
         // it's not bound to some other
        const ngModule = componentFactory instanceof
                                  ComponentFactoryBoundToModule ? Null :
                                  this._injector.get(NgModuleRef);
        const selectorOrNode = rootSelectorOrNode || componentFactory.selector;
        const compRef = componentFactory.create(Injector.NULL, [],
                                                  selectorOrNode, ngModule);
        ..
        this._loadComponent(compRef);
        ..
        return compRef;
      }
```

`_loadComponent()` is defined as:

```
    private _loadComponent(componentRef: ComponentRef<any>): void {
        this.attachView(componentRef.hostView);
        this.tick();
        this.components.push(componentRef);
        // Get the listeners lazily to prevent DI cycles.
```

```
      const listeners =
          this._injector.get(APP_BOOTSTRAP_LISTENER, [])
                          .concat(this._bootstrapListeners);
      listeners.forEach((listener) => listener(componentRef));
    }
```

Attached views are those that can be attached to a view container and are subject to dirty checking. Such views can be attached and detached, and an array of attached views is recorded.

```
private _views: InternalViewRef[] = [];
attachView(viewRef: ViewRef): void {
    const view = (viewRef as InternalViewRef);
    this._views.push(view);
    view.attachToAppRef(this);
}
detachView(viewRef: ViewRef): void {
    const view = (viewRef as InternalViewRef);
    remove(this._views, view);
    view.detachFromAppRef();
}
get viewCount() { return this._views.length; }
```

core/src/util

The core/src/util directory contains two files:

- decorators.ts
- lang.ts

decorators.ts includes definition of the `TypeDecorator` class, which is the basis for Angular’s type decorators. Its `makeDecorator()` function uses reflection to examine annotations and returns a `decoratorFactory` function declared inline. Similar make functions are supplied for parameters and properties.

Core/DependencyInjection Feature (core/src/di)

The core/src/di.ts source file exports a variety of dependency injection types:

```
export * from './di/metadata';
export {forwardRef, resolveForwardRef, ForwardRefFn} from './di/forward_ref';
export {Injector} from './di/injector';
export {ReflectiveInjector} from './di/reflective_injector';
export {StaticProvider, ValueProvider, ExistingProvider, FactoryProvider,
          Provider, TypeProvider, ClassProvider} from './di/provider';
export {ResolvedReflectiveFactory, ResolvedReflectiveProvider}
          from './di/reflective_provider';
export {ReflectiveKey} from './di/reflective_key';
export {InjectionToken} from './di/injection_token';
```

The core/src/di directory contains these files:

- forward_ref.ts
- injection_token.ts
- injector.ts
- metadata.ts
- opaque_token.ts
- provider.ts
- reflective_errors.ts

- reflective_injector.ts
- reflective_key.ts
- reflective_provider.ts

The metadata.ts file defines these interfaces:

```
export interface InjectDecorator {
  (token: any): any;
  new (token: any): Inject;
}
export interface Inject { token: any; }
export interface OptionalDecorator {
  (): any;
  new (): Optional;
}
export interface Optional {}
export interface InjectableDecorator {
  (): any;
  new (): Injectable;
}
export interface Injectable {}
export interface SelfDecorator {
  (): any;
  new (): Self;
}
export interface Self {}
export interface SkipSelfDecorator {
  (): any;
  new (): SkipSelf;
}
export interface SkipSelf {}
export interface HostDecorator {
  (): any;
  new (): Host;
}
export interface Host {}
```

metadata.ts also defines these variables:

```
export const Self: SelfDecorator = makeParamDecorator('Self');
export const SkipSelf: SkipSelfDecorator = makeParamDecorator('SkipSelf');
export const Inject: InjectDecorator = makeParamDecorator('Inject', (token:
any) => ({token}));
export const Optional: OptionalDecorator = makeParamDecorator('Optional');
export const Injectable: InjectableDecorator = makeDecorator('Injectable');
export const Host: HostDecorator = makeParamDecorator('Host');
```

Forward refs are placeholders used to faciliate out-of-sequence type declarations. The forward_ref.ts file defines an interface and two functions:

```
export interface ForwardRefFn { (): any; }

export function forwardRef(forwardRefFn: ForwardRefFn): Type<any> {
  (<any>forwardRefFn).__forward_ref__ = forwardRef;
  (<any>forwardRefFn).toString = function() { return stringify(this()); };
  return (<Type<any>><any>forwardRefFn);
}

export function resolveForwardRef(type: any): any {
  if (typeof type === 'function' && type.hasOwnProperty('__forward_ref__') &&
      type.__forward_ref__ === forwardRef) {
    return (<ForwardRefFn>type)();
  } else {
    return type;
  }
}
```

The injector.ts file defines the `Injector` abstract class:

```
export abstract class Injector {
  static THROW_IF_NOT_FOUND = _THROW_IF_NOT_FOUND;
  static NULL: Injector = new _NullInjector();
  abstract get<T>(token: Type<T>|InjectionToken<T>, notFoundValue?: T): T;
  abstract get(token: any, notFoundValue?: any): any;
  static create(providers: StaticProvider[], parent?: Injector): Injector {
    return new StaticInjector(providers, parent);
  }
}
```

Application code (and indeed, Angular internal code) passes a token to `Injector.get()`, and the implementation returns the matching instance. Concrete implementations of this class need to override the `get()` method, so it actually works as expected. See reflective_injector.ts for a derived class.

provider.ts defines a number of `Provider` classes and then uses them to define the `Provider` type:

```
export type Provider =
    TypeProvider | ValueProvider | ClassProvider |
              ExistingProvider | FactoryProvider | any[];
```

Core/Metadata Feature (core/src/metadata)

Think of metadata as little nuggets of information we would like to attach to other things. The <ANGULAR-MASTER>/core/src/metadata.ts file exports a variety of types from the core/src/metadata sub-directory:

```
export {ANALYZE_FOR_ENTRY_COMPONENTS, Attribute, ContentChild,
     ContentChildDecorator, ContentChildren, ContentChildrenDecorator,
     Query, ViewChild, ViewChildDecorator, ViewChildren,
     ViewChildrenDecorator} from './metadata/di';
export {Component, ComponentDecorator, Directive, DirectiveDecorator,
     HostBinding, HostListener, Input, Output, Pipe}
     from './metadata/directives';
export {AfterContentChecked, AfterContentInit, AfterViewChecked,
     AfterViewInit, DoCheck, OnChanges, OnDestroy, OnInit}
     from './metadata/lifecycle_hooks';
export {CUSTOM_ELEMENTS_SCHEMA, ModuleWithProviders, NO_ERRORS_SCHEMA,
     NgModule, SchemaMetadata} from './metadata/ng_module';
export {ViewEncapsulation} from './metadata/view';
```

The source files in the <ANGULAR-MASTER>/packages/core/src/metadata sub-directory are:

- di.ts
- directives.ts
- lifecycle_hooks.ts
- ng_module.ts
- view.ts

The di.ts file defines a range of interfaces for decorators – these include AttributeDecorator, ContentChildrenDecorator, ContentChildDecorator, ViewChildrenDecorator, ViewChildDecorator. It also defines and exports a number of consts that are imp[lementations of those interfaces, created using makePropDecorator.

The view.ts file defines an enum, a var and a class. The ViewEncapsulation enum is defined as:

```
export enum ViewEncapsulation {
  Emulated=0,
  Native=1,
  None=2
}
```

These represent how template and style encapsulation should work. None means don't use encapsulation, Native means use what the renderer offers (specifically the Shadow DOM) and Emulated is best explained by the comment:

```
/**
 * Emulate `Native` scoping of styles by adding an attribute containing
 * surrogate id to the Host Element and pre-processing the style rules
 * provided via {@link Component#styles styles} or
 * {@link Component#styleUrls styleUrls}, and adding the new
 * Host Element attribute to all selectors.
 *
 * This is the default option.
 */
```

The directives.ts file exports interfaces related to directive metadata. They include:

- DirectiveDecorator
- Directive
- ComponentDecorator
- Component
- PipeDecorator
- Pipe
- InputDecorator
- Input
- OutputDecorator
- Output
- HostBindingDecorator
- HostBinding
- HostListenerDecorator
- HostListener

The lifecycle_hooks.ts file defines a number of interfaces used for lifecycle hooks:

```
export interface SimpleChanges { [propName: string]: SimpleChange; }
export interface OnChanges { ngOnChanges(changes: SimpleChanges): void; }
export interface OnInit { ngOnInit(): void; }
export interface DoCheck { ngDoCheck(): void; }
export interface OnDestroy { ngOnDestroy(): void; }
export interface AfterContentInit { ngAfterContentInit(): void; }
export interface AfterContentChecked { ngAfterContentChecked(): void; }
export interface AfterViewInit { ngAfterViewInit(): void; }
export interface AfterViewChecked { ngAfterViewChecked(): void; }
```

These define the method signatures for handlers that application component interest in the lifecycle hooks must implement.

The ng_module.ts file contains constructs used to define Angular modules. An Angular application is built from a set of these and `NgModule` is used to tie them together:

```
export interface NgModule {
  providers?: Provider[];
  declarations?: Array<Type<any>|any[]>;
  imports?: Array<Type<any>|ModuleWithProviders|any[]>;
  exports?: Array<Type<any>|any[]>;
  entryComponents?: Array<Type<any>|any[]>;
  bootstrap?: Array<Type<any>|any[]>;
  schemas?: Array<SchemaMetadata|any[]>;
  id?: string;
}
```

An `NgModuleDecorator` is how `NgModule` is attached to a type:

```
export interface NgModuleDecorator {
  (obj?: NgModule): TypeDecorator;
  new (obj?: NgModule): NgModule;
}
```

We see their usage when we explore the boilerplate code that Angular CLI generates for us when we use it to create a new Angular project. Look inside

- <my-project>/src/app/app.module.ts

and we will see:

```
@NgModule({
  declarations: [
    <your-components>
  ],
  imports: [
    BrowserModule,
    FormsModule,
    HttpModule
  ],
  providers: [
    Title,
    <your-custom-providers>
  ],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

and when we look at:

- <my-project>/src/main.ts

we see:

```
import { platformBrowserDynamic } from '@angular/platform-browser-dynamic';
import { AppModule } from './app/app.module';
..
platformBrowserDynamic().bootstrapModule(AppModule)
                          .catch(err => console.log(err));
```

Core/Profile Feature (core/src/profile)

The profile directory has these files:

- profile.ts
- wtf_impl.ts

WTF is the Web Tracing Framework:

- http://google.github.io/tracing-framework/

> *"The Web Tracing Framework is a collection of libraries, tools, and scripts aimed at web developers trying to write large, performance-sensitive Javascript applications. It's designed to be used in conjunction with the built-in development tools of browsers but goes far beyond what they usually support at the cost of some user setup time."*
> *from: http://google.github.io/tracing-framework/overview.html*

Its github project is here:

- https://github.com/google/tracing-framework

wtf_impl.ts define the following interfaces:

```
export interface WtfScopeFn { (arg0?: any, arg1?: any): any; }
interface WTF { trace: Trace; }
interface Trace {
  events: Events;
  leaveScope(scope: Scope, returnValue: any): any;
  beginTimeRange(rangeType: string, action: string): Range;
  endTimeRange(range: Range): any;
}
export interface Range {}
interface Events {
  createScope(signature: string, flags: any): Scope;
}
export interface Scope { (...args: any[]): any; }
```

It maintains two variables:

```
let trace: Trace;
let events: Events;
```

It defines some functions to work with those variables:

```
export function createScope(signature: string, flags: any = null): any {
  return events.createScope(signature, flags);
}
export function leave<T>(scope: Scope): void;
export function leave<T>(scope: Scope, returnValue?: T): T;
export function leave<T>(scope: Scope, returnValue?: any): any {
  trace.leaveScope(scope, returnValue);
  return returnValue;
}
export function startTimeRange(rangeType: string, action: string): Range {
  return trace.beginTimeRange(rangeType, action);
}
export function endTimeRange(range: Range): void {
  trace.endTimeRange(range);
}
```

Finally it has a `detectWtf` function:

```
export function detectWTF(): boolean {
  const wtf: WTF = (global as any /** TODO #9100 */)['wtf'];
  if (wtf) {
    trace = wtf['trace'];
    if (trace) {
      events = trace['events'];
      return true;
    }
  }
  return false;
}
```

The profile.ts file exports WTF-related variables:

```
export {WtfScopeFn} from './wtf_impl';
export const wtfEnabled = detectWTF();
export const wtfCreateScope: (signature: string, flags?: any) => WtfScopeFn =
    wtfEnabled ? createScope : (signature: string, flags?: any) => noopScope;
export const wtfLeave: <T>(scope: any, returnValue?: T) => T =
    wtfEnabled ? leave : (s: any, r?: any) => r;
export const wtfStartTimeRange: (rangeType: string, action: string) => any =
    wtfEnabled ? startTimeRange : (rangeType: string, action: string) =>
null;
export const wtfEndTimeRange: (range: any) => void = wtfEnabled ?
endTimeRange : (r: any) => null;
```

Core Reflection Feature (core/src/reflection)

The reflection directory has these files:

- platform_reflection_capabilities.ts
- reflection_capabilities.ts
- reflection.ts
- reflector.ts
- types.ts

The types.ts file define these:

```
export type SetterFn = (obj: any, value: any) => void;
export type GetterFn = (obj: any) => any;
export type MethodFn = (obj: any, args: any[]) => any;
```

The reflection.ts file has these lines:

```
export {Reflector} from './reflector';
export const reflector = new Reflector(new ReflectionCapabilities());
```

The platform_reflection_capabilities.ts file defines this interface:

```
export interface PlatformReflectionCapabilities {
  isReflectionEnabled(): boolean;
  factory(type: Type<any>): Function;
  hasLifecycleHook(type: any, lcProperty: string): boolean;
  parameters(type: Type<any>): any[][];
  annotations(type: Type<any>): any[];
  propMetadata(typeOrFunc: Type<any>): {[key: string]: any[]};
  getter(name: string): GetterFn;
  setter(name: string): SetterFn;
  method(name: string): MethodFn;
  importUri(type: Type<any>): string;
  resourceUri(type: Type<any>): string;
```

```
    resolveIdentifier(name: string, moduleUrl: string,
                          members: string[], runtime: any): any;
    resolveEnum(enumIdentifier: any, name: string): any;
  }
```

The reflection_capabilities.ts provides an implementation of that interface called `ReflectionCapabilities`. We see the main part of reflection is in the reflector.ts file, which defines the `Reflector` class – its methods mostly forward calls to the supplied `ReflectionCapabilities` instance:

```
  /**
   * Provides access to reflection data about symbols.
   * Used internally by Angular to power dependency injection and compilation.
   */
  export class Reflector {
    constructor(public reflectionCapabilities:
                        PlatformReflectionCapabilities) {}
    updateCapabilities(caps: PlatformReflectionCapabilities)
                      { this.reflectionCapabilities = caps; }
    factory(type: Type<any>): Function
       { return this.reflectionCapabilities.factory(type); }
    parameters(typeOrFunc: Type<any>): any[][]
      { return this.reflectionCapabilities.parameters(typeOrFunc); }
    annotations(typeOrFunc: Type<any>): any[]
     { return this.reflectionCapabilities.annotations(typeOrFunc);}
    propMetadata(typeOrFunc: Type<any>): {[key: string]: any[]}
      { return this.reflectionCapabilities.propMetadata(typeOrFunc); }
    hasLifecycleHook(type: any, lcProperty: string): boolean
     { return this.reflectionCapabilities.hasLifecycleHook(type, lcProperty); }
    getter(name: string): GetterFn
       { return this.reflectionCapabilities.getter(name); }
    setter(name: string): SetterFn
       { return this.reflectionCapabilities.setter(name); }
    method(name: string): MethodFn
       { return this.reflectionCapabilities.method(name); }
    importUri(type: any): string
       { return this.reflectionCapabilities.importUri(type); }
    resourceUri(type: any): string
       { return this.reflectionCapabilities.resourceUri(type); }
    resolveIdentifier(name: string, moduleUrl: string,
         members: string[], runtime: any): any {
      return this.reflectionCapabilities.resolveIdentifier(
                                             name, moduleUrl, members, runtime);
    }
    resolveEnum(identifier: any, name: string): any {
      return this.reflectionCapabilities.resolveEnum(identifier, name);
    }
  }
```

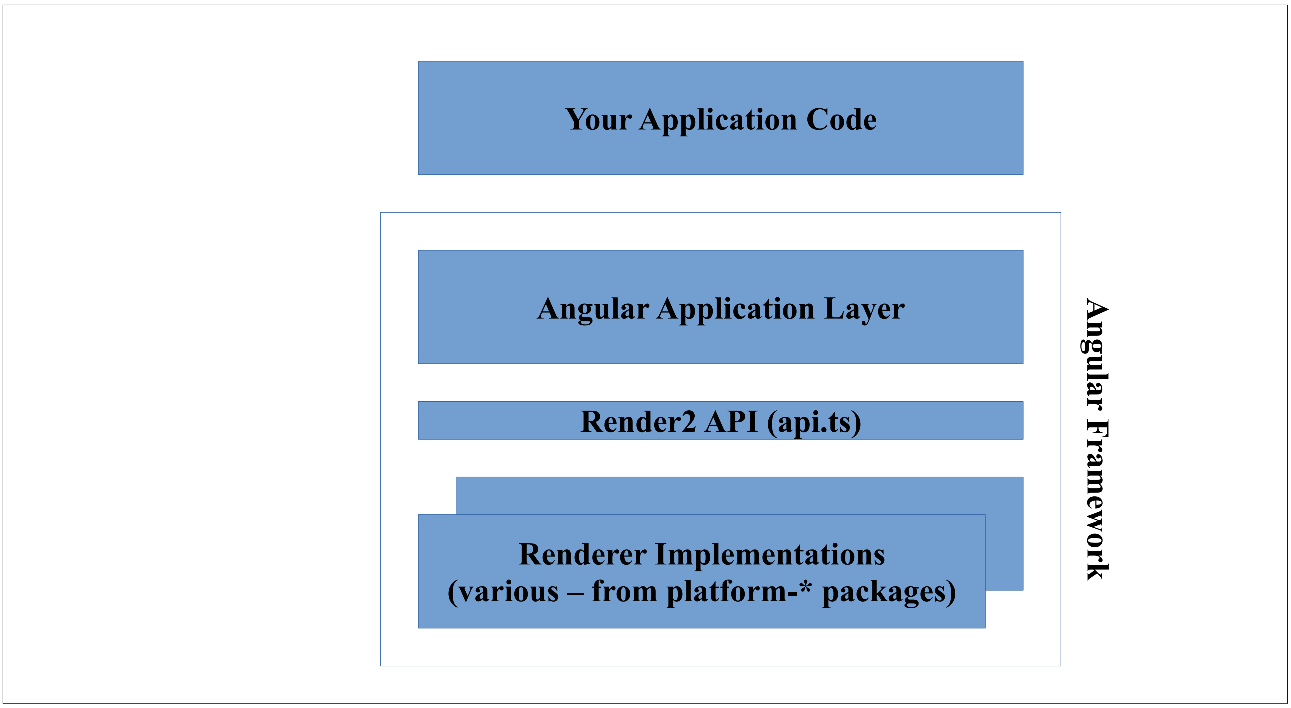
Core Render Feature (core/src/render)

> *Note: There is a new render view engine (called Render3) coming with Angular 6 – a good place to keep an eye on progress and how it is evolving is:*
> *https://github.com/angular/angular/tree/master/packages/core/src/render3*
>
> *What we describe below is Render2, which is used for Angular 5*

Layering for Angular applications involves your application code talking to the Angular framework, which is layered into an application layer and a renderer layer, with a renderer API in between. The core/src/render/api.ts file defines this thin API and nothing else. The API consists of these abstract classes - `RendererType2`, `Renderer2`, `RendererFactory2` and `RendererStyleFlags2`. Implementation of this API is not part of Core. Instead, the various Platform-X packages need to provide the actual implementations for different scenarios.

Scenarios with diverse rendering requirements include:

- UI web apps in regular browser
- web worker apps
- server apps
- native apps for mobile devices
- testing



The Renderer API is defined in terms of elements – and provides functionality e.g. to create elements, set their properties and listen for their events. The Renderer API is not defined in terms of a DOM. Indeed, the term "DOM" is not part of any of the method names in this API (though it is mentioned in some comments). In that way, how rendering is provided is an internal implementation detail, easily replaced in different scenarios if needed. Obviously, for a web app running in the main UI thread in a regular browser, the platform used for that needs to implement the Renderer API in terms of the browser's DOM (and platform-browser does). But take a web worker as an alternative, where there simply is no browser DOM – a different platform needs to provide an alternative rendering solution. We will be examining in detail how rendering implementations work when we cover platforms later.

A notable characteristic of the Renderer API is that, even though it is defined in terms of elements, it does not list anywhere what those elements are. Elements are identified in terms of string names, but what are valid names is not part of the renderer. Instead, there is an element schema registry defined in the template compiler (<ANGULAR-MASTER>/packages/compiler/src/schema) and we will examine it further when looking at the template compiler.

Now we will move on to looking at the renderer API. This API is exported from the

- <ANGULAR-MASTER>/packages/core/src/render.ts

and it contains this export:

```
export {
  Renderer2, RendererFactory2, RendererStyleFlags2, RendererType2,
   /* following are deprecated */
  RenderComponentType, Renderer, RootRenderer,} from './render/api';
```

We note a number of the exports have "2" in their name and when we examine the actual definitions we see those that do not are deprecated so will will not be covering those here. If looking at older documentation you may encounter them, but specifically for rendering, for up to date code you should be looking at rendering classes with 2 in the name. Also note '2' for rendering is not tied to Angular version 2 (actually that version of Angular used the older version of the rendering APIs).

The core/src/render directory has just one file:

- <ANGULAR-MASTER>/packages/core/src/render/api.ts

and this contains the rendering definitions we will see used elsewhere by platform-implementations.

RendererType2 is used to identify component types for which rendering is needed, and is defined as:

```
export interface RendererType2 {
  id: string;
  encapsulation: ViewEncapsulation;
  styles: (string|any[])[];
  data: {[kind: string]: any};
}
```

The RendererFactory2 class is used to register a provider with dependency injection and is defined as:

```
export abstract class RendererFactory2 {
  abstract createRenderer(hostElement: any,
                 type: RendererType2|null): Renderer2;
  abstract begin?(): void;
  abstract end?(): void;
  abstract whenRenderingDone?(): Promise<any>;
}
```

Essentially, its main method, createRenderer(), is used to answer this - "for a given host element, please give me back a renderer that I can use". This is key to wiring up flexible rendering of components via dependency injection.

An example usage is in:

- <ANGULAR-MASTER>/packages/platform-browser/src/browser.ts

where browserModule is defined as:

```
@NgModule({
  providers: [
    ..
    DomRendererFactory2,
    {provide: RendererFactory2, useExisting: DomRendererFactory2},
    ..
  ],
  exports: [CommonModule, ApplicationModule]
})
export class BrowserModule { .. }
```

Another example usage is in:

- <ANGULAR-MASTER>/packages/platform-webworker/src/worker_app.ts

where `WorkerAppModule` is defined as:

```
@NgModule({
  providers: [
    ..
    WebWorkerRendererFactory2,
    {provide: RendererFactory2, useExisting: WebWorkerRendererFactory2},
    RenderStore,
    ..
  ],
  exports: [
    CommonModule,
    ApplicationModule,
  ]
})
export class WorkerAppModule {}
```

The result of this is that different root renderers can be supplied via dependency injection for differing scenarios, and client code using the renderer API can use a suitable implementation. If that is how the `RendererFactory2` gets into dependency injection system, then of course the next question is, how does it get out?

The file

- <ANGULAR-MASTER>/packages/core/src/view/services.ts

has this:

```
function createProdRootView(
  elInjector: Injector, projectableNodes: any[][],
  rootSelectorOrNode: string | any,
  def: ViewDefinition, ngModule: NgModuleRef<any>, context?: any): ViewData {

 const rendererFactory: RendererFactory2 =
                          ngModule.injector.get(RendererFactory2);
  return createRootView(createRootData(elInjector, ngModule, rendererFactory,
     projectableNodes, rootSelectorOrNode), def, context);
}
```

which is called from:

```
function createProdServices() {
  return {
    setCurrentNode: () => {},
    createRootView: createProdRootView, ...
```

which in turn is called from:

```
export function initServicesIfNeeded() {
  if (initialized) { return;   }
  initialized = true;
  const services = isDevMode()
                      ? createDebugServices() : createProdServices();
```

which is finally called from inside:

- <ANGULAR-MASTER>/packages/core/src/view/entrypoint.ts

in `NgModuleFactory_.create()` method:

```
class NgModuleFactory_ extends NgModuleFactory<any> {
  ..
  create(parentInjector: Injector|null): NgModuleRef<any> {
    initServicesIfNeeded();
    ..
  }
}
```

Now we'll move on to the principal class in the Renderer API, `Renderer2`, which is abstract and declares the following methods:

get data
destroy
createElement
createComment
createText
destroyNode
appendChild
insertBefore
removeChild
selectRootElement
parentNode
nextSibling
setAttribute
removeAttribute
addClass
removeClass
setStyle
removeStyle
setProperty
setValue
listen

`Renderer2` in full is as follows:

```
export abstract class Renderer2 {
  abstract get data(): {[key: string]: any};
  abstract destroy(): void;
  abstract createElement(name: string, namespace?: string|null): any;
  abstract createComment(value: string): any;
  abstract createText(value: string): any;
  destroyNode: ((node: any) => void)|null;
  abstract appendChild(parent: any, newChild: any): void;
  abstract insertBefore(parent: any, newChild: any, refChild: any): void;
  abstract removeChild(parent: any, oldChild: any): void;
  abstract selectRootElement(selectorOrNode: string|any): any;
  abstract parentNode(node: any): any;
  abstract nextSibling(node: any): any;
  abstract setAttribute(el: any, name: string, value: string,
                                         namespace?: string|null): void;
  abstract removeAttribute(el: any, name: string,
                                         namespace?: string|null): void;
  abstract addClass(el: any, name: string): void;
  abstract removeClass(el: any, name: string): void;
  abstract setStyle(el: any, style: string, value: any,
                                         flags?: RendererStyleFlags2): void;
  abstract removeStyle(el: any, style: string, flags?: RendererStyleFlags2)
                                                                       : void;
  abstract setProperty(el: any, name: string, value: any): void;
  abstract setValue(node: any, value: string): void;
```

```
    abstract listen(
        target: 'window'|'document'|'body'|any, eventName: string,
        callback: (event: any) => boolean | void): () => void;
  }
```

Here only the interface is being defined – for actual implementation, refer to the various platform renderers in the different platform modules. The renderer is a simple abstraction, quite suitable for a variety of rendering engines.

Finally is `RendererStyleFlags2` defined as:

```
  export enum RendererStyleFlags2 {
    Important = 1 << 0,
    DashCase = 1 << 1
  }
```

It is used to supply a flag parameter to two of `Renderer2`'s methods:

```
  abstract setStyle(el: any, style: string, value: any,
                              flags?: RendererStyleFlags2): void;
    abstract removeStyle(el: any, style: string,
                              flags?: RendererStyleFlags2): void;
```

core/src/debug

This directory contains this file:

- debug_node.ts

The debug_node.ts file implements `EventListener`, `DebugNode` and `DebugElement` classes along with some helper functions. `EventListener` stores a name and a function, to be called after events are detected:

```
  export class EventListener {
    constructor(public name: string, public callback: Function) {}
  }
```

The `DebugNode` class represents a node in a tree:

```
  export class DebugNode {
    nativeNode: any;
    listeners: EventListener[];
    parent: DebugElement|null;

    constructor(nativeNode: any, parent: DebugNode|null,
                              private _debugContext: DebugContext) {
      this.nativeNode = nativeNode;
      if (parent && parent instanceof DebugElement) {
        parent.addChild(this);
      } else {
        this.parent = null;
      }
      this.listeners = [];
    }
    get injector(): Injector { return this._debugContext.injector; }
    get componentInstance(): any { return this._debugContext.component; }
    get context(): any { return this._debugContext.context; }
    get references(): {[key: string]: any} {
              return this._debugContext.references; }
    get providerTokens(): any[] { return this._debugContext.providerTokens; }
```

```
}
```

The debug node at attached as a child to the parent DebugNode. The nativeNode to which this DebugNode refers to is recorded. A private field, _debugContext records supplies additional debugging context. It is of type DebugContext, defined in view/types.ts as:

```
export abstract class DebugContext {
  abstract get view(): ViewData;
  abstract get nodeIndex(): number|null;
  abstract get injector(): Injector;
  abstract get component(): any;
  abstract get providerTokens(): any[];
  abstract get references(): {[key: string]: any};
  abstract get context(): any;
  abstract get componentRenderElement(): any;
  abstract get renderNode(): any;
  abstract logError(console: Console, ...values: any[]): void;
}
```

The DebugElement class extends DebugNode and supplies a debugging representation of an element.

```
export class DebugElement extends DebugNode {
  name: string;
  properties: {[key: string]: any};
  attributes: {[key: string]: string | null};
  classes: {[key: string]: boolean};
  styles: {[key: string]: string | null};
  childNodes: DebugNode[];
  nativeElement: any;

  constructor(nativeNode: any, parent: any, _debugContext: DebugContext) {
    super(nativeNode, parent, _debugContext);
    this.properties = {};
    this.attributes = {};
    this.classes = {};
    this.styles = {};
    this.childNodes = [];
    this.nativeElement = nativeNode;
  }
```

It includes these for adding and removing children:

```
  addChild(child: DebugNode) {
    if (child) {
      this.childNodes.push(child);
      child.parent = this;
    }
  }

  removeChild(child: DebugNode) {
    const childIndex = this.childNodes.indexOf(child);
    if (childIndex !== -1) {
      child.parent = null;
      this.childNodes.splice(childIndex, 1);
    }
  }
```

It includes this for events:

```
triggerEventHandler(eventName: string, eventObj: any) {
    this.listeners.forEach((listener) => {
      if (listener.name == eventName) {
        listener.callback(eventObj);
      }
    });
  }
```

The functions manage a map:

```
// Need to keep the nodes in a global Map so that
// multiple angular apps are supported.
const _nativeNodeToDebugNode = new Map<any, DebugNode>();
```

This is used to add a node:

```
export function indexDebugNode(node: DebugNode) {
  _nativeNodeToDebugNode.set(node.nativeNode, node);
}
```

Core ChangeDetection Feature (core/src/change_detection)

The change_detection directory has these files:

- change_detection.ts
- change_detection_util.ts
- change_detector_ref.ts
- constants.ts
- pipe_transform.ts

The pipe_transform.ts file defines the `PipeTransform` interface, needed for pipes:

```
export interface PipeTransform {
            transform(value: any, ...args: any[]): any; }
```

The constants.ts file defines two enums for change detection:

```
export enum ChangeDetectionStrategy {
  OnPush=0,
  Default=1,
}
export enum ChangeDetectorStatus {
  CheckOnce,
  Checked,
  CheckAlways,
  Detached,
  Errored,
  Destroyed,
}
```

Definitions in change_detection_utils.ts include:

```
export function devModeEqual(a: any, b: any): boolean {..}
export class WrappedValue {..}
export class ValueUnwrapper {..}
export class SimpleChange {..}
```

The change_detector_ref.ts file defines the `ChangeDetectorRef` class:

```
export abstract class ChangeDetectorRef {
  abstract markForCheck(): void;
  abstract detach(): void;
```

```
    abstract detectChanges(): void;
    abstract checkNoChanges(): void;
    abstract reattach(): void;
  }
```

The change_detection.ts file defines:

```
  export const keyValDiff: KeyValueDifferFactory[] =
                                      [new DefaultKeyValueDifferFactory()];
  export const iterableDiff: IterableDifferFactory[] =
                                      [new DefaultIterableDifferFactory()];
  export const defaultIterableDiffers = new IterableDiffers(iterableDiff);
  export const defaultKeyValueDiffers = new KeyValueDiffers(keyValDiff);
```

The differs sub-directory provides the actual implemntation for the change detection algorithms, in these files:

- default_iterable_differ.ts
- default_keyvalue_differ.ts
- iterable_differs.ts
- keyvalue_differs.ts

Core/Zone Feature (core/src/zone)

Source Tree

This directory contains this file:

- ng_zone.ts

The small Zone.js library (https://github.com/angular/zone.js) provides a way of managing multiple execution contexts when using asynchronous tasks. Angular has a dependency on it, and we see its use here in core/src/zone.

The ng_zone.ts file in Angular Core defines the `NgZone` class, which provides an Angular wrapper for zones. It is defined as:

```
  export class NgZone {
    readonly hasPendingMicrotasks: boolean = false;
    readonly hasPendingMacrotasks: boolean = false;
    readonly isStable: boolean = true;
    readonly onUnstable: EventEmitter<any> = new EventEmitter(false);
    readonly onMicrotaskEmpty: EventEmitter<any> = new EventEmitter(false);
    readonly onStable: EventEmitter<any> = new EventEmitter(false);
    readonly onError: EventEmitter<any> = new EventEmitter(false);
    constructor({enableLongStackTrace = false}) {..}
    static isInAngularZone(): boolean {..}
    static assertInAngularZone(): void {..}
    static assertNotInAngularZone(): void {..}
    run<T>(fn: (...args: any[]) => T,
       applyThis?: any, applyArgs?: any[]): T {..}
    runTask<T>(fn: (...args: any[]) => T,
       applyThis?: any, applyArgs?: any[], name?: string): T  {..}
    runGuarded<T>(fn: (...args: any[]) => T,
       applyThis?: any, applyArgs?: any[]): T {..}
    runOutsideAngular<T>(fn: (...args: any[]) => T): T {..}
  }
```

Its constructor implementation is worth studying. First note Angular requires Zone.js and throws an error if it is not found. If `wtfZoneSpec` or `longStackTraceZoneSpec` zones are required, it forks as needed:

```
constructor({enableLongStackTrace = false}) {
    if (typeof Zone == 'undefined') {
      throw new Error(`In this configuration Angular requires Zone.js`);
    }

    Zone.assertZonePatched();
    const self = this as any as NgZonePrivate;
    self._nesting = 0;

    self._outer = self._inner = Zone.current;
    if ((Zone as any)['wtfZoneSpec']) {
      self._inner = self._inner.fork((Zone as any)['wtfZoneSpec']);
    }
    if (enableLongStackTrace && (Zone as any)['longStackTraceZoneSpec']) {
      self._inner = self._inner.fork((Zone as any)
                                  ['longStackTraceZoneSpec']);
    }
    forkInnerZoneWithAngularBehavior(self);
  }
```

Core/Testability Feature (core/src/testability)

Testability is the provision of testing hooks that can be used by test-focused tooling, such as Angular's Protractor.

Core/Testability Public API

The public API for this feature is exported by core/src/core.ts:

```
export {GetTestability, Testability, TestabilityRegistry,
    setTestabilityGetter} from './testability/testability';
```

It exports consists of an interface – `GetTestability`, a function - `setTestabilityGetter`, and two injectable classes, `TestabilityRegistry` and `Testability`.

Core/Testability Usage

We see use of `TestabilityRegistry` in core/src/platform_core_providers.ts by `_CORE_PLATFORM_PROVIDERS`:

```
const _CORE_PLATFORM_PROVIDERS: StaticProvider[] = [
  ..
  {provide: TestabilityRegistry, deps: []},
```

The bootstrap method in `ApplicationRef` looks for configured `Testability` elements via dependency injection ❶ and if found ❷, then registers them ❸ with the `TestabilityRegistry` (which itself is also accessed via dependency injection):

```
@Injectable()constructor(
export class ApplicationRef {
  bootstrap<C>(..):ComponentRef<C> {
    ..
   const compRef = componentFactory.create(..);
    ..
❶    const testability = compRef.injector.get(Testability, null);
❷    if (testability) {
      compRef.injector.get(TestabilityRegistry)
3         .registerApplication(compRef.location.nativeElement, testability);
    }
  }
}
```

Note there is a class `BrowserGetTestability` in:

- <ANGULAR-MASTER>/packages/platform-browser/src/browser/testability.ts

that implements `GetTestability` with a static `init()` method that calls `setTestabilityGetter()`:

```
export class BrowserGetTestability implements GetTestability {
  static init() { setTestabilityGetter(new BrowserGetTestability()); }
```

Core/Testability Implementation

The implementation of the testability feature is in the testability sub-directory, which contains two file:

- testability.externs.js
- testability.ts

Its provides functionality for testing Angular components, and includes use of `NgZone`.

`GetTestability` is simply defined as:

```
/**
 * Adapter interface for retrieving the `Testability` service associated
 *  for a particular context.
 *
 * @experimental Testability apis are primarily intended to be used by
 * e2e test tool vendors like the Protractor team.
 */
export interface GetTestability {
  addToWindow(registry: TestabilityRegistry): void;
  findTestabilityInTree(registry: TestabilityRegistry, elem: any,
                           findInAncestors: boolean): Testability|null;
}
```

`setTestabilityGetter` is used to set the getter:

```
/**
 * Set the GetTestability implementation used by
 * the Angular testing framework.
 */
export function setTestabilityGetter(getter: GetTestability): void {
  _testabilityGetter = getter;
}
```

The `TestabilityRegistry` class is “A global registry of Testability instances for specific elements”. `TestabilityRegistry` maintains a map from any element to an instance of a testability. It provides a `registerApplication()` method which allows an entry to be added to this map, and a `getTestability()` method that is a lookup:

```
@Injectable()
export class TestabilityRegistry {
  _applications = new Map<any, Testability>();
  constructor() { _testabilityGetter.addToWindow(this); }
  registerApplication(token: any, testability: Testability) {
    this._applications.set(token, testability);
  }
  unregisterApplication(token: any) { this._applications.delete(token); }
  unregisterAllApplications() { this._applications.clear(); }
  getTestability(elem: any): Testability|null {
     return this._applications.get(elem) || null; }
  getAllTestabilities(): Testability[] {
     return Array.from(this._applications.values()); }
  getAllRootElements(): any[] { return Array.from(this._applications.keys());
}
  findTestabilityInTree(elem: Node, findInAncestors: boolean = true):
Testability|null {.. }
}
```

The `Testability` class is structured as follows:

```
/**
 * The Testability service provides testing hooks that can be accessed from
 * the browser and by services such as Protractor. Each bootstrapped Angular
 * application on the page will have an instance of Testability.
 */
@Injectable()
export class Testability implements PublicTestability {
  _pendingCount: number = 0;
  _isZoneStable: boolean = true;
  /**
   * Whether any work was done since the last 'whenStable' callback. This is
   * useful to detect if this could have potentially destabilized another
   * component while it is stabilizing.
   */
  _didWork: boolean = false;
  _callbacks: Function[] = [];
  constructor(private _ngZone: NgZone) { this._watchAngularEvents(); }
  _watchAngularEvents(): void {  }
  increasePendingRequestCount(): number { }
  decreasePendingRequestCount(): number {  }
  isStable(): boolean {  }
  whenStable(callback: Function): void { }
  getPendingRequestCount(): number { return this._pendingCount; }
  findProviders(using: any, provider: string, exactMatch: boolean): any[] { }
}
```

Core/Linker Feature (core/src/linker)

The Core/Linker feature is used to define an API for the template compiler and is instrumental in how compiled components work together.

When developers new to Angular hear about the linker, their mind immediately races to the conclusion that it is something like the C linker or linkers for other languages, but that is far from the case with Angular’s linker. Remember Angular is dealing with template syntax (a quasi-HTML representation of a page which includes embedded TypeScript logic) and this needs to work with component code written in TypeScript. So conceptually the angular linker is bringing different parts of your application together (so using the term “linker” is technically correct), but in practice how it works is quite different to what happens with an ANSI C linker.

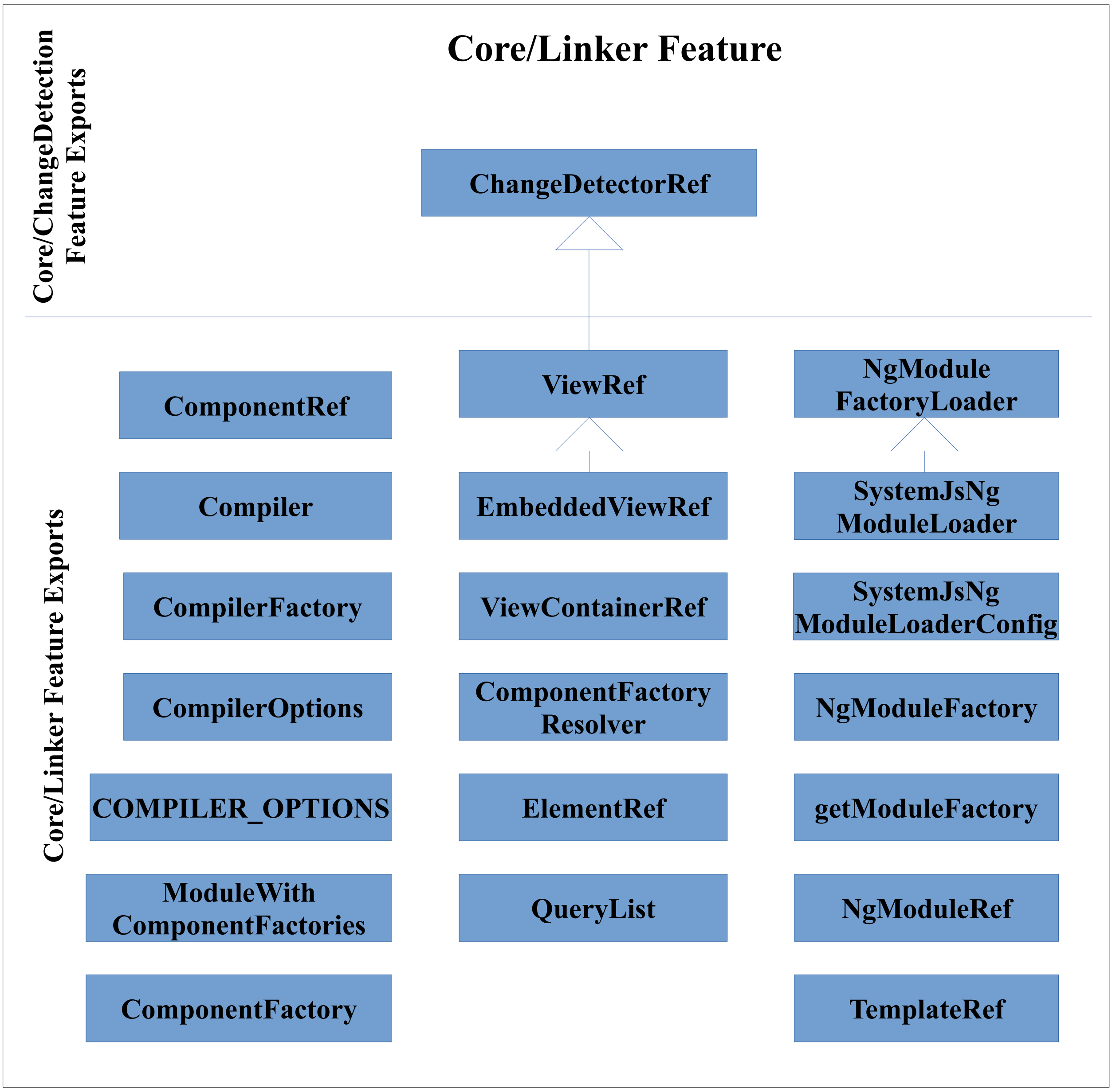
Core/Linker Public API

The public API for this feature is exported by the <ANGULAR-MASTER>/packages/core/src/core.ts file, which has this line:

```
export * from './src/linker';
```

The <ANGULAR-MASTER>/packages/core/src/linker.ts file lists the exports:

```
// Public API for compiler
export {COMPILER_OPTIONS, Compiler, CompilerFactory, CompilerOptions,
  ModuleWithComponentFactories} from './linker/compiler';
export {ComponentFactory, ComponentRef} from './linker/component_factory';
export {ComponentFactoryResolver} from './linker/component_factory_resolver';
export {ElementRef} from './linker/element_ref';
export {NgModuleFactory, NgModuleRef} from './linker/ng_module_factory';
export {NgModuleFactoryLoader, getModuleFactory}
  from './linker/ng_module_factory_loader';
export {QueryList} from './linker/query_list';
export {SystemJsNgModuleLoader, SystemJsNgModuleLoaderConfig}
  from './linker/system_js_ng_module_factory_loader';
export {TemplateRef} from './linker/template_ref';
export {ViewContainerRef} from './linker/view_container_ref';
export {EmbeddedViewRef, ViewRef} from './linker/view_ref';
```



As we see, there is one enum (`COMPILER_OPTIONS`), one method (`getModuleFactory`), one type (`CompilerOptions`) and the other public exports are classes. We note there is not much hierarchy in the public API layout.

Core/Linker Usage

core/Linker is really the base API for compilation and linking, but we will see these types being used elsewhere (in particular, in the Angular Compiler package). The source files in the Core/Linker feature are only a few hundred lines of code in total. The heavy lifting of compilation is done in the Compiler package, which is much, much larger. For example, a single one of its file, view_compiler.ts, is over a thousand lines long. We also see Core/Linker being used by the Compiler-CLI package, which is a command-line interface to the Compiler package.

The `SystemJsNgModuleLoader` class is used in the router module, to define the `ROUTER_PROVIDERS` array. The router/src/router_module.ts file has this:

```
  export const ROUTER_PROVIDERS: Provider[] = [
    ..
    {provide: NgModuleFactoryLoader, useClass: SystemJsNgModuleLoader} ];
```

Core/Linker Implementation

The source files in core/src/linker implement the Core/Linker feature:

- compiler.ts
- component_factory_resolver.ts
- component_factory.ts
- element_ref.ts
- ng_module_factory_loader.ts
- ng_module_factory.ts
- query_list.ts
- system_js_ng_module_factory_loader.ts
- template_ref.ts
- view_container_ref.ts
- view_ref.ts

A number of these files introduce types who names end in `Ref`:

- ElementRef
- TemplateRef
- ViewRef
- ViewContainerRef
- ComponentRef

If you are used to programming in a language such as C# where the phrase reference type has a specific meaning, note that in Angular this is not a language concept, and more a naming convention. These references are merely collections of methods and properties used to interact with the referenced construct.

The elements in the DOM are exposed to Angular apps as `ElementRef`s. In general, it is recommended not to work directly with `ElementRef`s, as a certain level of abstraction is very useful to enable Angular apps works on different rendering targets.

As Angular application developers, the template syntax files we create are processed by the Angular template compiler to produce a number of template refs. If a template representation has a simple set of elements (`<p>hello world</p>`) then a single `TemplateRef` will be created. If directives such as `NgFor` are used then the outer content will be in one `TemplateRef` and what is inside the `NgFor` will be in another. A `TemplateRef` is instantiated one or more times to make a `ViewRef`. There is not necessarily a one-to-one mapping between `TemplateRef`s and `ViewRef`s. Depending on the number of iterations to be applied to an `NgFor`, there will be that number of instances of `ViewRef`s, all based on the same `TemplateRef`.

A view is a hierarchy and child views can be inserted using `ViewContainerRef` (literally a container for a child view). A view is the unit of hierarchy that Angular exposes to app developers to dynamically modify what is displayed to users. So think in terms of adding and removing embedded views, not adding and removing individual HTML elements.

A ComponentRef contains a HostView which in turn can contain a number of embedded views.

Now we will move on to looking at the source, starting with looking at core/src/linker/compiler.ts. CompilerOptions provides a list of configuration options for a compiler (all are marked as optional):

```
export type CompilerOptions = {
  useJit?: boolean,
  defaultEncapsulation?: ViewEncapsulation,
  providers?: StaticProvider[],
  missingTranslation?: MissingTranslationStrategy,
  enableLegacyTemplate?: boolean,
  preserveWhitespaces?: boolean,
};
```

COMPILER_OPTIONS is an exported const:

```
// Token to provide CompilerOptions in the platform injector.
export const COMPILER_OPTIONS =
                 new InjectionToken<CompilerOptions[]>('compilerOptions');
```

CompilerFactory is an abstract class used to construct a compiler, via its createCompiler() abstract method:

```
export abstract class CompilerFactory {
  abstract createCompiler(options?: CompilerOptions[]): Compiler;
}
```

ModuleWithComponentFactories combines a NgModuleFactory and a ComponentFactory:

```
// Combination of NgModuleFactory and ComponentFactory.
export class ModuleWithComponentFactories<T> {
  constructor(
      public ngModuleFactory: NgModuleFactory<T>,
      public componentFactories: ComponentFactory<any>[]) {}
}
```

The Compiler class is used to perform template compilation:

```
@Injectable()
export class Compiler {
  compileModuleSync<T>(moduleType: Type<T>): NgModuleFactory<T> { .. }
  compileModuleAsync<T>(moduleType: Type<T>):
     Promise<NgModuleFactory<T>> { .. }
  compileModuleAndAllComponentsSync<T>(moduleType: Type<T>):
     ModuleWithComponentFactories<T> { ..  }
  compileModuleAndAllComponentsAsync<T>(moduleType: Type<T>):
     Promise<ModuleWithComponentFactories<T>> { .. }
  clearCache(): void {}
  clearCacheFor(type: Type<any>) {}
}
```

The two methods clearCache and clearCacheFor are both empty, the other methods just throw an error. So to use a compiler, an actual implementation is needed and that is where the separate Compiler package comes in. The `Compiler` class defined here is the base class for template compilers, and it is these derived classes where the actual template compilation occurs.

The four compile generic methods either synchronously or asynchronously compile an individual component, or an entire NgModule. All take a `Type<T>` as a parameter. The async versions returns the promise of one or more factories, whereas the sync versions return the actual factories.

The query_list.ts file defines the generic `QueryList<T>` class, which provides controlled access to a read-only array of items of type T.

The `ElementRef` class is used as a reference to the actual rendered element - what that is depends on the renderer.

```
export class ElementRef {
  public nativeElement: any;
  constructor(nativeElement: any) { this.nativeElement = nativeElement; }
}
```

In general, application developers are advised not to work directly with `ElementRef`s, as it makes their code renderer-specific, and may introduce security issues. We bring your attention to theses lines in the source:

```
* @security Permitting direct access to the DOM can make your application more
* vulnerable to XSS attacks. Carefully review any use of `ElementRef` in your
* code. For more detail, see the [Security Guide](http://g.co/ng/security).
```

The view_ref.ts file defines the `ViewRef` and `EmbeddedViewRef` abstract classes which are exported by the package's core/src/core.ts file (via core/src/linker.ts), and an interface, `InternalViewRef`, that is used internally with the core package itself.

`ViewRef` is defined as:

```
export abstract class ViewRef extends ChangeDetectorRef {
  abstract destroy(): void;
  abstract get destroyed(): boolean;
  abstract onDestroy(callback: Function): any;
}
```

`EmbeddedViewRef` is defined as:

```
export abstract class EmbeddedViewRef<C> extends ViewRef {
  abstract get context(): C;
  abstract get rootNodes(): any[];
}
```

`InternalViewRef` is defined as:

```
export interface InternalViewRef extends ViewRef {
  detachFromAppRef(): void;
  attachToAppRef(appRef: ApplicationRef): void;
}
```

The `attachToAppRef/detachFromAppRef` methods are called from `ApplicationRef`'s `attachView` and `detachView` methods:

```
 attachView(viewRef: ViewRef): void {
    const view = (viewRef as InternalViewRef);
    this._views.push(view);
    view.attachToAppRef(this);
  }
  detachView(viewRef: ViewRef): void {
    const view = (viewRef as InternalViewRef);
    remove(this._views, view);
    view.detachFromAppRef();
  }
```

The view_container_ref.ts file defines the abstract `ViewContainerRef` class. `ViewContainerRef` is a container for views. It defines four getters – `element` (for the anchor element of the container), `injector`, `parentInjector` and `length` (number of views attached to container). It defines two important create methods – `createEmbeddedView` and `createComponent`, which create the two variants of views supported. Finally, it has a few abstract helper methods – `clear`, `get`, `insert`, `indexOf`, `remove` and `detach` – which work on the views within the container.

```
export abstract class ViewContainerRef {
  abstract get element(): ElementRef;
  abstract get injector(): Injector;
  abstract get parentInjector(): Injector;
  abstract clear(): void;
  abstract get(index: number): ViewRef|null;
  abstract get length(): number;
  abstract createEmbeddedView<C>(templateRef: TemplateRef<C>,
     context?: C, index?: number): EmbeddedViewRef<C>;
  abstract createComponent<C>(
      componentFactory: ComponentFactory<C>,
      index?: number, injector?: Injector,
      projectableNodes?: any[][],
      ngModule?: NgModuleRef<any>): ComponentRef<C>;
  abstract insert(viewRef: ViewRef, index?: number): ViewRef;
  abstract move(viewRef: ViewRef, currentIndex: number): ViewRef;
  abstract indexOf(viewRef: ViewRef): number;
  abstract remove(index?: number): void;
  abstract detach(index?: number): ViewRef|null;
}
```

The difference between `createEmbeddedView` and `createComponent` is that the former takes a template ref as a parameter and creates an embedded view from it, whereas the latter takes a component factory as a parameter and uses the host view of the newly created component.

The component_factory.ts file exports two abstract classes – `ComponentRef` and `ComponentFactory`:

```
export abstract class ComponentFactory<C> {}
  abstract get selector(): string;
  abstract get componentType(): Type<any>;
  abstract get ngContentSelectors(): string[];
  abstract get inputs(): {propName: string, templateName: string}[];
  abstract get outputs(): {propName: string, templateName: string}[];
  abstract create(
      injector: Injector, projectableNodes?: any[][], rootSelectorOrNode?:
```

The `ComponentRef` abstract class is defined as:

```
export abstract class ComponentRef<C> {
  abstract get location(): ElementRef;
  abstract get injector(): Injector;
  abstract get instance(): C;
  abstract get hostView(): ViewRef;
  abstract get changeDetectorRef(): ChangeDetectorRef;
  abstract get componentType(): Type<any>;
  abstract destroy(): void;
  abstract onDestroy(callback: Function): void;
}
```

The template_ref.ts file defines the `TemplateRef` abstract class and the `TemplateRef_` concrete class.

```
export abstract class TemplateRef<C> {
  abstract get elementRef(): ElementRef;
  abstract createEmbeddedView(context: C): EmbeddedViewRef<C>;
}
```

The component_factory_resolver.ts file defines the `ComponentFactoryResolver` abstract class, which is part of the public API:

`ComponentFactoryResolver` is defined as:

```
export abstract class ComponentFactoryResolver {
  static NULL: ComponentFactoryResolver = new
_NullComponentFactoryResolver();
  abstract resolveComponentFactory<T>(component: Type<T>):
ComponentFactory<T>;
}
```

this file also defines `CodegenComponentFactoryResolver`, a concrete class that is exported via:

- <ANGULAR-MASTER>/packages/core/src/codegen_private_exports.ts

as it is used elsewhere within the Angular ecosystem.

`CodegenComponentFactoryResolver` is defined as:

```
export class CodegenComponentFactoryResolver implements
ComponentFactoryResolver {
1 private _factories = new Map<any, ComponentFactory<any>>();

  constructor(
2      factories: ComponentFactory<any>[],
       private _parent: ComponentFactoryResolver,
       private _ngModule: NgModuleRef<any>) {
3   for (let i = 0; i < factories.length; i++) {
      const factory = factories[i];
      this._factories.set(factory.componentType, factory);
    }
  }

4 resolveComponentFactory<T>(
       component: {new (...args: any[]): T}): ComponentFactory<T> {
5   let factory = this._factories.get(component);
    if (!factory && this._parent) {
6   factory = this._parent.resolveComponentFactory(component);
    }
```

```
      if (!factory) {
        throw noComponentFactoryError(component);
      }
7     return new ComponentFactoryBoundToModule(factory, this._ngModule);
    }
  }
```

CodegenComponentFactoryResolver has a private map field, _factories 1, and its constructor takes an array, factories 2. Don't mix them up! The constructor iterates 3 over the array (factories) and for each item, adds an entry to the map (_factories) that maps the factory's componentType to the factory. In its resolveComponentFactory() 4 method, CodegenComponentFactoryResolver looks up the map for a matching factory, and if present 5 selects that as the factory and if not, calls the resolveComponentFactory method 6 of the parent, and passes the selected factory to a new instance of the ComponentFactoryBoundToModule helper class 7.

The ng_module_factory_loader.ts file defines the NgModuleFactoryLoader abstract class as:

```
 export abstract class NgModuleFactoryLoader {
  abstract load(path: string): Promise<NgModuleFactory<any>>;
}
```

It is use for lazy loading. We will see an implementation in system_js_ng_module_factory_loader.ts.

The system_js_ng_module_factory_loader.ts file defines the SystemJsNgModuleLoader class, which loads NgModule factories using SystemJS.

```
// NgModuleFactoryLoader that uses SystemJS to load NgModuleFactory
@Injectable()
export class SystemJsNgModuleLoader implements NgModuleFactoryLoader {
  private _config: SystemJsNgModuleLoaderConfig;
```

Its constructor takes a _compiler as an optional parameter.

```
  constructor(private _compiler: Compiler, @Optional() config?:
SystemJsNgModuleLoaderConfig) {
    this._config = config || DEFAULT_CONFIG;
  }
```

In its load() method, if _compiler was provided, it calls loadAndCompile(), otherwise it calls loadFactory().

```
  load(path: string): Promise<NgModuleFactory<any>> {
    const offlineMode = this._compiler instanceof Compiler;
    return offlineMode ? this.loadFactory(path) : this.loadAndCompile(path);
  }
```

It is within loadAndCompile() that _compiler.compileAppModuleAsync() is called.

```
  private loadAndCompile(path: string): Promise<NgModuleFactory<any>> {
    let [module, exportName] = path.split(_SEPARATOR);
    if (exportName === undefined) {
      exportName = 'default';
    }
```

```
      return System.import(module)
          .then((module: any) => module[exportName])
          .then((type: any) => checkNotEmpty(type, module, exportName))
          .then((type: any) => this._compiler.compileModuleAsync(type));
    }
```

The ng_module_factory.ts file defines the `NgModuleRef` and `NgModuleInjector` abstract classes and the `AppModuleFactory` concrete class.

`NgModuleRef` is defined as:

```
/**
 * Represents an instance of an NgModule created via a NgModuleFactory.
 * `NgModuleRef` provides access to the NgModule Instance as well other
 *  objects related to this NgModule Instance.
 */
export abstract class NgModuleRef<T> {
  abstract get injector(): Injector;
  abstract get componentFactoryResolver(): ComponentFactoryResolver;
  abstract get instance(): T;
  abstract destroy(): void;
  abstract onDestroy(callback: () => void): void;
}
```

`NgModuleFactory` is used to create an NgModuleRef instance:

```
export abstract class NgModuleFactory<T> {
  abstract get moduleType(): Type<T>;
  abstract create(parentInjector: Injector|null): NgModuleRef<T>;
}
```

Core/View Feature (core/src/view)

The Core/View feature provides view management functionality. In Angular terminology, a view is an area of screen that can display content and where user events can be detected. A view is a bundle of elements. Views can be arranged hierarchically via the use of View Containers.

This comment from:

- <ANGULAR-MASTER>/packages/core/src/linker/view_ref.ts

explains the relationship between elements and views:

> *“A View is a fundamental building block of the application UI. It is the smallest grouping of elements which are created and destroyed together.*
>
> *Properties of elements in a View can change, but the structure (number and order) of elements in a View cannot. Changing the structure of Elements can only be done by inserting, moving or removing nested Views via a ViewContainerRef. Each View can contain many View Containers.”*

One could say views are the heart of an Angular application. Core/View is a substantial feature that represents over a third of the entire Core package source tree.

Private Exports API

The Core/View feature is not intended to be used directly by Angular applications. Core/View does not export anything as part of the public API to the Core Package. As we have already discussed, core/index.ts describes the public API for Core, and its one line content exports core/public_api.ts, which in turn exports core/src/core.ts and this exports nothing from the view sub-directory (searching for "view" results in no matches).

Some Core/Linker public exports are of classes which are used as base classes for types implemented in Core/View. In the file:

- <ANGULAR-MASTER>/packages/core/src/linker.ts

Your attention is drawn to these lines:

```
export {TemplateRef} from './linker/template_ref';
export {ViewContainerRef} from './linker/view_container_ref';
export {EmbeddedViewRef, ViewRef} from './linker/view_ref';
```

Core/View is intended to be used internally by other Angular packages. Hence we see its exports being defined as part of these two private export files:

- <ANGULAR-MASTER>/packages/core/src/codegen_private_exports.ts
- <ANGULAR-MASTER>/packages/core/src/core_private_export.ts

The first of these has these view-related exports:

```
export {
  clearOverrides as ɵclearOverrides,
  overrideComponentView as ɵoverrideComponentView,
   overrideProvider as ɵoverrideProvider
} from './view/index';
export {
  NOT_FOUND_CHECK_ONLY_ELEMENT_INJECTOR as
   ɵNOT_FOUND_CHECK_ONLY_ELEMENT_INJECTOR
} from './view/provider';
```

The second has these:

```
export {ArgumentType as ɵArgumentType,
  BindingFlags as ɵBindingFlags, DepFlags as ɵDepFlags,
  EMPTY_ARRAY as ɵEMPTY_ARRAY, EMPTY_MAP as ɵEMPTY_MAP,
  NodeFlags as ɵNodeFlags, QueryBindingType as ɵQueryBindingType,
  QueryValueType as ɵQueryValueType, ViewDefinition as ɵViewDefinition,
  ViewFlags as ɵViewFlags, anchorDef as ɵand,
  createComponentFactory as ɵccf, createNgModuleFactory as ɵcmf,
  createRendererType2 as ɵcrt, directiveDef as ɵdid, elementDef as ɵeld,
  elementEventFullName as ɵelementEventFullName,
  getComponentViewDefinitionFactory as ɵgetComponentViewDefinitionFactory,
  inlineInterpolate as ɵinlineInterpolate, interpolate as ɵinterpolate,
  moduleDef as ɵmod, moduleProvideDef as ɵmpd, ngContentDef as ɵncd,
  nodeValue as ɵnov, pipeDef as ɵpid, providerDef as ɵprd,
  pureArrayDef as ɵpad, pureObjectDef as ɵpod, purePipeDef as ɵppd,
  queryDef as ɵqud, textDef as ɵted, unwrapValue as ɵunv, viewDef as ɵvid
} from './view/index';
```

Core/View Implementation

The source file:

- <ANGULAR-MASTER>/packages/core/src/view/types.ts

defines helper types used elsewhere in Core/View. Let’s start with ViewContainerData which simply extends ViewContainerRef and adds an internal property to record view data for embedded views:

```
export interface ViewContainerData extends ViewContainerRef {
  _embeddedViews: ViewData[];
}
```

The TemplateData interface extends TemplateRef and just adds an array of ViewData instances:

```
export interface TemplateData extends TemplateRef<any> {
  // views that have been created from the template
  // of this element, but inserted into the embeddedViews of
  // another element. By default, this is undefined.
  _projectedViews: ViewData[];
}
```

The source file:

- <ANGULAR-MASTER>/packages/core/src/view/refs.ts

provides internal implementations of references (refs).

ViewContainerRef_ (note the trailing _) implements ViewContainerData which in turn implements the public ViewContainerRef.

It takes an ElementData for its anchor element in its constructor:

```
class ViewContainerRef_ implements ViewContainerData {
  _embeddedViews: ViewData[] = [];
  constructor(private _view: ViewData,
              private _elDef: NodeDef,
              private _data: ElementData) {}
  get element(): ElementRef {
     return new ElementRef(this._data.renderElement); }
  get injector(): Injector { return new Injector_(this._view, this._elDef); }
  get parentInjector(): Injector { ..  }
  get(index: number): ViewRef|null {.. }
  get length(): number { return this._embeddedViews.length; }
  createEmbeddedView<C>(templateRef: TemplateRef<C>, context?: C,
     index?: number): EmbeddedViewRef<C> {.. }
  createComponent<C>(
       componentFactory: ComponentFactory<C>, index?: number,
       injector?: Injector, projectableNodes?: any[][],
       ngModuleRef?: NgModuleRef<any>): ComponentRef<C> { .. }
  insert(viewRef: ViewRef, index?: number): ViewRef { .. }
  move(viewRef: ViewRef_, currentIndex: number): ViewRef {..}
  clear(): void {..}
}
```

The two create methods are implemented as follows:

```
  createEmbeddedView<C>(templateRef: TemplateRef<C>,
     context?: C, index?: number): EmbeddedViewRef<C> {
1   const viewRef = templateRef.createEmbeddedView(context || <any>{});
2   this.insert(viewRef, index);
    return viewRef;
  }

  createComponent<C>(
       componentFactory: ComponentFactory<C>,
       index?: number,
       injector?: Injector,
       projectableNodes?: any[][],
       ngModuleRef?: NgModuleRef<any>): ComponentRef<C> {
    const contextInjector = injector || this.parentInjector;
    if (!ngModuleRef && !
       (componentFactory instanceof ComponentFactoryBoundToModule)) {
      ngModuleRef = contextInjector.get(NgModuleRef);
    }
    const componentRef =
3     componentFactory.create(
        contextInjector, projectableNodes, undefined, ngModuleRef);
4 this.insert(componentRef.hostView, index);
    return componentRef;
  }
```

We see the difference between them – `createEmbeddedView()` calls 1 the `TemplateRef`'s `createEmbeddedView()` method and inserts 2 the resulting viewRef; whereas `createComponent()` calls 3 the component factory's `create` method, and with the resulting `ComponentRef`, inserts 4 its `HostView`. Note the return type is different for each create method – the first returns an `EmbededViewRef` whereas the second returns a `ComponentRef`.

The implementations of `insert`, `indexOf`, `remove` and `detach` result in use of appropriate view management APIs:

```
insert(viewRef: ViewRef, index?: number): ViewRef {
  const viewRef_ = <ViewRef_>viewRef;
  const viewData = viewRef_._view;
  attachEmbeddedView(this._view, this._data, index, viewData);
  viewRef_.attachToViewContainerRef(this);
  return viewRef;
}
move(viewRef: ViewRef_, currentIndex: number): ViewRef {
  const previousIndex = this._embeddedViews.indexOf(viewRef._view);
  moveEmbeddedView(this._data, previousIndex, currentIndex);
  return viewRef;
}
indexOf(viewRef: ViewRef): number {
  return this._embeddedViews.indexOf((<ViewRef_>viewRef)._view);
}
remove(index?: number): void {
  const viewData = detachEmbeddedView(this._data, index);
  if (viewData) {
    Services.destroyView(viewData);
  }
}
detach(index?: number): ViewRef|null {
  const view = detachEmbeddedView(this._data, index);
  return view ? new ViewRef_(view) : null;
}
```

The `ComponentRef_` concrete class extends `ComponentRef`. Its constructor takes in an `ViewRef`, which is used in the `destroy` method and to set the component's change detector ref and host view:

```
class ComponentRef_ extends ComponentRef<any> {
  public readonly hostView: ViewRef;
  public readonly instance: any;
  public readonly changeDetectorRef: ChangeDetectorRef;
  private _elDef: NodeDef;

  constructor(
       private _view: ViewData,
       private _viewRef: ViewRef,
       private _component: any) {
    super();
    this._elDef = this._view.def.nodes[0];
    this.hostView = _viewRef;
    this.changeDetectorRef = _viewRef;
    this.instance = _component;
  }
  get location(): ElementRef {
    return new ElementRef(asElementData(
                      this._view, this._elDef.nodeIndex).renderElement);
  }
  get injector(): Injector { return new Injector_(this._view, this._elDef); }
  get componentType(): Type<any> { return <any>this._component.constructor; }

  destroy(): void { this._viewRef.destroy(); }
  onDestroy(callback: Function): void { this._viewRef.onDestroy(callback); }
}
```

The `TemplateRef_` implementation has a constructor that takes a `ViewData` for the parent and a `NodeDef`. Its `createEmbeddedView` method returns a new `ViewRef_` based on those parameters.

```
class TemplateRef_ extends TemplateRef<any> implements TemplateData {
  _projectedViews: ViewData[];
  constructor(private _parentView: ViewData, private _def: NodeDef) {
    super(); }

  createEmbeddedView(context: any): EmbeddedViewRef<any> {
    return new ViewRef_(Services.createEmbeddedView(
                          this._parentView, this._def,
                          this._def.element !.template !, context));
  }

  get elementRef(): ElementRef {
    return new ElementRef(asElementData(
          this._parentView, this._def.nodeIndex).renderElement);
  }
}
```

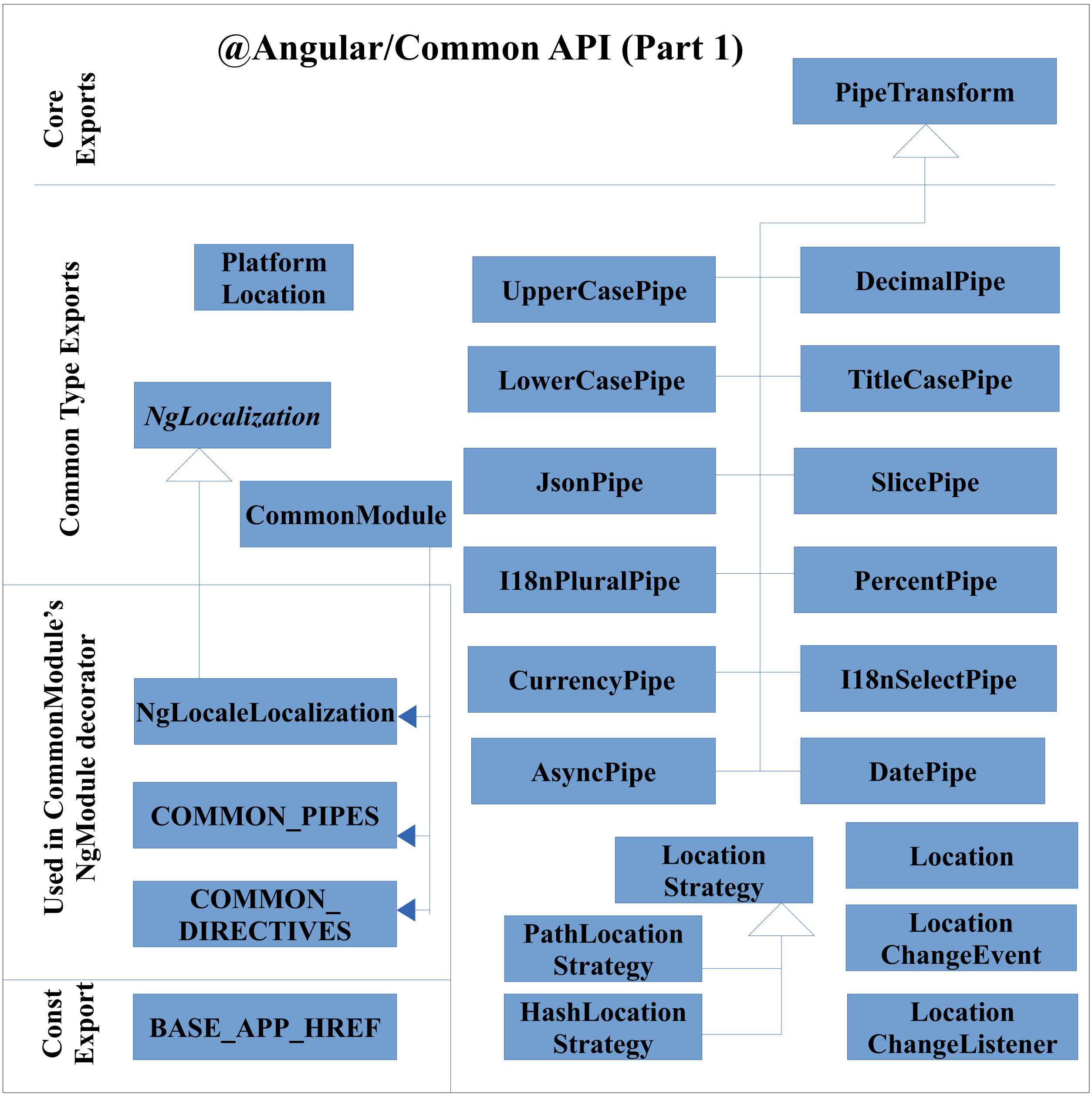
5: The Common Package

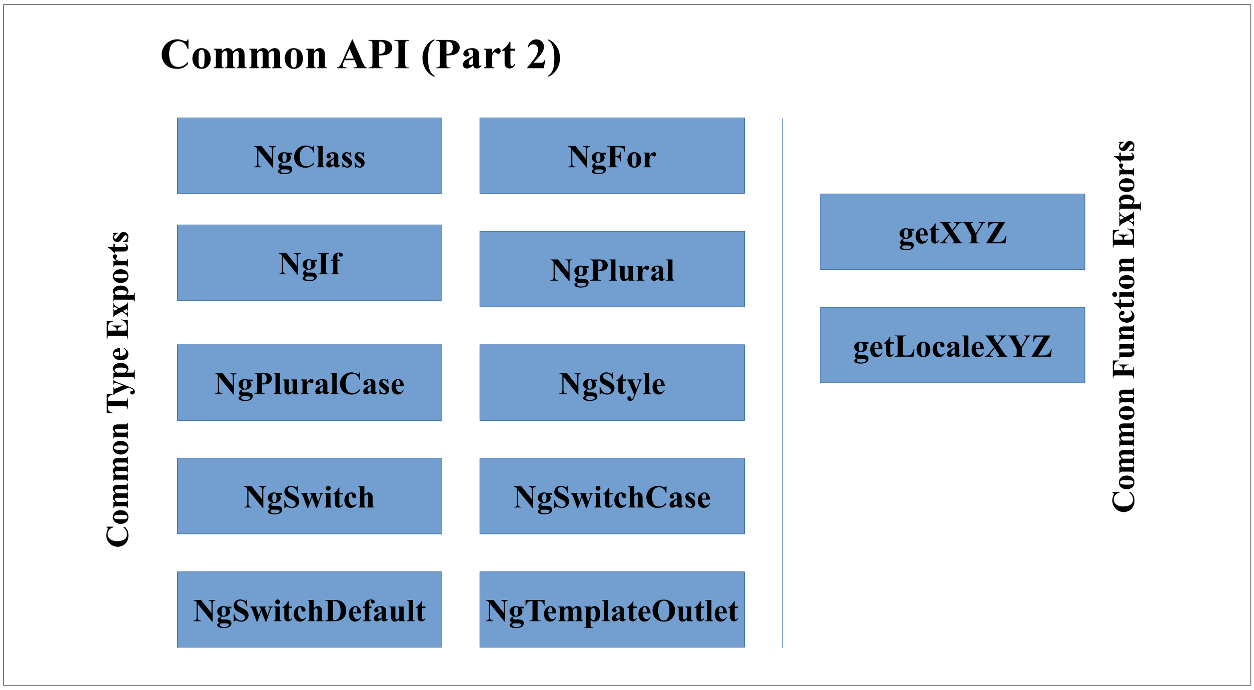
Overview

The Common package builds on top of the Core package and adds some shared functionality in areas such as directives, location and pipes.

Common Public API

The public API of the Common package can be represented as:





The export API is defined by:

- <ANGULAR-MASTER>/packages/common/index.ts

simply as:

```
export * from './public_api';
```

which is turn is defined as:

```
/**
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/common';

// This file only reexports content of the `src` folder. Keep it that way.
```

The src/common.ts file contains:

```
export * from './location/index';
export {NgLocaleLocalization, NgLocalization} from './i18n/localization';
export {registerLocaleData} from './i18n/locale_data';
export {Plural, NumberFormatStyle, FormStyle, Time, TranslationWidth,
  FormatWidth, NumberSymbol, WeekDay, getCurrencySymbol, getLocaleDayPeriods,
  getLocaleDayNames, getLocaleMonthNames, getLocaleId, getLocaleEraNames,
  getLocaleWeekEndRange, getLocaleFirstDayOfWeek, getLocaleDateFormat,
  getLocaleDateTimeFormat, getLocaleExtraDayPeriodRules,
  getLocaleExtraDayPeriods, getLocalePluralCase, getLocaleTimeFormat,
  getLocaleNumberSymbol, getLocaleNumberFormat, getLocaleCurrencyName,
  getLocaleCurrencySymbol} from './i18n/locale_data_api';
export {parseCookieValue as ɵparseCookieValue} from './cookie';
export {CommonModule, DeprecatedI18NPipesModule} from './common_module';
export {NgClass, NgForOf, NgForOfContext, NgIf, NgIfContext, NgPlural,
  NgPluralCase, NgStyle, NgSwitch, NgSwitchCase, NgSwitchDefault,
  NgTemplateOutlet, NgComponentOutlet} from './directives/index';
export {DOCUMENT} from './dom_tokens';
export {AsyncPipe, DatePipe, I18nPluralPipe, I18nSelectPipe, JsonPipe,
  LowerCasePipe, CurrencyPipe, DecimalPipe, PercentPipe, SlicePipe,
  UpperCasePipe, TitleCasePipe} from './pipes/index';
export {PLATFORM_BROWSER_ID as ɵPLATFORM_BROWSER_ID,
 PLATFORM_SERVER_ID as ɵPLATFORM_SERVER_ID,
 PLATFORM_WORKER_APP_ID as ɵPLATFORM_WORKER_APP_ID,
 PLATFORM_WORKER_UI_ID as ɵPLATFORM_WORKER_UI_ID,
 isPlatformBrowser, isPlatformServer, isPlatformWorkerApp,
 isPlatformWorkerUi} from './platform_id';
export {VERSION} from './version';
```

This exports the contents of the pipes/directives/location files in src.

The exported location types are listed in:

- <ANGULAR-MASTER>/packages/common/src/location/index.ts

as follows:

```
export * from './platform_location';
export * from './location_strategy';
export * from './hash_location_strategy';
export * from './path_location_strategy';
export * from './location';
```

platform_location.ts exports the `PlatformLocation` class and the `LocationChangeEvent` and `LocationChangeListener` intefaces. location_strategy.ts exports the `LocationStrategy` class and the `APP_BASE_HREF` const – this is important for routing, for more details refer to the discussion of "*Set the <base href>*" on this page:

- https://angular.io/guide/router

The other location files just export a class with the same name as the file.

Source Tree Layout

The source tree for the Common package contains these directories:

- http

- locales
- src
- test (unit tests in Jasmine)
- testing (test tooling)

and these files:

- BUILD.bazel
- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

The tsconfig-build.json content is:

```
{
  "extends": "../tsconfig-build.json",
  "compilerOptions": {
    "rootDir": ".",
    "baseUrl": ".",
    "paths": {
      "@angular/core": ["../../dist/packages/core"]
    },
    "outDir": "../../dist/packages/common"
  },
  "files": [
    "public_api.ts",
    "../../node_modules/zone.js/dist/zone.js.d.ts"
  ],

  "angularCompilerOptions": {
    "annotateForClosureCompiler": true,
    "strictMetadataEmit": false,
    "skipTemplateCodegen": true,
    "flatModuleOutFile": "common.js",
    "flatModuleId": "@angular/common"
  }
}
```

It list as files to build as public_api.ts and brings in zone.js.d.ts.

Source

common/src

The common/src directory has these sub-directories:

- directives
- i18n
- location
- pipes

and these source files:

- common_module.ts

- common.ts
- cookie.ts
- dom_tokens.ts
- platform_id.ts
- version.ts

The common_module.ts file defines the `CommonModule` type, which contains common declarations, exports and providers:

```
// Note: This does not contain the location providers,
// as they need some platform specific implementations to work.
/**
 * The module that includes all the basic Angular directives
 * like {@link NgIf}, {@link NgForOf}, ...
 */
@NgModule({
  declarations: [COMMON_DIRECTIVES, COMMON_PIPES],
  exports: [COMMON_DIRECTIVES, COMMON_PIPES],
  providers: [
    {provide: NgLocalization, useClass: NgLocaleLocalization},
  ],
})
export class CommonModule { }
```

dom_tokens.ts defines the `DOCUMENT` const (note the important comment):

```
/**
 * A DI Token representing the main rendering context.
 * In a browser this is the DOM Document.
 *
 * Note: Document might not be available in the Application Context
 * when Application and Rendering Contexts are not the same
 * e.g. when running the application into a Web Worker).
 */
export const DOCUMENT = new InjectionToken<Document>('DocumentToken');
```

The platform_id.ts file contains these simple functions to determine which platform is in use:

```
export function isPlatformBrowser(platformId: Object): boolean {
  return platformId === PLATFORM_BROWSER_ID;
}
export function isPlatformServer(platformId: Object): boolean {
  return platformId === PLATFORM_SERVER_ID;
}
export function isPlatformWorkerApp(platformId: Object): boolean {
  return platformId === PLATFORM_WORKER_APP_ID;
}
export function isPlatformWorkerUi(platformId: Object): boolean {
  return platformId === PLATFORM_WORKER_UI_ID;
}
```

common/src/i18n

The src/i18n/localization.ts file provides localization functionality, mainly in the area of plurals. It defines the `NgLocalization` abstract class, the `NgLocaleLocalization` concrete class and the `getPluralCategory()` function.

```
export abstract class NgLocalization {
  abstract getPluralCategory(value: any, locale?: string): string;
}
```

It declares a single abstract method, `getPluralCategory()`.

The `getPluralCategory()` function calls `NgLocalization.getPluralCategory()` to get the plural category for a value. We note the value passed to the function is of type `number`, whereas that passed to `NgLocalization.getPluralCategory()` is of type `any`:

```
export function getPluralCategory(
    value: number, cases: string[], ngLocalization: NgLocalization, locale?:
string): string {
  let key = `=${value}`;

  if (cases.indexOf(key) > -1) {
    return key;
  }
  key = ngLocalization.getPluralCategory(value, locale);

  if (cases.indexOf(key) > -1) {
    return key;
  }

  if (cases.indexOf('other') > -1) {
    return 'other';
  }

  throw new Error(`No plural message found for value "${value}"`);
}
```

One implementation of `NgLocalization` is provided, called `NgLocaleLocalization`, which takes in a `localeId` in its constructor:

```
//Returns the plural case based on the local
@Injectable()
export class NgLocaleLocalization extends NgLocalization {
  constructor(
      @Inject(LOCALE_ID) protected locale: string,
      /** @deprecated from v5 */
      @Optional()
      @Inject(DEPRECATED_PLURAL_FN) protected deprecatedPluralFn?:
          ((locale: string, value: number|string) => Plural)|null) {
    super();
  }

  getPluralCategory(value: any, locale?: string): string {
    const plural =
       this.deprecatedPluralFn ? this.deprecatedPluralFn(
          locale || this.locale, value) :
                        getLocalePluralCase(locale || this.locale)(value);
```

common/src/directives

This directory has the following source files:

- index.ts
- ng_class.ts
- ng_component_outlet.ts
- ng_for_of.ts

- ng_if.ts
- ng_plural.ts
- ng_style.ts
- ng_switch.ts
- ng_template_outlet.ts

The indexs.ts file exports the directive types:

```
export {
  NgClass,
  NgComponentOutlet,
  NgForOf,
  NgForOfContext,
  NgIf,
  NgIfContext,
  NgPlural,
  NgPluralCase,
  NgStyle,
  NgSwitch,
  NgSwitchCase,
  NgSwitchDefault,
  NgTemplateOutlet
};
```

along with a definition for `COMMON_DIRECTIVES`, which is:

```
/**
 * A collection of Angular directives that are likely to be used
 * in each and every Angular application.
 */
export const COMMON_DIRECTIVES: Provider[] = [
  NgClass,
  NgComponentOutlet,
  NgForOf,
  NgIf,
  NgTemplateOutlet,
  NgStyle,
  NgSwitch,
  NgSwitchCase,
  NgSwitchDefault,
  NgPlural,
  NgPluralCase,
];
```

The various ng_ files implement the directives. Lets take a peek at one example, ng_if.ts. It uses a view container to create an embedded view based on a template ref, if the supplied condition is true. We first see in its constructor it records the view container and template ref passed in as parameter:

```
@Directive({selector: '[ngIf]'})
export class NgIf {
  private _context: NgIfContext = new NgIfContext();
  private _thenTemplateRef: TemplateRef<NgIfContext>|null = null;
  private _elseTemplateRef: TemplateRef<NgIfContext>|null = null;
  private _thenViewRef: EmbeddedViewRef<NgIfContext>|null = null;
  private _elseViewRef: EmbeddedViewRef<NgIfContext>|null = null;

  constructor(private _viewContainer: ViewContainerRef,
                      templateRef: TemplateRef<NgIfContext>) {
    this._thenTemplateRef = templateRef;
}
```

We observe that the NgIf class does not derive from any other class. It is made into a directive by using the Directive decorator.

Then we see it has some setters defined as input properties, for the variations of if:

```
@Input()
set ngIf(condition: any) {
  this._context.$implicit = this._context.ngIf = condition;
  this._updateView();
}

@Input()
set ngIfThen(templateRef: TemplateRef<NgIfContext>) {
  this._thenTemplateRef = templateRef;
  this._thenViewRef = null;  // clear previous view if any.
  this._updateView();
}

@Input()
set ngIfElse(templateRef: TemplateRef<NgIfContext>) {
  this._elseTemplateRef = templateRef;
  this._elseViewRef = null;  // clear previous view if any.
  this._updateView();
}
```

Finally it has an internal method, _updateView, where the view is changed as needed:

```
private _updateView() {
  if (this._context.$implicit) {
    if (!this._thenViewRef) {
      this._viewContainer.clear();
      this._elseViewRef = null;
      if (this._thenTemplateRef) {
        this._thenViewRef =
  1         this._viewContainer.createEmbeddedView(
                            this._thenTemplateRef, this._context);
      }
    }
  } else {
    if (!this._elseViewRef) {
      this._viewContainer.clear();
      this._thenViewRef = null;
      if (this._elseTemplateRef) {
        this._elseViewRef =
  2         this._viewContainer.createEmbeddedView(
                            this._elseTemplateRef, this._context);
      }
    }
  }
}
```

The important calls here are (1 & 2) to this._viewContainer.createEmbeddedView, where the embedded view is created if the NgIf condition is true.

If NgIf creates an embedded view zero or once, then we expect NgFor to create embedded view zero or more times, depends on the count supplied to NgFor. We see this is exactly the case, when we look at ng_for_of.ts, which implements the NgFor class (and a helper class - NgForOfContext). The helper class is implemented as:

```
export class NgForOfContext<T> {
  constructor(
      public $implicit: T, public ngForOf: NgIterable<T>,
      public index: number, public count: number) {}

  get first(): boolean { return this.index === 0; }

  get last(): boolean { return this.index === this.count - 1; }

  get even(): boolean { return this.index % 2 === 0; }

  get odd(): boolean { return !this.even; }
}
```

NgFor is defined as:

```
@Directive({selector: '[ngFor][ngForOf]'})
export class NgForOf<T> implements DoCheck, OnChanges {

  private _differ: IterableDiffer<T>|null = null;
  private _trackByFn: TrackByFunction<T>;

  constructor(
      private _viewContainer: ViewContainerRef, private _template:
TemplateRef<NgForOfContext<T>>,
      private _differs: IterableDiffers) {}
}
```

The first thing to note about NgFor's implementation is the class implements DoCheck and OnChanges lifecycle. The DoCheck class is a lifecycle hook defined in @angular/core/src/metadata/lifecycle_hooks.ts as:

```
export interface DoCheck { ngDoCheck(): void; }
```

OnChanges is defined in the same file as:

```
export interface OnChanges { ngOnChanges(changes: SimpleChanges): void; }
```

Hence we would expect NgFor to provide ngDoCheck and ngOnChanges methods and it does. ngDoCheck() calls _applyChanges, where for each change operation a call to viewContainer.createEmbeddedView() is made.

common/src/location

This sub-directory contains these source files:

- hash_location_strategy.ts
- location.ts
- location_strategy.ts
- path_location_strategy.ts
- platform_location.ts

The location_strategy.ts file defines the LocationStrategy class and the APP_BASE_HREF opaque token.

```
export abstract class LocationStrategy {
  abstract path(includeHash?: boolean): string;
  abstract prepareExternalUrl(internal: string): string;
  abstract pushState(state: any, title: string, url: string, queryParams:
string): void;
  abstract replaceState(state: any, title: string, url: string, queryParams:
string): void;
  abstract forward(): void;
  abstract back(): void;
  abstract onPopState(fn: LocationChangeListener): void;
  abstract getBaseHref(): string;
}
```

The opaque token is defined as:

```
export const APP_BASE_HREF = new InjectionToken<string>('appBaseHref');
```

The two implementations of `LocationStrategy` are provided in hash_location_strategy.ts and path_location_strategy.ts. Both share the same constructor signature:

```
@Injectable()
export class HashLocationStrategy extends LocationStrategy {
  private _baseHref: string = '';
  constructor(
      private _platformLocation: PlatformLocation,
      @Optional() @Inject(APP_BASE_HREF) _baseHref?: string) {
    super();
    if (_baseHref != null) {
      this._baseHref = _baseHref;
    }
  }
```

The `PlatformLocation` parameter is how they access actual location information.

`PlatformLocation` is an abstract class used to access location (URL) information. Note `PlatformLocation` does not extend `Location` - which is a service class used to manage the browser’s URL. They have quite distinct purposes.

```
export abstract class PlatformLocation { }
  abstract getBaseHrefFromDOM(): string;
  abstract onPopState(fn: LocationChangeListener): void;
  abstract onHashChange(fn: LocationChangeListener): void;

  abstract get pathname(): string;
  abstract get search(): string;
  abstract get hash(): string;

  abstract replaceState(state: any, title: string, url: string): void;

  abstract pushState(state: any, title: string, url: string): void;

  abstract forward(): void;

  abstract back(): void;
}
```

An important part of the various (browser, server) platform representations is to provide a custom implementation of `PlatformLocation`.

The final file in common/src/location is location.ts, which is where Location is defined. The `Location` class is a service (perhaps it would be better to actually call it

LocationService) used to interact with URLs. A note in the source is important:

```
 * Note: it's better to use {@link Router#navigate} service to trigger route
 * changes. Use `Location` only if you need to interact with or create
 * normalized URLs outside of routing.
```

The Location class does not extend any other class, and its constructor only takes a LocationStrategy as as parameter:

```
@Injectable()
export class Location {
  _subject: EventEmitter<any> = new EventEmitter();
  _baseHref: string;
  _platformStrategy: LocationStrategy;

  constructor(platformStrategy: LocationStrategy) {
    this._platformStrategy = platformStrategy;
    const browserBaseHref = this._platformStrategy.getBaseHref();
    this._baseHref =
Location.stripTrailingSlash(_stripIndexHtml(browserBaseHref));
    this._platformStrategy.onPopState((ev) => {
      this._subject.emit({
        'url': this.path(true),
        'pop': true,
        'type': ev.type,
      });
    });
  }
```

One useful method is subscribe(), which allows your application code to be informed of popState events:

```
 // Subscribe to the platform's `popState` events.
 subscribe(
     onNext: (value: PopStateEvent) => void,
     onThrow?: ((exception: any) => void)|null,
     onReturn?: (() => void)|null): ISubscription {
   return this._subject.subscribe(
         {next: onNext, error: onThrow, complete: onReturn});
  }
```

common/src/pipes

This sub-directory contains these source files:

- async_pipe.ts
- case_conversion_pipes.ts
- date_pipe.ts
- i18n_plural_pipe.ts
- i18n_select_pipe.ts
- invalid_pipe_argument_error.ts
- json_pipe.ts
- number_pipe.ts
- slice_pipe.ts

All the pipe classes are marked with the Pipe decorator. All the pipes implement the PipeTransform interface. As an example, slice_pipe.ts has the following:

```
@Pipe({name: 'slice', pure: false})
export class SlicePipe implements PipeTransform {
  transform(value: any, start: number, end?: number): any {
    if (value == null) return value;

    if (!this.supports(value)) {
      throw invalidPipeArgumentError(SlicePipe, value);
    }

    return value.slice(start, end);
  }

  private supports(obj: any): boolean { return typeof obj === 'string' ||
Array.isArray(obj); }
}
```

COMMON_PIPES (in index.ts) lists the defined pipes and will often be used when creating components.

```
  export const COMMON_PIPES = [
    AsyncPipe,
    UpperCasePipe,
    LowerCasePipe,
    JsonPipe,
    SlicePipe,
    DecimalPipe,
    PercentPipe,
    TitleCasePipe,
    CurrencyPipe,
    DatePipe,
    I18nPluralPipe,
    I18nSelectPipe,
  ];
```

We saw its use in the NgModule decorator attached to CommonModule.

Finally, InvalidPipeArgumentError extends BaseError:

```
  export function invalidPipeArgumentError(type: Type<any>, value: Object) {
    return Error(
  `InvalidPipeArgument: '${value}' for pipe '${stringify(type)}'`);  }
```

6: The Common/HTTP Sub-package

The Common/Http sub-package provides client-side access to an HTTP stack with configurable HTTP backends (e.g. alternatives for test). For production use, it usually makes calls to the browser’s `XmlHttpRequest()` function.

Note that in ealier versions of Angular, HTTP was a top-level package (similar to core, common, router, forms) but in recent versions of Angular it has been moved to be a sub-package of Common. Be aware that in older books, blogs and code samples you will still find references to this older top-level HTTP package. You will also find its API still described in the Angular API documentation, with all its types marekd as “deprecated”. For new code you write it is recommended to use the Common/HTTP sub-package and that is what we describe here.

An interesting additional project called in-memory-web-api can be used for a test-friendly implementation. It is located here:

- https://github.com/angular/in-memory-web-api

This can work with the new Common/HTTP sub-package or the older HTTP top-level package. The link about describes how to set up each – make sure it is appropriate for your needs. A very important note on that page is:

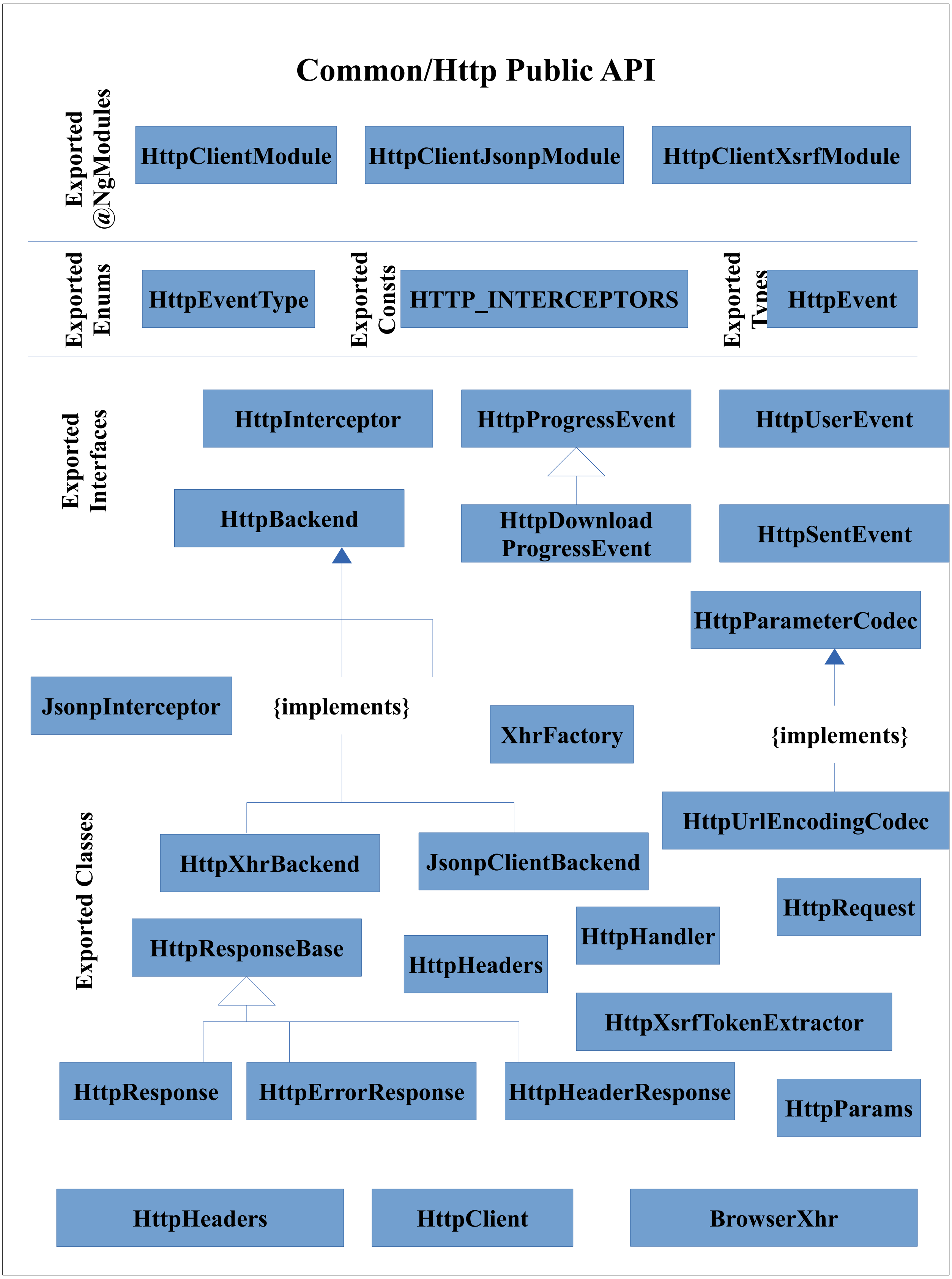
> *Always import the HttpClientInMemoryWebApiModule after the HttpClientModule to ensure that the in-memory backend provider supersedes the Angular version.*

Common/Http Public API

The common/http/src/index.ts file exports public_api.ts, which in turn defines the exports as:

```
export {HttpBackend, HttpHandler} from './src/backend';

export {HttpClient} from './src/client';
export {HttpHeaders} from './src/headers';
export {HTTP_INTERCEPTORS, HttpInterceptor} from './src/interceptor';
export {JsonpClientBackend, JsonpInterceptor} from './src/jsonp';
export {HttpClientJsonpModule, HttpClientModule, HttpClientXsrfModule,
interceptingHandler as ɵinterceptingHandler} from './src/module';
export {HttpParameterCodec, HttpParams, HttpUrlEncodingCodec} from
'./src/params';
export {HttpRequest} from './src/request';
export {HttpDownloadProgressEvent, HttpErrorResponse, HttpEvent,
HttpEventType, HttpHeaderResponse, HttpProgressEvent, HttpResponse,
HttpResponseBase, HttpSentEvent, HttpUserEvent} from './src/response';
export {HttpXhrBackend, XhrFactory} from './src/xhr';
export {HttpXsrfTokenExtractor} from './src/xsrf';
```

The exported public API of the Common/Http sub-package can be represented as:


Common/Http Public API
Exported @NgModules
HttpClientModule
HttpClientJsonpModule
HttpClientXsrfModule
Exported Enums
HttpEventType
Exported Consts
HTTP_INTERCEPTORS
Exported Tvnes
HttpEvent
Exported Interfaces
HttpInterceptor
HttpProgressEvent
HttpUserEvent
HttpBackend
HttpDownload ProgressEvent
HttpSentEvent
HttpParameterCodec
JsonpInterceptor
{implements}
XhrFactory
{implements}
HttpUrlEncodingCodec
Exported Classes
HttpXhrBackend
JsonpClientBackend
HttpRequest
HttpResponseBase
HttpHeaders
HttpHandler
HttpXsrfTokenExtractor
HttpResponse
HttpErrorResponse
HttpHeaderResponse
HttpParams
HttpHeaders
HttpClient
BrowserXhr

Source Tree Layout

The source tree for the Common/Http sub-package contains these directories:

- src
- test (unit tests in Jasmine)
- testing (test tooling)

and these files:

- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

http/src

The http/src directory has following source files:

- backend.ts
- client.ts
- headers.ts
- interceptors.ts
- jsonp.ts
- module.ts
- params.ts
- request.ts
- response.ts
- xhr.ts
- xsrf.ts

The module.ts file has a number of `NgModule` definitions, the main one being:

```
@NgModule({
  imports: [
    HttpClientXsrfModule.withOptions({
      cookieName: 'XSRF-TOKEN',
      headerName: 'X-XSRF-TOKEN',
    }),
  ],
  providers: [
    HttpClient,
    // HttpHandler is the backend + interceptors and is constructed
    // using the interceptingHandler factory function.
    {
      provide: HttpHandler,
      useFactory: interceptingHandler,
      deps: [HttpBackend, [new Optional(), new Inject(HTTP_INTERCEPTORS)]],
    },
    HttpXhrBackend,
    {provide: HttpBackend, useExisting: HttpXhrBackend},
    BrowserXhr,
    {provide: XhrFactory, useExisting: BrowserXhr},
  ],
})
export class HttpClientModule { }
```

That HttpXHRBackend provider for HttpClientModule may need to be replaced when using an in-memory-web-api for testing, as explained here (search for InMemoryWebApiModule):

- https://angular.io/docs/ts/latest/tutorial/toh-pt6.html

We note HttpClientModule uses HttpClientXsrfModule (we'll see where XSRF_COOKIE_NAME and XSRF_HEADER_NAME are defined when examining XSRF shortly):

```
@NgModule({
  providers: [
    HttpXsrfInterceptor,
    {provide: HTTP_INTERCEPTORS,
       useExisting: HttpXsrfInterceptor, multi: true},
    {provide: HttpXsrfTokenExtractor, useClass: HttpXsrfCookieExtractor},
    {provide: XSRF_COOKIE_NAME, useValue: 'XSRF-TOKEN'},
    {provide: XSRF_HEADER_NAME, useValue: 'X-XSRF-TOKEN'},
  ],
})
export class HttpClientXsrfModule {.. }
```

The headers.ts file provides the HttpHeaders class. This is essentially a wrapper around a Map data structure. It defines its primary data structure as:

```
private headers: Map<string, string[]>;
```

It offers functionality to work with that data structure.

```
// Immutable set of Http headers, with lazy parsing.
export class HttpHeaders {
  /**
   * Internal map of lowercase header names to values.
   */
  private headers: Map<string, string[]>;

  /**
   * Internal map of lowercased header names to the normalized
   * form of the name (the form seen first).
   */
  private normalizedNames: Map<string, string> = new Map();

  /**
   * Complete the lazy initialization of this object (needed before reading).
   */
  private lazyInit: HttpHeaders|Function|null;

  /**
   * Queued updates to be materialized the next initialization.
   */
  private lazyUpdate: Update[]|null = null;

  constructor(headers?: string|{[name: string]: string | string[]}) {.. }
}
```

The request.ts file implements the Request class. A request is a request method, a set of headers, and a content type. Depending on the request method, a body may or may not be needed. To supply initialization parameters, this interface is defined:

```
interface HttpRequestInit {
  headers?: HttpHeaders;
  reportProgress?: boolean;
  params?: HttpParams;
  responseType?: 'arraybuffer'|'blob'|'json'|'text';
  withCredentials?: boolean;
}
```

We see its use in the constructor for `Request`:

```
// Next, need to figure out which argument holds the HttpRequestInit
// options, if any.
let options: HttpRequestInit|undefined;

// Check whether a body argument is expected. The only valid way to omit
// the body argument is to use a known no-body method like GET.
if (mightHaveBody(this.method) || !!fourth) {
  // Body is the third argument, options are the fourth.
  this.body = (third !== undefined) ? third as T : null;
  options = fourth;
} else {
  // No body required, options are the third argument.
  // The body stays null.
  options = third as HttpRequestInit;
}

// If options have been passed, interpret them.
if (options) {..}
```

Similarly, the response.ts implements the `Response` classes, which are based on the `HttpResponseBase` class:

```
  export abstract class HttpResponseBase {
  // All response headers.
  readonly headers: HttpHeaders;
  // Response status code.
  readonly status: number;
  // Textual description of response status code.
  readonly statusText: string;
  //URL of the resource retrieved, or null if not available.
  readonly url: string|null;
  // Whether the status code falls in the 2xx range.
  readonly ok: boolean;
  // Type of the response, narrowed to either the full response
  // or the header.
  readonly type: HttpEventType.Response|HttpEventType.ResponseHeader;
}
```

The backend.ts file provides classes for pluggable connection handling. By providing alternative implementations of these, flexible server communication is supported. Note what the comments in the code say:

```
/**
 * Transforms an `HttpRequest` into a stream of `HttpEvent`s, one of
 * which will likely be a  * `HttpResponse`.
 *
 * `HttpHandler` is injectable. When injected, the handler instance
 * dispatches requests to the
 * first interceptor in the chain, which dispatches to the second, etc,
 * eventually reaching the `HttpBackend`.
 *
 * In an `HttpInterceptor`, the `HttpHandler` parameter is the
 * next interceptor in the chain.
 */
export abstract class HttpHandler {
  abstract handle(req: HttpRequest<any>): Observable<HttpEvent<any>>;
}

/**
 * A final `HttpHandler` which will dispatch the request via browser HTTP
 * APIs to a backend.
 *
 * Interceptors sit between the `HttpClient` interface and the `HttpBackend`.
 *
 * When injected, `HttpBackend` dispatches requests directly to the backend,
 * without going through the interceptor chain.
 */
export abstract class HttpBackend implements HttpHandler {
  abstract handle(req: HttpRequest<any>): Observable<HttpEvent<any>>;
}
```

The backend is important because it means a test-oriented in-memory backend could be switched for the real backend as needed, without further changes to HTTP code.

When communicating with a real remote server, the main workload is performed by `HttpXhrBackend` class which is defined in xhr.ts:

```
@Injectable()
export class HttpXhrBackend implements HttpBackend {
  constructor(private xhrFactory: XhrFactory) {}
```

The xsrf.ts file defines two injectable classes that helps with XSRF (Cross Site Request Forgery) protection:

```
// `HttpXsrfTokenExtractor` which retrieves the token from a cookie.
@Injectable()
export class HttpXsrfCookieExtractor implements HttpXsrfTokenExtractor {
  private lastCookieString: string = '';
  private lastToken: string|null = null;

  constructor(
       @Inject(DOCUMENT) private doc: any,
       @Inject(PLATFORM_ID) private platform: string,
       @Inject(XSRF_COOKIE_NAME) private cookieName: string) {}

  getToken(): string|null ..
  }
}



// `HttpInterceptor` which adds an XSRF token to eligible outgoing requests.
@Injectable()
export class HttpXsrfInterceptor implements HttpInterceptor {
  constructor(
      private tokenService: HttpXsrfTokenExtractor,
      @Inject(XSRF_HEADER_NAME) private headerName: string) {}
  intercept(req: HttpRequest<any>, next: HttpHandler):
Observable<HttpEvent<any>> {..
  }
}
```

This files also defines:

```
export const XSRF_COOKIE_NAME =
     new InjectionToken<string>('XSRF_COOKIE_NAME');
export const XSRF_HEADER_NAME =
     new InjectionToken<string>('XSRF_HEADER_NAME');
```

These are used when defining the @NgModule `HttpClientXsrfModule` as we saw earlier.

7: The Platform-Browser Package

Overview

A platform module is how an application interacts with its hosting environment. Duties of a platform include rendering (deciding what is displayed and how), multitasking (web workers), security sanitization of URLs/html/style (to detect dangerous constructs) and location management (the URL displayed in the browser).

We have seen how the Core module provides a rendering API, but it includes no implementations of renderers and no mention of the DOM. All other parts of Angular that need to have content rendered talk to this rendering API and rely on an implementation to actually deal with the content to be "displayed" (and what "displayed" means varies depending on the platform). You will find an implementation of renderer in the various platform packages – the main ones are defined here in the Platform-Browser package. Note that these render to a DOM adapter (and multiple of those exist), but Core and all the features sitting on top of Core only know about the rendering API, not the DOM.

Angular supplies five platform packages:

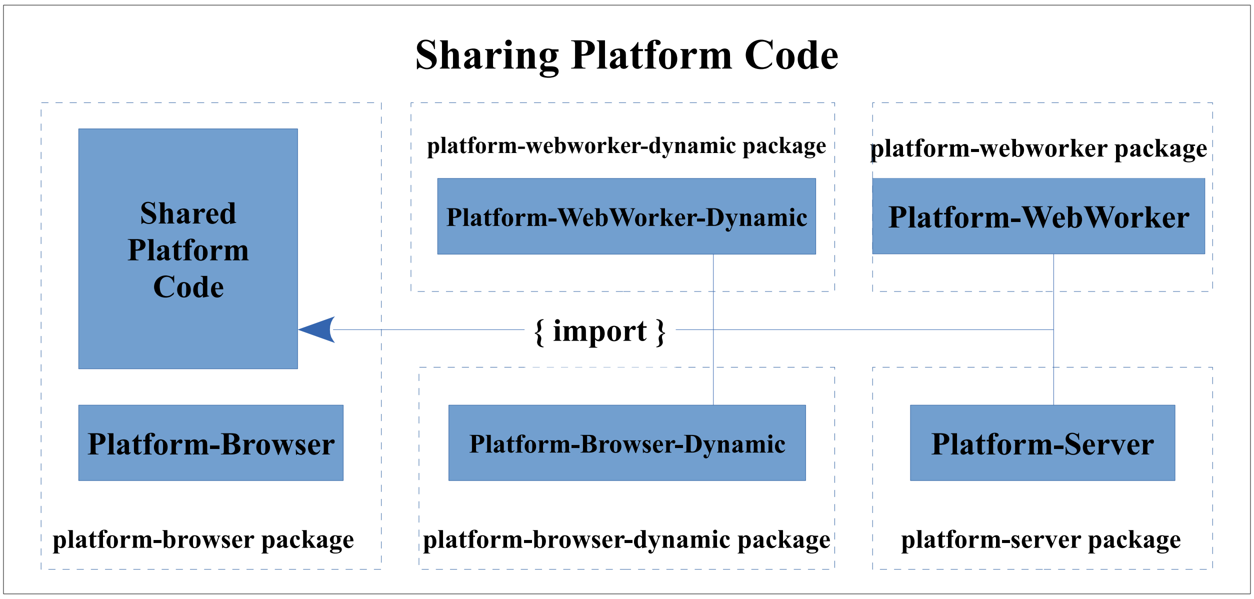
- platform-browser (runs in the browser's main UI thread and uses the offline template compiler),
- platform-browser-dynamic (runs in the browser's main UI thread and uses the runtime template compiler),
- platform-webworker (runs in a web worker and uses the offline compiler),
- platform-webworker-dynamic (runs in a web worker and uses the runtime template compiler) and
- platform-server (runs in the server and can uses either the offline or runtime template compiler)

Shared functionality relating to platforms is in Platform-Browser and imported by the other platform packages. So Platform-Browser is a much bigger packages compared to the other platform packages. In this chapter we will explore Platform-Browser and we will cover the others in the subsequent chapters.

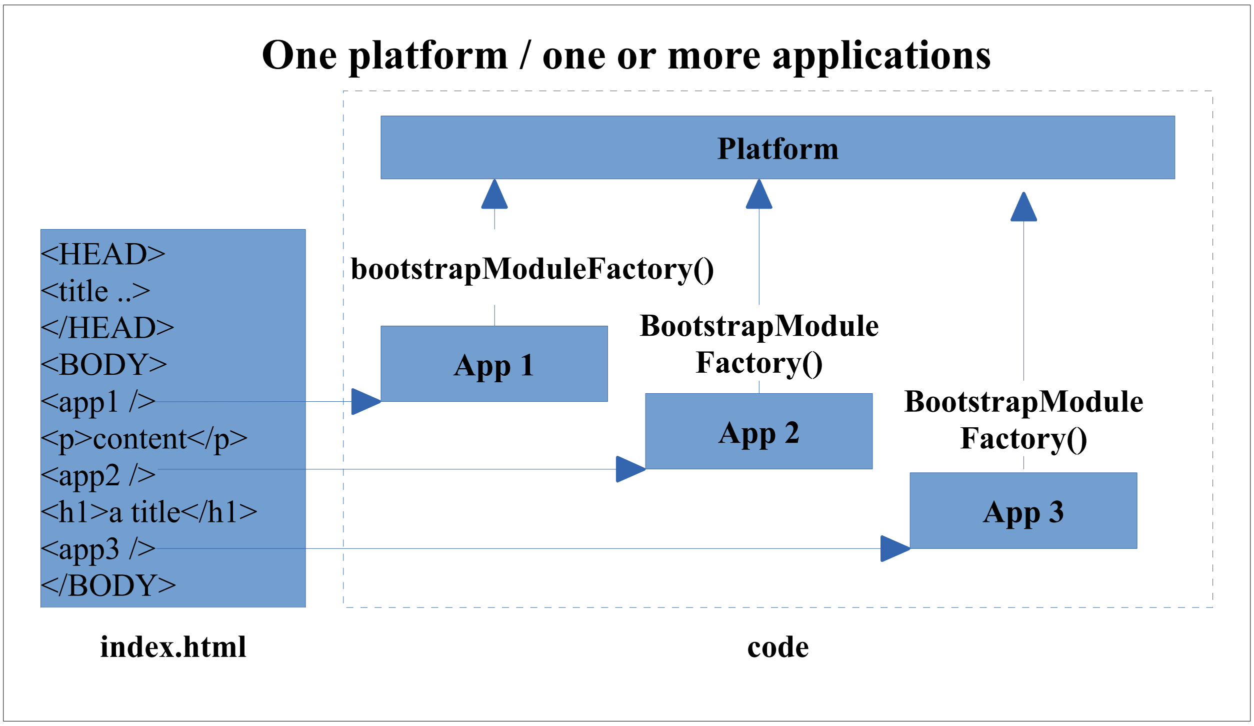
Platform-Browser is how application code can interact with the browser when running in the main UI thread and assumes the offline template compiler has been used to pre-generate a module factory. For production use, platform-browser is likely to be the platform of choice, as it results in the fastest display (no in-browser template compilation needed) and smallest download size (the Angular template compiler does not have to be downloaded to the browser).

The Platform-Browser package does not depend on the Compiler package since it assumes compilation has occurred Ahead-Of-Time (AOT) using Compiler-CLI, the command-line interface that wraps the Compiler package. In contrast, Platform-Browser-Dynamic does import directly from the Compiler package – for example, see:

- <ANGULAR-MASTER>/packages/platform-browser-dynamic/src/compiler_factory.ts



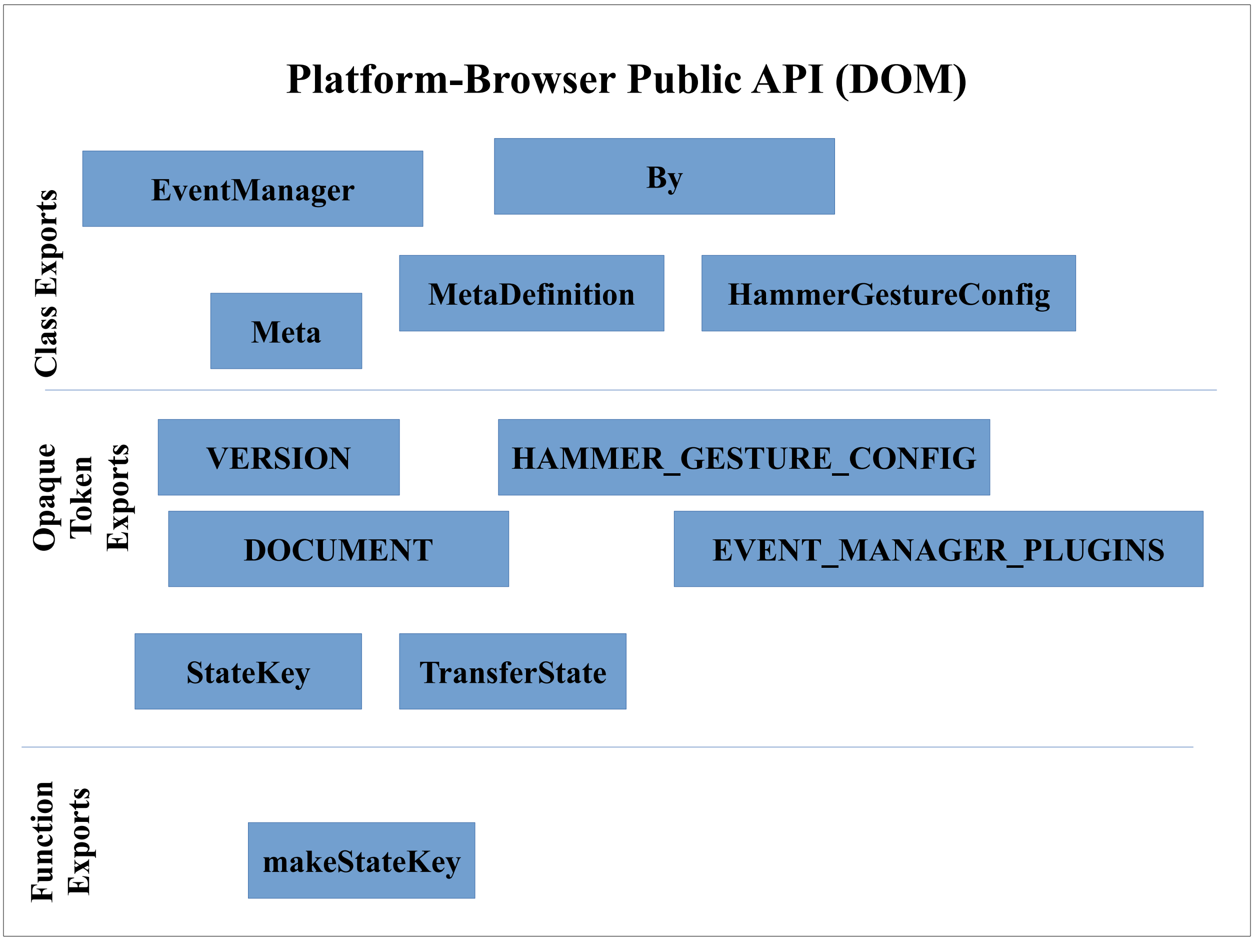
There is exactly one platform instance per thread (main browser UI thread or web worker). Multiple applications may run in the same thread, and they interact with the same platform instance.



Platform-Browser Public API

The platform-browser API can be sub-divided into these functional areas: browser-related, DOM and security.

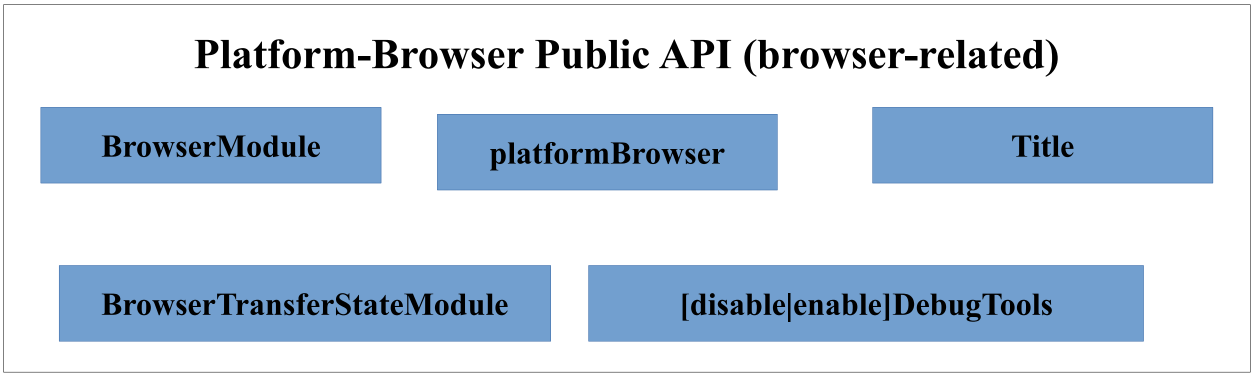
The DOM related API can be represented as:



Hammer is for touch input. `EventManager` handles the flow of events.

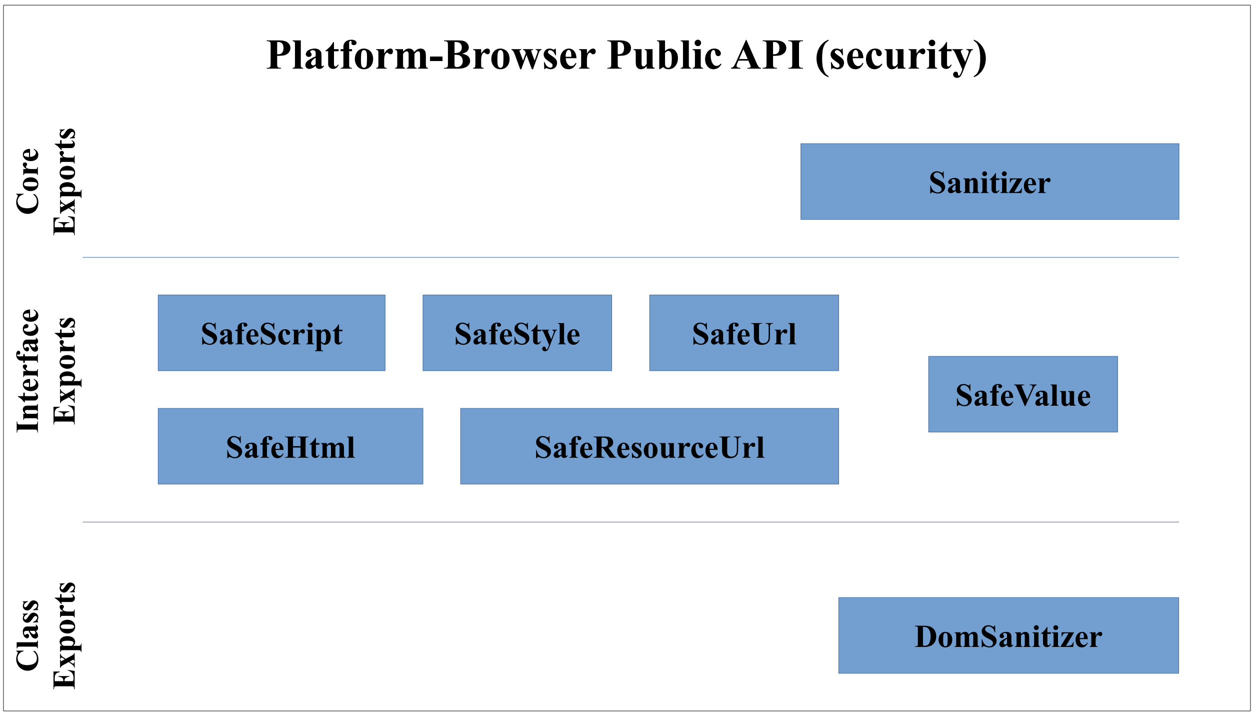
Some important classes – e.g. `DomAdapter` - are not publically exported. Instead, they are registered with the dependency injector and that is how they are made available to application code (we will shortly examine both in detail).

The browser-related API can be represented as:


Platform-Browser Public API (browser-related)
BrowserModule
platformBrowser
Title
BrowserTransferStateModule
[disable|enable]DebugTools

This covers the `NgModule`, the `createPlatformFactory` function, location information, a title helper class, and functions to enable and disable debug tooling.

The security-related API can be represented as:



The root directory of this package has:

- index.ts

which has the single line:

```
export * from './public_api';
```

and this turn has:

```
/**
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/platform-browser';
// This file only reexports content of the `src` folder. Keep it that way.
```

If we look at src/platform-browser.ts, we see the exported API of the Platform-Browser package:

```
export {BrowserModule, platformBrowser} from './browser';
export {Meta, MetaDefinition} from './browser/meta';
export {Title} from './browser/title';
export {disableDebugTools, enableDebugTools} from './browser/tools/tools';
export {BrowserTransferStateModule, StateKey, TransferState, makeStateKey}
  from './browser/transfer_state';
export {By} from './dom/debug/by';
export {DOCUMENT} from './dom/dom_tokens';
export {EVENT_MANAGER_PLUGINS, EventManager}
  from './dom/events/event_manager';
export {HAMMER_GESTURE_CONFIG, HammerGestureConfig}
  from './dom/events/hammer_gestures';
export {DomSanitizer, SafeHtml, SafeResourceUrl, SafeScript, SafeStyle,
  SafeUrl, SafeValue} from './security/dom_sanitization_service';
```

```
export * from './private_export';
export {VERSION} from './version';
```

The private_export.ts file exports types that are intended to be used by other Angular packages and not be normal Angular applications. It has this content:

```
export {BROWSER_SANITIZATION_PROVIDERS as ɵBROWSER_SANITIZATION_PROVIDERS,
INTERNAL_BROWSER_PLATFORM_PROVIDERS as ɵINTERNAL_BROWSER_PLATFORM_PROVIDERS,
initDomAdapter as ɵinitDomAdapter} from './browser';
export {BrowserDomAdapter as ɵBrowserDomAdapter} from
'./browser/browser_adapter';
export {BrowserPlatformLocation as ɵBrowserPlatformLocation} from
'./browser/location/browser_platform_location';
export {TRANSITION_ID as ɵTRANSITION_ID} from './browser/server-transition';
export {BrowserGetTestability as ɵBrowserGetTestability} from
'./browser/testability';
export {escapeHtml as ɵescapeHtml} from './browser/transfer_state';
export {ELEMENT_PROBE_PROVIDERS as ɵELEMENT_PROBE_PROVIDERS} from
'./dom/debug/ng_probe';
export {DomAdapter as ɵDomAdapter, getDOM as ɵgetDOM, setRootDomAdapter as
ɵsetRootDomAdapter} from './dom/dom_adapter';
export {DomRendererFactory2 as ɵDomRendererFactory2, NAMESPACE_URIS as
ɵNAMESPACE_URIS, flattenStyles as ɵflattenStyles, shimContentAttribute as
ɵshimContentAttribute, shimHostAttribute as ɵshimHostAttribute} from
'./dom/dom_renderer';
export {DomEventsPlugin as ɵDomEventsPlugin} from './dom/events/dom_events';
export {HammerGesturesPlugin as ɵHammerGesturesPlugin} from
'./dom/events/hammer_gestures';
export {KeyEventsPlugin as ɵKeyEventsPlugin} from './dom/events/key_events';
export {DomSharedStylesHost as ɵDomSharedStylesHost, SharedStylesHost as
ɵSharedStylesHost} from './dom/shared_styles_host';
```

Source Tree Layout

The source tree for the Platform-Browser package contains these directories:

- animations
- src
- test (unit tests in Jasmine)
- testing (test tooling)

and these files in the root directory:

- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

The tsconfig-build.json contains this list of files to compile:

```
{
  "extends": "../tsconfig-build.json",

  "compilerOptions": {
    "baseUrl": ".",
    "rootDir": ".",
    "paths": {
      "@angular/core": ["../../dist/packages/core"],
      "@angular/platform-browser/animations":
```

```
                    ["../../dist/packages/platform-browser/animations"],
        "@angular/common": ["../../dist/packages/common"]
      },
      "outDir": "../../dist/packages/platform-browser"
    },

    "files": [
      "public_api.ts",
      "../../node_modules/@types/hammerjs/index.d.ts",
      "../../node_modules/zone.js/dist/zone.js.d.ts",
      "../goog.d.ts"
    ],

    "angularCompilerOptions": {
      "annotateForClosureCompiler": true,
      "strictMetadataEmit": false,
      "skipTemplateCodegen": true,
      "flatModuleOutFile": "platform-browser.js",
      "flatModuleId": "@angular/platform-browser"
    }
  }
```

Source

platform-browser/src

This directory contains these sub-directories:

- browser
- dom
- security

and this file:

- browser.ts

The browser.ts file defines providers (`INTERNAL_BROWSER_PLATFORM_PROVIDERS` and `BROWSER_SANITIZATION_PROVIDERS`) and the `NgModule`-decorated `BrowserModule`, all important in the bootstrapping of an Angular application.

`INTERNAL_BROWSER_PLATFORM_PROVIDERS` is used to define platform-related providers for dependency injection:

```
export const INTERNAL_BROWSER_PLATFORM_PROVIDERS: StaticProvider[] = [
  {provide: PLATFORM_ID, useValue: PLATFORM_BROWSER_ID},
  {provide: PLATFORM_INITIALIZER, useValue: initDomAdapter, multi: true},
  {provide: PlatformLocation,
    useClass: BrowserPlatformLocation, deps: [DOCUMENT]},
  {provide: DOCUMENT, useFactory: _document, deps: []},
];
```

Sanitization providers mitigate XSS risks – note the comment:

```
/**
 * @security Replacing built-in sanitization providers exposes
 * the application to XSS risks.
 * Attacker-controlled data introduced by an unsanitized provider could
 * expose your application to XSS risks.
 * For more detail, see the [Security Guide](http://g.co/ng/security).
 */
```

```
export const BROWSER_SANITIZATION_PROVIDERS: StaticProvider[] = [
  {provide: Sanitizer, useExisting: DomSanitizer},
  {provide: DomSanitizer, useClass: DomSanitizerImpl, deps: [DOCUMENT]},
];
```

It is used in the definition of `NgModule`:

```
@NgModule({
  providers: [
    BROWSER_SANITIZATION_PROVIDERS,
    {provide: ErrorHandler, useFactory: errorHandler, deps: []},
    {provide: EVENT_MANAGER_PLUGINS, useClass: DomEventsPlugin, multi: true},
    {provide: EVENT_MANAGER_PLUGINS, useClass: KeyEventsPlugin, multi: true},
    {provide: EVENT_MANAGER_PLUGINS, useClass: HammerGesturesPlugin,
                                                                multi: true},
    {provide: HAMMER_GESTURE_CONFIG, useClass: HammerGestureConfig},
    DomRendererFactory2,
    {provide: RendererFactory2, useExisting: DomRendererFactory2},
    {provide: SharedStylesHost, useExisting: DomSharedStylesHost},
    DomSharedStylesHost,
    Testability,
    EventManager,
    ELEMENT_PROBE_PROVIDERS,
    Meta,
    Title,
  ],
  exports: [CommonModule, ApplicationModule]
})
export class BrowserModule {
  constructor(@Optional() @SkipSelf() parentModule: BrowserModule) {
    if (parentModule) {
      throw new Error(
          `BrowserModule has already been loaded. If you need access to
          common directives such as NgIf and NgFor from a lazy loaded module,
          import CommonModule instead.`);
    }
  }
```

The `initDomAdapter` function sets the current DOM adapter to be `BrowserDomAdapter` (covered shortly).

```
export function initDomAdapter() {
  BrowserDomAdapter.makeCurrent();
  BrowserGetTestability.init();
}
```

As we saw, this function is used in an initializer by the app provider list:

```
export const INTERNAL_BROWSER_PLATFORM_PROVIDERS: StaticProvider[] = [
  {provide: PLATFORM_INITIALIZER, useValue: initDomAdapter, multi: true},
  .. ];
```

This in turn is used by the call to createPlatformFactory:

```
export const platformBrowser: (extraProviders?: StaticProvider[]) =>
PlatformRef = createPlatformFactory(platformCore, 'browser',
                    INTERNAL_BROWSER_PLATFORM_PROVIDERS);
```

Platform-browser/src/dom

We will sub-divide the code in the DOM sub-directory into four categories – adapter/renderer, animation, debug and events.

We have seen how the Core package defines a rendering API and all other parts of the Angular framework and applicaton code uses it to have content rendered. But Core has no implementation. Now it is time to see an implementation, based on the DOM. That is the role of these files:

- dom_tokens.ts
- shared_styles_host.ts
- util.ts
- dom_adapter.ts
- dom_renderer.ts

dom_tokens.ts exports a const:

```
/**
 * A DI Token representing the main rendering context.
 * In a browser this is the DOM Document.
 *
 * Note: Document might not be available in the Application Context when
 * Application and Rendering Contexts are not the same (e.g. when running
 * the application into a Web Worker).
 */
export const DOCUMENT = commonDOCUMENT;
```

shared_styles_host.ts manages a set of styles.

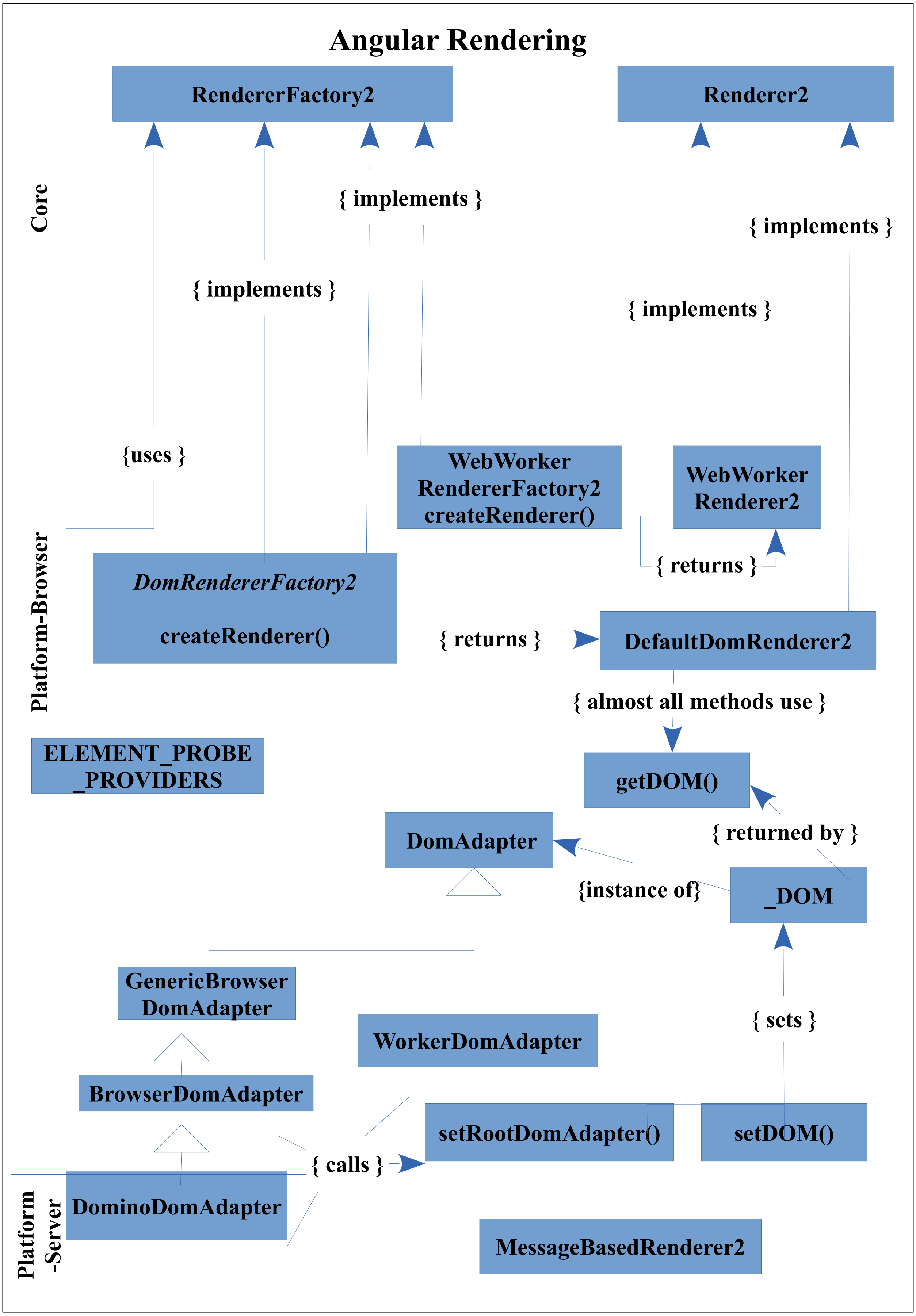
Utils.ts contains simple string helpers:

```
export function camelCaseToDashCase(input: string): string {
  return input.replace(
     CAMEL_CASE_REGEXP, (...m: string[]) => '-' + m[1].toLowerCase());
}

export function dashCaseToCamelCase(input: string): string {
  return input.replace(
     DASH_CASE_REGEXP, (...m: string[]) => m[1].toUpperCase());
}
```

The two main files involved in delivering the DomRenderer are dom_adapter.ts and dom_renderer.ts. A DomAdapter is a class that represents an API very close to the HTML DOM that every web developer is familiar with. A DOM renderer is an implementation of Core’s Rendering API in terms of a DOM adapter.

The benefit that a DomAdapter brings (compared to hard-coding calls to the actual DOM inside a browser), is that multiple implementations of a DomAdapter can be supplied, including in scenarios where the real DOM is not available (e.g. server-side, or inside webworkers).

The following diagram shows how Core’s renderer API, renderer implementations and DOM adapters are related. For many applications, the entire application will run in the main browser UI thread and so `BrowserDomAdapter` will be used alongside `DefaultDomRenderer2`.


Angular Rendering
RendererFactory2
Renderer2
Core
{ implements }
{ implements }
{ implements }
{ implements }
Platform-Browser
{uses }
WebWorker RendererFactory2
createRenderer()
WebWorker Renderer2
{ returns }
DomRendererFactory2
createRenderer()
{ returns }
DefaultDomRenderer2
{ almost all methods use }
ELEMENT_PROBE _PROVIDERS
getDOM()
{ returned by }
DomAdapter
{instance of}
_DOM
GenericBrowser DomAdapter
WorkerDomAdapter
{ sets }
BrowserDomAdapter
setRootDomAdapter()
setDOM()
{ calls }
Platform -Server
DominoDomAdapter
MessageBasedRenderer2

For server applications with Platform-Server, a specialist DOM adapter called DominoAdapter will be used, and this results in content being written to an HTML file. DominoAdapter is implemented in the Platform-Server package here:

- <ANGULAR-MASTER>/packages/platfrom-server/src/domino_adapter.ts

It is based in this project:

- https://github.com/fgnass/domino

We'll explore this further when examining the Platform-Server package.

For more advanced browser applications that will use web workers, things are a little more complicated and involves these main classes: `WorkerRenderer2`, `MessageBasedRender2` and `WorkerDomAdapter`. `WorkerDomAdapter` is used merely for logging and does not place a significant part in rendering from workers. A message broker based on a message bus exchanges messages between the web worker and main browser UI thread. `WorkerRenderer2` runs in the web worker and forward all rendering calls over the message broker to the main browser UI thread, where an instance of `MessageBasedRender2` (which, despite its name, does not implement Core's renderer API) receives them and calls the regular `DefaultDomRenderer2`. We will shortly examine in detail how rendering works with web workers. We'll explore rendering and web workers in the later chapter on Platform-WebWorker.

When trying to figure out how the DOM adaptor works, the best place to start is:

- <ANGULAR-MASTER>/packages/platform-browser/src/dom_adaptor.ts

The dom_adapter.ts class defines the abstract `DomAdapter` class, the `_DOM` variable and two functions, `getDOM()` and `setDOM()` to get and set it.

```
let _DOM: DomAdapter = null !;

export function getDOM() {
  return _DOM;
}

export function setDOM(adapter: DomAdapter) {
  _DOM = adapter;
}

export function setRootDomAdapter(adapter: DomAdapter) {
  if (!_DOM) {
    _DOM = adapter;
  }
}
```

The `DomAdapter` class is a very long list of methods similar to what you would find a normal DOM API (pay attention to the security warning!)– here is a sampling of what it contains:

```
/**
 * Provides DOM operations in an environment-agnostic way.
 * @security Tread carefully! Interacting with the DOM directly is
 * dangerous and can introduce XSS risks.
 */
 export abstract class DomAdapter {
    abstract getInnerHTML(el: any): string;
    abstract getOuterHTML(el: any): string;
    abstract nodeName(node: any): string;
    abstract nodeValue(node: any): string|null;
    abstract type(node: any): string;
    abstract content(node: any): any;
    abstract firstChild(el: any): Node|null;
    abstract nextSibling(el: any): Node|null;
    abstract parentElement(el: any): Node|null;
    abstract childNodes(el: any): Node[];
    abstract childNodesAsList(el: any): Node[];
    abstract clearNodes(el: any): any;
    abstract appendChild(el: any, node: any): any;
    abstract removeChild(el: any, node: any): any;
    abstract replaceChild(el: any, newNode: any, oldNode: any): any;
    abstract insertBefore(parent: any, ref: any, node: any): any;
    abstract insertAllBefore(parent: any, ref: any, nodes: any): any;
    abstract insertAfter(parent: any, el: any, node: any): any;
    abstract setInnerHTML(el: any, value: any): any;
    abstract supportsDOMEvents(): boolean;
    abstract supportsNativeShadowDOM(): boolean;
    abstract getHistory(): History;
    abstract getLocation(): Location;
    abstract supportsCookies(): boolean;
    abstract getCookie(name: string): string|null;
    abstract setCookie(name: string, value: string): any;
  }
```

The dom_renderer.ts file defines the DOM renderer that relies on `getDOM()` to supply a `DomAdapter`. The main class it supplies is `DomRendererFactory2` which implements `RendererFactory2`. We saw earlier how `DomRendererFactory2` is used in the `NgModule` declaration:

```
  @NgModule({
    providers: [
      ..
      DomRendererFactory2,
      {provide: RendererFactory2, useExisting: DomRendererFactory2},
    ],
    ..
  })
  export class BrowserModule { .. }
```

The `DomRendererFactory2` class manages a map of strings to `Renderer2` instances.

```
  export class DomRendererFactory2 implements RendererFactory2 {
    private rendererByCompId = new Map<string, Renderer2>();
    private defaultRenderer: Renderer2;

    constructor(
         private eventManager: EventManager,
         private sharedStylesHost: DomSharedStylesHost) {
      this.defaultRenderer = new DefaultDomRenderer2(eventManager);
    }
```

Its `createRenderer()` method performs a switch on the encapsulation type and returns an appropriate `Renderer2`:

```
  createRenderer(element: any, type: RendererType2|null): Renderer2 {
      if (!element || !type) {
        return this.defaultRenderer;
      }
      switch (type.encapsulation) {
        case ViewEncapsulation.Emulated: {
          let renderer = this.rendererByCompId.get(type.id);
          if (!renderer) {
            renderer =
                new EmulatedEncapsulationDomRenderer2(
                          this.eventManager, this.sharedStylesHost, type);
            this.rendererByCompId.set(type.id, renderer);
          }
          (<EmulatedEncapsulationDomRenderer2>renderer).applyToHost(element);
          return renderer;
        }
        case ViewEncapsulation.Native:
          return new ShadowDomRenderer(
              this.eventManager, this.sharedStylesHost, element, type);
        default: {
          if (!this.rendererByCompId.has(type.id)) {
            const styles = flattenStyles(type.id, type.styles, []);
            this.sharedStylesHost.addStyles(styles);
            this.rendererByCompId.set(type.id, this.defaultRenderer);
          }
          return this.defaultRenderer;
        }
      }
    }
```

`DefaultDomRenderer2` is where renderering actually occurs. It implements `Renderer2`. As an example, let’s look at its `createElement()` method:

```
    createElement(name: string, namespace?: string): any {
      if (namespace) {
        return document.createElementNS(NAMESPACE_URIS[namespace], name);
      }

      return document.createElement(name);
    }
```

DOM debugging is supported via:

- src/dom/debug/by.ts
- src/dom/debug/ng_probe.ts

The `By` class may be used with Core’s `DebugElement` to supply predicates for its query functions. It supplies three predicates – all, css and directive:

```
  // Predicates for use with {@link DebugElement}'s query functions.
  export class By {
    //Match all elements.
    static all(): Predicate<DebugElement> { return (debugElement) => true; }

    // Match elements by the given CSS selector.
    static css(selector: string): Predicate<DebugElement> {
      return (debugElement) => {
        return debugElement.nativeElement != null ?
            getDOM().elementMatches(
                                debugElement.nativeElement, selector) : false;
      };
    }
    // Match elements that have the given directive present.
    static directive(type: Type<any>): Predicate<DebugElement> {
      return (debugElement) =>
                debugElement.providerTokens !.indexOf(type) !== -1;
    }
  }
```

DOM events are supported via:

- src/dom/events/dom_events.ts
- src/dom/events/event_manager.ts
- src/dom/events/hammer_common.ts
- src/dom/events/hammer_gestures.ts
- src/dom/events/key_events.ts

event_manager.ts provides two classes – `EventManager` and `EventManagerPlugin`.

`EventManager` manages an array of `EventManagerPlugin`s, which is defined as:

```
  export abstract class EventManagerPlugin {
    constructor(private _doc: any) {}

    manager: EventManager;

    abstract supports(eventName: string): boolean;

    abstract addEventListener(
         element: HTMLElement, eventName: string, handler: Function): Function;

    addGlobalEventListener(
         element: string, eventName: string, handler: Function): Function {
      const target: HTMLElement =
                     getDOM().getGlobalEventTarget(this._doc, element);
      if (!target) {
        throw new Error(
                `Unsupported event target ${target} for event ${eventName}`);
      }
      return this.addEventListener(target, eventName, handler);
    }
  }
```

It provides two methods to add event listeners to targets represented either by an `HTMLElement` or a string. `EventManager` itself is defined as an injectable class:

```
  @Injectable()
  export class EventManager {
    private _plugins: EventManagerPlugin[];
    private _eventNameToPlugin = new Map<string, EventManagerPlugin>();

    constructor(
         @Inject(EVENT_MANAGER_PLUGINS) plugins: EventManagerPlugin[],
         private _zone: NgZone) {
      plugins.forEach(p => p.manager = this);
      this._plugins = plugins.slice().reverse();
    }

    addEventListener(
         element: HTMLElement, eventName: string, handler: Function): Function {
```

```
    const plugin = this._findPluginFor(eventName);
    return plugin.addEventListener(element, eventName, handler);
  }

  addGlobalEventListener(
      target: string, eventName: string, handler: Function): Function {
    const plugin = this._findPluginFor(eventName);
    return plugin.addGlobalEventListener(target, eventName, handler);
  }

  getZone(): NgZone { return this._zone; }
```

Its constructor is defined in such a way as to allow dependency injection to inject an array of event manager plugins. We note this list is reversed in the constructor, which will impact the ordering of finding a plugin for an event type.

The other files in src/dom/events supply event manager plugins.

Note the comment in `DomEventsPlugin`:

```
@Injectable()
export class DomEventsPlugin extends EventManagerPlugin {
  ..
  // This plugin should come last in the list of plugins,
  // because it accepts all events.
  supports(eventName: string): boolean { return true; }
}
```

Touch events via the hammer project are supported via the hammer_common.ts and hammer_gesture.ts files. The list of supported touch events are:

```
const EVENT_NAMES = {
  // pan
  'pan': true,
  'panstart': true,
  'panmove': true,
  'panend': true,
  'pancancel': true,
  'panleft': true,
  'panright': true,
  'panup': true,
  'pandown': true,
  // pinch
  'pinch': true,
  'pinchstart': true,
  'pinchmove': true,
  'pinchend': true,
  'pinchcancel': true,
  'pinchin': true,
  'pinchout': true,
  // press
  'press': true,
  'pressup': true,
  // rotate
  'rotate': true,
  'rotatestart': true,
  'rotatemove': true,
  'rotateend': true,
  'rotatecancel': true,
  // swipe
  'swipe': true,
  'swipeleft': true,
  'swiperight': true,
  'swipeup': true,
  'swipedown': true,
  // tap
  'tap': true,
};
```

This is used by `HammerGesturesPlugin`:

```
@Injectable()
export class HammerGesturesPlugin extends EventManagerPlugin {
  constructor(
      @Inject(DOCUMENT) doc: any,
      @Inject(HAMMER_GESTURE_CONFIG) private _config: HammerGestureConfig) {
    super(doc);
  }

  supports(eventName: string): boolean {
    if (!EVENT_NAMES.hasOwnProperty(
         eventName.toLowerCase()) && !this.isCustomEvent(eventName)) {
      return false;
    }

    if (!(window as any).Hammer) {
      throw new Error(
       `Hammer.js is not loaded, can not bind ${eventName} event`);
    }
    return true;
  }
```

Its `addEventListener` method is implemented as:

```
addEventListener(
  element: HTMLElement, eventName: string, handler: Function): Function {
    const zone = this.manager.getZone();
    eventName = eventName.toLowerCase();

1   return zone.runOutsideAngular(() => {
      // Creating the manager bind events, must be done outside of angular
      const mc = this._config.buildHammer(element);
      const callback = function(eventObj: HammerInput) {
        zone.runGuarded(function() { handler(eventObj); });
      };
      mc.on(eventName, callback);
      return () => mc.off(eventName, callback);
    });
  }
```

Note the use of `zone.runOutsideAngular()` 1. Also note it does not implement `addGlobalEventListener`. Its constructor expects a `HAMMER_GESTURE_CONFIG` from dependency injection. The Hammer package is used in the injectable `HammerGestureConfig` class:

```
@Injectable()
export class HammerGestureConfig {
  events: string[] = [];
```

```
    overrides: {[key: string]: Object} = {};

    buildHammer(element: HTMLElement): HammerInstance {
      const mc = new Hammer(element);

      mc.get('pinch').set({enable: true});
      mc.get('rotate').set({enable: true});

      for (const eventName in this.overrides) {
        mc.get(eventName).set(this.overrides[eventName]);
      }

      return mc;
    }
  }
```

These event manager plugins need to be set in the NgModule configuration. We see how this is done in BrowserModule:

```
  @NgModule({
    providers: [
      ..
     {provide: EVENT_MANAGER_PLUGINS, useClass: DomEventsPlugin, multi: true},
      {provide: EVENT_MANAGER_PLUGINS, useClass: KeyEventsPlugin, multi: true},
      {provide: EVENT_MANAGER_PLUGINS, useClass: HammerGesturesPlugin, multi:
  true},
      {provide: HAMMER_GESTURE_CONFIG, useClass: HammerGestureConfig},
    ],
    exports: [CommonModule, ApplicationModule]
  })
  export class BrowserModule {..}
```

Platform-browser/src/browser

This directory contains these files:

- browser_adapter.ts
- generic_browser_adapter.ts
- meta.ts
- server-transition.ts
- testability.ts
- title.ts
- transfer_state.ts
- location/browser_platform_location.ts
- location/history.ts
- tools/browser.ts
- tools/common_tools.ts
- tools/tools.ts

generic_browser_adapter.ts defines the abstract GenericBrowserDomAdapter class that extends DomAdapter with DOM operations suitable for general browsers:

```
  export abstract class GenericBrowserDomAdapter extends DomAdapter { .. }
```

For example, to check if shadow DOM is supported, it evaluates whether the createShadowRoot function exists:

```
  supportsNativeShadowDOM(): boolean {
      return typeof(<any>document.body).createShadowRoot === 'function';
```

```
}
```

`GenericBrowserDomAdapter` does not provide the full implementation of `DomAdapter` and so a derived class is needed also.

browser_adapter.ts supplies the concrete `BrowserDomAdapter` class, which does come with a full implementation of `DomAdapter`:

```
/**
 * A `DomAdapter` powered by full browser DOM APIs.
 * @security Tread carefully! Interacting with the DOM directly
 * is dangerous and can introduce XSS risks.
 */
export class BrowserDomAdapter extends GenericBrowserDomAdapter {..}
```

Generally its methods provide implementation based on window or document – here are some samples:

```
getUserAgent(): string { return window.navigator.userAgent; }
getHistory(): History { return window.history; }
getTitle(doc: Document): string { return doc.title; }
setTitle(doc: Document, newTitle: string) { doc.title = newTitle || ''; }
```

title.ts supplies the `Title` service:

```
/**
 * A service that can be used to get and set the title of a
 * current HTML document.
 *
 * Since an Angular application can't be bootstrapped on the entire
 * HTML document (`<html>` tag)
 * it is not possible to bind to the `text` property of
 * the `HTMLTitleElement` elements
 * (representing the `<title>` tag). Instead, this service can be
 * used to set and get the current title value.
 */
@Injectable()
export class Title {
  constructor(@Inject(DOCUMENT) private _doc: any) {}
  /**
   * Get the title of the current HTML document.
   */
  getTitle(): string { return getDOM().getTitle(this._doc); }

  /**
   * Set the title of the current HTML document.
   * @param newTitle
   */
  setTitle(newTitle: string) { getDOM().setTitle(this._doc, newTitle); }
}
```

The tools sub-directory contains tools.ts and common_tools.ts. The `AngularProfiler` class is defined in common_tools.ts:

```
export class AngularProfiler {
  appRef: ApplicationRef;

  constructor(ref: ComponentRef<any>) {
      this.appRef = ref.injector.get(ApplicationRef);
   }
```

```
    timeChangeDetection(config: any): ChangeDetectionPerfRecord {
      ..
      return new ChangeDetectionPerfRecord(msPerTick, numTicks);
    }
  }
```

The `timeChangeDetection` method measures performance.

Tools.ts defines two functions `enableDebugTools()` and `disableDebugTools()` to add 1 and remove 2 a ng property to global:

```
  const PROFILER_GLOBAL_NAME = 'profiler';

  /**
   * Enabled Angular debug tools that are accessible via your browser's
   * developer console.
   *
   * Usage:
   *
   * 1. Open developer console (e.g. in Chrome Ctrl + Shift + j)
   * 1. Type `ng.` (usually the console will show auto-complete suggestion)
   * 1. Try the change detection profiler `ng.profiler.timeChangeDetection()`
   *    then hit Enter.
   *
   * @experimental All debugging apis are currently experimental.
   */
  export function enableDebugTools<T>(ref: ComponentRef<T>): ComponentRef<T> {
1   exportNgVar(PROFILER_GLOBAL_NAME, new AngularProfiler(ref));
    return ref;
  }

  /**
   * Disables Angular tools.
   *
   * @experimental All debugging apis are currently experimental.
   */
  export function disableDebugTools(): void {
2   exportNgVar(PROFILER_GLOBAL_NAME, null);
  }
```

The src/browser/location sub-directory contains browser_platform_location.ts and history.ts. browser_platform_location.ts contains the injectable class `BrowserPlatformLocation`:

```
  /**
   * `PlatformLocation` encapsulates all of the direct calls to platform APIs.
   * This class should not be used directly by an application developer.
  Instead, use
   * {@link Location}.
   */
  @Injectable()
  export class BrowserPlatformLocation extends PlatformLocation {
    public readonly location: Location;
    private _history: History;

    constructor(@Inject(DOCUMENT) private _doc: any) {
      super();
      this._init();
    }
    ..
  }
```

This manages two private fields, location and history:

```
   public readonly location: Location;
    private _history: History;
```

which are initialized with `getDOM()`:

```
    constructor(@Inject(DOCUMENT) private _doc: any) {
      super();
      this._init();
    }
    // This is moved to its own method so that `MockPlatformLocationStrategy`
  can overwrite it
    _init() {
      (this as{location: Location}).location = getDOM().getLocation();
      this._history = getDOM().getHistory();
    }
```

history.ts contains this simple function:

```
  export function supportsState(): boolean {
    return !!window.history.pushState;
  }
```

Platform-browser/src/security

This directory contains these files:

- dom_sanitization_service.ts
- html_sanitizer.ts
- style_sanitizer.ts
- url_sanitizer.ts

Security sanitizers help prevent the use of dangerous constructs in HTML, CSS styles and URLs. Sanitizers are configured via an `NgModule` setting. This is the relevant extract from platform-browser/src/browser.ts:

```
  export const BROWSER_SANITIZATION_PROVIDERS: StaticProvider[] = [
    {provide: Sanitizer, useExisting: DomSanitizer},
    {provide: DomSanitizer, useClass: DomSanitizerImpl, deps: [DOCUMENT]},
  ];
  @NgModule({
    providers: [
      BROWSER_SANITIZATION_PROVIDERS,
      .. ],
    exports: [CommonModule, ApplicationModule]
  })
  export class BrowserModule {..}
```

The dom_sanitization_service.ts file declares a range of `safeXYZ` interfaces, implementation classes for them, the `DomSanitizer` class and the `DomSanitizerImpl` class. It starts by importing the `SecurityContext` enum and `Sanitizer` abstract class from Core:

- <ANGULAR_MASTER>/packages/core/src/security.ts

Let’s recall they are defined as:

```
export enum SecurityContext {
  NONE = 0,
  HTML = 1,
  STYLE = 2,
  SCRIPT = 3,
  URL = 4,
  RESOURCE_URL = 5,
}
export abstract class Sanitizer {
  abstract sanitize(
     context: SecurityContext, value: {}|string|null): string|null;
}
```

In dom_sanitization_service.ts the safe marker interfaces are declared as:

```
// Marker interface for a value that's safe to use in a particular context.
export interface SafeValue {}

// Marker interface for a value that's safe to use as HTML.
export interface SafeHtml extends SafeValue {}

// Marker interface for a value that's safe to use as style (CSS).
export interface SafeStyle extends SafeValue {}

// Marker interface for a value that's safe to use as JavaScript.
export interface SafeScript extends SafeValue {}

// Marker interface for a value that's safe to use as a URL linking
// to a document.
export interface SafeUrl extends SafeValue {}

// Marker interface for a value that's safe to use as a URL to load
// executable code from.
export interface SafeResourceUrl extends SafeValue {}
```

The `DomSanitizer` abstract class implements Core’s `Sanitizer` class. Do read the large comment at the beginning – you really do not want to be bypassing security if at all possible.

```
/**
 * DomSanitizer helps preventing Cross Site Scripting Security bugs (XSS) by
 * sanitizing values to be safe to use in the different DOM contexts.
 *
 * For example, when binding a URL in an `<a [href]="someValue">` hyperlink,
 * `someValue` will be sanitized so that an attacker cannot inject e.g. a
 * `javascript:` URL that would execute code on the website.
 *
 * In specific situations, it might be necessary to disable sanitization, for
 *  example if the application genuinely needs to produce a `javascript:`
 *  style link with a dynamic value in it.
 * Users can bypass security by constructing a value with one of the
 * `bypassSecurityTrust...` methods, and then binding to that value from the
 *  template.
 *
 * These situations should be very rare, and extraordinary care must be taken
 *  to avoid creating a Cross Site Scripting (XSS) security bug!
 *
 * When using `bypassSecurityTrust...`, make sure to call the method as early
 * as possible and as close as possible to the source of the value, to make
```

```
   *  it easy to verify no security bug is created by its use.
   *
   * It is not required (and not recommended) to bypass security if the value
   *  is safe, e.g. a URL that does not start with a suspicious protocol, or an
   *  HTML snippet that does not contain dangerous code. The sanitizer leaves
   *  safe values intact.
   *
   * @security Calling any of the `bypassSecurityTrust...` APIs disables
   * Angular's built-in sanitization for the value passed in. Carefully check
   * and audit all values and code paths going
   * into this call. Make sure any user data is appropriately escaped for this
   * security context.
   * For more detail, see the [Security Guide](http://g.co/ng/security).
   */
export abstract class DomSanitizer implements Sanitizer {
  abstract sanitize(context: SecurityContext,
                    value: SafeValue|string|null): string|null;
  abstract bypassSecurityTrustHtml(value: string): SafeHtml;
  abstract bypassSecurityTrustStyle(value: string): SafeStyle;
  abstract bypassSecurityTrustScript(value: string): SafeScript;
  abstract bypassSecurityTrustUrl(value: string): SafeUrl;
  abstract bypassSecurityTrustResourceUrl(value: string): SafeResourceUrl;
}
```

The `DomSanitizerImpl` injectable class is what is supplied to NgModule:

```
@Injectable()
export class DomSanitizerImpl extends DomSanitizer {
  constructor(@Inject(DOCUMENT) private _doc: any) { super(); }
```

It can be divided into three sections, the `checkNotSafeValue` method, the sanitize method and the `bypassSecurityTrustXYZ` methods. The `checkNotSafeValue` method throws an error is the value parameter is an instance of `SafeValueImpl`:

```
  private checkNotSafeValue(value: any, expectedType: string) {
    if (value instanceof SafeValueImpl) {
      throw new Error(
          `Required a safe ${expectedType}, got a ${value.getTypeName()} ` +
          `(see http://g.co/ng/security#xss)`);
    }
  }
```

The `sanitize` method switches on the `securityContext` enum parameter, if it is `NONE`, then value is simply returned, otherwise additional checking is carried out, which varies depending on the security context:

```
  sanitize(ctx: SecurityContext, value: SafeValue|string|null): string|null {
    if (value == null) return null;
    switch (ctx) {
      case SecurityContext.NONE:
        return value as string;
      case SecurityContext.HTML:
        if (value instanceof SafeHtmlImpl)
          return value.changingThisBreaksApplicationSecurity;
        this.checkNotSafeValue(value, 'HTML');
        return sanitizeHtml(this._doc, String(value));
      case SecurityContext.STYLE:
        if (value instanceof SafeStyleImpl)
          return value.changingThisBreaksApplicationSecurity;
        this.checkNotSafeValue(value, 'Style');
        return sanitizeStyle(value as string);
      case SecurityContext.SCRIPT:
        if (value instanceof SafeScriptImpl)
          return value.changingThisBreaksApplicationSecurity;
        this.checkNotSafeValue(value, 'Script');
        throw new Error('unsafe value used in a script context');
      case SecurityContext.URL:
        if (value instanceof SafeResourceUrlImpl ||
                                        value instanceof SafeUrlImpl) {
          // Allow resource URLs in URL contexts,
           // they are strictly more trusted.
          return value.changingThisBreaksApplicationSecurity;
        }
        this.checkNotSafeValue(value, 'URL');
        return sanitizeUrl(String(value));
      case SecurityContext.RESOURCE_URL:
        if (value instanceof SafeResourceUrlImpl) {
          return value.changingThisBreaksApplicationSecurity;
        }
        this.checkNotSafeValue(value, 'ResourceURL');
        throw new Error(
            'unsafe value used in a resource URL context
            (see http://g.co/ng/security#xss)');
      default:
        throw new Error(`Unexpected SecurityContext ${ctx}
            (see http://g.co/ng/security#xss)`);
    }
  }
```

The bypassSecurityTrust methods returns an appropriate SafeImpl instance:

```
    bypassSecurityTrustHtml(value: string): SafeHtml { return new
  SafeHtmlImpl(value); }
    bypassSecurityTrustStyle(value: string): SafeStyle { return new
  SafeStyleImpl(value); }
    bypassSecurityTrustScript(value: string): SafeScript { return new
  SafeScriptImpl(value); }
    bypassSecurityTrustUrl(value: string): SafeUrl { return new
  SafeUrlImpl(value); }
    bypassSecurityTrustResourceUrl(value: string): SafeResourceUrl {
      return new SafeResourceUrlImpl(value);
    }
```

8: The Platform-Browser-Dynamic Package

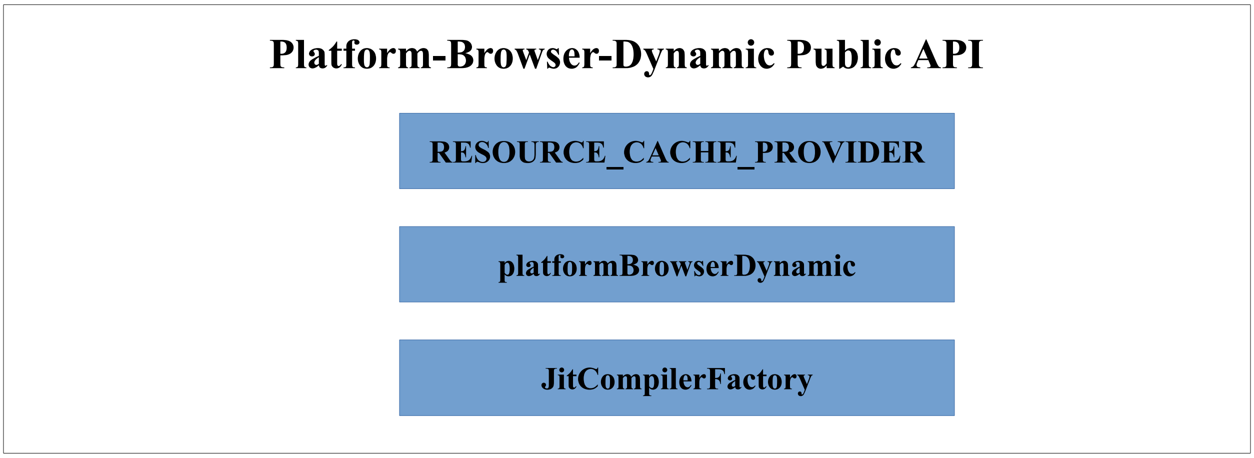
Overview

The term “dynamic” essentially means use the runtime template compiler and its absence means use the offline template compiler.

When Angular applications are bootstrapping they need to supply a platform. Those applications that wish to use runtime template compilation will need to supply a platform from Platform-Browser-Dynamic. If the application is to run in the browser’s main thread the platform to use is `platformBrowserDynamic`. If the application is to run in a web worker, then the platform to use is `platformWorkerAppDynamic` from the Platform-WebWorker-Dynamic package (discussed in a later chapter).

Platform-Browser-Dynamic API

The exported Public API of the Platform-Browser-Dynamic package can be represented as:



It’s index.ts has just one line:

```
export * from './public_api';
```

and the public_api.ts file has these lines:

```
/**
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/platform-browser-dynamic';

// This file only reexports content of the `src` folder. Keep it that way.
```

The ./src/platform-browser-dynamic.ts file is where the exports are actually defined:

```
export * from './private_export';
export {VERSION} from './version';
export {JitCompilerFactory} from './compiler_factory';

export const RESOURCE_CACHE_PROVIDER: Provider[] =
    [{provide: ResourceLoader, useClass: CachedResourceLoader, deps: []}];

export const platformBrowserDynamic = createPlatformFactory(
    platformCoreDynamic, 'browserDynamic',
    INTERNAL_BROWSER_DYNAMIC_PLATFORM_PROVIDERS);
```

The `platformBrowserDynamic` const is is how applications that use the runtime template compiler bootstrap a platform. We will need to see how `INTERNAL_BROWSER_DYNAMIC_PLATFORM_PROVIDERS` registers the compiler with dependency injection (it is defined in src/platform_providers.ts).

The `RESOURCE_CACHE_PROVIDER` const manages a cache of downloaded resources.

The `JitCompilerFactory` class creates a factory to access a just-in-time compiler.

The src directory for Platform-Browser-Dynamic also contains this private export file:

- <ANGULAR-MASTER>/packages/platform-browser-dynamic/src/private_export.ts

and it contains the following:

```
export {CompilerImpl as ɵCompilerImpl} from './compiler_factory';
export {platformCoreDynamic as ɵplatformCoreDynamic}
   from './platform_core_dynamic';
export {INTERNAL_BROWSER_DYNAMIC_PLATFORM_PROVIDERS as
   ɵINTERNAL_BROWSER_DYNAMIC_PLATFORM_PROVIDERS} from './platform_providers';
export {ResourceLoaderImpl as ɵResourceLoaderImpl}
   from './resource_loader/resource_loader_impl';
```

Source Tree Layout

The source tree for the Platform-Browser-Dynamic package contains these directories:

- src
- src/resource_loader
- test (unit tests in Jasmine)
- testing (test tooling)

and these files in the root directory:

- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

The tsconfig-build.json contains this config for the Angular compiler:

```
"angularCompilerOptions": {
  "annotateForClosureCompiler": true,
  "strictMetadataEmit": false,
  "skipTemplateCodegen": true,
  "flatModuleOutFile": "platform-browser-dynamic.js",
  "flatModuleId": "@angular/platform-browser-dynamic"
}
```

Source

src

This directory contains these files:

- compiler_factory.ts
- compiler_reflector.ts
- platform_core_dynamic.ts
- platform_providers.ts

Let's start with platform_providers.ts, which contains:

```
export const INTERNAL_BROWSER_DYNAMIC_PLATFORM_PROVIDERS: StaticProvider[] =
[
  INTERNAL_BROWSER_PLATFORM_PROVIDERS,
  {
    provide: COMPILER_OPTIONS,
    useValue: {providers:
      [{provide: ResourceLoader, useClass: ResourceLoaderImpl, deps: []}]},
    multi: true
  },
  {provide: PLATFORM_ID, useValue: PLATFORM_BROWSER_ID},
];
```

This extends `INTERNAL_BROWSER_PLATFORM_PROVIDERS` with two additional provider configurations. The first is `COMPILER_OPTIONS`, which itself needs a `ResourceLoader` (defined in the Compiler module), that we see is set to use `ResourceLoaderImpl` (defined in this package). The second is `PLATFORM_ID` which uses the value `PLATFORM_BROWSER_ID` (from the Common package).

This file:

- ANGULAR-MASTER/packages/platform-browser-dynamic/src/compiler_factory.ts

defines the `JitCompilerFactory` class.

Its _`mergeOptions` method takes a `CompilerOptions` parameter and returns a `CompilerOptions` instance with these additional entries:

```
function _mergeOptions(optionsArr: CompilerOptions[]): CompilerOptions {
  return {
    useJit: _lastDefined(optionsArr.map(options => options.useJit)),
    defaultEncapsulation: _lastDefined(
        optionsArr.map(options => options.defaultEncapsulation)),
    providers: _mergeArrays(optionsArr.map(options => options.providers !)),
    missingTranslation: _lastDefined(optionsArr.map(
        options => options.missingTranslation)),
    enableLegacyTemplate: _lastDefined(optionsArr.map(
        options => options.enableLegacyTemplate)),
    preserveWhitespaces: _lastDefined(optionsArr.map(
        options => options.preserveWhitespaces)),
  };
}
```

src/resource_loader

This directory has two files:

- resource_loader_cache.ts
- resource_loader_impl.ts

CachedResourceLoader is a cached version of a ResourceLoader (from the Compiler package). When the template compiler needs to access documents, it passes the job on to a configured resource loader. ResourceLoader is defined in:

- <ANGULAR-MASTER>/packages/compiler/src/resource_loader.ts

as:

```
/**
 * An interface for retrieving documents by URL that the compiler uses
 * to load templates.
 */
export class ResourceLoader {
  get(url: string): Promise<string>|string { return ''; }
}
```

CachedResourceLoader uses a promise wrapper to resolve or reject a get request:

```
/**
 * An implementation of ResourceLoader that uses a template cache to avoid
 * doing an actual ResourceLoader.
 *
 * The template cache needs to be built and loaded into window.$templateCache
 * via a separate mechanism.
 */
export class CachedResourceLoader extends ResourceLoader {
  private _cache: {[url: string]: string};

  constructor() {
    super();
    this._cache = (<any>global).$templateCache;
    if (this._cache == null) {
      throw new Error(
     'CachedResourceLoader: Template cache was not found in $templateCache.');
    }
  }

  get(url: string): Promise<string> {
    if (this._cache.hasOwnProperty(url)) {
      return Promise.resolve(this._cache[url]);
    } else {
      return <Promise<any>>Promise.reject(
          'CachedResourceLoader: Did not find cached template for ' + url);
    }
  }
}
```

ResourceLoaderImpl is a different injectable implementation of ResourceLoader that use XMLHttpRequest():

```
@Injectable()
export class ResourceLoaderImpl extends ResourceLoader {
  get(url: string): Promise<string> {
    let resolve: (result: any) => void;
```

```
      let reject: (error: any) => void;
      const promise = new Promise<string>((res, rej) => {
        resolve = res;
        reject = rej;
      });
      const xhr = new XMLHttpRequest();
      xhr.open('GET', url, true);
      xhr.responseType = 'text';
      xhr.onload = function() {..};
      xhr.onerror = function() { reject(`Failed to load ${url}`); };
      xhr.send();
      return promise;
    }
  }
```

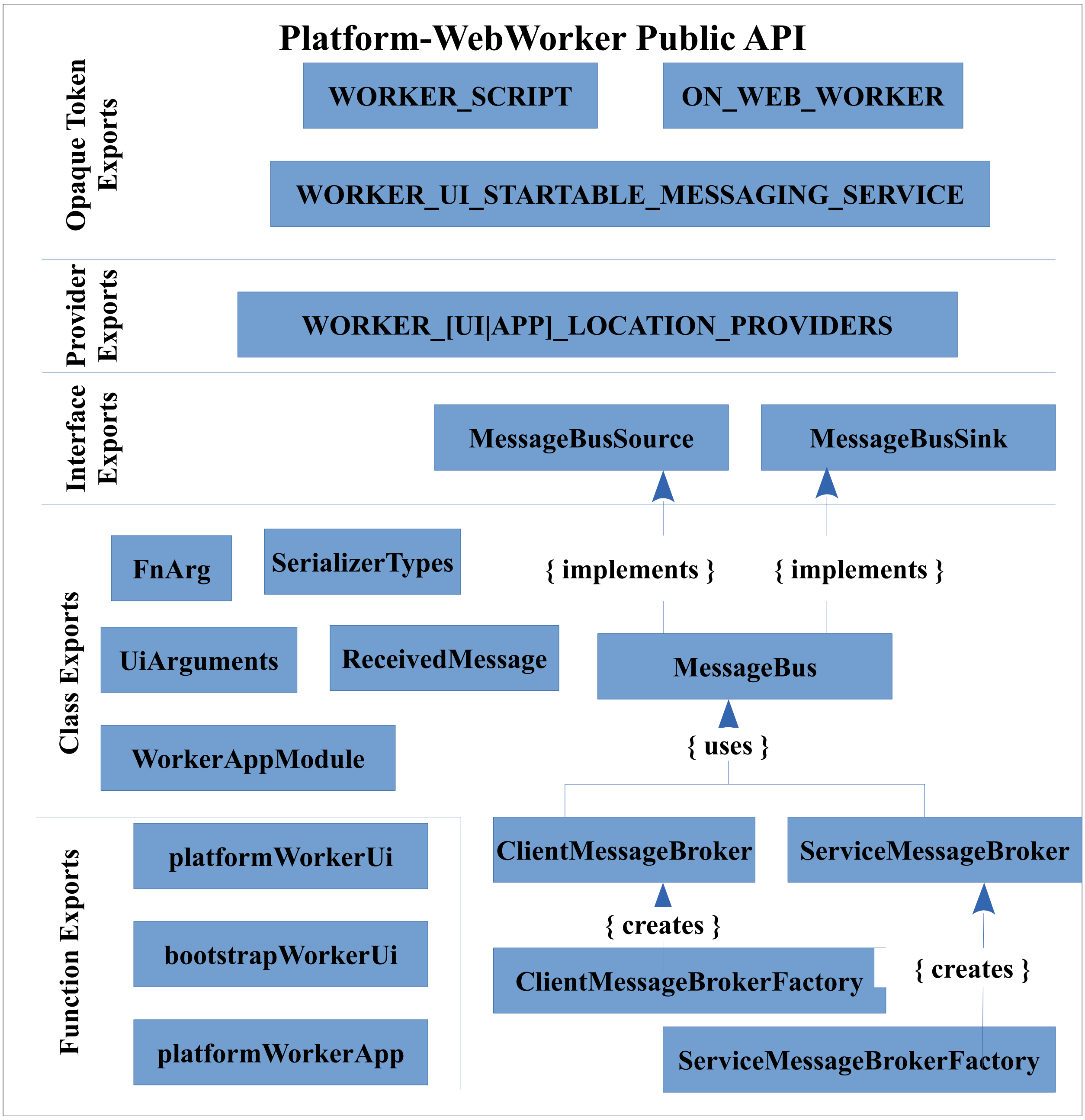
9: The Platform-WebWorker Package

Overview

Platform-WebWorker enables applications run inside a web worker.

Platform-WebWorker Public API

The Platform-WebWorker Public API is large and can be represented as:



The index.ts file is simply:

```
export * from './public_api';
```

and public_api.ts has this content:

```
/**
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/platform-webworker';
// This file only reexports content of the `src` folder. Keep it that way.
```

The src/platform-webworker.ts file lists the various exports and defines the `bootstrapWorkerUi` function:

```
export {VERSION} from './version';
export {ClientMessageBroker, ClientMessageBrokerFactory, FnArg, UiArguments}
   from './web_workers/shared/client_message_broker';
export {MessageBus, MessageBusSink, MessageBusSource}
   from './web_workers/shared/message_bus';
export {SerializerTypes} from './web_workers/shared/serializer';
export {ReceivedMessage, ServiceMessageBroker, ServiceMessageBrokerFactory}
   from './web_workers/shared/service_message_broker';
export {WORKER_UI_LOCATION_PROVIDERS}
   from './web_workers/ui/location_providers';
export {WORKER_APP_LOCATION_PROVIDERS}
   from './web_workers/worker/location_providers';
export {WorkerAppModule, platformWorkerApp} from './worker_app';
export {platformWorkerUi} from './worker_render';

// Bootstraps the worker ui.
export function bootstrapWorkerUi(
     workerScriptUri: string,
      customProviders: StaticProvider[] = []) : Promise<PlatformRef> {
   // For now, just creates the worker ui platform...
   const platform = platformWorkerUi([
     {provide: WORKER_SCRIPT, useValue: workerScriptUri},
     ...customProviders,
   ]);

   return Promise.resolve(platform);
}
```

Source Tree Layout

The source tree for the Platform-WebWorker package contains these directories:

- src
- test (unit tests in Jasmine)

(there is no testing directory) and these files:

- index.ts
- package.json
- rollup.config.js
- testing.ts
- tsconfig-build.json

Source

platform-webworker/src

In addition to the export files, this directory contains the following files:

- worker_app.ts
- worker_render.ts

worker_app.ts supplies functionality for an application that runs in a worker and worker_render.ts supplies functionality for the the main UI thread. They communicate via a message broker layered above a simple message bus.

A web worker cannot use the DOM directly in a web browser. Therefore Angular's Platform-WebWorker creates a message bus between the web worker and the main UI thread and rendering (and event processing) takes place over this message bus.

The `platformWorkerApp` const creates a platform factory for a worker app:

```
export const platformWorkerApp = createPlatformFactory(
    platformCore, 'workerApp', [{provide: PLATFORM_ID, useValue:
PLATFORM_WORKER_APP_ID}]);
```

Two important helper functions are supplied. `createMessageBus` creates the message bus that will supply communications between the main UI thread and the web worker:

```
export function createMessageBus(zone: NgZone): MessageBus {
  const sink = new PostMessageBusSink(_postMessage);
  const source = new PostMessageBusSource();
  const bus = new PostMessageBus(sink, source);
  bus.attachToZone(zone);
  return bus;
}
```

`setupWebWorker` makes the web worker's DOM adapter implementation as the current DOM adapter. The DOM renderer is used both for apps running in a normal browser UI thread and apps running in web workers. What is different is the DOM adapter – for a browser UI thread, the DOM adapter just maps to the underlying browser DOM API. There is no underlying DOM API in a web worker. So for an app running in a web worker, the worker DOM adapter needs to forward all DOM actions across the message bus to the browser's main UI thread.

```
export function setupWebWorker(): void {
  WorkerDomAdapter.makeCurrent();
}
```

Finally, the `NgModule` is defined:

```
// The ng module for the worker app side.
@NgModule({
  providers: [
    BROWSER_SANITIZATION_PROVIDERS,
    Serializer,
    {provide: DOCUMENT, useValue: null},
    ClientMessageBrokerFactory,
    ServiceMessageBrokerFactory,
    WebWorkerRendererFactory2,
    {provide: RendererFactory2, useExisting: WebWorkerRendererFactory2},
    {provide: ON_WEB_WORKER, useValue: true},
    RenderStore,
    {provide: ErrorHandler, useFactory: errorHandler, deps: []},
    {provide: MessageBus, useFactory: createMessageBus, deps: [NgZone]},
    {provide: APP_INITIALIZER, useValue: setupWebWorker, multi: true},
  ],
  exports: [
    CommonModule,
    ApplicationModule,
  ]
})
export class WorkerAppModule { }
```

The worker_render.ts file has implementations for the worker UI. This runs in the main UI thread and uses the `BrowserDomAdapter`, which writes to the underlying DOM API of the browser. `platformWorkerUi` represents a platform factory:

```
  export const platformWorkerUi =
      createPlatformFactory(platformCore, 'workerUi',
  _WORKER_UI_PLATFORM_PROVIDERS);
```

The providers used are as followed:

```
  export const _WORKER_UI_PLATFORM_PROVIDERS: StaticProvider[] = [
    {provide: NgZone, useFactory: createNgZone, deps: []},
    {
      provide: MessageBasedRenderer2,
      deps: [ServiceMessageBrokerFactory, MessageBus,
              Serializer, RenderStore, RendererFactory2]
    },
    {provide: WORKER_UI_STARTABLE_MESSAGING_SERVICE,
       useExisting: MessageBasedRenderer2, multi: true},
    BROWSER_SANITIZATION_PROVIDERS,
    {provide: ErrorHandler, useFactory: _exceptionHandler, deps: []},
    {provide: DOCUMENT, useFactory: _document, deps: []},
    {
      provide: EVENT_MANAGER_PLUGINS,
      useClass: DomEventsPlugin,
      deps: [DOCUMENT, NgZone],
      multi: true
    },
    {provide: EVENT_MANAGER_PLUGINS, useClass: KeyEventsPlugin,
       deps: [DOCUMENT], multi: true},
    {
      provide: EVENT_MANAGER_PLUGINS,
      useClass: HammerGesturesPlugin,
      deps: [DOCUMENT, HAMMER_GESTURE_CONFIG],
      multi: true
    },
    {provide: HAMMER_GESTURE_CONFIG, useClass: HammerGestureConfig, deps: []},
    APP_ID_RANDOM_PROVIDER,
    {provide: DomRendererFactory2, deps: [EventManager, DomSharedStylesHost]},
    {provide: RendererFactory2, useExisting: DomRendererFactory2},
    {provide: SharedStylesHost, useExisting: DomSharedStylesHost},
    {
      provide: ServiceMessageBrokerFactory,
      useClass: ServiceMessageBrokerFactory,
      deps: [MessageBus, Serializer]
    },
    {
      provide: ClientMessageBrokerFactory,
      useClass: ClientMessageBrokerFactory,
      deps: [MessageBus, Serializer]
    },
    {provide: Serializer, deps: [RenderStore]},
    {provide: ON_WEB_WORKER, useValue: false},
    {provide: RenderStore, deps: []},
    {provide: DomSharedStylesHost, deps: [DOCUMENT]},
    {provide: Testability, deps: [NgZone]},
    {provide: EventManager, deps: [EVENT_MANAGER_PLUGINS, NgZone]},
    {provide: WebWorkerInstance, deps: []},
    {
      provide: PLATFORM_INITIALIZER,
      useFactory: initWebWorkerRenderPlatform,
      multi: true,
      deps: [Injector]
    },
    {provide: PLATFORM_ID, useValue: PLATFORM_WORKER_UI_ID},
    {provide: MessageBus, useFactory: messageBusFactory, deps:
  [WebWorkerInstance]},
  ];
```

Note the provider configuration for `WORKER_UI_STARTABLE_MESSAGING_SERVICE` is set to multi - thus allowing multiple messaging services to be started. Also note that `initWebWorkerRenderPlatform` is registered as a `PLATFORM_INITIALIZER`, so it is going to be called when the platform launches.

`WebWorkerInstance` is a simple injectable class representing the web worker and its message bus (note the `init` method just initializes the two fields):

```
/**
 * Wrapper class that exposes the Worker
 * and underlying {@link MessageBus} for lower level message passing.
 */
@Injectable()
export class WebWorkerInstance {
  public worker: Worker;
  public bus: MessageBus;

  public init(worker: Worker, bus: MessageBus) {
    this.worker = worker;
    this.bus = bus;
  }
}
```

Now let's look at `initWebWorkerRenderPlatform`:

```
function initWebWorkerRenderPlatform(injector: Injector): () => void {
  return () => {
1   BrowserDomAdapter.makeCurrent();
    BrowserGetTestability.init();
    let scriptUri: string;
    try {
2     scriptUri = injector.get(WORKER_SCRIPT);
    } catch (e) {
      throw new Error(
          'You must provide your WebWorker\'s
```

```
           initialization script with the WORKER_SCRIPT token');
    }
    const instance = injector.get(WebWorkerInstance);
3   spawnWebWorker(scriptUri, instance);
4   initializeGenericWorkerRenderer(injector);
  };
}
```

It returns a function that makes the browser Dom adatper the current adapter 1; then gets the worker script from di 2; then calls `spawnWebWorker` 3; and finally calls `initializeGenericWorkerRenderer` 4. The `spawnWebWorker` function is defined as:

```
// Spawns a new class and initializes the WebWorkerInstance
function spawnWebWorker(uri: string, instance: WebWorkerInstance): void {
1 const webWorker: Worker = new Worker(uri);
2 const sink = new PostMessageBusSink(webWorker);
  const source = new PostMessageBusSource(webWorker);
  const bus = new PostMessageBus(sink, source);
3 instance.init(webWorker, bus);
```

It first creates a new web worker 1; then it create the message bus with its sinka dn source 2 and finally it calls `WebWorkerInstance.init` 3 which we have already seen. The `initializeGenericWorkerRenderer` function is defined as:

```
function initializeGenericWorkerRenderer(injector: Injector) {
  const bus = injector.get(MessageBus);
  const zone = injector.get<NgZone>(NgZone);
  bus.attachToZone(zone);

  // initialize message services after the bus has been created
  const services = injector.get(WORKER_UI_STARTABLE_MESSAGING_SERVICE);
  zone.runGuarded(() =>
       { services.forEach((svc: any) => { svc.start(); }); });
}
```

It first asks the dependency injector for a message bus and a zone and attached the bus to the zone. Then it also asks the dependency injector for a list of `WORKER_UI_STARTABLE_MESSAGING_SERVICE` (remember we noted it was configured as a multi provider), and for each service, starts it.

platform-webworker/src/web_workers

The source files for web_workers are provided in three sub-directories, one of which has shared messaging functionality use both by the UI side and worker side and the communication, the second refers only to the UI side and the third only to the worker side.

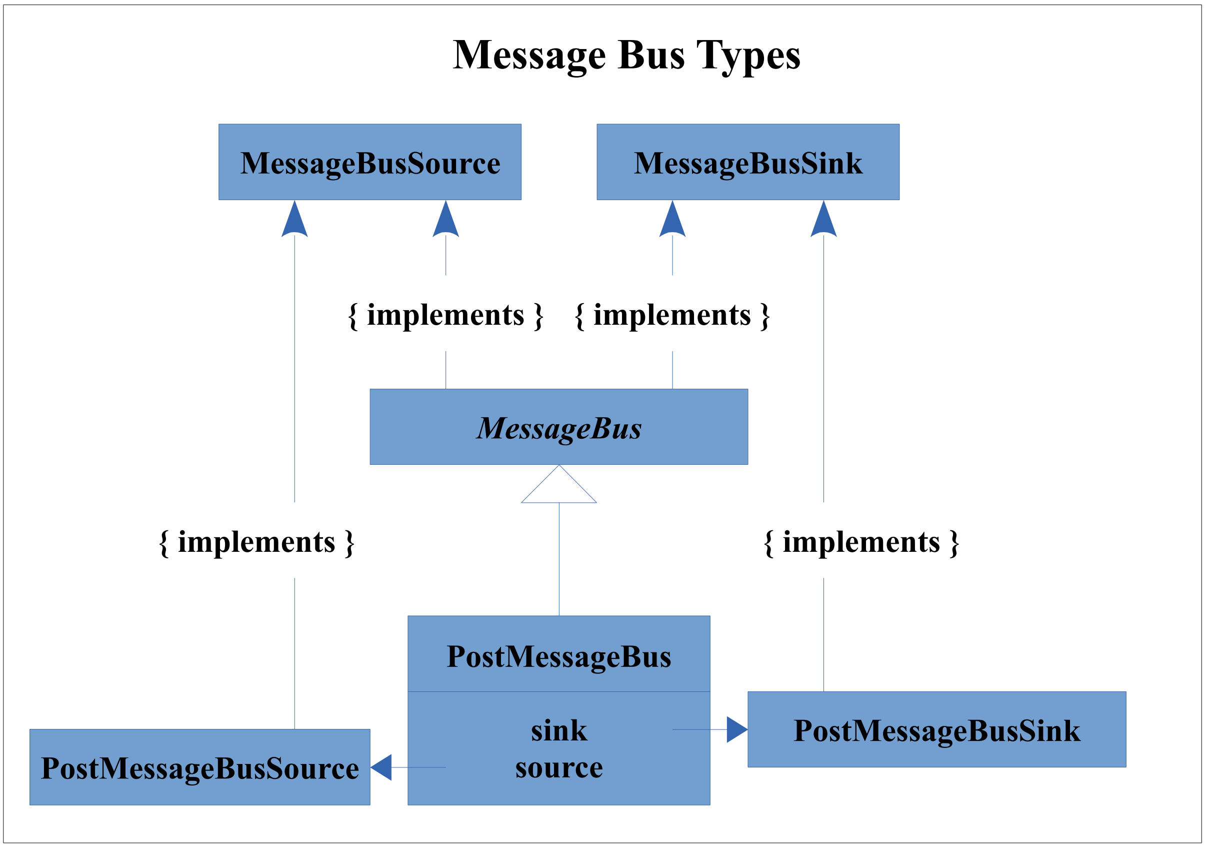
- shared/api.ts
- shared/client_message_broker.ts
- shared/message_bus.ts
- shared/messaging_api.ts
- shared/post_message_bus.ts
- shared/render_store.ts
- shared/serializer.ts
- shared/service_message_broker.ts
- ui/event_dispatcher.ts
- ui/event_serializer.ts

- ui/location_providers.ts
- ui/platform_location.ts
- ui/renderer.ts
- worker/location_providers.ts
- worker/platform_location.ts
- worker/renderer.ts
- worker/worker_adapter.ts

Communication between the UI thread and the webworker is handled by a low-level multi-channel message bus. The shared/messaging_api.ts file defines the names of the three channels used by Angular:

```
/**
 * All channels used by angular's WebWorker components are listed here.
 * You should not use these channels in your application code.
 */
export const RENDERER_2_CHANNEL = 'v2.ng-Renderer';
export const EVENT_2_CHANNEL = 'v2.ng-Events';
export const ROUTER_CHANNEL = 'ng-Router';
```

If you are familiar with TCP/IP, the channel name here serves the same purpose as a port number – it is needed to multiplex multiple independent message streams on a single data connection. Note the 2 in the names. This means these channels are for the updated renderer architecture.



The message_bus.ts file defines an abstract `MessageBus` class and two interfaces, `MessageBusSource` and `MessageBusSink`. Let’s look at the interfaces first. `MessageBusSource` is for incoming messages. This interface describes the functionality a message source is expected to supply. It has methods to initialize a channel based on a string name, to attach to a zone, and to return an RxJS observable (`EventEmitter`) that can be observed in order to read the incoming messages.

```
export interface MessageBusSource {
  /**
   * Sets up a new channel on the MessageBusSource.
   * MUST be called before calling from on the channel.
   * If runInZone is true then the source will emit events inside the
   * angular zone. if runInZone is false then the source will emit
   * events inside the global zone.
   */
  initChannel(channel: string, runInZone: boolean): void;

  /**
   * Assigns this source to the given zone.
   * Any channels which are initialized with runInZone set to true will
   * emit events that will be
   * executed within the given zone.
   */
  attachToZone(zone: NgZone): void;

  /**
   * Returns an {@link EventEmitter} that emits every time a message
   * is received on the given channel.
   */
  from(channel: string): EventEmitter<any>;
}
```

Similarly, `MessageBusSink` is for outgoing messages. Again it allows a named channel to be initialized, attacing to a zone and returns a RxJS observer (`EventEmitter`) used to send messages:

```
export interface MessageBusSink {
  /**
   * Sets up a new channel on the MessageBusSink.
   * MUST be called before calling to on the channel.
   * If runInZone is true the sink will buffer messages and send only
   * once the zone exits.
   * if runInZone is false the sink will send messages immediately.
   */
  initChannel(channel: string, runInZone: boolean): void;

  /**
   * Assigns this sink to the given zone.
   * Any channels which are initialized with runInZone set to true will
   * wait for the given zone to exit before sending messages.
   */
  attachToZone(zone: NgZone): void;

  /**
   * Returns an {@link EventEmitter} for the given channel
   * To publish methods to that channel just call next on the
   * returned emitter
   */
  to(channel: string): EventEmitter<any>;
}
```

`MessageBus` is an abstract class that implements both `MessageBusSource` and `MessageBusSink`:

```
/**
 * Message Bus is a low level API used to communicate between the UI and
 * the background.
 * Communication is based on a channel abstraction. Messages published in a
 * given channel to one MessageBusSink are received on the same channel
 * by the corresponding MessageBusSource.
 */
export abstract class MessageBus implements MessageBusSource, MessageBusSink
{
  /**
   * Sets up a new channel on the MessageBus.
   * MUST be called before calling from or to on the channel.
   * If runInZone is true then the source will emit events inside the
   * angular zone and the sink will buffer messages and send only once
   * the zone exits.
   * if runInZone is false then the source will emit events inside the
   * global zone and the sink will send messages immediately.
   */
  abstract initChannel(channel: string, runInZone?: boolean): void;

  /**
   * Assigns this bus to the given zone.
   * Any callbacks attached to channels where runInZone was set to
   * true on initialization
   * will be executed in the given zone.
   */
  abstract attachToZone(zone: NgZone): void;

  /**
   * Returns an {@link EventEmitter} that emits every time a message
   * is received on the given channel.
   */
  abstract from(channel: string): EventEmitter<any>;


  /**
   * Returns an {@link EventEmitter} for the given channel
   * To publish methods to that channel just call next on the
   * returned emitter
   */
  abstract to(channel: string): EventEmitter<any>;
}
```

So far the message bus description has only specified what the functionality that needs to be supplied. A single implementation is supplied, in post_message_bus.ts, based on the `postMessage` API. This defines three classes, `PostMessageBusSource`, `PostMessageBusSink` and `PostMessageBus`, that implement the above similarly named types.

```
/**
 * A TypeScript implementation of {@link MessageBus} for communicating
 * via JavaScript's  postMessage API.
 */
@Injectable()
export class PostMessageBus implements MessageBus {..}
```

A useful private class is supplied called `_Channel` that keeps track of two pieces of data:

```
/**
 * Helper class that wraps a channel's {@link EventEmitter} and
 * keeps track of if it should run in the zone.
 */
class _Channel {
  constructor(public emitter: EventEmitter<any>, public runInZone: boolean){}
}
```

Channels are initialized with `PostMessageBusSource.initChannel()`:

```
 initChannel(channel: string, runInZone: boolean = true) {
    if (this._channels.hasOwnProperty(channel)) {
      throw new Error(`${channel} has already been initialized`);
    }initChannel(channel: string, runInZone: boolean = true) {
    if (this._channels.hasOwnProperty(channel)) {
      throw new Error(`${channel} has already been initialized`);
    }

    const emitter = new EventEmitter(false);
    const channelInfo = new _Channel(emitter, runInZone);
    this._channels[channel] = channelInfo;
  }
```

So we see a channel is nothing more that a name that maps to a `_Channel`, which is just an `EventEmitter` and a boolean (`runInZone`). `PostMessageBusSource` manages a map of these called _channels:

```
export class PostMessageBusSource implements MessageBusSource {
  private _zone: NgZone;
  private _channels: {[key: string]: _Channel} = {};
```

The `from()` method just returns the appropriate channel emitter:

```
 from(channel: string): EventEmitter<any> {
    if (this._channels.hasOwnProperty(channel)) {
      return this._channels[channel].emitter;
    } else {
      throw new Error(`${channel} is not set up. Did you forget to call
initChannel?`);
    }
  }
```

The constructor calls `addEventListener` to add an event listener:

```
constructor(eventTarget?: EventTarget) {
    if (eventTarget) {
      eventTarget.addEventListener('message',
       (ev: MessageEvent) => this._handleMessages(ev));
    } else {
      // if no eventTarget is given we assume we're in a
     // WebWorker and listen on the global scope
      const workerScope = <EventTarget>self;
      workerScope.addEventListener('message',
       (ev: MessageEvent) => this._handleMessages(ev));
    }
  }
```

The `_handleMessages` function passes on each message to the `_handleMessage` function, which emits it on the approapriate channel:

```
private _handleMessage(data: any): void {
    const channel = data.channel;
    if (this._channels.hasOwnProperty(channel)) {
      const channelInfo = this._channels[channel];
      if (channelInfo.runInZone) {
        this._zone.run(() => { channelInfo.emitter.emit(data.message); });
      } else {
        channelInfo.emitter.emit(data.message);
      }
    }
  }
```

The PostMessageBusSink implementation is slightly different because it needs to use postMessageTarget to post messages. Its constructor creates a field based on the supplied PostMessageTarget parameter:

```
export class PostMessageBusSink implements MessageBusSink {
  private _zone: NgZone;
  private _channels: {[key: string]: _Channel} = {};
  private _messageBuffer: Array<Object> = [];

  constructor(private _postMessageTarget: PostMessageTarget) {}
```

The initChannel method subscribes to the emitter with a next handler that either (when runnign inside the Angular zone) adds the message to the messageBuffer where its sending is deferred, or (if running outside the Angular zone), calls _sendMessages, to immediately send the message:

```
initChannel(channel: string, runInZone: boolean = true): void {
    if (this._channels.hasOwnProperty(channel)) {
      throw new Error(`${channel} has already been initialized`);
    }

    const emitter = new EventEmitter(false);
    const channelInfo = new _Channel(emitter, runInZone);
    this._channels[channel] = channelInfo;
    emitter.subscribe((data: Object) => {
      const message = {channel: channel, message: data};
      if (runInZone) {
        this._messageBuffer.push(message);
      } else {
        this._sendMessages([message]);
      }
    });
  }
```

_sendMessages() just sends the message array via PostMessageTarget:

```
private _sendMessages(messages: Array<Object>){
    this._postMessageTarget.postMessage(messages);
}
```

So we saw with initChannel that the subscription to the emitter either calls _sendMessages immediately or parks the message in a message buffer, for later transmission. So two questions arise – what triggers that transmission and how does it work. Well, to answer the second question first, _sendMessages is also called for the bulk transmission, from inside the _handleOnEventDone message:

```
private _handleOnEventDone() {
    if (this._messageBuffer.length > 0) {
      this._sendMessages(this._messageBuffer);
      this._messageBuffer = [];
    }
  }
```

So, what calls `_handleOnEventDone`? Let's digress to look at the `NgZone` class in

- <ANGULAR-MASTER>/packages/core/src/zone/ngzone.ts

which has this getter:

```
    /**
     * Notifies when the last `onMicrotaskEmpty` has run and there are no
     * more microtasks, which implies we are about to relinquish VM turn.
     * This event gets called just once.
     */
    readonly onStable: EventEmitter<any> = new EventEmitter(false);
```

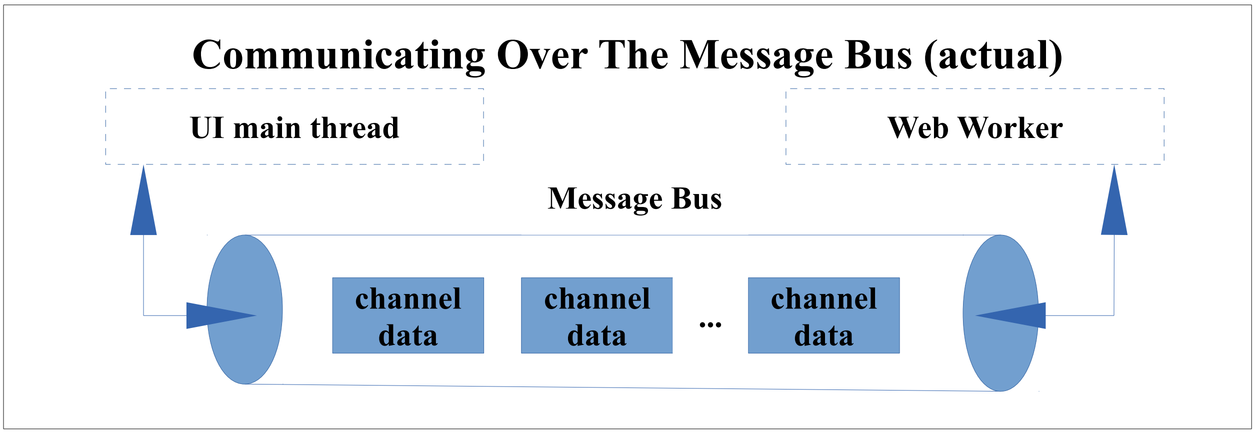
So when the zone has no more work to immediately carry out, it emits a message via `onStable`. Back to `PostMessageBusSink` – which has this code, that subscribes to the `onStable` event emitter:

```
  attachToZone(zone: NgZone): void {
      this._zone = zone;
      this._zone.runOutsideAngular(
          () => { this._zone.onStable.subscribe(
                   {next: () => { this._handleOnEventDone(); }}); });
  }
```

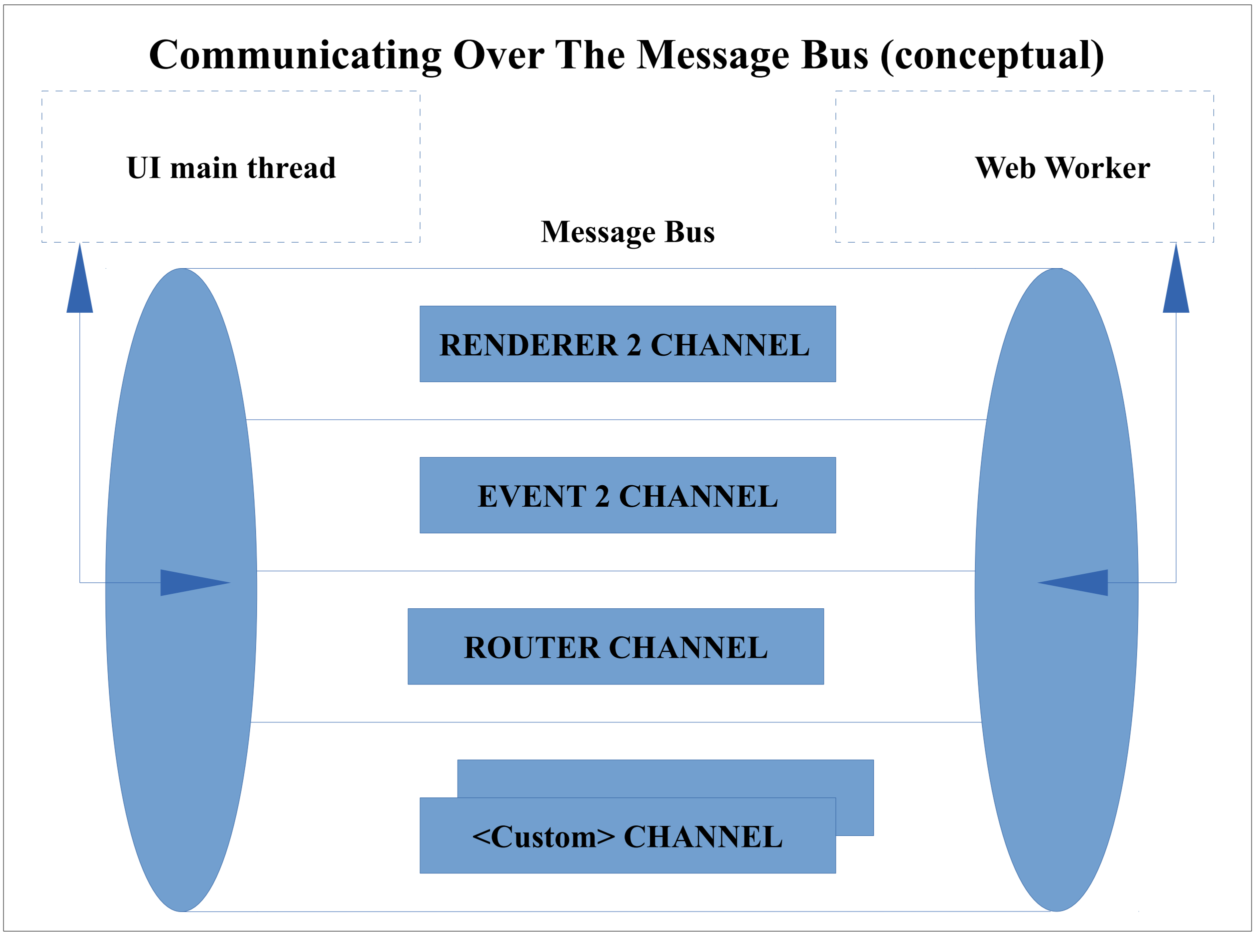
With all the hard work done in `PostMessageBusSource` and `PostMessageBusSink`, the implementation of `PostMessageBus` is quite simple:

```
  /**
   * A TypeScript implementation of {@link MessageBus} for communicating
   * via JavaScript's postMessage API.
   */
  @Injectable()
  export class PostMessageBus implements MessageBus {
    constructor(public sink: PostMessageBusSink, public source:
  PostMessageBusSource) {}

    attachToZone(zone: NgZone): void {
      this.source.attachToZone(zone);
      this.sink.attachToZone(zone);
    }

    initChannel(channel: string, runInZone: boolean = true): void {
      this.source.initChannel(channel, runInZone);
      this.sink.initChannel(channel, runInZone);
    }

    from(channel: string): EventEmitter<any> { return
  this.source.from(channel); }

    to(channel: string): EventEmitter<any> { return this.sink.to(channel); }
  }

  /**
   * Helper class that wraps a channel's {@link EventEmitter} and
   * keeps track of if it should run in the zone.
   */
```

```
class _Channel {
  constructor(public emitter: EventEmitter<any>,public runInZone: boolean) {}
}
```



A different way of looking at the message bus is as a set of independent channels:



In summary, the message bus in Angular is a simple efficient messaging passing mechanism with web workers. It is based on a single connection, with opaque messages consisting of a channel name (string) and message data:

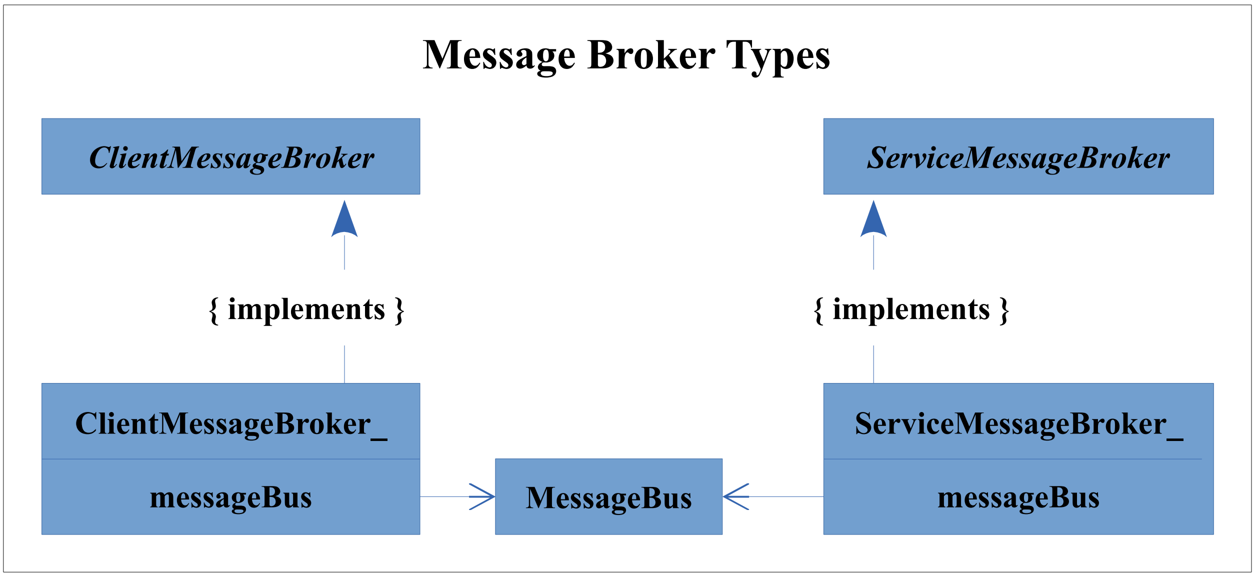
```
var msg = {channel: channel, message: data};
```

Angular also supplies a richer message broker layered above this simple message bus.

The files client_message_broker.ts and service_message_broker.ts along with a number of helper files for serialization implement the message broker.

The service_message_broker.ts file defines the `ReceivedMessage` class that represents a message:

```
export interface ReceivedMessage {
  method: string;
  args: any[];
  id: string;
  type: string;
}
```



The class `ServiceMessageBrokerFactory` provide a factory for the service message broker:

```
@Injectable()
export class ServiceMessageBrokerFactory {
  /** @internal */
  _serializer: Serializer;

  /** @internal */
  constructor(private _messageBus: MessageBus, _serializer: Serializer) {
    this._serializer = _serializer;
  }

  /**
   * Initializes the given channel and attaches a new {@link
ServiceMessageBroker} to it.
   */
  createMessageBroker(channel: string, runInZone: boolean = true):
ServiceMessageBroker {
    this._messageBus.initChannel(channel, runInZone);
    return new ServiceMessageBroker(this._messageBus, this._serializer,
channel);
  }
}
```

The service message broker is created based on the supplied message bus, serializer and channel name. The abstract `ServiceMessageBroker` class contains just one abstract class declaration, `registerMethod`:

```
/**
 * Helper class for UIComponents that allows components to register methods.
 * If a registered method message is received from the broker on the worker,
 * the UIMessageBroker deserializes its arguments and calls the
 * registered method. If that method returns a promise, the UIMessageBroker
 * returns the result to the worker.
 */
export class ServiceMessageBroker {
  private _sink: EventEmitter<any>;
  private _methods = new Map<string, Function>();

  /** @internal */
  constructor(messageBus: MessageBus,
       private _serializer: Serializer, private channel: string) {
    this._sink = messageBus.to(channel);
    const source = messageBus.from(channel);
    source.subscribe({next: (message: any) => this._handleMessage(message)});
  }
```

It has two private fields, an event emitter `_sink` and a map from string to function `_methods`. In its constructor it subscribes its internal method `_ handleMessage` to `messageBus.from` (this handles incoming messages), and set `_sink` to `messageBus.to` (this will be used to send messages).

`_handleMessage()` message creates a `ReceivedMessage` based on the map parameter, and then if message.method is listed as a supported message in `_methods`, looks up `_methods` for the appropriate function to execute, to handle the message:

```
private _handleMessage(message: ReceivedMessage): void {
  if (this._methods.has(message.method)) {
    this._methods.get(message.method) !(message);
  }
}
```

The next question is how methods get registered in _methods. That is the job of `registerMethod()`, whose implementation adds an entry to the `_methods` map based on the supplied parameters. Its key is the `methodName` supplied as a parameter and its value is an anonymous method, with a single parameter, message, of type `ReceivedMessage`:

```
registerMethod(

    methodName: string, signature: Array<Type<any>|SerializerTypes>|null,
    method: (..._: any[]) => Promise<any>| void,
       returnType?: Type<any>|SerializerTypes): void {
     this._methods.set(methodName, (message: ReceivedMessage) => {
    const serializedArgs = message.args;
    const numArgs = signature ? signature.length : 0;
    const deserializedArgs = new Array(numArgs);
    for (let i = 0; i < numArgs; i++) {
      const serializedArg = serializedArgs[i];
1     deserializedArgs[i] =
         this._serializer.deserialize(serializedArg, signature ![i]);
    }
2   const promise = method(...deserializedArgs);
    if (returnType && promise) {
3     this._wrapWebWorkerPromise(message.id, promise, returnType);
    }
  });
}
```

We see at its 1 deserialization occuring with the help of the serializer, and at 2 method is called with the deserialized arguments, and at 3 we see if a returnType is needed, _ wrapWebWorkerPromise is called, to handle the then of the promise, which emits the result to the sink:

```
private _wrapWebWorkerPromise(
               id: string,
               promise: Promise<any>,
               type: Type<any>|SerializerTypes): void {
  promise.then((result: any) => {
    this._sink.emit({
      'type': 'result',
      'value': this._serializer.serialize(result, type),
      'id': id,
    });
  });
}
```

The client side of this messaging relationship is handled by client_message_broker.ts. It defines some simple helper types:

```
interface PromiseCompleter {
  resolve: (result: any) => void;
  reject: (err: any) => void;
}
interface RequestMessageData {
  method: string;
  args?: any[];
  id?: string;
}

interface ResponseMessageData {
  type: 'result'|'error';
  value?: any;
  id?: string;
}
export class FnArg {
  constructor(
      public value: any, public type: Type<any>|SerializerTypes =
SerializerTypes.PRIMITIVE) {}
}
export class UiArguments {
  constructor(public method: string, public args?: FnArg[]) {}
}
```

To construct a client message borker it defines the `ClientMessageBrokerFactory` which, in its `createMessageBroker` method, calls `initChannel` on the message bus and returns a new `ClientMessageBroker`:

```
@Injectable()
export class ClientMessageBrokerFactory {
  _serializer: Serializer;
  constructor(private _messageBus: MessageBus, _serializer: Serializer) {
    this._serializer = _serializer;
  }

  // Initializes the given channel and attaches a new
  // {@link ClientMessageBroker} to it.
  createMessageBroker(channel: string,
               runInZone: boolean = true): ClientMessageBroker {
    this._messageBus.initChannel(channel, runInZone);
    return new ClientMessageBroker(
                     this._messageBus, this._serializer, channel);
  }
}
```

ClientMessageBroker has an important method to run on service, which calls a method with the supplied UiArguments on the remote service side and returns a promise with the return value (if any). ClientMessageBroker is implemented as follows:

```
  export class ClientMessageBroker {
    private _pending = new Map<string, PromiseCompleter>();
    private _sink: EventEmitter<any>;
    public _serializer: Serializer;

    constructor(
       messageBus: MessageBus, _serializer: Serializer, private channel: any) {
      this._sink = messageBus.to(channel);
      this._serializer = _serializer;
      const source = messageBus.from(channel);

      source.subscribe(
       {next: (message: ResponseMessageData) => this._handleMessage(message)});
    }
```

It has three fields, _pending, _sink and _serializer. _pending is a map from string to PromiseCompleter. It is used to keep track of method calls that require a return value and are outstanding – the message has been set to the service, and the result is awaited. In its constructor _sink is set to the messageBus.to and serializer set to the Serializer parameter. Also a source subscription is set for _handleMessage.

Messages for which a return value is expected have a message id generated for them via:

```
    private _generateMessageId(name: string): string {
      const time: string = stringify(new Date().getTime());
      let iteration: number = 0;
      let id: string = name + time + stringify(iteration);
      while (this._pending.has(id)) {
        id = `${name}${time}${iteration}`;
        iteration++;
      }
      return id;
    }
```

It is this string that is the key into the _pending map. We will now see how it is set up in runOnService and used in _handleMessage. RunOnService is what the client calls when it wants the service to execute a method. It returns a promise, which is a return value is required, it is completed when the service returns it.

Let’s first examine `runOnService` when `returnType` is null. This creates an array of serialized arguments in `fnArgs` 1, sets up an object literal called message with properties “method” and “args” 2, and then calls `_sink.emit(message)` 3:

```
  runOnService(args: UiArguments,
      returnType: Type<any>|SerializerTypes|null): Promise<any>|null {
    const fnArgs: any[] = [];
    if (args.args) {
      args.args.forEach(argument => {
        if (argument.type != null) {
1         fnArgs.push(
              this._serializer.serialize(argument.value, argument.type));
        } else {
          fnArgs.push(argument.value);
        }
      });
    }

    let promise: Promise<any>|null;
    let id: string|null = null;

    if (returnType != null) { .. }
2   const message: RequestMessageData = {
      'method': args.method,
      'args': fnArgs,
    };
    if (id != null) {
      message['id'] = id;
    }
3   this._sink.emit(message);

    return promise;
  }
```

Things are a little more complex when a return value is required. A promise and a promise completer are created 1; `_generateMessageId()` is called 2 to generate a unique message id for this message; an entry is made into `_pending` 3, whose key is the id and whose value is the promise completer. The then of the promise 4 returns the result 5a (deserialized if needed 5b). Before the message is sent via `sink.emit`, the generated message id is attached to the message6.

```
  if (returnType != null) {
1   let completer: PromiseCompleter = undefined !;
    promise =
      new Promise((resolve, reject) => { completer = {resolve, reject}; });
2   id = this._generateMessageId(args.method);
3   this._pending.set(id, completer);

    promise.catch((err) => {
      if (console && console.error) {
        // tslint:disable-next-line:no-console
        console.error(err);
      }

      completer.reject(err);
    });

4   promise = promise.then(
5a           (v: any) => this._serializer ?
5b                 this._serializer.deserialize(v, returnType) : v);
        } else {
          promise = null;
        }
    const message: RequestMessageData = {
          'method': args.method,
          'args': fnArgs,
        };
        if (id != null) {
 6        message['id'] = id;
        }
        this._sink.emit(message);
```

The _handleMessage accepts a ResponseMessageData parameter. It extracts 1 the message id, which it uses to look up _pending 2 for the promise. If message data has a result field, this is used in a call to the promise.resolve 3, otherwise promise.reject 4 is called:

```
    private _handleMessage(message: ResponseMessageData): void {
        if (message.type === 'result' || message.type === 'error') {
1         const id = message.id !;
2         if (this._pending.has(id)) {
            if (message.type === 'result') {
3             this._pending.get(id) !.resolve(message.value);
            } else {
4             this._pending.get(id) !.reject(message.value);
            }
            this._pending.delete(id);
          }
        }
      }
```

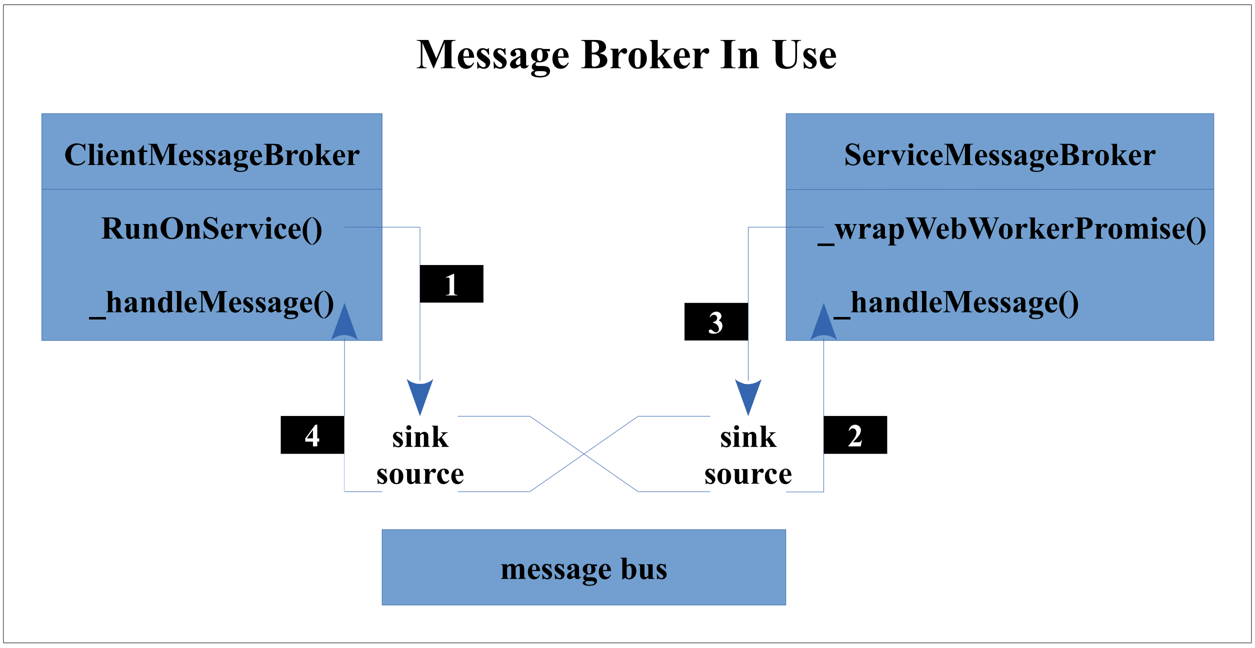
Two helper files are involved with serialization – render_store.ts and serializer.ts. The RenderStore class, define in render_store.ts, manages two maps – the first, _lookupById, from number to any, and the second, lookupByObject, from any to number. It supplies methods to store and remove objects and serialize and deserialize them.

The Serializer class is defined in serializer.ts and has methods to serialize and deserialize. The serialize method is:

```
    @Injectable()
    export class Serializer {
      constructor(private _renderStore: RenderStore) {}

      serialize(obj: any, type: Type<any>|SerializerTypes =
    SerializerTypes.PRIMITIVE): Object {
        if (obj == null || type === SerializerTypes.PRIMITIVE) {
          return obj;
        }
        if (Array.isArray(obj)) {
          return obj.map(v => this.serialize(v, type));
        }
        if (type === SerializerTypes.RENDER_STORE_OBJECT) {
          return this._renderStore.serialize(obj) !;
        }
        if (type === RenderComponentType) {
```

```
        return this._serializeRenderComponentType(obj);
      }
      if (type === SerializerTypes.RENDERER_TYPE_2) {
        return this._serializeRendererType2(obj);
      }
      if (type === LocationType) {
        return this._serializeLocation(obj);
      }
      throw new Error(`No serializer for type ${stringify(type)}`);
    }

    deserialize(map: any, type: Type<any>|SerializerTypes =
  SerializerTypes.PRIMITIVE, data?: any):
        any {
      if (map == null || type === SerializerTypes.PRIMITIVE) {
        return map;
      }
      if (Array.isArray(map)) {
        return map.map(val => this.deserialize(val, type, data));
      }
      if (type === SerializerTypes.RENDER_STORE_OBJECT) {
        return this._renderStore.deserialize(map);
      }
      if (type === RenderComponentType) {
        return this._deserializeRenderComponentType(map);
      }
      if (type === SerializerTypes.RENDERER_TYPE_2) {
        return this._deserializeRendererType2(map);
      }
      if (type === LocationType) {
        return this._deserializeLocation(map);
      }
      throw new Error(`No deserializer for type ${stringify(type)}`);
    }

    private _serializeLocation(loc: LocationType): Object {
      return {
        'href': loc.href,
        'protocol': loc.protocol,
        'host': loc.host,
        'hostname': loc.hostname,
        'port': loc.port,
        'pathname': loc.pathname,
        'search': loc.search,
        'hash': loc.hash,
        'origin': loc.origin,
      };
    }

    private _deserializeLocation(loc: {[key: string]: any}): LocationType {
      return new LocationType(
          loc['href'], loc['protocol'], loc['host'], loc['hostname'],
  loc['port'], loc['pathname'],
          loc['search'], loc['hash'], loc['origin']);
    }

    private _serializeRenderComponentType(type: RenderComponentType): Object {
      return {
        'id': type.id,
        'templateUrl': type.templateUrl,
        'slotCount': type.slotCount,
        'encapsulation': this.serialize(type.encapsulation),
        'styles': this.serialize(type.styles),
      };
    }

    private _deserializeRenderComponentType(props: {[key: string]: any}):
  RenderComponentType {
      return new RenderComponentType(
          props['id'], props['templateUrl'], props['slotCount'],
          this.deserialize(props['encapsulation']),
  this.deserialize(props['styles']), {});
    }

    private _serializeRendererType2(type: RendererType2): {[key: string]: any}
  {
      return {
        'id': type.id,
        'encapsulation': this.serialize(type.encapsulation),
        'styles': this.serialize(type.styles),
        'data': this.serialize(type.data),
      };
    }

    private _deserializeRendererType2(props: {[key: string]: any}):
  RendererType2 {
      return {
        id: props['id'],
        encapsulation: props['encapsulation'],
        styles: this.deserialize(props['styles']),
        data: this.deserialize(props['data'])
      };
    }
  }
```

Based on the type an appropriate serialization helper method is called.



The last file in the shared directory is api.ts, which has this one line:

```
export const ON_WEB_WORKER =
                      new InjectionToken<boolean>('WebWorker.onWebWorker');
```

It is used to store a boolean value with dependency injection, stating whether the current code is running in a webworker or not. At this point it would be helpful to review how shared functionality is actually configured with dependency injection. On the worker side:

- <ANGULAR-MASTER>/packages/platform-webworker/src/worker_app.ts

has this:

```
// The ng module for the worker app side.
@NgModule({
  providers: [
    ..
    {provide: ON_WEB_WORKER, useValue: true},
    RenderStore,
    ..
  ],
  exports: [
    CommonModule,
    ApplicationModule,
  ]
})
export class WorkerAppModule { }
```

Note `ON_WEB_WORKER` is set to true.

On the ui main thread side:

- <ANGULAR-MASTER>/packages/platform-webworker/src/worker_render.ts

has this:

```
export const _WORKER_UI_PLATFORM_PROVIDERS: StaticProvider[] = [
  ..
  {provide: Serializer, deps: [RenderStore]},
  {provide: ON_WEB_WORKER, useValue: false},
  {provide: RenderStore, deps: []},
 ..
];

export const platformWorkerUi =
    createPlatformFactory(platformCore, 'workerUi',
      _WORKER_UI_PLATFORM_PROVIDERS);
```

Note `ON_WEB_WORKER` is set to false.

Now we will move on to looking at the worker-specific code in:

- <ANGULAR-MASTER>/packages/platform-webworker/src/web_workers

In worker_adapter.ts, `WorkerDomAdapter` extends `DomAdapter` but only implements the logging functionality – for everything else an exception is raised. `WorkerDomAdapter` is not how workers render, instead is just logs data to the console.

```
/**
 * This adapter is required to log error messages.
 *
 * Note: other methods all throw as the DOM is not accessible
 * directly in web worker context.
 */
export class WorkerDomAdapter extends DomAdapter {

  static makeCurrent() { setRootDomAdapter(new WorkerDomAdapter()); }

log(error: any) {
    // tslint:disable-next-line:no-console
    console.log(error);
  }

// everything erlse throws an exception
insertAllBefore(parent: any, el: any, nodes: any) {
   throw 'not implemented'; }
insertAfter(parent: any, el: any, node: any) { throw 'not implemented'; }
  setInnerHTML(el: any, value: any) { throw 'not implemented'; }
```

The renderer.ts file supplies the `WebWorkerRendererFactory2` and `WebWorkerRenderer2` classes and this is where worker-based rendering is managed.

`WebWorkerRenderer2` implements the Renderer API and forwards all calls to runOnService from the root renderer. `WebWorkerRenderer2` is running the webworker where there is no DOM, so any rendering needs to be forwarded to the main UI thread, and that is what `runOnService` is doing here.

This is a sampling of the calls:

```
export class WebWorkerRenderer2 implements Renderer2 {
  data: {[key: string]: any} = Object.create(null);

  constructor(private _rendererFactory: WebWorkerRendererFactory2) {}

  private asFnArg = new FnArg(this, SerializerTypes.RENDER_STORE_OBJECT);

  destroy(): void { this.callUIWithRenderer('destroy'); }

  createElement(name: string, namespace?: string): any {
    const node = this._rendererFactory.allocateNode();
    this.callUIWithRenderer('createElement', [
      new FnArg(name),
      new FnArg(namespace),
      new FnArg(node, SerializerTypes.RENDER_STORE_OBJECT),
    ]);
    return node;
  }

  createComment(value: string): any {
    const node = this._rendererFactory.allocateNode();
    this.callUIWithRenderer('createComment', [
      new FnArg(value),
      new FnArg(node, SerializerTypes.RENDER_STORE_OBJECT),
    ]);
    return node;
  }

  appendChild(parent: any, newChild: any): void {
    this.callUIWithRenderer('appendChild', [
      new FnArg(parent, SerializerTypes.RENDER_STORE_OBJECT),
      new FnArg(newChild, SerializerTypes.RENDER_STORE_OBJECT),
    ]);
  }
```

`WebWorkerRendererFactory2` implements Core’s `RendererFactory2` by setting up the client message broker factory.

```
@Injectable()
export class WebWorkerRendererFactory2 implements RendererFactory2 {
  globalEvents = new NamedEventEmitter();

  private _messageBroker: ClientMessageBroker;

  constructor(
      messageBrokerFactory: ClientMessageBrokerFactory, bus: MessageBus,
      private _serializer: Serializer, public renderStore: RenderStore) {
    this._messageBroker =
             messageBrokerFactory.createMessageBroker(RENDERER_2_CHANNEL);
1   bus.initChannel(EVENT_2_CHANNEL);
2   const source = bus.from(EVENT_2_CHANNEL);
3   source.subscribe({next: (message: any) => this._dispatchEvent(message)});
  }
```

An additional and very important role of `WebWorkerRendererFactory2` is to configure event handling. We see at 1 `initChannel()` being called for the `EVENT_2_CHANNEL`, at 2 the message source being accessed, and at 3 a subscription being set up with the `_dispatchEvent()` method, which is implemented as:

```
    private _dispatchEvent(message: {[key: string]: any}): void {
    const element: WebWorkerRenderNode =
        this._serializer.deserialize(
            message['element'], SerializerTypes.RENDER_STORE_OBJECT);

    const eventName = message['eventName'];
    const target = message['eventTarget'];
    const event = message['event'];

    if (target) {
      this.globalEvents.dispatchEvent(eventNameWithTarget(target, eventName),
event);
    } else {
      element.events.dispatchEvent(eventName, event);
    }
  }
```

The ui specific code is in:

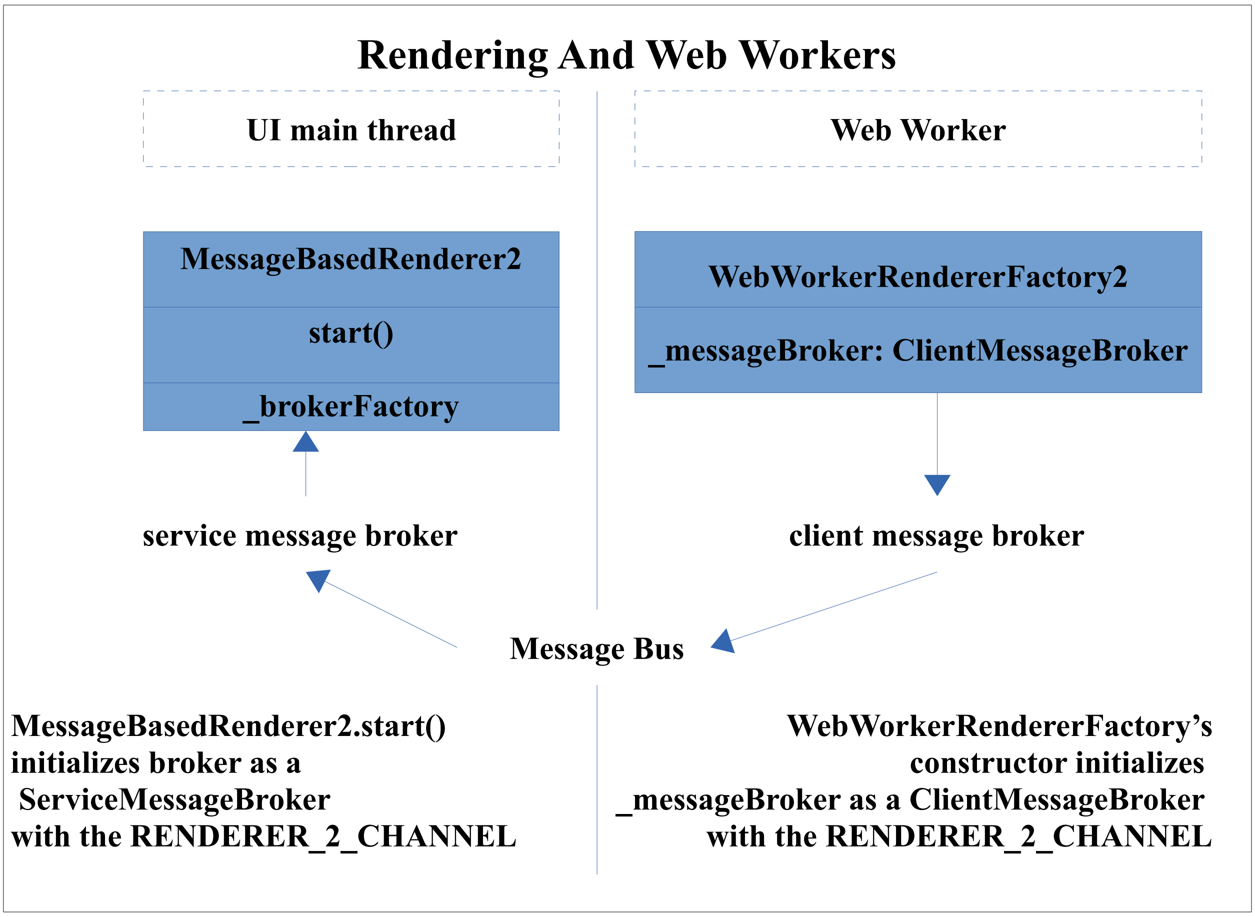
- <ANGULAR-MASTER>/packages/platform-webworker/src/web_workers/ui

The renderer.ts file implements the `MessageBasedRenderer2` class. Note this class, despite its name, does not implement any types from Core’s rendering API. Instead, it accepts a `RendererFactory2` instance as a constructor parameter, and forwards all rendering requests to it. Its constructor also has a few other parameters which it uses as fields and it also defines one extra, an `EventDispatcher`.

```
@Injectable()
export class MessageBasedRenderer2 {
  private _eventDispatcher: EventDispatcher;

  constructor(
       private _brokerFactory: ServiceMessageBrokerFactory,
       private _bus: MessageBus,
       private _serializer: Serializer, private _renderStore: RenderStore,
       private _rendererFactory: RendererFactory2) {}
```

Its `start()` method initializes the `EVENT_2_CHANNEL`, creates a new `EventDispatcher`, and then has a very long list of calls to `registerMethod` – when such messages are received, then the configured local method is called. Here is a short selection of the `registerMethod` calls:

```
 start(): void {
  const broker =
           this._brokerFactory.createMessageBroker(RENDERER_2_CHANNEL);

  this._bus.initChannel(EVENT_2_CHANNEL);
  this._eventDispatcher =
     new EventDispatcher(this._bus.to(EVENT_2_CHANNEL), this._serializer);

  const [RSO, P, CRT] = [
    SerializerTypes.RENDER_STORE_OBJECT,
    SerializerTypes.PRIMITIVE,
    SerializerTypes.RENDERER_TYPE_2,
  ];

  const methods: any[][] = [
    ['createRenderer', this.createRenderer, RSO, CRT, P],
    ['createElement', this.createElement, RSO, P, P, P],
    ['createComment', this.createComment, RSO, P, P],
    ['createText', this.createText, RSO, P, P],
    ['appendChild', this.appendChild, RSO, RSO, RSO],
    ['insertBefore', this.insertBefore, RSO, RSO, RSO, RSO],
    ['removeChild', this.removeChild, RSO, RSO, RSO],
    ['selectRootElement', this.selectRootElement, RSO, P, P],
    ['parentNode', this.parentNode, RSO, RSO, P],
    ['nextSibling', this.nextSibling, RSO, RSO, P],
    ['setAttribute', this.setAttribute, RSO, RSO, P, P, P],
    ['removeAttribute', this.removeAttribute, RSO, RSO, P, P],
    ['addClass', this.addClass, RSO, RSO, P],
    ['removeClass', this.removeClass, RSO, RSO, P],
    ['setStyle', this.setStyle, RSO, RSO, P, P, P],
    ['removeStyle', this.removeStyle, RSO, RSO, P, P],
    ['setProperty', this.setProperty, RSO, RSO, P, P],
    ['setValue', this.setValue, RSO, RSO, P],
    ['listen', this.listen, RSO, RSO, P, P, P],
    ['unlisten', this.unlisten, RSO, RSO],
    ['destroy', this.destroy, RSO],
    ['destroyNode', this.destroyNode, RSO, P]

  ];

  methods.forEach(([name, method, ...argTypes]: any[]) => {
    broker.registerMethod(name, argTypes, method.bind(this));
  });
}
```


Rendering And Web Workers
UI main thread
Web Worker
MessageBasedRenderer2
start()
_brokerFactory
WebWorkerRendererFactory2
_messageBroker: ClientMessageBroker
service message broker
client message broker
Message Bus
MessageBasedRenderer2.start() initializes broker as a ServiceMessageBroker with the RENDERER_2_CHANNEL
WebWorkerRendererFactory's constructor initializes _messageBroker as a ClientMessageBroker with the RENDERER_2_CHANNEL

The local methods usually call the equivalent method in the configured renderer, and often stores the result in the `RenderStore`. Here is `_createElement()`:

```
private createElement(r: Renderer2, name: string,
                              namespace: string, id: number) {
    this._renderStore.store(r.createElement(name, namespace), id);
  }
```

For event listening, the event dispatcher is used:

```
private listen(r: Renderer2, el: any, elName: string,
                   eventName: string, unlistenId: number) {
    const listener = (event: any) => {
      return this._eventDispatcher.dispatchRenderEvent(
                                          el, elName, eventName, event);
    };

    const unlisten = r.listen(el || elName, eventName, listener);
    this._renderStore.store(unlisten, unlistenId);
  }
```

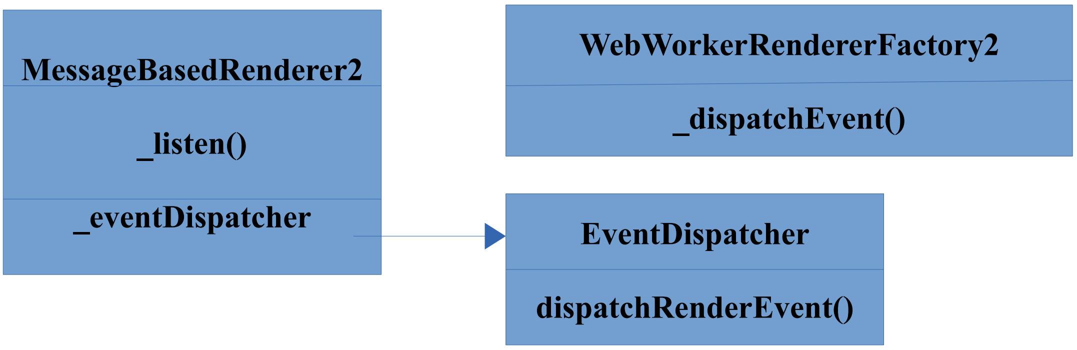
The `EventDispatcher` class is defined in event_dispatcher.ts and has a constructor and one method, `dispatchRenderEvent()`:

```
export class EventDispatcher {
  constructor(private _sink: EventEmitter<any>,
     private _serializer: Serializer) {}
```

```
dispatchRenderEvent(element: any, eventTarget: string,
     eventName: string, event: any): boolean {
  let serializedEvent: any;

  switch (event.type) {
    ..
    case 'keydown':
    case 'keypress':
    case 'keyup':
      serializedEvent = serializeKeyboardEvent(event);
      break;
    ..
    default:
      throw new Error(eventName + ' not supported on WebWorkers');
  }
  this._sink.emit({
    'element': this._serializer.serialize(
                 element, SerializerTypes.RENDER_STORE_OBJECT),
    'eventName': eventName,
    'eventTarget': eventTarget,
    'event': serializedEvent,
  });
  return false;
}
```

The switch in the middle is a long list of all the supported events and appropriate calls to an event serializer. Above we show what is has for keyboard events.

Event Handling And Web Workers



WebWorkerRendererFactory2's constructor subscribes _dispatchEvent() to EVENT_2_CHANNEL source

NOTE: _listen() calls _eventDispatcher.dispatchRenderEvent()

MessageBasedRenderer2.start() initializes _eventDispatcher with the EVENT_2_CHANNEL sink

10: The Platform-WebWorker-Dynamic Package

Overview

Platform-WebWorkers-Dynamic is the smallest of all the Angular packages. It define one const, `platformWorkerAppDynamic`, which is a call to `createPlatformFactory()`.

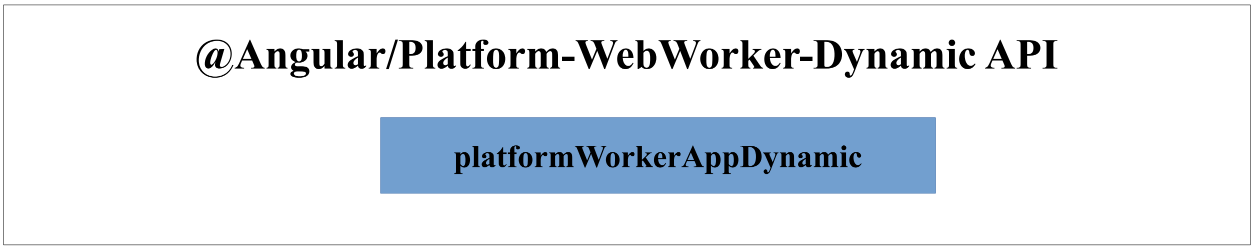
The reason to manage this as a separate package is this one line from package.json:

```
"peerDependencies": {
    ..
    "@angular/compiler": "0.0.0-PLACEHOLDER",
    ..
  },
```

It brings in the runtime compiler, which is quite large. We wish to avoid this if it not used (it is not needed in the non-dynamic packages, which use the offline compiler).

Platform-WebWorker-Dynamic API

The exported API of the Platform-WebWorker-Dynamic package can be represented as:



@Angular/Platform-WebWorker-Dynamic API

platformWorkerAppDynamic

Source Tree Layout

The source tree for the Platform-WebWorker-Dynamic package contains this directory:

- src

Currently there are no test nor testing sub-directories. It also has these files:

- index.ts
- package.json
- public_api.ts
- rollup.config.js
- tsconfig-build.json

The index.ts file is simply:

```
export * from './public_api';
```

The public_api.ts file is:

```
/**
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/platform-webworker-dynamic';
// This file only reexports content of the `src` folder. Keep it that way.
```

The src/platform-webworker-dynamic.ts file is:

```
// other imports
import {
     ɵResourceLoaderImpl as ResourceLoaderImpl,
     ɵplatformCoreDynamic as platformCoreDynamic}
from '@angular/platform-browser-dynamic';

    createPlatformFactory(platformCoreDynamic, 'workerAppDynamic', [
      {
        provide: COMPILER_OPTIONS,
        useValue: {providers: [{provide: ResourceLoader,
          useClass: ResourceLoaderImpl, deps: []}]}, multi: true },
      {provide: PLATFORM_ID, useValue: PLATFORM_WORKER_UI_ID}
    ]);
```

Note that both `ResourceLoaderImpl` and `platformCoreDynamic` are imported from the platform-browser-dynamic package.

11: The Platform-Server Package

Overview

Platform-Server represents a platform when the application is running on a server.

Most of the time Angular applications run in the browser and use either Platform-Browser (with the offline template compiler) or Platform-Browser-Dynamic (with the runtime template compiler). Running Angular applications on the server is a more specialist deployment. It can be of interest for search engine optimization and for pre-rendering output, which is later downloaded to browsers (this can speed up initial display of content to users for some types of applications; and also ease development with backend databases that might not be exposed via REST API to browser code). Platform-Server is used by Angular Universal as its platform module.

When considering Platform-Server, there are two questions the curious software engineer might ponder. Firstly, we wonder, if for the browser there are dynamic and non-dynamic versions of the platform, why not for the server? The answer to this is that for the browser, one wishes to support low-end devices serviced by poor network connections, so reducing the burden on the browser is of great interest (hence using the offline template compiler only); but one assumes the server has ample disk space and RAM and a small amount of extra code is not an issue, so bundling both kinds of server platforms (one that uses the offline template compiler, the other - “dynamic” - that uses the runtime template compiler) in the same module simplifies matters.

The second question is how rendering works on the server (where there is no DOM)? The answer is the rendered output is written via the Angular renderer API to an HTML file, which then can be downloaded to a browser or made available to a search engine - we need to explore how this rendering works (but for the curious, a library called Domino is used which provides a DOM for node apps).

Platform-Server API

Its index.ts is simply:

```
export * from './public_api';
```

Its public_api.ts file is:

```
/**export {
 * @module
 * @description
 * Entry point for all public APIs of this package.
 */
export * from './src/platform-server';

// This file only reexports content of the `src` folder. Keep it that way.
```

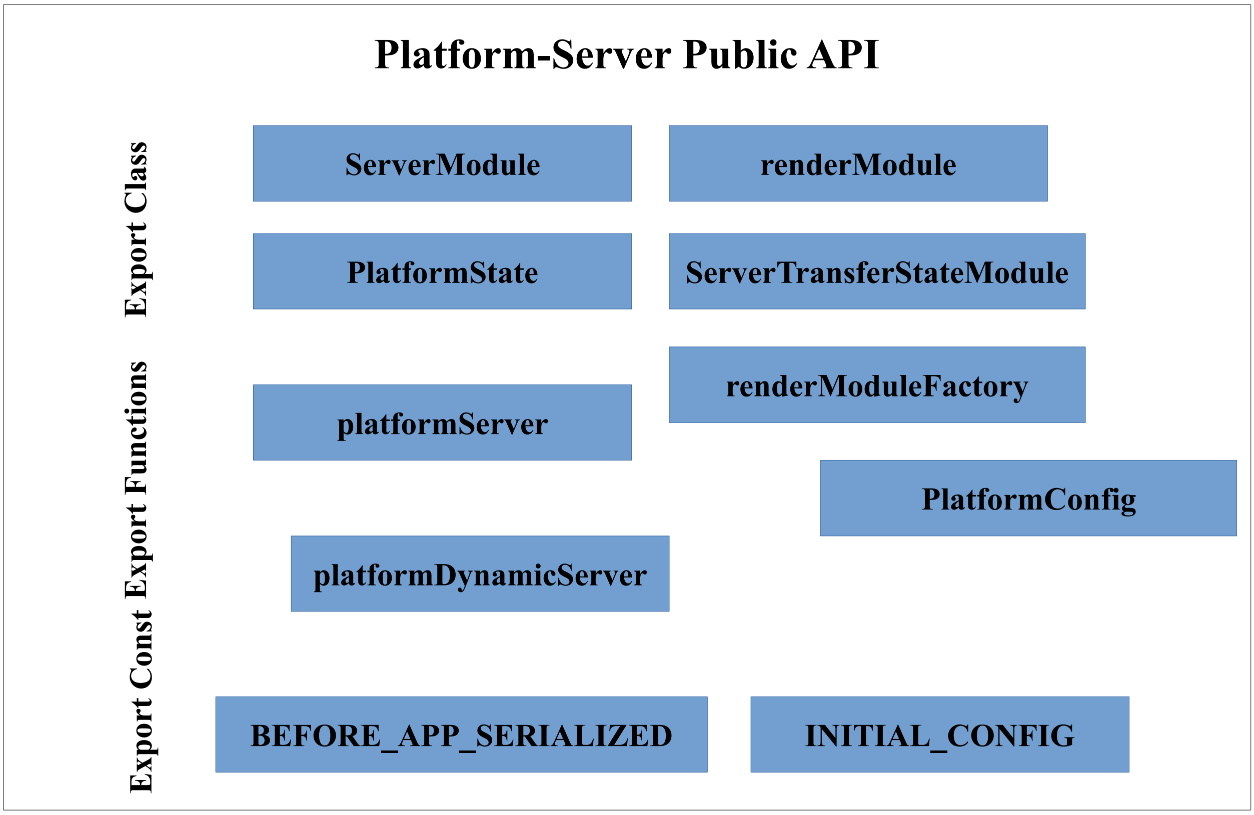
Its src/platfrom-server.ts file (that’s a hyphen rather than an underscore) is:

```
export {PlatformState} from './platform_state';
export {ServerModule, platformDynamicServer, platformServer} from './server';
export {BEFORE_APP_SERIALIZED, INITIAL_CONFIG, PlatformConfig}
   from './tokens';
export {ServerTransferStateModule} from './transfer_state';
export {renderModule, renderModuleFactory} from './utils';
export * from './private_export';
export {VERSION} from './version';
```

The main src directory for Platform-Server also contains this private_export.ts file:

```
export {INTERNAL_SERVER_PLATFORM_PROVIDERS as
     ɵINTERNAL_SERVER_PLATFORM_PROVIDERS, SERVER_RENDER_PROVIDERS
     as ɵSERVER_RENDER_PROVIDERS} from './server';
export {ServerRendererFactory2 as ɵServerRendererFactory2}
     from './server_renderer';
```

The exported API of the Platform-Server package can be represented as:



`ServerModule` represents the `NgModule` for this module. `platfromServer()` uses the offline compiler. `plaformDynamicServer()` uses the runtime compiler. Both are calls to the Core Module's `createPlatformFactory()`.

Source Tree Layout

The source tree for the Platform-Server package contains these directories:

- integrationtest
- src
- test (unit tests in Jasmine)
- testing (test tooling)

and these files:

- index.ts
- package.json
- public_api.ts
- rollup.config.js
- testing.ts
- tsconfig-build.json

Package.json has dependencies listed as:

```
"peerDependencies": {
  "@angular/animations": "0.0.0-PLACEHOLDER",
  "@angular/core": "0.0.0-PLACEHOLDER",
  "@angular/common": "0.0.0-PLACEHOLDER",
  "@angular/compiler": "0.0.0-PLACEHOLDER",
  "@angular/platform-browser": "0.0.0-PLACEHOLDER",
  "@angular/platform-browser-dynamic": "0.0.0-PLACEHOLDER"
},
"dependencies": {
  "tslib": "^1.7.1",
  "domino": "^1.0.29",
  "xhr2": "^0.1.4"
},
```

domino is the server-side DOM editing package that we need.

Source

platform-server/src

These source files are present:

- domino_adapter.ts
- http.ts
- location.ts
- platform_state.ts
- server_renderer.ts
- server.ts
- styles_host.ts
- tokens.ts
- transfer_state.ts
- utils.t

There are no sub-directories beneath src.

The server.ts file declares this const:

```
export const INTERNAL_SERVER_PLATFORM_PROVIDERS: StaticProvider[] = [
  {provide: DOCUMENT, useFactory: _document, deps: [Injector]},
  {provide: PLATFORM_ID, useValue: PLATFORM_SERVER_ID},
  {provide: PLATFORM_INITIALIZER, useFactory: initDominoAdapter, multi: true,
    deps: [Injector]}, {
     provide: PlatformLocation,
     useClass: ServerPlatformLocation,
     deps: [DOCUMENT, [Optional, INITIAL_CONFIG]]
  },
  {provide: PlatformState, deps: [DOCUMENT]},
  // Add special provider that allows multiple instances
  // of platformServer* to be created.
  {provide: ALLOW_MULTIPLE_PLATFORMS, useValue: true}
];
```

The factory functions `platformServer` and `platformDynamicServer` create server platforms that use the offline template compiler and the runtime template compiler respectively.

It adds two additional provider configurations. Firstly, `PLATFORM_INITIALIZER`, which is an initializer function called before bootstrapping. Here we see it initializes the domino adapter, in a call to the local function `initDominoAdapter()` which calls `makeCurrent()` for the `DominoAdapter`:

```
  function initDominoAdapter(injector: Injector) {
    return () => { DominoAdapter.makeCurrent(); };
  }
```

Secondly, it adds `PlatformLocation`, which is used by applications to interact with location (URL) information. It is set to a local class, `ServerPlatformLocation`, which mostly just throws exceptions:

```
  /**
   * Server-side implementation of URL state.
   * Implements `pathname`, `search`, and `hash`
   * but not the state stack.
   */
  @Injectable()
  export class ServerPlatformLocation implements PlatformLocation {
    public readonly pathname: string = '/';
    public readonly search: string = '';
    public readonly hash: string = '';
    private _hashUpdate = new Subject<LocationChangeEvent>();

    constructor(
        @Inject(DOCUMENT) private _doc: any,
            @Optional() @Inject(INITIAL_CONFIG) _config: any) {
      const config = _config as PlatformConfig | null;
      if (!!config && !!config.url) {
        const parsedUrl = parseUrl(config.url);
        this.pathname = parsedUrl.pathname;
        this.search = parsedUrl.search;
        this.hash = parsedUrl.hash;
      }
    }
    ..
    forward(): void { throw new Error('Not implemented'); }
    back(): void { throw new Error('Not implemented'); }
  }
```

server.ts declares two exported functions:

```
  export const platformServer =
      createPlatformFactory(platformCore, 'server',
     INTERNAL_SERVER_PLATFORM_PROVIDERS);

  export const platformDynamicServer =
      createPlatformFactory(platformCoreDynamic, 'serverDynamic',
     INTERNAL_SERVER_PLATFORM_PROVIDERS);
```

We saw earlier that `platformCore` is defined in:

- <ANGULAR-MASTER>/packages/core/src/platform_core_providers.ts

as:

```
const _CORE_PLATFORM_PROVIDERS: StaticProvider[] = [
  {provide: PLATFORM_ID, useValue: 'unknown'},
  {provide: PlatformRef, deps: [Injector]},
  {provide: TestabilityRegistry, deps: []},
  {provide: Console, deps: []},
];
export const platformCore = createPlatformFactory(
                              null, 'core', _CORE_PLATFORM_PROVIDERS);
```

`platformCoreDynamic` adds additional provider config (for the dynamic compiler) to `platformCore` and is defined in:

- <ANGULAR-MASTER>/packages/platform-browser-dynamic/src/platfrom-browser-dynamic.ts

as:

```
export const platformCoreDynamic = createPlatformFactory(platformCore,
'coreDynamic', [
  {provide: COMPILER_OPTIONS, useValue: {}, multi: true},
  {provide: CompilerFactory, useClass: JitCompilerFactory, deps:
[COMPILER_OPTIONS]},
]);
```

`createPlatformFactory()` is defined in:

- <ANGULAR-MASTER>/packages/core/src/application_ref.ts

it calls Core’s `createPlatform()` with the supplied parameters, resulting in a new platform being constructed.

The last part of Platform-Server’s server.ts file is the definition of the `NgModule`:

```
// The ng module for the server.
@NgModule({
  exports: [BrowserModule],
  imports: [HttpModule, HttpClientModule, NoopAnimationsModule],
  providers: [
    SERVER_RENDER_PROVIDERS,
    SERVER_HTTP_PROVIDERS,
    {provide: Testability, useValue: null},
  ],
})
export class ServerModule { }
```

The domino_adapter.ts file create a DOM adapter for Domino. The Domino library is a DOM engine for HTML5 that runs in Node. Its project page is:

- https://github.com/fgnass/domino

and states:

> *“As the name might suggest, domino's goal is to provide a DOM in Node.”*

The domino_adapter.ts file provides an adapter class, `DominoDomAdapter`, based on Domino's serialization functionality that implements a `DomAdapter` suitable for use in server environments.

The domino_adapter.ts file has these functions to parse and serialze a document:

```
/**
 * Parses a document string to a Document object.
 */
export function parseDocument(html: string, url = '/') {
  let window = domino.createWindow(html, url);
  let doc = window.document;
  return doc;
}

/**
 * Serializes a document to string.
 */
export function serializeDocument(doc: Document): string {
  return (doc as any).serialize();
}
```

We see `serializeDocument` being called from:

- <ANGULAR-MASTER>/packages/platform-server/src/platform_state.ts

as:

```
@Injectable()
export class PlatformState {
  constructor(@Inject(DOCUMENT) private _doc: any) {}

  /**
   * Renders the current state of the platform to string.
   */
  renderToString(): string { return serializeDocument(this._doc); }

  /**
   * Returns the current DOM state.
   */
  getDocument(): any { return this._doc; }
}
```

`BrowserDomAdapter` is defined in:

- <ANGULAR-MASTER>/packages/platfrom-browser/src/browser/browser_adapter.ts

`DominoDomAdapter` simply extends `BrowserDomAdapter`:

```
/**
 * DOM Adapter for the server platform based on
 *  https://github.com/fgnass/domino.
 */
export class DominoAdapter extends BrowserDomAdapter {

  private static defaultDoc: Document;
```

Its static `makeCurrent()` method, that we saw Universal Angular uses for server-side rendering, initializes those three variables and then calls `setRootDomAdapter()`:

```
    static makeCurrent() { setRootDomAdapter(new DominoAdapter()); }
```

Recall that `setRootDomAdapter()` is defined in:

- <ANGULAR-MASTER>/packages/platform-browser/src/dom/dom_adapter.ts

as:

```
  let _DOM: DomAdapter = null !;

  export function setRootDomAdapter(adapter: DomAdapter) {
    if (!_DOM) {
      _DOM = adapter;
    }
  }
  export function getDOM() {
    return _DOM;
  }
```

and that `getDOM()` is used by the `DOMRenderer`. Hence our DominoDomAdapter gets wired into the DOM renderer.

Many of the DOM adapter methods throw exceptions as they do not make sense server-side:

```
    getHistory(): History { throw _notImplemented('getHistory'); }
    getLocation(): Location { throw _notImplemented('getLocation'); }
    getUserAgent(): string { return 'Fake user agent'; }
```

12: The Router Package

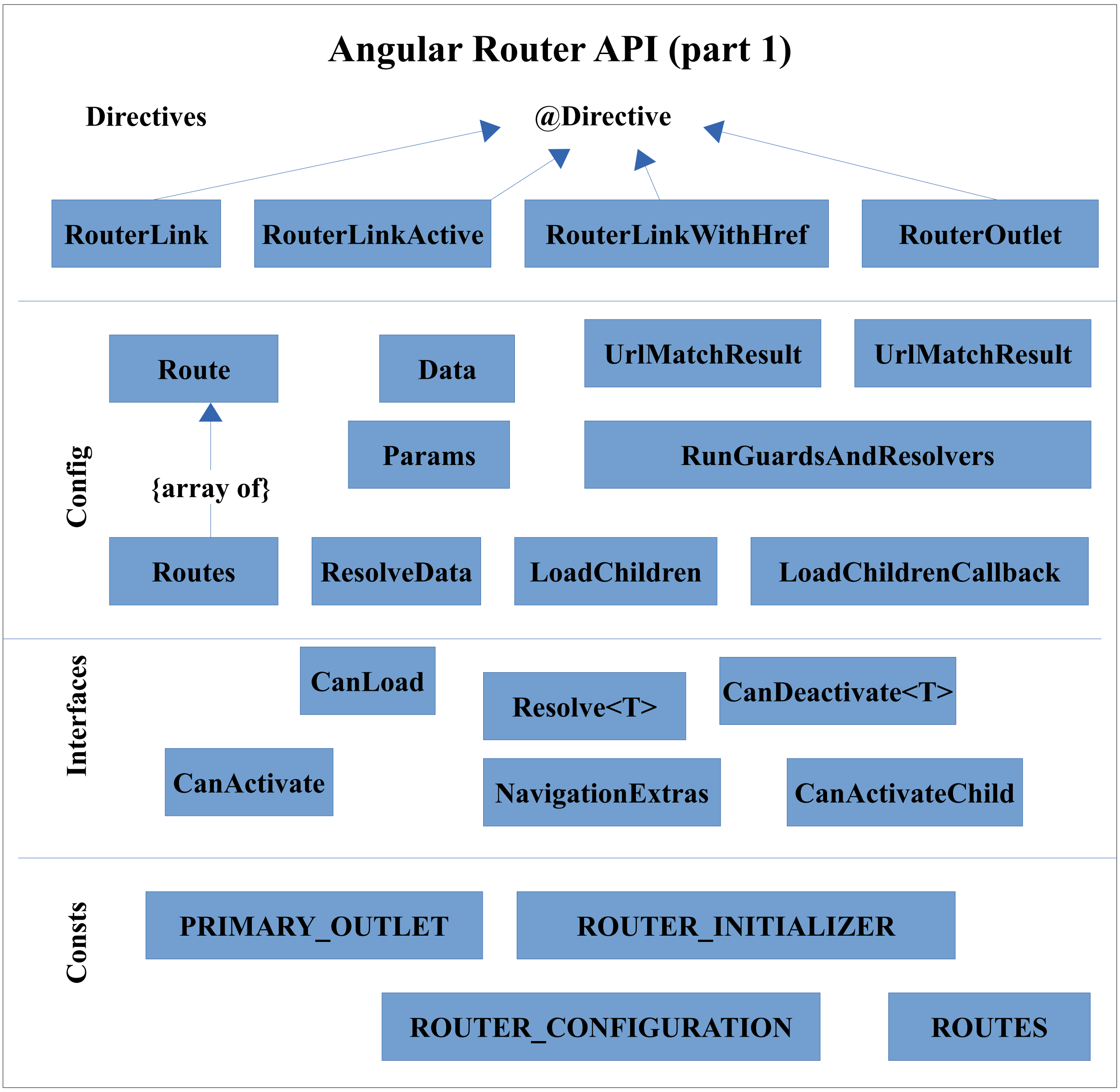
Overview

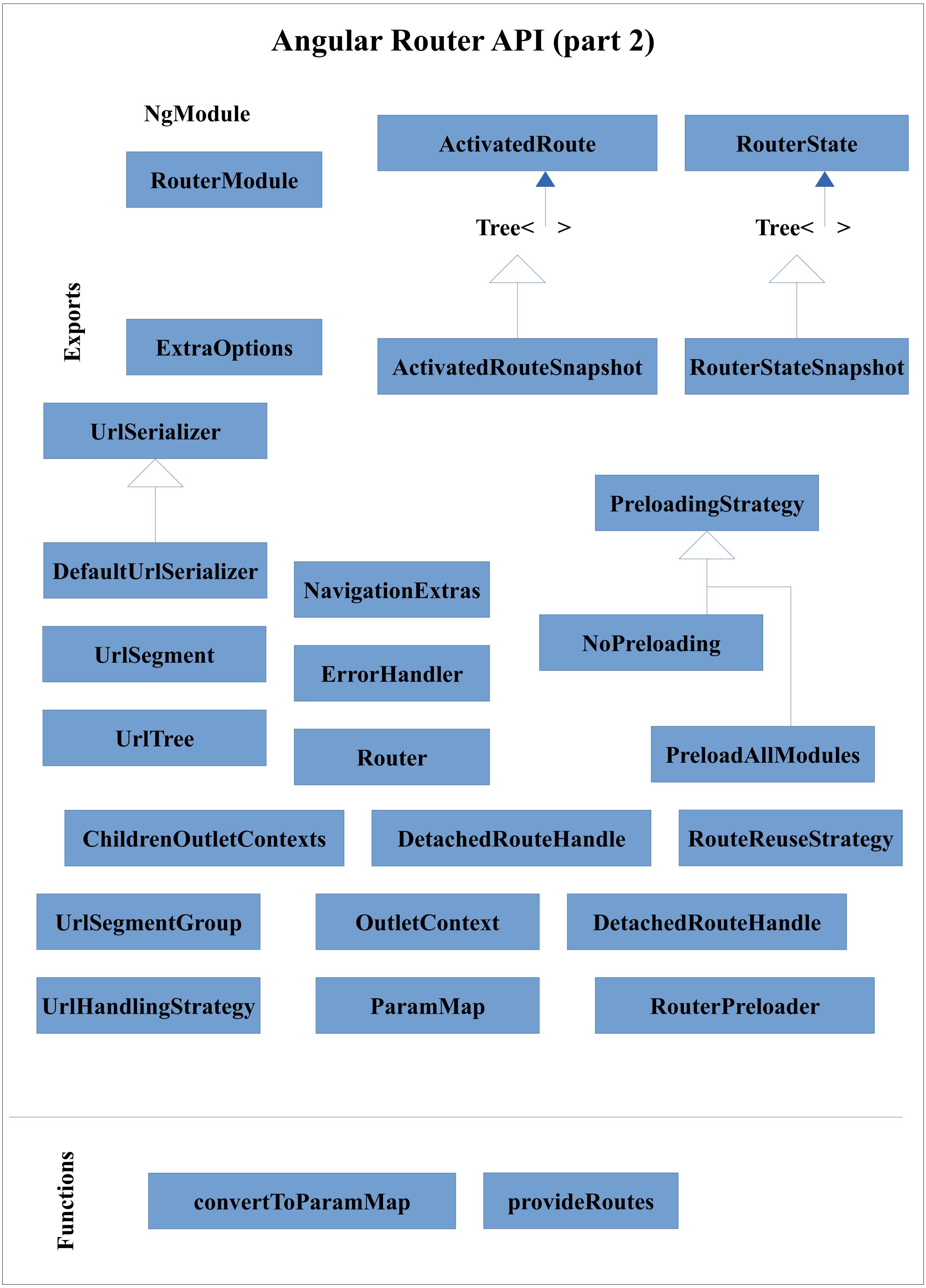
The Angular Router package provides functionality to:

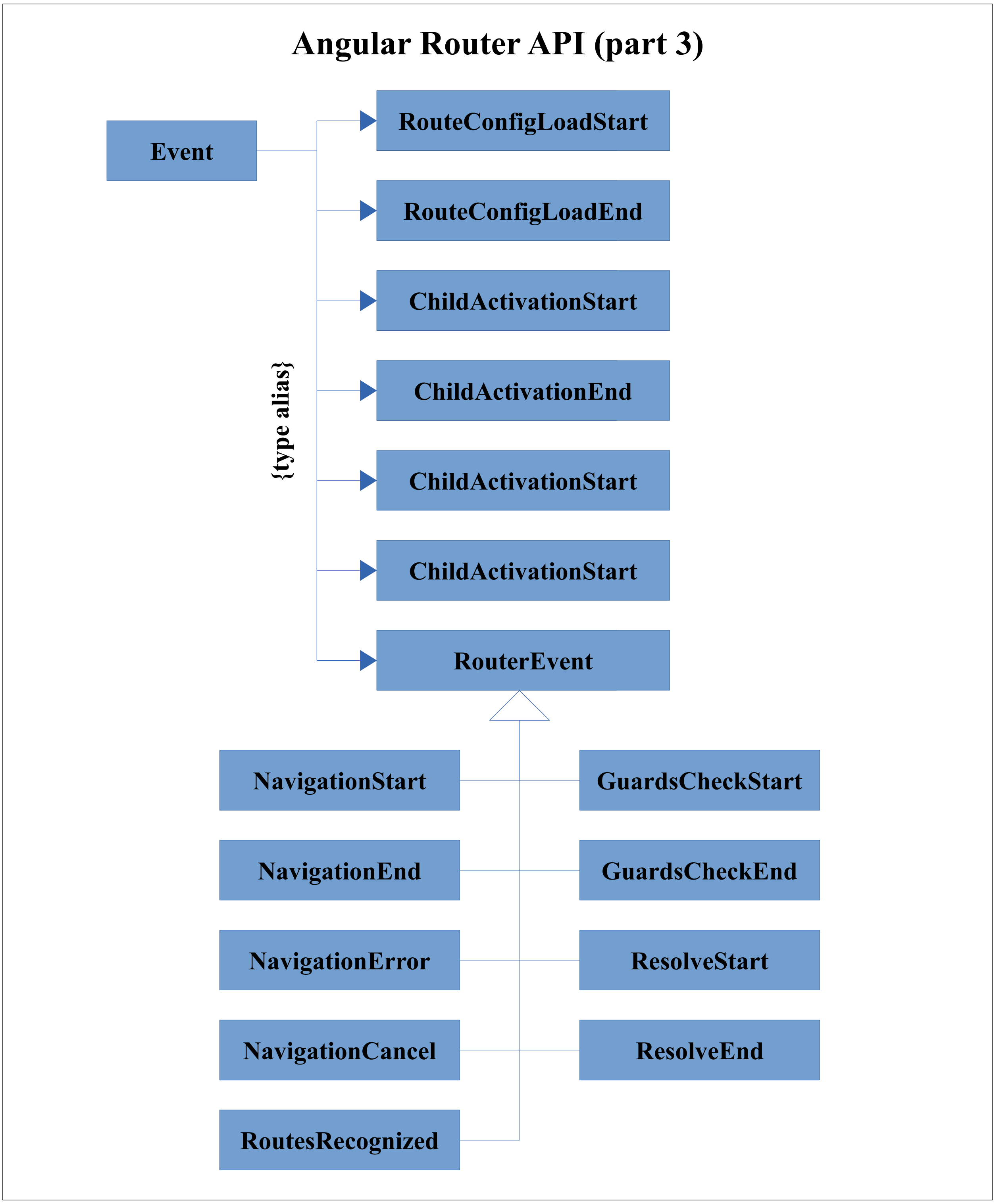
- manage naviation based on URLs and reflect state in the URL
- manage application state and state transitions
- Eargerly load, lazily-load and preload modules as needed

Router API

The exported API of the Angular Router package can be represented as:




Angular Router API (part 2)
NgModule
RouterModule
ActivatedRoute
RouterState
Tree< >
Tree< >
Exports
ExtraOptions
ActivatedRouteSnapshot
RouterStateSnapshot
UrlSerializer
PreloadingStrategy
DefaultUrlSerializer
NavigationExtras
NoPreloading
UrlSegment
ErrorHandler
UrlTree
Router
PreloadAllModules
ChildrenOutletContexts
DetachedRouteHandle
RouteReuseStrategy
UrlSegmentGroup
OutletContext
DetachedRouteHandle
UrlHandlingStrategy
ParamMap
RouterPreloader
Functions
convertToParamMap
provideRoutes



The Angular Router source tree is at:

- <ANGULAR-MASTER>/packages/router

Its root directory contains index.ts, which just exports the contents of public_api.ts, which in turn exports the contents of .src/index.ts.

This lists the exports and gives an initial impression of the size of the router package:

```
export {Data, LoadChildren, LoadChildrenCallback, ResolveData, Route, Routes,
  RunGuardsAndResolvers, UrlMatchResult, UrlMatcher} from './config';
export {RouterLink, RouterLinkWithHref} from './directives/router_link';
export {RouterLinkActive} from './directives/router_link_active';
export {RouterOutlet} from './directives/router_outlet';
export {ActivationEnd, ActivationStart, ChildActivationEnd,
  ChildActivationStart, Event, GuardsCheckEnd, GuardsCheckStart,
  NavigationCancel, NavigationEnd, NavigationError, NavigationStart,
  ResolveEnd, ResolveStart, RouteConfigLoadEnd, RouteConfigLoadStart,
  RouterEvent, RoutesRecognized} from './events';
export {CanActivate, CanActivateChild, CanDeactivate, CanLoad, Resolve}
  from './interfaces';
export {DetachedRouteHandle, RouteReuseStrategy}
  from './route_reuse_strategy';
export {NavigationExtras, Router} from './router';
export {ROUTES} from './router_config_loader';
export {ExtraOptions, ROUTER_CONFIGURATION, ROUTER_INITIALIZER, RouterModule,
  provideRoutes} from './router_module';
export {ChildrenOutletContexts, OutletContext}
  from './router_outlet_context';
export {NoPreloading, PreloadAllModules, PreloadingStrategy, RouterPreloader}
  from './router_preloader';
export {ActivatedRoute, ActivatedRouteSnapshot, RouterState,
  RouterStateSnapshot} from './router_state';
export {PRIMARY_OUTLET, ParamMap, Params, convertToParamMap} from './shared';
export {UrlHandlingStrategy} from './url_handling_strategy';
export {DefaultUrlSerializer, UrlSegment, UrlSegmentGroup, UrlSerializer,
  UrlTree} from './url_tree';
export {VERSION} from './version';
```

It also has the line:

```
export * from './private_export';
```

As already discussed, such private exports are intended for other packages within the Angular Framework itself, and not to be directly used by Angular applications. The private_export.ts file has these exports (note names are prepended with ’ɵ’);

```
export {ROUTER_PROVIDERS as ɵROUTER_PROVIDERS} from './router_module';
export {flatten as ɵflatten} from './utils/collection';
```

Source Tree Layout

The source tree for the Router package contains these directories:

- scripts
- src
- test (unit tests in Jasmine)
- testing (testing tools)

The Router package root directory contains these files:

- BUILD.bazel
- index.ts
- karma-test-shim.ts
- karma.config.js
- LICENSE
- package.json

- public_api.ts
- README.md
- rollup.config.js
- tsconfig-build.json

Source

router/src

The router/src directory contains:

- apply_redirects.ts
- config.ts
- create_router_state.ts
- create_url_tree.ts
- events.ts
- interfaces.ts
- index.ts
- interfaces.ts
- pre_activation.ts
- private_export.ts
- recognize.ts
- resolve.ts
- route_reuse_strategy.ts
- router_config_loader.ts
- router_module.ts
- router_outlet_context.ts
- router_preloader.ts
- router_state.ts
- router.ts
- shared.ts
- url_handling_strategy.ts
- url_tree.ts
- version.ts

We'll start by looking at:

- <ANGULAR-MASTER>/packages/router/src/router_module.ts

which defines the RouterModule class and related types.

It defines three consts:

```
const ROUTER_DIRECTIVES =
     [RouterOutlet, RouterLink, RouterLinkWithHref, RouterLinkActive];
```

The first, `ROUTER_DIRECTIVES`, is the collection of router directives that can appear in Angular templates defining where the routed content is to be located on the page, and how links used for routing are to be displayed. `ROUTER_DIRECTIVES` is specified in the declarations and exports of the `@NgModule` metadata for `RouterModule`:

```
@NgModule({declarations: ROUTER_DIRECTIVES, exports: ROUTER_DIRECTIVES})
export class RouterModule { .. }
```

The other two are injection tokens for DI:

```
export const ROUTER_CONFIGURATION =
     new InjectionToken<ExtraOptions>('ROUTER_CONFIGURATION');
export const ROUTER_FORROOT_GUARD =
     new InjectionToken<void>('ROUTER_FORROOT_GUARD');
```

It also defines the `ROUTER_PROVIDERS` array of providers (which is only used by forRoot, not forChild):

```
export const ROUTER_PROVIDERS: Provider[] = [
  Location,
  {provide: UrlSerializer, useClass: DefaultUrlSerializer},
  {provide: Router, useFactory: setupRouter, .. },
  ChildrenOutletContexts,
  {provide: ActivatedRoute, useFactory: rootRoute, deps: [Router]},
  {provide: NgModuleFactoryLoader, useClass: SystemJsNgModuleLoader},
  RouterPreloader,
  NoPreloading,
  PreloadAllModules,
  {provide: ROUTER_CONFIGURATION, useValue: {enableTracing: false}},
];
```

An important provider there is `Router`, which is the actually routing service. This is set up in DI to return the result of the `setupRouter` factory method. An abbreviated version of this is as follows:

```
export function setupRouter(..) {
  const router = new Router(
       null, urlSerializer, contexts, location, injector,
       loader, compiler, flatten(config));

  if (urlHandlingStrategy) ..

  if (routeReuseStrategy) ..

  if (opts.errorHandler) ..

  if (opts.enableTracing) ..

  if (opts.onSameUrlNavigation)..

  if (opts.paramsInheritanceStrategy) ..

  return router;
}
```

It instantiates the router service and for each specified option / strategy takes appropciarte action. Then it returns the new router service instance. It is important that there is only a single router service per application the web browser only have a single URL per session) and we need to track how this is so.

RouterModule is defined as:

```
@NgModule({declarations: ROUTER_DIRECTIVES, exports: ROUTER_DIRECTIVES})
export class RouterModule {
  // Note: We are injecting the Router so it gets created eagerly...
  constructor(
     @Optional() @Inject(ROUTER_FORROOT_GUARD) guard: any,
     @Optional() router: Router) {}
  static forRoot(routes: Routes, config?: ExtraOptions): ModuleWithProviders
```

```
      { .. }
    static forChild(routes: Routes): ModuleWithProviders { .. }
  }
```

Note that both `forRoot` and `forChild` return a `ModuleWithProviders` instance. What they put in it is different. Recall that this type is defined in:

- <ANGULAR-MASTER>/packages/core/src/metadata/ng_module.ts

as follows:

```
  // wrapper around a module that also includes the providers.
  export interface ModuleWithProviders {
    ngModule: Type<any>;
    providers?: Provider[];
  }
```

`ForChild` is intended for all except the root routing module. It returns `ngModule` and a list of providers that only contains the result of calling `provideRoutes`:

```
  static forChild(routes: Routes): ModuleWithProviders {
      return {ngModule: RouterModule, providers: [provideRoutes(routes)]};
    }
```

Critically, it does not contain ROUTER_PROVIDERS. In contrast, `forRoot` adds this and many more providers:

```
   static forRoot(routes: Routes, config?: ExtraOptions): ModuleWithProviders {
      return {
        ngModule: RouterModule,
        providers: [
          ROUTER_PROVIDERS,
          provideRoutes(routes),
          {provide: ROUTER_FORROOT_GUARD,  .. },
          {provide: ROUTER_CONFIGURATION, .. },
          {provide: LocationStrategy, .. },
          {provide: PreloadingStrategy, .. },
          {provide: NgProbeToken, .. },
          provideRouterInitializer(),
        ],
      };
    }
```

`ExtraOptions` are additional options passed in to `forRoot` (it is not used with `forChild`):

```
  export interface ExtraOptions {
    enableTracing?: boolean;
    useHash?: boolean;
    initialNavigation?: InitialNavigation;
    errorHandler?: ErrorHandler;
    preloadingStrategy?: any;
    onSameUrlNavigation?: 'reload'|'ignore';
    paramsInheritanceStrategy?: 'emptyOnly'|'always';
  }
```

For example, if we wished to customize how preloading worked, we need to set the `preloadingStrategy` option.

The `provideRouterInitializer()` function providers a list of initializers:

```
export function provideRouterInitializer() {
  return [
    RouterInitializer,
    {
      provide: APP_INITIALIZER,
      multi: true,
      useFactory: getAppInitializer,
      deps: [RouterInitializer]
    },
    {provide: ROUTER_INITIALIZER,
       useFactory: getBootstrapListener, deps: [RouterInitializer]},
    {provide: APP_BOOTSTRAP_LISTENER, multi: true,
                                 useExisting: ROUTER_INITIALIZER},
  ];
}
```

This uses the `RouterInitializer` class, whose purpose is best explained by this comment in the code:

```
/**
 * To initialize the router properly we need to do in two steps:
 *
 * We need to start the navigation in a APP_INITIALIZER to block the
 * bootstrap if a resolver or a guards executes asynchronously. Second, we
 * need to actually run activation in a BOOTSTRAP_LISTENER. We utilize the
 * afterPreactivation hook provided by the router to do that.
 *
 * The router navigation starts, reaches the point when preactivation is
 * done, and then pauses. It waits for the hook to be resolved. We then
 * resolve it only in a bootstrap listener.
 */
@Injectable()
export class RouterInitializer { .. }
```

We saw when examining the Core package that its:

- <ANGULAR_MASTER>/packages/core/src/application_init.ts

defines `APP_INITIALIZER` as:

```
// A function that will be executed when an application is initialized.
export const APP_INITIALIZER =
           new InjectionToken<Array<() => void>>('Application Initializer');
```

Interfaces.ts declares a number of useful interfaces.

```
export interface CanActivate {
  canActivate(route: ActivatedRouteSnapshot, state: RouterStateSnapshot):
      Observable<boolean>|Promise<boolean>|boolean;
}
export interface CanActivateChild {
  canActivateChild(childRoute: ActivatedRouteSnapshot,
   state: RouterStateSnapshot):
      Observable<boolean>|Promise<boolean>|boolean;
}
export interface CanDeactivate<T> {
  canDeactivate(
       component: T, currentRoute: ActivatedRouteSnapshot,
       currentState: RouterStateSnapshot,
      nextState?: RouterStateSnapshot
    ): Observable<boolean>|Promise<boolean>|boolean;
}
export interface Resolve<T> {
  resolve(route: ActivatedRouteSnapshot, state: RouterStateSnapshot
  ): Observable<T>|Promise<T>|T;
}
export interface CanLoad {
   canLoad(route: Route): Observable<boolean>|Promise<boolean>|boolean;
}
```

router_config_loader.ts defines a class - `RouterConfigLoader` – and an opaque token, `ROUTES`. After some bookkeeping, `RouterConfigLoader` creates a new instance of LoadedRouterConfig it:

```
export const ROUTES = new InjectionToken<Route[][]>('ROUTES');

export class RouterConfigLoader {
  constructor(
      private loader: NgModuleFactoryLoader, private compiler: Compiler,
      private onLoadStartListener?: (r: Route) => void,
      private onLoadEndListener?: (r: Route) => void) {}

  load(parentInjector: Injector, route: Route):
                                        Observable<LoadedRouterConfig> {
     ..
     return new LoadedRouterConfig(
       flatten(module.injector.get(ROUTES)), module);
 }
```

The router_state.ts file contains these classes (and some helper functions):

- RouterState
- ActivatedRoute
- ActivatedRouteSnapshot
- RouterStateSnapshot

`RouterState` is defined as:

```
// RouterState is a tree of activated routes.
// Every node in this tree knows about the "consumed" URL
// segments, the extracted parameters, and the resolved data.
export class RouterState extends Tree<ActivatedRoute> {
  constructor(
      root: TreeNode<ActivatedRoute>,
      public snapshot: RouterStateSnapshot) {
    super(root);
    setRouterState(<RouterState>this, root);
  }
}
```

`RouterStateSnapshot` is defined as:

```
/**
 * @whatItDoes Represents the state of the router at a moment in time.
 * RouterStateSnapshot is a tree of activated route snapshots. Every node in
 * this tree knows about the "consumed" URL segments, the extracted
 * parameters, and the resolved data.
 */
export class RouterStateSnapshot extends Tree<ActivatedRouteSnapshot> {
  constructor(
      public url: string, root: TreeNode<ActivatedRouteSnapshot>) {
```

```
      super(root);
      setRouterState(<RouterStateSnapshot>this, root);
    }
  }
```

The `setRouterStateSnapshot()` function is defined as:

```
  function setRouterState<U, T extends{_routerState: U}>(state: U, node:
  TreeNode<T>): void {
    node.value._routerState = state;
    node.children.forEach(c => setRouterState(state, c));
  }
```

So its sets the router state for the current node, and then recursively calls `setRouterState()` to set it for all children.

The `ActivatedRoute` class is used by the router outlet directive to describe the component it has loaded:

```
  // Contains the information about a route associated with a component loaded
  // in an outlet. An `ActivatedRoute` can also be used to traverse the
  // router state tree
  export class ActivatedRoute {
    ..
    constructor(..) {
      this._futureSnapshot = futureSnapshot;
    }

    /** The configuration used to match this route */
    get routeConfig(): Route|null { return this._futureSnapshot.routeConfig; }

    /** The root of the router state */
    get root(): ActivatedRoute { return this._routerState.root; }

    /** The parent of this route in the router state tree */
    get parent(): ActivatedRoute|null {
       return this._routerState.parent(this); }

    /** The first child of this route in the router state tree */
    get firstChild(): ActivatedRoute|null {
       return this._routerState.firstChild(this); }

    /** The children of this route in the router state tree */
    get children(): ActivatedRoute[] {
       return this._routerState.children(this); }

    /** The path from the root of the router state tree to this route */
    get pathFromRoot(): ActivatedRoute[] {
       return this._routerState.pathFromRoot(this); }

    get paramMap(): Observable<ParamMap> {..}

    get queryParamMap(): Observable<ParamMap> { .. }
  }
```

router/src/directives

This directory has the following files:

- router_link.ts

- router_link_active.ts
- router_outlet.ts

The router_link.ts file contains the `RouterLink` directive:

```
@Directive({selector: ':not(a)[routerLink]'})
export class RouterLink {
  @Input() queryParams: {[k: string]: any};
  @Input() fragment: string;
  @Input() queryParamsHandling: QueryParamsHandling;
  @Input() preserveFragment: boolean;
  @Input() skipLocationChange: boolean;
  @Input() replaceUrl: boolean;
  private commands: any[] = [];
  private preserve: boolean;

  constructor(
       private router: Router, private route: ActivatedRoute,
       @Attribute('tabindex') tabIndex: string,
       renderer: Renderer2, el: ElementRef) {

    if (tabIndex == null) {
      renderer.setAttribute(el.nativeElement, 'tabindex', '0');
    }
  }
```

The router link commands are set via:

```
@Input()
 set routerLink(commands: any[]|string) {
   if (commands != null) {
     this.commands = Array.isArray(commands) ? commands : [commands];
   } else {
     this.commands = [];
   }
 }
```

When the link is clicked, the `onClick()` method is called:

```
@HostListener('click')
 onClick(): boolean {
   const extras = {
     skipLocationChange: attrBoolValue(this.skipLocationChange),
     replaceUrl: attrBoolValue(this.replaceUrl),
   };
   this.router.navigateByUrl(this.urlTree, extras);
   return true;
 }
```

The urlTree getter uses `Router.createlUrlTree()`:

```
get urlTree(): UrlTree {
    return this.router.createUrlTree(this.commands, {
      relativeTo: this.route,
      queryParams: this.queryParams,
      fragment: this.fragment,
      preserveQueryParams: attrBoolValue(this.preserve),
      queryParamsHandling: this.queryParamsHandling,
      preserveFragment: attrBoolValue(this.preserveFragment),
    });
  }
```

The same file also contains the `RouterLinkWithHref` directive:

```
@Directive({selector: 'a[routerLink]'})
export class RouterLinkWithHref implements OnChanges, OnDestroy { .. }
```

This has a href:

```
 // the url displayed on the anchor element.
 @HostBinding() href: string;
```

and manages the `urlTree` as a field and sets it from the constructor via a call to:

```
private updateTargetUrlAndHref(): void {
    this.href = this.locationStrategy.prepareExternalUrl(
                             this.router.serializeUrl(this.urlTree));
  }
```

The router_link_active.ts file contains the `RouterLinkActive` directive:

```
@Directive({
  selector: '[routerLinkActive]',
  exportAs: 'routerLinkActive',
})
export class RouterLinkActive implements OnChanges,
    OnDestroy, AfterContentInit { .. }
```

This is used to add a CSS class to an element representing an active route. Its constructor is defiend as:

```
constructor(
   private router: Router,
   private element: ElementRef,
   private renderer: Renderer2,
       private cdr: ChangeDetectorRef) {

  this.subscription = router.events.subscribe(s => {
      if (s instanceof NavigationEnd) {
        this.update();
      }
    });
  }
```

Its `update` method uses the configured renderer to set the element class:

```
  private update(): void {
    if (!this.links || !this.linksWithHrefs || !this.router.navigated)
return;
    Promise.resolve().then(() => {
      const hasActiveLinks = this.hasActiveLinks();
      if (this.isActive !== hasActiveLinks) {
        (this as any).isActive = hasActiveLinks;
        this.classes.forEach((c) => {
          if (hasActiveLinks) {
            this.renderer.addClass(this.element.nativeElement, c);
          } else {
            this.renderer.removeClass(this.element.nativeElement, c);
          }
        });
      }
    });
  }
```

The router_outlet.ts file contains the `RouterOutlet` class:

```
// Acts as a placeholder that Angular dynamically fills based on the
// current router * state.
@Directive({selector: 'router-outlet', exportAs: 'outlet'})
export class RouterOutlet implements OnDestroy, OnInit {
  private activated: ComponentRef<any>|null = null;
  private _activatedRoute: ActivatedRoute|null = null;
  private name: string;

  @Output('activate') activateEvents = new EventEmitter<any>();
  @Output('deactivate') deactivateEvents = new EventEmitter<any>();

  constructor(
       private parentContexts: ChildrenOutletContexts,
  1    private location: ViewContainerRef,
  2    private resolver: ComponentFactoryResolver,
       @Attribute('name') name: string,
       private changeDetector: ChangeDetectorRef) {

    this.name = name || PRIMARY_OUTLET;
    parentContexts.onChildOutletCreated(this.name, this);
  }
```

This is where application component whose lifecycle depends on the router live. We note the `ViewContainerRef` 1 and `ComponentFactoryResolver` 2 parameters to the constructor.

`ngOnInit` will either call `attach` 1 or `activateWith` 2, depending on whether there is an existing component:

```
ngOnInit(): void {
    if (!this.activated) {
      // If the outlet was not instantiated at the time the
      // route got activated we need to populate
      // the outlet when it is initialized (ie inside a NgIf)
      const context = this.parentContexts.getContext(this.name);
      if (context && context.route) {
        if (context.attachRef) {
          // `attachRef` is populated when there is an
          // existing component to mount
 1        this.attach(context.attachRef, context.route);
        } else {
          // otherwise the component defined in the configuration is created
 2        this.activateWith(context.route, context.resolver || null);
        }
      }
    }
  }
```

attach is defined as:

```
// Called when the `RouteReuseStrategy` instructs to
// re-attach a previously detached subtree
  attach(ref: ComponentRef<any>, activatedRoute: ActivatedRoute) {
    this.activated = ref;
    this._activatedRoute = activatedRoute;
    this.location.insert(ref.hostView);
  }
```

When its activateWith method is called, the resolver will be asked to resolve a component factory for the component:

```
activateWith(
       activatedRoute: ActivatedRoute,
       resolver: ComponentFactoryResolver|null) {
    if (this.isActivated) {
      throw new Error('Cannot activate an already activated outlet');
    }
    this._activatedRoute = activatedRoute;
    const snapshot = activatedRoute._futureSnapshot;
    const component = <any>snapshot.routeConfig !.component;
    resolver = resolver || this.resolver;
    const factory = resolver.resolveComponentFactory(component);
    const childContexts =
      this.parentContexts.getOrCreateContext(this.name).children;
    const injector = new OutletInjector(activatedRoute,
                        childContexts, this.location.injector);
    this.activated = this.location.createComponent(
                        factory, this.location.length, injector);

    // Calling `markForCheck` to make sure we will run the change
    // detection when the     // `RouterOutlet` is inside a
    //  `ChangeDetectionStrategy.OnPush` component.
    this.changeDetector.markForCheck();
    this.activateEvents.emit(this.activated.instance);
  }
}
```

The location field is of type `ViewContainerRef`, which we saw being set in the constructor. `ViewContainerRef` is defined in:

- <ANGULAR-MASTER>/packages/core/ src/linker/view_container_ref.ts

```
export abstract class ViewContainerRef {
  // Returns the number of Views currently attached to this container.
  abstract get length(): number;

  // Instantiates a single Component and inserts its Host View into this
  // container at the specified `index`.
  // The component is instantiated using its ComponentFactory which can be
  // obtained via ComponentFactoryResolver.resolveComponentFactory
  // If `index` is not specified, the new View will be inserted as the last
  // View in the container. Returns the {@link ComponentRef} of the Host
  // View created for the newly instantiated Component.
  abstract createComponent<C>(
       componentFactory: ComponentFactory<C>, index?: number,
       injector?: Injector, projectableNodes?: any[][],
       ngModule?: NgModuleRef<any>): ComponentRef<C>;
}
```

So the component is appended as the last entry in the `ViewContainer`.

Appendix 1: Render3 in Angular 6

Notes: This is an early draft of our coverage of the new Render3 in Angular 6. It will evolve as Render3 itself evolves. For now we maintain our coverage in this separate appendix, in future we will add it to the main text.

Clipcode is particularly interested in Render3 as we offer this workshop to our customers with specialist custom platform/custom renderer needs.

All Angular source extracts taken from MASTER branch (Feb 9th, 2018)

Overview

Rendering in Angular is undergoing further evolution. It seems it was not too long ago that Angular 2's original Render architecture evolved to Render2, and now along comes the very new Render3, quite a different approach to a view engine.

The main change can be summed up with just this one function (from src/render3/interfaces/renderer.ts):

```
export const domRendererFactory3: RendererFactory3 = {
  createRenderer: (hostElement: RElement | null,
     rendererType: RendererType2 | null): Renderer3 => { return document;} ❶
};
```

By default, the new renderer is compatible with the `document` object from the standard DOM. Actually, it is better not just to say "compatible with" but to say "is". When running in the browser UI thread, where the DOM is available, then this `document` object (provided by the web browser itself, not Angular) is the renderer – it is directly used to render content. An app literally cannot perform quicker than that. Regardless of which framework you use and how it structures its rendering pipeline, ultimately the `document` object will have to be called. So why not call it directly in scenarios where it is supported (that means inside the browser UI thread). For other rendering scenarios (web worker, server) then something that looks like the `document` object will need to be provided.

For readers coming from a C++, C#, Java or similar background, it is very important to understand that TypeScript (and JavaScript) uses structural subtyping (also affectionately called "duck typing") and not nominal typing as used by those other languages. In TypeScript, a type that implements the fields of another type can be used in its place – there is no neccessity for implementing common interfaces. So the fact that the `document` object from the standard DOM does not implement Angular's `Render3` but yet is been used in a function to return such a type (see ❶ above), is not a problem, so long as it implements all the fields that `Render3` needs (which it does, as we shall soon discover).

Note on naming – we like to use "Render3" (instead of "Render 3" with a space), as it helps with Google search, etc. The code-name for this is "Ivy", we will see that used in places in the code and with the new `enableIvy` command-line switch to Compiler-CLI.

System Model

A good way to think of the new Render3 view engine is that it is a special kind of virtual CPU dedicated to Angular view processing. Let’s call it a View Processing Unit (VPU). That’s a term we just made up, but it nicely explains how everything fits together. All the participants in an explanation of how a traditional CPU works (instruction set, micro-operations, compact execution format, human-readable assembly format, compiler, linker, etc.) are (kind of) present with our imaginary VPU also, and play the same roles. Just like with a real CPU, its usage has two parts – compile time and execution time. We assume use of the Ahead-Of-Time (AOT) compiler in Angular, which is becoming the norm.

Our story starts with application developers writing “source code” for our VPU in Angular Template Syntax as normal. Nothing has changed there.

Then they need to compile and link this to make an executable for the Render3 VPU. This involves using functionality from:

- <ANGULAR-MASTER>/packages/core/src/linker
- <ANGULAR-MASTER>/packages/compiler
- <ANGULAR-MASTER>/packages/compiler-cli

The only difference from using Angular compilation in the past is now application developers have to pass the `enableIvy` switch to Angular’s Ahead-Of-Time (AOT) compiler. This tells the Angular template compiler to generate code specifically for the Renderer 3 VPU (and not the older Render2 approach). What happens after that can be a black box to regular Angular application developers – they need not concern themselves which what transpires. Everything “just works”. When you compile C++, Java or C# code – as an application developer you don’t really need to know how the (LLVM) bitcode, bytecode or Intermediate Language is processed. Similarly regular Angular application developers don’t really need to know how the Render3 instruction set is processed. Of course, we are not regular developers - we are mighty curious and do want to know what happens “under the hood”. So let’s delve a bit deeper, starting with the Render3 instruction set.

If we are pretending we are using a VPU, then obviously we need an instruction set. We see Render3 has one, and it is exported from:

- <ANGULAR-MASTER>/packages/core/src/render3/index.ts

In the `export { } from ‘./instructions’` statement there, we see it has a compact format – one or two letters (as might be used in code to be efficiently executed) and it has a developer-friendly (full-name) format. We could even call the latter assembly language for our VPU! Here are a few sample instructions:

```
export {
  ..
  componentRefresh as r,
  elementAttribute as a,
  elementProperty as p,
  elementStart as E,
  elementEnd as e,
  text as T,
  embeddedViewStart as V,
  embeddedViewEnd as v,
} from './instructions';
```

Using the compact format will obviously produce much smaller apps but is quite cryptic, whereas using the full-name format is much clearer for developers to read. [At the moment in the Angular 6 codebase, the full name format is not exported, but it would be a good improvement to have – as an option – to run a "dis-assembler" on the compact format]. Indeed, it would also be nice to code directly in this full-name format (like specialist developers code directly in assembly language for a normal CPU – not needed all the time, but can be useful).

What happens after Angular application developers kick off the AOT compiler (or ask Angular CLI to do so) with the -enableIvy switch? Compiler-CLI first does some initial preparation and then requests the Compiler package to build an executable based on the compact format of the instructions from above. A huge amount of effort has gone into making the delivered app to be as compact and as efficient a possible (e.g. using Closure). Enterprise Angular applications are getting very large so it is highly important that the delivery units for Angular applications are as efficient as possible.

That's it from the compile-time perspective. At some later point the finished app need to run on a VPU. And so starts the execution time perspective.

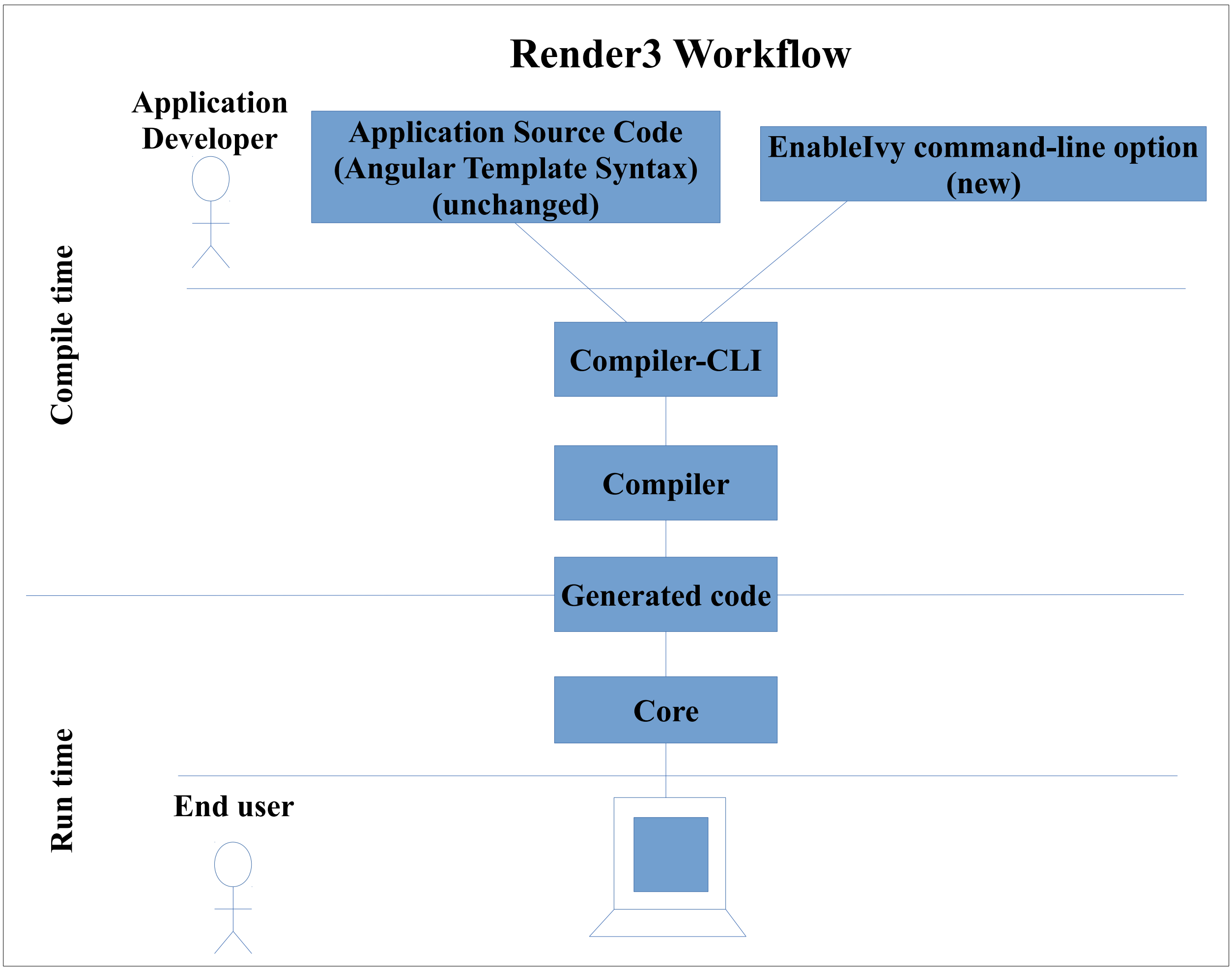
Our VPU needs actual implementation for its instructions. That is exactly what we find in the nearly 2,000 lines of code in:

- <ANGULAR-MASTER>/packages/core/src/render3/instructions.ts

For each instruction in the VPU instruction set, there is a function here that "executes" the instruction. As a simple example, the `T` instruction (or `text` in full-name format) defined earlier has an implementation like so:

```
  /**
   * Create static text node
   *
   * @param index Index of the node in the data array.
   * @param value Value to write. This value will be stringified.
   * If value is not provided than the actual creation of the text node
   * is delayed.
   */
  export function text(index: number, value?: any): void {
    ngDevMode &&
        assertEqual(currentView.bindingStartIndex, null, 'bindingStartIndex');
    const textNode = value != null ?
        ((renderer as ProceduralRenderer3).createText ?
             (renderer as ProceduralRenderer3).createText(stringify(value))
           : (renderer as ObjectOrientedRenderer3).createTextNode !
                                                 (stringify(value))) : null;
    const node = createLNode(index, LNodeFlags.Element, textNode);
    // Text nodes are self closing.
    isParent = false;
    appendChild(node.parent !, textNode, currentView);
  }
```

Every modern CPU has instructions implemented with micro-operations – this allows CPU vendors to adjust / optimize instruction execution, without having to alter the syntax of the instruction. In the context of our imaginary VPU, the role of micro-operations is played by renderers. We saw at the beginning of this appendix that for the normal browser UI thread, the standard `document` object is the renderer, so the above code is really, really fast on a browser UI thread. A different kind of renderer is needed when working on the server or in a web worker (this part of Render3 is not yet implemented, but examining our coverage of platform-server and platform-web-worker shows what is likely to be put in place). Importantly, the instructions in the instruction set need not change, just the micro-operations (the renderer). We see in the code snippet above implementing the `text` instruction, calls are made out to a renderer from time to time.



Now we will explore in more depth what is happening to deliver Render3 functionality. Three packages are involved – Core, Compiler and Compiler-CLI.

Render3 In The Compiler-CLI Package

At compile time, developers need to pass in the `enableIvy` switch to the AOT compiler, so that the new Render3 is used. When we read this:

- https://next.angular.io/guide/aot-compiler

(note the "next" in that URL), we see a description of this switch:

> *enableIvy*
>
> *Tells the compiler to generate definitions using the Render3 style code generation. This option defaults to false.*
>
> *Not all features are supported with this option enabled. It is only supported for experimentation and testing of Render3 style code generation.*
>
> ***Note: Is it not recommended to use this option as it is not yet feature complete with the Render2 code generation.***

This switch is used by the ivy "hello-world" test:

- <ANGULAR-MASTER>/packages/compiler-cli/test/ngc_spec.ts

To see how this is implemented, we first need to look at:

- <ANGULAR-MASTER>/packages/compiler-cli/src/transformers/api.ts

It defines an interface, `CompilerOptions`, that extends `ts.CompilerOptions` with Angular-specific fields. In particular, it adds this:

```
export interface CompilerOptions extends ts.CompilerOptions {
  /**
   * Tells the compiler to generate definitions using the Render3 style code
   * generation. This option defaults to `false`.
   *
   * Not all features are supported with this option enabled. It is only
   * supported for experimentation and testing of Render3 style code
   * generation.
   *
   */
  enableIvy?: boolean;
}
```

It also defines `EmitFlags`, which is of interest to us (note the `default` includes codegen):

```
export enum EmitFlags {
  DTS = 1 << 0,
  JS = 1 << 1,
  Metadata = 1 << 2,
  I18nBundle = 1 << 3,
  Codegen = 1 << 4,

  Default = DTS | JS | Codegen,
  All = DTS | JS | Metadata | I18nBundle | Codegen,
}
```

We see the `enableIvy` field being used in :

- <ANGULAR-MASTER>/packages/compiler-cli/src/transformers/program.ts

by the `emit` function:

```
emit(parameters: {
    emitFlags?: EmitFlags,
    cancellationToken?: ts.CancellationToken,
    customTransformers?: CustomTransformers,
    emitCallback?: TsEmitCallback
  } = {}): ts.EmitResult {
    return this.options.enableIvy === true ? this._emitRender3(parameters) :
                                             this._emitRender2(parameters);
  }
```

So if the `enableIvy` switch is present, we call `_emitRender3`. (by default, it is not, so `_emitRender2` is called, as with Angular 5).

This file also contains the `defaultEmitCallback`:

```
const defaultEmitCallback: TsEmitCallback =
    ({program, targetSourceFile, writeFile, cancellationToken,
       emitOnlyDtsFiles, customTransformers}) =>
    1   program.emit(targetSourceFile, writeFile, cancellationToken,
          emitOnlyDtsFiles, customTransformers);
```

We see at 1 where the compilation is actually initiated with the set of custom transformers which was passed in as a parameter.

One other important helper function is:

```
private calculateTransforms(
       genFiles: Map<string, GeneratedFile>|undefined,
       partialModules: PartialModule[]|undefined,
       customTransformers?: CustomTransformers): ts.CustomTransformers {

    const beforeTs: ts.TransformerFactory<ts.SourceFile>[] = [];
    if (!this.options.disableExpressionLowering) {
      beforeTs.push(getExpressionLoweringTransformFactory(
          this.loweringMetadataTransform, this.tsProgram));
    }
    if (genFiles) {
1     beforeTs.push(
       getAngularEmitterTransformFactory(genFiles, this.getTsProgram()));
    }
    if (partialModules) {
      beforeTs.push(getAngularClassTransformerFactory(partialModules));

      // If we have partial modules, the cached metadata might be incorrect
      //  as it doesn't reflect the partial module transforms.
      this.metadataCache = this.createMetadataCache(
                     [this.loweringMetadataTransform,
                     new PartialModuleMetadataTransformer(partialModules)]);
    }
    if (customTransformers && customTransformers.beforeTs) {
      beforeTs.push(...customTransformers.beforeTs);
    }
    const afterTs =
            customTransformers ? customTransformers.afterTs : undefined;
    return {before: beforeTs, after: afterTs};
  }
```

We see at 1 how those partial modules are processed. In particular, we see the use of the new `getAngularClassTransformerFactory` function and the new `PartialModuleMetadataTransformer` function. Let's follow both of those. `getAngularClassTransformerFactory` is defined in:

- <ANGULAR-MASTER>/packages/compiler-cli/src/transformers/r3_transform.ts

as follows:

```
/*
 * Returns a transformer that adds the requested static methods
 * specified by modules.
 */
export function getAngularClassTransformerFactory(modules: PartialModule[]):
TransformerFactory {
  if (modules.length === 0) {
    // If no modules are specified, just return an identity transform.
    return () => sf => sf;
  }
  const moduleMap =
     new Map(modules.map<[string, PartialModule]>(m => [m.fileName, m]));
  return function(context: ts.TransformationContext) {
    return function(sourceFile: ts.SourceFile): ts.SourceFile {
      const module = moduleMap.get(sourceFile.fileName);
      if (module) {
        const [newSourceFile] =
            updateSourceFile(sourceFile, module, context);
        return newSourceFile;
      }
      return sourceFile;
    };
  };
}
```

Two important types are also defined in r3_transform.ts to describe what a `Transformer` and a `TransformerFactory` are:

```
export type Transformer = (sourceFile: ts.SourceFile) => ts.SourceFile;
export type TransformerFactory =
              (context: ts.TransformationContext) => Transformer;
```

The `PartialModuleMetadataTransformer` function is defined in:

- <ANGULAR-MASTER>/packages/compiler-cli/src/transformers/r3_metadata_transform.ts

as:

```
export class PartialModuleMetadataTransformer implements MetadataTransformer
{
  private moduleMap: Map<string, PartialModule>;

  constructor(modules: PartialModule[]) {
    this.moduleMap =
     new Map(modules.map<[string, PartialModule]>(m => [m.fileName, m]));
  }

  start(sourceFile: ts.SourceFile): ValueTransform|undefined {
    const partialModule = this.moduleMap.get(sourceFile.fileName);
    if (partialModule) {
      const classMap = new Map<string, ClassStmt>(
          partialModule.statements.filter(isClassStmt)
            .map<[string, ClassStmt]>(s => [s.name, s]));
      if (classMap.size > 0) {
        return (value: MetadataValue, node: ts.Node): MetadataValue => {
            // For class metadata that is going to be transformed to
            // have a static method ensure the metadata contains a
            // static declaration the new static method.
          if (isClassMetadata(value) && node.kind ===
    ts.SyntaxKind.ClassDeclaration) {
      const classDeclaration = node as ts.ClassDeclaration;
      if (classDeclaration.name) {
       const partialClass = classMap.get(classDeclaration.name.text);
       if (partialClass) {
        for (const field of partialClass.fields) {
         if (field.name && field.modifiers &&
           field.modifiers.some(
            modifier => modifier === StmtModifier.Static)) {
        value.statics = {...(value.statics || {}), [field.name]: {}};
         }
        }
       }
      }
     }
     return value;
    };
   }
  }
 }
}

function isClassStmt(v: Statement): v is ClassStmt {
 return v instanceof ClassStmt;
}
```

Now we are ready go back to program.ts to look at:

```
private _emitRender3(
1  {emitFlags = EmitFlags.Default, cancellationToken, customTransformers,
2   emitCallback = defaultEmitCallback}: {
    emitFlags?: EmitFlags,
    cancellationToken?: ts.CancellationToken,
    customTransformers?: CustomTransformers,
    emitCallback?: TsEmitCallback
3  } = {}): ts.EmitResult {
  const emitStart = Date.now();


  // .. Check emitFlags
  // .. Set up code to emit partical modules
  // .. Set up code for file writing (not shown)
  // .. Build list of custom transformers
  // .. Make emitResult
  return emitResult;
 }
```

This takes a range of input parameters (note `emitFlags` 1 and `emitCallback` 2) and then returns an instance of `ts.EmitResult` 3. The `emitFlags` says what needs to be emitted – if nothing, then we return immediately:

```
if ((emitFlags & (EmitFlags.JS | EmitFlags.DTS
   | EmitFlags.Metadata | EmitFlags.Codegen)) === 0) {
 return {emitSkipped: true, diagnostics: [], emittedFiles: []};
}
```

The partial modules are processed with this important call to `emitAllPartialModules` in Angular's Compiler package (we will examine this in detail shortly):

```
    const modules = this.compiler.emitAllPartialModules(this.analyzedModules);
```

The `_analyzedModules` field is defined as:

```
  private _analyzedModules: NgAnalyzedModules|undefined;
```

and initialized earlier in a call to:

```
  private get analyzedModules(): NgAnalyzedModules {
      if (!this._analyzedModules) {
        this.initSync();
      }
      return this._analyzedModules !;  1
  }
```

Note the `!` at the end of the return **1**: this is the TypeScript non-null assertion operator, a new language feature explained as:

> *"A new ! post-fix expression operator may be used to assert that its operand is non-null and non-undefined in contexts where the type checker is unable to conclude that fact. Specifically, the operation x! produces a value of the type of x with null and undefined excluded." (TypeScript release notes)*

Returning to our coverage of `_emitRender3` – after the call to `this.compiler.emitAllPartialModules` to emit the modules, the custom transformers are configured (note the partial modules parameter):

```
      const tsCustomTansformers = this.calculateTransforms(
        /* genFiles */       undefined,
        /* partialModules */ modules,
                             customTransformers);
```

The `emitResult` is set up like so (note the `customTransformers` in there) and then returned:

```
      const emitResult = emitCallback({
        program: this.tsProgram,
        host: this.host,
        options: this.options,
        writeFile: writeTsFile, emitOnlyDtsFiles,
        customTransformers: tsCustomTansformers
      });

      return emitResult;
```

We should briefly mention differences between `_emitRender3` and `_emitRender2`, also in program.ts. The latter is a much larger function compared to `_emitRender3`:

```
  private _emitRender2(
        {emitFlags = EmitFlags.Default, cancellationToken, customTransformers,
         emitCallback = defaultEmitCallback}: {
          emitFlags?: EmitFlags,
          cancellationToken?: ts.CancellationToken,
          customTransformers?: CustomTransformers,
          emitCallback?: TsEmitCallback
        } = {}): ts.EmitResult {
      ..
      let {genFiles, genDiags} = this.generateFilesForEmit(emitFlags);
      ..
  }
```

It also used a different helper function, `generateFilesForEmit`, to make a different call into Angular's Compiler package. So importantly we have two separate call paths into the Angular Compiler package:

```
   private generateFilesForEmit(emitFlags: EmitFlags):
        {genFiles: GeneratedFile[], genDiags: ts.Diagnostic[]} {
     ..
     let genFiles = this.compiler.emitAllImpls(this.analyzedModules).filter(
                         genFile => isInRootDir(genFile.genFileUrl, this.options));

      return {genFiles, genDiags: []};
  }
```

Render3 in The Compiler Package

Inside the Angular Compiler package:

- <ANGULAR_MASTER>/packages/compiler

the Render3 feature resides mainly in four files. They are:

- <ANGULAR-MASTER>/packages/compiler/src/aot/partial_module.ts
- <ANGULAR-MASTER>/packages/compiler/src/aot/compiler.ts
- <ANGULAR-MASTER>/packages/compiler/src/render3/r3_identifiers.ts
- <ANGULAR-MASTER>/packages/compiler/src/render3/r3_view_compiler.ts

Let's start with partial_module.ts. It has these few lines, to describe what a partial module type is:

```
import * as o from '../output/output_ast';

export interface PartialModule {
  fileName: string;
  statements: o.Statement[];
}
```

We have seen from our coverage of Compiler-CLI that it makes a call to `emitAllPartialModules` inside the Compiler package. This is to be found in the src/aot/compiler.ts file and so is exported by this line from src/compiler.ts (yes: same files names, different directories):

```
export * from './aot/compiler';
```

it is defined as:

```
 emitAllPartialModules({ngModuleByPipeOrDirective, files}:
NgAnalyzedModules): PartialModule[] {
    // Using reduce like this is a select
    // many pattern (where map is a select pattern)
    return files.reduce<PartialModule[]>((r, file) => {
      r.push(...this._emitPartialModule(
          file.fileName, ngModuleByPipeOrDirective, file.directives,
            file.pipes, file.ngModules, file.injectables));
      return r;
    }, []);
  }
```

It calls the internal `_emitPartialModule` method:

```
  private _emitPartialModule(
      fileName: string,
      ngModuleByPipeOrDirective: Map<StaticSymbol, CompileNgModuleMetadata>,
      directives: StaticSymbol[],
      pipes: StaticSymbol[],
      ngModules: CompileNgModuleMetadata[],
      injectables: StaticSymbol[]): PartialModule[] {

    const classes: o.ClassStmt[] = [];
    const context = this._createOutputContext(fileName);
```

After initializing context information, it loops 1 over the directives array and if a component is found 2, calls `compileIvyComponent` 2, otherwise calls `compileIvyDirective` 3:

```
// Process all components and directives
1   directives.forEach(directiveType => {
      const directiveMetadata =
         this._metadataResolver.getDirectiveMetadata(directiveType);
      if (directiveMetadata.isComponent) {
        ..
        const {template: parsedTemplate} =
            this._parseTemplate(
         directiveMetadata, module, module.transitiveModule.directives);
2       compileIvyComponent(
         context, directiveMetadata, parsedTemplate, this._reflector);
      } else {
3       compileIvyDirective(context, directiveMetadata, this._reflector);
      }
    });

    if (context.statements) {
      return [{fileName, statements:
       [...context.constantPool.statements, ...context.statements]}];
    }
    return [];
  }
```

We note the import at the top of the file:

```
import {
     compileComponent as compileIvyComponent,
     compileDirective as compileIvyDirective}
       from '../render3/r3_view_compiler';
```

So in src/render3/r3_view_compiler.ts let's track `compileComponent` and `compileDirective`.

The render3 sub-directory in the Compiler package's src directory is new for Render3. It contains just two files, r3_view_compiler and r3_identifiers.ts. r3_identifiers.ts is imported into r3_view_compiler.ts with this line:

```
import {Identifiers as R3} from './r3_identifiers';
```

So anywhere in r3_view_compiler.ts we see "R3" being used for naming (over 50 times), it means something in r3_identifiers.ts is being used. r3_identifiers.ts is not referenced from anywhere else in the Compiler package.

r3_identifier.ts contains a long list of external reference identifiers for the various instructions. Here is a sampling (note that "o" is imported from output_ast.ts):

```
import * as o from '../output/output_ast';
const CORE = '@angular/core';
export class Identifiers {
  /* Methods */
  static NEW_METHOD = 'n';
  static HOST_BINDING_METHOD = 'h';

  /* Instructions */
  static createElement: o.ExternalReference = {name: 'ɵE', moduleName: CORE};
  static elementEnd: o.ExternalReference = {name: 'ɵe', moduleName: CORE};
  static text: o.ExternalReference = {name: 'ɵT', moduleName: CORE};
  static bind: o.ExternalReference = {name: 'ɵb', moduleName: CORE};
  static bind1: o.ExternalReference = {name: 'ɵb1', moduleName: CORE};
  static bind2: o.ExternalReference = {name: 'ɵb2', moduleName: CORE};
  static projection: o.ExternalReference = {name: 'ɵP', moduleName: CORE};
  static projectionDef: o.ExternalReference =
                              {name: 'ɵpD', moduleName: CORE};
  static injectElementRef: o.ExternalReference =
                              {name: 'ɵinjectElementRef', moduleName: CORE};
  static injectTemplateRef: o.ExternalReference =
                              {name: 'ɵinjectTemplateRef', moduleName: CORE};
  static defineComponent: o.ExternalReference =
                              {name: 'ɵdefineComponent', moduleName: CORE};
  ..
};
```

The `compileDirective` function is implemented in src/render3/r3_view_compiler.ts as:

```
export function compileDirective(
     outputCtx: OutputContext,
     directive: CompileDirectiveMetadata,
     reflector: CompileReflector) {

  const definitionMapValues:
     {key: string, quoted: boolean, value: o.Expression}[] = [];

  // e.g. 'type: MyDirective`
  definitionMapValues.push(
      {key: 'type',
       value: outputCtx.importExpr(directive.type.reference),
       quoted: false});

  // e.g. `factory: () => new MyApp(injectElementRef())`
1 const templateFactory =
     createFactory(directive.type, outputCtx, reflector);
2 definitionMapValues.push(
     {key: 'factory', value: templateFactory, quoted: false});

  // e.g 'inputs: {a: 'a'}`
  if (Object.getOwnPropertyNames(directive.inputs).length > 0) {
    definitionMapValues.push(
        {key: 'inputs',
         quoted: false,
         value: mapToExpression(directive.inputs)});
  }

  const className = identifierName(directive.type) !;
  className || error(`Cannot resolver the name of ${directive.type}`);
  // Create the partial class to be merged with the actual class.
3 outputCtx.statements.push( 4 new o.ClassStmt(
      /* name */ className,
      /* parent */ null,
      /* fields */[new o.ClassField(
          /* name */ 'ngDirectiveDef',
          /* type */ o.INFERRED_TYPE,
          /* modifiers */[o.StmtModifier.Static],
          /* initializer */ 5 o.importExpr(R3.defineDirective).callFn(
                                    [o.literalMap(definitionMapValues)]))],
      /* getters */[],
      /* constructorMethod */ new o.ClassMethod(null, [], []),
      /* methods */[]));
}
```

It first 1 creates a template factory and then pushes it on the definition map values array 2. Then it uses the output context 3 to push a new `Class` statement 4 onto the array of statements. We note the `initializer` is set to `R3.defineDirective` 5.

The `compileComponent` function (also in r3_view_compiler.ts) is a little bit more complex. Let's look at it in stages. Its signature is:

```
export function compileComponent(
    outputCtx: OutputContext,
    component: CompileDirectiveMetadata,
    template: TemplateAst[],
    reflector: CompileReflector) {

  const definitionMapValues:
     {key: string, quoted: boolean, value: o.Expression}[] = [];
  // e.g. `type: MyApp`
  definitionMapValues.push(
      {key: 'type',
       value: outputCtx.importExpr(component.type.reference),
       quoted: false});
  … // some code regarding selectors (omitted)
```

Then it sets up a template function expression on the definition map values:

```
// e.g. `factory: function MyApp_Factory()
// { return new MyApp(injectElementRef()); }`
  const templateFactory = 1 createFactory(
                              component.type, outputCtx, reflector);
  definitionMapValues.push({
     key: 'factory',
     value: templateFactory,
     quoted: false});
```

We note the call to the `createFactory` function 1, which we need to follow up in a bit. Then it sets up a template definition builder and again adds it to the definition map values array:

```
  // e.g. `template: function MyComponent_Template(_ctx, _cm) {...}`
  const templateTypeName = component.type.reference.name;
  const templateName =
       templateTypeName ? `${templateTypeName}_Template` : null;

  const templateFunctionExpression =
  1   new TemplateDefinitionBuilder(
          outputCtx, outputCtx.constantPool, reflector, CONTEXT_NAME,
            ROOT_SCOPE.nestedScope(), 0,component.template !.ngContentSelectors,
           templateTypeName, templateName)
      2      .buildTemplateFunction(template, []);
      definitionMapValues.push({
         key: 'template',
         value: templateFunctionExpression,
         quoted: false});
```

We note the use of the `TemplateDefinitionBuilder` class 1, and the call to its `buildTemplateFunction` method 2, both of which we will examine shortly. Then it sets up the class name (and uses the ! non-null assertion operator to ensure it is not null):

```
        const className = identifierName(component.type) !;
```

Finally it adds the new class statement:

```
     // Create the partial class to be merged with the actual class.
      outputCtx.statements.push(new o.ClassStmt(
          /* name */ className,
          /* parent */ null,
          /* fields */[new o.ClassField(
              /* name */ 'ngComponentDef',
              /* type */ o.INFERRED_TYPE,
              /* modifiers */[o.StmtModifier.Static],
              /* initializer */ 1  o.importExpr(R3.defineComponent).callFn(
                                 [o.literalMap(definitionMapValues)]))],
          /* getters */[],
          /* constructorMethod */ new o.ClassMethod(null, [], []),
          /* methods */[]));
```

We note the `initializer` is set to `R3.defineComponent` 1.

The `createFactory` function is defined as:

```
    function createFactory(
        type: CompileTypeMetadata, outputCtx: OutputContext,
        reflector: CompileReflector): o.FunctionExpr {
      let args: o.Expression[] = [];
```

It first resolves three reflectors:

```
      const elementRef =
          reflector.resolveExternalReference(Identifiers.ElementRef);
      const templateRef =
          reflector.resolveExternalReference(Identifiers.TemplateRef);
      const viewContainerRef =
          reflector.resolveExternalReference(Identifiers.ViewContainerRef);
```

Then it loops through the `type.diDeps` dependencies, and pushes a relevant import expression, based on the token ref:

```
     for (let dependency of type.diDeps) {
        if (dependency.isValue) {
          unsupported('value dependencies');
        }
        if (dependency.isHost) {
          unsupported('host dependencies');
        }
        const token = dependency.token;
        if (token) {
```

```
      const tokenRef = tokenReference(token);
      if (tokenRef === elementRef) {
        args.push(o.importExpr(R3.injectElementRef).callFn([]));
      } else if (tokenRef === templateRef) {
        args.push(o.importExpr(R3.injectTemplateRef).callFn([]));
      } else if (tokenRef === viewContainerRef) {
        args.push(o.importExpr(R3.injectViewContainerRef).callFn([]));
      } else {
        const value =
            token.identifier != null ?
              outputCtx.importExpr(tokenRef) : o.literal(tokenRef);
        args.push(o.importExpr(R3.inject).callFn([value]));
      }
    } else {
      unsupported('dependency without a token');
    }
  }

  return o.fn(
      [],
      [new o.ReturnStatement(
       new o.InstantiateExpr(outputCtx.importExpr(type.reference), args))],
      o.INFERRED_TYPE, null, type.reference.name ?
         `${type.reference.name}_Factory` : null);
}
```

The `TemplateDefinitionBuilder` class (also located in r3_view_compiler.ts) is large (350 lines+) and can be considered the heart of Render3 compilation. It implements the `TemplateAstVisitor` interface. This interface is defined in:

- <ANGULAR-MASTER>/packages/compiler/src/template_parser/template_ast.ts

as follows:

```
// A visitor for {@link TemplateAst} trees that will process each node.
export interface TemplateAstVisitor {
  visit?(ast: TemplateAst, context: any): any;
  visitNgContent(ast: NgContentAst, context: any): any;
  visitEmbeddedTemplate(ast: EmbeddedTemplateAst, context: any): any;
  visitElement(ast: ElementAst, context: any): any;
  visitReference(ast: ReferenceAst, context: any): any;
  visitVariable(ast: VariableAst, context: any): any;
  visitEvent(ast: BoundEventAst, context: any): any;
  visitElementProperty(ast: BoundElementPropertyAst, context: any): any;
  visitAttr(ast: AttrAst, context: any): any;
  visitBoundText(ast: BoundTextAst, context: any): any;
  visitText(ast: TextAst, context: any): any;
  visitDirective(ast: DirectiveAst, context: any): any;
  visitDirectiveProperty(ast: BoundDirectivePropertyAst, context: any): any;
}
```

Back in r3_view_compiler.ts, the definition of `TemplateDefinitionBuilder` begins with:

```
class TemplateDefinitionBuilder
  implements TemplateAstVisitor, LocalResolver {

  constructor(
      private outputCtx: OutputContext,
      private constantPool: ConstantPool,
      private reflector: CompileReflector,
      private contextParameter: string,
      private bindingScope: BindingScope,
      private level = 0,
      private ngContentSelectors: string[],
      private contextName: string|null,
      private templateName: string|null) {}
```

We saw the call to `buildTemplateFunction` early in `compileComponent` – its has this signature:

```
    buildTemplateFunction(
          asts: TemplateAst[], variables: VariableAst[]): o.FunctionExpr {
```

It returns an instance of `o.FunctionExpr`. We note the import at the top of the file:

```
  import * as o from '../output/output_ast';
```

So `o.FunctionExpr` means the `FunctionExpr` class in:

- <ANGULAR-MASTER>/packages/compiler/src/output/output_ast.ts

This class is defined as follows:

```
  export class FunctionExpr extends Expression {
    constructor(
        public params: FnParam[],
        public statements: Statement[],
        type?: Type|null,
        sourceSpan?: ParseSourceSpan|null,
        public name?: string|null) {

      super(type, sourceSpan);
    }
    ...
  }
```

While we are looking at output_ast.ts, we see this `fn` function:

```
  export function fn(
      params: FnParam[],
      body: Statement[], type?: Type | null,
      sourceSpan?: ParseSourceSpan | null,
      name?: string | null): FunctionExpr {

    return new FunctionExpr(params, body, type, sourceSpan, name);
  }
```

It just makes a `FunctionExpr` from the supplied parameters.

An interesting function in src/template_parser/template_ast.ts is `templateVisitAll`:

```
  /**
   * Visit every node in a list of {@link TemplateAst}s with the given
   * {@link TemplateAstVisitor}.
   */
  export function templateVisitAll(
       visitor: TemplateAstVisitor,
       asts: TemplateAst[],
       context: any = null): any[] {
```

```
    const result: any[] = [];
    const visit = visitor.visit ?
          (ast: TemplateAst) => visitor.visit !(ast, context) ||
  ast.visit(visitor, context) :
          (ast: TemplateAst) => ast.visit(visitor, context);
    asts.forEach(ast => {
      const astResult = visit(ast);
      if (astResult) {
        result.push(astResult);
      }
    });
    return result;
  }
```

Now let’s return to the critically important `buildTemplateFunction` method of `TemplateDefinitionBuilder` in r3_view_compiler.ts – a summary of its definition is:

```
     buildTemplateFunction(
         asts: TemplateAst[],
         variables: VariableAst[]): o.FunctionExpr {

        // Create variable bindings
        ...
        // Collect content projections
        ...
1       templateVisitAll(this, asts);
        ..
2       return o.fn(
            [
              new o.FnParam(this.contextParameter, null),
3                 new o.FnParam(CREATION_MODE_FLAG, o.BOOL_TYPE)
            ],
            [
4             // Temporary variable declarations (i.e. let _t: any;)
              ...this._prefix,

              // Creating mode (i.e. if (cm) { ... })
              ...creationMode,

              // Binding mode (i.e. ep(...))
              ...this._bindingMode,

              // Host mode (i.e. Comp.h(...))
              ...this._hostMode,

              // Refresh mode (i.e. Comp.r(...))
              ...this._refreshMode,

              // Nested templates (i.e. function CompTemplate() {})
              ...this._postfix
            ],
 5          o.INFERRED_TYPE, null, this.templateName);
      }
```

We see it first visits the template tree 1. Then it returns the result of a call 2 to the `fn` function we just looked at, passing in three entries – 3 an array of `FnParams`, 4 an array of statements and 5 `o.INFERRED_TYPE`. What is happening here is that each node in the template tree is being visited, and where appropriate, statements are being emitted to the output statement array with the correct Render3 instruction. The instruction function is used to add a statement like so:

```
private instruction(
     statements: o.Statement[],
     span: ParseSourceSpan|null,
     reference: o.ExternalReference,
     ...params: o.Expression[]) {
    statements.push(
     o.importExpr(reference, null, span).callFn(params, span).toStmt());
  }
```

For example, when a text node is visited, the Render3 text instruction (`R3.text`) should be emitted. We see this happening with the `visitText` method:

```
private _creationMode: o.Statement[] = [];

visitText(ast: TextAst) {
   // Text is defined in creation mode only.
   this.instruction(
       this._creationMode, ast.sourceSpan, R3.text,
         o.literal(this.allocateDataSlot()), o.literal(ast.value));
 }
```

There is an equivalent method for elements, `visitElement`, which is somewhat more complex. After some setup code, it has this:

```
// Generate the instruction create element instruction
   this.instruction(this._creationMode, ast.sourceSpan,
     R3.createElement, ...parameters);
```

There is also a `visitEmbeddedTemplate` method, which emits a number of Render3 instructions:

```
visitEmbeddedTemplate(ast: EmbeddedTemplateAst) {
  ...
   // e.g. C(1, C1Template)
   this.instruction(
       this._creationMode, ast.sourceSpan,
       R3.containerCreate, o.literal(templateIndex),
       directivesArray, o.variable(templateName));

   // e.g. Cr(1)
   this.instruction(
       this._refreshMode, ast.sourceSpan,
       R3.containerRefreshStart, o.literal(templateIndex));

   // Generate directives
   this._visitDirectives(
       ast.directives, o.variable(this.contextParameter),
       templateIndex, directiveIndexMap);

   // e.g. cr();
   this.instruction(
       this._refreshMode, ast.sourceSpan, R3.containerRefreshEnd);

   // Create the template function
   const templateVisitor = new TemplateDefinitionBuilder(
       this.outputCtx, this.constantPool, this.reflector, templateContext,
       this.bindingScope.nestedScope(), this.level + 1,
       this.ngContentSelectors, contextName, templateName);
```

```
      const templateFunctionExpr = templateVisitor.buildTemplateFunction(
                                                ast.children, ast.variables);
      this._postfix.push(templateFunctionExpr.toDeclStmt(templateName, null));
    }
```

Render3 in the Core Package

API Model

There is no public API to Render3. The Core package contains the Render3 (and Render2) code. Its index.ts file just exports the contents of public_api.ts, which in turn exports the contents of ./src/core.ts.

Regarding the public API, this has one render-related line, an export of:

```
  export * from './render';
```

The ./src/render.ts file exports no Render3 API. It does export the Render2 API, like so:

```
  export {RenderComponentType, Renderer, Renderer2, RendererFactory2,
      RendererStyleFlags2, RendererType2, RootRenderer} from './render/api';
```

Note that Render2 is just the ./src/render/api.ts file with less than 200 lines of code (the core/src/render sub-directory only contains that one file)- it defines the above types but does not contain an implementation. You can read it in full here:

- <ANGULAR-MASTER>/packages/core/src/render/api.ts

Render3 does have a private API. The ./src/core.ts file contain this line:

```
  export * from './core_render3_private_export';
```

The ./src/core_render3_private_export .ts file has this:

```
  export {
    defineComponent as ɵdefineComponent,
    detectChanges as ɵdetectChanges,
    renderComponent as ɵrenderComponent,
    ComponentType as ɵComponentType,
    C as ɵC, E as ɵE, L as ɵL, T as ɵT, V as ɵV, b as ɵb, b1 as ɵb1, b2 as ɵb2,
    b3 as ɵb3, b4 as ɵb4, b5 as ɵb5, b6 as ɵb6, b7 as ɵb7, b8 as ɵb8,bV as ɵbV,
    cR as ɵcR, cr as ɵcr, e as ɵe, p as ɵp, s as ɵs, t as ɵt, v as ɵv, r as ɵr,
  } from './render3/index';
```

Private APIs are intended for use by other Angular packages and not by regular Angular applications. Hence the Greek theta character ('ɵ') is added as a prefix to private APIs, as in common with other such private APIs within Angular.

The reason for the many very short type names is that the Angular Compiler will be generating lots of source code based on Render3 for your application's Angular template files and it is desirable to have this as compact as possible, without the need to run a minifier. Typically no human reads this generated code, so compactness is desired rather than readability.

If we examine:

- <ANGULAR-MASTER>/packages/core/src/Render3/index.ts

we see it starts by explaining the naming scheme:

```
// Naming scheme:
// - Capital letters are for creating things:
// T(Text), E(Element), D(Directive), V(View),
// C(Container), L(Listener)
// - lower case letters are for binding: b(bind)
// - lower case letters are for binding target:
//     p(property), a(attribute), k(class), s(style), i(input)
// - lower case letters for guarding life cycle hooks: l(lifeCycle)
// - lower case for closing: c(containerEnd), e(elementEnd), v(viewEnd)
```

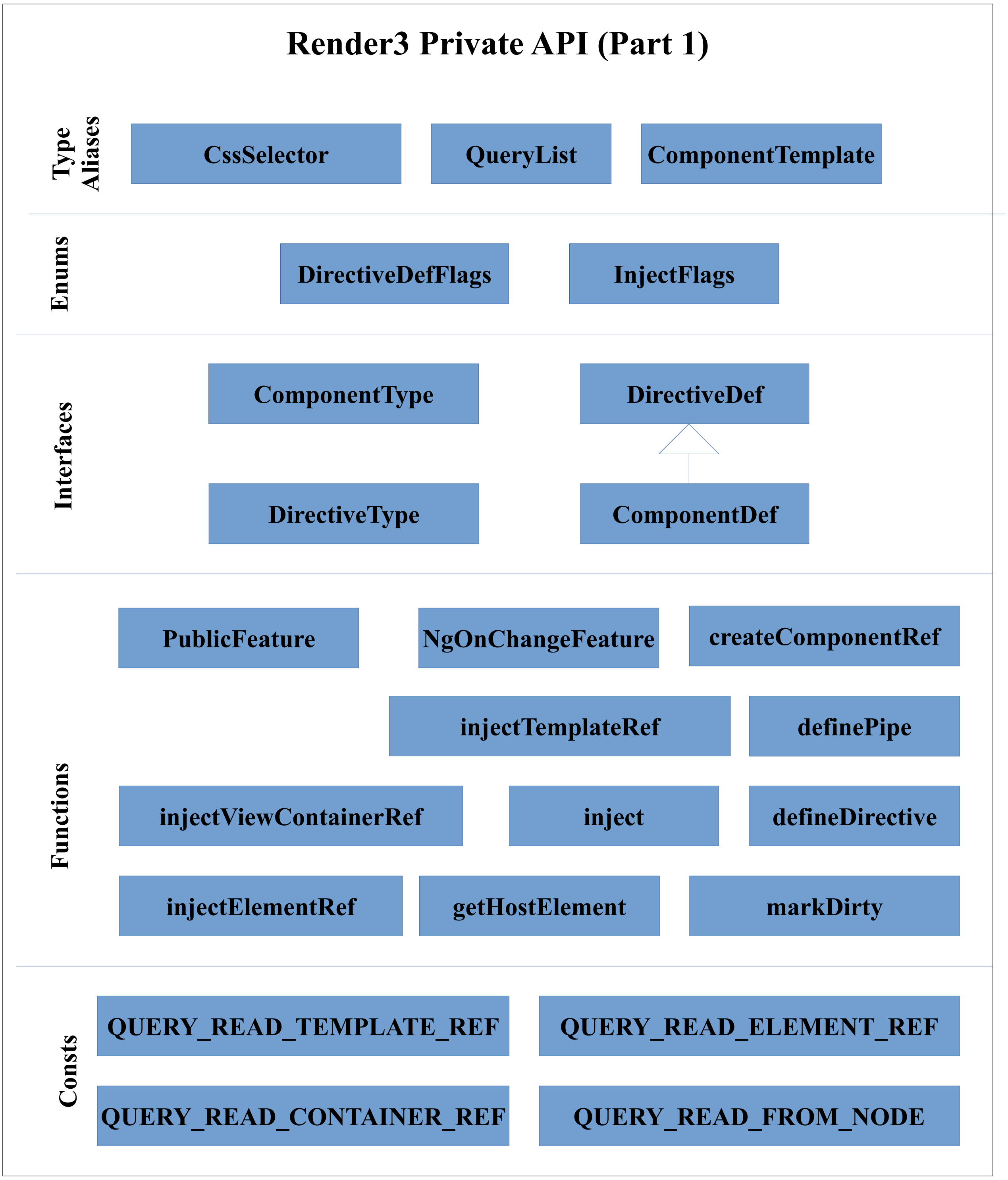
Then it has a long list of exports of instructions, many with abbreviations:

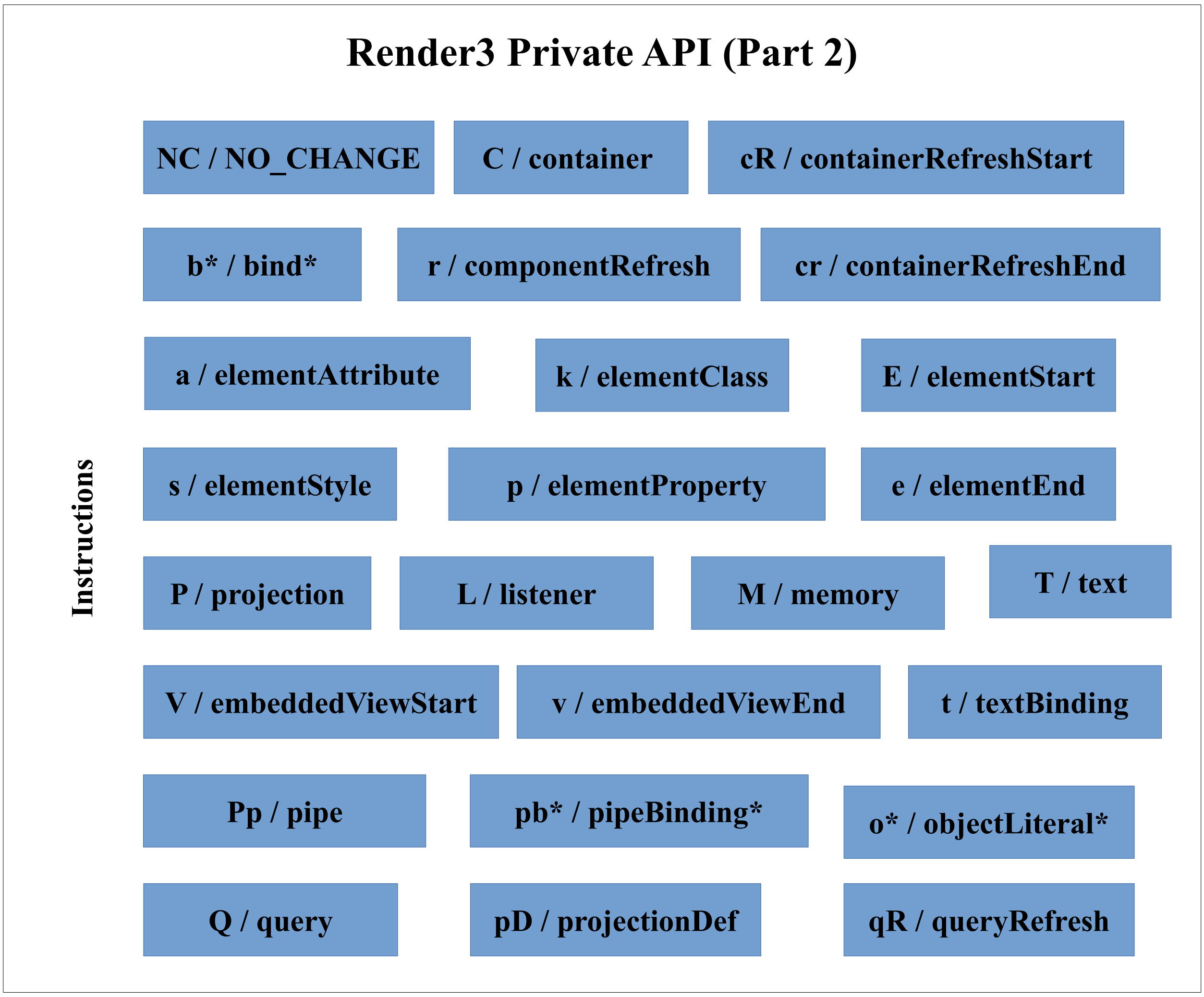
```
Export {
  QUERY_READ_CONTAINER_REF,
  QUERY_READ_ELEMENT_REF,
  QUERY_READ_FROM_NODE,
  QUERY_READ_TEMPLATE_REF,
  InjectFlags, inject,
  injectElementRef,
  injectTemplateRef,
  injectViewContainerRef
} from './di';
export {
  NO_CHANGE as NC,
  bind as b,
  bind1 as b1,
  bind2 as b2,
  bind3 as b3,
  bind4 as b4,
  bind5 as b5,
  bind6 as b6,
  bind7 as b7,
  bind8 as b8,
  bindV as bV,
  componentRefresh as r,
  container as C,
  containerRefreshStart as cR,
  containerRefreshEnd as cr,
  elementAttribute as a,
  elementClass as k,
  elementEnd as e,
  elementProperty as p,
  elementStart as E,
  elementStyle as s,
  listener as L,
  memory as m,
  projection as P,
  projectionDef as pD,
  text as T,
  textBinding as t,
  embeddedViewStart as V,
  embeddedViewEnd as v,
} from './instructions';
export {
  pipe as Pp,
  pipeBind1 as pb1,
  pipeBind2 as pb2,
  pipeBind3 as pb3,
  pipeBind4 as pb4,
  pipeBindV as pbV,
} from './pipe';
export {
  QueryList,
  query as Q,
  queryRefresh as qR,
} from './query';
export {
  objectLiteral1 as o1,
  objectLiteral2 as o2,
  objectLiteral3 as o3,
  objectLiteral4 as o4,
  objectLiteral5 as o5,
  objectLiteral6 as o6,
  objectLiteral7 as o7,
  objectLiteral8 as o8,
} from './object_literal';

export {
  ComponentDef,
  ComponentTemplate,
  ComponentType,
  DirectiveDef,
  DirectiveDefFlags,
  DirectiveType,
  NgOnChangesFeature,
  PublicFeature,
  defineComponent,
  defineDirective,
  definePipe,
};

export {createComponentRef,
 detectChanges, getHostElement,
 markDirty, renderComponent};

export {CssSelector} from
      './interfaces/projection';
```

Each of the one- or two-letter exports corresponds to an instruction in .src/Render3/instructions.ts. In the following diagram we give the short export name and the full name, which more clearly explains the intent of the instruction. We have seen how Core's Render3 is being used by the compiler and compiler-cli packages:

- <ANGULAR-MASTER>/packages/compiler/src/render3
- <ANGULAR-MASTER>/packages/compiler-cli/src/transformers/r3_transform.ts

It is not used by the Router or the platform- packages (which do use Render2).





Render3 Private API (Part 2)

Instructions

NC / NO_CHANGE
C / container
cR / containerRefreshStart
b* / bind*
r / componentRefresh
cr / containerRefreshEnd
a / elementAttribute
k / elementClass
E / elementStart
s / elementStyle
p / elementProperty
e / elementEnd
P / projection
L / listener
M / memory
T / text
V / embeddedViewStart
v / embeddedViewEnd
t / textBinding
Pp / pipe
pb* / pipeBinding*
o* / objectLiteral*
Q / query
pD / projectionDef
qR / queryRefresh

Source Model

The source tree for the Render3 feature directly contains these source files:

- assert.ts
- component.ts
- definition.ts
- di.ts
- hooks.ts
- index.ts
- instructions.ts
- ng_dev_mode.ts
- node_assert.ts
- node_manipulation.ts
- node_selector_matcher.ts
- object_literal.ts
- pipe.ts
- query.ts
- util.ts

and these documents:

- perf_notes.md

- TREE_SHAKING.md

It also has one sub-directory, interfaces, which contains these files:

- container.ts
- definition.ts
- injector.ts
- node.ts
- projection.ts
- query.ts
- renderer.ts
- view.ts

It could be said Render3 is a re-imagining of what rendering means for an Angular application. The principal change is that the DOM comes back as the main API that is used to render, and the idea of custom renderers goes away. In scenarios where the DOM does not exist (such as a web worker or on the server), then a polyfill DOM will be needed.

In some pieces of Render3 code, we see use of the 'L' and 'R' prefixes. This is explained in a comment in the source:

```
The "L" stands for "Logical" to differentiate between `RNodes` (actual
rendered DOM node) and our logical representation of DOM nodes, `LNodes`.
<ANGULAR-MASTER>/packages/core/src/render3/interfaces/node.ts
```

Interfaces

When trying to figure out how Render3 works, a good place to start is with its interfaces. Let's look at this first:

- <ANGULAR-MASTER>/packages/core/src/render3/interfaces/renderer.ts

There are some simple helper interfaces describing a node, an element and a text node. The node is defined as have three methods to insert, append and remove a child:

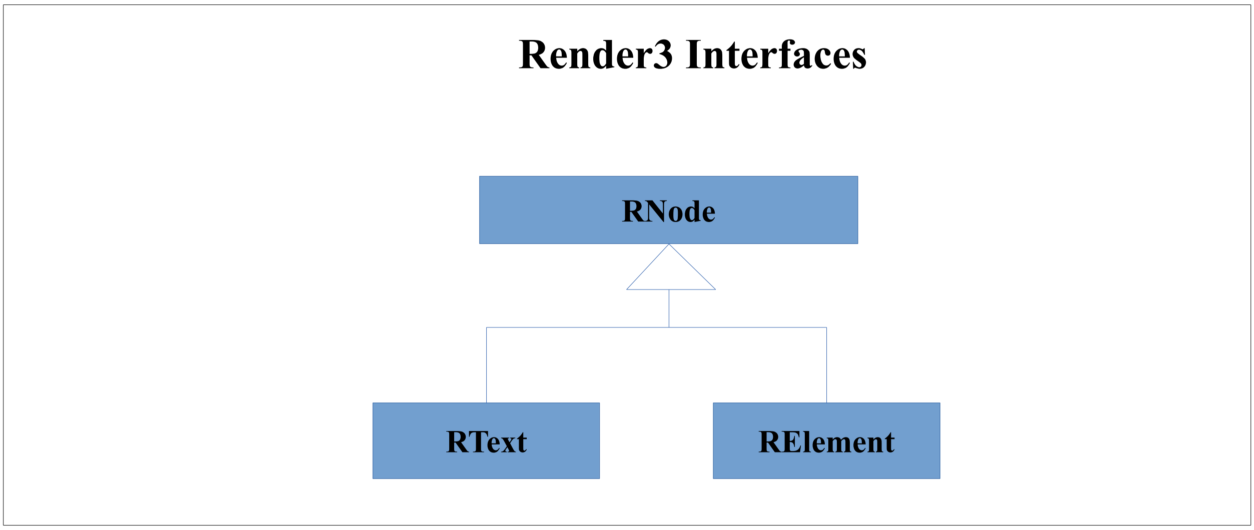
```
/** Subset of API needed for appending elements and text nodes. */
export interface RNode {
  removeChild(oldChild: RNode): void;

  // Insert a child node.
  // Used exclusively for adding View root nodes into ViewAnchor location.
  insertBefore(
     newChild: RNode, refChild: RNode|null, isViewRoot: boolean): void;

  //Append a child node.
  //Used exclusively for building up DOM which are static (ie not View roots)
  appendChild(newChild: RNode): RNode;
}
```

The element allows adding and removing of listeners, working with attributes and properties and style configuration – it is defined as:

```
/**
 * Subset of API needed for writing attributes, properties, and setting up
 * listeners on Element.
 */
export interface RElement extends RNode {
    style: RCssStyleDeclaration;
    classList: RDomTokenList;
    setAttribute(name: string, value: string): void;
    removeAttribute(name: string): void;
    setAttributeNS(
       namespaceURI: string, qualifiedName: string, value: string): void;
    addEventListener(
       type: string, listener: EventListener, useCapture?: boolean): void;
    removeEventListener(
       type: string, listener?: EventListener, options?: boolean): void;
    setProperty?(name: string, value: any): void;
  }
```

The text node adds a `textContent` property:

```
export interface RText extends RNode { textContent: string|null; }
```



It has this factory code. Note the return type from `createRenderer` is `Render3` ❶ – and that for the `domRendererFactory3` implementation ❷ this is the normal DOM `document`:

```
export interface RendererFactory3 {
  createRenderer(hostElement: RElement|null,
                   rendererType: RendererType2|null): Renderer3; ❶
  begin?(): void;
  end?(): void;
}
export const domRendererFactory3: RendererFactory3 = {
  createRenderer: (
     hostElement: RElement | null,
     rendererType: RendererType2 | null): Renderer3 => { return document;} ❷
};
```

This is key to moving back to regular DOM usage for code that runs in the main browser UI thread, and yet allowing alternatives elsewhere. `Renderer3` is a type alias:

```
export type Renderer3 = ObjectOrientedRenderer3 | ProceduralRenderer3;
```

This represents the two kinds of renderers that are supported. The bolded text in the comment highlights the usage scenario for the first of these:

```
/**
 * Object Oriented style of API needed to create elements and text nodes.
 *
 * This is the native browser API style, e.g. operations are methods on
 * individual objects like HTMLElement. With this style, no additional
 * code is needed as a facade (reducing payload size).
 */
export interface ObjectOrientedRenderer3 {
  createElement(tagName: string): RElement;
  createTextNode(data: string): RText;
  querySelector(selectors: string): RElement|null;
}
```

`ProceduralRender3` is intended to be used from web workers and server-side:

```
/**
 * Procedural style of API needed to create elements and text nodes.
 *
 * In non-native browser environments (e.g. platforms such as web-workers),
 * this is the facade that enables element manipulation. This also
 * facilitates backwards compatibility with Renderer2.
 */
export interface ProceduralRenderer3 {
  destroy(): void;
  createElement(name: string, namespace?: string|null): RElement;
  createText(value: string): RText;
  destroyNode?: ((node: RNode) => void)|null;
  appendChild(parent: RElement, newChild: RNode): void;
  insertBefore(parent: RNode, newChild: RNode, refChild: RNode|null): void;
  removeChild(parent: RElement, oldChild: RNode): void;
  selectRootElement(selectorOrNode: string|any): RElement;
  setAttribute(el: RElement, name: string, value: string,
                                    namespace?: string|null): void;
  removeAttribute(el: RElement, name: string, namespace?: string|null): void;
  addClass(el: RElement, name: string): void;
  removeClass(el: RElement, name: string): void;
  setStyle(el: RElement, style: string, value: any,
      flags?: RendererStyleFlags2|RendererStyleFlags3): void;
  removeStyle(el: RElement, style: string,
     flags?: RendererStyleFlags2|RendererStyleFlags3): void;
  setProperty(el: RElement, name: string, value: any): void;
  setValue(node: RText, value: string): void;
  listen(target: RNode, eventName: string,
     callback: (event: any) => boolean | void): () => void;
}
```

Let's now look at view.ts. It includes the following to work with static data:

```
// The static data for an LView (shared between all templates of a
// given type). Stored on the template function as ngPrivateData.
export interface TView {
  data: TData;
  firstTemplatePass: boolean;
  initHooks: HookData|null;
  checkHooks: HookData|null;
  contentHooks: HookData|null;
  contentCheckHooks: HookData|null;
  viewHooks: HookData|null;
  viewCheckHooks: HookData|null;
  destroyHooks: HookData|null;
  objectLiterals: any[]|null;
}
```

`TData` is defined as:

```
/**
 * Static data that corresponds to the instance-specific data array on an
 * Lview. Each node's static data is stored in tData at the same index that
 * it's stored in the data array. Each directive's definition is stored here
 * at the same index as its directive instance in the data array. Any nodes
 * that do not have static data store a null value in tData to avoid a
 * sparse array.
 */
export type TData = (TNode | DirectiveDef<any>| null)[];
```

A tree of `LView`s or `LContainer`s will be needed, so this type is a node in the hierarchy:

```
/** Interface necessary to work with view tree traversal */
export interface LViewOrLContainer {
  next: LView|LContainer|null;
  child?: LView|LContainer|null;
  views?: LViewNode[];
  parent: LView|null;
}
```

An LView stores info relating to processing a view’s instructions. Detailed comments (not shown here) for each of its fields are in the source.

```
/**
 * `LView` stores all of the information needed to process the instructions
 * as they are invoked from the template. Each embedded view and component
 * view has its own `LView`. When processing a particular view, we set the
 * `currentView` to that `LView`. When that view is done processing, the
 * `currentView` is set back to whatever the original `currentView` was
 * before (the parent `LView`).
 * Keeping separate state for each view facilities view insertion / deletion,
 * so we don't have to edit the data array based on which views are present.
 */
export interface LView {
  creationMode: boolean;
  readonly parent: LView|null;
  readonly node: LViewNode|LElementNode;
  readonly id: number;
  readonly renderer: Renderer3;
  bindingStartIndex: number|null;
  cleanup: any[]|null;
  lifecycleStage: LifecycleStage;
  child: LView|LContainer|null;
  tail: LView|LContainer|null;
  next: LView|LContainer|null;
  readonly data: any[];
  tView: TView;
  template: ComponentTemplate<{}>|null;
  context: {}|null;
  dynamicViewCount: number;
  queries: LQueries|null;
}
```

The container.ts file looks at containers, which are collections of views and sub-containers. It exports one type, `TContainer`:

```
/**
```

```
 * The static equivalent of LContainer, used in TContainerNode.
 *
 * The container needs to store static data for each of its embedded views
 * (TViews). Otherwise, nodes in embedded views with the same index as nodes
 * in their parent views will overwrite each other, as they are in
 * the same template.
 *
 * Each index in this array corresponds to the static data for a certain
 * view. So if you had V(0) and V(1) in a container, you might have:
 *
 * [
 *   [{tagName: 'div', attrs: ...}, null],     // V(0) TView
 *   [{tagName: 'button', attrs ...}, null]    // V(1) TView
 * ]
 */
export type TContainer = TView[];
```

and one interface, `LContainer`: (note the source file contained detailed comments for each field):

```
/** The state associated with an LContainer */
export interface LContainer {
  nextIndex: number;
  next: LView|LContainer|null;
  parent: LView|null;
  readonly views: LViewNode[];
  renderParent: LElementNode|null;
  readonly template: ComponentTemplate<any>|null;
  dynamicViewCount: number;
  queries: LQueries|null;
}
```

The query.ts file contains the `QueryReadType` class:

```
export class QueryReadType<T> { private defeatStructuralTyping: any; }
```

and the `LQuery` interface:

```
/** Used for tracking queries (e.g. ViewChild, ContentChild). */
export interface LQueries {
  child(): LQueries|null;
  addNode(node: LNode): void;
  container(): LQueries|null;
  enterView(newViewIndex: number): LQueries|null;
  removeView(removeIndex: number): void;
  track<T>(
       queryList: QueryList<T>,
       predicate: Type<any>|string[],
       descend?: boolean,
       read?: QueryReadType<T>|Type<T>): void;
}
```

The projection.ts file define LProjection as:

```
// Linked list of projected nodes (using the pNextOrParent property).
export interface LProjection {
  head: LElementNode|LTextNode|LContainerNode|null;
  tail: LElementNode|LTextNode|LContainerNode|null;
}
```

The injector.ts file has this:

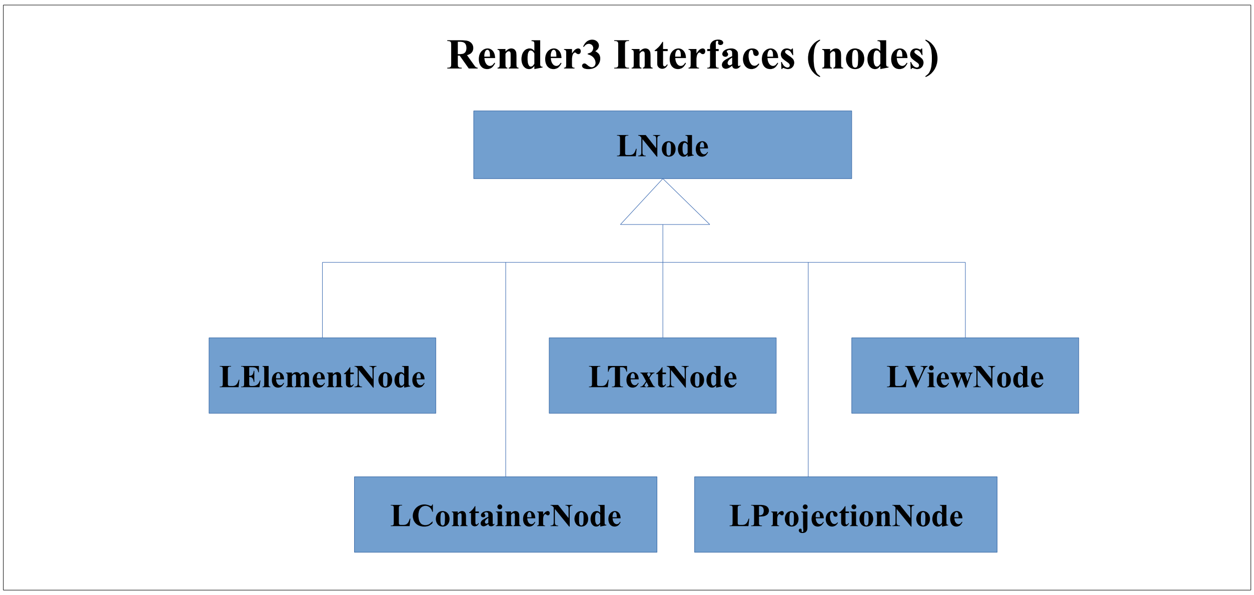
```
export interface LInjector {
  readonly parent: LInjector|null;
  readonly node: LElementNode|LContainerNode;
  bf0: number;
  bf1: number;
  bf2: number;
  bf3: number;
  cbf0: number;
  cbf1: number;
  cbf2: number;
  cbf3: number;
  injector: Injector|null;
  /** Stores the TemplateRef so subsequent injections of the TemplateRef get
the same instance. */
  templateRef: TemplateRef<any>|null;
  /** Stores the ViewContainerRef so subsequent injections of the
ViewContainerRef get the same
   * instance. */
  viewContainerRef: ViewContainerRef|null;
  /** Stores the ElementRef so subsequent injections of the ElementRef get
the same instance. */
  elementRef: ElementRef|null;
}
```

The node.ts file is large and contains a hierarchy of node-related types.

The root, `LNode`, is defined (abbreviated) as:

```
/**
 * LNode is an internal data structure which is used for the incremental DOM
 * algorithm. The "L" stands for "Logical" to differentiate between `RNodes`
 * (actual rendered DOM node) and our logical representation of DOM nodes,
 * `Lnodes`. The data structure is optimized for speed and size.
 *
 * In order to be fast, all subtypes of `LNode` should have the same shape.
 * Because size of the `LNode` matters, many fields have multiple roles
 * depending on the `LNode` subtype.
 */
export interface LNode {
  flags: LNodeFlags;
  readonly native: RElement|RText|null|undefined;
  readonly parent: LNode|null;
  child: LNode|null;
  next: LNode|null;
  readonly data: LView|LContainer|LProjection|null;
  readonly view: LView;
  nodeInjector: LInjector|null;
  queries: LQueries|null;
  pNextOrParent: LNode|null;
  tNode: TNode|null;
}
```

Each of the other types adds a few additional fields to represent that node type.



Render3 Interfaces (nodes)

LNode

LElementNode

LTextNode

LViewNode

LContainerNode

LProjectionNode