

**Deliverable D3.1**

**Document title**

|  |  |
| --- | --- |
| Editor: | Paulo Chainho, PT Inovação |
| Deliverable nature: | (R) Document, Report |
| Dissemination level: (Confidentiality) | Public (PU) |
| Contractual delivery date: | 30/09/2015 |
| Actual delivery date: | 30/09/2015 |
| Suggested readers: | Service providers’ designers and developers |
| Version: | 0.1 |
| Total number of pages: |  |
| Keywords: | Fixed: Communication networks, media, information society  Free: Hyper-linked entities, Future Internet architecture, Trustful communications, Social trustful networks, WebRTC, Independent Identity, IdP, Peer-to-peer communications,H2H, M2M, Graph ID |

***Abstract***

Please include an abstract of not more than 10 lines here.

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*This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 645342. This publication reflects only the author’s view and the European Commission is not responsible for any use that may be made of the information it contains.*

Impressum

Full project title: Trustful hyper-linked entities in dynamic networks

Short project title: reTHINK

Number and title of work-package:

Number and title of task:

Document title:

Editor: Paulo Chainho, PT Inovação

Work-package leader: Paulo Chainho, company: PT Inovação

Estimation of PM spent on the Deliverable:

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# Executive summary

Include an executive summary (maximum 2 pages).

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## Objectives

## Innovation

As can be seen in Figure (**???**)

## Structure

# Requirements

## Runtime Requirements

## Messaging Node Requirements

## Network QoS Policy Enforcement Requirements

## Service Framework Requirements

# State of the Art

## Security in Runtime

In this document, we present an overview about the security in runtime component of the project. In first place, we will define the security goals we want to achieve. Then, possible attacks against those goals are explained. Finally, we present the state of the art on how current systems solve the referred problems, splitting the security runtimes in two distinct areas:

* Web Browsers
* Secure elements

In the Web Browsers section, we will present security mechanisms for JavaScript code protection in fully-featured environments (the web browsers themselves), while in the Secure Elements section, the state of the art on code security runtimes for systems featuring less functionality and computation capabilities but requiring tighter security requirements during its operation.

**Security goals:** The following points consist in specific security goals that the hyperty instances must achieve.

G1 - to protect the confidentiality and integrity of the state of hyperty instances. G2 - to protect the integrity of the code of hyperty instances. G3 - to enforce the security policies attached to hyperty code.

**Possible attack vectors:** Multiple attack types can be performed against the hyperty instances, at multiple levels (software, OS, hardware). We now present and detail the most well-known attack vectors occuring at each level.

*Malicious hyperty code:* E.g., by exploiting a bug in the hyperty runtime (HR), a malicious hyperty manages to escape from its sandboxed environment and escalates its privileges to gain access to a victim hyperty instance. The attacker can then read or modify sensitive data (break G1), modify the code (break G2), or modify the security policy (break G3) of the victim.

*Compromised browser:* E.g., the local user logs in to the computer, and attaches a debugger to the browser’s process. This gives the user full access to the browser’s state, including the HR’s. Therefore all G1, G2, and G3 can be violated. A similar attack can be performed by malware that subverts the browser’s security mechanisms and allows for an attacker to control the HR.

*Compromised operating system:* E.g., a kernel rootkit subverts the kernel, and gains access to the entire memory state of the browser process in which the victim hyperty instance is running. Just like in the previous cases, all G1, G2, G3 can be violated. Jail-breaking the kernel can bring similar consequences.

*Compromised hardware:* E.g., an attacker manages to gain physical access to the host computer and has the capability to extract secrets directly from the RAM memory or by probing the system bus. This attack can violate the security goals G1, G2, and G3.

### Web Browsers

#### Monolithic vs Modular Architectures:

Traditionally, commercial and open-source web browsers employed a monolithic architecture. This means that both user’s and web application’s data are combined into a single security domain, which brings serious performance/usability and security issues. On the performance/usability side, if a web application crashes during its execution, the whole web browser can be affected, harming the user experience. On the security side, if an attacker exploits an unpatched vulnerability in the browser while a user is using it, he may gain access to the whole user space, being able to execute code on behalf of that user and access its private sensitive information, like credentials.

Nowadays, web browsers evolved into modular architectures, in order to achieve privilege separation and overcome monolithic architectures’ flaws. This way, browser developers came up with multiple different architectures to achieve this separation between what is user’s property (credentials, preferences) and what is “web’s” property (applications’ code). Multiple techniques were employed in these architectures to achieve this separation:

* **Sandboxing:** In computer security, a sandbox is a security mechanism which allows untrusted programs to run within a trusted environment, without affecting its trustiness. This is usually done by restricting the resources (disk, memory, network) the untrusted software can access. An example is creating scratch memory and disk spaces where it can read/write and limiting the network capabilities it can use, in order to prevent the host environment from getting damaged. This is what Chromium browser [1] applies to separate the user and the web side in a modular architecture. It features two modules:
* A **browser kernel module** which acts on behalf of the user and is responsible for implementing the tab-based windowing system of the browser, storing user’s data as its preferences, bookmarks, credentials and cookies and also working as a middleware between the native operating system window manager and every instance of the second browser module, the rendering engine.
* The **rendering engine** provides the web application behaviour. It interprets and executes web content, serving calls to the DOM API. It is the unique browser part in contact with the untrsuted web content. Apart from that, it is also responsible for enforcing the same-origin policy between the user and a website he’s visiting.



image

Figure 1. Chromium sandbox scheme

#### Browser Extensions Security:

Browser extensions provide useful additional functionality to web browsers, such as facilitating the access to a website’s content or even as almost standalone applications running on the browser environment. However, these extensions often introduce serious security issues into both user’s browser and websites, because most of the times they’re written by well-meaning developers who are not security experts. Extensions can read and alter users’ bookmarks and preferences, websites’ content and perform requests over the network, many times on behalf of the browser user. Browser extensions are mostly written in JavaScript and HTML, and since JavaScript provides methods for converting a string to code (e.g. eval), an extension may be dangerous if misused. Typically, benign extensions face two types of attackers:

* **Network attackers:** Targeting end-users who connect to insecure networks (public Wi-Fi hotspots), these attacks consist in reading and altering HTTP traffic, in order to detect if an extension adds an HTTP Script - JavaScript file loaded over HTTP - to itself, and altering the code in such case.
* **Web attackers:** A malicious website can launch a XSS attack on an extension if the extension treats the website as trusted, possibly stealing the browser’s userdata, like credentials. This way, it can scale up to attack multiple websites within the same entry point.

According to [2], Google Chrome and its extension platform apply three mechanisms to prevent these vulnerabilities: \* **Privilege Separation:** Every Chrome extension has two types of components which run in separate processes: zero or more content scripts and zero or one core extension. Content scripts read and modify websites as needed. The core extension implements functionality not directly involving websites, like browser UI jobs or long-running background tasks. These two types of components communicate by sending structured clones over a trused channel. Each website that an extension communicates with, receives its own isolated instance of a content script, making content scripts highly bound to attacks. However, only the core extension is able to communicate with the Chrome extension’s API, reducing the risk that a content script is able to access the user data space. The architecture scheme of a Google Chrome extension is on Fig. 2. \* **Isolated Words:** This mechanism ensures that content scripts and websites have separate JavaScript heaps and DOM objects. Consequently, content scripts never exchange pointers with websites, protecting them against web attackers. \* **Permissions:** Extension developers have to specify the desired permissions in kind of a manifest file that is packaged with the extension. For example, the bookmarks permission is needed for the extension to be able to read and alter the user’s bookmarks. Only core extension can use permissions to invoke browser API methods, while content scripts are limited to interacting with the core extension and the website it is running on. This way, an extension is limited to the permissions its developer requested, so an attacker is not able to request new permissions for a compromised extension in runtime.



image

Figure 2. The architecture of a Google Chrome extension.

#### XSS Detection Techniques:

Cross-Site Scripting attacks are getting more common on the web, since they allow an attacker to get control of a user’s browser and execute malicious code (usually JavaScript/HTML) within the trusted context of a web application. This can result in the attacker being able to access any sensitive information associated to the application (cookies, session IDs, etc.). The study of XSS attacks can be split into two distinct categories, according to [3]:

* **Persistent/Stored attacks:** Occurs when a malicious user registers itself into a web application and posts a malicious JavaScript to the application, which, by its turn, save it into the application’s data repository, persistently. After that, if another user fetches the content uploaded by the malicious one onto his browser, and since this code is coming out of the trusted context of the web application, the user’s browser will allow the script to access any possibly sensitive resource it is willing to, overcoming this way the security imposed by the same-origin policy. Apart from stealing the user’s information, XSS attacks can also be used to redirect users to a malicious website which can then perform other distinct attacks within its context. A persistent XSS attack scheme is presented on Fig. 3.



image

Figure 3. Scheme of a persistent XSS attack.

* **Non-persistent/Reflected attacks:** Unlike the first type, reflected attacks do not persistently store malicious code in the web application data space. Instead of that, the content is automatically reflected back to the user through a third-party mechanism. For example, by using a spoofed email, an attacker can make a user click on a link containing malicious code, which will finally be interpreted by the user’s browser, but within the trusted context fo the web application. This type of XSS attacks is often combined with other techniques as phishing, and is the most common type of XSS attacks in web applications. Figure 4 shows a scheme of the architecture of a non-persistent XSS attack.



image

Figure 4. Scheme of a non-persistent XSS attack.

#### XSS (and other types) prevention techniques:

* **Analysis and Filtering of the Exchanged Information:**

This technique consists in defining a list of characters or tags which users are allowed to exchange with the web application, in the form of text inputs, uploaded files, etc. Then, a filtering process simply rejects everything that is not part of the list. Other approach, reported in [4], is having a proxy-server at the web application’s site in order to filter both incoming and outcoming requests. This filtering takes into account a set of rules defined by the application developers. Although, a simple use of regular expressions is able to evade both the referred methods and proxy-servers can rapidly become a performance bottleneck on the application deployment. Authors of [5] also suggested placing a proxy-server on the server-side of the application, but in order to differentiate trusted and untrusted traffic, driving each type to separate channels. This partitioning process uses Information Flow Control techniques to taint information and track it thenceforward. On other point of view, approaches seen in [6,7] propose the content filtering to happen at the client-side. On the one hand, authors of [6] try to achieve the prevention of XSS attacks by blacklisting links embedded within the web application’s pages, making them unavailable for the client. However, the authors say this approach can only detect basic XSS attacks based on the violation of same-origin policy. On the other hand, authors of [7] present another client-proxy solution that is intended to detect malicious requests reflected from the attacker to the victim (non-persistent XSS attacks). If such a request is detected, the malicious characters are re-encoded by the proxy, trying to avoid the success of the attack.

* **Security Enforcement on the Web Browser Runtime:**

There are also other strategies which try to avoid the need for intermediate elements like proxy-servers by proposing startegies to enforce the runtime context of the web browser. In [8], authors propose an auditing system for the JavaScript interpreter of the Mozilla Firefox browser, which detects misuses on JS operations and take counter-measures to avoid violations on browser’s security. Other approach is also followed by [9], which presents the use of dynamic taint tracking on JavaScript code, in order to detect whether browser’s sensitive resources are going to be transferred to an untrusted third-party. In such case, the user is warned and can decide whether he allows or denies the transfer. Finally, the approach followed by [10] propose a policy-based management where a list of actions is embedded into the documents exchanged between the browser and the server. These actions help the browser to decide whether or not a script should be executed. Although, a lack of semantics in the policy-language and the restrictiveness of the approach due to the sandboxing-like mechanism are some of the drawbacks.

### Secure Elements

#### Java Card: Internet Computing on a Smart Card

In secure computing, a smart card is a typical card with a built-in computer chip. Until a few years ago, it was only used to produce credit and debit cards, whose information can only be accessed when in possession of the card itself and a PIN code. Due to the short information on how to communicate and program them, until a few years ago this useful technology wasn’t being used on computer security in general.

* **Hardware:**

This single-chip computer is an off-the-shelf **8-bit microcontroller** with added tamper-safe features. While most 8-bit microcontrollers can support at least **64 KBytes** of 8-bit memory, popular smart cards contain 4 to 20 Kbytes of memory, due to size constraints. The memory space of a smart card is divided into RAM, EEPROM and ROM. RAM is used to store temporary values when a program is running, while EEPROM is used to store sensitive data as an encryption key or the account holder info on credit cards. Finally, ROM is used to store the basic programs that run on the smart card. The single-chip computer is embedded in a plastic chip carrier, and both of them hold several tamper-resistant and tamper-detection features.



image

Figure 5. Java Smart Card scheme [11]

* **Software**

The paucity of 8-bit assembly language courses, books and software tools led engineers to break the smart card application bottleneck by building a Java virtual machine with its runtime support into a 12-Kbyte smart card. **Java** was the obvious answer for three reasons: \* Java brings smart card programming into the mainstream of software development \* Java “safe programming” security model based on a runtime interpreter is a nontrivial side benefit, due to its processor independence. A Java card can be deployed on multiple smart card models. \* Java interpreters were tested to the limit, holes had been found, and fixed

With this in mind, engineers concluded that Java could preserve the required security in the smart card operation, while allowed a more friendly and well-known programming approach. However, available memory was an issue when deploying such heavy language runtime like Java. Features like garbage collection and exceptions handling were not included in Java Card because of that.

* **Internet Computing with Java Smart Card**

Java Cards combine smart card’s identity-verification features with the Java “sandbox”, guaranteeing that only allowed applications run on the card and that applications are protected from each other.

#### Cloud of Secure Elements

Cloud of Secure Elements (CoSE) [12] is an emerging concept whose goal is to provide trusted computing resources to mobile and cloud applications. To reach that, it relies on an infrastructure composed by multiple secure microcontrollers, named Secure Elements.

CoSE, in a WEB-like paradigm, are meant to support Uniform Resource Identifiers (URIs) for users to locate the different secure elements and use their embedded resources. These resources usually target two service types: Near Field Communication (NFC) facilities for mobile applications and trusted cryptogrtaphic features for cloud applications.



image

Figure 6. CoSE architecture

* **Architecture**

A Cloud of Secure Elements has the following components, as Fig. 6 shows:

* NFC kiosks, typically deliver payment facilities
* Users with NFC-enabled devices or terminals needing trusted cryptographic resources
* Grid of Secure Elements (GoSE)
* Secure elements, with resources identifiable by URI
* Remote administration entities, performing management operations over applications and secure elements
* **Grid of Secure Elements (GoSE)**

A grid of secure elements is an Internet server hosting multiple secure elements. Each element may be plugged in through USB readers, hardware sockets or electronic boards. Communication may be achieved with RACS protocol (works over IP/TCP/TLS stack) and performs both the association between elements and unique identifiers and data exchange with secure elements.

# Malicious Code on Java Cards: Attacks and Countermeasures

Despite all the advantages on using Java language in smart cards, such as the absence of low-level memory vulnerabilities, Java Cards still have an open door for attacks through malicious code. This attack entry is possible because an on-card bytecode verifier (BCV) is optional on Java Cards, and those who don't feature it, are more open to malicious code that might damage other applets running on the system or even the platform itself.

### Defenses against malicious code

Here we present the different mechanisms for protection against malicious code actions present in Java Cards.

#### Bytecode verification

Bytecode verification of Java code guarantees type safety, and thus, memory safety. On normal Java platform, bytecode verification occurs at load time. Although, since Java Cards do not support dynamic class loading, this verification must occur at the time an applet is installed to the card. However, most Java Cards do not feature an on-card BCV and rely on a digital signature of a third party who is trusted to have performed bytecode verification off-card.

#### Applet firewall

The applet firewall is an additional defense mechanism present in Java Cards. The firewall performs runtime checks to prevent applets from accessing and/or altering data of other applets (concretely, in a different security context). For every object within an applet, the firewall records its context, and for any field or method accessed this context is checked. Only the Java Card Runtime Environment (JCRE) has unlimited permission, since it executes in root-mode, on a UNIX terminology.

### Getting malicious code on cards

#### CAP file manipulation

This is the easiest way of introducing ill-typed code on a Java Card. This can be achieved by editing a CAP (Converted APplet) file to introduce a type flaw in the bytecode and install it to the card. Although, this will only work for cards without an on-card BCV and with unsigned CAP files. In example, by changing a baload (byte load) opcode onto a saload (short load) one, will make the platform treat a byte array as a short array, and can potentially lead to accessing other applet's memory space.

#### Abusing Shareable Interface Objects

The shareable mechanism of Java Card can be used to create type confusion between applets without any direct editing on CAP files. Shareable interfaces allow direct communication between security contexts. Using this to create type confusion is pretty simple: Let two applets communicate through a shareable interface, but compile and generate CAP files for both applets using different definitions of the shareable interface, which is possible because the applets are compiled and loaded separately. This way we can achieve an attack like the CAP file manipulation but without ever touching the CAP file directly.

#### Abusing the transaction mechanism

The Java Card transaction mechanism is probably the tricliest aspect of the Java Card platform. It allows multiple byte-code instructions to be turned into an atomic operation, offering a roll-back mechanism in case the operation is aborted, either through card tear or calling an API method. Buggy implementations of the transaction mechanism in some cards tend to make it not behave as expected. When object references are spread around the code, by assignments to instance fields and local variables, it becomes difficult for the mechanism to keep track of all the references that should be nulled out. The root cause of the problem is that stack-allocated variables, such as short[] localArray are not subject to roll-back in the event of a programatically transaction abort (through API method call).

### Dynamic countermeasures

Now we present some dynamic runtime checks implemented by some VMs in order to prevent ill-typed code to damage the Java Card platform. These were verified by [13], by performing tests on multiple Java Card models of multiple manufacturers against the referred vulnerabilities.

* Runtime type checking
* Object (array) bounds checking
* Physical (byte size) bounds checking
* Firewall checks
* Integrity checks in memory

## Automated Analysis of Security-Critical JavaScript APIs

Current web applications usually rely on JavaScript in order to offer additional features like maps, widgets or social media content. Although, since these additions may manipulate a page Document Object Model (DOM), steal cookies or navigate on the page, untrusted third-party JavaScript may pose security threats to the hosting page.

A widely-used approach is to combine a language-based sandbox to restrict the capabilities of untrusted JavaScript with an API offered by the trusted code part to the untrusted one. This API encapsulates all security-critical resources and guarantees they are only accessed in a safe way.

Given this, the authors of [14] proposed ENCAP, a tool that verifies API confinement, analyzing the isolation level it can offer to the critical objects it is intended to protect. ENCAP relies on a context-insensitive and flow-insensitive static analysis method. It analyses the API implementation and generates a conservative Datalog model of all API methods. Also, they propose SESlight, an ECMA JavaScript-subset language which only allows a strict (syntactically and semantically verified) subset of the whole language to be used.

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*should we also study these references: http://seclab.stanford.edu/websec/jsPapers/csf09-camera-ready.pdf*

## Projects

The WONDER project has enlightened some foundations paths to be followed in a post-IMS era dominated by Web technologies that reTHINK is currently exploiting. Notably, the novel Signalling On-the-fly (SigOfly) concept was conceived and successfully demonstrated to enable seamless interoperability between different WebRTC service domains. reTHINK Protocol On-the-fly concept extends WONDER, the Signalling On-the-fly concept to any other service domain where needed protocol stacks can be executed in a Web Runtime.

The WONDER Library used to validate SigOfly concept can be used in reTHINK as a good starting point to design and implement reTHINK runtime APIs and reTHINK Javascript framework.

## Runtime

A very comprehensive analysis and evaluation of existing web runtime solutions was performed.

In order to evaluate the possibility to modify native implementations of WebRTC engines, Ericsson OpenWebRTC and Google WebRTC.org solutions were considered. OpenWebRTC is a promising modular WebRTC implementation based on popular GStreamer multimedia framework open source solution. Unfortunately, OpenWebRTC is not much supported by Ericsson lacking required documentation to let it be adapted to fulfil reTHINK new requirements. Google WebRTC.org solution is the reference implementation of WebRTC specification providing all APIs defined in the standards. However, the effort required to change it to fulfill reTHINK requirements is estimated to be very high. On the other hand, having an extended version of an existing WebRTC implementation would require the user to install a new reTHINK Browser. For all the above reasons, it was decided to re-use existing native implementations of WebRTC engines without modifications.

Javascript engine solutions were evaluated to analyse the possibility to adapt them in order to fulfill reTHINK runtime requirements, notably in terms of security (sandboxing). The V8 JavaScript Engine is an open source JavaScript engine developed by Google for the Google Chrome web browser. It has since seen use in many other solutions and it is considered the most powerful Javascript engine in terms of features and performance. It has mechanisms to facilitate its extension with new features but lacks required mechanisms for sandbox creation. One evaluated alternative, is to use nodejs that runs on top of V8 as well as having nodejs inside Docker taking advantage of its management and security features. Both solutions fulfill reTHINK security requirements and will be considered for reTHINK runtime implementations that are not based on browsers.

Firefox OS is a good candidate to implement reTHINK runtime in mobile devices supporting this Operating Systems. It natively suports JavaScript and HTML APIs 5 (including WebRTC) as programming language, and a robust privilege model to communicate directly with cellphone hardware, and application marketplace.

Three WebRTC based Media Server solutions were evaluated. Jitsi Videobridge supports Selective Forwarding Unit (SFU) for multiuser video communication and it is based on XMPP architecture. Kurento, supports MCU/SFU Star topologies and a modular architecture to implement media processing services. Janus Gateway is a flexible and modular WebRTC gateway that can be used to deploy a full-fledged WebRTC gateway on a cloud provider or just a small nettop/box to handle a specific use case, looking at applications as pluggable modules that a client can connect to through this gateway. These solutions, are good candidates to support server side Hyperties providing media related services.

## State of the Art Summary

The reTHINK project describes a framework that provides solutions to manage real time communication capabilities. To implement this framework the project team tried to use the most suitable existing standards which provides compability which existing technoligies. Using consolidated and widely used standards also make the development more efficient since Open Source libraries can be used in the developments. Addtionally to well-known standards, the project team has also tried to find emerging standards which can be adapted for ReTHINK requirements. In those cases, a tradeoff analysis has been made to determine if the choice of a not consolidated standard is optimal in terms of cost of use due to the lack of existing libraries and projects which use them.

The IETF has been creating and promoting the Internet standards since 1986. The IETF is organized in a large number of Working Groups (WG) which works on specific areas. For ReTHINK project, the team has focused on standards delivered by several WG (namely Rtcweb, TRAM, HTTP/2 and Network). The Rtcweb WG has defined a set of RFCs (many of them are still drafts) which are used in WebRTC, it defines how WebRTC works on the wire. Many of the used protocols already existed but many of them were created ad-hoc to meet WebRTC requirements. Other RFCs are informational and hes been released to gather the WG knowledge in a formal way. The TRAM (TURN Revised and Modernized) working group is carrying out a modernization of the protocols used to transport real-time media over Internet which is the final function of ReTHINK framework.

HTTP/2 is the new version of HTTP/1.1 which has been used in the web for the last 16 years. It provides a new low level design to optimize current Web applications keeping the semmantic of HTTP/1.1 which is still valid. HTTP/1.1 has been historically transported over TCP, however to take advantage of all the new features of HTTP/2 a new transport protocol build over UDP has been designed: QUIC. HTTP/2 draft is based on SPDY but it includes new features and will soon become a definitive RFC. The draft belongs to the HTTP WG. QUIC was developed by Google but it has been recently become an IETF Draft taking over the last changes in the protocol until close the defintiive RFC. HTTP/2 over QUIC has been considered as an alternative for messaging in the ReTHINK framework as it is optimized to be used over wireless connection and minimizes the delay in every communication.

The IETF is in charge of standarizes all the protocols on the wire in Internet. In turn, the W3C (WWW Consortium) is the main international standards organization for the World Wide Web. It standarizes how the browser behave (e.g. WebRTC 1.0 API exposed by the browsers) and and the lenguages (e.g. HTML and Javascript) which can be executed by a standar browser. It is main role is to promote and homogenize the evolution of the Web. During the state of the Art research work we focused on the standards susceptible of being used by any element within the ReTHINK framework.

The WebRTC 1.0 API has been standarized by the W3C is the way in which a Javascript application interacts with the browser to establish real-time sessions with other WebRTC endpoints. A comprehensive knowledge of this API was necessary to make design decissions and to define the architecture and the data model of the framework.

A Community group has been created within the W3C to promote an alternative WebRTC API called ORTC (Object Real-Time Communications) which gives more control to the WebRTC developer making easier to implement some scenarios. There are still not implementations of ORTC in production-ready browser, however the features introduced by this standard which is likely to become the base of the WebRTC 2.0 API have been considered during the design phase.

Another relevant W3C API is the Push API which allows a push service to send "push messages" to a webapp regardless of whether the webapp is currently active on the user agent. This is specially usefull for webapps running on mobile devices where the webapp may need to receive a notification while the browser is not in foreground.

The use of another feature supported by browser called Service Workers has been already evaluated to be used to implement different parts of the Runtime environment. Despite the fact that this specification is still a Working Draft of the W3C it is already supported by the most important browsers. However, this is feature is not supported by server side Javascript-based runtime environment, it only can be used when the Runtime is executed by a browser.

There is another interesting W3C Draft called "Application Lifecycle and Events" which extends the Service Workers with APIs for managing the lifecycle of an application and associated events. This Draft allows web developers to create applications that manage the application lifecycle and react to system events e.g. email or VoIP application. However, this Draft has been not been adopted by many vendors so far.

In this section the standars released by the Open Mobile Alliance (OMA) were also reviewed. The OMA is a Mobile Operator driven industry forum for the definition of interoperable mobile service enablers. OMA defines APIs to offer functionalities and resources of Operator networks to developers. Amongst the API and protocols standarized by the OMA the team decided to reviewed those which are relevant for the project such as the Authorization Framework for Network APIs, the RESTful Network API for WebRTC Signaling, Quality of Service API and Notification Channel. The LWM2M/COAT protocol which was designed to be supported by constrained devices has also been considered as a suitable alternative to interact with the Registry and Discovery services.

Finally, a recent standar called Smart Device Template (SDT) and released by the HGI (Home Gateway Iniative) has been reviewed. It provides a framework to create a consistent representation of Smart Home devices. This makes easier the integration of new devices in Home Gateway or in the cloud being specially interesting to implement M2M within the ReTHINK framework.

# Specification

### Specification of Runtime component

#### [Runtime Architecture](runtime-architecture.md)

#### [Runtime Security Analysis](securityanalysis.md)

#### [Data Synch Communication Model](data-synch-model.md)

#### [Runtime Architecture Dynamic View](dynamic-view/readme.md)

#### [APIs](runtime-apis.md)

#### [Runtime Implementation](implementation/readme.md)

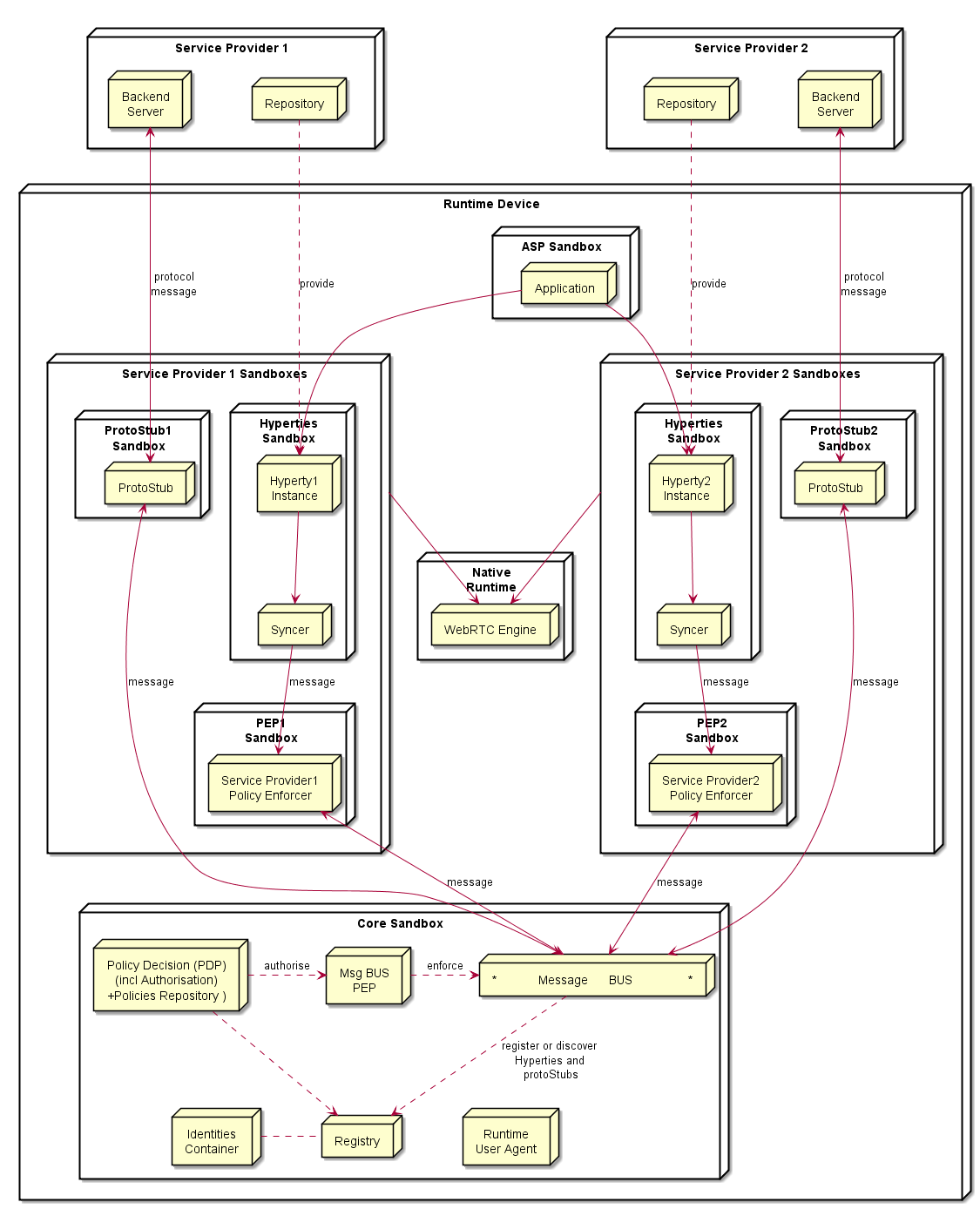
## Runtime Architecture

According to [ongoing discussions](https://github.com/reTHINK-project/core-framework/issues/41): \* one sandbox for the ASP providing the Application \* one sandbox per Hyperty Service Provider Domain that includes the Router/Policy Engine and associated protoStub \* the ProtoStub is used to communicate with Service Provider backend services. \* Hyperty instances communicates with Msg bus through Router/Policy Engine which may also act as a kind of firewall \* according to recommendations provided in the [runtime security analysis](securityanalysis.md), protoStubs and Router/Policy Engines execute isolated in independent sandboxes. \* to prevent cross origin attacks / spy, access to Message BUS may be subject to authorisation \* Different Points of Policy Enforcement: \* Policies enforced at Hyperty Sender Domain Router for outgoing messages \* Policies enforced to control the access to message Bus \* Policies enforced at Hyperty Receiver Domain Router for incoming messages

The different types of policies to be applied on these different points, namely in the Message BUS, requires further research to avoid performance overhead and potential conflicts. Initial thoughts: Message BUS PEP would enforce general access control policies that are agnostic of sender and target domains, or specific to the domain managing the device runtime (Core Runtime Provider). The access control to CRUD operations on standardised data objects like the Communication Data Object (eg only the owner of an active communication may apply delete or update operations on it) is a good candidate.

Below, it is depicted a functional architecture of the Runtime:

*Provide first a higher level architecture without showing detailed components. Distinguish internal APIs from external Interfaces which should be identified according to names defined in D2.2.*



Runtime Architecture

### Service Provider Sandboxes

According to Browser Sandbox model, each Service Provider Sandboxes executes components downloaded from the same Service Povider domain including Hyperties, protocol stubs used to connect and communicate with Service Provider Domain and PEP enabled Connector.

Functionalities to support Hyperty Communication through data object synchronisation are provided by the Syncer component based on Object.observer API. Details are discussed [here](https://github.com/reTHINK-project/architecture/blob/master/docs/datamodel/data-synch/readme.md).

#### Connector/Policy Engine

Handles communication between Hyperties and the local Message Bus, enforcing when needed valid Policies on this communicayion (e.g. authorisation policies) according to Service Provider domain policies. It also enforces access control policies to synchronised object (Object Monitor functionalities as proposed [here](https://github.com/reTHINK-project/architecture/issues/52)).

#### Protocol Stub

Protocol Stack to be used to communicate with Service Provider Backend Servers (including Messaging Server or other functionalities like IdM) according to Protocol on the Fly and codec on the fly concept.

Protocol stubs are reachable through the Message BUS. In this way it is ensured that all messages received and sent goes through the message bus where policies can be enforced and additional data can be added or changed including message addresses and identity tokens.

### Core Runtime

#### Policy Decision Point and Message BUS authorisation

It provides Policy decision functionalities for the Service Provider Router sandbox according to Policies downloaded and stored locally when associated Hyperties are deployed. The possibility to consult Policies stored remotely should also be investigated. It also provides authorisation / access control to the Message BUS.

#### Message BUS

Supports local message communication between Hyperty Instances in a loosely coupled manner. Access to message BUS is subject to authorisation to prevent cross origin attacks / spy from malicious Hyperties.

See [postaljs](https://github.com/postaljs/postal.js)

#### Registry

Local Runtime Hyperty registry where Hyperty local addresses are registered and discoverable by other local Hyperties. The Runtime Registry should ensure synchronisation with Remote Domain Registry (to be provided by WP4)

#### Identities Containers

Contains Tokens that associates Hyperties with Users, it also provides Identity assertions. Something similar to [WebRTC IdP Proxy](http://w3c.github.io/webrtc-pc/#identity) but not limited to WebRTC.

#### Runtime User Agent

Manages Core Sandbox components including its deployment and update from Core Runtime Provider. It also handles Device bootstrap and the deployment of Hyperties and Protocol Stubs in the Runtime. It includes a Catalogue Protocol Stub to interface with any reTHINK Service Provider Catalogue service to query and download required Catalogue Data Objects, according to [Catalogue Service interface design][interface-catalogue](https://github.com/reTHINK-project/architecture/blob/master/docs/interface-design/Interface-Design.md#73-catalogue-interface).

## Native Runtime

Functionalities that are natively provided by the runtime.

### WebRTC Media Engine

Provides the support for Stream communication betweeb Hyperties according to WebRTC Standards.

# Security analysis of the Hyperty Runtime

## Introduction

The security analysis contained in this document refers to the runtime architecture described in [[1]](https://github.com/reTHINK-project/core-framework/blob/master/docs/specs/runtime/runtime-architecture.md).

In reTHINK, the trusted computing base (TCB) of the Hyperty Runtime encompasses the following components: the Native Runtime, the Core Sandbox components, and the underlying JavaScript engine, Operating System, and hardware platform. If the native runtime is compromised, so it will be the support for WebRTC stream communication between hyperties. Subverting the core sandbox components can compromise: the correct decision and enforcement of policies by the PDP, the proper routing of messages through the Message Bus, the flawless registration and discovery of Hyperty and protoStubs by the Registry, and the correct maintenance of identities by the Identities Container. Subverting the JavaScript Engine can interfere with the correctness and security of JavaScript code, whose execution necessarily requires a JavaScript engine such as V8. The code that depends on the JavaScript engine includes the runtime components specific to the reTHINK architecture (Router PEP, PDP, Message Bus, Registry, Identities Container, and WebRTC engine), and all the user or developer code hosted by the Hyperty runtime, namely Hyperty Instances, ProtoStubs, and Applications. Given that the JavaScript Engine depends on both the Operating System and the hardware platform, compromising the latter can also affect the JavaScript engine and all the other components sitting on top of it.

Next, we analyze the security properties of our system assuming that all components of the trusted computing base are intact. Then, we assess the security of the Hyperty Runtime when deployed on target platforms that exhibit different characteristics with respect to the platforms’ software and hardware configuration. In particular, we explore five platform configurations: *browser*, *application*, *server*, *router*, and *embedded*. We analyze the security of each platform under different threat models.

## Mitigated threats assuming an intact TCB

When the TCB is intact, our architecture ensures correct isolation of client JavaScript code (i.e., Hyperties, ProtoStubs, and Applications). Isolation is enforced both among client code instances and between client code instances and the environment (e.g., external applications, or OS resources). In addition, our architecture provides for the correct enforcement of the policy rules attached to Hyperty code. Such policies can regulate different aspects of a hyperty’s behavior: access control to local resources (e.g., cookies, files, network, etc), routing, charging, and privacy restrictions. Finally, our architecture ensures the authenticity of client code and the identity of the involved entities.

In the basic threat model, we assume that an attacker can server arbitrary client code to the Hyperty Runtime. The attacker can impersonate a legitimate service provider and serve malicious ProtoStub or Hyperty code. When instantiated on the Hyperty Runtime, this code can attempt to execute JavaScript instructions in order to access private data held: by other client code (including applications’), by the Hyperty Runtime TCB, or by the surrounding environment (e.g., the JavaScript Engine, or the Operating System). Malicious ProtoStub or Hyperty code may also aim to tamper with any of the just mentioned software components of the system. In particular, malicious code may try to tamper with Hyperty policies or with the respective policy decision and enforcement engine in order to escalate privileges. Finally, malicious code may launch denial of service attacks (e.g., by executing CPU intensive code). Below in this document, we expand on this threat model to consider potential vulnerabilities of our system when deployed on different environments.

Next, we describe how our system defends against several classes of potential attacks. We add to this list some attacks that can be currently launched. We provide some recommendations for fixing such attacks.

### T1: Unauthorized access by client code

The basic mechanism of our architecture to prevent unauthorized access by client code is sandboxing. Each Hyperty instance running in the system runs in its own sandbox. A sandbox defines a security perimeter for the Hyperty instance, preventing it from reading or writing the memory (or other resources) in use by other Hyperty instances or by other components in the surrounding environment. Along with a Hyperty instance, a sandbox also hosts the ProtoStub instance required by the local Hyperty instance to communicate with external services. Therefore, potentially malicious ProtoSub code will be prevented from accessing resources that are not authorized. To communicate outside the sandbox, the runtime provides well defined interfaces: the Router PEP, which is used by the Hyperty instance to communicate with the PDP and with the Message Bus, and an API to communicate with the Messaging Server. The PDP is responsible for enforcing the policy associated with the Hyperty instance.

Note that, in our architecture, sandboxing is also used to isolate other software components. In particular, there is the Core Sandbox, which hosts the Hyperty Runtime components implemented in JavaScript. Both the client code sandboxes and the core sandboxes are enforced by the JavaScript engine.

### T2: Policy subversion

Every Hyperty instance running in the system is constrained by a policy. In general, a policy can enclose several policy fragments, each of them defining subpolicies of different types. There are four types of policies: access control policies, routing policies, charging usage policies, and privacy policies. These policies are responsible for regulating, supervising, or restricting the operations that a hyperty can perform, e.g., prevent access to a local file, enforce a predefined network route, or define the usage costs of a service. To prevent a malicious Hyperty instance (or ProtoSub) from subverting the security policy and escalate its privileges, the policy decision component (PDP) and the policy repository are located in the Core Sandbox, and therefore outside the Hyperty instance’s reach. As a result, policy integrity and enforcement are safe from malicious client code.

### T3: Threats to client code authenticity

The authenticity of client code -- Hyperty or ProtoStub -- can be compromised if at least one of two things occurred without detection before the code is loaded and instantiated into a sandbox: an attacker modified the original code bytes (e.g., by embedding malware into a Hyperty code), or (ii) modified the identity of the code or of its manufacturer. To prevent these attacks, our architecture requires that every client code distribution, be it Hyperty or ProtoStub, is digitally signed by its manufacturer. By checking these signatures before instantiating the Hyperty or ProtoStub code on the sandboxes and assuming that the cryptographic primitives are correct, the Hyperty Runtime is able to guarantee the integrity and identity of the code.

### T4: Denial of service attacks

A malicious Hyperty instance or ProtoStub implementation can launch denial of service attacks by holding to specific resources, e.g., hogging the CPU by sitting on an infinite loop, or flooding the network with bogus messages. The JavaScript engine featuring the Hyperty Runtime prevents such attacks by placing a limit to the maximum utilization of a given service by a client code instance, for example by bounding the CPU cycles that a Hyperty instance is allowed to execute uninterrupted.

### Possible attacks in the current architecture

Given that ProtoStub, Hyperty instances, and the Router PEP share the same sandboxes, some attacks are possible: (i) a malicious Hyperty instance or ProtoStub can compromise the Router PEP, (ii) a malicious Hyperty can subvert a ProtoStub, or (iii) a malicious ProtoStub can compromise a Hyperty instance.

* The first attack causes no particular damage outside the enclosing sandbox. Because the Router PEPs holds no secrets, there’s no risks of confidentiality breaches. On the other hand, the Router PEP provides services to the sandbox’s client code. As a result, compromising the integrity of the Router PEP could result at most in integrity and availability violations to the JavaScript client instances enclosed in the sandbox.
* The second attack -- a malicious Hyperty subverts a ProtoStub -- could be problematic if the ProtoStub contains secrets bundled into the ProtoStub code itself. Secrets can refer not necessarily to sensitive data (which is unlikely given that ProtoStubs implement communication protocols), but proprietary IT-protected code owned by the developer or by the service provider. The current architecture provides no protection against this attack.
* Lastly, the third attack -- a malicious ProtoStub -- can be the most severe one. If a buggy ProtoStub is exploited, an attacker can gain access to execution state of the Hyperty instances sharing the same sandbox. If a Hyperty instance processes sensitive user data or handles key material, such an exploit can result in a data breach. The current version of the Hyperty Runtime architecture offers no protection against this attack.

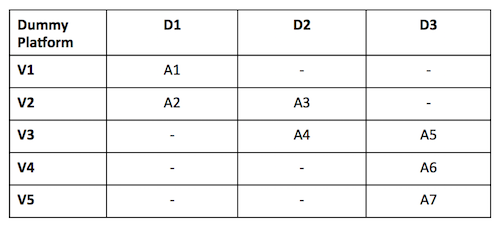
In order to mitigate attacks (ii) and (iii), we recommend that Hyperty instances and ProtoSubs execute isolated in independent sandboxes.

## Vulnerability assessment of the Hyperty Runtime

The threats described in the previous section can be thwarted by the Hyperty Runtime so long as the TCB of the system remains intact. In this section, we study the potential vulnerabilities of the TCB when deployed on a specific target platform. We envision five potential target platforms: browser, standalone application, middlebox, server, and secure element. Next, before we present our analysis for each platform, we describe our methodology to ensure a uniform assessment of the system across platforms.

### Methodology

Our basic methodology to assess the vulnerabilities of the Hyperty Runtime’s TCB is based on a *vulnerability matrix*. A vulnerability matrix indicates representative practical attacks that can be carried out against the TCB on a given platform as a mean to compromising the security of the system. The security is compromised by successfully achieving one of the goals described in the section above: permit unauthorized access by client code (T1), subvert hyperty policies (T2), compromise the authenticity of client code (T3), and launch denial of service attacks (T4). Such practical attacks to the TCB are classified in the vulnerability matrix along two dimensions: (i) the attack vector along the computer stack where vulnerabilities can be exploited (e.g.., targeting the operating system), and (ii) the difficulty level of launching attacks based on the required technical skills and resources.



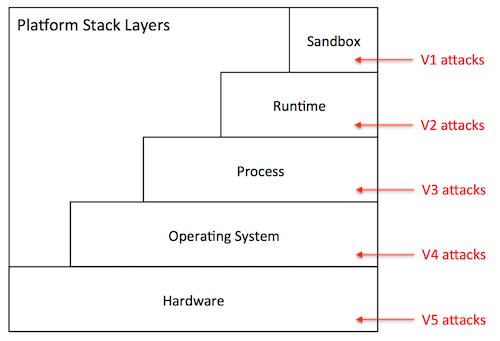
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The figure above shows an example of a vulnerability matrix for a dummy platform. The content of each cell contains attacks that the TCB is vulnerable to. Each attack is identified, e.g, as A1, or A7, and naturally must be accompanied by a description of the attack, e.g., “A1: inspection of JavaScript code through the browser”, “A7: probing the system bus”. The columns represent the difficulty level and the rows the attack vector (both will be explained below). The vulnerability matrix will then allow us to grasp how exposed the TCB is to attacks: the lower the difficulty degree of the attacks is the more vulnerable the Hyperty Runtime will be when deployed on that particular target platform.

The attacks presented in the vulnerability matrix are launched by a given attack agent. The attack agents to be considered depend on the specific platform and may include, for example, the local user, malware, the system administrator, a thief, etc. The behavior of an attack agent is characterized by an *attack profile*, which specifies the subset of all possible attacks to the Hyperty Runtime’s TCB that a given agent can perform. For example, considering a browser platform, the attack profile of an adversarial average web user certainly includes attacks like “inspection of JavaScript code through the browser”, but not “probing the system bus”. Therefore, when drawing the vulnerability matrix of the TCB for a given platform, we determine which attacks the TCB may be subjected to based on the profiles of the attacker agents that we expect to find in that particular usage scenario.

Next, we describe the classification for attack vectors and difficulty levels:

**Attack vectors.** Attack vectors can be classified in five types, ordered top-down, from the highest to the lowest layer of the computer stack, as shown in the figure below:



image

* *Sandbox level (V1)*: The attacker has direct access to the sandbox environment, hence to the code and execution state of Hyperty instances. For example, on a browser platform, users typically have access to the JavaScript of a given page. This means that a malicious user could leverage that mechanism to tamper with the JavaScript code of locally running Hyperty instances.
* *Runtime level (V2)*: The attacker has direct access to the code or execution state of the Hyperty Runtime. Depending on the specific exploit, he can mount attacks that disable the defenses against any of the attacks described in the previous section. For example, on a browser platform, a V2 attack can be achieved by installing a malicious browser extension that bypasses the policy enforcement mechanism of the Hyperty Runtime.
* *Process level (V3)*: the attacker has access to the execution state of the process where the Hyperty Runtime is hosted. Just like V2 attacks, this type of attack can result in catastrophic consequences. Examples of attacks performed at the process level include attaching a debugger to the Hyperty Runtime process and inspect its internal data structures, or dumping the process’s memory to disk by reading from /dev/mem.
* *Operating system level (V4)*: the adversary has access to the execution state of the operating system, and therefore to the execution state of the Hyperty Runtime. Similarly to V2 and V3, V4 attacks can be catastrophic. An attack performed at this layer consists, for example, of adding a rootkit to the operating system in order to keep track of the all ingress and outgress communication performed by the Hyperty instances running on the host.
* *Hardware level (V5)*: the adversary has physical access to the hardware of the platform and can launch simple attacks that do not involve tampering with the circuitry. Attacks in this category include, removal or inspection of the hard disk, probing the system bus in order to extract secrets from volatile memory, etc. An attack at this level may also include tampering with the silicon chips, perform side-channel attacks, etc. Such attacks require a high-level of expertise and committed resources. In theory, attacks performed at this level can reveal the entirety of the system state, including operating system’s. In practice, however, such attacks are more directed to extract specific secrets when V3 attacks or above are not possible.

**Difficulty level.** The difficulty level of launching an attack depends on several factors, namely the privileges owned by the adversary (e.g., user or superuser), the skills required to perform the exploit (e.g., run a debugger or tamper with silicon), and the resources that are necessary to commit to successfully carry out the exploit (e.g., specific software exploits, memory probes, etc.). Based on these factors, we define three difficulty levels for a given attack:

* *Easy (D1)*: The attack is easy to perform. Based on the privileges owned by the attacker, the tools that are necessary to launch the attack are accessible, well documented, and are simple to handle. Some examples of D0 attacks include: (i) on a browser platform, a malicious user leverages the browser interface controls in order to modify the JavaScript code of a given Hyperty, (ii) on a server platform, a disgruntled system administrator leverages superuser privileges to disable the policy enforcement mechanisms of the Hyperty Runtime where client Hyperty instances are being executed.
* *Medium (D2)*: The attack requires considerable skills and / or resources. It can be launched by mastering the tools presently available in the system (e.g., tools provided by the operating system, debuggers) or installing new ones that can be found on the Internet (including malware or exploits). The attacker has not enough skills or resources to find new vulnerabilities in the system or to develop its own exploits known vulnerabilities. Examples of such attacks include, for example, attaching debuggers to extract in-memory secrets from the Hyperty Runtime, patch the Hyperty Runtime using exploit code published on the Web, etc.
* *Hard (D3)*: The attack is very sophisticated. To mount the attack, the attacker must be able to develop its own exploit code, find new vulnerabilities in the system, and / or launch software hardware attacks. For example, finding a new vulnerability in a device driver’s code, and write the code to exploit that vulnerability. The attacks performed at the deep hardware level are also considered hard to execute.

### Browser platform

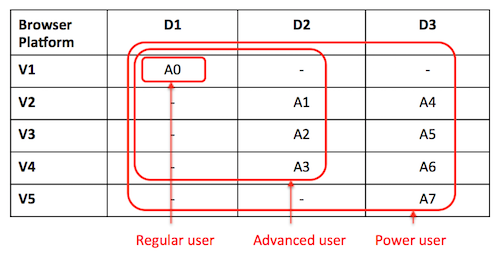
One of the primary platforms targeted by reTHINK is the browser. The browser platform will be highly heterogeneous; we may be talking about desktops, laptops, or mobile devices featuring many different configurations with respect to: hardware architecture, operating system in use, installed software, and specific browser distribution and extensions. Nevertheless, a general architecture of the browser platform is shown in the figure below.



image

Essentially, the Hyperty Runtime runs inside a browser’s process. This process is in fact a “subprocess” of the browser that implements a sandboxing mechanism of its own (as in the Chrome browser). The Hyperty Runtime is responsible for the secure execution of JavaScript code inside individual sandboxes: the core sandbox encloses additional components of the reTHINK framework written in JavaScript, the client sandbox is used for securing JavaScript client code (i.e., Hyperty instances and ProtoStubs), and ASP sandboxes provide a home for Hyperty applications. As shown in the figure, the Hyperty Runtime’s hosting process depends on the operating system, which in turn depends on the underlying hardware configuration. Aside to the browser processes, we find all sorts of application processes and operating system services.

From the security point of view, the threats to the TCB are mainly caused by an adversarial user. To better characterize these threats, we define three attacker profiles and draw the vulnerability matrix as follows:



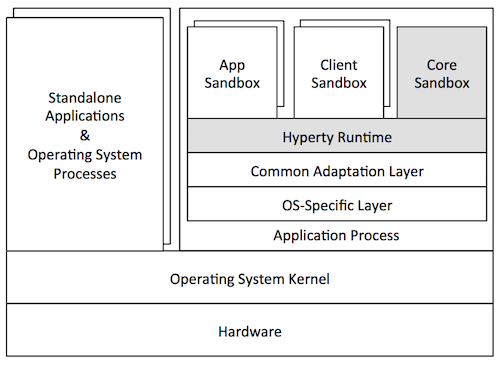
image

* *Regular user*: This attacker profile captures the class of users with an average proficiency level in computing, but is willing to subvert the security properties enforced by the TCB. He has only user privileges that enable him to launch the browser, and run Hyperty-based applications. A regular user is expected to mount the following attacks:
* *A0*: access and modify client Javascript code through the browser interface.
* *Advanced user*: This profile captures users with superuser privileges and some degree of skills and knowledge of the system. He is informed about existing tools and techniques that can be used to hack into the system’s components, has access to exploits published online, and can handle auxiliary tools (e.g., debuggers, Unix advanced commands, etc.). If necessary he can root or jailbreak the operating system by following instructions (if we are talking about mobile devices). He can assemble and disassemble the basic hardware components of the system (e.g., plugging in / out the hard disk). In addition to attack A0, an advanced user can perform attacks in different layers such as these:
* *A1*: compromise the runtime by installing a malicious browser extension,
* *A2*: dump the memory contents of the process to disk,
* *A3*: install a rootkit on the operating system that keeps track of Hyperty instances’ communication.
* *Power user*: This user is highly skilled. He gathers deep knowledge of the system and can launch sophisticated attacks. He is able investigate for vulnerabilities in the software (including in the Hyperty Runtime or in the OS) and build its own exploits. He has the resources and tools to launch hardware attacks that involve tampering with silicon. Summing up to the attacks described previously, a power user can mount more sophisticated attacks on various layers of the stack:
* *A4*: find and exploit a bug in the Hyperty Runtime
* *A5*: attach a debugger to the browser’s subprocess and inspect / modify its memory,
* *A6*: build a device driver to continuously monitor the execution of Hyperty Instances,
* *A7*: probe the system bus in order to extract private key material in use by Hyperty Instances.

**Vulnerability assessment:** As illustrated by the vulnerability matrix, the browser platform is vulnerable to a range of attacks. Some of these attacks can be mounted by regular users with relative ease. In addition, there are several ways for advanced users to successfully compromise the TCB by exploiting the system at different layers in the stack. As a result, we recommend that the browser platform should be avoided for hosting client code (i.e., Hyperty Instances, ProtoStubs, or Applications) and policies which the local user has incentives to subvert. Examples of such code include: Hyperty instances restricted by specific usage charging policies, ProtoStubs that encode proprietary communication protocols, or Applications that access copyrighted digital data.

### Application platform

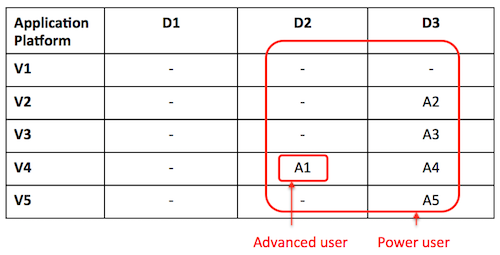
A variant of the browser platform just presented is to run the Hyperty Runtime and client code as a standalone application. A practical usage scenario, for example, is to bundle the Hyperty Runtime in mobile apps and deploy them on mobile devices such as smartphones or tablets. Alternatively, we also envision that the Hyperty Runtime can be packaged as a classical standalone application for desktop platforms, for example Linux- or Windows-based. To allow for the development and maintenance of such applications, reTHINK will provide an SDK, which will include APIs and platform specific libraries for adapting the Hyperty Runtime to the underlying operating system platform.



image

The figure above illustrates a hypothetical application platform tailored for Android mobile devices. Just like in the browser platform, the Hyperty Runtime is hosted by an application process. The host application is responsible for mediating the system calls issued by the Hyperty Runtime to the operating system and for providing a user interface to the Hyperty Runtime and client JavaScript applications (and hyperties). This application comprises additional software components: a platform-independent adaptation layer, and platform-specific libraries, e.g., for IO, storage, and memory management. In the example, the platform-specific libraries are tailored for the Android API.

From the security point of view, application and browser platform are quite similar; for that reason we adopt the same attacker profiles (regular user, advanced user, and power user). The main difference between architectures is twofold. First, the host application will prevent direct introspection of the JavaScript code running inside Hyperty Runtime sandboxes. As a result, the application architecture is able to mitigate simple attacks to the browser (A0 in the browser’s vulnerability matrix), raising the bar for regular users. Second, the host application will not support software extensions. This will prevent some advanced attacks to the runtime based on installation of malicious extension code, and to the browser process (see attacks A1 and A2, respectively, in the browser’s vulnerability matrix). Apart from that, the vulnerability matrices are comparable. Next, we present the vulnerability matrix of the application platform and provide alternative examples for attacks on Android devices.



image

* *Advanced user*: An advanced user can compromise the entire system by launching attacks at the OS level:
* *A1*: root the device and instrument the operating system in order to introspect the Hyperty instances’ sandboxes.
* *Power user*: A power user can mount more sophisticated attacks on various layers of the stack:
* *A2*: find and exploit a bug in the Hyperty Runtime,
* *A3*: find a bug in the host application code and exploit it,
* *A4*: monitor the execution of Hyperty Instances by rooting the device,
* *A5*: hack the device hardware to extract sensitive Hyperty data from memory.

**Vulnerability assessment:** As illustrated by the vulnerability matrix, the application platform (targeting Android devices) is more robust to attacks than the browser platform. This is mainly due to the fact the application architecture allows us to close some security holes in the browser architecture that cannot be thwarted without modifying the code of the browser. Nevertheless, it is still possible to for an advanced user to compromise the system by rooting the device, which will likely dissuade the average user. Nevertheless, we recommend prudence in deploying client code (i.e., Hyperty Instances, ProtoStubs, or Applications) and policies which the local user has high incentives to subvert.

### Server platform

reTHINK also targets server platforms. The idea is to allow Hyperties and client applications to deliver their services from the cloud or from a local cluster. In such environments, there is a server infrastructure which is carefully configured to provide specific services to users (e.g., web hosting, VM hosting). Part of that configuration requires the installation and setup of specific server-side applications (SSAs), e.g., web server, DB server, etc. There are two typical server configurations for hosting server-side applications (SSAs): virtualized or non-virtualized. In virtualized environments, SSAs run inside virtual machines, which in turn are managed by virtual machine monitors (VMMs), such as Xen or VMware. In non-virtualized environments, SSAs execute natively on servers configured with a classical operating system like Linux. Regardless of whether the server platform is virtualized or not, the SSA will always depend on an operating system, even if the OS runs inside a VM. Therefore, to provide Hyperty support for server platforms, the Hyperty Runtime will be packaged as a standalone SSA.

### Router platform

### Embedded platform

## Runtime APIs

*Should we use Typescript interfaces to define Runtime APIs?*

### Message BUS

To send messages with optional call back

postMessage( Message.Message message , callback)

To listen to messages published on a certain resource

addListener( listener, URL.URL resource )

### Hyperty

init( postMessage )  
report(message)

### Policy Enforcer

To set postMessage() function to be used by the Policy Enforcer to send messages usually the "MessageBUS".

setSender( postMessage )

To set postMessage() function to be used by the Policy Enforcer to receive messages usually the Hyperty or a Syncher. In case the resouce parameter is provided this postMessage() is only valid for messages containing the same resource url.

setReceiver( postMessage, resource )

To receive messages from the message BUS

postMessage(message)

### Syncher

*should we distinguish between Reporter and Observer syncher?*

To set postMessage() function to be used by the Syncher to send messages usually a "Policy Enforcer" but it could also be the MessageBUS.

setSender( postMessage )

Hyperty instance uses this function to provide the object to be changed by the (observer) syncher according to messages received. The Hyperty instance has previsouly used the *Object.observe* javascript api to set as an observer of this object

Promise <SyncObject> createAsObserver( receivedMessage )

To create a new object and ask another Hyperty instance to observe it. A Create Message will be generated and sent by the Syncher. Promise is used to handle Response messages to this object.

Promise <SyncObject> createAsReporter( resourceURL, schemaURL, toURL, dataObject?)

By default the events triggered by changes performed on this object by the Resporter Hyperty will trigger the synchronisation process. Otherwise the Hyperty instance should invoke a separate function, *addAttribute()*, *updateAttribute()*, *deleteAttribute()* defined below and afterwards invoke the *synch()* function to trigger the synchronisation process.

To add an attribute to object without triggering the synchronisation process:

addAttribute(resourceURL, attributeName, attributeValue)

To update an attribute without triggering the synchronisation process:

updateAttribute(resourceURL, attributeName, attributeValue)

To delete an attribute without triggering the synchronisation process:

deleteAttribute(objectId, attributeName)

To delete an Object:

delete(objectId)

To trigger the synchronisation process:

Promise synch(objectId)

To receive messages from other Hyperties that will be reported to the Hyperty:

postMessage(message)

### protoStub

To initialise the protocol stub including as input parameters its allocated component runtime url, the runtime BUS postMessage function to be invoked on messages received by the protocol stub and required configuration retrieved from protocolStub descriptor.

init( RuntimeURL runtimeProtoSubURL, bus.postMessage, ProtoStubDescriptor.configuration configuration )  
  
connect( )  
  
  
disconnect( )  
postMessage(message)  
addListener( onMessage )

### HypertySandbox

postMessage(message)

### Runtime UA

Download Hiperty from Catalogue URL

loadHyperty( URL )

Download Stub from Catalogue URL or domain url

loadStub( URL )

Used to check for updates about components handled in the Catalogue including protocol stubs and Hyperties. *check relationship with lifecycle management provided by Service Workers*

checkForUpdate(CatalogueURL)  
  
discoverHiperty(applId, OSname, capability\_list)   
accomodate interoperability in H2H and proto on the fly for newly discovered devices in M2M

### Registry

To register a new Hyperty in the runtime which returns the HypertyURL allocated to the new Hyperty.

HypertyURL registerHyperty( hypertySandbox.postMessage, hypertyUrl)

To unregister a previously registered Hyperty

unregisterHyperty( HypertyURL )

To register a new Protocol Stub in the runtime including as input parameters the function to postMessage, the DomainURL that is connected with the stub, which returns the RuntimeURL allocated to the new ProtocolStub.

HypertyRuntimeURL registerStub( stub.postMessage, DomainURL )

To unregister a previously registered protocol stub

unregisterStub( HypertyRuntimeURL )

To receive status events from components registered in the Registry

onEvent( Message.Message event )

To discover protocol stubs available in the runtime for a certain domain. If available, it returns the runtime url for the protocol stub that connects to the requested domain. Required by the runtime BUS to route messages to remote servers or peers (*do we need something similar for Hyperties?*).

RuntimeURL discoverProtostub( DomainURL )

### Identities Container

Functions to deal with assertions compliant with [WebRTC RTCIdentityProvider](http://w3c.github.io/webrtc-pc/#identity-provider-interaction)

IdAssertion generateAssertion( contents, origin, usernameHint )  
validateAssertion( assertion, origin )

### LHCB

getCurrentConnectivityStatistics()  
sendConnectivityStatisticsToBroker()

### Dynamic view of Runtime

*it should be aligned with* [*WP2 Dynamic View*](https://github.com/reTHINK-project/architecture/tree/master/docs/dynamic-view)

#### [Basics](basics/readme.md)

#### [Identity Management](identity-management/readme.md)

#### [H2H Communication](h2h-communication/readme.md)

#### [M2M Communication](m2m-communication/readme.md)

### Readme

#### [deploy runtime](deploy-runtime.md)

#### [deploy protocol Stub](deploy-protostub.md)

#### [deploy Hyperty](deploy-hyperty.md)

#### [Message BUS Routing](bus-msg-routing.md)

#### [Intra domain local communication](intra-local-comm.md)

#### [Inter domain local communication](inter-local-comm.md)

#### [Intra domain remote communication](intra-remote-comm.md)

#### [Inter domain remote communication](inter-remote-comm.md)

### Deploy runtime



Deploy Core Runtime Components in the Native Runtime

In case the device does not support the Hyperty Core Runtime components eg an existing browser like Chrome or a Network Node.js Server, they have to be deployed in the Device.

**Notes from 6th July H2H Comm Work Session:**

Runtime Core components should be as much as possible independent on the Runtime type. They should be deployed once and executed at the background. The next time the runtime is started there should be no need to download the core runtime again unless there is a new version. Runtime core components should be singletons (?) shared by different Apps and Hyperty instances. In order to support these characteristics for the Browser, Runtime Core components should be implemented with Web/Service Workers (FFS).

The Core Runtime is provided by a specific Service Provider that handles a central repository or catalog of the needed Core Runtime components.

This process may be triggered by the deployment of an Hyperty or Protocol Stub using some existing libraries like require.js. Such possibility has to be validated with experimentations.

### Deploy Protocol Stub



Deploy Protocol Stub

Steps 1-2 : The protocol stub deployment may be triggered by the deployment of an Hyperty or by some attempt from a local Hyperty to communicate with a remote Hyperty running in the domain served by the protocol Stub. In this case the Runtime Registry would take the initiative to start the protocol stub deploy (FFS). Such trigger may take advantage of some existing libraries like require.js (to be validated with experimentations). The Runtime UA only downloads and deploys requested protocol stub after checking in the Registry that there is no protocol stub available in the runtime.

Steps 3 - 4 : the Runtime UA is able to derive the URL to download the protocol stub from the domain url, since it is a well known URI defined in the reTHINK Architecture Interfaces. The Runtime UA uses the protocol stub well known URI to download and instantiate it in the runtime.

Steps 5 - 7 : the new protocol stub is registered in the Runtime Registry, which allocates and return the runtime address (RuntimeURL) for the new runtime component. In addition, the runtime Registry requests the runtime BUS to add its listener to receive events about the protocol stub status.

Steps 8 - 10 : the Runtime UA retrieves required configuration data for the new protocol stub and initialises it.

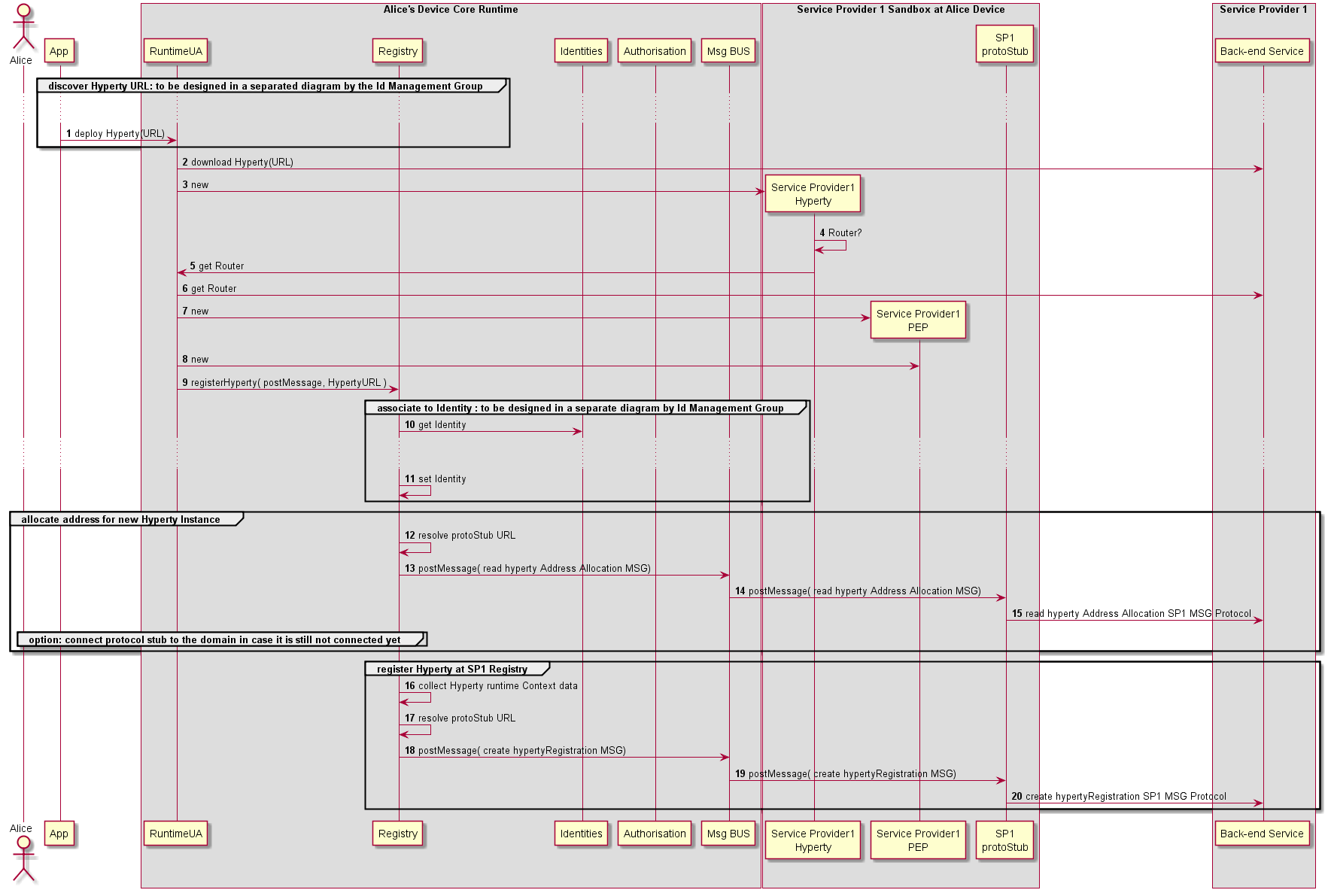
Protocol stubs are connected by using credentials handled by the Core Runtime Identities Container which are detailed in the [domain login use case](../identity-management/domain-login.md).

Steps 11 - 12 : protocol stub publishes its status (including events about when it is connected or disconnected) in its resource status. Components registered on the protocol stub status resources, like the Registry, are notified about the new protocol status.

Message to publish Protocol Stub Status

"id" : "1"  
"type" : "UPDATE",  
"from" : "hyperty-runtime://sp1/protostub/123",  
"resource" : "hyperty-runtime://sp1/protostub/123/status",  
  
"body" : { "value" : "LIVE" }

### Deploy Hyperty



Deploy Hyperty

Message to request address allocated for new Hyperty Instance:

"id" : "1"  
"type" : "CREATE",  
"from" : "hyperty-runtime://sp1/runalice/registry",  
"to" : "sp1/msg-node/address-allocation",  
"body" : { "hypertyUrl" : "hyperty://sp1/hy123" }

Message to Responde to request address allocated for new Hyperty Instance:

"id" : "1"  
"type" : "RESPONSE",  
"from" : "sp1/msg-node/address-allocation",  
"to" : "hyperty-runtime://sp1/runalice/registry",  
"body" : { "hypertyInstanceURL" : "hyperty-instance://sp1/alice/hy123" }

Message to Register new Hyperty Instance:

"id" : "1"  
"type" : "CREATE",  
"from" : "hyperty-runtime://sp1/runalice",  
"to" : "sp1/registry",  
"body" : { "hypertyURL" : "hyperty://sp1/hy123", "hypertyInstanceURL" : "hyperty-instance://sp1/hy123,  
"hypertyRuntimeURL" : "hyperty-runtime://sp1/runalice,  
...}

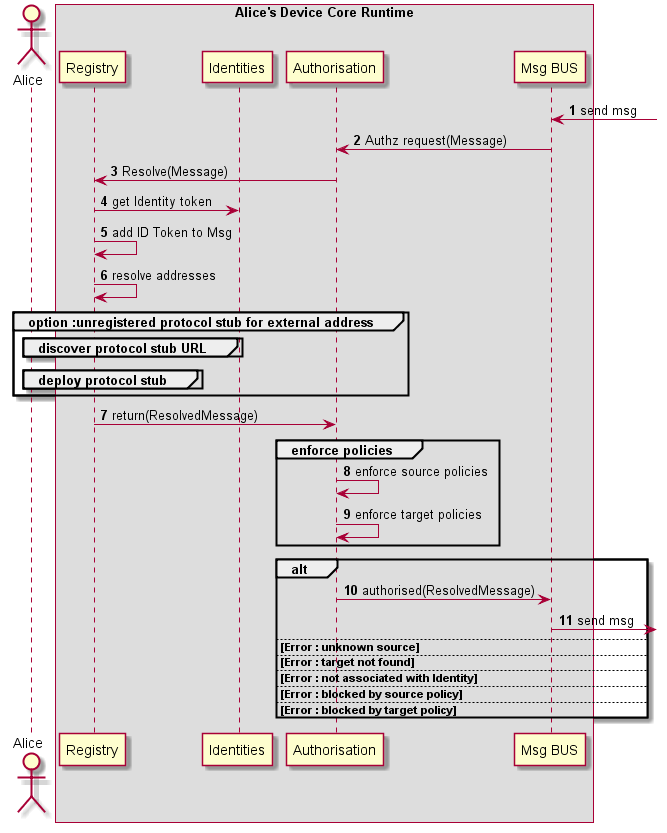
The Hyperty deployment may be triggered by an App or by some attempt from a local Hyperty to communicate with a remote User. In this case the Runtime Registry would take the initiative to start the protocol stub deploy (FFS). Such trigger may take advantage of some existing libraries like require.js (to be validated with experimentations).

**Open Issue:** In the diagram above, the Hyperty is instantiated by the native Javascript engine as a normal javascript function/object, and in its constructor the registration process is performed. Another option, is to have in the Core Runtime, a Hyperty loader functionality (a Service/Web Worker?) that would handle the instantiation of the Hyperty and its registration in the runtime.

Hyperties are reachable through domain routers (should we change the name?) to: 1- enable enforcement of domain proprietary policies 2- the Hyperty (data synch) communication model would be implemented by the router (connector is a better name?) and not by the Hyperty itself

When registered, Hyperties are associated with an Identity by the Registry / Identities container. Then all, messages sent by the Hyperty will be signed with a token according to the Identity associated to the Hyperty. To be designed by the Identity Manager group.

### Message Routing in Message BUS



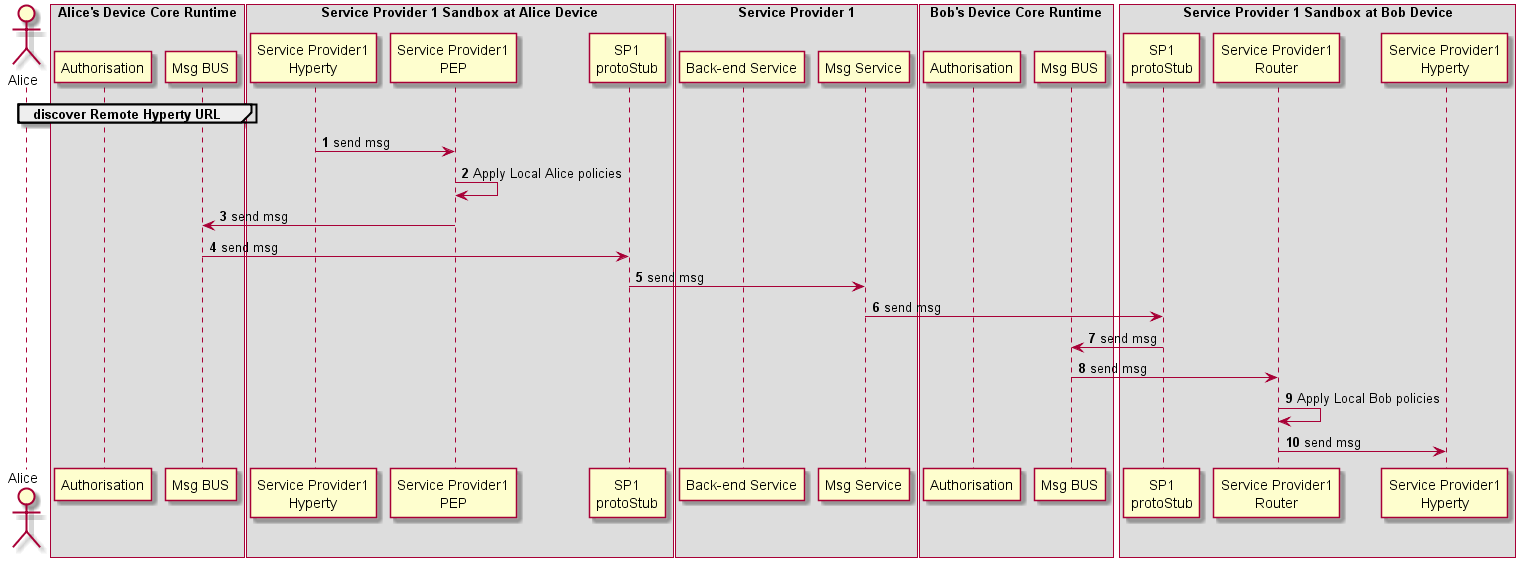
Routing messages in Message BUS

### Intra-domain Local Communication



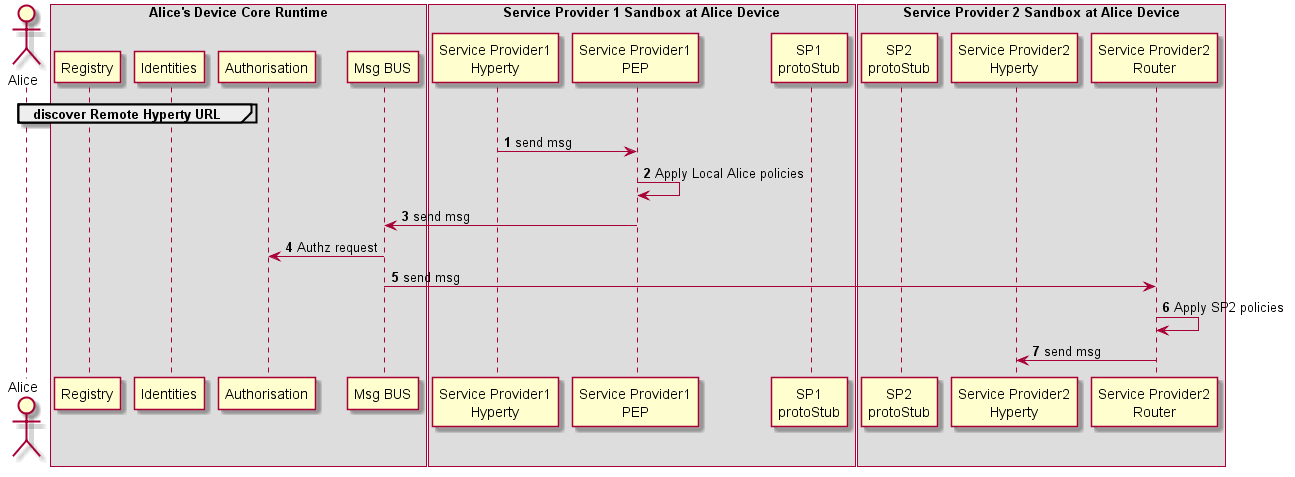
Intradomain Local Communication between Hyperties

### Intra-domain Remote Communication



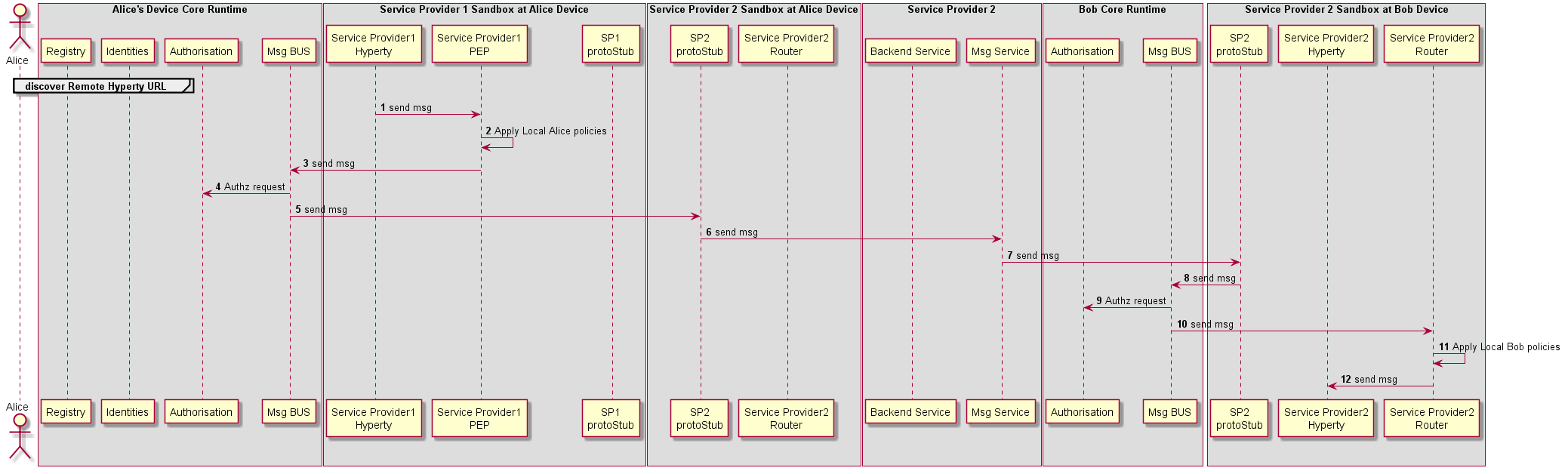
Deploy Hyperty

### Inter-domain Local Communication



Interdomain Local Communication between Hyperties

### Inter-domain Remote Communication



Interdomain Remote Communication between Hyperties

### H2H Intradomain Communication

To be aligned with the [Communication setup model based on the Reporter-Observer pattern](https://github.com/reTHINK-project/architecture/blob/master/docs/datamodel/communication/data-synch-communication-model.md)

As agreed in the conf call of 13th July, this use case is splitted into 2 diagrams:

#### [Alice Invites Bob](h2h-intra-comm-1-alice-invites.md)

#### [Bob receives Invitation from Alice](h2h-intra-comm-2-bob-receives-invitation.md)

#### [Alice is aknowledged Bob received Invitation](h2h-intra-comm-3-alice-is-aknowledged-invitation-received.md)

#### [Bob Accepts Invitation and Updates the Communication Object which is reported to Alice - To be Removed](h2h-intra-comm-4-accepted.md)

#### [Bob's App interaction and Alice's connection update] (h2h-intra-comm-4-notification-update.md)

#### [Bob gathers WebRTC resources] (h2h-intra-comm-5-bob-webrtc.md)

#### [Synchronization of Alice's Data Object](#synchronization-of-alices-data-object) (h2h-intra-comm-6-alice-DO-synch.md)

### H2H Inter-domain Communication

#### [Alice Invites Bob](h2h-inter-comm-1-alice-invites.md)

The remaining steps are similar to intra domain communication *or should we consider the usage of different IdPs?*

### H2H Intradomain Communication - create communication

This MSC diagrams shows the most relevant steps to support the initial invitation of Alice to Bob.

H2H Intradomain Communication : Alice invites Bob

H2H Intradomain Communication : Alice invites Bob

Steps 1 - 4 : Alice decides to invite Bob for a communication. The discovery of Bob's Hyperty Instance URL is described here(../identity-management/discovery.md).

Steps 5 - 7 : the Hyperty Instance creates the Connection, the LocalConnectionDescription and the LocalIceCandidates data objects as defined [here](https://github.com/reTHINK-project/architecture/blob/master/docs/datamodel/communication/readme.md#connection).

Steps 8 - 9 : the Hyperty Instance requests the Syncher to ask Bob to create and observe these objects. Syncher generates CREATE messages for each object and puts it in the Body in JSON format. For simplification purposes we assume the CREATE msg contains the Connection object plus local SDP and local IceCandidates:

[**Create Message**](https://github.com/reTHINK-project/architecture/tree/master/docs/datamodel/message#createmessagebody)

"id" : "1"  
"type" : "CREATE",  
"from" : "hyperty-instance://sp1/alicehy123",  
"to" : "hyperty-instance://sp1/bobhy123",  
"contextId" : "qwertyuiopasdfghjkl",  
"body" : { "resource" : "comm://sp1/alice/123456", "value" : "<json object with connection, sdp and ice candidates>"}

Steps 10 : Alice's PEP applies local policies if required including outgoing communication request access control

Steps 11 : Alice ID Token assertion is added to the message (see [here](../identity-management/user-identity-assertion.md) for more details).

Steps 12 - 14 : the message is routed through Alice Message BUS reaching Service Provider Back-end Messaginge Service.

### H2H Intradomain Communication - create communication

This MSC diagrams shows how Bob receives invitation from Bob.

H2H Intradomain Communication : bob receives invitation

H2H Intradomain Communication : bob receives invitation

Steps 1 - 3 : Service Provider Back-end Messaginge Service routes the message to Bob's Message BUS, reaching Bob's PEP component

Step 4 : Bob's PEP applies local policies if required including incoming communication request access control

Steps 5 - 8 : the message is forwarded to Bob's Syncher which creates the requested new objects and reports to Bob's Hyperty Instance the new created objects.

Steps 9 - 12 : As soon as the new Objects were created by Bob's syncher, it responds back to Alice to confirm the objects were created with a [Response Message](https://github.com/reTHINK-project/architecture/tree/master/docs/datamodel/message#responsemessagebody):

"id" : "1"  
"type" : "RESPONSE",  
"from" : "hyperty-instance://sp1/bobhy123",  
"to" : "hyperty-instance://sp1/alicehy123",  
"contextId" : "qwertyuiopasdfghjkl",  
"body" : { "code" : "200" , "description" : "ok"}

### H2H Intradomain Communication - create communication

This MSC diagrams shows how Alice is aknowledged that Bob received the invitation

H2H Intradomain Communication : Alice is Aknowledged

H2H Intradomain Communication : Alice is Aknowledged

### Incoming call is notified to Bob's application and Alice is updated

(step 5) The Application which interacts with the human user setups a callback in to be notifed when the Connection data Object is modified.

(step 6) When a Data Connection Object receives any modification request from another Hyperty, the callback setup in the step before is called. The App is aware of the incoming invitation to establish a media session.

(step 7) The App can show this invitation to the human user in some way through a human interface. (step 8)In such a case the human typically will acept the communication. (step 9) The App acepts teh invitation through the API exposed by the the Service Provider Hyperty. In orther to start the media session a Local Data Object is created (step 10) where the data related to the local parameters of the media session is going to be established.

(step 11) The Syncher elemtn from the Hyperty setups an Observer callback in the Local Data Object which will be called when the Local Data Object changes. (step 12) The observer reports that there is a communication in progress t othe Syncher.

### Bob starts WebRTC API (TBC)

(Step 18) The Hyperty call the WebRTC API from the browser including the remote parameters from the Remote Data Object. The same happens when a new Ice Candidate is updated in the Remote Data Object (step 19 and Step 20).

While remote Ice Candidate are added (step 19 and Step 20 may take place several times as Trickle Ice is supported) the Hyperty calls the Peer Connection method to create an SDP answer (step 21) to be sent to it with all the parameters used to establish the media session between Alice and Bob but the Ice Candidates which will be received asynchronaly later. When the SDP with the local description is ready a callback is called and the SDP is sent to the Hyperty (step 22).

(Step 23) The Hyperty calls the Peer setLocalDesciption API method from the WebRTC API exposed by the browser so that the browser is aware of the media parameters which are going to be used to establish the media session with Alice. At this point the gathering process of local Ice Candidates starts.

## Synchronization of Alice's Data Object

(Step 28)The local Data object reports that there have been changes in the connection parameters and the Syncher sends a CRUD message through the Policy Enforcer to Update the Remote Data Object at Alice's Hyperty (Step 29). (Step 30) the Policy Enforcer checks if the message is compliant with the local policies and the message is sent to the ProtoStub (Step 31) to be in turn sent to the Service Provider 1 Back-End (Step 32)

### H2H Interdomain Communication - create communication

This MSC diagrams shows the most relevant steps to support the initial invitation of Alice to Bob, where Alice and Bob are in different domains.

H2H Intradomain Communication : create communication

H2H Intradomain Communication : create communication

Steps 1 - 4 : Alice decides to invite Bob for a communication. The discovery of Bob's Hyperty Instance URL is described here(../identity-management/discovery.md).

Steps 5 - 7 : the Hyperty Instance creates the Connection, the LocalConnectionDescription and the LocalIceCandidates data objects as defined [here](https://github.com/reTHINK-project/architecture/blob/master/docs/datamodel/communication/readme.md#connection).

Steps 8 - 9 : the Hyperty Instance requests the Syncher to ask Bob to create and observe these objects. Syncher generates CREATE messages for each object and puts it in the Body in JSON format. For simplification purposes we assume the CREATE msg contains the Connection object plus local SDP and local IceCandidates:

[**Create Message**](https://github.com/reTHINK-project/architecture/tree/master/docs/datamodel/message#createmessagebody)

"id" : "1"  
"type" : "CREATE",  
"from" : "hyperty-instance://sp1/alicehy123",  
"to" : "hyperty-instance://sp2/bobhy123",  
"contextId" : "qwertyuiopasdfghjkl",  
"body" : { "resource" : "comm://sp1/alice/123456", "value" : "<json object with connection, sdp and ice candidates>"}

Steps 10 : Alice's PEP applies local policies if required including outgoing communication request access control

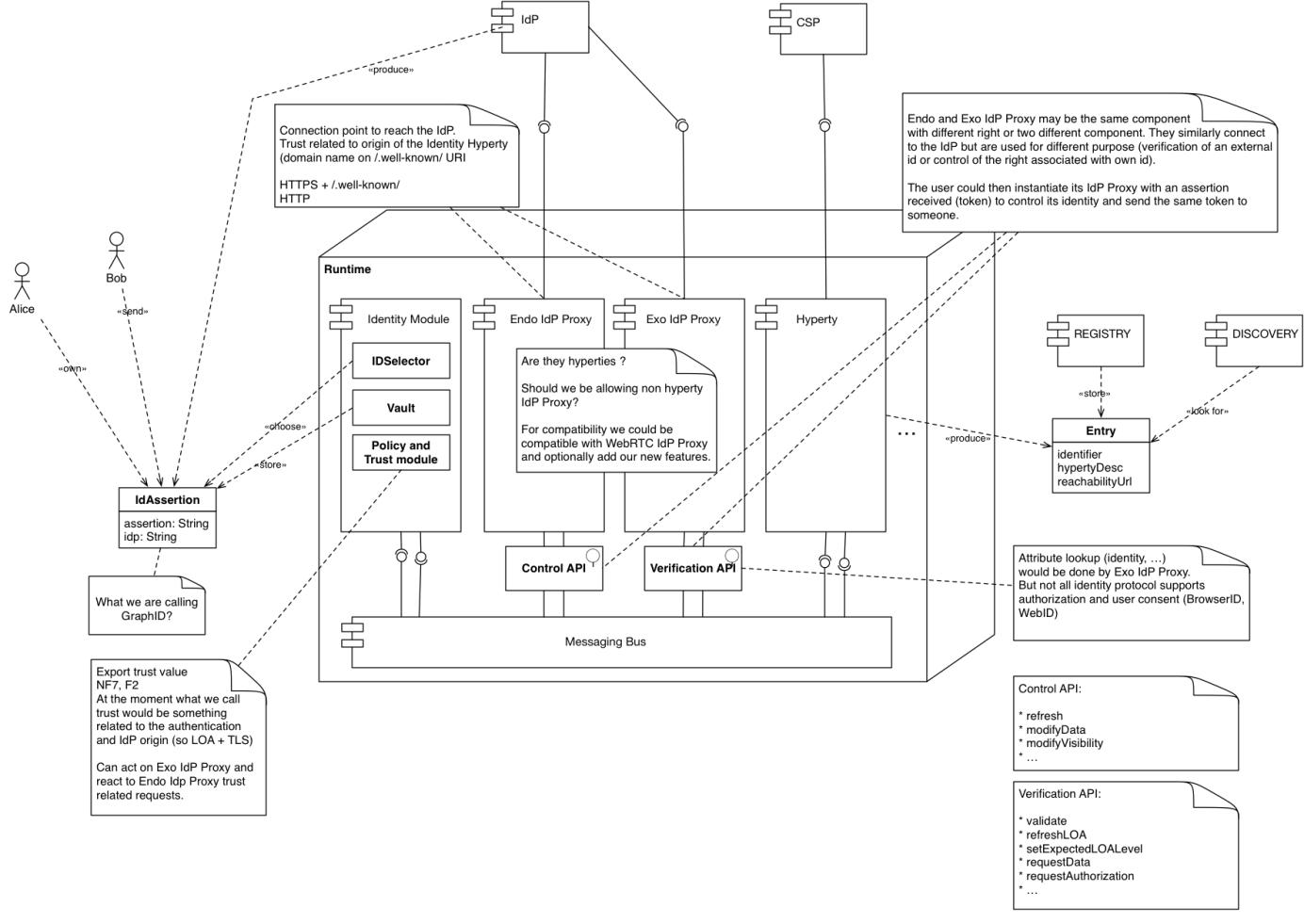
Steps 11 : the message is routed towards Alice Message BUS.

Steps 12 : SP2 protostub is deployed in the runtime if not deployed yet as defined [here](../basics/deploy-protostub.md)

Steps 13 - 14: Message BUS routes the message to SP2 protocol stub which proceses it to send it to Service Provider 2 Back-end Messaginge Service.

### Identity Management dynamic view

**Kevin contribution:**



Kevin proposal

**questions and answers as discussed on 7th July meeting:**

* **Q: Identity Module similar to Runtime Arch Identities Container?**
* A: Yes
* **Q: If Yes, I would separate authorisation related functionalities from IDSelector/Vault to support other types of policies**
* A: agreed
* **Q: Endo IdP Proxy / Exo Proxy seems to be more related with protocol stubs ie it is a stub that enables runtime components to interact with back-end side Identity Management functionalities. Anyway, not clear the differences between the two**
* A: In principle IdP Proxy can be partially supported by a IdP protocol stub, but some functionalities can be supported by an Hyperty or by the Identities Container. Such separation requires further study and work on specific Use Cases. Endo is to handle "my identity" and Exo is to verify the Identities of others.
* **Q: Registry / Discovery are runtime local?**
* A: yes

According to work session on the 14th July, the following use cases were distributed among partners:

#### [User Registration](user-registration.md)

PTIN

#### [Discovery](discovery.md) : Protocol Stub URL, Hyperty, User

DT

#### [Login into Domain](domain-login.md)

PTIN

#### [Associate User Identity to Hyperty Instance](user-to-hyperty-binding.md)

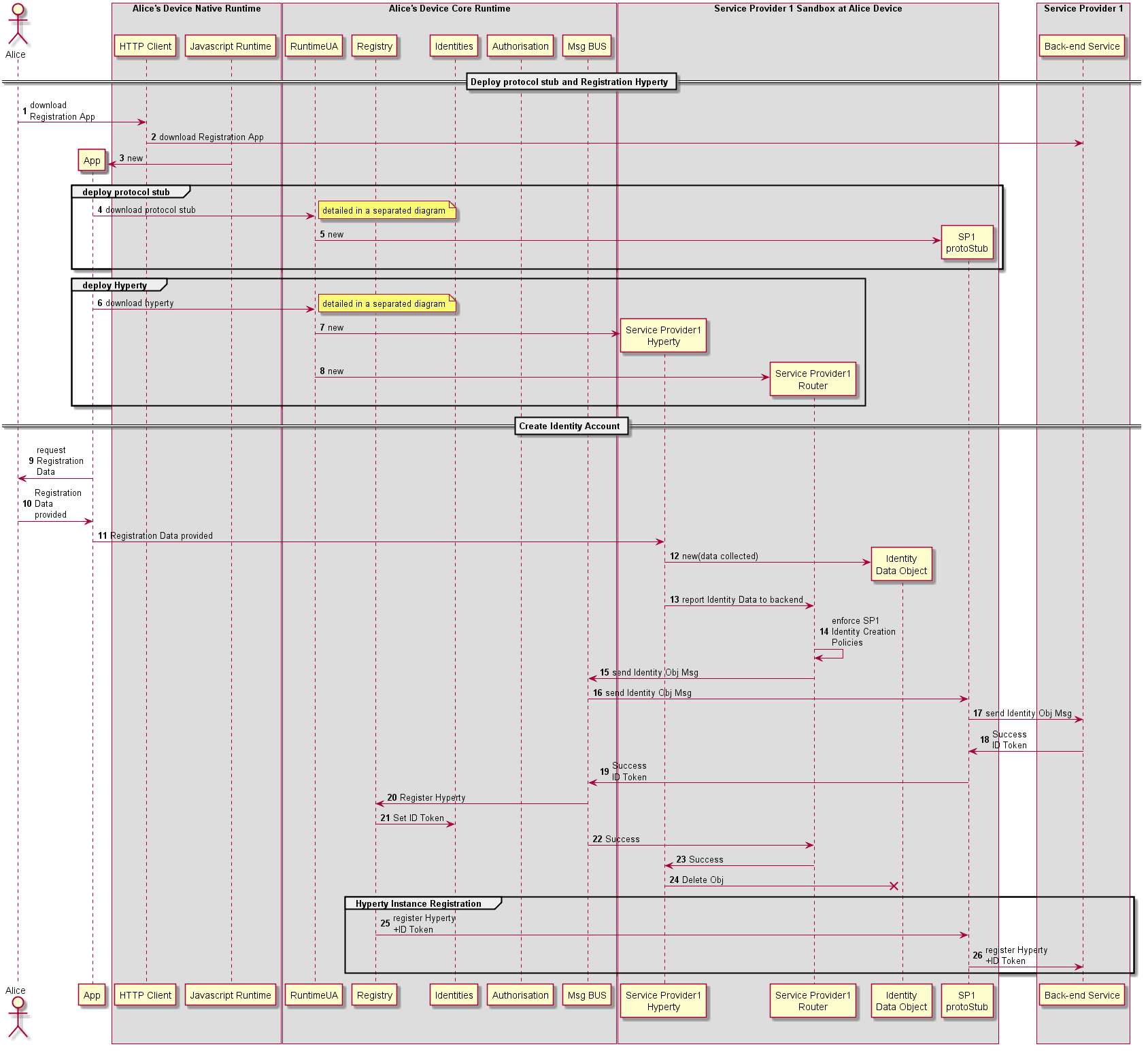
INESC, Orange(?)

#### [Assert User Identity](user-identity-assertion.md)

Quobis, Orange(?) **pending**

#### [User Profile Management](user-profile-management.md)

### User Registration



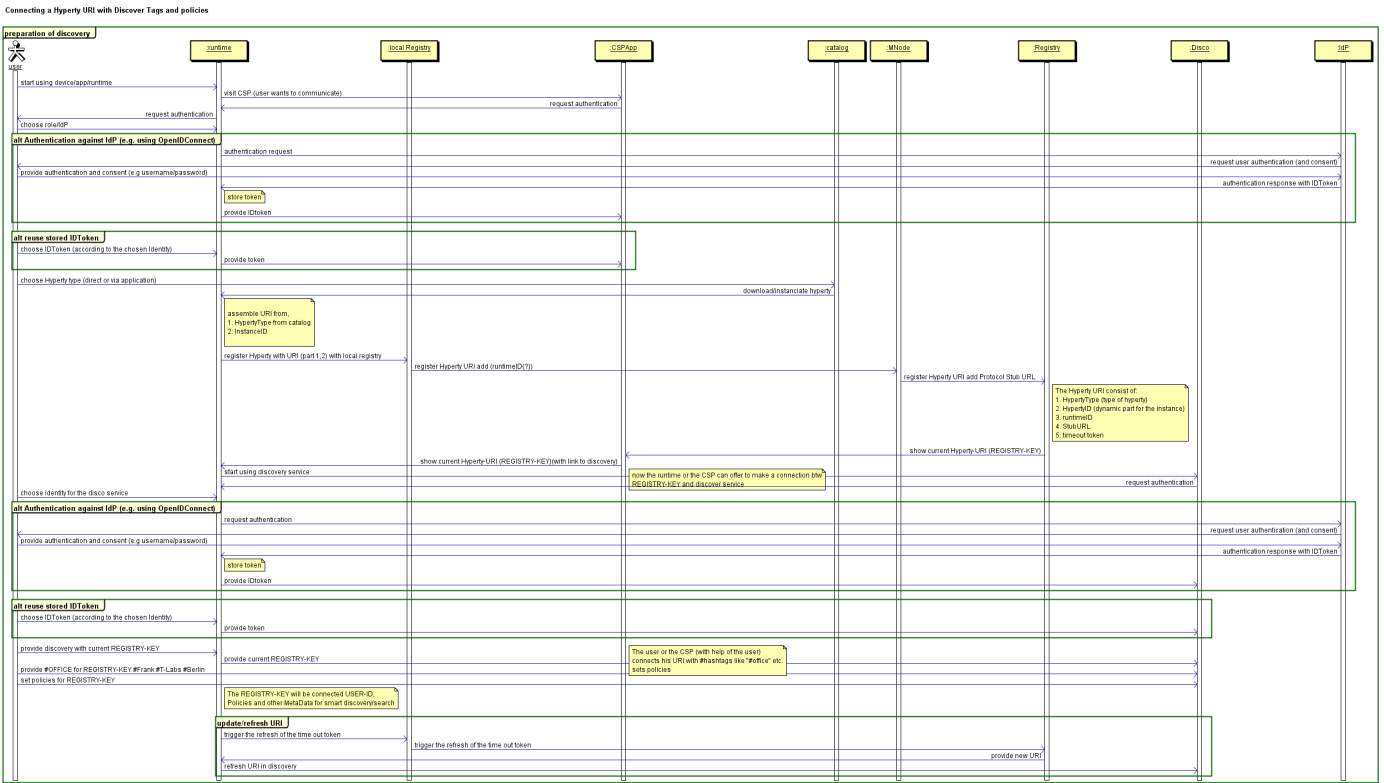
User Registration

In this use case, it is considered there is a single protocol stub to interact with all back-end services including Identity Management. Another option is to have different protocol stubs to interact with different back-end services including authentication, authorisation and messaging services.

## Discovery

The picture shows Discovery of a Hyperty. The first picture is about the preparation or "How comes the HYperty URL into the Discovery service?". The second pictury is about "How to find this information?" and "How to use it?".

### Prepare Discovery



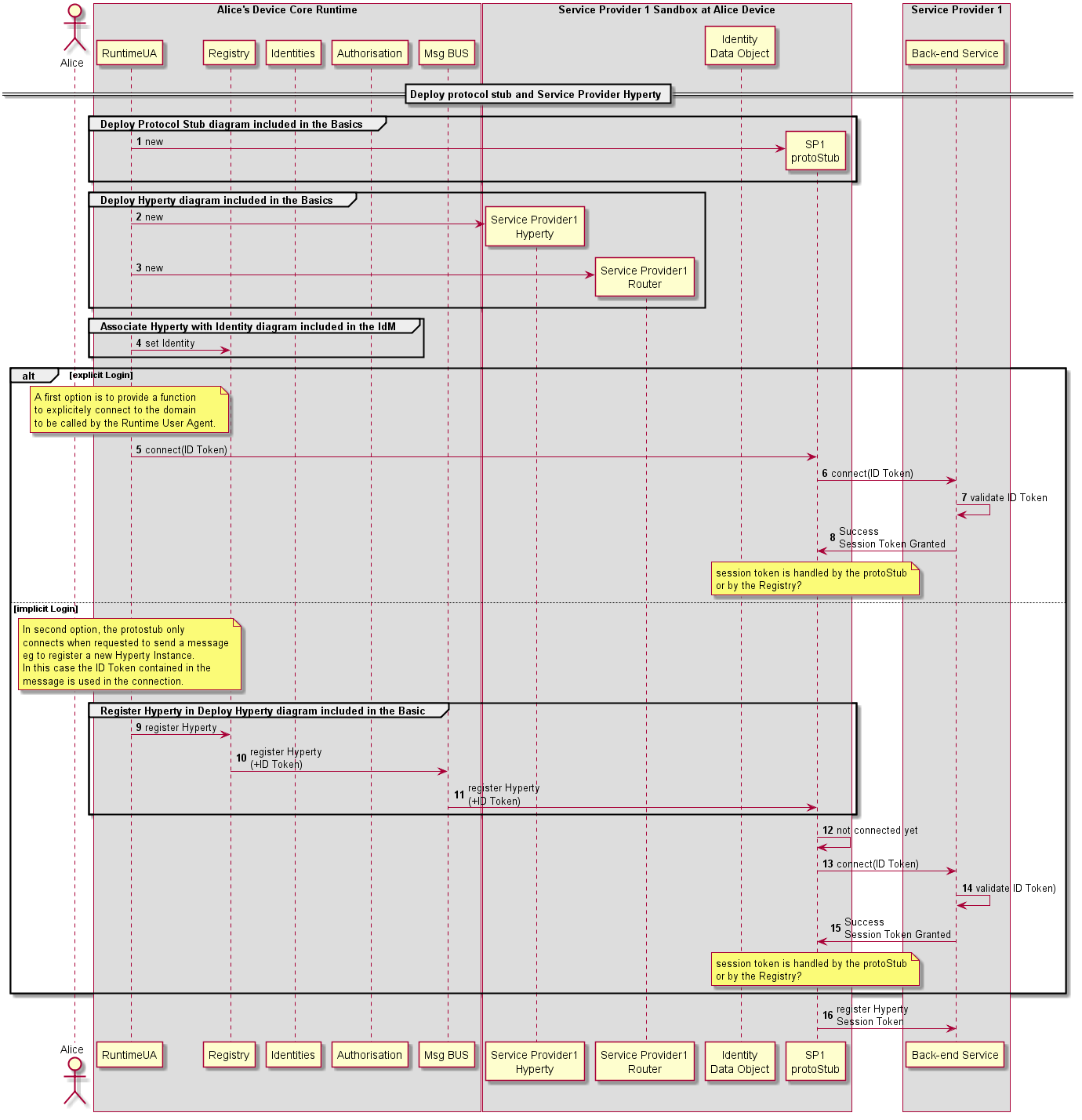
Prepare Discovery

### Use Discovery



Use Discovery

### Domain Login



Domain Login

In this use case, it is considered there is a single protocol stub to interact with all back-end services including Identity Management. Another option is to have different protocol stubs to interact with different back-end services including authentication, authorisation and messaging services.

### Associate User Identity to Hyperty Instance



User-to-Hyperty Binding Scheme

#### Description of the protocol steps:

This sequence details the steps needed to associate the user identity to a given Hyperty instance.

*1*- Create ProtoSutb1 sandbox.

*2*- Create Hyperty 1 instance for Service Provider 1.

*3*- Create SP1 router and the respective PEP connector.

*4*- The application using Hyperty 1, triggers a request to set the Identity to be associated to this Hyperty instance. This request is sent to the SP1 router to be touted to the RunTime UA

*5*- Optimally the SP1 router checks the policies of the application itself in regard to the internal identity rule/policies. note that, this verification is internal and not related with the verification performed by the Core Runtime.

*6*- SP1Router send the request (if authorized by the Application internal rules) to associate a identity to the Hyperty 1 instance. This request is sent to the Core Runtime Message Bus. This request includes the Identification Token of Hyperty 1.

*7*- The MsgBus sends the Hyperty-user association to the RunTime UserAgent.

*8*- The RunTime UserAgent 'selects' the user identity to be used (eventually by asking Alice which used ID to use) and sends it to the Registry.

*9*- The registry sends a request to the Identities Engine.

*10*- The Identities Engine replies with the identity token (ID Token) for the selected user. This step assumes that a identity Token has already exists for the requested user. If it does not, a [Domain Login](domain-login.md) must be performed.

*11*- The Registry sends a request to the Authorization/Policy engine to verify if the User Identity association request by the Hyperty Instance is authorized by the existing Policies.

*12*- If the association is allowed a success message is replied to the registry. If not a reject message is replied (not depicted in the figure).

*13*- The Register Engine generates an Association Token. This Association Token will allow the Hyperty instance to use the requested ID Token.

*14*- The created ID Association Token is sent to the SP1 router.

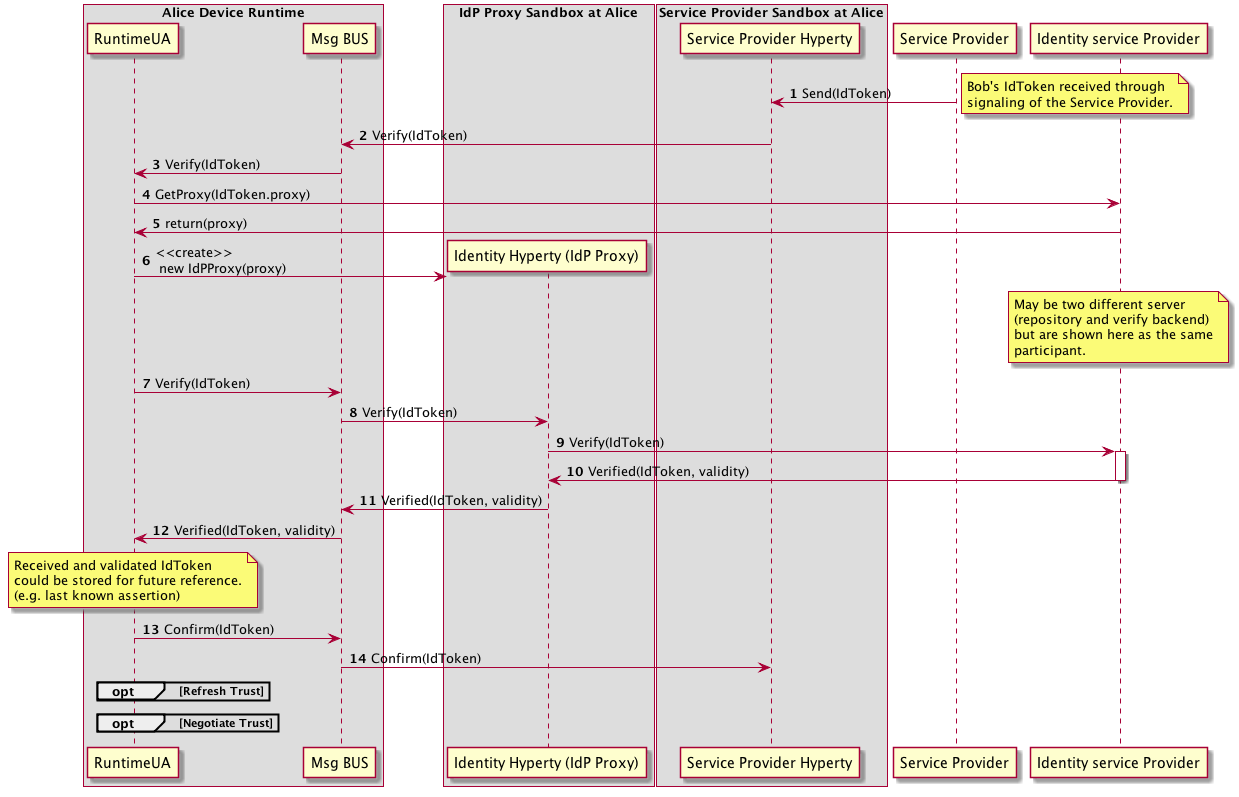
*15*- The router forwards the ID Association Token to the Hyperty instance (how requested it).

*16*- Hyperty 1 created a new ID Association Token object.

Note: This association protocol is assuming that the request for the ID association is triggered by the Application/Hyperty instance. The Second option is for the association action to be triggered by the User Agent (RuntimeUA). In this case steps 4 to 7 need to be changed.

Question: Which option should be provided? If both, which should be the default one?

### User identity assertion sequence diagram (proposition)



uid-assertion-seq

In this sequence, Alice Hyperty receives an Identity Assertion from its signaling/backend service. Before prompting the user with the asserted identity (e.g. an incoming call notification) it must be verified. The hyperty thus uses the Verification API to ask the runtime to verify the received assertion. Communication with the Runtime is done through the Msg bus.

Upon receiving the verification request, the runtimeUA instantiate an IdP Proxy from a URL. This URL is given in the IdToken. Alternatively the IdP Proxy may already have been instantiated. Once instantiated, the RuntimeUA uses it to verify the IdToken. Communication with the IdP Proxy is also done through the Msg bus.

If the IdToken is validated, the RuntimeUA confirms the validity to the Hyperty.

## M2M Intra-domain communication

To be aligned with [WP2 dynamic viw](https://github.com/reTHINK-project/architecture/tree/master/docs/dynamic-view/M2M%20Communication)

### [Overview](m2m-comm-overview.md)

### [Bootstrap, Authentication and Registration](m2m-bootstrap-auth-registration.md)

FOKUS (Ancuta)

To be aligned with [Domain Login](../identity-management/domain-login.md)

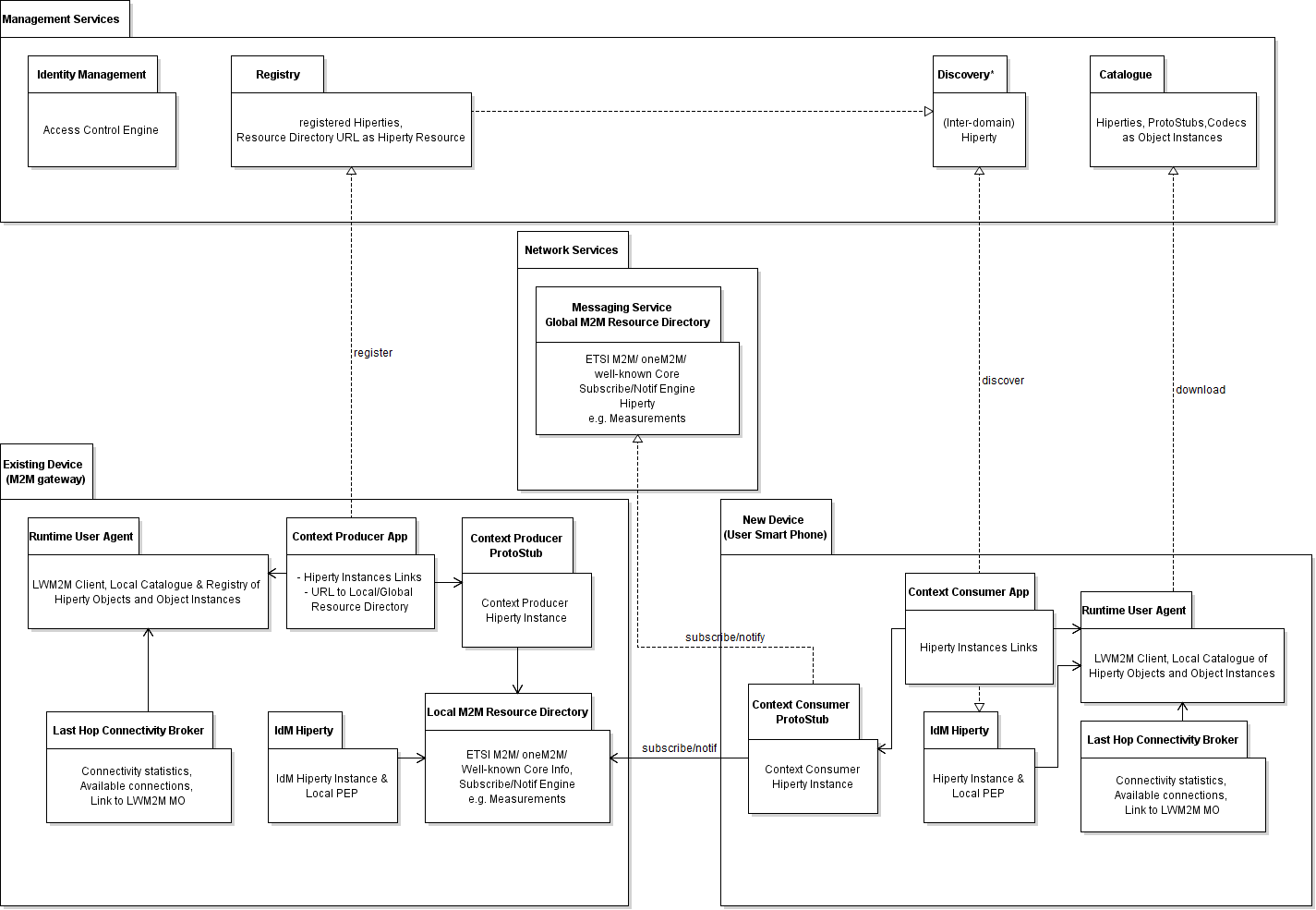
To be aligned with [Domain Login](../basics/deploy-hyperty.md) and [Associate User Identity with Hyperty Instance](../identity-management/user-to-hyperty-binding.md)

#### [Context Discovery](m2m-intra-comm-3-discovery.md)

Paulo (PTIN)

#### [PUB-SUB Communication](m2m-intra-comm-4-pub-sub.md)

Paulo (PTIN)

The overview of the M2M End-User runtime components and their interaction with the Management Services and Network Services is presented in the diagram below. 



Diagram

### M2M Intra Communication : Context Discovery



Context Discovery in M2M Intradomain Communication

[**Previous: Device Bootstrap, Authentication Registration**](m2m-bootstrap-auth-registration.md)

Steps 1 - 4: The Energy Context Consumer Hyperty requests to Discover the Home Energy Context through the Gateway Protocol Stub.

**READ Message**

"id" : "1"  
"type" : "READ",  
"from" : "hyperty-instance://alice.home/washmachinehy123",  
"to" : "alice.home",  
"body" : { "resource" : "alice.home/registry/context",   
 "criteria" : {"tag" : "energy"},  
 "projection" : {"url" : 1} }

Steps 5: The Residential Gateway finds the Energy Context Provider (HEMS) instance in its registry. It performs a match between its descriptor and the Energy Context Consumer (Wash Machine) descriptor to verify that both are compliant.

Steps 6 - 9: The Home Energy Context URL is returned to the Energy Context Consumer Hyperty.

**RESPONSE to READ Message**

"id" : "1"  
"type" : "RESPONSE",  
"from" : "alice.home",  
"to" : "hyperty-instance://alice.home/washmachinehy123",  
"body" : { "code" : "200" , "description" : "ok",  
 "value" : {"url" : "ctxt://alice.home/energy"}}

### M2M Intra Communication : PUB-SUB Communication

[**Previous: Context Discovery**](m2m-intra-comm-3-discovery.md)



Context Discovery in M2M Intradomain Communication

Steps 1 - 4: The Energy Context Consumer Hyperty requests to Subscribe the Home Energy Context through the Gateway Protocol Stub.

**SUBSCRIBE Message**

"id" : "1"  
"type" : "SUBSCRIBE",  
"from" : "hyperty-instance://alice.home/washmachinehy123",  
"to" : "alice.home",  
"body" : { "resource" : "ctxt://alice.home/energy" }



Context Discovery in M2M Intradomain Communication

Two options to handle with Subscription Auhtorisation:

**Option 1: Authorisation enforced in the GW**

Steps 1 : The Residential Gateway uses local policies to authorise the subscription request.

Steps 2 - 6: The Residential GW requests the Device holding the Context to retrieve the most updated Energy Context Data object. Through a READ message.

**READ Message**

"id" : "1"  
"type" : "READ",  
"from" : "alice.home",  
"to" : "hyperty-instance://alice.home/hemshy123",  
"body" : { "resource" : "ctxt://alice.home/energy" }

**Option 2: Authorisation enforced in the Device**

Steps 7 - 11 : The subscription request is forwarded to existing device Policy Enforcer which applies local policies to give permission to forward the message to the Producer Hyperty. It is assumed the Core Runtime asserts the message ID Token is coming from a trustful device ie it is registered in the GW domain with authorisation by Alice. (to be detailed in a separated IdM related diagram). *question:* should the Policy Enforcer respond with the Context Data Object without interacting with the Hyperty instance but only with the object?

Steps 12 - 15: The Hyperty responds with the most updated Context Data object.

**RESPONSE to READ or SUBSCRIBE Message**

"id" : "1"  
"type" : "RESPONSE",  
"from" : "hyperty-instance://alice.home/hemshy123",  
"to" : "hyperty-instance://alice.home/washmachinehy123", // for subscribe message response  
"to" : "alice.home", // for read message response  
"body" : { "code" : "200" , "description" : "ok",  
 "value" : { <Energy Context Data Object>}}



Context Discovery in M2M Intradomain Communication

Steps 1 - 4: The Subscription Response with Energy Context Data Object reachs the Consumer Hyperty.

Steps 5 - 8: Context Consumer Hyperty instantiates the received Energy Context Data Object and sets as an observer of it. Then, instantiates an Observer Syncher to observe it.

#### Implementation Considerations according to Device Types

The following runtime types according to devices types are considered:

1. Devices featuring Browsers like PCs, Smartphones and Tablets
2. Native Apps featuring some GUI deployed in End-user Devices like PCs, Smartphones and Tablets
3. IoT/M2M Gateways that aggregates sensors and atuators using different IoT/M2M networking technologies
4. Network Server Virtual Machine used eg Media Server, Media Gateway, App Server, etc

For each of these runtime types we should analyse the best strategy to support Hyperty Runtime functionalities identified above.

Possible Strategies: \* Browser Extensions \* Docker+NodeJs \* Docker+JDK8 \* NodeJs \* JDK8 \* Javascript shim layer to be used in Browsers without extensions ie files implementing the Shim layer would be downloaded with the Hyperty

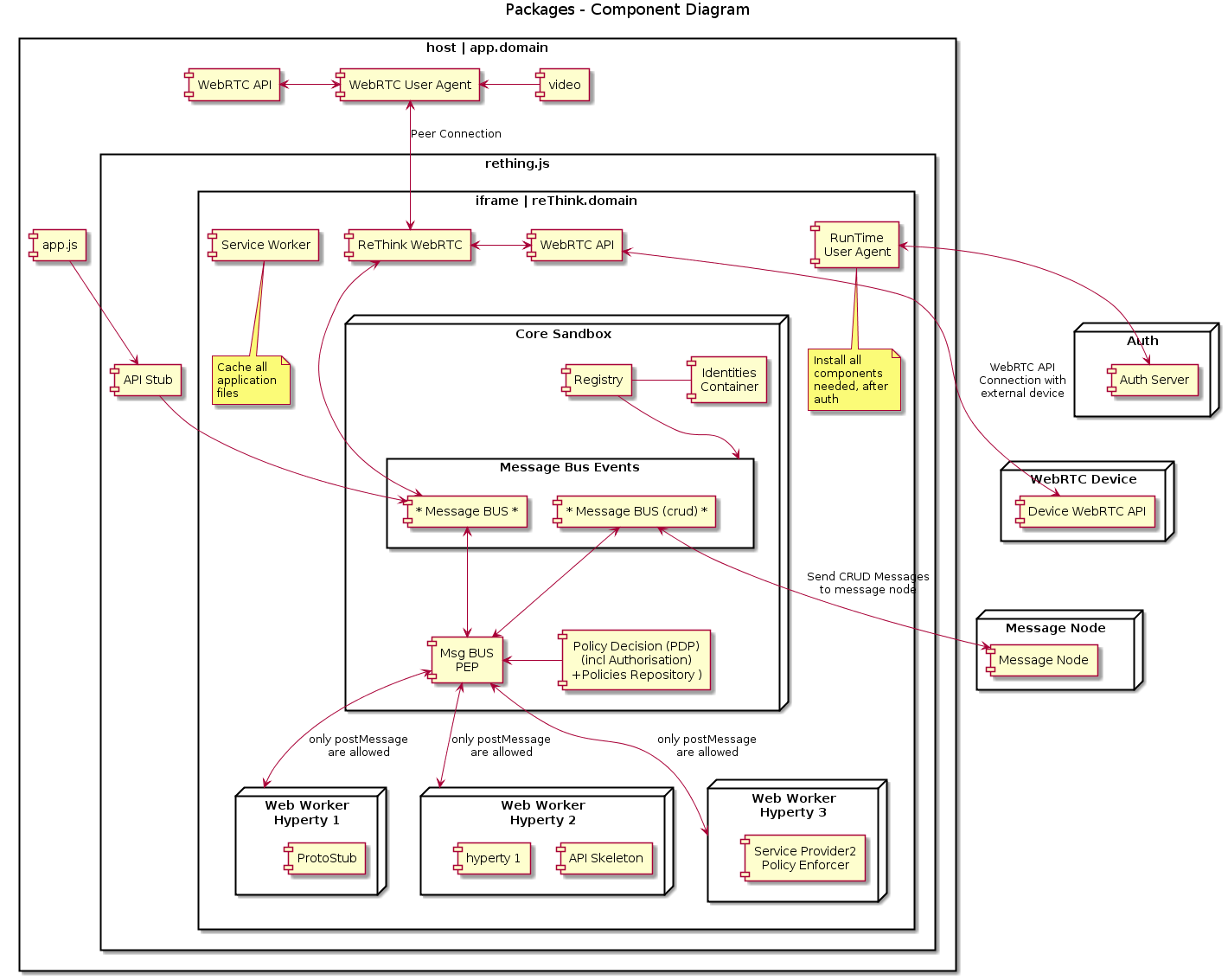
##### [Browser Runtime](browser-runtime.md)

##### [Standalone Runtime](browser-runtime.md)

##### [M2M/IoT Gateway Runtime](gw-runtime.md)

#### Browser Runtime Implementation

* A Service Worker is used to manage the cache of Runtime Core Components
* Hyperties and Protocol Stubs are implemented inside Web Workers
* Runtime Core components, Hyperties and Protocol Stub are executed inside an iFrame loaded from reTHINK runtime provider domain
* Web Workers are only able to interact each other with self.postMessage(..) which is caught by window.addEventListener('message', handleSizingResponse, false); implemented by the Runtime MsgBUS Core Component
* The same Service Worker may also be used to manage the cache of Hyperties and protostubs
* Since it is not possible to use webrtc APIs inside a web worker, there will be a "reTHINK WebRTC" component inside the iFrame but outside the web worker, that is in charge of interacting with the WebRTC API on behalf of Hyperties running inside Web Workers, through messages exchanged between Hyperties and the "reTHINK WebRTC". There will be a "HypertyWebRTCAgent" that will expose standard WebRTC APIs to be used by the Hyperty. In this way the Hyperty is not aware that it is not interacting directly with the native WebRTC API. It should be analysed whether communication between "reTHINK WebRTC" and "HypertyWebRTCAgent" will be supported by the Message BUS or by something else.
* Since the Hyperty API to be consumed by the Application can't be directly used by the App (cos it is inside a Web Worker) there will a kind of RPC communication through messages exchanged between the HypertyAPIStub component running on the App side and an API Skeleton running on Hyperty side. It should be analysed whether communication between these components will be supported by the Message BUS or by something else.
* in addition, and since it is not possible to pass WebRTC Media and Data Streams handled inside the iFrame towards the Application that is outside the iFrame, a local loop peerconnection is established between the "reTHINK WebRTC" and the "HypertyAPIStub" running on Application side. See more details below.



## Runtime Architecture with IFrame

After some investigation we find away to send stream from app client to iframe with our domain. We use peer connection to send media stream.

#### how it works

The peer getUserMedia from app client and make a call to peer inside the rethink iframe, and this answer with null stream (we send stream one way), after this, peer can send the stream through peer connection to another client.

We need to do an experimentation code to make an complete validation for this architecture.

# Considerations about the implementation of Runtime for standalone applications

A couple of tools have emerged to build native apps using standard web technologies. Among them: - crosswalk - cordova / phonegap / ionic

## Crosswalk

Crosswalk is a runtime for mobile and desktop web applications. It enables to deploy standard web application for various devices (Android/IOS/Linux). It is based on Chrome and Blink for rendering.

By using the Crosswalk Project, an application developer can:

* Use all the features available in modern web browsers: HTML5, CSS3, JavaScript.
* Access the latest recommended and emerging web standards.
* Use experimental APIs not available in mainstream web browsers.
* Control the upgrade cycle of an application by distributing it with its own runtime.
* Add custom extensions to an application, to leverage platform features not exposed by Crosswalk or the standardized web platform.
* Crosswalk supports WebRTC applications so it makes possible to send and receive real-time flows from Android and iOS devices.

## Crosswalk Architecture



crosswalk

Crosswalk supports an efficient way of creating your own Web APIs as extensions by writing native Java code. This way the user can expose new platform and device APIs as they need them. New Api could be available in crosswalk before they get standardized at the W3C level.

## cordova /Ionic / phonegap

Apache Cordova is a library used to create native mobile applications using Web technologies. The application is created using HTML, CSS and JavaScript and compiled for each specific platform using the platform native tools. Cordova provides a standard set of JavaScript APIs to access device features on all supported platforms. Additional features can be provided through the development of plugins

## Cordova functionnal schema



cordova

The application itself is implemented as a web page, by default a local file named index.html, that references whatever CSS, JavaScript, images, media files, or other resources are necessary for it to run. The app executes as a WebView within the native application wrapper, which you distribute to app stores.

At its core, Cordova offers a simple but powerful API to call Javascript functions that map to native code or plugins. This means you can transfer any kind of data from native land into web land. Cordova can do almost a native app can do, it just needs the right plugins that send the right data to your web code

## Cordova plugins

A Cordova plugin bridges a bit of functionality between the WebView powering a Cordova application and the native platform the Cordova application is running on. Plugins are composed of a single JavaScript interface used across all platforms, and native implementations following platform-specific Plugin interfaces that the JavaScript will call into. It should be noted that all of the core Cordova APIs are implemented using this exact architecture. Cordova has a high quality plugin API, we just need more great plugins that expose data from the native layer, not just hard coded features or UIs. While the default plugins are very simple and easy to use, they don’t scale well when you want to build something really custom

## Some plugin examples

### iosrtc

iosrtc is a wrapper around Google’s WebRTC library and simply provides PeerConnection, getMediaDevices and getUserMedia APIs , without any limitations or artificial constraints.

### Crosswalk-based Cordova Android

Crosswalk-based Cordova Android is derived from Cordova Android and uses Crosswalk as the HTML5 runtime. It is an Android application library that allows for Cordova-based projects to be built for the Android Platform. It is aimed at replacing default Android Webview with Crosswalk Webview, bringing all new functionalities of Chrome.

This solution has been succesfully used by companies part of the reTHINK project to develop WebRTC hybrid applications so it is a suitable candidate to be used to implement standalone reTHINK applications for Android.

## Cordova vs PhoneGap

Cordova is the community powered version of PhoneGap, which is Adobe’s productized version and ecosystem on top of Cordova.

## Cordova vs Ionic

Ionic uses and extends Cordova

## Webview

The WebView class is an extension of Android's View class that allows you to display web pages as a part of your activity layout. It does not include any features of a fully developed web browser, such as navigation controls or an address bar. All that WebView does, by default, is show a web page. This allows to leverage features provided by the browser engine in any App without adding extra libraries.

Since Android 4.4 (KitKat), the WebView component is based on the Chromium open source project. WebViews now include an updated version of the V8 JavaScript engine and support for modern web standards previously missing in old WebViews. New Webviews also share the same rendering engine as Chrome for Android, so rendering should be much more consistent between the WebView and Chrome.

In Android 5.0 (Lollipop), the WebView has moved to an APK so it can be updated seperately to the Android platform.

### Webview WebRTC support

From WebView v36 WebRTC is supported so it makes easier to add WebRTC capabilities to any native. Webview 36.0.0.0 is still a developer preview version so it can not be used in official Apps currently but it is expected to become soon the stable release..

### Crosswalk vs Webview

The size of the apps is lower compared to Crosswalk applications which must include all the libraries to implement the browser functionality. The WebView can be updated separately from the rest of the application. This can be an advantage as it will allows to fix any kind of issue and support new features, but it may cause issues if the App using it is not updated to fix any possible incompability.

One of the obvious drawbacks is that Webview is not available in iOS.

### Runtime implementation in Constrained Devices

NodeJs is considered one of the options for implementing the Runtime API for platforms like Raspberry PI and [Beagle Board](http://beagleboard.org/bone):

http://elinux.org/Node.js\_on\_RPi

http://beagleboard.org/Support/BoneScript

https://www.npmjs.com/package/node-sandbox

A package for LWM2M is already available for NodeJs (https://github.com/telefonicaid/lwm2m-node-lib).

#### Also potentially relevant:

http://samsung.github.io/iotjs/

also see: https://github.com/reTHINK-project/core-framework/blob/master/docs/specs/runtime/implementation/standalone-runtime.md

## [Messaging Node Architecture](msg-node-architecture.md)

## [Specification of Messaging Node implementation with Vertx.io version 3.0](vertx_specs.md)

## [Specification of Messaging Node implementation with Node.js](nodejs_specs.md)

## [Specification of Messaging Node implementation with matrix.org](matrix_specs.md)

## Messaging Node Architecture

Below, it is depicted a functional architecture of the Messaging Node:



Messaging Node Architecture

The Messaging Node is comprised by three main types of functionalities:

The Core Functionalities, Connectors and Protocol Stubs.

### Core Functionalities

#### Message BUS

Routes messages to internal Messaging Node components and external elements by using Connectors or Protocol Stubs. It supports different communication patterns including publish/subscribe communication.

#### Access Control

Message Routing including pub/sub Subscriptions are subject to Access Control in cooperation with authentication and authorisation provided by Identity Management functionalities.

#### Session Management

Session Management functionalities are used to control messaging connections to service provider back-end services. For example, when user turns-on the device and connects to its domain, providing credentials as required by Identity Management functionalities. In general, each message should contain a valid token that was generated when the used connected to the Messaging Node. It also manages the registry of protocol stubs and connectors supported by the Messaging Nodes to support the routing of messages to these components.

#### Address Allocation Management

Manages allocation of messaging addresses to Hyperty Instances in cooperation with Session Management when users connect to the domain.

It also manages the allocation of messaging addresses to foreign Hyperty Instances i.e. Hyperty Instances that are provided from external domains but that use the protofly concept to interact with Hyperty Instances served by this Messaging Node.

### Protocol Stub

In special situations eg when the download of external software (protocol stubs) into end-user devices is not allowed, it should be possible to have interoperability between Messaging Nodes from different domains by using the protofly concept.

Thus, a Protocol Stack to be used to communicate with another Messaging Node can be deployed.

### Connectors

Connectors implements protocol stacks used to interoperate with external elements from the domains, including:

* IdM Connector to interact with remote Identity Management functionalities
* Registry Connector to interact with remote Registry functionalities
* End-User Device Connector to interact with Hyperty Instances running in the end-user device
* Network Server Connector to interact with Hyperty Instances running in a Network Server

# Vertx Specification

*For each* [*functional block*](msg-node-architecture.md) *identify existing vertx components that can be reused and extended If extensions are neede they should be specificied by designing apis to be implemented*

## Core Functionalities

* Main objective of core func. is to authorize, filter and process messages. Messages are JSON objects that should have 2 blocks, HEADER and BODY, and are processed from different components of core. Inbound messages should be processed in a Pipeline. The sequence is "Session Management" -> "Access Control" -> "Message BUS"
* Pipeline components will implement a simple interface that we can reuse from io.vertx.core.Handler<E> replacing E with a PipelineContext object. Using the vertx Handler has the advantage to be compatible with io.vertx.ext.web.Router, that can be a replacement for the Pipeline.
* Outbound messages should be processed in a Pub/Sub system. If message BODY block are for CRUD operations, there should be a Pub/Sub protocol for object/model subscriptions, where should this be processed? The address scheme of the vertx EventBus is not enough for this functionality. We need to control the Pub/Sub functionality better than what vertx give to us with the address scheme! Hyperties need to subscribe to objects/collections not just addresses.

### Pipeline

By now, additional components are identified (Pipeline, PipelineContext). This is similar to vertx Router but without the URL addressing scheme. The io.vertx.ext.web.Router class could be a possible candidate for Pipeline functionalities, however the Router is hard coded to work with HTTP protocols, and there is no need for static configurations of routing schemes. I would advise to implement a simple Pipeline system instead of using the Router, less dependencies and better decoupled from the protocol.

### Session Management

Connection (WebSocket, SockJS) events/messages for OPEN and CLOSE should be intercepted by this component. A session instance is linked to a connection resource (WebSocket, SockJS) if authorized. Every message header is intercepted, session token is verified and if exist, a "user" or other identification URL is replaced in HEADER. The JSON object is forwarded to "Access Control" component.

### Address Allocation Management

This is not a Pipeline component (it doesn't process messages), but it's used by the "Session Management" to allocate Hyperty identification URL's that will be linked to a Session when the Hyperty is connected. This will be used to translate Hyperty an URL address into the correspondent Connector Resource.

### Access Control

This component is able to analyze HEADER (identification URL from "Session Management") and BODY blocks and decide if the message should be forwarded to the "Message Bus" or denied. There is a possibility to add a rule engine in this step, but it's not specified for now, what kind of rule engine.

### Message BUS

Main objective of the MB is to process the BODY block, that contains information of the protocol, CRUD operation or other defined information. Vertx EventBus can be used directly for the Message Bus component. Important headers of the original JSON (like the identification URL) must be forwarded to io.vertx.core.eventbus.Message.headers() map.

## Protocol Stub Sandbox

## Connectors

### End User Device Connector

The aim of this Connector is to enable interaction with Hyperty instances running in the end-user device. This component will need to interact somehow with the Protocol Stub sandbox to achieve this, since the communication protocol will not be standardized. It will need to implement a simple protocol for sending and receiving requests. In itself it is not responsible for processing communication requests, that is left to the protocol stack. It merely forwards messages to and from the Hyperty instance.

### Network Server Connector

The aim of this Connector is to enable interaction with Hyperty instances running in a network server. This component will need to interact somehow with the Protocol Stub sandbox to achieve this, since the communication protocol will not be standardized. It will need to implement a simple protocol for sending and receiving requests. In itself it is not responsible for processing communication requests, that is left to the protocol stack. It merely forwards messages to and from the Network server.

### Registry Connector

The Registry provides an interface for registration and deregistration of Hyperty instances, as well as for keeping the published information up to date. For each Hyperty instance, the Registry stores data (hyperty location, type, description, start-time, presence information of user) that enables other applications to contact it. The implementation of the Registry service is thought to be basically a distributed database. It will provide service interfaces for CRUD operations to allow users to retrieve data for a given GraphID, publish (i.e. create, update, and delete) their own information on the ring. To verify authenticity and integrity of the published data, digital signatures will be applied. The Connector will exposed the available interfaces of the Registry Services to users of managing Hyperty instances. This will have to be implemented as a standalone application with an adapter interface to the Event Bus for encoding and decoding messages and deployed as a fat executable jar which contain all the dependencies it needs to run on vertx.

### IdM Connector

This Connector is to provide functionalities for interacting with the remote Identity Management Functionailities. It is unclear if this should be for authentication purpose, or simply for CRUD operations. In WP4 there is also discussion on an Identity Module.

*As hyperties need to be linked to an end-user identity when downloaded and instantiated on a device, an Identity Module should be present on the device. This module at minimum should act as an identity selector for the user and as a secure local repository for identity tokens provided by IdPs*

If this is the case, then it is unclear to me what the connector on the Messaging Node should do. However, if the connector is thought to provide authentication and authorisation, Vert.x offers Auth APIs (Common, JDBC, JWT and Shiro) JWT auth sounds interesting as it uses JSON web tokens.

Another interesting library is the authentication and discorvery is [vertx-pac4j] (https://github.com/pac4j/vertx-pac4j). This vertx module provides multiple authenication mechanisms (OAuh, CAS, HTTP, OpenID, SAML2.0 and OpenIDConnect) for different IdPs. However, it is based on vertx.2. So if it suits the requirements, we will need to adapt to vertx.3.

# Node.js Specification

*For each* [*functional block*](msg-node-architecture.md) *identify existing Node.js modules that can be either reused or extended. If extensions are neede they should be specificied by designing apis to be implemented*

## Core Functionalities

* Main objective of core func. is to authorize, filter and process messages. Messages are JSON objects that should have 2 blocks, HEADER and DATA, and are processed from different components of core.
* Outbound messages should be processed in a Pub/Sub system. If message DATA blocks are for CRUD operations, there should be a Pub/Sub protocol for object/model subscriptions, where should this be processed? The address scheme of t

### Low level connection management

Socket.io is a popular Node.js library to handle connections at aplication level. It can use Websocket and it falls back to HTTP automatically if WS connectivity is not possible.

### Session Management

Events/messages for OPEN and CLOSE received by Socket.io should be intercepted by this component. A session instance is linked to a connection resource (WebSocket, SockJS) if authorized. Every message header is intercepted, session token is verified and if exist, a "user" or other identification URL is replaced in HEADER. The JSON object is forwarded to "Access Control" component. We have to discuss with our dev team it sth can be re-used to implement the session management or we have to implement it

### Address Allocation Management

This is not a Pipeline component (it doesn't process messages), but it's used by the "Session Management" to allocate Hyperty identification URL's that will be linked to a Session when the Hyperty is connected. This will be used to translate Hyperty an URL address into the correspondent Connector Resource.

### Access Control

This component is able to analyze HEADER (identification URL from "Session Management") and DATA blocks and decide if the message should be forwarded to the "Message Bus" or denied. There is a possibility to add a rule engine in this step, but it's not specified for now, what kind of rule engine.

### Message BUS

Main objective of the MB is to process the DATA block, that contains information of the protocol, CRUD operation or other defined information. Vertx EventBus can be used directly for the Message Bus component. Important headers of the original JSON (like the identification URL) must be forwarded to io.vertx.core.eventbus.Message.headers() map. For the Message Bus we could use some RabbitMQ by using Rabbit.js node library.

## Protocol Stub Sandbox

We understand that we must have a Protocol Stub Sandbox to be able to interact to other Messaging Servers and the protocol stub will be retrieved from repository servers. The messgaing server which wants to interact with another one must download the Protocol Stub from the Repository and then it will be able to exchange messages. I guess this is doable in Node.js, but I have to check with our Dev team what's the best way to implement this in Node.js.

## Connectors

This connector could be ad-hoc developemtns in Node.js, receiving messages from the session management layer.

### End User Device Connector

The aim of this Connector is to enable interaction with Hyperty instances running in the end-user device. This component will need to interact somehow with the Protocol Stub sandbox to achieve this, since the communication protocol will not be standardized. The Protocol Stub should expose a common API which will be interacted from the connector. This has been already addressed in the WONDER project so we need to check with Paulo the approach the followed

### Network Server Connector

The aim of this Connector is to enable interaction with Hyperty instances running in a network server. This component will need to interact somehow with the Protocol Stub sandbox to achieve this, since the communication protocol will not be standardized. It will need to implement a simple protocol for sending and receiving requests. In itself it is not responsible for processing communication requests, that is left to the protocol stack. It merely forwards messages to and from the Network server.

### Registry Connector

The Registry provides an interface for registration and deregistration of Hyperty instances, as well as for keeping the published information up to date. For each Hyperty instance, the Registry stores data (hyperty location, type, description, start-time, presence information of user) that enables other applications to contact it. The implementation of the Registry service is thought to be basically a distributed database. It will provide service interfaces for CRUD operations to allow users to retrieve data for a given GraphID, publish (i.e. create, update, and delete) their own information on the ring. To verify authenticity and integrity of the published data, digital signatures will be applied. The Connector will exposed the available interfaces of the Registry Services to users of managing Hyperty instances.

#### LWM2M library

There is an available [LWM2M/COAP library for Node.js](https://github.com/telefonicaid/lwm2m-node-lib) which may be helpful to implement a COAP/interface for constrained devices along with other interfaces for the rest of devices.

### IdM Connector

This Connector is to provide functionalities for interacting with the remote Identity Management Functionailities. Node.js can easily interact with OAuth servers in order to authenticate and authorize users.

It this is for authentication purpose the authentication agqinst the IdP has to be done at the begining. If the CRUD operations have to be authorized on a per identity basis (e.g. user A, correctly authenticated, is only allowed to do 'RU' over a Data Objet) we should get

### Node Sandbox framework

[Node-sandbox](https://www.npmjs.com/package/node-sandbox) allows to run untrusted code outside of the main node process. The code can be interfaced with code running in the sandbox via RPC (or any library that works over the node Stream API).

## Usage of Redis with NodeJs

Redis can be used to add scalability/redundancy to the messaging node. It can also facilitate the development and the integration of new connectors, Here is a quick architecture :

User A ---- NodeJs 1 ----- REdis ------ NodeJs Connector to IdM  
 User B -------| | |------- NodeJs Connector to another CSP  
 | |------- NodeJs Connector to Kurento  
 User C -----NodeJs 2 ------| |------- NodeJs Connector to an IMS GW

Communication between Users and NodeJs can be managed by socket.io

Communication between NodeJs and Redis can be managed by a NodesJs Redis client module : https://github.com/NodeRedis/node\_redis

Communication between the differents NodeJs instance can be managed by the PUB/SUB mechanism of Redis. : http://redis.io/topics/pubsub

Redis instance can be a single instance or a Redis cluster

# Matrix.org based Messaging Node Specification

*For each* [*functional block*](msg-node-architecture.md) *identify existing matrix.org modules that can be either reused or extended. If extensions are needed they should be specificied by designing apis to be implemented*

### Core Functionalities

This section attempts to match the functional blocks of the Message Node architecture to features and functional blocks of the matrix.org architecture.

#### Message BUS

The requirements towards the Message Bus are defined as: \* to route messages to internal Messaging Node components and external elements by using Connectors or Protocol Stubs. \* to support different communication patterns including publish/subscribe communication.

The pure routing requirements are fulfilled out-of-the-box by standard matrix features. In order to route messages to internal Messaging Node components it might be required to treat such components as "users" that can be addressed and perform the same communication tasks as normal users.

Connectors are comparable to protocol stubs, except that they are not downloaded to the Messaging Node clients and instead are executed in the scope of the Messaging Node. Such Connectors can provide support for different "legacy" clients that don't support Protocol-on-the-fly. Matrix does not provide this out-of-the-box. Additional components have to be implemented that should be plugged into the first step of the message flow and perform the required protocol translations. The Matrix concept of "Application Services" could eventually applied here (see later section "Stub and Connector Management").

#### Access Control

Message Routing including pub/sub Subscriptions are subject to Access Control in cooperation with authentication and authorisation provided by Identity Management functionalities.

As described in the following section matrix.org requires registration/subscription and login in order to exchange any messages with other users. These authentication and authorisation methods however always apply to a complete user- and communication session, i.e. ALL messages that are exchanged in this scope.

In case it is required to perform an access control "per message" based on variable policies, some more effort needs to be done. This feature would require an integration of a "policy service", which is discussed in the matrix developer community already but not specified yet.

The concept of "passive" Application Services that matrix.org provides seems not suitable, because it does not allow to block traffic.

In order to achieve this without deeper changes in the matrix core, a kind of Message proxy could be integrated as first step into the message flow. This proxy would then check the messages and apply the policies. It would forward matching messages and should reject the rest.

The design of such a component should be closely coordinated with the MessagingStub that is used to connect to this Matrix based Messaging Node, because it should be the first contact point for the stub.

#### Session Management

The requirements regarding session management as described in [functional block](msg-node-architecture.md) can be separated in 3 different aspects which are handled in the following sub-chapters. \* User session control \* Communication session control \* Stub and connector management

##### User session control

In order to use matrix.org users have to be registered/subscribed with a HomeServer.

In order to connect to matrix HomeServers (e.g. after switching on their devide), users have to pass a login sequence. During this sequence an access token is generated which is valid for this login session. This access token must be present in all sub-sequent requests during this user session. The supported authentication methods are not specified and left implementation specific for the particular HomeServers. The specification lists following standard methods: \* m.login.password \* m.login.recaptcha \* m.login.oauth2 \* m.login.email.identity \* m.login.dummy The HomeServer Client API provides means to request the supported methods before login.

##### Communication session control

Communication sessions between two or more users require a valid user session. Communication session are always based on "rooms". Messages are sent to room-ids and not to individual users. Users must explicitely create or join rooms in order to send and receive messages. Some rooms might be open - others may require an invitation to become a room member. Rooms are persistent, i.e. they exist also if not all room members are currently logged in. The message history is maintained by the Matrix HomeServers and can be requested by clients.

##### Stub and connector management

Matrix.org provides powerful means to connect, federate and synchronize Matrix HomeServers from different domains. The resolution of the peer HomeServers connectivity is done via DNS. The message exchange between them is secured by encryption mechanisms.

However - for the communication with non-Matrix infrastructures there is no common way. The most appropriate approach is to use Application Functions, which are application specific services that can be attached to HomeServers and listen for filtered messages in order to perform special tasks with them.

This mechanism seems well suited for the implementation of "breakout" communication to other types of signalling infrastructures. The matrix.org community has implemented a proof of this concept that connects the Matrix ecosystem with the IRC (reference?) world. Messages that contain a specially prefixed address are filtered out, converted to IRC messages, forwarded to the corresponding IRC client and vice versa.

In the scope of the reTHINK project this concept can be leveraged by a specialized Application Function that filters out messages for non-matrix targets and uses the Protocol-on-the-fly concept to connect and exchange messages with the appropriate domain.

The "Stub and connector management" function is responsible for the management of these Stubs. This can potentially be part of this new special Application Function.

#### Address Allocation Management

Manages allocation of messaging addresses to Hyperty Instances in cooperation with Session Management when users connect to the domain. It also manages the allocation of messaging addresses to foreign Hyperty Instances i.e. Hyperty Instances that are provided from external domains but that use the protofly concept to interact with Hyperty Instances served by this Messaging Node.

Each hyperty instance should be treated as an individual client of the Messaging Node that registers with an own identity and needs a login before it can exchange messages. The Messaging Node allocates the identity of a hyperty during the registration/subscription process. The allocated identity of is sufficient to serve as a messaging address for domain internal communication.

External Hyperties from foreign domains (that might use different communication protocols and identifiers) might need an address representation in the own domain that is compatible with the local addressing scheme. A SIP based domain, for instance, will require a representation of an external entitiy as a SIP URI in order to route messages correctly. The Messaging Node is responsible for the creation and assignment of such transient addresses.

In Matrix.org this can be achieved with Application Services, which maintain an own namespace of virtual users and are able to operate (send/receive) "on behalf" of an certain virtual user.

### Protocol Stub

An approach to achieve this was described above in section "Stub and connector management" before.

### Connectors

* IdM Connector to interact with remote Identity Management functionalities
* Registry Connector to interact with remote Registry functionalities
* End-User Device Connector to interact with Hyperty Instances running in the end-user device
* Network Server Connector to interact with Hyperty Instances running in a Network Server

The concept of connectors can be supported by the implementation of appropriate Application Services, as mentioned above already. These connectors would be executed in the scope of the Messaging Node and perform the required protocol translations.

# Conclusions

# References