Reduce JavaScript Payloads with Code Splitting

By Jeremy Wagner
(https://developers.google.com/web/resources/contributors/jeremywagner)
Jeremy is a contributor to Web**Fundamentals**

By Addy Osmani
(https://developers.google.com/web/resources/contributors/addyosmani)
Eng Manager, Web Developer Relations

TL;DR:

- Modern sites often combine all of their JavaScript into a single, large bundle. When JavaScript is served this way, loading performance suffers. Large amounts of JavaScript can also tie up the main thread, delaying interactivity. This is *especially* true of devices with less memory and processing power.
- An alternative to large bundles is code-splitting, which is where JavaScript is split into smaller chunks. This enables sending the minimal code required to provide value upfront, improving page-load times. The rest can be loaded on demand.
- Do you need code-splitting? Check Lighthouse's JavaScript Bootup Time is Too High audit (https://developers.google.com/web/tools/lighthouse/audits/bootup) and the code coverage panel (https://developers.google.com/web/updates/2017/04/devtools-release-notes#coverage) in DevTools to measure the impact of your app's scripts on performance and how many scripts are unused.
- Code-splitting can be done in the following ways:
    - **Vendor splitting** separates vendor code (e.g., React, lodash, *etc.*) away from your app's code. This allows you to keep application and vendor code separate. This isolates the negative performance impacts of cache invalidation for returning users when either your vendor or app code changes. This should be done in *every* app.
    - **Entry point splitting** separates code by entry point(s) in your app, which are the scripts where tools like webpack and Parcel start when they build a dependency

tree of your app. This is best for pages or apps where client side routing is not used, or a blended app where some parts use server side routing and others are part of a single page application.

- **Dynamic splitting** separates code where dynamic `import()` statements are used. This type of splitting is often best for single page applications.

- Choose tools that split code for you (Preact CLI (https://github.com/developit/preact-cli/), PWA Starter Kit (https://github.com/Polymer/pwa-starter-kit/), *etc.*) where possible. React (https://reactjs.org/docs/code-splitting.html), Vue (https://vuejsdevelopers.com/2017/07/03/vue-js-code-splitting-webpack/), and Angular (https://angular.io/guide/lazy-loading-ngmodules) support manual code-splitting.

Maybe you've heard this before, but there's a *lot* of JavaScript on web pages now (https://httparchive.org/reports/state-of-javascript#bytesJs), and on median mobile hardware, that can be a Bad Thing™ (https://speedcurve.com/blog/your-javascript-hurts/). Yet, setting arbitrary limits on what's too much JavaScript is not the best approach. Every application is different. What's not much JavaScript in one app is far too much in another. Users and their devices vary!

That's why it's important to consider *how* you serve JavaScript. Do you bundle all of your scripts into one big file and serve it on all pages? If so, you'll want to reconsider this approach, and consider code splitting!

Too much too soon

Many apps place all their scripts into one file and deliver a large bundle at initial load. This file contains not just support for the initial route, but support for *every* interaction in *every* route — regardless of whether those routes are ever visited!

This all-or-nothing approach can be inefficient. Every second spent loading, parsing, and executing bytes of unused code prolongs your app's time to interactivity (TTI) (https://developers.google.com/web/tools/lighthouse/audits/time-to-interactive), which means users are forced to wait unnecessarily before they can use it. This problem is felt more by users on mobile devices where slower processors or network connections can impose further delays. The figure below shows how much longer parsing and compiling can take on a mobile device versus a desktop or laptop with a more powerful processor:

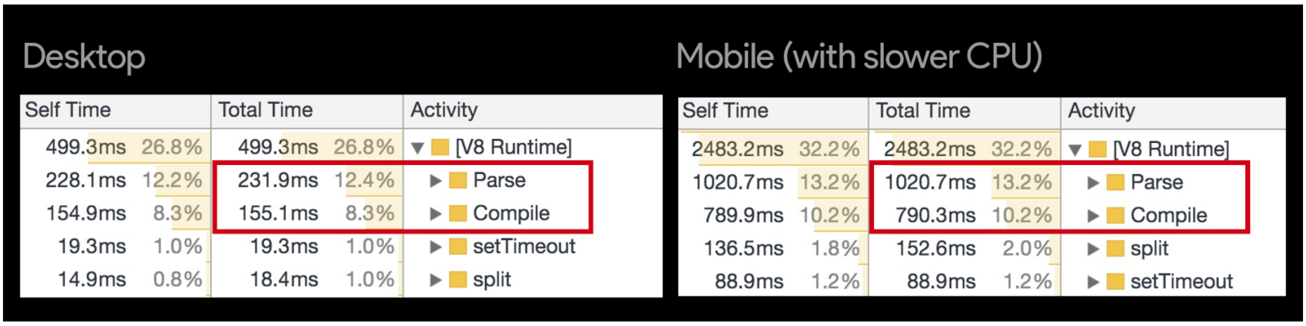


Figure 1. JavaScript startup times on different devices. Source: JavaScript Startup Performance (https://medium.com/reloading/javascript-start-up-performance-69200f43b201) by Addy Osmani (https://twitter.com/addyosmani).

We know that faster apps are *better* apps. People enjoy using them more, and there are numerous case studies for how they improve various business metrics (https://wpostats.com/). Compared to the all-or-nothing approach, code splitting emphasizes bundling the minimum of code that can be delivered and parsed as needed for the current route, rather than all at once.

Do I need to code split?

"Do I even need to split code in my app?" is a valid question, and as is the case with many web development questions. If your app has many routes rich with functionality and makes heavy use of frameworks and libraries, the answer is almost certainly "yes". However, only you can answer that question for yourself, as you'll need to rely on your own understanding of your app's architecture and the scripts it loads, as well as a mixture of tools such as Lighthouse (https://developers.google.com/web/tools/lighthouse/), DevTools, real devices, and WebPagetest (https://www.webpagetest.org/).

For newbies, Lighthouse audits require the least amount of effort. In Chrome, you can open Lighthouse in DevTools via the Audits panel, and audit your site. There's one audit you'll want to pay attention to with regard to JavaScript performance problems, and that's the JavaScript Bootup Time is Too High (https://developers.google.com/web/tools/lighthouse/audits/bootup) audit. This audit flags JavaScript that significantly delays your app's Time to Interactive (TTI):

JavaScript boot-up time is too high 2,190 ms

Consider reducing the time spent parsing, compiling, and executing JS. You may find delivering smaller JS payloads helps with this. Learn more.

URL	Script Evaluation	Script Parsing & Compile
…v1_18_0/TweenMax.min.js (www.gstatic.com)	303 ms	5 ms
https://www.android.com	221 ms	2 ms
…rs=AGLTcCN4y…/cb=gapi.loaded_0 (apis.google.com)	74 ms	45 ms
…modernizr/modernizr.js (www.gstatic.com)	48 ms	3 ms

Figure 2. The JavaScript Bootup Time is Too High audit in Lighthouse illustrating which scripts are responsible for excessive processing activity.

Fortunately, you can use the information gleaned from this audit in concert with the code coverage tool found in the drawer in DevTools (which you can open with the `esc` key when DevTools is focused) to find out what scripts contain unused code for the current route.

js ☑ Content scripts

URL	Type	Total B…	Unused Bytes ▼	
https://www.android.com/static/2016/**js**/main.min.js	JS	221 549	157 663 71.2 %	
https://apis.google.com/_/scs/apps-static/… /cb=gapi.loaded_0	JS	133 999	96 235 71.8 %	
https://www.gstatic.com/external_hosted/g… /TweenMax.min.**js**	JS	107 961	71 761 66.5 %	

Figure 3. The code coverage panel in DevTools showing how much JavaScript is used on the current page.

Note: Even if you use code splitting in your app, you still may find some unused code being loaded on pages. Tree shaking (https://developers.google.com/web/fundamentals/performance/optimizing-javascript/tree-shaking/) could be part of the solution to eliminating that unused code!

While Lighthouse is great for assessing performance, you should remember that it does so *synthetically.* The capabilities and processing power of devices run along a massive gradient, ranging from blazingly fast all the way to excruciatingly slow, with many users on devices somewhere in between. It's crucial that you test on *real devices*, specifically those that are *not* the on the bleeding edge. Just because your site doesn't struggle to load on an iPhone X doesn't mean that someone's older (but still serviceable) Galaxy S5 will perform similarly. If you're unable to procure a real device for testing, you can always fall back on WebPagetest (https://www.webpagetest.org/), which allows you to assess performance across a variety of platforms.

Set a budget and stick to it

If you treat performance as a one-off task, your performance improvements *will* eventually go by the wayside, as the addition of new features and tech debt will erase the gains you've made. Performance budgets help you to to cement gains, and prevent the addition of new features from killing your app's performance.

Performance budgets enable shared enthusiasm for keeping a site's user experience within the constraints needed to keep it fast. They usher in a culture of accountability that enable business stakeholders to weigh the impact to user-centric metrics of each change to a site.

Embracing performance budgets encourage teams to think seriously about the consequences of any decisions they make from early on in the design phases right through to the end of a milestone.

Performance Budgets are aided by having internal processes for operationalizing a performance culture within a business. Organizational performance budgets ensure that a budget is owned by everyone rather than just being defined by one group (e.g engineering). Ensuring fast page loads are one of the most common performance budgets teams set.

When budgets have been set and the entire organization is aware early on what the budget parameters are, you're able to say performance isn't just an engineering issue, but a critical piece of the whole package as a site is constructed. It provides a guideline for design and engineering when considering performance and should be checked with each decision that could impact performance.

When teams are crafting their performance budgets, they need to review their research and be aware of the metrics that matter most to their users. If you're trying to get interactive quickly on a low-mid end device, you can't ship 5MB of JavaScript.

Walking back from Alex Russell's performance budgeting goals outlined in "Can You Afford It?" (https://infrequently.org/2017/10/can-you-afford-it-real-world-web-performance-budgets/), this may be:

- Time-To-Interactive < 5s on 3G over an emulated (or real) Moto G4 (https://en.wikipedia.org/wiki/Moto_G4)
- JavaScript budget of < 200 KB if targeting mobile. If you're just starting out, align with a budget that's less than the HTTP Archive medians (https://httparchive.org/reports/state-of-javascript#bytesJs) for desktop.
- Budgets for other resources can be drawn from a total page weight target. If a page cannot be larger than 600 KB, your budget for images, JS, CSS, etc will need to fit in. It's important we remind developers more resources can be lazy loaded as needed, but the initial costs should be clearly budgeted.

A range of options are available for sites looking for inspiration on how to set budgets: you can check your competitor's sites or consult industry medians derived from case studies in your vertical.

Getting hands on with code splitting

Simply *talking* about code splitting without having concrete examples to point to may only leave readers with more questions. To improve clarity, this guide will show you the different ways you can split code by way of an example app (https://github.com/malchata/code-splitting-example), which you can use as a reference.

Note: Some of the techniques in the example app (such as hash-based versioning of output filenames and using html-webpack-plugin (https://github.com/jantimon/html-webpack-plugin)) are covered in this guide (https://developers.google.com/web/fundamentals/performance/webpack/use-long-term-caching).

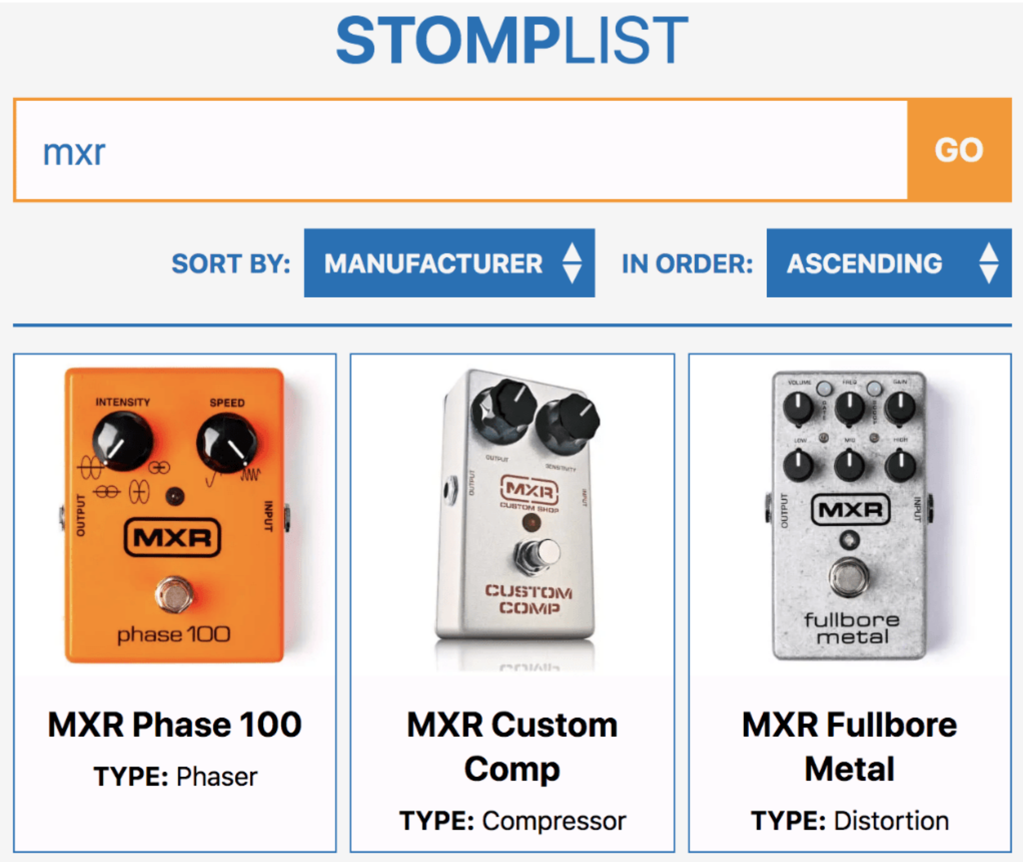


Figure 4. The example app, which is a searchable database of guitar effect pedals.

The app has three routes:

1. The search page, (also the default route) where users can search for guitar effect pedals (https://en.wikipedia.org/wiki/Effects_unit#Stompboxes).
2. The pedal detail page, which is shown when the user clicks on a pedal in the search results. Users can also add a pedal to their favorites list from here.
3. The favorite pedals page, which lists the user's favorite pedals.

Most examples will show you how to split code along these routes using webpack (https://webpack.js.org/), but the dynamic code splitting section will also show you how to split code using Parcel (https://parceljs.org/) as well. Let's start by showing how you can split your app JavaScript by entry point in webpack.

Spitting code by multiple entry points

If you're not familiar with the term, an *entry point* (https://webpack.js.org/concepts/entry-points/) is a file where webpack starts to analyze your app's dependencies. To use the tree analogy, it's the trunk of your app where assets, routes, and functionality branch from. Some apps have a single entry point but others may have multiple entry points (https://webpack.js.org/concepts/entry-points/#multi-page-application).

When this approach makes sense: You're developing an app that's not a single page application (SPA). Or perhaps even a blended application where some pages don't use client side routing, but other pages might. In cases like these, it makes sense to split code across multiple entry points.

What to look out for: If your entry points share vendor libraries or modules, duplicate code can occur across your scripts. We'll address this in a bit.

There are three entry points in the example app that correspond to each of the routes described earlier, which are *index.js*, *detail.js*, and *favorites.js*. These scripts contain Preact (https://preactjs.com/) components which render pages for those routes.

Note: If you want to look at the example app's codebase with entry point-based code splitting fully implemented, check out the app repo's webpack-entry-point-splitting branch (https://github.com/malchata/code-splitting-example/tree/webpack-entry-point-splitting)!

Configuring webpack to split code across multiple entry points

In webpack, we can split code by entry points by specifying them in the `entry` config (https://webpack.js.org/configuration/entry-context/#entry) like so:

```
module.exports = {
  // ...
  entry: {
    main: path.join(__dirname, "src", "index.js"),
    detail: path.join(__dirname, "src", "detail.js"),
    favorites: path.join(__dirname, "src", "favorites.js")
  },
  // ...
};
```

Conveniently, when there are multiple entry points, webpack treats them all as separate dependency trees, meaning that code is automatically split into named chunks like so:

```
                   Asset       Size  Chunks             Chunk Names
js/favorites.15793084.js   37.1 KiB       0  [emitted]  favorites
   js/detail.47980e29.js   44.8 KiB       1  [emitted]  detail
     js/main.7ce05625.js   49.4 KiB       2  [emitted]  main
              index.html  955 bytes          [emitted]
             detail.html  957 bytes          [emitted]
          favorites.html  960 bytes          [emitted]
```

As you may guess, chunk names come from the object keys in the entry config, which makes identifying which chunk contains code for which page a snap. The app also uses html-webpack-plugin to generate HTML files that include the corresponding chunks for each page.

Removing duplicate code

Though we've created nicely split chunks for each page, there's still a problem: There's a lot of duplicate code in each chunk. This is because webpack treats each entry point as its own dependency tree without assessing what code is shared between them. If we turn on source maps in webpack (https://webpack.js.org/configuration/devtool/) and analyze our code with a tool like Bundle Buddy (https://github.com/samccone/bundle-buddy) or webpack-bundle-analyzer (https://github.com/webpack-contrib/webpack-bundle-analyzer), we can see how much duplicate code is in each chunk.

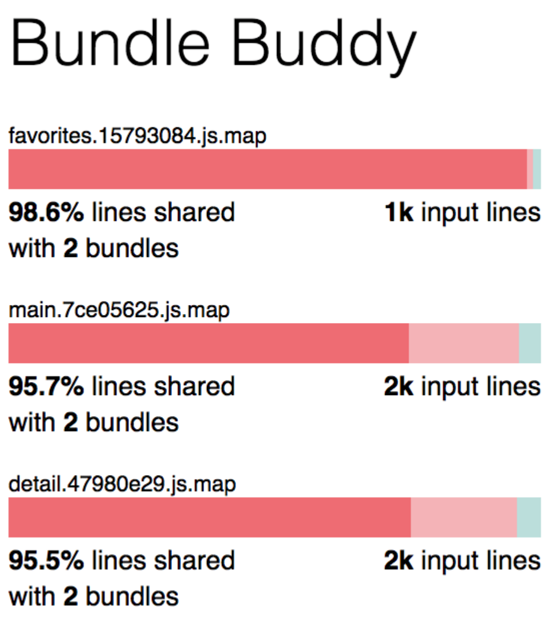


Figure 5. Bundle Buddy showing how many lines of code are shared between bundles.

Here, the duplicate code comes from vendor scripts. To remedy this, we'll tell webpack to create a separate chunk for those scripts. To do this, we'll use the `optimization.splitChunks` configuration object (https://webpack.js.org/plugins/split-chunks-plugin/#optimization-splitchunks):

```
module.exports = {
  // ...
  optimization: {
    splitChunks: {
      cacheGroups: {
        // Split vendor code to its own chunk(s)
        vendors: {
          test: /[\\/]node_modules[\\/]/i,
          chunks: "all"
        }
      }
    },
    // The runtime should be in its own chunk
    runtimeChunk: {
        name: "runtime"
    }
   },
  // ...
};
```

This configuration says "I want to output separate chunks for vendor scripts" (those loaded from the _node*modules* folder). This works because all vendor scripts are installed by npm to _node*modules*, which we check for with the `test` option (https://webpack.js.org/plugins/split-chunks-plugin/#splitchunks-cachegroups-test). The `runtimeChunk` option (https://webpack.js.org/configuration/optimization/#optimization-runtimechunk) is also specified to move webpack's runtime (https://webpack.js.org/concepts/manifest/#runtime) into its own chunk to avoid duplication of it in our app code. When we add these options to the config and rebuild the app, the output shows that our app's vendor scripts have been moved to a separate file:

```
                                      Asset      Size  Chunks
js/vendors~detail~favorites~main.29eb30bb.js  30.1 KiB       0  [emitted]  vei
                          js/main.06d0afde.js  16.5 KiB       2  [emitted]  ma:
                        js/detail.1acdbb27.js  13.4 KiB       3  [emitted]  de·
                     js/favorites.230214a7.js  5.52 KiB       4  [emitted]  fa\
                       js/runtime.2642dc2d.js  1.46 KiB       1  [emitted]  rui
                                   index.html   1.1 KiB          [emitted]
                                  detail.html   1.1 KiB          [emitted]
                               favorites.html   1.1 KiB          [emitted]
```

Because the vendor scripts, the runtime, and shared code are now split to dedicated chunks, we've reduced the size of the entry point scripts, as well. Thanks to our efforts, Bundle Buddy gives us a better result:

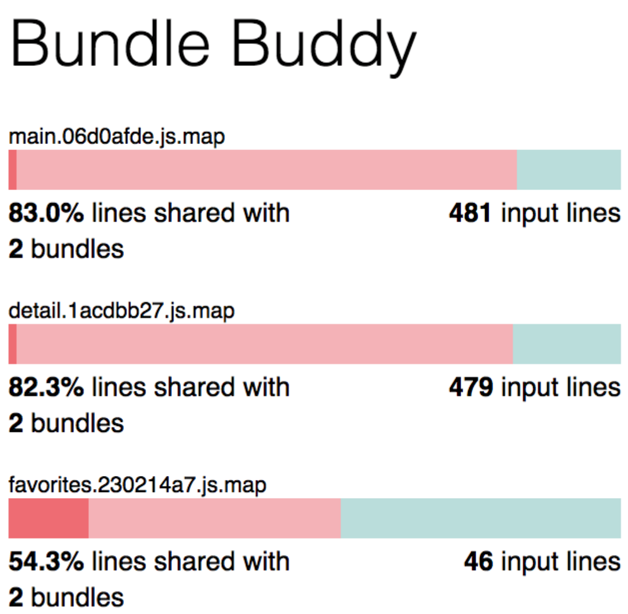


Figure 6. Bundle Buddy showing reduced input lines and shared code between bundles.

Before we split the vendor code, a few thousand lines of code were shared between bundles. Now it's significantly less than that. While separating vendor code into separate chunks *can* incur additional HTTP request(s), that may only be an issue if your app is still on HTTP/1. Additionally, serving your scripts like this is *way* better for caching. If you have one giant bundle, but either your app or vendor code changes, the entire bundle would need to be downloaded again.

Note: [Don't forget to set an optimal caching policy](https://developers.google.com/web/fundamentals/performance/optimizing-content-efficiency/http-caching) (https://developers.google.com/web/fundamentals/performance/optimizing-content-efficiency/http-caching) for your returning users!

If you *really* want to go for the gold, though, you can eliminate most or all shared code between bundles and employ a type of splitting called "commons splitting". In the example app, this can be achieved by creating another entry under `cacheGroups` like so:

```
module.exports = {
  // ...
  optimization: {
    splitChunks: {
      cacheGroups: {
        // Split vendor code to its own chunk(s)
        vendors: {
          test: /[\\/]node_modules[\\/]/i,
          chunks: "all"
        },
        // Split code common to all chunks to its own chunk
        commons: {
          name: "commons",    // The name of the chunk containing all common c
          chunks: "initial",  // TODO: Document
          minChunks: 2        // This is the number of modules
        }
      }
    },
    // The runtime should be in its own chunk
    runtimeChunk: {
      name: "runtime"
    }
  },
  // ...
};
```

When we employ commons splitting, code common amongst chunks will be split to a new chunk named `commons`, which is reflected in the output:

```
                   Asset      Size  Chunks             Chunk Names
  js/commons.e039cc73.js    40 KiB       0  [emitted]  commons
     js/main.5b71b65c.js  7.82 KiB       2  [emitted]  main
   js/detail.b3ac6f73.js  5.17 KiB       3  [emitted]  detail
```

```
js/favorites.8da9eb04.js  2.18 KiB       4  [emitted]  favorites
  js/runtime.2642dc2d.js  1.46 KiB       1  [emitted]  runtime
              index.html  1.08 KiB          [emitted]
             detail.html  1.08 KiB          [emitted]
          favorites.html  1.08 KiB          [emitted]
```

When we re-run Bundle Buddy, we should receive a notice that our bundles no longer have duplicate code across chunks.

While removing all duplicate code is a worthwhile goal, it's important to also be pragmatic. Seek to dedupe as much code as possible, but understand that doing so with this configuration may enlarge initial bundles by pulling in code that may not be used on the current page. Which can be mitigated by lazy loading scripts, which we'll cover next!

Splitting code dynamically

Splitting code by multiple entry points as demonstrated above is logical and intuitive, but it may not be practical for your app. Another method is to lazy load scripts with the dynamic `import()` statement (https://developers.google.com/web/updates/2017/11/dynamic-import):

```
import("./myFancyModule.js").then(module => {
  module.default(); // Call a module's default export
  module.andAnotherThing(); // Call a module's named export
});
```

Since `import()` returns a Promise (https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Promise), you can also use `async` (https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/async_function) /`await` (https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Operators/await):

```
let module = await import("./myFancyModule.js");
module.default(); // Access a module's default export
module.andAnotherThing(); // Access a module's named export
```

Whichever method you prefer, both Parcel and webpack can detect `import()`s and split code imported by them accordingly.

When this approach makes sense: You're developing a single page application with many discrete pieces of functionality that not all users may, well, *use*. Lazy loading this functionality can reduce JS parse/compile activity as well as bytes sent over the network.

What to look out for: Dynamically importing a script kicks off a network request, which means user actions could be delayed as a result. There *are* ways to mitigate this, though, which we'll cover soon.

Let's start by covering how dynamic code splitting works in Parcel.

Dynamic code splitting with Parcel

The most intuitive tool to use for dynamic code splitting is Parcel (https://parceljs.org/). Without any configuration, Parcel builds a dependency tree accounting for both static and dynamic modules, and outputs scripts with names that nicely align with your inputs.

Note: If you're interested in seeing how the example app does dynamic code splitting with Parcel, check out the parcel-dynamic-splitting branch (https://github.com/malchata/code-splitting-example/tree/parcel-dynamic-splitting).

In this version of the example app, client side routing is provided by preact-router (https://github.com/developit/preact-router) and preact-async-route (https://github.com/prateekbh/preact-async-route). Without dynamically imported modules, all components needed by all routes would need to be imported (and thus downloaded by the client) up front:

```
import Router from "preact-router";
import { h, render, Component } from "preact";
import Search from "./components/Search/Search";
import PedalDetail from "./components/PedalDetail/PedalDetail";
import Favorites from "./components/Favorites/Favorites";

render(<Router>
  <Search path="/" default/>
  <PedalDetail path="/pedal/:id"/>
  <Favorites path="/favorites"/>
</Router>, document.getElementById("app"));
```

Here, we're loading every component for every route whether or not the user ever visits them. When we architect apps this way, we're missing out on a potential opportunity to improve loading performance by lazy loading JavaScript. In the case of this example app, we can defer the components needed for the `/pedal/:id` and `/favorites` routes by using dynamic `import()` and preact-async-route like so:

```
import Router from "preact-router";
import AsyncRoute from "preact-async-route";
import { h, render, Component } from "preact";
```

```
import Search from "./components/Search/Search";

render(<Router>
  <Search path="/" default/>
  <AsyncRoute path="/pedal/:id" getComponent={() => import("./components/Peda
  <AsyncRoute path="/favorites" getComponent={() => import("./components/Favo
</Router>, document.getElementById("app"));
```

You'll notice a few things that are different from the previous example:

1. We're statically importing only the **`Search`** component. This is because the default route uses this component, so it's reasonable to load it up front.
2. preact-async-route handles asynchronous routing via the **`AsyncRoute`** component.
3. The **`PedalDetail`** and **`Favorites`** components are lazy loaded when the user navigates to the routes using them by the **`AsyncRoute`** component via **`import()`** statements.

When we build the app, Parcel outputs the following:

```
dist/src.e54c18ce.js            65.56 KB    2.87s
dist/PedalDetail.7f417dfd.js     7.66 KB    1.52s
dist/Favorites.02c87dad.js       3.06 KB    1.17s
dist/index.html                   964 B    882ms
```

With zero configuration, Parcel automatically splits dynamically imported scripts into lazy-loadable chunks that can be loaded on demand.

Warning: This example doesn't employ vendor splitting!

When we land on the default route, only the scripts needed are loaded to support it. When the user navigates to either the pedal detail or favorites routes, the scripts for those routes will be loaded on demand.

Dynamic code splitting with webpack

Like Parcel, webpack can split dynamic imports to separate files. It does so with little guidance, in fact. It's just that when webpack encounters **`import()`** calls, it doesn't name the output files like Parcel does:

```
                 Asset       Size  Chunks             Chunk Names
        js/main.2c418923.js   10.2 KiB       0  [emitted]  main
           js/2.6b340cb3.js   3.32 KiB       2  [emitted]
```

```
           js/3.a52088da.js  349 bytes       3  [emitted]
           js/4.232e6590.js  521 bytes       4  [emitted]
js/vendors~main.526c9b0c.js   42.9 KiB       5  [emitted]  vendors~main
     js/runtime.8b59d0ff.js   2.26 KiB       6  [emitted]  runtime
           js/1.175d2b19.js   6.11 KiB       1  [emitted]
                 index.html   1.08 KiB          [emitted]
```

Here, you can see that webpack assigns IDs to **`import()`**s rather than names. This doesn't matter so much for your app's users, but it can problematic for development reasons. To get around this, we'll need to use a special kind of comment known as an *inline directive* to tell webpack what the output file names should be:

```
render(<Router>
  <Search path="/" default/>
  <AsyncRoute path="/pedal/:id" getComponent={() => import(/* webpackChunkName
  <AsyncRoute path="/favorites" getComponent={() => import(/* webpackChunkName
</Router>, document.getElementById("app"));
```

In the above snippet, an inline directive called **`webpackChunkName`** tells webpack what the name of a chunk should be. When used within **`import()`** calls, webpack gives proper names to chunks like so:

```
                          Asset       Size  Chunks             Chunk Names
           js/main.b72863fc.js   10.2 KiB       0  [emitted]  main
      js/Favorites.0ce4835e.js   3.33 KiB       2  [emitted]  Favorites
     js/simpleSort.ef5256f9.js  358 bytes       3  [emitted]  simpleSort
js/toggleFavorite.fc4ea97d.js  534 bytes       4  [emitted]  toggleFavorite
  js/vendors~main.526c9b0c.js   42.9 KiB       5  [emitted]  vendors~main
       js/runtime.a735e0fe.js   2.32 KiB       6  [emitted]  runtime
    js/PedalDetail.ba7a0692.js   6.12 KiB       1  [emitted]  PedalDetail
                    index.html   1.08 KiB          [emitted]
```

This syntax is a bit unwieldy in my opinion, but it works. If you want to how the example app does dynamic code splitting with webpack, check out the app repo's webpack-dynamic-splitting branch
(https://github.com/malchata/code-splitting-example/tree/webpack-dynamic-splitting).

Loading performance considerations

A potential pain point with code splitting is it increases the amount of requests for scripts which, even in HTTP/2 environments, presents challenges. Let's cover some ways you can improve loading performance in apps where code splitting is used.

There's that "budget" word again

At the start of this guide, we talked at a high level about performance budgets, which can be difficult to enforce if the practice isn't followed in your organization. If you use webpack in your project, you can configure your app to throw an error for builds emitting assets that are too large by way of the `performance` configuration object (https://webpack.js.org/configuration/performance/). With this config object, we can effectively enforce budgets for asset sizes like so:

```
module.exports = {
  // ...
  performance: {
    hints: "error",
    maxAssetSize: 102400
  }
};
```

This configuration effectively tells Webpack "if any asset larger than 100 KB is emitted during build, throw an error". This is certainly a draconian configuration (and is one you probably can't put into an existing app without running into some trouble), but if you're serious about sticking to a budget, the `performance` object can help you do just that. Be sure to check out other options available in this object, such as `maxEntrypointSize` (https://webpack.js.org/configuration/performance/#performance-maxentrypointsize).

Precache scripts with a service worker

One of the Ps of the PRPL pattern (https://developers.google.com/web/fundamentals/performance/prpl-pattern/) stands for *precache*, which involves precaching remaining routes and functionality with a service worker when it initializes. Precaching is great for performance in the following ways:

1. It doesn't impact loading performance of the app's initial load, because service worker registration and subsequent precaching occurs later on in the page loading process.
2. Precaching remaining routes and functionality with a service worker ensures they're available immediately when they're requested later.

Of course, adding a service worker to an app with code generated by modern tooling can be challenging, owing to a number of reasons (such as output filenames with hashes in them). Thankfully, Workbox (https://developers.google.com/web/tools/workbox/) has a webpack plugin that can generate a service worker for your app with little effort. At a minimum, you can install workbox-webpack-plugin (https://www.npmjs.com/package/workbox-webpack-plugin) and bring it into your webpack config like so:

```
const { GenerateSW } = require("workbox-webpack-plugin");
```

From there, you can add an instance of **`GenerateSW`** to the **`plugins`** config:

```
module.exports = {
  // ...
  plugins: [
    // ... other plugins omitted
    new GenerateSW()
  ]
  // ...
};
```

With this configuration, Workbox generates a service worker that precaches *all* JavaScript in your app. This is probably fine for small apps, but for large ones you'll may want to limit what's precached. This can be done via the plugin's **`chunks`** option to whitelist chunks:

```
module.exports = {
  // ...
  plugins: [
    new GenerateSW({
      chunks: ["main", "Favorites", "PedalDetail", "vendors"]
    })
  ]
  // ...
};
```

Using the whitelist approach, we can ensure the service worker precaches only the scripts we want. To see how Workbox is used in the example app, check out the repo's webpack-dynamic-splitting-precache (https://github.com/malchata/code-splitting-example/tree/webpack-dynamic-splitting-precache) branch!

Prefetching and preloading scripts

Precaching scripts with a service worker is one way to improve loading performance for your app, but they should be treated as a progressive enhancement. In the absence of (or even in addition to) them, you may want to consider prefetching or preloading chunks.

Both **`rel=prefetch`** and **`rel=preload`** are resource hints that fetch a specified resource before the browser otherwise would, which can improve loading performance by masking latency. Though they're both very similar at first glance, they behave quite differently:

1. [`rel=prefetch`](https://www.w3.org/TR/resource-hints/#prefetch) (https://www.w3.org/TR/resource-hints/#prefetch) is a *low priority* fetch for non-critical resources to be used later. Requests kicked off by `rel=prefetch` occur when the browser is idle.

2. `rel=preload` (https://www.w3.org/TR/preload/) is a *high priority* fetch for critical resources used by the current route. Requests for resources kicked off by `rel=preload` may occur sooner than when the browser would otherwise discover them. Preloading is *super* nuanced, though, so you'll want to check out this guide (https://developers.google.com/web/fundamentals/performance/resource-prioritization#preload) (and potentially the spec (https://www.w3.org/TR/preload/)) for guidance.

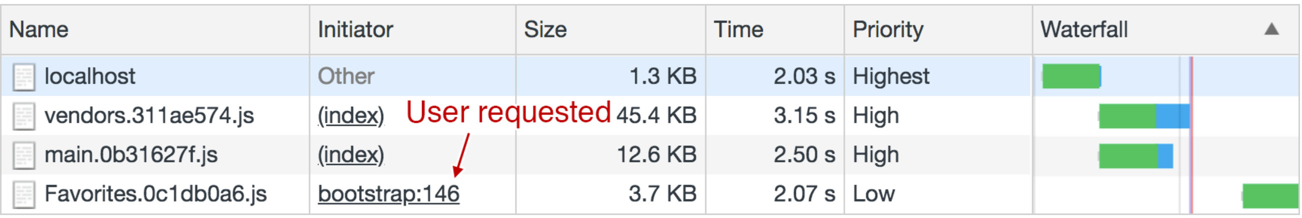
If you want an in-depth explainer on these resource hints, read this article (https://medium.com/reloading/preload-prefetch-and-priorities-in-chrome-776165961bbf). For the sake of this guide, though, I'll limit guidance in this area as it applies to webpack.

Prefetching

It may be reasonable to prefetch scripts for routes or functionality you're reasonably certain users will visit or use, but have not yet done so. A good use case for prefetching in this guide's example app occurs where we mount the app's `Router` component in the *index.js* entry point:

```
render(<Router>
  <Search path="/" default/>
  <AsyncRoute path="/pedal/:id" getComponent={() => import(/* webpackChunkName
  <AsyncRoute path="/favorites" getComponent={() => import(/* webpackPrefetch
</Router>, document.getElementById("app"));
```

Here, we've added the `webpackPrefetch` inline directive (in addition to `webpackChunkName`) to the `AsyncRoute` for the favorites page. If no prefetching was done for the scripts on this route, a user requesting them could experience latency like this:



Name	Initiator	Size	Time	Priority	Waterfall
localhost	Other	1.3 KB	2.03 s	Highest	
vendors.311ae574.js	(index)	45.4 KB	3.15 s	High	
main.0b31627f.js	(index)	12.6 KB	2.50 s	High	
Favorites.0c1db0a6.js	bootstrap:146	3.7 KB	2.07 s	Low	

Figure 7. A request for scripts for the favorites route on a throttled (Slow 3G) connection.

On a slow connection, the user may have to wait for a few seconds before the scripts for the favorites route finally arrives. Using `webpackPrefetch`, though, we can make this less painful and idly prefetch that JavaScript when the user first lands on the app:

Name	Initiator	Size	Time	Priority	Waterfall
localhost	Other	1.3 KB	2.03 s	Highest	
vendors.39caf6a7.js	(index)	43.2 KB	3.18 s	High	
main.205dcea8.js	(index)	15.3 KB	2.60 s	High	
Favorites.0c1db0a6.js	bootstrap:36	3.7 KB	2.07 s	Lowest	
Favorites.0c1db0a6.js	bootstrap:161	(from disk cache)	2 ms	Low	

prefetch request
user request

Figure 8. A request for scripts for the favorites route is prefetched after the initial route loads. When the user explicitly requests it, the browser immediately pulls it from its cache.

Prefetches are generally low risk, as they don't significantly contend for bandwidth since the resource is fetched during idle time with low priority. That said, the potential to waste bandwidth is there, so you'll want to make sure whatever you're prefetching has a reasonable chance of being used.

Note: If you want to see how this all works, check out the webpack-dynamic-splitting-prefetch branch (https://github.com/malchata/code-splitting-example/tree/webpack-dynamic-splitting-prefetch) of the code!

Preloading

Preloading is similar to, but ultimately different than prefetching. The `webpackPreload` inline directive can invoke a preload much the same way `webpackPrefetch` does for a prefetch. In my admittedly anecdotal experience, however, using `webpackPreload` to preload dynamic imports is roughly as beneficial as simply bundling all functionality for a given route into one large chunk.

Preloading, in my opinion, makes the most sense for scripts critical to rendering the initial route. Twitter does this to speed up loading of the Twitter Lite (https://mobile.twitter.com/home) app:

```
<link rel="preload" as="script" crossorigin="anonymous" href="https://abs-0.twimg.com/responsive-web/web/ltr/runtime.e09be5e3da8a16b2.js" nonce>
<link rel="preload" as="script" crossorigin="anonymous" href="https://abs-0.twimg.com/responsive-web/web/ltr/vendor.a682d78892de8f8b.js" nonce>
<link rel="preload" as="script" crossorigin="anonymous" href="https://abs-0.twimg.com/responsive-web/web/ltr/i18n/en.01e13c1caf8b63d7.js" nonce>
<link rel="preload" as="script" crossorigin="anonymous" href="https://abs-0.twimg.com/responsive-web/web/ltr/main.952af1b56585b8dd.js" nonce>
```

Figure 9. Twitter Lite DOM snapshot in DevTools revealing several preloaded JavaScript resources.

Unfortunately, `webpackPreload` only works with dynamic `import()` calls, so in order to preload chunks critical to the initial route in the example app, we need to rely on another method involving a plugin called preload-webpack-plugin (https://github.com/GoogleChromeLabs/preload-webpack-plugin). Once this plugin is installed, we bring it into the webpack config like so:

```
const PreloadWebpackPlugin = require("preload-webpack-plugin");
```

Then we configure the plugin to preload the **`main`** and **`vendors`** chunks by adding an instance of the plugin to the **`plugins`** array:

```
plugins: [
  // Other plugins omitted...
  new PreloadWebpackPlugin({
    rel: "preload",
    include: ["main", "vendors"]
  })
]
```

This configuration will place preload hints via **`<link>`** elements in the **`<head>`** for both the **`vendors`** and **`main`** chunks.

```
<link as="script" href="/js/main.dffbeb06.js" rel="preload">
<link as="script" href="/js/vendors.7952b536.js" rel="preload">
```

Figure 10. Preload hints added to the **`<head>`** of the document for the **`main`** and **`vendors`** chunks as seen in DevTools.

While this doesn't confer much of a performance boost in the example app, it *can* boost loading performance in apps where there are many chunks of JavaScript and other resources that would otherwise contend for bandwidth. To see preloading in action in the example app, check out the webpack-dynamic-splitting-preload branch (https://github.com/malchata/code-splitting-example/tree/webpack-dynamic-splitting-preload).

Note: preload-webpack-plugin *must* be used with html-webpack-plugin! When adding it to your **`plugins`** array, be sure to place it *after* the last instance of html-webpack-plugin.

Conclusion and resources

There's no doubt that code splitting is tough. What's more, *how* you'll split code in your specific app will take time for you to figure out. If you want to know more, or just want different takes on the subject, check out this list of resources:

- Official webpack code splitting docs. (https://webpack.js.org/guides/code-splitting/)
- Official Parcel.js code splitting docs. (https://parceljs.org/code_splitting.html)
- Official React code splitting docs. (https://reactjs.org/docs/code-splitting.html)

- [Official Vue code splitting docs.](https://vuejsdevelopers.com/2017/07/03/vue-js-code-splitting-webpack/) (https://vuejsdevelopers.com/2017/07/03/vue-js-code-splitting-webpack/)
- [Official Angular code splitting docs.](https://angular.io/guide/lazy-loading-ngmodules) (https://angular.io/guide/lazy-loading-ngmodules)
- [Dynamic import() guidance here on Web Fundamentals.](https://developers.google.com/web/updates/2017/11/dynamic-import) (https://developers.google.com/web/updates/2017/11/dynamic-import)

Rest assured, though, that code splitting will improve performance for your app, which will reap rewards as users will find your app more engaging and easier to use. Good luck!

Special thanks to Patrick Meenan, Jason Miller, Jeff Posnick (https://developers.google.com/web/resources/contributors/jeffposnick), *Sam Saccone, Philip Walton* (https://developers.google.com/web/resources/contributors/philipwalton), *for their valuable feedback, which significantly improved the quality of this article.*
