Browsernative Microservices

Jan Peteler, FH Würzburg-Schweinfurt, jan.peteler@student.fhws.de

Januar 2017

Abstract

Building complex web applications nowadays require additional layers of abstraction and often heavily depend on indispensable frameworks. While they perfectly circumstance the global paradigm of the DOM they remain highly proprietary attached to the framework. New w3c specifications build right into the browser provide a native service API in the need to create standardized web components for the browser. As of 2017 all major browsers will ship those technologies in their browsers. The paper not only provides an introduction to the specification. As an assessment criteria of it will match those specifications against the concept of microservices which is an modular system architecture to build scalable applications.

Contents

1. Simplicity and the web

Simplicity is prerequisite for reliability. - Edsger W. Dijkstra

Computers can scale, humans can't. Ever since complex systems made by humans have been constrained by humans mental capabilities. Like in the analogy of juggling balls our brain can just "juggle" a few items at a time. Rich Hickey, the inventor of the programming language Clojure gave an inspirational keynote on the topic of **simplicity**.[1] In every sphere of a human's life simplicity aligns perception with mental capacities.

Derived from the Latin word **simplex**, *simple* can be understood as "literally, uncompounded or onefold"[1] which points towards an unidimensional state. While complexity describes the multilayered und entangled nature of conditions simplicity empowers the human brain to reason about issues straightforward. It certainly has some overlappings with *easy*, but while *easy* is more of a relative spirit, *simple* can be laid out as an objective manner and therefore universally applicable.

Software development is undoubtedly rich in complexity and full of subtle pitfalls. In a typical scenario a growing software project evolves in one or another opinionated direction over time. Layers of abstractions wrestle against aged legacy code requiring additional middleware. Mutating assets create subtle bugs and so forth. Eventually the small piece of software may end up in a highly complected monolith which will determine future design decisions to a painful degree. Opaqueness of the system will slow down innovation to a minimum in the need of 'keeping the lights on'.

On the other side of this dystopian scenario a truly modular system architecture abandons many of those potential inconsistencies. The whole system is divided in pluggable parts, object mutation is either traceable or avoided altogether in favor of immutable data structures. As Rich Hickey argues, design decisions should be made under the **impression of extending, substitution, moving,**

[1] Etymology Dictionary

combining and repurposing.[1] The ability to reason about the program at any given time is crucial for future decisions and implementations, recalling the unidimensional nature of simplicity.

Simplicity in 'the web', read as a loose generalization of 'everything that runs in the browser' is certainly a story full of misconceptions. While simplicity in the backend is mostly a matter of principles and patterns, any browser-based frontend is restricted on the highly deterministic nature of the browser platform.

In the last four years the average transfer size of a webpage doubled to currently around 2.5 MB.[2] Leaving images, fonts or other content aside, the size of HTML, CSS and JS sums up to a total average of 550 KB. One character weights around 1 byte which means an average webpage is delivering 550.000 characters or around 125 pages of single-spaced text. Frederic Filloux analyzed the payload on different newspaper websites and came to the conclusion, that only roundabout 5-6 % of the transferred characters are made for human consumption.[2]

Having a 95 % overhead is rather undesirable for both the consumers and the creators of the website. Since it is a widespread problem without a definable point of failure one can argue 'the platform itself' is the failure. By design, every pageload results in a monolithic DOM tree managed by the browser engine. Whether rendering just a bunch of static text nodes or an ever changing webapp, the underlying global nature of the DOM tree remains the same. Every additional piece of code added to the webpage will invisibly add another fold of complexity to this global object.

In a non-deterministic runtime environment, encapsulation and modularization is a typical pattern to make complexity manageable and to accommodate future uncertainty.[3, p. 1] Since years the average JS payload is steadily rising which can be interpreted as a trend towards more dynamic websites. The demands to the browser platform have changed from a static page renderer to a **dynamic UI machine** without significantly changing the underlying architecture. Under the current situation only additional layers of abstraction can handle complexity.

In the recent years many **frameworks**, libraries and methodologies approached the global nature of the DOM by scoping assets and design rules into maintainable components. While the DOM cannot be scoped, JS can. Many frameworks like React, Angular or Vue, just to name a few, ditched the old rule of separated HTML, CSS and JS in favor of an additional layer of abstracted JS components. Quite often those frameworks mimic a MVC pattern on top of the browser engine which is a reasonably simple pattern to build UIs. While frameworks are a valid approach for building scalable web applications they remain highly opinionated, embody inherent complexity themselves and can change and break over time. Another drawback is code inflation which is a crucial point for performance. All of those bottlenecks in the web demand for a new standardized ways for creating and evolving complex web services.

[2] HTTPArchive Trends

In the year 2013 thinkers, creators and browser vendors joined together to propose *The Extensible Web Manifesto*.[3] The claim of the manifesto was to enhance the current web platforms with new low-level capabilities. Those capabilities aimed to empower creators of the web to write more declarative code and to abandon artificial abstractions. Four years later, the enhancement of JavaScript leapfrogged and many new low-level APIs were brought to life. With this new APIs at hand, a progressive web developer can create robust websites with less code and less additional libraries. This paper is an approach to unfold these **browsernative** technologies to create overall simple and resilient **microservices** for the browser

2. Microservices

In search of a better, simpler web architecture one might look on already established patters proofed to fulfill enterprise needs. Microservices are a good approach for tearing big monolithic systems into fine-grained simple services with explicit defined boundaries. In a nutshell a microservice is a small, autonomous service that works together with other services seamlessly.[4, p. 2] Or with the words of Fowler and Lewis: "... the microservice architectural style is an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms, often an HTTP resource API."[5] Yet at this point a reader might spot some similarities with microservices and the browser-based development: Both wrestle with the problem of monolithic architecture and both use lightweight communication mechanisms. In fact, many big companies of 'the web' like Amazon or Netflix successfully transformed their monolithic system into a service based system which gives a taste of the power behind microservices.[5]

Microservices incorporate a wide array of ideas from developing scalable software like **domain-driven design** to pursuing the real world structure in the code.[4, p. 2] Another concept focuses on **continuous delivery** for pushing software rapidly through **automated deployment** mechanisms into production.[5] Furthermore, microservices transcend the technical perspective and reach into team organization.

As a primary source of comprehensive information this paper relies on the work of Sam Newman[4] and the work of Fowler and Lewis[5]. The purpose of this section is to develop confidence about the architecture of microservices in the context of the browser platform.

[3] The Extensible Web Manifesto

2.1. Componentization via Services

"A **component** is a unit of software that is independently replaceable and upgradeable." [5] Components are the building blocks of microservices. And microservices are the building blocks of applications. Essentially the difference between microservices and components is just the level of abstraction. Whether a concrete microservice or a much more generic component, both share a similar set of principles. Therefore this paper refers to both parts when talking about **services**.

The first principle of services is the **loose coupling principle**: changing and deploying one service should not result in changing other parts of the system.[4, p. 30] Picking CSS for example, where variables tend to be shadowed by higher specific values making it increasingly difficult to keep changes, ought to merely affect one place in the application. Therefore a *browsernative microservice* is expected to push encapsulation and to avoid variable mutations outside its scope as much as possible. One solution would be scoped CSS / JS to avoid variables leaking into the global namespace, as well as to hide implementation details in order to avoid mutating values.

The second principle of services is the **high cohesion principle**: Whether designing a microservice or its components, we want related behavior sit together and unrelated behavior to sit elsewhere.[4, p. 30] High cohesion can be enhanced towards the more dynamic **Single Responsibility Principle**: "Gather together those things that change for the same reason and separate those things that change for different reasons."[6] In a very quick and dirty code quality analysis, the quality can be measured just by counting the code changes which occur in order to implement a new functionality. An arbitrary threefold MVC system should require a maximum of three changes to implement or change functionalities. The problem in browser based development is not only the global paradigm which makes changes deliberately unpredictable. The high cohesion principle is violated by the traditional separation along the siloed entities HTML, JS and CSS. Understanding the relation of HTML markup towards another CSS file generates incidental complexity. Different approaches emerged over the recent years to join these entities. A *browsernative service* sought for a combination of the web native trinity HTML, JS and CSS.

Traditional web development relies on libraries to enhance the service capabilities of the web platform. Compared to libraries a component service offers multiple advantages for building, deployment and shipping. As expressed earlier *components for the web*, or web components, are self-contained which means they embody all needed functionality to get their job done. Therefore they have a much better evolution mechanism in the service contracts. Changing functionality will not break other services. A component can be progressively enhanced which guarantees functionality throughout different versions whereas a library is only loosely coupled to the implementation and therefore hard to track in functionality. Changing a library may result in an unforeseen amount

of time fixing implementations. It is not unusual to see websites embodying different versions of the same library to guarantee functionality which lowers page performance significantly.

Another issue where web components stand out is related to performance and especially the critical first page rendering. Libraries for the browsers are traditionally 'shipped' as non static immediately-invoked functions. Following the Google RAIL model, a user-centric performance measurement, a page load ought to take less than 1 second to catch up users' attention.[7] There are many ways to optimize the critical first render but as a rule of thumb a build-in web component might be always superior to libraries in terms of first rendering. The fine-grained lifecycle methods which will be described in the technical section of this paper give the developer far reaching optimization opportunities.

The last argument in favor of components over libraries is the more explicit interface.[5] While the functionality of a library needs documentation to be accessible, a component functionality is exposed via the components' signature. HTML markup is an expressive syntax and therefore convenient for steering a web component using merely attributes and values.

2.2. Organized around Business Capabilities

> "organizations which design systems ... are constrained to produce designs which are copies of the communication structures of these organizations". [8]

Emphasizing the human factor in microservices is a key feature. Microservices are a product of real-world usage.[4, p. 1] Instead of splitting the team along the technology stack (UI Experts -> Middleware -> Database) a microservice approach models teams around **business capabilities**.[5] Consequently every team is capable of planning, designing, implementing, testing and maintaining their very own microservice. Along the technology stack every member gains high competence in the service architecture which can be positive for evolving the service over its whole lifecycle.

Real-world domains tend to be complex and multifaceted. To unfold their complexity, domains can be subdivided into **bounded context**.[4, p. 31] For example, customer service is a business domain but with varying bounded contexts. One context can be sales, another context could be support etc. Every context makes different assumptions about the underlying model and draws an explicit interface where it decides what to share with other contexts.[4, p. 30] Evaluating each bounded context within each business domain will eventually shape the data persistency model likewise the interface to the service. This methodology can be iterated over and over again. A sales service for example might be evaluated to different sales contexts resulting in differing interfaces on differing devices shaped by browsernative microservices. By dividing the service

into clear defined business boundaries it becomes easier to define a smart API of the service.

Assigning service responsibility to a team, the so called **Definition of Done** shifts from 'accomplishing projects' to 'accomplishing products'. This new paradigm not only changes the administrative overhead like budgeting or resource allocation. Furthermore, it creates a kind of responsibility connection from the team to the service which can be best described as **shared governance** model. "Each team collectively share responsibility for evolving the technical vision of the system."[4, p. 247] Expectedly, those teams are more motivated within their very own service and exhibit a more sophisticated iteration time.[5]

For many companies working in the spheres of the internet, the client side is highly important for their business. In fact, business goals and capabilities can be derived from frontend needs. The state of the web is not only a story of numerous artifacts, it is also a story of a highly fragmented market along devices, operating systems, differing sizes and functionalities. Different devices again have different assumptions about the technology stack. Splitting teams along the stack results in an slow paced back and forth negotiation about every change to be made can result in prolonged and therefor expensive iteration. As browser technologies, design guidelines and devices change rapidly it makes sense to shift responsibility towards the team altogether.

2.3. Smart endpoints and dumb pipes

To ensure the microservice functionality among teams and different services requires thoughtful decentralization. Emphasizing once more the real-world capabilities of microservices a message channel architecture can be derived from patterns known from traditional postal services. A physical letter has only two smart endpoints, entitled to read and process the message while packaging as well as the connection itself is mostly standardized. **Smart endpoints and dumb pipes** is coined to the approach of designing communication mostly decoupled and as cohesive as possible.[5] Applying these rules to the web platform can result into building unified JSON message objects passed along 'dumb' middleware components. A typical browser event comes close to this definition and suits arguably well for in-memory communication between web components and microservices.

Microservices heavily rely on simple HTTP request-response with resource APIs and lightweight messaging.[5] Newman recommends technologic-agnostic REST APIs to free data persistence from implementation constraints.[4, p. 247] The advantage of this overall simple communication model is the suitability for both frontend-backend likewise backend-backend communication. A service therefore can evolve from a heavy backend with a lot of network roundtrips to a leaner backend seamlessly. The browser build-in **fetch API** which is essentially a HTTP request can be heavily incorporated into a browsernative microservice to

ensure communication to services in the backend.

2.4. Decentralized Governance

Microservices are separate entities and decentralization is important to ensure autonomy. This paper already described fragmented services bounded to singular business context, choreographed by simple communication protocols developed and evolved by autonomous teams.

This distributed nature empowers teams to create their own technology stack, tools and services designed in the spirit of language- and platform independence and to share their knowledge across other parties.[5] In the recent years many big companies like Facebook, Google, Netflix and others followed that spirit and published their ideas and implementations open source. The previously mentioned React for example is a product of Facebook's need to ensure a consistent frontend experience. In fact, many tools and techniques are byproduct of vital interaction of specific domain problems and their solutions.

The spirit of freedom cannot be applied universally to *browsernative microservices* as the browser and its underlying DOM will, to a certain degree, be the limiting factor. Talking about the browser, a reader might be falsely tempted to narrow his perception towards the obvious VIEW layer only. In recent years the major browser engines have grown to fully-fledged app deployment platforms offering connectors to build-in databases, multithreading support and ever-growing JS build-ins like speech synthesis or push notifications. So-called **Progressive Web Apps**[4], a bunch of criteria for building good browser apps, can achieve a similar look and feel like native apps. And last but not least services like NativeScript[5] effectively compiling 'the web' to native machine code lower the boundary between native and browser code even further.

JS is the widely accepted language of the web. Nevertheless, a microservice engineering team might choose another language for various reasons. Transpiling languages to JS as target language is a stable solution nowadays. Languages like TypeScript, ClojureScript or PureScript compile to JS even exclusively. Once web components hit a critical mass there will be most likely some library support or foreign function interface towards ES6 modules, which are mandatory in the new specifications.

Another more real life decentralization aspect derives from the easiness of deployment in a safe, sandboxed environment. Web components virtually ship no overhead or require dedicated build tools. This makes them ideal candidates for sharing and open source publishing similar to the largest JS package registry NPM. In the spirit of NPM web components can be perceived as frontend packages with an HTML interface instead of a JS signature. Webcomponents.org

[4]Progressive Web Apps
[5]NativeScript ## 2.5. Decentralized Data Management

is a registry for ready-to-use components of every scale and purpose where even Google shares a lot of their material design elements.

Data Management in a microservice follows the same modular philosophy as the service implementation. As mentioned before, different bounded contexts make different assumptions of the underlying models. Decentralized decisions about conceptual models demand decentralized data storage decisions.[5] Todays web architectures aim to leverage an increasing amout of **processing to the client** to avoid time-consuming roundtrips especially in mobile networks.[9] Since network roundtrips are costly it is a good advice to only query as much data as needed and cache as much as possible. The build-in LocalStorage or its successor IndexedDB are mature persistence technologies and libraries like PouchDB[6] even offer adapters for syncing to the server out of the box.

"Microservices prefer letting each service manage its own database."[Fowler2014] Ben Issa, chief architect of ING Australia emphasizes this pragmatism on APIs in a conference talk. At ING the frontend demands tailor the backend APIs. APIs may be produced automatically and not even Issa knows how many APIs exists.[10] At ING, they are using a pattern called **backends for frontends** empowering the team to craft their UI and backend in a one-to-one relationship.[4, p. 72]

To see this pattern in the field a reader might have a look at Facebook's GraphQL[7]. GraphQL is a query language for the frontend. The backend solely replies to the frontend needs. Another well documented example in the field is Cognitects Datomic[8], where parts of the database will be reflected to the client. A so-called Transactor ensures ACID compliance.

The simplified microservice example later in this paper assumes a generic build-in API accompanied by build-in frontend components. Instead of gluing frontend and backend together on runtime the microservice is designed holistically containing both front- and backends. For the sake of simplicity data management will not be explored into depth throughout this paper.

2.6. Infrastructure Automation

Microservices tend to increase complexity as this model adds a sheer number of moving parts to the system which requires proper orchestration.[4, p. 246] Arguably every sophisticated web developer already came across build tools like Webpack or infrastructure automation tools like Gulp. Therefore, testing and deploying web components should not be an obstacle in development.

In the global nature of web development the development could not be completely decoupled from the production environment. This circumstance left developers

[6] PouchDB
[7] GraphQL
[8] Datomic

switching back and forth between files developing tricky opinionated (and more often biased) ways to glue related parts together. Bret Victor, UI designer at Apple defined the importance of an **immediate feedback principle** for developing user interfaces.[11] In his talk he emphasizes the importance of an immediate connection between the creator of a product and the product itself. Any change must result in an immediate visible feedback. Web components catch up with this principle as they allow isolated development within a single file containing all bits and pieces of a single service. Every major browser devtool offers a direct file manipulation functionality, so development can be even in place.

When it comes to standardized development previously mentioned, Ben Issa described the ING standard workflow as follows. Every component is packed in its own **git repo** containing:

- Internationalization conformity (i18n)
- Accessibility conformity (a11y)
- Tests for the component
- Demos of the component
- Blueprints to mock the one to one APIs
- Docs

Even though this example is an opinionated perception it gives a sense of a mature component built for the web. This example should illustrate that all parts of the component put together in one place as well as tests, demos and blueprints are part of the component from day one. Every check-in is handled as a release candidate and can be independently tested and deployed by a fully automated machinery.[10] Due to an exhaustive amount of testing and deployment tools for JS an automated infrastructure should not be an obstacle.

2.7. Design for failure

In theory a microservice is designed with focus on monitoring of both the architectural elements and business relevant metrics.[5] Due to the modular structure, weak points can occur in the orchestration of the services. A microservice should track down every communication flow and provide defaults and meaningful error messages where communication might stuck. Testing every single component with predefined synthetic events ensures functionality. Nevertheless, browser support may vary and legacy browsers remain a general problem for enhancing websites with new technologies and therefore demand further configuration.

Combination of different resources in the browser always demand optimization to avoid unexpected side-effects like *flash of unstyled content*. Googles Polymer propagates a general-purpose pattern called **PRLP**[9]:

- Push critical resources for the initial route

[9] PRLP pattern

- Render initial route
- Pre-cache remaining routes
- Lazy-load and create remaining routes on demand

Following this pattern a critical resource can evaluate browser maturity beforehand and switch to a **polyfill** or another fallback solution instead of the latest browser optimized version. After the initial paint, critical resources like top-level microservices or related parts can be loaded and registered.

Regarding the evolution of the web, the 'next billion' internet users will most likely use Android, have decent specs mobile phones, use an evergreen browser but won't have a reliable internet connection.[12] While **Progressive Enhancement** was once related to build websites both for browsers with and without JS support, the demands have changed towards an **offline first** principle avoiding network connectivity failures.[12] A *browsernative microservice* therefore not only tries to cache data as much as possible, it should also bring in a lot of program logic as described in the previous chapters.

2.8. Evolutionary design

Microservices tend to become smaller over time. An evolutionary design approach emphasizes decomposition and scrapping the service. "The key property of a component is the notion of independent replacement and upgradeability."[5] Therefore we can safely change and chop services. Lazy components of the system which will not change often should be separated from parts undergoing a lot of churn.[5] Services which change for the same reason might be moved together or even could be merged.

Pursuing flexibility in web development is a selling point as innovation cycles in browser development are fast and technologies can change quickly. Frontend related hardware, software and methodologies innovate rapidly over time.

Browsernative microservices should be perceived as complementary technology in contrast to full-service frameworks like Angular. Being a native technology, they pursue a strong interoperability approach to existing systems. Andrew Rota, for example, came up with a pattern using small, encapsulated and stateless web components as leaves in the tree of React components instead of native HTML elements.[13] Even React can eventually profit from the expressiveness of custom components using a custom `<meaningful-button>` over a native `<button>`. Most likely there will always be some cutting edge framework promising advantages over native code. Whatever new framework will be on the rise within the next years, native components can eliminate future uncertainty, allowing rapid reassembling towards new architectures.

3. W3C specifications

Building a native microservice running on the 'bare-metal' browser engine requires a bunch of new specifications and assumptions. Most importantly multiple **Web Components** specifications are needed. Web Components is not a single standard. They are a kind of amalgam of combined APIs from multiple w3c specs which can be used independently. A web developer may choose one spec which can be combined with other frameworks.

Depending on the context, some people argue for only two specs which essentially make it possible to create a scoped component but do not care about its distribution[14]. Some people prefer three specs [15], but the majority advocate the four specs variant, which is listed on the quasi-official webcomponents.org website. For the purpose of this article, the four specs variant will be discussed briefly to provide a rough understanding.

Disclaimer: This paper introduces many new browser build-ins with the focus on accessibility. At the time of writing, all examples can be tested in the console of the latest versions of **Google Chrome, Opera and Apple Safari**.[10] On Mozilla Firefox they could be manually enabled. However, browser implementation changes quickly and soon technology adoption will not be an issue in all major browsers. Meanwhile all new standards can be used through **polyfills** even on legacy browsers.

3.1. Custom elements (whatwg)

Custom elements are the fundamental building blocks for web components introducing the **Single Responsibility Principle** to the browser. In short, they provide a way to create custom HTML tags subsuming behavior, design and functionality. An obligatory **HelloWorld** will give a flavor about the spec:

```
> HelloWorld.js
class HelloWorld extends HTMLElement {
 constructor() {
  super(); // mandatory in constructor
  this.onclick = e => alert("hello");
 }
}
customElements.define('hello-world', HelloWorld)

> index.html
<hello-world>say hello</hello-world>
```

This example should be almost self-explanatory in functionality. *Custom elements* come in the fashion of ES6 Classes in favor of the JS prototype-based inheritance

[10] Are we componentized yet?

model which was part of an older specification. Every valid element must **extend the base `HTMLElement` interface** which "ensures the newly created element inherits the entire DOM API and any properties/methods that you add to the class become part of the element's DOM interface."[16] Like any other ES6 class any *Custom element* can be specialized further using the typical inheritance model allowing higher levels of abstraction.

The beauty of *custom elements* comes with the **bounded `this` keyword** which points to the element itself. Instead of querying and assigning behavior after creation of the node, custom elements ship their functionality on initialization of the element. The so called *fat-arrow* (`=>`) is just a new ES6 syntax feature for an anonymous function declaration.

After declaration the new HTML element needs to be registered in the global build-in `customElements` object with a dedicated tag name acting as key to the element. Mind the dash inside the tag name to conform the spec. Finally, the new element can be mounted inside the HTML document.

3.1.1. Lifecycle methods

In addition to the constructor which runs procedures on initialization, the spec defines **lifecycle callbacks** for controlling elements' behavior towards DOM interaction. Many popular frameworks like React or Angular rely on similar approaches:

- connectedCallback()
  called upon the time of **connecting or upgrading the node** which means the moment the node is rendered inside the DOM. Typically this method is called straight after the constructor, if the node is inserted directly. For a faster initial render of the page it is highly preferable to put many proceedings in this method. Usually this method contains setup code such as fetching resources or rendering elements according to attributes.[16]
- disconnectedCallback()
  called upon the time of **node removal**. Cleanup code like removing event listeners or disconnecting web sockets can be put here.
- attributeChangedCallback(attrName, oldVal, newVal)
  This method provides an **onchange handler** for certain elements' attributes. This method is used to guide elements' transition from an old value to a new state. Due to performance issues this callback is only triggered for attributes registered in a dedicated array shipped with the element.
- adoptedCallback()
  called when moving the node **between documents**. This method comes handy when using HTML Imports described later.

3.1.2. Custom attributes

As mentioned before any custom element must extend the `HTMLElement` interface ensuring base properties and methods used throughout all HTML elements like id, class, addEventListner etc. Additionally, it is possible to define custom attributes using the *custom elements'* **getter / setter interface** to steer the behavior of the element. Note that the get/set keywords as well as the previously used constructor are optional!

```
> HelloWorld.js
class HelloWorld extends HTMLElement {
  set sayhello(val) {
    this._hello = val;
  }
  get sayhello() {
    return this._hello;
  }
}
customElements.define('hello-world', HelloWorld);
// Instantiation via JS instead of HTML
var el = new HelloWorld();
el.sayhello = "earth"; // "Call" the setter
el.sayhello;// Yields "earth"
```

Native DOM properties always reflect their values between HTML and JS.[17, Para. 2.6.1] Declaring `<hello-world id="hello">` equals to the JS declaration `new HelloWorld().id = "hello"`.

This behavior will not work out-of-the-box with methods defined by setters as they are strictly JS. Mounting `<hello-world sayhello="mars">` would not result in calling the `sayhello` method in the previous setup. Value reflection can be implemented inside *custom elements* using the native methods `getAttributes` and `setAttributes`. Using them exhaustively throughout lifecycle methods the new components can be configured to read and listen to HTML attributes accordingly.

Designing a *custom element* this way creates HTML elements with named attribute interfaces reaching deep into JS functionality. With this mental model in mind a web developer can create highly dynamic web components.

3.1.3. Customized build-in elements

One aspect not mentioned yet is the possibility of extending other build-in elements by extending other interfaces instead of the `HTMLElement` interface. While this functionality is perfectly spec'd it is strongly rejected by some browser

vendors.[11] Most likely the spec will change in future in one or other direction concerning this issue and therefore customized build-in elements are left out in this paper intentionally.

3.2. Shadow DOM (w3c)

A *shadow DOM* is just an isolated DOM tree living inside another DOM tree. The spec refers the hosting tree as **light DOM tree** and the attached DOM as **shadow DOM tree**. Conceptually *shadow DOM* issues a single important function for building scalable software which is namely **encapsulation**. While custom elements provide a good way to encapsulate JS behavior *shadow DOM* tends strongly to the direction of style and event encapsulation.

With an ever increasing complexity of single-page applications the global nature of the DOM creates a daunting situation for code organization and leads over times to highly fragmented bits of CSS or obscured CSS selectors. Of course this situation dramatically lowers code clarity and reusability. The only solution which will not break with the existing global paradigm of the DOM is to allow separate pieces of encapsulated code sit on top of the global DOM - introducing the shadowed DOM approach.

Enhancing the previous example the new encapsulated `HelloWorld` would look like the following code snippet:

```
> HelloWorld.js
class HelloWorld extends HTMLElement {
 constructor() {
   this.attachShadow({mode: 'open'});
   shadowRoot.innerHTML = '<p>hello</p>';
 }
}
```

The new global method `attachShadow` adds a new document root to the `HelloWorld` which has the same properties as a normal, light document object. Note that the `shadowRoot` object is **marked as open** which ensures that some events can bubble out and outer JS can capture the new root.

Filling the *shadow DOM* with an `innerHTML` string is rather impractical. To fill a *shadow DOM* with life, it usually pulls light DOM child nodes nested under the hosting node using a technique called `slots`.

3.2.1. Slots

Contradicting the simplified `HelloWorld` example, a *shadow DOM* should not contain dynamic content. Changing or interacting with the paragraph node from

[11] https://github.com/w3c/webcomponents/issues/509

the previous example would require nested JS calls querying the hosting node, entering the *shadow DOM* and applying a function. Imported JS behavior from third-party libraries in the *light DOM* cannot easily reach inside the *shadow DOM*, too.

This is the reason why the shadowed document root should rather be perceived as **static document** filled and managed solely by the render engine. `Slots` are target areas for *light DOM* nodes used to mark the endpoints in question.

```
> index.html
<HelloWorld-with-ShadowDOM>
  <!--
    All child nodes will be moved inside the
    shadowRoot if shadowRoot.innerHTML = '<slot></slot>'
    -->
  <p>hello I will be scoped</p>
</HelloWorld-with-ShadowDOM>
```

From a technical perspective, the *light DOM* nodes are not moved inside the *shadow DOM*. They are just rendered in place. This is a subtle but important difference towards handling a node. All JS behavior and CSS styles applied in the *light DOM* will be valid in the *shadow DOM*. The render engine literally takes the nodes and drops them inside the `slot` tag. This procedure is commonly referred as **flattening** of the DOM trees.

It is possible to add semantics to the *shadow DOM* in naming the slots which free the *light DOM* from the responsiblity to deliver nodes in a correct top-to-bottom order. Combining *shadow DOM* with HTML templates equips the web developer with a flexible **HTML template engine**.

FROM: light DOM	TO: shadow DOM
`<p slot="hello">Named</p>`	`<slot name="hello">hello only</slot>`
`<p>Unnamed</p>`	`<slot>Unnamed nodes</slot>`

Writing a little documentation inside the `<slot>` tag is considered as a good practice as it provides the developer with visual clues about what nodes must be delivered. This functionality makes a *shadow DOM* pretty much self-explanatory. Inside a default slot tag the render engine expands all *light DOM* children without a named `slot` attribution.

3.2.2. Styling

As mentioned in the last section, there is a distinct difference between nodes. Nodes declared and rendered exclusively in the *shadow DOM* are not affected by any styling from outside. Nodes which are distributed will be styled in the *light DOM* and can be additionally painted in the *shadow DOM*.

Note that styles from the outside have an higher specificity than styles assigned after distribution. Therefore it is generally a good advice to minimize the global stylings to some base stylings for uniformity of the web site while leaving the specific stylings to the component. It is possible to **reset all styles** inside the *light DOM* before distributing nodes using the `all: initial` reset. To ensure a consistent look between different shadow roots this technique should be used carefully.

Regarding the importance of style encapsulation, a couple of **new CSS rules** emerged that are exclusively targeting the *shadow DOM*. The points below outline styling possibilities for the use INSIDE the *shadow DOM*:

- ::slotted(selector)
  applies to distributed nodes and repaints them after distribution. Slotted will not override outsides styles but can complement previously unset style rules.
- :host
  The host property will add styles or change inherited ones inside shadow DOM. Aforementioned style resets can be placed here.
- :host(condition)
  Like the previous rule this selector will style the shadow DOM but this time based on attributes/conditions assigned to the hosting node.
- :host-context(condition)
  Like the previous rule this selector will style the shadow DOM but will look after context set at the host node or even at the host ancestor.

Using the **functional selectors** `host()` or `host-context()` allows the creation of context-aware custom elements. A possible usecase would be 'theming' a component.

3.2.3. Behavior

As mentioned before, any logic applied to *light DOM* nodes stays within the node even after redistribution. For the sake of separation of concerns the business logic should be part of the custom element (the *light DOM*) and not the part of the *shadow DOM*. On the other hand there are numerous scenarios where JS is used for styling or animation of an element. In this case it might be more straightforward to **apply JS inside the *shadow DOM*** to avoid mixing logic handlers with styling.

It seems that a *light DOM* node is in the *shadow DOM* context after distribution. Visually this may be true but logically the node stays in the normal document. To reach a distributed node from the *shadow DOM* to apply some JS behavior for styling, it needs the extra way over the slot node. Calling `assinedNodes()` on the hosting slot element returns a linkage to the distributed node which can be accessed and manipulated like in the *light DOM* context.

Wrapping up this section, *shadow DOM* provides a non-hacky way to create uniform looking custom elements and even enhance styling possibilities without adding overhead. For small components with just a little styling, *shadow DOM* might be over engineered. Eventually it all depends on the question of 'how hard is it to implement it without shadow DOM' - which cannot be answered in general. For a more in-depth guide, Google Engineer Eric Bidelman wrote a primer on *shadow DOM*[18].

There is still a missing link between *light DOM* and *shadow DOM*. The attentive reader may have already noticed the weak point in the HelloWorld example: how to 'vitalize' the *shadow DOM* with slot tags or other element structuring instead of markup strings. While strings work perfectly fine in this simple case a string of markup is rather cumbersome and error-prone and does not scale well. When putting quotes inside other quotes things break quickly. Strings make development harder because code editor features like indentation or syntax highlighting will not be supported. The HTML templates are set to fill this gap.

3.3. HTML templates (whatwg)

Among all other new specifications *HTML templates* are the most mature and adopted standard in the browser environment. All major browsers support it since years.

A core concept in templates is browser performance. Elements inside a `template` tag will be parsed on runtime - but not constructed and rendered into the content tree. They are remaining plain HTML markups sitting in the document until the time of activation.

Activation usually takes four steps:

1. **Querying the template node in question**
   const node = document.querySelector('template');
2. **Parsing the content and preparing the templates' content**
   const content = node.content;
   Returns a DocumentFragment object.
3. **Optional: Cloning the fragment for multiple use**
   const clone = content.cloneNode("deep");
4. **Appending the clone/original to destination**
   document.body.appendChild(clone);

As easy and minimal as *HTML templates* are, they skip a crucial feature other template implementations used to have. As template tags are basically just containers for HTML markup there is no idiomatic way to define **placeholders** for dynamic content. Templates could be mocked up this way using JS for altering the content but a much cleaner way leverages the previously described slot technique from shadow DOM.

```
> hello-world-component.html
<hello-world>
  <template id="hello">
  <!-- styling -->
    <style>
      #hellowrap {
        font-weight: bold;
        color: orange;
      }
    </style>

    <!-- structure -->
    <div id="hellowrap">
      <slot name="placeholder">
        Named placeholder
      </slot>
    </div>
  </template>

  <!-- light DOM / typical inserted at index.html -->
  <p slot="placeholder">
    Hello World Web Component
  </p>
</hello-world>

<script>
  class HelloWorld extends HTMLElement {
    constructor() {
      super();
      this.attachShadow({mode: 'open'});
      const temp = this.querySelector('template#hello');
      this.shadowRoot.appendChild(temp.content);
    }
  }
  customElements.define('hello-world', HelloWorld);
</script>
```

The updated `HelloWorld` component looks already pretty mature. It combines all the previously mentioned standards into one HTML file. Custom elements serve the logic, shadow DOM scopes the styles and *HTML templates* efficiently glue light DOM and shadow DOM together. This separation of concerns comes with a surplus in flexibility. In a real world scenario `HelloWorld` could reference multiple *HTML templates* and switch them around without any fuss. Even further a developer might split up templates into named **STYLE templates and CONTENT templates** to increase reusability even further.

The last standard in the row of four is not concerned with the implementation

of a web component. HTML imports serves the need for an efficient distribution mechanism of components and other HTML resources.

3.4. HTML imports (w3c)

Importing the `HelloWorld` component is a one-liner:

```
> index.html
<link rel="import" href="Hello.html" async>

<hello-world>
  <p slot="placeholder">
    Hello World Web Component
  </p>
</hello-world>
```

The `async` flag is optional but recommended like in any other fetching event. Once the imported HTML document comes into scope, activation follows a very similar process compared to the aforementioned HTML templates:

1. **Querying the link node**
2. **Parsing the content and preparing the render**
   const content = linknode.import; -> Contrary to HTML templates a complete document object is constructed.
3. **Optional: Cloning some nodes for multiple use**
4. **Appending the clone/original to destination**

Again this is the imperative way to handle a generic *HTML import*. In the declarative world of web components a component is **parsed, auto-activated and anchored** solely by its tag name `<hello-world>` on purpose. The very own lifecycle method **adoptedCallback()** in custom elements shows the strong interconnection between those standards.

HTML imports can import everything wrappable in HTML markup. Stylesheets, scripts, documents, media files and even further import statements can form a semantic *HTML import* statement.

The far reaching possibilities of a single standard has its drawbacks. According to Mozilla *HTML imports* are not fully compatible with the dependency model of the new ES6 modules.[12] In the current situation Mozilla, Apple and Microsoft will not implement *HTML imports* soon if any. Only Google's blink web engine supports *HTML imports* as they are the driving force behind the web components specs in general. Despite the discrepancies among browser vendors, *HTML imports* are part of this paper as no other native standard can ship bundled HTML, CSS and JS which is a core concept behind web components.

[12] https://hacks.mozilla.org/2014/12/mozilla-and-web-components/

3.5. CustomEvent (whatwg)

Events are first-class citizens in the browser providing a neat communication channel for dynamic interactions. *CustomEvent* is part of the DOM since years but with the rise of web components it will most likely become an indispensable building block of web components.

```
> hello-world-component.html

<hello-world>
 <button>Launch CustomEvent</button>
</hello-world>

<script>
 customElements.define('hello-world',
 class extends HTMLElement {
  constructor() {
    super();

   // Craft a helloevent
    const helloevent = new CustomEvent('helloevent', {
    bubbles: true,
    detail: 'Contains scalar or object'
   });

   // Launch helloevent if child button clicks
   this.addEventListener('click', click => {
    this.dispatchEvent(helloevent)
    click.stopPropagation();
   })
  }
 });
</script>
```

Naming events after the emitting tag makes the **API almost self-explanatory**. The `detail` property can be loaded with scalars as well as objects. Subsequent parent nodes may catch the custom event with a clear understanding about the source node.

Chaining and aggregating events from child nodes can be frequently used within web components. One use case could be creating a custom button like in the previous example. As mentioned earlier in the Custom Elements section at 3.1.3. , the pattern of **extending native elements** should be dismissed as certain browser vendors imposed distaste towards this functionality. A common workaround to an eventual creation of an extended native element could be made with a thin wrapper around the native element and chaining a *CustomEvent* after the click event.

Another common web components' use case can be a **middleware** subscribing to certain child events and acting upon them. For example embedding another third-party web component or widget which can be wrapped in a middleware component to align it to system conventions. This involves catching events, buffering, destructuring and creation of own events. By design, events only bubble upstream towards parent nodes. For handing down information towards the child nodes we need to query the child node directly.

3.6. Web worker (whatwg)

Like CustomEvent, *web workers* have been around for a long time and therefore enjoy full browser support. They emerged at around 2009 when discussions about browser performance were still in the early days. *Web workers* however addressed a fundamental performance bottleneck of the JS language.

JS runs in a single-threaded language environment. Every script in the browser environment, from handling UI events to query and process large amounts of data or manipulating the DOM runs on a single thread[19]. Putting a lot of work into the single main thread can slow down the web service significantly. From time to time scripts can block or fail for whatever reason which leads to a frozen or crashed UI. A worker can overcome the bottleneck of the single-threaded nature with spawning new **background threads** which allows the UI to stay responsive even when computation-heavy tasks need to perform. Furthermore, a worker adds a performance advantage embracing the multi core CPU architecture most devices are running on today. To grasp the full potential of workers, a reader might dive deeper into the Angular 2 architecture, where most of the application layer is abstracted from the main rendering thread into worker threads.[ˆJbanov]

4. Building a browsernative microservice

After getting confidence in microservice principles and technical background the paper should briefly join them to form a *browsernative microservice*. Needless to say that the following example is overall simplified towards illustrating the connection between browsernative technologies and microservice patterns. Furthermore it is an opinionated approach and should not be perceived as a 'single source of truth'.

Google's Polymer project is a good place for learning about web components in depth and make use of their toolbox. One of their proof of concept is the so-called **Polymer Shop**[13] which is a fully-fledged online shop nested within a single root element `<shop-app>`. This app is made of several main views and many more invisible wrapper elements for routing, service worker caching, theming, etc. The whole shop runs as a single application fetching and updating remote

[13] Polymer Shop

resources and switching views. Let us assume we work in a sales engineering team of the Polymer Shop and we need to rebuild the checkout microservice.

The current checkout can be found at https://shop.polymer-project.org/checkout. At the time of writing, the checkout is a single, 671 lines of code long Polymer component including all required fields for signing in, shipping, billing and summarizing the order. In the spirit of microservices we will split up the microservice into independent components. The shopping cart data is pulled out of a local storage JSON entity, set up previously by another custom element.

By breaking down the service the **team defined the business boundaries** within the checkout process and came up with following granular service blocks:

1. Sign in
2. Shipping details
3. Payment details
4. Review and place order

Translated into a raw **Custom Element** HTML structure, the top-level microservice might look like the following snippet:

```
>shop-checkout.html
<shop-checkout>
  <sign-in></sign-in>
  <shipping-details></shipping-details>
  <payment-details></payment-details>
  <place-order></place-order>
</shop-checkout>
```

Yet already we see the simplicity arouse from web components as they persue a clean markup. Each of the child components may act independently over other child nodes utilizing the **loose coupling principle**. Each child ships all the HTML, CSS and JS code needed to fulfil its work following the **high cohesion principle**. Each component may contain different views to accommodate different **bounded contexts resulting from different devices**. And last but not least, all of them communicate over an **unobtrusive message bus** via the service root component `<shop-checkout>`.

Before diving deeper into implementation, it is worth to clarify an **architectural pattern** behind components. To any reader of the paper who already came across React, the concept of components may look familiar. Dan Abramov, the creator of Redux, once defined a simple dichotomous pattern for creating UI components.

Firstly, Abramov defined a pattern around **presentational components** only related with the concern about *how things look*. This component literally does not know anything about the service in question which makes the component highly flexible and reusable. It is controlled solely from the outside, receiving data and dispatching unbiased events on user interaction.[20] Most probably every presentational component embodies more HTML/CSS markup and less

JS code. It should encapsulate its styles from bleeding out and protect its styles from being overwritten. Furthermore, it may contain several templates to change its look on different demands.

Secondly, Abramov described components he refers to as **containers**. A container component is concerned with *how things work*.[20] Containers act as invisible wrappers around presentational components acting in the sense of UNIX filters. Their job is to fetch data from child nodes, aggregating events, interacting with the model and push state back to the presentational components. Consequently they might contain more JS and less if any HTML markup. We probably do not need to utilize shadow DOM as no styles are involved.

Last but not least, the pattern can be expanded for illustrational purposes to **native components** such as every build-in HTMLElement like an ordinary HTMLButtonElement. Native components are mostly deeply nested elements providing the actual functionality in the browser UI. They are solely controllable and styleable from the outside and are therefore wrapped in presentational components and/or containers.

Lets start the service description top-down beginning with the **service root container** managing the overall service.

4.1. Service root

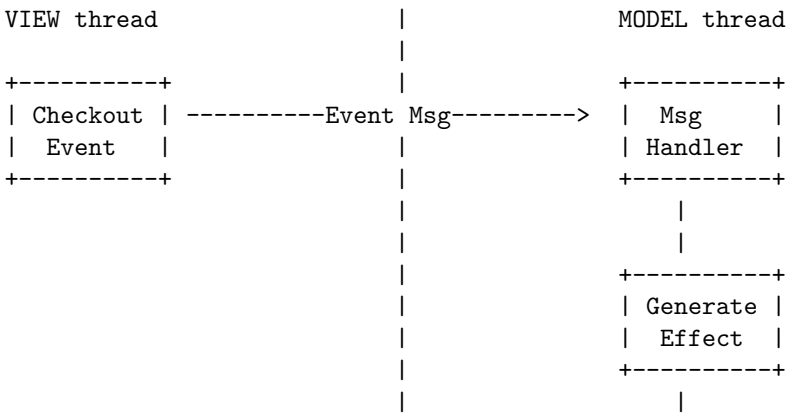
The root container `<shop-checkout>` is basically just an encapsulation layer in terms of service functionalities. Encapsulation of CSS will not be an issue at this point as no styling is involved. A simplified *root container* for the checkout might look like the following code snippet:

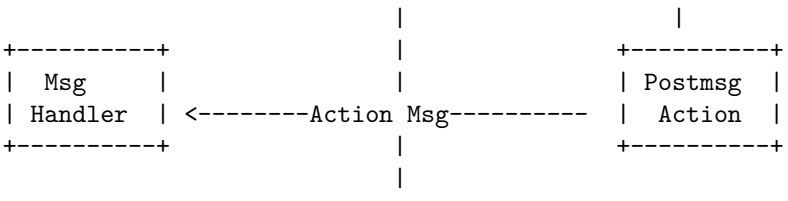
```
> shop-checkout.html
<!-- IMPORTS -->
<link rel="import" href="sign-in.html" async>
...
<!-- VIEW -->
<shop-checkout>
  <sign-in></sign-in>
  ...
</shop-checkout>

<!-- CONTROLLER -->
<script>
class ShopCheckout extends HTMLElement {
  constructor() {
    super();
    this.MODEL = new Worker('checkout-model.js');
  }
```

```
  connectedCallback() {
    // listen to msg from MODEL
    this.MODEL.addEventListener('message', [Msg Handler])
    // listen to child nodes
    this.addEventListener('checkout', e => {
      // delegate event to handler
      this._sendToMODEL = e;
    });
  }

  set _sendToMODEL(e) {
    const id = e.target.id,
          name = e.target.localName,
          load = e.detail,
          letter = Object.assign({}, { id, name, load });
    // send to MODEL
    this.MODEL.postMessage(letter);
  }
  ...
}
customElements.define('shop-checkout', ShopCheckout);
</script>
```

The purpose of this simplified code snippet is to outline the **MVC threefold** in the *service root*. The MODEL is pushed into the worker thread, the CONTROLLER in the custom element and the VIEW in the HTML structuring. On runtime the *root container* acts like a **message dispatcher** implementing the microservice principle of **smart endpoints and dumb pipes**.

In order to interact with the MODEL every child node must implement the dedicated `checkout` CustomEvent (which will be explained further on in the next section). Illustrating the **unidirectional communication** from the *service root* perspective may look like the following plot:





Effects are yielded by the asynchronous operation of messages and create actions returned to sender. Effects can be created by external operations, like subscription to an WebSocket, too. Effects may be created with additional resources from the server or syncing with local storage like those in the polymer-shop.

While the msg handlers are basic 'dumb' switch statements the **smartness** solely arises from intelligent controllers processing the message. This communication model offers lots of possibilities for **evolutionary design** as child nodes can be loosely dropped. Every child node can be expanded into another full microservice or split up into separate nodes without notice of the *service root*. Communication may fail without harming effects, providing a default console log.

4.2. Container components

The second layer of the checkout microservice like `<sign-in>` or `<shipping-details>` still contains mostly logic and little or less styling. The job of a *container component* is to control its underlying presentational components and to define a **set of ACTIONS towards the model**. Every *container* mounted directly under the service root may have a dedicated area inside the worker thread reserved for its duties. For example, a typical `<sign-in>` contains merely two fields, username and password and a submit button. The *container component* waits for a submit action, aggregating the credentials, and might add some semantics to them. Field values and the action message will be dispatched towards the model for further processing like initiating an authorization process.

Every *container component* is eligible to aggregate subordinate events from its children, buffer them and interact with the model via a **unified message system**. A base class, from which `<sign-in>` or `<shipping-details>` can be extended, might look like this:

```
class SimpleContainer extends HTMLElement {
  // constructor, static methods ...
  set _dispatch(msg) {
    this.dispatchEvent(
      new CustomEvent('checkout', {
      bubbles: true,
      detail: msg
      })
    );
  }
```

```
  set _receive(msg) {
    // switch to methods
    console.log(`${this.localName} received ${msg}`);
  }
}
```

Extending the `SimpleContainer` will equip every *container node* with the unified message interface. Calling `this._dispatch(msg)` within the *container* will trigger an event. The service root will implement a simple event listener for `checkout` events. After receiving an answer from the MODEL a service root can query the *container child node* in question and push forward the answer over the `_receive` property.

There might be even **more middleware containers** pulled in between presentational leafs and the service root to fulfil some extra work like filters on the event or without caring about checkout events altogether. Changing or enhancing any functionality requires only the controller in the *container* in question and the endpoint section at the model. **Infrastructure automation** might be achieved by dynamically evaluating the mounted *containers* beneath the service root and modeling the 'backend' model accordingly. Due to its standardized message system the *containers* are testable within standardized tests exposing them to different synthetic events.

4.3. Presentational components

In comparison to the former container the *presentational component* is build mostly around views and styling with just a little logic to switch templates around or to alter styling accordingly. As much as the container can be perceived as a wrapper for logic, the *presentational component* can be perceived as **wrapper for styling** needs. To extend the last `<sign-in>` example a *presentational component* structure could look like the following top-level structure:

```
<sign-in>
  <sign-in-styling theme="dark" ...>
    <!-- Native components // form button ... -->
  </sign-in-styling>
</sign-in>
```

The `<sign-in-styling>` contains all required input fields and Oauth connectors to Google or Facebook but **will not care about events they create**. A *presentation component* is usually steered via HTML attributes. Contrary to the former containers, the *presentational component* highly utilizes **shadow DOM and HTML templates**.

```
> sign-in-styling.html
<!-- IMPORTS -->
<link rel="import" href="facebook-oauth.html" async>
```

```
<link rel="import" href="mobile-template.html" async>
...

<!-- VIEW -->
<sign-in-styling>
  <template id="highres">
    <style>...</style>
    <div id="content">
      <facebook-oauth>Yet another element</facebook-oauth>
      <slot name="form"></slot>
      <slot name="button"></slot>
    </div>
  </template>

  <template id="lowres">...</template>
  <mobile-template>Template custom element</template>
</sign-in-styling>

<script>
  class SignInStyling extends HTMLElement {
    constructor() {
      super();
      this.attachShadow({mode: 'open'});
      if (window.innerWidth > 1280) {
        const temp = this.querySelector('#highres');
        this.shadowRoot.appendChild(temp.content);
      }
      // this.getAttribute('theme') for configuration
      // selecting nodes for altering
    }
    attributeChangedCallback(attrName, oldVal, newVal) {
      // react on changing attributes
    }
  }
  customElements.define('sign-in-styling', SignInStyling);
</script>
```

As mentioned before, HTML templates provide an opportunity to define **CSS modules**. Tags like `<style>` and `<slot>` create a kind of stencil filled by content from the `index.html`. As it is possible to expand templates in place it could also be possible to define **template components** like the `mobile-template.html` to atomize the component further and to increase code brevity.

Overall, the `<shop-checkout>` should provide a taste of web components and their ingredients in practical usage. On a bigger scale things would certainly look different and less static than in the given example. Still, the microservice approach is intended to be somewhat visible in this example.

5. Thinking further

In the search for an independent **browsernative** approach this paper left out third-party libraries so far. Nevertheless, it should be clear to this point that the example in the last section is far away from being usable in production. At first, from a technical perspective web components are relatively young and at the time of writing only usable in **newer Chrome and Opera browsers**. Most probably it will take a long time until native web components can be safely used without additional legacy support. The troublesome *HTML imports* spec will certainly need even longer which inevitably opens up the question if web components are useful from today onwards. And second, do web components align with the notion of simplicity if too many downsides and possible pitfalls require attention?!

Any profound discussion about web components would be incomplete without touching component alternatives like **React**. In the last couple years React introduced new concepts to web development like the idea of state, passing data as properties and declarative event management just to name a few. Those design decisions were made to simplify browser development with full browser support right from the start. Overall, React's perception about UI development created much of a hype around the library and technologies like the virtual DOM while web components never caught up in momentum at a comparable rate. According to Github, Google's Polymer project is even six months older than React but has less than one third of its stars. Other notable web component projects like Bosonic[14] or Mozilla's X-tag[15] are more dead than alive, too.

It seems like the web developing community in a broader sense values **standardized procedures, tooling and browser support** in frameworks like React (and many others to be fair). Previously mentioned web component libraries clearly missed a real selling point compared to React or Angular. Providing guidelines, simpler syntax and features are missed out or are too cumbersome to use at all. For the future it remains unclear if web components eventually gain wider adoption within the UI developing community or will be adopted as low-level technology for framework development emphasized by Sebastian Markbage, one of the React creators.[21]

Even though the drawbacks seems heavy weight, there are notable attempts to bring web components into production. A very good example is the "reactish" library Skate[16]. Following the functional rendering model from React, it combines native methods with additional functionalities known from React like declarative event management. Given the focus on native technologies it only weights around 4kb (minified and gzipped) which is ten times less than React. **Micro UI frameworks** like Skate could certainly be the near future of web development, offering a real selling point. Previously mentioned specs could

[14] https://github.com/bosonic/bosonic/
[15] https://github.com/x-tag/core
[16] https://github.com/skatejs/skatejs/

lead to a modular, pluggable building pipelines offering the same features and tooling as React already does. After all, web components fit better with the microservice **decentralization aspect** than 'walled garden' frameworks.

The role of web components may not result in an isolated implementation but move towards a common denominator for future Reacts, Angulars, Vues etc. This makes **web components worth considering them as recyclable technology**. The more mature UI framework Riot already expressed its intention to gradually develop towards web components.[17]

[1] R. Hickey, "Rails conf 2012 keynote: Simplicity matters by rich hickey." 2012 [Online]. Available: https://www.youtube.com/watch?v=rI8tNMsozo0&t=46s

[2] F. Filloux, "Bloated html, the best and the worse," 2016 [Online]. Available: https://mondaynote.com/bloated-html-the-best-and-the-worse-cac6eb06496d

[3] C. Y. Baldwin and K. B. Clark, "Modularity in the Design of Complex Engineering Systems," in *Complex engineered systems: Science meets technology*, D. Braha, A. A. Minai, and Y. Bar-Yam, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2006, pp. 175–205 [Online]. Available: http://dx.doi.org/10.1007/3-540-32834-3{_}9

[4] S. Newman, *Building microservices*. O'Reilly Media, Inc., 2016.

[5] M. Fowler and J. Lewis, "Microservices: A definition of this new architectural term," Jan. 2014 [Online]. Available: http://www.martinfowler.com/articles/microservices.html

[6] R. C. Martin, "The single responsibility principle." [Online]. Available: http://programmer.97things.oreilly.com/wiki/index.php/The_Single_Responsibility_Principle

[7] M. Kearney, "Measure performance with the rail model." 2016 [Online]. Available: https://developers.google.com/web/fundamentals/performance/rail

[8] M. E. Conway, "How do committees invent?" 1968 [Online]. Available: http://www.melconway.com/Home/Committees_Paper.html

[9] J. Bonér, "Latency numbers every programmer should know." 2012 [Online]. Available: https://gist.github.com/jboner/2841832

[10] B. Issa, "The way of the web." Polymer Summit 2016, Oct-2016 [Online]. Available: https://www.youtube.com/watch?v=8ZTFEhPBJEE

[11] B. Victor, "Inventing on principle." 2012 [Online]. Available: https://vimeo.com/36579366

[12] N. Lawson, "Progressive enhancement isn't dead, but it smells funny." 2016 [Online]. Available: https://nolanlawson.com/2016/10/13/

[17] http://riotjs.com/compare/#web-components

progressive-enhancement-isnt-dead-but-it-smells-funny/

[13] A. Rota, "React.js conf 2015 - the complementarity of react and web components." 2015 [Online]. Available: https://www.youtube.com/watch?t=124&v=g0TD0efcwVg

[14] D. Buchner, "Demythstifying web components," 2016 [Online]. Available: http://www.backalleycoder.com/2016/08/26/demythstifying-web-components/

[15] A. van Kesteren, "Mozilla and web components: Update," 2014 [Online]. Available: https://hacks.mozilla.org/2014/12/mozilla-and-web-components/

[16] E. Bidelman, "Custom elements v1: reusable web components." 2016 [Online]. Available: https://developers.google.com/web/fundamentals/primers/customelements/. [Accessed: 01-Dec-2016]

[17] *HTML living standard — last updated 11 january 2017.* [Online]. Available: https://html.spec.whatwg.org/multipage/

[18] E. Bidelman, "Shadow dom v1: Self-contained web components." 2016 [Online]. Available: https://developers.google.com/web/fundamentals/getting-started/primers/shadowdom

[19] E. Bidelman, "The basics of web workers." 2010 [Online]. Available: https://www.html5rocks.com/en/tutorials/workers/basics/

[20] D. Abramov, "Presentational and Container Components – Medium." 2015 [Online]. Available: https://medium.com/@dan_abramov/smart-and-dumb-components-7ca2f9a7c7d0. [Accessed: 01-Dec-2016]

[21] D. A. Rauschmayer, "Tree-shaking with webpack 2 and babel 6." 2015 [Online]. Available: http://www.2ality.com/2015/12/webpack-tree-shaking.html