

UNIVERSITY OF APPLIED SCIENCES RAPPERSWIL
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BACHELOR THESIS

XMPP-Grid Broker

Authors:

Fabian HAUSER and
Raphael ZIMMERMANN

Advisor:

Prof. Dr. Andreas Steffen

External Co-Examiner:

Dr. Ralf Hauser,
PrivaSphere AG

Internal Co-Examiner:

Prof. Dr. Thomas Bocek

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Task Description



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XMPP-Grid Broker

Studenten: Fabian Hauser, Raphael Zimmermann

Betreuer: Prof. Dr. Andreas Steffen

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Einführung

Die IETF Security Automation and Continuous Monitoring (SACM) Working Group verfolgt eine Publish-Subscribe Architektur [1] basierend auf dem XMPP Protokoll [2] mit dem potentiell Hunderte oder Tausende von Endpunkten (PCs oder IoT Geräte) in real-time Sicherheitsinformationen in einem XMPP-Grid publizieren können. Security Information und Event Management (SIEM) Systeme können sich dann als Subscriber gezielt auf gewisse Themen (realisiert als XMPP Nodes) abonnieren.

Ein Rapid-Prototype [3] eines XMPP-Grids basierend auf einem Openfire [4] XMPP Server und einem Python Broker Script wurde am IETF 100 Hackathon Singapur im November 2017 vordemonstriert.

Für die Administration des XMPP-Grids soll eine Broker Applikation mit einem grafischen Management Interface erstellt werden. Damit sollen Themen (XMPP-Nodes) erstellt und gelöscht, sowie Owner, Publisher oder Subscriber Rechte vergeben werden können. Es soll die Möglichkeit geschaffen werden, Themen hierarchisch zu Collections [8] zusammenzufassen. Ebenfalls sollen Management-Views über verfügbare Themen, persistierte Items, Subscriber und Publisher generiert werden können.

Aufgabenstellung

- Einarbeiten in den XMPP Grid Internet Draft [1], den XMPP Standard [2], sowie die XEP-0004 [5], XEP-0030 [6], XEP-0060 [7] und XEP-0248 [8] Extensions.
- Erfassen der Requirements für einen XMPP Grid Broker.
- Erarbeiten eines Architekturkonzepts für den XMPP Grid Broker, sowie Evaluation von geeigneten Technologien für die Implementation.
- Implementation, Test und Dokumentation

Links

- [1] IETF I-D *draft-ietf-mile-xmpp-grid*
<https://tools.ietf.org/html/draft-ietf-mile-xmpp-grid>
- [2] IETF RFC 6120 *Extensible Messaging and Presence Protocol (XMPP): Core*
<https://tools.ietf.org/html/rfc6120>
- [3] IETF 100 Hackathon *XMPP-Grid Broker Prototype*
https://github.com/sacmwg/vulnerability-scenario/tree/master/ietf_hackathon/strongSwan
- [4] Openfire Homepage
<https://www.igniterealtime.org/projects/openfire/>
- [5] XEP-0004 *Data Forms*
<https://xmpp.org/extensions/xep-0004.html>
- [6] XEP-0030 *Service Discovery*
<https://xmpp.org/extensions/xep-0030.html>
- [7] XEP-0060 *Publish-Subscribe*
<https://xmpp.org/extensions/xep-0060.html>
- [8] XEP-0248 *PubSub Collection Nodes*
<https://xmpp.org/extensions/xep-0248.html>

Rapperswil, 19. Februar 2018



Prof. Dr. Andreas Steffen

Abstract

Fabian HAUSER and Raphael ZIMMERMANN

XMPP-Grid Broker

The IETF Managed Incident Lightweight Exchange (MILE) working group proposes the standard “Using XMPP for Security Information Exchange” which describes how an XMPP based publish-subscribe mechanism (XMPP-Grid) can be used to exchange security-relevant information between network endpoints.

Today, no implementation of an administration interface (XMPP-Grid Broker) for XMPP-Grids exists, which is production ready and platform independent.

The goal of this thesis is to engineer a specialised and platform independent XMPP-Grid Broker that configures existing XMPP Controllers (XMPP server). The XMPP-Grid Broker should enable administrators to configure XMPP-Grids in a usable and productive way.

The focus of the application should be set on portability, extensibility and the security aspects in a production environment.

We propose the architecture of an XMPP-Grid Broker to configure XMPP Controllers and present an implementation based on the Angular5 framework.

The resulting implementation enables administrators to create and configure communication Topics, apprehend the underlying hierarchy and manage permissions. Additionally, persistent items of Topics can be inspected and published.

The XMPP-Grid Broker implementation incorporates the specified functionality, demonstrating that the architecture is robust. Some supplementary helpers, such as autocomplete or filtering, could not be implemented efficiently due to limitations of the underlying XMPP standards.

Management Summary

Motivation

The IETF standard draft “Using XMPP for Security Information Exchange” describes how devices can exchange security-relevant information within a network, so-called “XMPP-Grid”, using the widely adopted messaging protocol “XMPP”. Such security-relevant information can be used to take protective measures automatically, e.g. to block devices running outdated software.

An administration interface, in the standard draft referred to as XMPP-Grid Broker, is used to configure an XMPP-Grid. Today, no such XMPP-Grid Broker exists that is production ready and cross-platform.

Project Goals, Approach

The goal of this thesis is to engineer an XMPP-Grid Broker that allows administrators to configure XMPP-Grids in a usable and productive way. The resulting application should only depend on the underlying standards and not on specific implementations to support the further standardisation process.

A comprehensive analysis of the underlying standards is carried out in the first part of this thesis. Particular attention is given to portability, extensibility and security aspects in a production environment. By this analysis, a systematic selection of possible architecture options is executed in the form of architectural decisions.

Results

The resulting implementation enables administrators to create and configure communication Topics, apprehend the hierarchy of the underlying XMPP-Grid and manage permissions of network participants. Additionally, persisted messages can be inspected and published on communication Topic.

The XMPP-Grid Broker is implemented as Angular5 web application that connects directly from the web browser to the XMPP-Grid. Secure communication is assured by the use of mutual authentication over TLS.

Prospects

The XMPP-Grid Broker implementation incorporates the specified functionality, demonstrating that the architecture is robust.

In the future, the XMPP-Grid Broker might be extended by usability features like autocomplete or filtering. Currently, these features could not be implemented efficiently due to missing support in the underlying XMPP standard, which would have to be extended.

We hope that our work contributes to the further standardisation of XMPP-Grids and that it becomes an established standard used in practical industry applications.

Acknowledgements

We would like to thank our advisor, Prof. Dr. Andreas Steffen, for his continuous support and helpful comments.

Tobias Brunner provided us with valuable feedback on our architecture and introduction section.

Furthermore, we would like to thank Andrea Jurt Massey for her feedback regarding writing and language use.

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Chapter 1

Introduction

“Every accomplishment starts with the decision to try.”

— unknown

In this chapter, we present the motivation and legitimisation of our thesis and highlight the scope delimitations.

1.1 Motivation

In this first section, we shall legitimate this thesis and explain the value and applicability of our proposed solution.

1.1.1 Present Situation

The Internet Engineering Task Force (IETF) standard draft *Using XMPP for Security Information Exchange* [6] as summarised in section 2.4.1 defines a protocol to exchange security-relevant information between endpoints. The draft was created by the Managed Incident Lightweight Exchange (MILE) Working Group to support computer and network security incident management.

Hereafter, we refer to this IETF standard draft as *XMPP-Grid standard*.

To demonstrate the viability of the *XMPP-Grid* standard a rapid prototype was developed in November 2017 [25].

1.1.2 Problem and Vision

Currently, no implementation of the *XMPP-Grid* standard management functionality exists which is ready for production use regarding usability and security.

To solve this problem, a graphical interface with bindings to a suitable *Broker* must be proposed and implemented. The interface should permit network administrators to manage and review *Topics*, persisted items and *Platforms*. Additionally, subscription and publishing permissions of *Topics* and *Platforms* must be manageable.

The graphical interface supports administrators to better understand the underlying hierarchy and affiliations of *Topics*, as well as their security implications. As the interface uses familiar terminology known to an administrator, no in-depth understanding of the underlying *XMPP* technology is required to configure and comprehend an *XMPP-Grid*. Finally, the interface also provides better usability than existing command line interfaces and *XMPP* configuration software, which leads to fewer configuration mistakes and improved efficiency.

We hope that with the help of our implementation the IETF draft “Using *XMPP* for Security Information Exchange” will become an established security standard used in practical industry applications.

1.2 Scope Delimitation

As described in the Task Description, the focus of this thesis is on the evaluation, design and implementation of the *XMPP-Grid* Broker. Adding missing functionality or fixing complex bugs in existing server or client implementations are beyond the scope of this thesis.

Chapter 2

Analysis

“Without requirements or design, programming is the art of adding bugs to an empty text file.”

— Louis Srygley

2.1 Terminology

Taking into account that developers and operators of security reporting systems are the intended audience for this thesis, we mostly use the Security Automation and Continuous Monitoring (SACM) terminology [3] and thereby follow the same guidelines as the *XMPP-Grid* standard [6].

2.2 Technical Background

The following sections introduce the underlying *XMPP* protocol and the relevant extensions (*XEPs*) used by the *XMPP-Grid* standard as well as a summary of it and the corresponding *XMPP* terminology.

2.2.1 *XMPP* (eXtensible Messaging and Presence Protocol)

The Extensible Messaging and Presence Protocol (in short *XMPP*) is an open protocol that enables the near-real-time exchange of small data between any network endpoints, hereafter called *Platforms* [20]. While originally designed as an Instant Messaging (IM) protocol, *XMPP* can be used for a wide range of data exchange applications [19].

XMPP is made of small building blocks defined in the core protocol [20] and numerous extensions called *XEPs* [22]. The core is comprised of functionality for setup and encryption of communication channels, *XML* streams, error handling and more. Additional functionality such as *Service Discovery* [12] and *Publish-Subscribe* [14] are defined in separate extensions.

Although *XMPP* supports peer-to-peer communication, it is often used in a traditional client-server architecture. A client (*Platform*) can send data to any addressable entity (any other *Platforms*) using *Jabber* Identifiers, hereafter called *JID*. If the receiving *JID* has a different domain from the current server (*Controller*), the message is forwarded to the responsible *XMPP* server under its domain [20].

The data exchanged over *XMPP* is *XML*, which makes the protocol structured and extensible, but leads to some protocol overhead. *XMPP* communicates over unidirectional data streams with a server, which are basically long-lived *TCP* connections. The client opens a channel to the server over this connection, and the

server opens one back (i.e. `<stream>` XML tags). In both streams, an XML document is opened after the connection is established. During the conversation, an arbitrary amount of *stanzas* (specified XML child elements) are written to the stream. Before a connection may be terminated, the root element is closed (i.e. `</stream>`) and both streams form valid XML documents [20][15].

The core *stanza* types are *Messages* (`<message/>`), *Presence* (`<presence/>`) and *Info/Query* (`<iq/>`). *Messages* can contain arbitrary data similar to email but are optimised for immediate delivery. *Presence stanzas* deal with network availability and the propagation of user presence information. An *Info/Query stanza* consists of a request and response (similar to the GET and POST HTTP methods), which is used for feature negotiation, configuration and general information exchange. Because of these coarse semantics, *XMPP* provides a generalized communication layer [20][19].

Figure 2.1 illustrates an example setup with two servers and three clients.

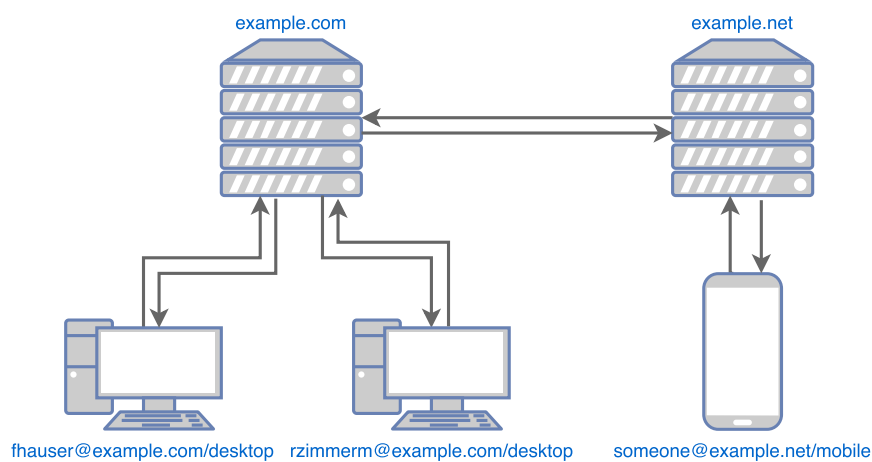


FIGURE 2.1: Two XMPP domains (servers), one with two users and one with a single mobile user.

2.2.2 Relevant XMPP Extensions

The *XMPP-Grid* standard [6] is based on multiple *XEPs*, most notably *Publish-Subscribe*. In this section, we give an overview of the most relevant used *XEPs*.

XEP-0004: Data Forms is a flexible protocol that can be used in workflows such as service configuration as well as for application-specific data description and reporting. The protocol provides form processing, common field types and extensibility mechanisms [8].

XEP-0030: Service Discovery enables entities to discover information about the identity and capabilities of other entities, e.g. whether the entity is a server or not, or items associated with an entity, e.g. a list of *Publish-Subscribe* nodes [12].

XEP-0059: Result Set Management allows entities to manage the receipt of large result sets, e.g. by paging through the result or limiting the number of results. *Result Set Management* is often desired when dealing with large dynamic result sets, as from service discovery or publish-subscribe, and when time or other resources are limited [16].

XEP-0060: Publish-Subscribe

The *Publish-Subscribe* Extension, hereafter referred to as *PubSub* or *Broker*, enables *XMPP* entities (*Provider*) to broadcast information via *Topics* to subscribed entities (*Consumer*) [14].

Nodes, hereafter referred to as *Topics*, are the communication hubs. Entities can create *Topics* and configure them, e.g. set up subscription timeouts or limit publishing and subscription rights. The configuration mechanism is based on data forms (XEP-0004). An *XMPP*-Server *may* restrict node creation to certain entities, which means that possibly not every *XMPP*-Server that supports *Publish-Subscribe* also implements this feature [4].

The protocol defines a hierarchy of six affiliations of which only the implementation of ‘owner’ and ‘none’ is *required*. Implementing the remaining four affiliations is *recommended*. An owner of a *Topic* can manage the subscriptions and affiliations of other entities associated with a given *Topic*.

To simplify the creation of *Topics*, *PubSub* defines five *Topic* access models (‘node access models’) that *should* be available: ‘open’, ‘presence’, ‘roaster’, ‘authorize’ and ‘whitelist’.

The open model allows uncontrolled access while ‘presence’ and ‘roaster’ are specific for IM. Using the authorize model, the owner has to approve all subscription requests. The whitelist model enables the owner to maintain a list of entities that are allowed to subscribe.

2.3 Requirements Analysis

We collected the functional requirements in the form of user stories. User stories are an established and widespread concept for describing and managing requirements in agile software projects. In comparison to traditional tools for requirement analysis, user stories are more concise, leaving more space for changes. [29]

We created some separate user stories for non-functional requirements. Additional non-functional requirements can be added during the project in the form of constraints. [29]

In the early phase of the project, we collected an initial set of user stories based on the task description and discussions with Prof. Dr. Steffen. This initial set covered the creation and deletion of *Topics* as well as granting publish and subscribe privileges. All user stories are listed in Appendix A.6 Requirements.

After setting broad priorities, Prof. Dr. Steffen approved the initial set of user stories that then served as the basis for the architectural concept draft.

Detailed implementation prioritisation of the user stories are carried out before every sprint in agreement with Prof. Dr. Steffen.

2.4 Domain Analysis

2.4.1 IETF Standard Draft: Using XMPP for Security Information Exchange

This IETF standard draft describes how the *XMPP* protocol can be used for the exchange and distribution of security-relevant information between network devices with the XEPs discussed in Section 2.2. The standard presumes use of the Incident Object Description Exchange Format (IODEF) [7].

One of the primary motivation for using *XMPP* for this task is the fast propagation of such security-relevant data. Using *XMPP* for such a task also comes with

its downsides. Most notably, because the *XMPP* server (*Broker/Controller*) is the central configuration component in charge of managing access permission, its compromise has serious consequences.

The standard describes a trust model, a thread model as well as specific countermeasures, e.g. to use at least TLS 1.2. These countermeasures also define restrictions of the *XMPP* protocol and its extensions, e.g. by limiting the *Topic* access models of *PubSub* to whitelist and authorized only [6].

Information Exchange in the IODEF

The *XMPP-Grid* standard states that ‘although [the exchanged] information can take the form of any structured data (XML, JSON, etc.), this document illustrates the principles of *XMPP-Grid* with examples that use the Incident Object Description Exchange Format (IODEF)’ [6].

As IODEF is not strictly defined nor explicitly recommended by the *XMPP-Grid* standard, the implementation of this protocol is not within the scope of this thesis.

2.4.2 Domain Specific Language

Figures 2.2 and 2.3 present an overview of the relevant interactions and relationships between the different components as specified in the *XMPP-Grid* standard [6] and as used in the referenced XEPs (see Section 2.2).

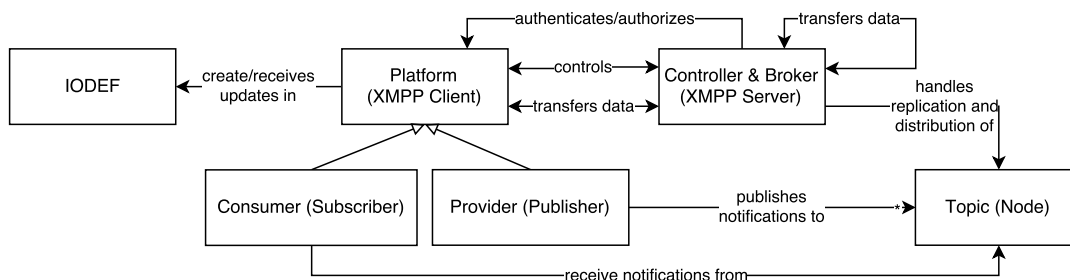


FIGURE 2.2: Domain Specific Language of the *XMPP-Grid* standard

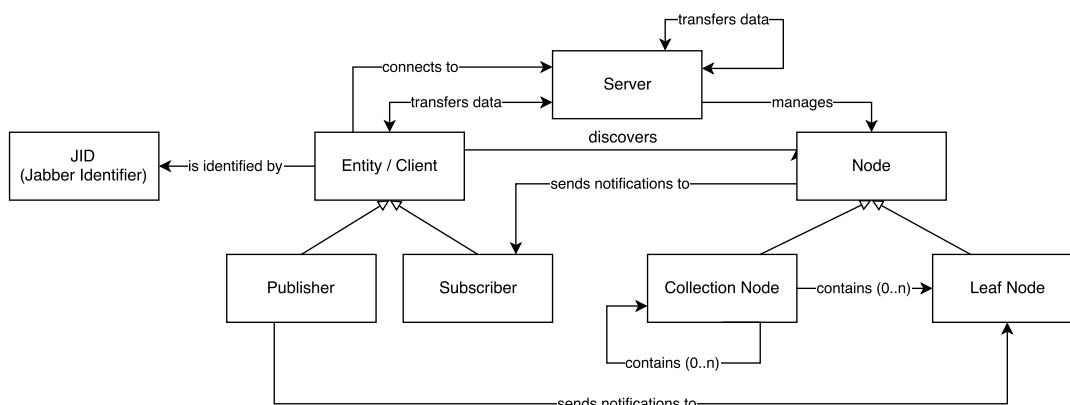


FIGURE 2.3: Domain Specific Language of used *XMPP* XEPs

Chapter 3

Concept

*“Perfection (in design) is achieved not when there is nothing more to add,
but rather when there is nothing more to take away.”*

— Antoine de Saint-Exupery

3.1 Architecture

In this chapter, we present the architecture and fundamental architectural decisions of the *XMPP-Grid Broker* application. All architectural decisions we took are fully documented in Appendix A.3 Architectural Decisions.

We illustrate the concepts and structures using the *C4 Model for Software Architecture* [5].

3.1.1 Actors and Context

The context diagram pictured in Figure 3.1 shows the surrounding systems and actors that are given for the *XMPP-Grid Broker*, as described in the Task Description.

One or more administrators manage the *XMPP-Grid* by adding or removing *Platforms* and configuring *Topics*. To minimize the required work and reduce the error-proneness, they interact with the *XMPP-Grid Broker*, whose implementation is the primary goal of this thesis.

The *XMPP-Grid Broker* configures the *XMPP-Grid*, which consists of a *Controller* and *Platforms*.

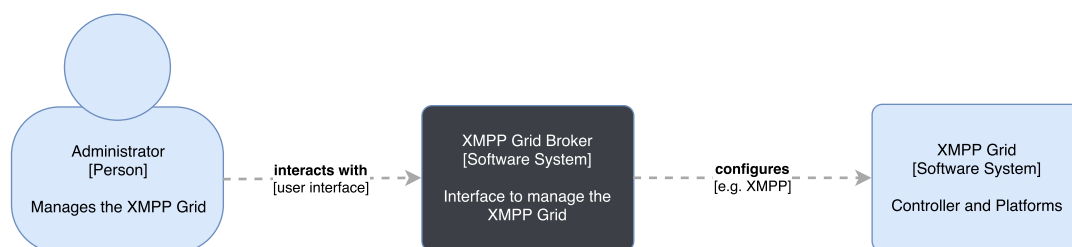


FIGURE 3.1: Architecture diagram showing the context of the *XMPP-Grid Broker* application.

3.1.2 Architectural Style and Platform

To implement the *XMPP-Grid Broker*, we evaluated three possible architecture styles: An *XMPP* server plug-in (e.g. extension for the Openfire *XMPP* server), an implementation with the Jabber Component Protocol [21] or an implementation acting as a regular *XMPP* client ("bot").

We decided to build an *XMPP* client/bot, because it is not coupled to a specific *XMPP* server as a server plug-in and, in contrast to the *XMPP* component, supports a strong authentication mechanism with SASL.

The full decision argument is documented in Appendix A.3 Architectural Decisions.

Platform

The proposed *XMPP* client might be implemented in different ways: as rich client application with a command line or graphical interface as illustrated in Figure 3.2, or in the form of a web application, illustrated in Figures 3.3 and 3.4.

3.1.3 Rich Client Application

In contrast to a rich client application, a web application has the significant advantage to be easily installable and upgradable with minimal requirements on the user's side (i.e. only requires a web browser to be executed). Therefore, we decided to implement the *XMPP-Grid Broker* as web application.

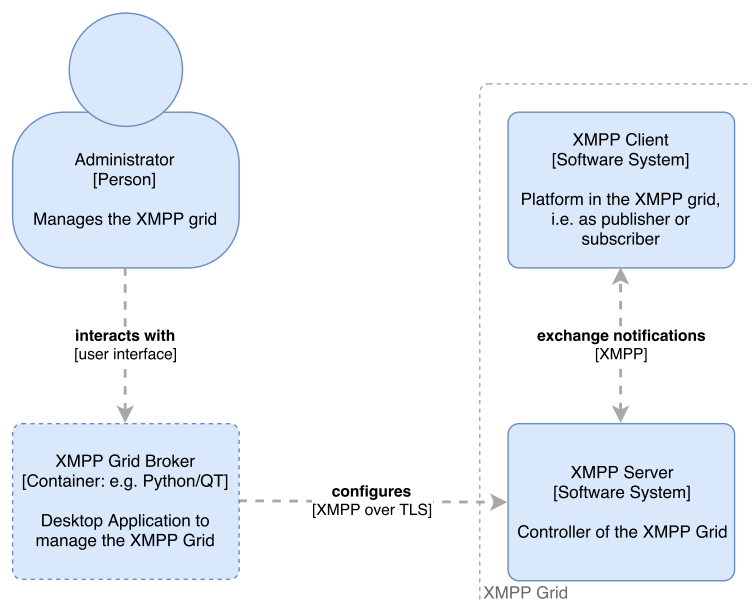


FIGURE 3.2: Architecture Container Diagram showing a possible rich client architecture.

3.1.4 Web Application Topology

To manage the *Controller* from our interface, we considered the implementation of either directly connecting to the *XMPP* server over WebSockets [26] or HTTP (BOSH [17]), or to communicate indirectly with the *XMPP* server via custom web API proxy. These topologies are illustrated in Figure 3.3 and Figure 3.4.



FIGURE 3.3: Architecture Container Diagram showing the web application topology with WebSockets or BOSH.

Web API Proxy

A web API proxy could be realised with a custom browser-to-proxy protocol, as implemented in the *XMPP-FTW* JavaScript library¹. However, this approach leads to a high coupling between a concrete library and the web application.

Another approach would be the implementation of a custom WebSocket-to-*XMPP* Proxy, which allows connecting to *XMPP* servers that do not support WebSockets or BOSH. If such a proxy is implemented transparently, the client is not aware of the server limitations. Therefore, the client implementation is no different from direct communication with an *XMPP* server.

As the '*XMPP* over WebSocket' protocol differs from the normal *XMPP* protocol, a transparent proxy implementation would inevitably need to hold the connection state and implement custom keep-alive mechanisms [26].



FIGURE 3.4: Architecture Container Diagram showing the web API proxy topology.

¹<http://docs.xmpp-ftw.org/>

Implemented Web Application Topology

As described in the according architectural decision (see Appendix A.3), we decided on the direct connection via WebSockets, if possible with a fallback to BOSH. This topology simplifies the implementation and deployment of the application in comparison to a web API proxy. WebSockets offer stateful TCP-sockets to exchange data with the *XMPP* server in contrast to BOSH, which uses HTTP long polling to emulate a bidirectional stream and is, therefore, less efficient [17].

To increase the *XMPP* server security, an HTTP reverse proxy (e.g. *nginx*²) between the client and the *XMPP* server might be added as shown in Figure 3.5. The reverse proxy might also be used to serve the web application and provide authentication (see Section 3.1.5) and security features (see Section 3.4.3).

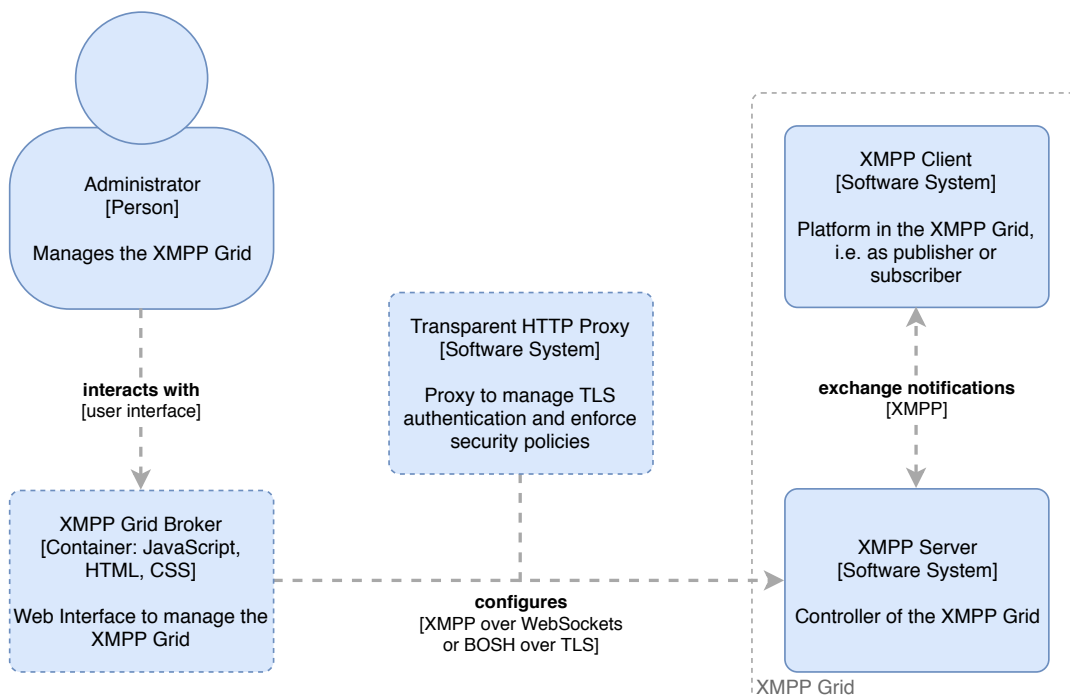


FIGURE 3.5: Architecture Container Diagram showing the implemented web application topology.

3.1.5 Authentication and Connection Security

XMPP uses SASL as authentication mechanism [20]. To authenticate against the *XMPP-Grid Controller*, we decided to use the SASL EXTERNAL [30] mechanism whenever possible to authenticate the client.

We decided against the alternative SASL authentication method, SASL SCRAM [10], that is also recommended by in the *XMPP-Grid* standard [6]. As described in the corresponding architectural decision (Appendix A.3), the main reason for SASL EXTERNAL is its higher level of security and its relatively simple scaling capabilities.

SASL EXTERNAL implies that the authentication takes place on a lower layer than the actual *XMPP* protocol. In our case, this implies authentication over TLS, i.e. X.509 end-user certificates as specified in RFC6120 [20].

²<https://nginx.org/>

Currently, not all *XMPP* servers that implement BOSH and Websockets also implement SASL EXTERNAL with TLS authentication (e.g. Openfire currently supports TLS authentication with BOSH but not with Websockets³). To circumvent this limitation, a HTTP reverse proxy as described in Section 3.1.4 might be used, which handles the TLS authentication.

3.2 Wireframes

We created wireframes for most screens to visualise the initial set of user stories. They helped us to find missing requirements, most notably the support of collections. All wireframes are listed in Appendix A.7 Wireframes.

3.3 Security Considerations

Regarding only the *XMPP-Grid* Broker application, there are three primary attack vectors:

Client-side attacks, e.g. via web browser, web browser extension or malicious software on the client operating system.

Web server attacks, e.g. misconfiguration or insufficient hardening.

***XMPP* server attacks**, e.g. misconfiguration or insufficient hardening.

Details on all attack vectors are discussed in the following sections.

3.3.1 The *XMPP* Protocol

An in-depth security analysis of the *XMPP* protocol is beyond the scope of this thesis. A detailed discussion of security concerns can be found in the *XMPP* specification [20] and most XEPs [14][23]. In this section, we highlight the most crucial security concerns relevant to this thesis.

Transport Security

XMPP reuses many established and standardised mechanisms to improve the protocol security. By layering protocols in a strict manner (*XMPP* with SASL over TLS over TCP), many attack scenarios such as replaying or eavesdropping are minimised. The protocol also requires clients and servers to validate the certificates of the other party. [24][20]

Protocol

Since *XMPP* is based on XML, it inherits some of its security implications. *XMPP* prohibits some XML features such as comments and external entity references which mitigate common attacks. [20]

The protocol itself cannot mitigate attacks where an attacker gains access to account credentials. To reduce the risk of these attack vectors best practices such as storing certificates and passwords securely must be followed.

³<https://github.com/igniterealtime/Openfire/blob/02c22e/src/java/org/jivesoftware/openfire/websocket/OpenfireWebSocketServlet.java>

PubSub Collection Nodes

The use of PubSub collection nodes [23] can leak private data if not configured properly. Administrators must take great care when configuring collection nodes. The *XMPP-Grid* Broker should support administrators to detect such data leaks.

3.3.2 Client Security

Because the web gives rise to many potential security concerns, above all a modern web browser is critical for client security. Legacy web browsers can not provide an adequate level of security. [9]

Most web browser support extension mechanisms which have rather significant capabilities. The usage of untrusted or uncertified browser extensions is strictly discouraged. [18]

The same applies to the client operating system and all software installed on clients.

Authentication and Authorisation

Regarding authentication and authorisation, the *XMPP* server does most of the heavy lifting such as storing passwords and validating certificates. On the client side, the web browser does most of that work too (i.e. validating certificates).

The responsibility of our client implementation is to establish a secure channel to the *XMPP* server and warn the user if a problem occurs during this process (e.g. invalid server certificate).

Angular Framework

Using the Angular framework impacts client security significantly. Angular is built with security in mind and is adopted in the industry in security-relevant environments. Therefore, Angular receives frequent security updates and is well tested. It's unlikely that a similar security level might be reached with plain JavaScript in a reasonable implementation timespan.

On their project website, Angular recommends the following three best practices regarding security [1].

- Keep up with the latest Angular library releases.
- Don't modify your copy of Angular.
- Avoid Angular APIs marked in the documentation as "Security Risk".

We can ensure the latter two by making them acceptance criteria. Keeping current with the latest Angular releases is harder, as our work on this project is limited. To ensure that future updates can easily be applied we deviate as little as possible from the standard angular setup (e.g. by not ejecting the Webpack configuration⁴).

Keeping Angular up-to-date is of paramount importance as potential vulnerabilities (e.g. XSS) can be exploited if not patched.

⁴<https://github.com/Angular/Angular-cli/wiki/eject>

Angular Content Security

Except for *Persisted Items*, no *XMPP* content is displayed directly but serves as the basis for rendered HTML components. To protect against malicious payloads, the received XML messages must be validated before their usage.

Persisted Items can contain arbitrary content and must therefore be escaped before rendering to prevent Cross-Site Scripting (XSS) attacks.

Angular supports these measures by treating all values (except Angular templates) as untrusted by default. To prevent user-generated data to influence Angular templates, the offline template compiler is used. To fully utilise the security measures provided by Angular, their APIs must be used at all times instead of direct use of the DOM-APIs. [1]

Using Content-Security-Policy (CSP) provides additional XSS-protection mechanisms [28]. The *XMPP-Grid* Broker should document an appropriate CSP that must be supported in a production environment.

3.3.3 Server Security

Authentication and Authorisation

The *XMPP* server implements most of the authentication and authorisation mechanisms used in a *XMPP-Grid* Broker implementation, such as storing passwords and validating certificates.

If BOSH or WebSockets are used, the *XMPP* server should support most HTTP security features as listed in Section 3.3.3. Additionally, the origin of WebSockets and BOSH requests must be verified (by either the `Origin-Header` or CORS support. [13][27]

The web server hosting the client application has no active authentication or authorisation responsibility, except to ensure the integrity and authenticity of the application, i.e. by using TLS.

Web Server

To minify security concerns on the server side, we decided to keep the application files static (See A.3 Architectural Decisions). This allows operators to use any standard web server (e.g. NGINX, Apache, etc.) to serve the client. Securing such standard web servers is common knowledge for operators and is beyond the scope of this analysis.

In addition to these general best practices, we explicitly recommend the following security measures to improve client security:

- Enable Content Security Policy (CSP) [28].
- Use secure TLS configurations such as secure Cipher Suites, strictly Honor Cipher Order, HSTS, HPKP and OCSP Stapling⁵.

XMPP Server

XMPP server security depends on the chosen implementation and the application domain. Discussing *XMPP* server security in detail is beyond the scope of this thesis. Operators should adhere to the security recommendations of their *XMPP* server

⁵https://wiki.mozilla.org/Security/Server_Side_TLS

vendor and follow general security best practices as outlined by the *XMPP-Grid* standard [6].

3.4 Security Risk Mitigation

To mitigate the security risks as discussed in Section 3.3, the measures as described in the following subsections are implemented.

3.4.1 Development

1. Conduct Code Reviews for all newly added code using GitHub pull requests and a security checklist (See next section)
2. Conduct an architectural analysis with an industry expert⁶
3. Automate build and release processes to minimise the time required to patch.
4. Stay as close to the default Angular setup to simplify further updates
5. Avoid additional third-party dependencies whenever possible

3.4.2 Client Security Checklist

- The latest Angular-version is used
- No customizations are made to the Angular version
- No direct access to DOM-APIs
- APIs marked in the documentation as “Security Risk” are *not* used
- No usage of any Methods starting with `bypassSecurityTrust`.
- The client is fully Content Security Policy compliant
- The client is fully Same Origin Policy (SOP) / Cross-Origin Resource Sharing (CORS) compliant
- Only compile templates offline using the offline template compiler.
- User input is always escaped using the mechanisms provided by the framework (eg. Angular Forms)
- *XMPP*-Messages are validated to contain only the specified result-types

3.4.3 Operations Security

Administrators must configure the surrounding systems correctly to mitigate certain security risks. To support administrators, we recommend the following measures.

Content Security Policy

The Content Security Policy (CSP) helps to mitigate certain types of attacks such as Cross Site Scripting (XSS) as a second line of defence [28]. The recommended values are directly documented in the project source code repository.

⁶Was carried out on 2018-04-16, see A.5 Meeting Minutes.

Verify Origin

The *XMPP* server should be configured to only accept WebSockets/BOSH connections from the origin of the *XMPP* Broker application. The 'Origin' Header sent by the web browser must match the domain on which the *XMPP* Broker application is hosted. Otherwise, connection requests must be ignored. If a *XMPP* server does not support this feature, a proxy server should be used to verify the 'Origin' header. In the provided development setup, this security feature is not implemented.

Chapter 4

Implementation and Testing

“Any fool can write code that a computer can understand. Good programmers write code that humans can understand.”

— Martin Fowler

4.1 Development Setup

4.2 Encountered Problems

4.2.1 Limitations of A.6.1.5 Multiple Administrators

Requirement A.6.1.5 states that multiple administrators should be able to access the application.

When authenticating users with SASL EXTERNAL, the client certificate extension field ‘xmppAddr’ is interpreted as user *JID* by the *XMPP* server.

In practice, most *XMPP-Grid Broker* deployments will require an HTTP proxy in front of the *XMPP* server as security measure¹. Usually, the HTTP proxy can also be used to serve the *Broker* application. Such an HTTP proxy might also accept multiple different client certificates.

If the client connects to the *XMPP* server over secure WebSockets (WSS) in combination with SASL EXTERNAL, the WebSocket URL must already be authenticated, as most browsers do not permit certificate selection on background requests². This might be achieved by serving the *Broker* from the same domain or by using client certificate policies³.

As the proxy intercepts the TLS connection, it must verify the client certificate sent by the browser and establish a connection to the *XMPP* server using a client certificate as well. Therefore, the ‘xmppAddr’ field of the proxy’s client certificate is used by the *XMPP* server. If multiple users should be differentiated on the *XMPP* server, an HTTP proxy might choose different client certificates for connecting to the *XMPP* server based on the web browser’s client certificate ‘xmppAddr’.

4.2.2 Limitations of A.6.1.6 Audit Trail

Actions of administrators should be traceable with an audit trail according to requirement A.6.1.6.

¹ More information on this can be found in Section 3.1.4 Implemented Web Application Topology.

²<https://bugs.chromium.org/p/chromium/issues/detail?id=329884#c24>

³<https://support.google.com/chrome/a/answer/6080885?hl=en#manage-certs>

As outlined in Section 4.2.1, practical deployments of *XMPP-Grid Brokers* will mostly use a HTTP proxy. Additionally, to handling the client authentication, the proxy can be used to keep an audit trail of client requests. These requests can then be correlated with the query log on the *XMPP* server.

Creating audit trails on the client side does not provide additional safety, as users might prevent trail entries by manipulating the client application. Therefore, no such mechanism was implemented.

4.3 Code Quality

4.3.1 Complexity

4.4 Testing

4.5 Documentation

Chapter 5

Discussion and Conclusion

“Wisdom is not a product of schooling but of the lifelong attempt to acquire it.”

— Albert Einstein

5.1 Achieved Result

5.2 Discussion

5.3 Lessons Learned

5.4 Future work

5.5 Conclusion

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Glossary

Broker

"A *SACM* Broker Controller is a *Controller* that contains *control plane* functions to provide and/or connect services on behalf of other *SACM* components via interfaces on the *control plane*" [3]

Component

An encapsulation of software that communicates using Interfaces, that is composed of *SACM* capabilities. [3, 11]

Consumer

"In *SACM*, an entity that contains functions to receive information from other *Components*; as used here, the term refers to an *XMPP Publish-Subscribe* Subscriber." [6]

control plane

"An architectural component that provides common control functions to all *SACM* components." [3]

Controller

"In *SACM*, a ‘component containing control plane functions that manage and facilitate information sharing or execute on security functions’; as used here, the term refers to an *XMPP* server, which provides core message delivery [RFC6120] used by publish-subscribe entities." [6, 3]

Data Forms

XMPP Data Forms Extension

Info/Query

XMPP Info/Query stanza

Jabber

Original Name of *XMPP*

JID

Jabber IDentifier, e.g. bob@example.com/mobile

Message

XMPP Message stanza

Persisted Item

XMPP messages that are persisted in a *Topic*.

Platform

"Any entity that connects to the *XMPP*-Grid in order to publish or consume security-related data." [6]

Presence

XMPP Presence stanza

Provider

"In *SACM* An entity that contains functions to provide information to other *Components*; as used here, the term refers to an *XMPP Publish-Subscribe* Publisher." [6]

Publish-Subscribe

XMPP Publish Subscribe Extension

PubSub

Common abbreviation for *Publish-Subscribe*

Result Set Management

XMPP Result set Management Extension

SACM

Abbreviation for Security Automation and Continuous Monitoring

Service Discovery

XMPP Service Discovery Extension

stanza

A *XMPP* a fragment of XML that is sent over a stream, e.g. *Message*.

TCP

Transmission Control Protocol

TLS

Transport Layer Security

Topic

"A contextual information channel created on a Broker at which messages generated by a Provider are propagated in real time to one or more Consumers. Each Topic is limited to a specific type and format of security data (e.g., IODEF) and provides an *XMPP* interface by which the data can be obtained." [6]

XEP

XMPP Extension Protocol

XML

eXtensible Markup Language

XMPP

eXtensible Messaging and Presence Protocol

XMPP-Grid

"A method for using the Extensible Messaging and Presence Protocol (*XMPP*) [RFC6120] to collect and distribute security-relevant information among network *Platforms*, endpoints, and any other network-connected device." [6]

Appendices

A.1 Project Plan

XMPP-Grid Broker: Project Plan

Authors:

Fabian HAUSER and
Raphael ZIMMERMANN

Advisor:

Prof. Dr. Andreas STEFFEN

Spring Term 2018

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Chapter 1

Project Overview

The goal of the bachelor thesis is to build a broker application and graphical user interface to administer XMPP-Grids according to draft-ietf-mile-xmpp-grid, as described in the task description [3].

Chapter 2

Project Organization

All team members have the same strategic rights and duties. Prof. Dr. Andreas Steffen is our project advisor.

2.1 Roles

Due to the small team size, most roles are performed by both team members.

Raphael Zimmermann

project management, software engineering, quality assurance.

Fabian Hauser

infrastructure management, software engineering, quality assurance.

Chapter 3

Project Management

3.1 Components

For a better overview and to allow us a sophisticated time assessment, we decided to group tasks into categories, i.e. JIRA components. Components represent processes, documents and products which are to be released.

Currently, tasks are separated into following components:

- Application
- Final Submission Document
- Management
- Poster
- Presentation
- Project Plan

3.2 Time Budget

The project started with the Kickoff Meeting on 19.02.2018 and will be completed after 16 weeks by 15.06.2018. The two team members are available for 360 hours each during the semester which corresponds to a weekly time budget of 20 hours per person and two weeks with a weekly time budget of 40 hours per person.

Apart from the statutory holidays, there are no further absences planned.

3.3 Schedule

The project schedule is an iterative process based on elements of SCRUM.

We decided on a sprint duration of approximately week, but allow deviations in working hours depending on statutory holidays.

3.3.1 Iterations & Milestones

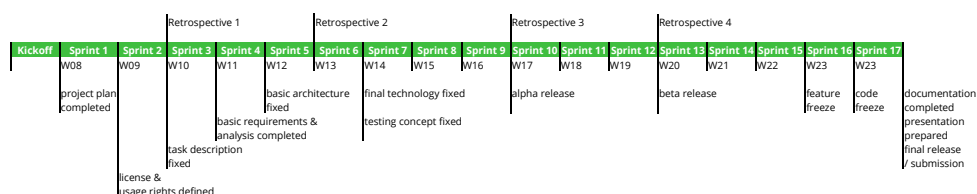


FIGURE 3.1: Overview of the 16 iterations

The goals and milestones resulting from each sprint are shown in Figure 3.2.

TABLE 3.1: Meeting Time Budget

Meeting Type	Total Duration per Person	Total Duration for the Team
Supervision Meetings	12 hours	24 hours
Standup Meetings	16 hours	32 hours
Sprint Planning Meetings	18 hours	36 hours
Retrospective	4 hours	8 hours
Total	50 hours	100 hours

3.3.2 Meetings

The team works every Monday (08:00 - 12:00) and Tuesday (08:00 - 17:00) together in the study room and remotely Fridays (08:00 - 17:00). Wednesday and Friday begin with a daily stand-up meeting taking no longer than 15 minutes. Sprint planning meetings are carried out on Tuesday at 10:00. Table 3.1 shows an overview of the total meeting time budget.

Regular meetings with the project advisor take usually place on Monday in Prof. Dr. Steffen's office.

Raphael Zimmermann will take meeting notes for every meeting. Meeting minutes are published on the project website afterwards.

Sprint	Sprint 1	Sprint 2	Sprint 3	Sprint 4
Tag	0.1.0	0.2.0	0.3.0	0.4.0
Date	20.02.2018 – 27.02.2018	27.02.2018 – 06.03.2018	06.03.2018 – 13.03.2018	13.03.2018 – 20.03.2018
Milestones	- license & usage rights defined	- task description fixed	- basic requirements & analysis completed	- basic architecture fixed
Time Budget	40	40	40	40
Tasks	- setup remaining project infrastructure - read relevant API standards etc. - begin with chapter "initial situation" - analyze existing python proof-of-concept	- collect non-functional requirements (NFRs) - complete set of user stories - draft testing concept - research frameworks and technology; Prepare architectural decisions - chapter "Initial Situation" completed - signed task description	- extend NFRs; user stories, wireframes - make first architectural decisions - draft testing concept - implement proof of concepts for critical components	- make big architectural decisions - implement proof of concepts for critical components
Documents / Chapters / Artefacts				
Sprint	Sprint 5	Sprint 6	Sprint 7	Sprint 8
Tag	0.5.0	0.6.0	0.7.0	0.8.0
Date	20.03.2018 – 27.03.2018	27.03.2018 – 03.04.2018	03.04.2018 – 10.04.2018	10.04.2018 – 17.04.2018
Milestones		- final technology fixed - testing concept fixed		
Time Budget	40	40	40	40
Tasks	- implement proof of concepts for critical components - draft testing concept	- implement proof of concepts for critical components - finalise testing concept - Chapter "Our Approach" completed	- Implement most important user stories - make further architectural decisions	- Implement most important user stories - make further architectural decisions
Documents / Artefacts				
Sprint	Sprint 9	Sprint 10	Sprint 11	Sprint 12
Tag	0.9.0	0.10.0	0.11.0	0.12.0
Date	17.04.2018 – 24.04.2018	24.04.2018 – 01.05.2018	01.05.2018 – 08.05.2018	08.05.2018 – 15.05.2018
Milestones	- alpha release			- beta release
Time Budget	40	40	40	40
Tasks	- Implement most important user stories - make further architectural decisions - write integration tests - alpha release bundle	- Implement secondary user stories - write integration tests	- Implement secondary user stories - write integration tests	- Implement secondary user stories - write integration tests - beta release bundle
Documents / Artefacts				
Sprint	Sprint 13	Sprint 14	Sprint 15	Sprint 16
Tag	0.13.0	0.14.0	0.15.0	0.16.0
Date	15.05.2018 – 22.05.2018	22.05.2018 – 29.05.2018	29.05.2018 – 05.06.2018	05.06.2018 – 12.06.2018
Milestones			- future freeze	- code freeze
Time Budget	40	40	40	80
Tasks	- Implement remaining user stories - improve code base - write integration tests	- Implement remaining user stories - improve code base - write integration tests	- Implement remaining user stories - improve code base - write integration tests	- fix eventual bugs - write documentation - final release bundle - poster - abstract
Documents / Artefacts				
Sprint	Sprint 17			
Tag	1.0.0			
Date	12.06.2018 – 15.06.2018			
Milestones	- documentation completed - presentation prepared - final release / submission			
Time Budget	40			
Tasks	- write documentation - submit documents - personal reports - management summary - presentations - time accounting			
Documents / Artefacts				

FIGURE 3.2: Detailed overview with tasks and milestones of all 16 sprints.

Chapter 4

Risk Management

An assessment of the project-specific risks is carried out in Table 4.2 as time loss during the whole project. The risk matrix in Table 4.1 provides an overview of the risk weighting.

To account for these risks, we reduce our weekly sprint time by the total weighted risk applicable to the planned task topics (on average approximately 13.5%). We also review the risk assessment after every sprint, adapt it and take measures if necessary.

Severity Probability	High ($\geq 5d$)	Medium ($2-5d$)	Low ($\leq 2d$)
High ($\geq 60\%$)	1		
Medium (30-60%)	6		
Low ($\leq 30\%$)		3, 4, 5	

TABLE 4.1: The risk matrix. Numbers reference to the risk assessment Table 4.2

TABLE 4.2: Risk assessment table. Time in hours over the total project duration.

#	Title	Description	Prevention / Reaction	Risk [h]	Probability	= [h]
1	Incomplete reference documentation	The reference documentation / standards are incomplete or difficult to comprehend.	Discuss missing parts with project advisor	60	60%	36
2	Communication errors	Errors due to miscommunication or misapprehension.	Maintain a high level of interaction, precise specification of tasks responsibilities, conduct meetings if ambiguities exist.	30	50%	15
3	Problems with project infrastructure	The used project infrastructure is not or only partially available, or data loss occurs within management software.	Clean setup and self-hosting of the tools to prevent third-party dependencies.	45	30%	13.5
4	Scope creep	The project's scope is extended over the project course.	Define the project scope and limitations precisely. Discuss changes with the project advisor.	45	30%	13.5
5	Dependency errors	There are errors/bugs in third-party dependencies, i.e. libraries.	Carefully select libraries and limit third-party dependency to a minimum.	30	30%	9
6	Missing dependency documentation	Selected libraries are lacking proper documentation	The documentation quality of a library should be a selection criterion.	30	40%	12
Total weighted risk						99

Chapter 5

Infrastructure

5.1 Project Management and Development

For project management we utilise JIRA[1]. As document/code storage, git repositories on Github are used, the continuous integration/deployment will be defined in the course of the project.

These applications are hosted on our HSR project server, which runs a standard Ubuntu Linux 17.10.

5.1.1 Development Tools

The development tools will be defined in the course of the project.

5.2 Backup and Data Safety

An incremental backup of the project server including the source code and documentation is created on an independent system every night.

As our documents and code is stored in a git repository, they are also distributed on all development systems.

Chapter 6

Quality Measures

To maintain a high standard of quality, we take the following measures:

- short sprint reviews
- four extended retrospectives
- code reviews
- automated unit and integration testing
- publish all documentation on the project website using continuous integration/delivery.
- using continuous integration for source code

6.1 Documentation

The official documents such as the final submission document, meeting minutes as well as this project plan are written in \LaTeX respectively ASCIIDoc and published on the project website ¹ containing all PDF documents.

The sources are in both cases kept under version control in the same repository, which allows us to use the same tools and processes for documentation and code. The continuous integration server builds and publishes the website whenever new changes are pushed to the repository.

6.2 Project Management

Because the project plan allows for an iterative process, we use JIRA with its SCRUM-features (such as sprint creation or boards) for project management.

6.2.1 Sprint Planning

Each sprint is mapped to JIRA, which allows the project advisor to trace the project progress. Sprints are represented as boards on which the current state and assignee of any issue is easily visible ("To Do", "In Progress", "Review", "Done").

6.2.2 Definition of Done

An issue may be closed if *all* of the following conditions are met:

- All functionality conforms to the specification. Any deviations must be discussed and decided by the team.
- The source code is reasonably documented.

¹<https://xgb.redbackup.org>

- No code is commented out.
- No warnings and errors by the compiler or any other quality tool.
- A review is performed and accepted in a pull request.
- The corresponding branch is merged into the stable branch (e.g. master).
- All documents are up to date including the project website.
- Reasonable unit and integration tests exist and pass.
- The complete continuous integration pipeline works.
- All time is logged.

6.3 Development

We decided to use GitHub Flow[2], a straightforward development workflow.

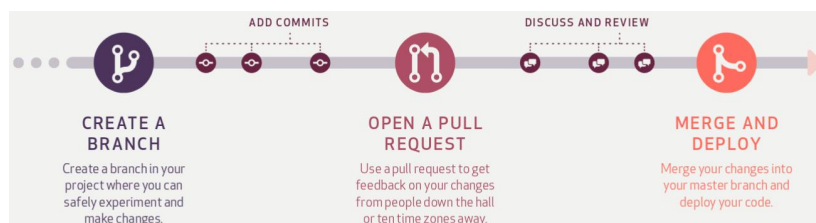


FIGURE 6.1: GitHub Flow illustrated (Source [2])

Since the effective technology will be fixed later in the project, concrete coding guidelines, tools, metrics and an error policy will be defined when appropriate.

6.4 Testing

All functionality must be automatically testable using continuous integration. Any non-trivial function/method must be verified with unit tests.

Integration tests verify extended test scenarios.

A minimal performance analysis will be carried out at the end of the project.

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List of Abbreviations / Glossary

A.2 Development Guide

Development Guide

Tools

- Git \geq 2.0 for version control

Writing Guidelines

In order to have a consistent style of writing, we defined the following guidelines. These guidelines apply to all documents related to the redbackup project.

- Keep it brief, clear and objective
- Write short and straightforward sentences
- Do not use synonyms for concepts etc. (always use the same wording, e.g. 'client' or 'node')
- Abbreviations must be introduced the first time they occur in the text (except well-known ones)
- Prevent ambiguity in sentences
- Use personal style ("we") whenever appropriate; usually for the description of our work.
- When a gender-specific pronoun is required, use "he/she".
- Use present tense except for the description of (our) completed work.

Definition of Done

To maintain our high quality needs, we determined following definition of done guidelines:

- All functionality conforms to the specification. Any deviations must be discussed and decided by the team.
- A review is performed and accepted in a pull request.
 - The source code is reasonably documented.
 - No code is commented out.
 - No warnings and errors by the compiler or any other quality tool.
 - Reasonable unit and integration tests exist and pass.
 - All documentations are up to date including the project website.
 - The complete continuous integration pipeline works.
 - The code is formatted according to the guidelines (i.e. according to RustFmt)
- The corresponding branch is merged into the stable branch (e.g. master).
- All time is logged.

A.3 Architectural Decisions

Architectural Decisions

Architecture Style

There are three common variants to participate in XMPP communication and manage server configurations: As XMPP-server plugin, XMPP component or an XMPP Client/Bot.

The implementation style fundamentally restricts the set of implementation languages and has a profound impact on the fundamental architecture.

The following aspects must be taken into account to find the most suitable architecture style:

- All required management functionality must be supported over the available APIs and protocols.
- Compatibility with most XMPP servers
- Keep the implementation complexity as low as possible

Considered Options

- XMPP server plugin, e.g. for [Openfire Plugin](#).
- XMPP Component ([XEP-0114](#)).
- XMPP Client/Bot

Decision Outcome

Chosen option: XMPP Client/bot, because it is not coupled to a specific XMPP server as the Server Plugin and, in contrast to the XMPP Component, supports strong authentication.

Pros and Cons of the Options

Server Plugin

- Good, because all features could be implemented directly on the XMPP server.
- Good, because there is minimal protocol overhead and abstraction.
- Bad, because a very high coupling to a specific XMPP server is required and compatibility/interoperability is therefore limited
- Bad, because the high coupling to a specific XMPP server usually limits the possible implementation language.

XMPP Component

- Good, because the application style fits very well in the Components model.
- Bad, because the specification of Components is marked as *Historical* and might therefore not be implemented by many XMPP Servers.
 - Note: Openfire supports Components

- Bad, because some XMPP client libraries might support Components.
- Bad, because the authentication mechanisms might not suffice the required standards of the XMPP-Grid standard.
- Bad, because it uses a own handshake based digest authentication message.

XMPP Client/Bot

- Good, because a Bot is basically a normal XMPP client, which is supported by every XMPP server
- Good, because all XMPP client libraries implement this feature.
- Good, because secure connections to the XMPP server are supported (SASL).
- Bad, because the application is conceptually not a normal XMPP-Client.

Platform

The chosen platform has a fundamental impact on the resulting application as well as on the user experience: Where is it used, from whom and from which device.

Considered Options

- Client Application with Command Line Interface
- Client Application with Graphical User Interface
- Web application

Decision Outcome

Chosen option: Web Application because it can easily be installed, updated and provides maximal user acceptance. The development team has experience in writing web applications meaning they know common pitfalls and limitations of the platform. Command line users might use the already existing proof of concept instead.

Pros and Cons of the Options

Client Application with Command Line Interface

- Good, because cross-platform support can be achieved relatively easy (depending on the chosen language/runtime).
- Good, because the development team has experience writing command line applications.
- Good, because all OS-functionality is available.
- Good, because command line tools are relatively simple to implement.
- Bad, because additional runtimes might be required (python, JVM, .NET etc.).
- Bad, because not all users appreciate command line tools.
- Bad, because cross-platform testing is expensive.
- Bad, because mobile devices (phones, tablets, chromebooks) are not supported.
- Bad, because updates must be performed on every client.
- Bad, because additional rights are required for setup.

Client Application with Graphical User Interface

- Good, because graphical interfaces have a broad acceptance.
- Good, because all OS-functionality is available.
- Bad, because additional runtimes might be required (python, JVM, .NET etc.).
- Bad, because additional libraries are required (e.g. QT).

- Bad, because cross-platform testing is expensive.
- Bad, because mobile-devices (phones, tablets, chromebooks) are not supported.
- Bad, because updates must be performed on every client.
- Bad, because additional rights are required for setup.
- Bad, because the development team has no experience writing graphical user interfaces.

Web Application

- Good, because graphical interfaces have a broad acceptance.
- Good, because the development team has experience writing command line applications.
- Good, because no additional runtime on the client side (except the browser) is required.
- Good, because no additional rights are required for setup.
- Good, because updates must only be performed on the server side (clients need no updates but the platform, i.e. the browser).
- Good, because it scales well.
- Bad, because only limited OS-functionality is available.
- Bad, because testing of multiple browsers and browser versions is expensive.
- Bad, because the supported features vary significantly depending on the browser and version.
- Bad, because a backend server is required although its importance might vary on the chosen architecture.
- Bad, because it has a potentially large attack vector depending on how and where it is deployed.

SASL Authentication Strategy

User Story: 1.2 Authentication: Secure XMPP Connection

The [XMPP-Grid standard](#) states in section 8.3.1 that

The XMPP-Grid Controller MUST authenticate the XMPP-Grid Platform either using the SASL EXTERNAL mechanism or using the SASL SCRAM mechanism (with the SCRAM-SHA-256-PLUS variant being preferred over the SCRAM-SHA-256 variant and SHA-256 variants [RFC7677] being preferred over SHA-1 variants [RFC5802]).

The chosen authentication mechanism has an impact on the implementation of the Broker application as well as on the XMPP server support.

Note that this architectural decision has no impact on the communication between the Controller and other Platforms (i.e. other XMPP clients and the XMPP server).

Considered Options

- SASL SCRAM
 - SASL SCRAM-SHA-256-PLUS is described in [RFC 7677](#).
 - In summary, SASL SCRAM-SHA-256-PLUS means XMPP over TLS with the client authenticating using a username (JID) and password with challenge-response-exchange.
 - In our case, we may assume that SASL SCRAM-SHA-256-PLUS is currently the only variant supporting a strong hash mechanism
- SASL EXTERNAL
 - SASL EXTERNAL is described in [RFC 4422 Appendix A](#).
 - The SASL EXTERNAL mechanism for XMPP in combination with [TLS/PKIX](#) certificates is described in [XEP-0178](#).
 - In our case, we may assume SASL EXTERNAL means XMPP over TLS with the client authenticating using an X.509 certificate, as this is currently the only practical available implementation.

Decision Outcome

Chosen option: SASL EXTERNAL, because it offers the highest security level and is well suited for large-scale deployments.

Pros and Cons of the Options

SASL SCRAM

- Good, because SASL SCRAM is widely supported and used by XMPP servers.
- Good, because SASL SCRAM is easy to use for small deployments, as it only requires a JID and password for authentication.
- Good, because SASL SCRAM fulfils the XMPP-Grid standard requirements.
- Bad, because the key management is on the XMPP Controller, which leads to a single point of failure and might lead to additional administration efforts.
- Bad, because shared keys (i.e. the password) are used, which cannot be limited to a validity date or selectively revoked.
- Bad, because shared keys (i.e. the password) are difficult to manage in a large scale, decentralised and automated infrastructure.

SASL EXTERNAL

- Good, because a very high-security level can be achieved with X.509 certificates.
- Good, because certificates can be integrated efficiently in a large scale, (mostly) decentralised and automated infrastructure.
- Good, because SASL SCRAM fulfils the XMPP-Grid standard requirements.
- Bad, because a Certification Authority (CA) must be used to issue certificates, which may lead to additional administration efforts and complexity, especially for small deployments.
- Bad, because not all XMPP server and clients have comprehensive support for SASL EXTERNAL.
 - Openfire does not support SASL EXTERNAL with WebSockets, however, it is supported with BOSH.
 - Ejabberd only supports SASL EXTERNAL in the paid professional edition.

Role Management

The XMPP Publish-Subscribe mechanism (XEP-0060) lacks an explicit description of how to implement role-based authentication for Topics(nodes). It implies two possibilities on how to do so: collection nodes and the roster access model.

The following aspects must be taken into account:

- Preferably use existing XMPP protocols/mechanisms
- The chosen strategy must be usable in most practical use-cases.

Considered Options

- Usage of Collection Nodes (XEP-0248)
- Roster Access Model which supports groups (XEP-0144)
- Custom Roles implemented on the Broker

Decision Outcome

Chosen option: Usage of Collection Nodes (XEP-0248), because the mechanism is the least intrusive that yet allows a powerful role-concept. We must, however, keep in mind that the XEP is deferred and might therefore not be fully supported by all XMPP servers.

Pros and Cons of the Options

Usage of Collection Nodes (XEP-0248)

- Good, because existing XMPP mechanisms can be used.
- Good, because with it few consumers can subscribe to many Topics indirectly.
- Good, because publishing permissions are managed on a Topic level which encourages per-device Topics.
- Good, because this mechanism is used in production.
- Bad, because XEP-0248 is deferred
- Bad, because the Collection Nodes must be structured in a specific way to support access management

Roster Access Model which supports groups (XEP-0144)

- Good, because existing XMPP mechanisms can be used.
- Good, because XEP-0144 is a draft (not deferred).
- Bad, because the roster concept aims for IM.
- Bad, because the Roster Access Models is discouraged by the IETF XMPP-Grid standard.

Custom Roles implemented on the Broker

- Good, because it enables maximal flexibility
- Bad, because existing XMPP mechanisms cannot be used.
- Bad, because the Controller must manage its own data instead of delegating it to the XMPP server.
- Bad, because the Controller must periodically check that the affiliations are still appropriately configured on the XMPP server.

Webapplication Communication Topology

As we decided to build a web-application, it remains open how the communication the backing XMPP server flows.

Considered Options

- **XMPP from the Browser with WebSockets (RFC 7395)**
Directly speak XMPP over a WebSocket connection with the XMPP server.
- **XMPP from the Browser with BOSH (XEP-0206)**
Directly speak XMPP over a HTTP long polling connection with the XMPP server.
- **XMPP via WebAPI Proxy**
Create a standalone application that proxies the XMPP server and exposes a web-API to the client (e.g. a RESTful API).

Decision Outcome

Chosen option: XMPP from the Browser with WebSockets to reduce duplicated code and use standardised XMPP features. In case the required features are not implemented, a fallback to BOSH should be possible.

In comparison to XMPP via WebAPI Proxy, WebSockets simplify the deployment of new features because they must not be added in two places (the UI and the WebAPI). In comparison to BOSH, WebSockets offer a stateful TCP-connection based on relatively modern standards while BOSH support is provided by many frameworks as a fallback option.

Pros and Cons of the Options

XMPP from the Browser with WebSockets (RFC 7395)

- Good, because when building an SPA-Client, it is sufficient to serve just static files which provides a higher level of security and performance.
- Good, because actively maintained clients exists (e.g. stanza.io). Some libraries also support fallback to BOSH.
- Good, because existing client-certificates can be re-used.
- Good, because existing XMPP-mechanisms are used.
- Bad, because additional server plugins must be enabled which is an additional attack vector. (Workaround: Implement a custom proxy)
- Bad, because it is not a standard yet (Proposed Standard).
- Bad, because SASL EXTERNAL is not well supported with WebSockets
 - Openfire does not implement SASL EXTERNAL with WebSockets.
 - WebSockets connections over authenticated TLS is not extensively specified, support may

therefore vary depending on the browser implementation.

- Bad, because it might lead to security issues (i.e. CSRF) if used in combination with SASL EXTERNAL/TLS, if no strict request-origin verification is done by the server implementation.

XMPP from the Browser with BOSH (XEP-0206)

- Good, because when building an SPA-Client, it is sufficient to serve just static files which provide higher levels of security and performance.
- Good, because actively maintained clients exists (e.g. strophe.js).
- Good, because existing client-certificates can be re-used.
- Good, because existing XMPP-mechanisms are used.
- Bad, because additional server plugins must be enabled which is an additional attack vector. (Workaround: Implement a custom proxy)
- Bad, because it is not a standard yet (Draft).
- Bad, because not all HTTP-features might be implemented by the XMPP server, which might be a security risk.
 - OPTION preflight requests are not supported by Openfire.
 - A reverse HTTP proxy might be used, to support additional HTTP security features.

XMPP via WebAPI Proxy

- Good, because it decouples the client from the effective XMPP calls (separation of concerns).
- Good, because only minimal HTTP and JavaScript features are used leading to a broad compatibility.
- Bad, because the indirection can limit the performance significantly.
- Bad, because a server application must be installed and maintained (security updates).
- Bad, because existing XMPP-mechanisms are not used.

Frontend Framework

To create a user interface for the web-application frontend, we must utilise a framework. User Interfaces are too complex these days to implement them in pure JavaScript.

The frontend framework fundamentally restricts the set of implementation languages and has a profound impact on the web interface architecture.

The following aspects must be taken into account to find the most suitable architecture style:

- The effort to learn and master the frameworks best practices must be reasonable.
- The framework must be scalable because the web application is not trivial.
- The number of third party libraries must be kept to a minimum to prevent cost-intense maintenance work in the future.

Considered Options

- [SPA](#) with Angular5
- [SPA](#) with React
- [SPA](#) with Vue.js
- Django App

Decision Outcome

Chosen option: Angular because it comes with batteries included and we, therefore, must not rely on additional third-party libraries for everyday tasks. Because Angular is opinionated, there is a clear way to do things which will help us to structure the application. For these benefits, we are willing to accept a steeper learning curve.

Pros and Cons of the Options

SPA mit Angular5

- Good, because it scales well.
- Good, because the performance is automatically optimised for production builds.
- Good, because it comes with all tools required for building and structuring a sophisticated SPA: components, modules, dependency injection and more.
- Good, because it is very popular, especially in (modern) enterprise applications.
- Good, because it has a large community and is built by Google.
- Good, because it is opinionated, there is a clear way to do things.
- Good, because it uses TypeScript that brings additional safety.
- Bad, because it is heavyweight and hard to learn/understand.

- Bad, because API migrations in the past were costly and hard.
- Bad, because it uses TypeScript which brings indirections and cannot be eliminated.
- Neutral: It is a tool for everything and cannot be used partially.

SPA mit React

- Good, because it scales well.
- Good, because it is lightweight.
- Good, because it encourages functional programming and discourages state.
- Good, because it provides components.
- Good, because it uses modern JavaScript features (ES6).
- Good, because it has a large community and is built by Facebook.
- Bad, because its "lightweightness" leads to lots of third-party dependencies.
- Bad, because it is not trivial to learn (e.g. "pseudo" inline HTML requires custom attributes `className`).
- Bad, because it only defines a minimal core and many standard problems must be solved manually.
- Bad, because additional libraries such as Redux must be used and understood to create complex applications.
- Neutral: Uses JS for everything which is a matter of taste.
- Neutral: Can be used partially.

SPA mit Vue.js

- Good, because it scales well.
- Good, because it is lightweight.
- Good, because it provides components.
- Good, because it makes no assumptions about the JavaScript version used.
- Good, because it elegantly separates template (HTML), styling (CSS) and logic (JS).
- Good, because the core team also maintains fundamental additional such as routing and state management.
- Good, because it has a large and active community.
- Bad, because its "lightweightness" leads to lots of third-party dependencies.
- Bad, because it only defines a relatively small core and some standard problems must be solved manually.
- Bad, because there is no standard way for non-trivial setups (complex SPA, automated testing, etc.).
- Bad, because additional libraries such as Vuex must be used and understood to create complex applications.

- Neutral: Can be used partially.

Django App

- Good, because Django has excellent documentation.
- Good, because Django has a (mostly) stable API.
- Good, because Django is used in other projects in the [INS](#).
- Good, because Django has a very active community.
- Bad, because multiple languages (Python and JavaScript) are required in the frontend.
- Bad, complex client logic (e.g. paging) must still be implemented in JavaScript and might require an additional framework.
- Bad, because it is very heavyweight (includes ORM, migrations and much more) with lots of features that we do not need.
- Bad, because it requires a backend instance in comparison to the SPAs.

UI Library

To create a modern and aesthetically pleasing cross-browser user experience and to reduce the implementation efforts, a UI-library shall be used.

Considered Options

- [Angular Material](#): Material Design components for Angular
- [Semantic UI Angular 2](#)
- [Spectre.css](#) with custom Components

Decision Outcome

Chosen option: Spectre.css with custom Components, because it has minimal third-party dependencies.

Positive consequences:

- From a security point of view, a pure CSS library does not require updates.
 - An Angular component library might introduce security vulnerabilities (e.g. XSS).
 - If the CSS library project is discontinued, the XMPP-Grid Broker can continue to use the latest available version.

Negative consequences:

- Additional effort is required for creating and testing new components.
- Angulars component features such as style scoping are not fully utilised.

Frontend Structure

We must establish a clean architectural structure to keep the frontend maintainable.

Considered Options

- Monolith: All components and services in a single module to support fast-prototyping
- Module-Based: Hierarchical Module-Structure, grouping related components.

Decision Outcome

We decided on the module-based option as it follows software engineering best practices for long-lived projects. We accept a slower starting phase to benefit in the long-term from a clean architecture.

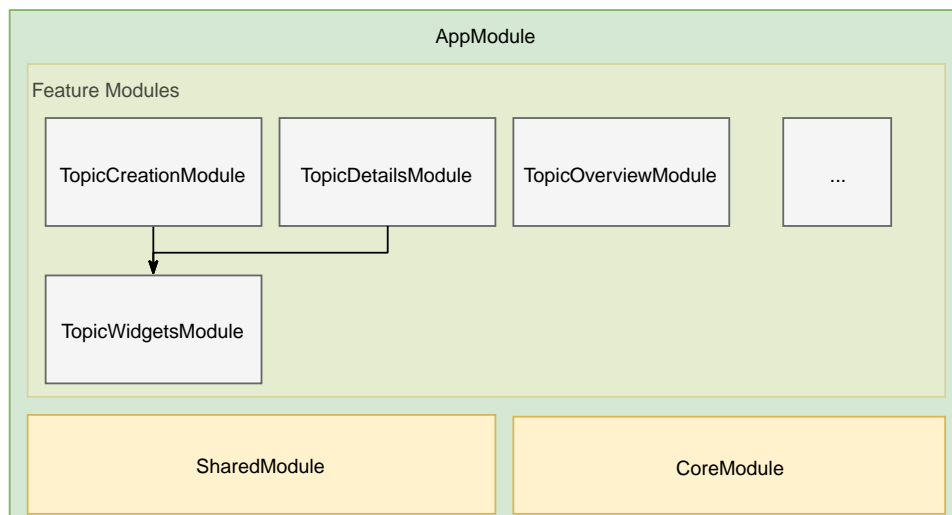
Following the [Angular Style Guide](#), we decided on two primary modules: **core**, **shared** as well as additional widget and feature modules.

Each module can have submodules to refine the structure even further.

Because the current scope is rather small, all modules are loaded eagerly.

The **core** module contains the XMPP connection setup, authentication and other functionality that is required at all times.

The **shared** module contains simple components that do not depend on any services but are just plain components used to render common structures, e.g. buttons.



XMPP Client Library

To communicate via XMPP from the client via Websockets or Bosh an existing client library shall be used to benefit from an existing implementation.

Primarily, the following aspects are relevant for the decision, ordered by priority:

1. Community Support: How well is the project maintained
2. Plugin API: Is it easy to create or replace existing plugins
3. TypeScript binding: Are there existing TypeScript bindings?

Considered Options

- stanza.io
- strophe.js

Decision Outcome

Chosen option: stanza.io, because it offers solid community support and provides a clean plugin API with minimal dependencies. Although strophe.js has a more active community, some plugins have dependencies on jQuery and are implemented in CoffeeScript. That is the main reason why we selected stanza.io over strophe.js.

To fully benefit from TypeScript, we could implement the TypeScript bindings. <https://www.typescriptlang.org/docs/handbook/declaration-files/introduction.html>

Evaluations of the Options

stanza.io

1. Community Support
 - > 20 Contributors
 - primarily maintained by one person
 - Project receives frequent updates since 2014
 - Used by 40 Repos and 3 Packages (2018-04-10)
 - > 10 Pull-Requests closed/merged since 2017-01-01
2. Plugin API
 - New plugins can easily be added
 - Existing plugins can be replaced
3. TypeScript binding
 - No TypeScript bindings exist

strophe.js

1. Community Support (only core repository)

- > 50 Contributors
- minor fixes in the last year by different contributors
- Project regularly updated since 2008
- Used by >90 Repos and >20 Packages (2018-04-10)
- > 25 Pull-Requests closed/merged since 2017-01-01

2. Plugin API

- Some Plugins depend on jQuery
- Minimal core allows to add and replace existing plugins simply
- Many plugins are written in CoffeeScript (whereas the core is in JavaScript)

3. TypeScript binding

- Bindings for the core exist (not tested!), see [@types/strophe on NPM](#)

A.4 Time Accounting

TODO

A.5 Meeting Minutes

Meeting 2018-02-19

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Administrative tasks
2. Where to start
3. Date and time for the next meeting
 - 2018-02-26, 09:00 in SFFs office

Discussions / Decisions

1. Administrative tasks
 - All documentation artifacts will be published on the project website.
 - We will use JIRA for project planning.
 - We will decide later, which continuous integration tools we use.
 - The decision must allow the INS to take over the project after the BA.
 - reasons for the decision must be documented.
 - Decisions on the programming language and frameworks are made later.
 - Our experience and productivity in a given eco system must be considered as well.
2. Where to start
 - Read the draft [XMPP for Security Information Exchange](#).
 - Learn more about XMPP (Read the specs and the mentioned XEPs).
 - IODEF payloads are not the main focus of this project.
 - It would be nice if a first draft is ready for the IETF Hackathon, starting on March 17.
 - Main goals of the project:
 - Design a solid architecture (Openfire plugin or standalone?).
 - Implement the requirements according to the IETF Draft:
 - Vanilla XMPP with Discovery und Publish/Subscribe XEPs.
 - Define Topics/Nodes and manage permissions.

- Administrative utilities such as purge, list topics, show number of items, identifier etc.
 - Most is already implemented in the form of a proof of concept.
3. Date and time for the next meeting:
- 2018-02-26, 09:00 in SFFs office

Upcoming absences

no upcoming absences

Meeting 2018-02-26

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Open questions regarding the task
2. Date for oral exam
3. Is there a presentation during the semester?
4. Date and time for the next meeting

Discussions / Decisions

1. Open questions regarding the task
 - Some requirements can influence the chosen architecture fundamentally (e.g. to write a "bot", a component or a plugin)
 - a "normal" user (in the "bot" or the component variant) might have limited access to some node. According to SFF, this issue can be ignored because, in a real-world application, such behaviour should be limited by strict policies.
 - SFF emphasises that the authentication mechanisms use must be robust and certificate based.
 - Next steps:
 - Write User stories
 - Draw basic architecture in C4-Diagrams
 - Risk analysis (e.g. abuse cases)
 - Evaluation of XMPP servers and libraries. SFF notes that we should not spend too much time evaluating the server and assume that OpenFire fulfils most requirements.
 - Issues to address in the XMPP servers and library evaluation:
 - Can an administrator restrict users to create new topics
 - Recommended features can be checked queried using service discovery. We can also check for undesired configurations (e.g. everyone can publish)
 - Ensure that the libraries support all required functionality, especially authentication!
 - Assess the performance and usability of the libraries

- It is desirable if the service runs is "always on", e.g. to answer subscription requests. However, this is not strictly required according to SFF.
- Any kind of Interface is conceivable, a web interface, however, is very flexible. The core functionality does not have to be available separately.
- The scope of the website is fine according to SFF.

2. License

- GNU-FDL for the documentation is fine
- The license for the code will be AGPL but might change depending on the frameworks we use

3. Is there a presentation during the semester?

- An interim with the internal co-examiner will be carried out.
- The primary purpose of this presentation is to get familiar with the requirements of the co-examiner (testing, documentation, protocols etc.)
- Should be carried out if a small demo is ready

4. Date for oral exam

- If possible, the oral exam will be carried out in early July.
- We will continuously complete parts of the document to reduce the examination efforts

5. Date and time for the next meeting

Upcoming absences

no upcoming absences

Meeting 2018-03-05

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Discuss and clarify Requirements/Wireframes
2. Current state of the Task Description
3. Date and time for the next meeting

Discussions / Decisions

1. Discuss and clarify Requirements/Wireframes
 - We discussed the open issues in the current requirements draft.
 - The application is meant to run in production and must, therefore, meet strict security requirements
 - Especially TLS \geq 1.2 and certificate-based
 - The existing python scripts were the prototype and this project is intended to be a proper implementation
 - Response time is not very crucial for this application as it is designed for maintenance work and not real-time interventions.
 - We must propose an authentication model, e.g. using TLS mutual authentication and exactly one broker user.
 - SFF notes that SASL is quite complex. We might not need it although the IETF draft explicitly requires it.
 - The number of consumers and producers depends strongly on the concrete application. In most cases, however, there will be much more publishers than subscribers. SFF gave the following estimates as reference values.
 - > 1000 Producers
 - 100 Subscribers
 - 1-4 Toplevel Topics
 - > 1000 Subtopics (eg. one for every publisher)
 - > 10000 Persisted Items (note that these items might contain large payloads)

- We plan to include search, filtering and paging functionality for most listings. We will include these features in the next requirements draft.
- SFF points out that subtopics are missing in the current draft as well as the wireframes. We will include this in the next requirements draft.
- SFF notes that a role concept might be needed to simplify the administration. We might be able to use existing XMPP features for this (e.g. XEP-0144).
- According to SFF, Subscription Requests and Validation are nice to have but have low priority.
 - Instead of validation, unsupported functionality should not be visible
- For deleting persisted items, SFF suggests a "bulk delete" functionality, which allows administrators to delete all items that match certain criteria.
- SFF prefers a standalone application over a server plugin to reduce coupling.
- The implementation language is not of paramount importance to SFF although he prefers Python or Java. A single page app written in JavaScript using a Python backend is also a viable option for him.
 - We should not rely on too many third-party libraries that save us several hours during the project but might require extra maintenance effort in the future (SFF gave a Django paging extension as an example)

2. Current State of the Task Description

- SFF will complete the task description after he receives the revised user stories and wireframes.

3. Date and time for the next meeting

- 2018-03-12, 09:00 in SFFs office

Upcoming absences

- No weekly meeting on 2018-03-19 (SFF is absent)

Meeting 2018-03-12

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Discuss Requirements / Wireframes
2. Architectural Decisions
 - Architectural Decision: Roles
 - Architectural Decision: XMPP over Websockets/BOSH/Backend
 - Architectural Decision: Client Framework
3. Current State of the Task Description
4. Date and time for the next meeting

Discussions / Decisions

1. Discuss Requirements / Wireframes
 - We will send SFF the updated wireframes and requirements.
 - Next week, SFF will accept/reject the current state as the target set of requirements for the thesis.
 - SFF considers the current wireframes as good.
2. Architectural Decisions
 - Architectural Decisions Template
 - SFF appreciates the current format.
 - We must give more context for non-experts (e.g. what is an XMPP-Bot?).
 - Architectural Decision: Roles
 - We discussed the pros and cons as described in the Architectural Decision.
 - The biggest downside is the limited Openfire support as well as the deferred state of XEP-0248.
 - SFF ratifies this solution.
 - Architectural Decision: XMPP over Websockets/BOSH/Backend
 - SFF says, that this is an interesting approach to experiment with.

- We must conduct experiments to ensure that all functionality indeed works as expected.
 - SFF says, that from a security aspect, a new interface is not that bad as long as it uses secure authentication mechanisms such as TLS.
 - If we decide to use WebSockets/BOSH, we should investigate how an adapter could be implemented.
 - Architectural Decision: Client Framework (e.g. React, Vue, Angular)
 - For SFF, the most important criteria is to not rely on too many third-party dependencies.
 - Otherwise, we should use the best tool for the task.
 - The institute has not preferred framework.
3. Current State of the Task Description
- Will be finished until the next meeting, based on our revised requirements.
 - SFF will send the current draft.
4. Date and time for the next meeting
- No weekly meeting on 2018-03-19
 - Next weekly meeting is on 2018-03-23 10:00

Upcoming absences

- No weekly meeting on 2018-03-19 (SFF is absent)

Meeting 2018-03-23

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Discuss Requirements / Wireframes
2. Current State of the Task Description
3. The current state of co-examinator
4. "Broker" Term
5. Architectural analysis with an industry expert ([XGB-97](#))
6. Date and time for the next meeting

Discussions / Decisions

1. Discuss Requirements / Wireframes
 - SFF accepts the current state of the wireframes.
2. Current State of the Task Description
 - We collectively declared the Task Description final.
 - SFF suggests to move it up in the document before the abstract ([XGB-105](#)).
3. The current state of co-examinator
 - Prof. Dr Thomas Bocek is the co-examinator of this thesis.
 - We will organise the interim presentation in 2-5 weeks from now, ideally combined with a weekly meeting and not on Tuesdays.
4. "Broker" Term
 - While reading the XMPP-Grid IETF draft, we were confused by the definition of "Broker", and whether it applies to our application.
 - SFF sees no discrepancy. We might not implement the complete broker but at least parts of it.
5. Architectural security analysis with an industry expert ([XGB-97](#))
 - SFF suggests conducting the security analysis with Tobias Brunner on a Monday.
6. Date and time for the next meeting

- No weekly meeting on 2018-03-26 (SFF absent)
- No weekly meeting on 2018-04-02 (Easter Monday)
- Next weekly meeting on 2018-04-09

Upcoming absences

- No weekly meeting on 2018-03-26 (SFF absent)
- No weekly meeting on 2018-04-02 (Easter Monday)

Meeting 2018-04-09

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Current State and Next Steps
2. Administrative Tasks
3. Date and time for the next meeting

Discussions / Decisions

1. Current State and Next Steps
 - rzimmerm presents a demo of the current client
 - fhauser explains the TLS client certificate issues we encountered in the last weeks.
 - SFF suggest to make and document assumptions (eg. nginx and openfire are co-located) and begin with the implementation
 - SFF suspects issues with the XMPP client libraries
2. Administrative Tasks
 - Intermediate Presentation: SFF suggest we do this in the next three weeks with a working demo including XMPP
 - Final Presentation:
 - 2018-06-27 is the ideal date for rzimmerm and fhauser
 - We will contact Prof. Dr. Thomas Bocek concerning this date
 - SFF will contact Dr. Ralf Hauser
3. Date and time for the next meeting
 - Next weekly meeting on 2018-04-16

Upcoming absences

none

Meeting 2018-04-16

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF
- Tobias Brunner

Minute Taker: rzimmerm

Agenda

1. Administrative Tasks
2. Demo
3. Architectural Security Review
4. Date and time for the next meeting

Discussions / Decisions

1. Administrative Tasks
 - intermediate presentation
 - No response yet from Prof. Dr. Thomas Bocek. We will ask him today in the exercises session.
 - SFF is unavailable next Monday and suggests to do the presentation without him
 - Final presentation
 - No response yet from Prof. Dr. Thomas Bocek. We will ask him today in the exercises session.
 - SFF will contact Dr. Ralf Hauser until next week
2. Demo
 - fhauser demonstrates a working XMPP connection from the Angular application using TLS with Client certificates
 - rzimmerm demonstrates the generic data forms implementation
 - We will enable SFF to try it out with his setup next Week.
3. Architectural Security Review
 - Tobias Brunner notes, that TLS Client Certificates without an Origin policy can be problematic
 - When using WebSockets or Bosh, the XMPP server (or Nginx) must verify the Origin header

4. Date and time for the next meeting

- SFF is unavailable next Monday.
- The meeting is postponed to 2018-04-26

Upcoming absences

- SFF: 2018-04-23
- fhauser: 2018-04-30

Meeting 2018-04-26

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Administrative Tasks
2. How to Test-Drive
3. Presentation Date
4. Review: Issues we encountered
5. Date and time for the next meeting

Discussions / Decisions

1. Administrative Tasks
 - The Interim presentation took place on Monday
2. How to Test-Drive
 - SFF wants to try out the application as discussed last week
 - To use an existing XMPP server, we recommend using the development setup with another upstream XMPP server
 - The CA and Client Certificate for connecting to the XMPP server must be replaced
 - The upstream URL must be replaced
 - We will publish an alpha release this week
3. Presentation Date
 - Prof. Dr. Thomas Bocek is available on 2018-06-27
 - SFF will clarify if this date works for the other groups and the expert as well.
4. Review: Issues we encountered
 - We were missing some functionality in the XMPP standards
 - loading all available configuration options before the creation of a topic
 - Lost updates when updating the topic configuration (eg. `max-items` and `node_type`)
 - We decided to only focus on the features as Openfire support it
5. Date and time for the next meeting

- fhauser is absent on 2018-04-30 (Zivilschutz)
- The meeting is postponed to 2018-05-07

Upcoming absences

- fhauser: 2018-04-30 (Zivilschutz)

Meeting 2018-05-07

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Review: Test-Drive
2. Prioritisation: On what should we focus?
3. Presentation Date
4. Date and time for the next meeting

Discussions / Decisions

1. Review: Test-Drive
 - SFF has not been able to try it out yet.
 - SFF wants to have a look at it tomorrow
2. Prioritisation: On what should we focus?
 - We discussed all open user stories
 - The core functionality is (almost) complete
 - Subtopics/Parent Collections view is missing
 - Subscription view is missing
 - Persisted Items
 - SFF wants us to add persisted items next
 - Autocomplete has a low priority for SFF
 - We also discussed the "problematic" user stories, e.g. that a logout mechanism is not possible.
 - We agree that they are no show-stoppers.
3. Presentation Date
 - Prof. Dr. Thomas Bocek is available on 2018-06-27
 - SFF will clarify if this date works for the other groups and the expert as well.
4. Date and time for the next meeting
 - SFF is absent on 2018-04-14

- The meeting is postponed to 2018-05-17, 09:00

Upcoming absences

- SFF: 2018-04-14
- Whitmonday: 2018-04-21

Meeting 2018-05-17

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Current State & Issues
2. Review: Test-Drive
3. Presentation Date
4. Date and time for the next meeting

Discussions / Decisions

1. Current State & Issues
 - We showed SFF the demo of the persisted items view
 - We discussed the limitations of the XEPs (XEP-0060, XEP-0059) and their implication on the feature set that we can implement
 - For SFF it's not the highest priority to implement these features (e.g. autocomplete, search and filtering)
2. Review: Test-Drive
 - SFF was quite busy and has not had the time yet to try it out
3. Presentation Date
 - SFF will contact Dr. Ralf Hauser today
4. Date and time for the next meeting
 - Next weekly meeting on 2018-04-28
 - If SFF has feedback concerning the test drive, a short-dated meeting will be carried out on 2018-04-24.

Upcoming absences

- Whitmonday: 2018-05-21

Meeting 2018-05-28

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Review: Test-Drive
2. Presentation
3. Date and time for the next meeting

Discussions / Decisions

1. Review: Test-Drive
 - The location of the install instruction was not clear
 - Having a documentation repository can be confusing
 - We will add a note admonition to the documentation page
2. Presentation
 - The date and time for the presentation is fixed: 2018-06-27T15:00
 - We will start with a presentation (20-30 minutes) covering...
 - the problem
 - our solution
 - the biggest challenges
 - special/notable efforts
 - demo
3. Date and time for the next meeting
 - Next weekly meeting on 2018-06-04 09:00

Upcoming absences

None

Meeting 2018-06-04

Attendees

- Fabian Hauser, fhauser
- Raphael Zimmermann, rzimmerm
- Prof. Dr. Andreas Steffen, SFF

Minute Taker: rzimmerm

Agenda

1. Review: Test-Drive
2. Date and time for the next meeting

Discussions / Decisions

1. Review: Test-Drive
2. Date and time for the next meeting
 - Next weekly meeting on 2018-XX-XX

Upcoming absences

None

A.6 Requirements

The following sections describe the primary requirements in the form of user stories [2]. Figure 1 shows an overview of the primary use stories.

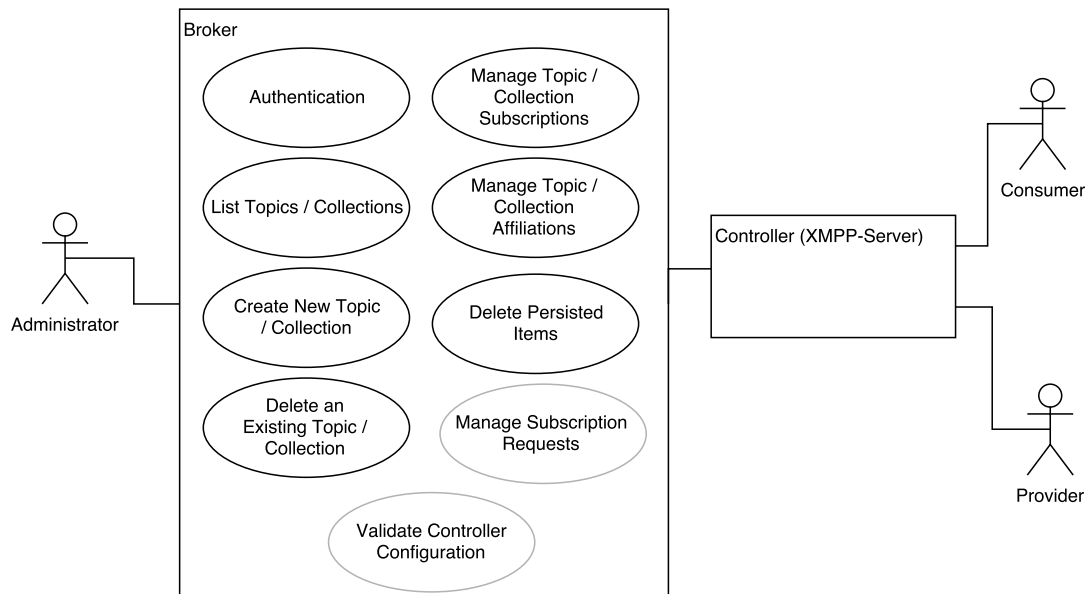


FIGURE 1: UML Use Case Diagram presenting an overview of the primary user stories.

A.6.1 Authentication

A.6.1.1 Login

As an Administrator,
I want to log in
- preferably using an existing client TLS certificate -
so that only I can inspect and manage Topics.

A.6.1.2 Secure XMPP Authentication

As an Administrator concerned with security requirements,
I want to use either SASL EXTERNAL or SASL SCRAM mechanism for authentication -

- preferably the SCRAM-SHA-256-PLUS variant and
- preferably using mutual certificate-based authentication including revocation status checking

- so that the Controller is fully compatible with the *XMPP-Grid* standard [6].
To achieve this goal, I am willing to accept:

- More costly and less user friendly authentication
- limited compatibility of supported *XMPP* servers

A.6.1.3 Secure XMPP Connection

As an Administrator concerned with security requirements,
I want to use minimally TLS 1.2 [RFC5246] to communicate with the *XMPP* server
at all times
to achieve maximal security and compatibility with the *XMPP-Grid* standard [6].

A.6.1.4 Secure Connection

As an Administrator concerned with security requirements,
I want to use minimally TLS 1.2 [RFC5246] to communicate with the Broker
to achieve maximal security.

A.6.1.5 Multiple Administrators

As an Administrator,
I want to grant access to administrators
so that they can also manage the application.

A.6.1.6 Audit Trail

As an Administrator concerned with security requirements,
I want to be able to access an audit log
- preferably using existing *XMPP* mechanisms -
so that I can reconstruct what other Administrations did on the Controller.

A.6.1.7 Logout

As an Administrator,
I want to log out
so that I can terminate a session.

A.6.2 List Topics and Collections

A.6.2.1 List All Topics

As an Administrator,
I want to see a list of all Topics of the associated Controller
so that I can quickly assimilate which Topics exist.

A.6.2.2 List All Top-Level-Collections

As an Administrator,
I want to see a list of all Top-Level-Collections of the associated Controller
so that I can quickly assimilate which Collections exist.

A.6.2.3 List All Parent-Collections of a Topic

As an Administrator,
I want to see a list of all transitive parent Collections that contain a given Topic
so that I can quickly assimilate in which Collections items are published.

A.6.2.4 List All Subtopics and Subcollection of a Collection

As an Administrator,
I want to see a list of all Collections and Topics that a given Collection contains
so that I can quickly assimilate the collection hierarchy.

A.6.2.5 List Available Topics With Limited Access (optional)

As an Administrator,
I want to see a list of all Topics of the associated Controller to which I have limited
access to,
to simplify troubleshooting and locate errors.

A.6.2.6 List Available Collections With Limited Access (optional)

As an Administrator,
I want to see a list of all Collections of the associated Controller to which I have
limited access to,
to simplify troubleshooting and locate errors.

A.6.2.7 Topic and Collection Paging

As an Administrator,
I want to be able to page through any set of Collection/Topic with more than 10
Items
so that I can work with more than 1000 Collections and Topics more effectively.

A.6.2.8 Topic and Collection Name Filter

As an Administrator,
I want to be able to quickly filter any set of Collections/Topics with more than 10
Items
so that I can work with more than 1000 Collections and Topics more effectively.

A.6.3 Create a New Topic

As an Administrator,
I want to create a new Topic on the associated Controller
so that I am not tied to a fixed set of Topics.

A.6.4 Create a New Collection

As an Administrator,
I want to create a new Collection on the associated Controller
so that I can flexibly patch Topics together.

A.6.4.1 Override Default Topic Configuration

As an Administrator in the process of creating a new Topic,
I want to override the default configuration (e.g. the affiliations)
so that I can restrict access and provide reasonable defaults.

A.6.4.2 Override Default Collection Configuration

As an Administrator in the process of creating a new Collection,
I want to override the default configuration (e.g. the affiliations)
so that I can restrict access and provide reasonable defaults.

A.6.4.3 Initial Topic Consumers and Providers

As an Administrator in the process of creating a new Topic,
I want to specify an initial set of Consumers and Providers
so that I can restrict access to that Topic and provide reasonable defaults.

A.6.4.4 Initial Collection Consumers

As an Administrator in the process of creating a new Collection,
I want to specify an initial set of Consumers
so that I can restrict access to that Collection and provide reasonable defaults.

A.6.5 Delete an Existing Topic

As an Administrator,
I want to delete an existing Topic on the associated Controller
so that I can get rid of obsolete Topics.

A.6.6 Delete an Existing Collection

As an Administrator,
I want to delete an existing Collection on the associated Controller
so that I can get rid of obsolete Collections.

A.6.6.1 Fault Prevention On Topic-Delete

As an Administrator in the process of deleting a Topic,
I want a mechanism to prevent me from deleting the wrong Topic on the associated Controller
(e.g. require me to enter the name of the Topic manually).

A.6.6.2 Fault Prevention On Collection-Delete

As an Administrator in the process of deleting a Collection,
I want a mechanism to prevent me from deleting the wrong Collection on the associated Controller
(e.g. require me to enter the name of the Collection manually).

A.6.7 Manage Topic/Collection Subscriptions

A.6.7.1 List Consumers

As an Administrator,
I want to list all Consumers (including their JIDs) of a given Topic/Collection on the associated Controller,
so that I can verify that specific Consumers are subscribed, and others are not.

A.6.7.2 Inspect Detailed Subscription Configuration

As an Administrator,
I want to inspect the detailed Topic/Collection subscription configuration of a given Consumer,
so that I can reproduce and reason about the receipt of data on that Consumer and find potential misconfiguration.

A.6.7.3 Partially Modify Subscription Configuration

As an Administrator,
I want to modify parts of the Topic/Collection subscription configuration of a given Consumer,
so that I can fix misconfiguration.

A.6.7.4 Unsubscribe Consumer

As an Administrator,
I want to manually unsubscribe a specific Consumer from a particular Topic/Collection on the associated Controller,
so that I can remove obsolete or undesired subscriptions.

A.6.7.5 Subscribe Consumer

As an Administrator,
I want to manually subscribe a specific Consumer on a particular Topic/Collection on the associated Controller,
so that I can faster setup and manage Consumers.

A.6.8 Manage Topic Affiliations**A.6.8.1 Inspect Affiliations**

As an Administrator,
I want to list all Affiliations (JID and "Role") for a particular Topic/Collection on the associated Controller
so that I can find potential misconfiguration.

A.6.8.2 Modify Affiliations

As an Administrator,
I want to modify the Affiliation ("Role") of a given JID for a particular Topic/Collection on the associated Controller
so that I can fix potential misconfiguration.

A.6.8.3 Fault Prevention When Modifying My Affiliation

As an Administrator in the process of modifying my Affiliation for a particular Topic/Collection on the associated Controller,
I want a mechanism to prevent me from accidentally downgrading my rights.

A.6.8.4 Meaningful Error For Topics/Collection With Limited Access

As an Administrator,
I want to receive a meaningful error message when inspecting a Topic/Collection to which I have limited access
so that I can quickly comprehend why the configuration options are limited.

A.6.9 Manage Persisted Items of a Topic

A.6.9.1 Inspect Persisted Items

As an Administrator,
I want to list all Persisted Items for a particular Topic on the associated Controller
so that I can get an overview and check for misconfiguration.

A.6.9.2 Filter Persisted Items

As an Administrator,
I want to be able to filter all persisted Items of a specific Topic by

- the timestamp of its publication
- the publishers JID

so that I can work with more than 10000 persisted items more effectively.

A.6.9.3 Paged Persisted Items

As an Administrator working with filtered persisted items,
I want to be able to page through the resulting items
- given that this feature is supported by the associated Controller -
so that I can work with more than 10000 persisted items more effectively.

A.6.9.4 Delete a Persisted Item From a Topic

As an Administrator,
I want to delete a particular persisted item from a specific Topic
- given that this feature is supported by the associated Controller -
so that I can clean up test items and remove obsolete or corrupted items.

A.6.9.5 Purge All Persisted Items From a Topic

As an Administrator,
I want to purge persisted items from a specific Topic
- given that this feature is supported by the associated Controller -
so that I can clean up test items and remove obsolete or corrupted items.

A.6.9.6 Delete Set of Persisted Item From a Topic (optional)

As an Administrator,
I want to delete a set of persisted item that match a given criteria from a specific Topic
- given that this feature is supported by the associated Controller -
so that I can clean up test items and remove obsolete or corrupted items.

A.6.10 Manage Subscription Requests (optional)

A.6.10.1 List Subscription Request

As an Administrator,
I want to list pending subscription requests for a given Topic
- given that this feature is supported by the associated Controller -
so that I can quickly assimilate pending requests.

A.6.10.2 Accept Subscription Request

As an Administrator,
I want to accept a pending subscription request for a given Topic
- given that this feature is supported by the associated Controller -
to enable more dynamic access models than just maintaining a black- or whitelist.

A.6.10.3 Reject Subscription Request

As an Administrator,
I want to reject a pending subscription request for a given Topic
- given that this feature is supported by the associated Controller -
so that I can deny user access in accordance with the *XMPP* standards.

A.6.11 Validate Controller Configuration (optional)

A.6.11.1 Validate Supported XEPs Configurations

As an Administrator,
I want to validate that a minimum set of XEPs are supported by the associated Controller
so that I can quickly identify incompatibilities.

A.6.11.2 Validate Optional XEP Implementations

As an Administrator,
I want to validate that the required features that are marked as optional or recommended in the XEPs are implemented by the associated Controller
so that I can quickly identify incompatibilities.

A.7 Wireframes

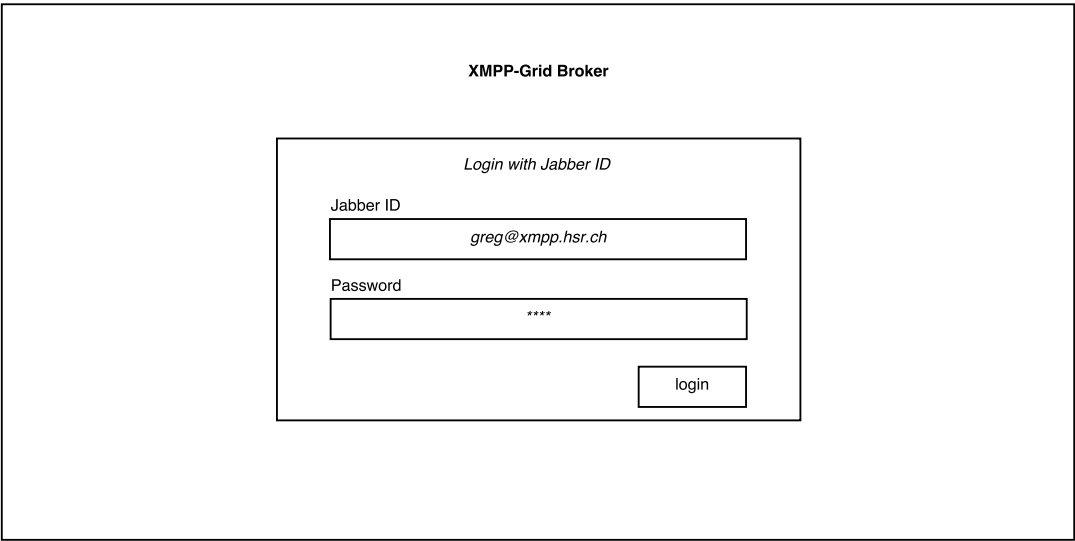


FIGURE 2: Login-Screen Wireframe

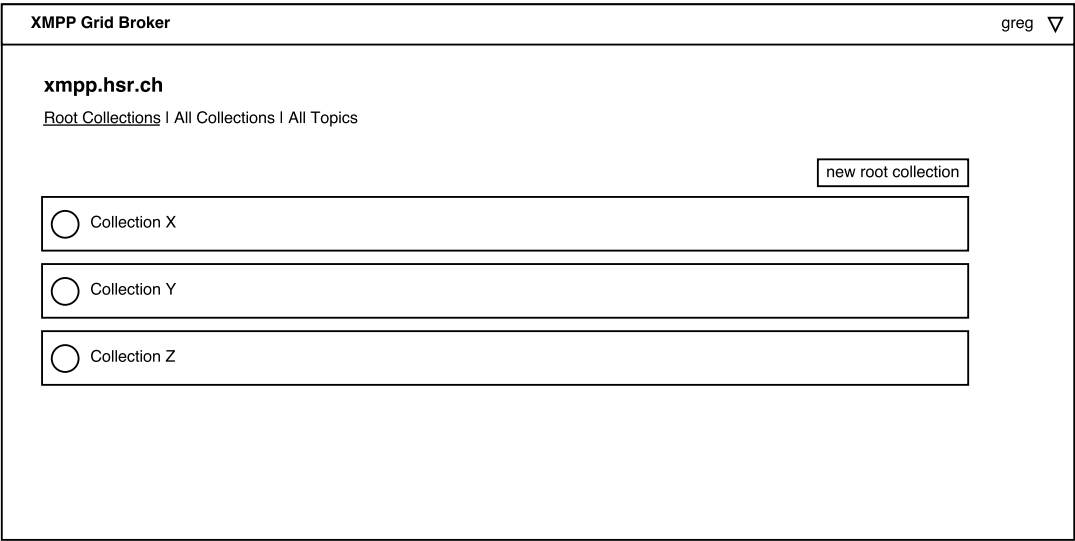


FIGURE 3: Controller Overview Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch

Root Collections | [All Collections](#) | All Topics

search

new collection

Collection X

Collection Y

Collection Z

SubColl 1

<< Prev 1 2 3 4 5 6 Next >>

FIGURE 4: All Collections Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch

Root Collections | All Collections | [All Topics](#)

search

new topic

Topic 1

view

Topic 2

edit

Topic 3

edit

Topic 4

edit

<< Prev 1 2 3 4 5 6 Next >>

FIGURE 5: All Topics Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch > New Collection...

Collection name

collection name

▾ Affiliations

josh@xmpp.hsr.ch

Publisher ▾

delete

bare JID (foo@example.com)

Subscriber ▾

add

▾ Contained Topics

Topic XYZ

delete

topic name

add

Autocomplete

▸ Advanced Configuration...

cancel

create collection

FIGURE 6: New Collection Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch > New Topic...

Topic name

topic name

▽ Affiliations

josh@xmpp.hsr.ch

Publisher ▾

delete

bare JID (foo@example.com)

Subscriber ▾

add

▽ Parent Collections

Collection 1

delete

collection name

Autocomplete

add

▶ Advanced Configuration...

cancel

create topic

FIGURE 7: New Topic Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch > Root Collection 1 > Subcollection 1

Overview | Affiliations | Configuration

Affiliations and Configuration tabs are identical with those of topics.

Subcollections:

add subcollection...

○ Subcollection 2

edit | remove

Subtopics:

add subtopic...

○ Topic 1

edit | remove

○ Topic 2

edit | remove

○ Topic 3

edit | remove

○ Topic 4

edit | remove

FIGURE 8: Collection Overview Wireframe

XMPP Grid Broker

greg ▾

xmpp.hsr.ch > Topic 1

Subscriptions (1) | Affiliations | Configuration | Parent Collections | Persisted Items

Pending Subscription Requests

○ joe@xmpp.hsr.ch

accept | reject

Subscribed Consumers

manually subscribe...

○ josh@xmpp.hsr.ch

edit | unsubscribe

○ josh@xmpp.hsr.ch

edit | unsubscribe

○ josh@xmpp.hsr.ch

edit | unsubscribe

○ josh@xmpp.hsr.ch

edit | unsubscribe

FIGURE 9: Topic Overview Wireframe

xmpp.hsr.ch

greg ▾

xmpp.hsr.ch > Topic 1

Subscriptions | Affiliations | Configuration | Parent Collections | Persisted Items

Affiliations:

josh@xmpp.hsr.ch

Publisher ▾

remove

josh@xmpp.hsr.ch

Publisher ▾

remove

josh@xmpp.hsr.ch

Publisher ▾

remove

josh@xmpp.hsr.ch

Publisher ▾

remove

new affiliation

FIGURE 10: Topic/Collection Affiliations Wireframe

xmpp.hsr.ch

greg ▾

xmpp.hsr.ch > Topic 1

Subscriptions | Affiliations | Configuration | Parent Collections | Persisted Items

Configuration:

title

A friendly name for the node

?

deliver_payloads

☐

?

notify_config

☒

?

persist_items

☒

?

update

Danger Zone:

delete this topic

convert this topic into a collections

FIGURE 11: Topic/Collection Configuration Wireframe

xmpp.hsr.ch

greg ▾

xmpp.hsr.ch > Topic 1

Subscriptions | Affiliations | Configuration | Parent Collections | Persisted Items

Parent Collections:

Collection 1

collection name

Autocomplete

delete

add

FIGURE 12: Topic Parent Collections Items Wireframe

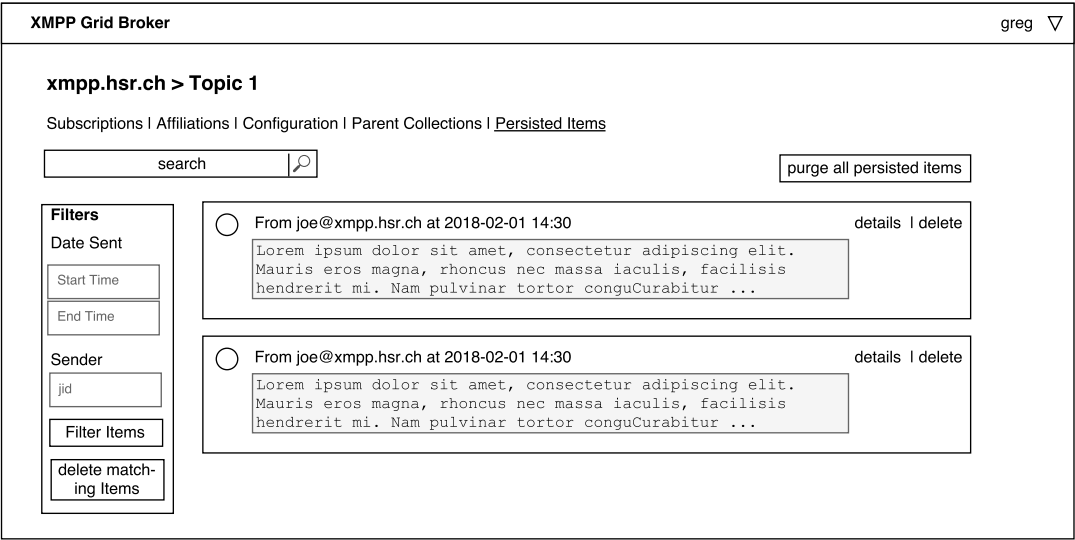


FIGURE 13: Persisted Items Wireframe

A.8 Comparison of *XMPP* Server and Libraries

A.8.1 Server

To find a suited server to develop, test and document our application with, we considered the three major open source *XMPP* servers, which are still under active maintenance and provide extensive documentation on their XEP-implementations.

For our implementation, we might require the following XEPs respectively RFCs. Any deviations are noted under “XEP/RFC Support”.

XEP-0004 Data Forms

XEP-0030 Service Discovery

XEP-0059 Result Set Management

XEP-0060 Publish-Subscribe

XEP-0114 Jabber Component Protocol

XEP-0133 Service Administration

XEP-0178 Best Practices for Use of SASL EXTERNAL with Certificates

XEP-0206 *XMPP* Over BOSH

XEP-0248 PubSub Collection Nodes

RFC-7395 An *XMPP* Subprotocol for WebSocket

A.8.1.1 Openfire

Programming Language Java

Plugin Architecture Java JAR¹

XEP/RFC Support	XEP-0133	Partial, also not explicitly supported ²
	XEP-0178	Partial, also not explicitly supported ³
	XEP-0248	Partial, as part of outdated XEP-0060 ⁴
	All other required XEPs are supported ⁵	

¹<http://download.igniterealtime.org/openfire/docs/latest/documentation/plugin-dev-guide.html>

²<https://issues.igniterealtime.org/browse/OF-284>

³<https://github.com/Connectify/Openfire/blob/master/src/java/org/jivesoftware/openfire/net/SASLAuthentication.java> and <https://issues.igniterealtime.org/browse/OF-1191>

⁴<https://igniterealtime.jiveon.com/thread/38929>

⁵<http://download.igniterealtime.org/openfire/docs/latest/documentation/protocol-support.html>

A.8.1.2 Prosody

Programming Language	Lua
Plugin Architecture	Luascript ⁶
XEP/RFC Support	XEP-0059 Not supported
	XEP-0178 Not supported
	XEP-0248 Not supported
	All other required XEPs are supported ⁷

A.8.1.3 Ejabberd

Programming Language	Erlang
Plugin Architecture	Erlang/Elixir ⁸
XEP/RFC Support	XEP-0178 Partial, commercially only ⁹
	RFC-7395 Partial, not explicitly supported ¹⁰
	All other required XEPs are supported ¹¹

A.8.2 Libraries

To find a suited library to implement our application with, we considered various open source *XMPP* libraries, which are still under active maintenance and provide extensive documentation on their XEP-implementations. We also limited the programming languages to Python, Java and JavaScript as discussed in the project meeting of 2018-03-05 (see A.5 Meeting Minutes).

For our implementation, we might require the following XEPs. Any deviations are noted under “Limitations”.

XEP-0004 Data Forms

XEP-0030 Service Discovery

XEP-0059 Result Set Management

XEP-0060 Publish-Subscribe

XEP-0114 Jabber Component Protocol

XEP-0133 Service Administration

XEP-0178 Best Practices for Use of SASL EXTERNAL with Certificates

XEP-0206 *XMPP* Over BOSH

XEP-0248 PubSub Collection Nodes

⁶<https://prosody.im/doc/developers/modules>

⁷<https://prosody.im/doc/modules> and <https://prosody.im/doc/xep-list>

⁸<https://docs.ejabberd.im/developer/extending-ejabberd/modules/>

⁹Server to server only in community edition

¹⁰<https://docs.ejabberd.im/xmpp>

¹¹<http://www.ejabberd.im/protocols>

RFC-7395 An *XMPP* Subprotocol for WebSocket (mentioned only if differs from XEP-0206 implementation status)

Name	Language	Plugins	Limitations
SleekXMPP ¹²	Python 2	Yes ¹³	Not Supported: XEP-114, XEP-133, XEP-248, XEP-0206 Partial: XEP-0060 ¹⁴
SliXMPP ¹⁵	Python 3	Yes ¹⁶	Not Supported: XEP-114, XEP-133, XEP-248, XEP-0206 Partial: XEP-0060 ¹⁷
aioxmpp ¹⁸	Python 3.4	Yes ¹⁹	Not Supported: XEP-0114, XEP-0133, XEP-0178, XEP-248, XEP-0206
Smack ²⁰	Java	Yes ²¹	Not Supported: XEP-0114, XEP-0206
Babbler ²²	Java	Yes ²³	Not Supported: XEP-0133, XEP-0248
XMPP-FTW ²⁴	JS(Browser)	Yes ²⁵	Not Supported: XEP-0114, XEP-0133, XEP-0248 Unclear: XEP-0206, XEP-0178 Note: Requires Server Abstraction
stanza.io ²⁶	JS(Browser)	Yes ²⁷	Not Supported: XEP-0114, XEP-0133, XEP-0248 Partial: XEP-0178 ²⁸
strophe.js ²⁹	JS(Browser)	Yes ³⁰	Not Supported: XEP-0114, XEP-0133, XEP-0248 Partial: XEP-0178 ³¹

¹²<http://sleekxmpp.com/xeps.html>

¹³http://sleekxmpp.com/create_plugin.html

¹⁴Client-side only

¹⁵<https://github.com/poezio/slixmpp/blob/master/docs/xeps.rst>

¹⁶https://github.com/poezio/slixmpp/blob/master/docs/create_plugin.rst

¹⁷Client-side only

¹⁸<https://docs.zombofant.net/aioxmpp/devel/#from-xmpp-extension-proposals-xeps>

¹⁹<https://docs.zombofant.net/aioxmpp/devel/api/public/index.html#apis-mainly-relevant-for-extension-developers>

²⁰<https://download.igniterealtime.org/smack/docs/latest/documentation/extensions/index.html>

²¹<https://github.com/igniterealtime/Smack/tree/master/documentation>

²²<https://sco0ter.bitbucket.io/babbler/xeps.html>

²³<https://sco0ter.bitbucket.io/babbler/customextensions.html>

²⁴<http://docs.xmpp-ftw.org/manual/>

²⁵<http://docs.xmpp-ftw.org/>

²⁶https://github.com/legastero/stanza.io/blob/master/docs/Supported_XEPs.md

²⁷https://github.com/legastero/stanza.io/blob/master/docs/Create_Plugin.md

²⁸Not explicitly supported

²⁹<https://github.com/strophe/strophejs-plugins>

³⁰<https://github.com/strophe/strophejs-plugins>

³¹Not explicitly supported

Declaration of Authorship

We, Fabian HAUSER and Raphael ZIMMERMANN, declare that this thesis and the work presented in it are our own, original work. All the sources we consulted and cited are clearly attributed. We have acknowledged all main sources of help.

Fabian Hauser

Raphael Zimmermann

Rapperswil, May 29, 2018