UNIVERSITY OF APPLIED SCIENCES RAPPERSWIL
DEPARTMENT OF COMPUTER SCIENCE

BACHELOR THESIS

XMPP-Grid Broker

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Spring Term 2018

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Task Description

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Bachelorarbeit 2018

XMPP-Grid Broker

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Ausgabe: Montag, 19. Februar 2018

Abgabe: Freitag, 15. Juni 2018

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

Management Summary

Acknowledgements

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

Contents

Chapter 1

Introduction

"Every accomplishment starts with the decision to try."
— unknown

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

1.1 Motivation

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

1.1.1 Present Situation

The IETF standard draft ***Using XMPP for Security Information Exchange*** [7] 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.

To demonstrate the viability of the draft a rapid prototype was developed in November 2017 [25].

1.1.2 Problem and Vision

Currently, there exists no implementation of the *XMPP* grid draft management functionality 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.

1.2 Delimitation

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 the intended audience for this thesis are developers and operators of security reporting systems, we mostly use the Security Automation and Continuous Monitoring (SACM) terminology [4] and thereby follow the same guidelines as the XMPP grid draft [7].

2.2 Technical Background

The following sections introduce the underlying XMPP protocol and the relevant extensions (*XEPs*) used by the XMPP grid draft 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* [13] and *Publish-Subscribe* [15] 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 *JID* of the receiver has a different domainpart than 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][16].

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.

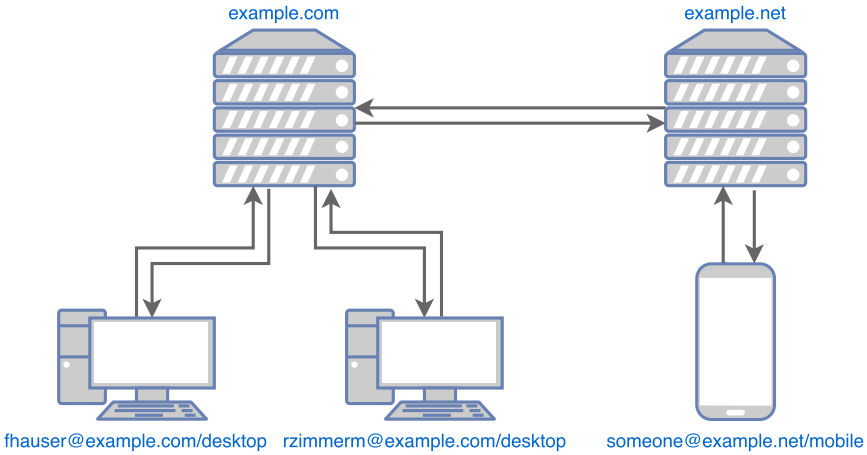

FIGURE 2.1: Two XMPP domains (servers), one with two users and one with a single mobile user.

2.2.2 Relevant XMPP Extensions

The XMPP grid draft [7] 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 [9].

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 [13].

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 time or other resources are limited [17].

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*) [15].

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 [5].

The protocol defines a hierarchy of six affiliations of which only the implementation of 'owner' and 'none' is ***required***. The implementation of 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 blured, 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 coarse prioritisation, 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 Internet-Draft: Using XMPP for Security Information Exchange

This IETF Internet draft describes how the XMPP protocol enhanced with the in Section 2.2 discussed XEPs, most notably the *PubSub* extension, can be used for the exchange and distribution of security-relevant information between network devices. The draft assumes use of the Incident Object Description Exchange Format (IODEF) [8].

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 compromisation has serious consequences.

The draft describes a trust model, 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 [7].

Information Exchange in the IODEF

The XMPP Grid draft 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)" [7].

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

2.4.2 Domain Specific Language

Figure 2.2 and 2.3 present an overview of the relevant interactions and relationships between the different components as specified in the XMPP grid draft [7] and as used in the referenced XEPs (see Section 2.2).

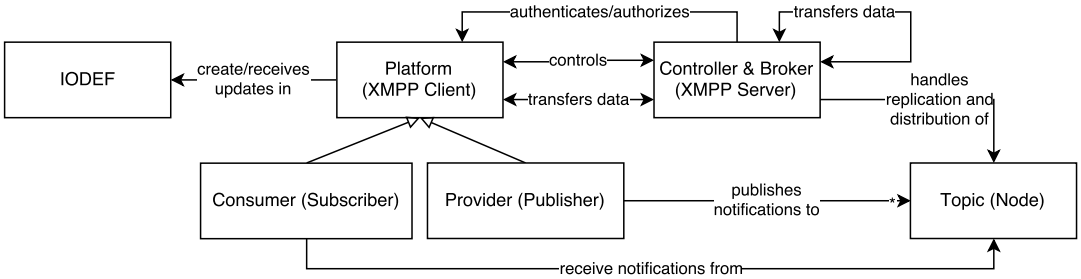

FIGURE 2.2: Domain Specific Language of the XMPP grid draft

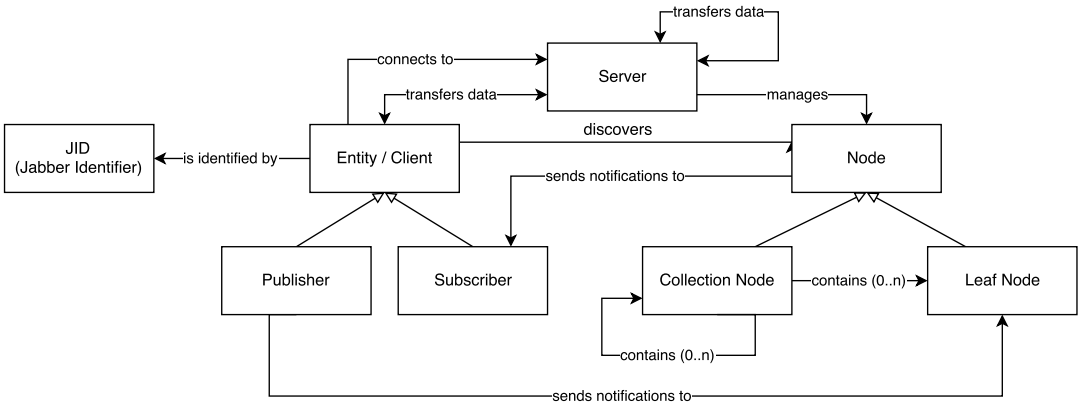

FIGURE 2.3: Domain Specific Language of used XMPP XEPs

2.5 Risk Analysis

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 [6].

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 .

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*.

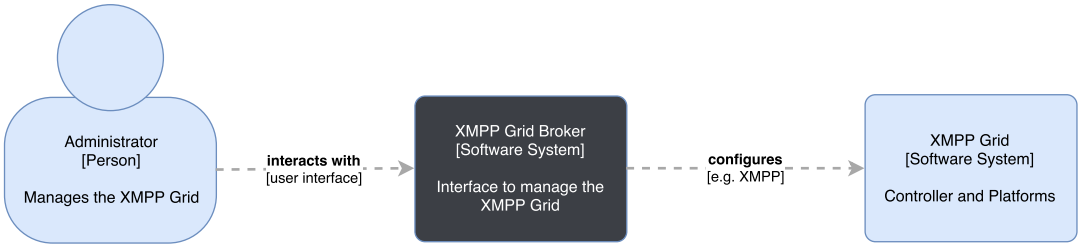

FIGURE 3.1: Architecture diagram showing the context of the XMPP grid broker application.

3.1.2 Architectural Style and Platform

To implement the XMPP grid broker, we evaluated three possible architecture styles: An XMPP Server Plugin (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 the Server Plugin 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 three 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 Figure 3.3 and 3.4.

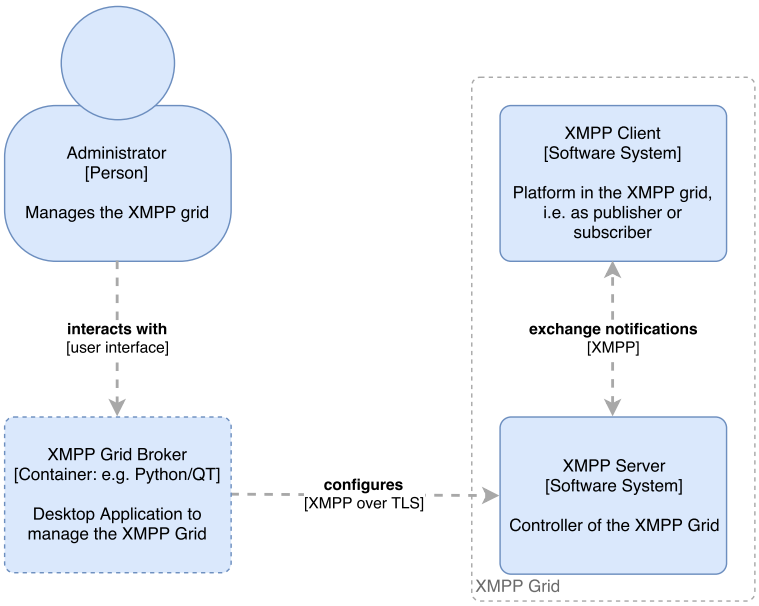

FIGURE 3.2: Architecture Container Diagram showing a possible rich client architecture.

A web application has the significant advantage to be easily installable, upgradable and has 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.

3.1.3 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 [18]), or to communicate indirectly with the XMPP server via custom WebAPI Proxy. These topologies are illustrated in Figure 3.3 and Figure 3.4.

As elaborated in the according design decision (see Appendix A.3), we decided for the direct connection via WebSockets, with a fallback to BOSH if the required features are not supported (e.g. SASL EXTERNAL authentication). This topology simplifies the implementation and deployment of the application in comparison to

a WebAPI 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 [18].

Using the XMPP Service Discovery [13], the XMPP server may be queried for supported features, so that only supported functionality is presented to the application user.

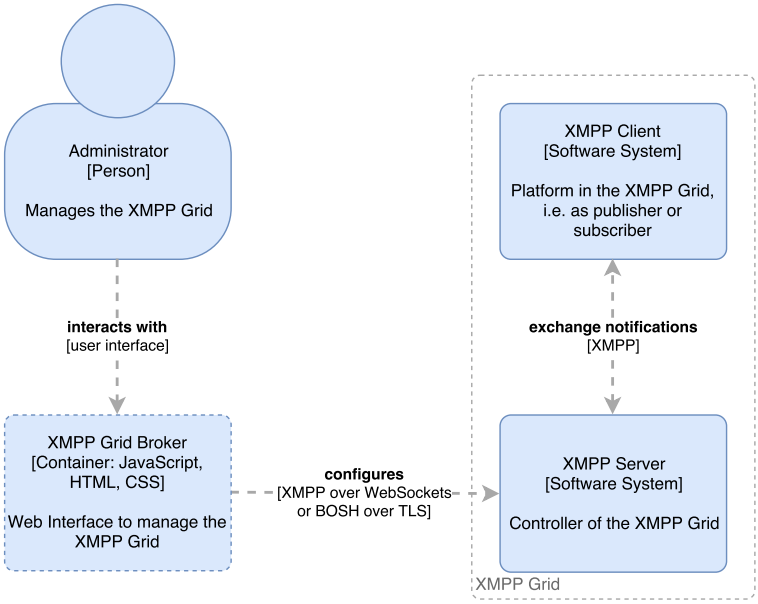

FIGURE 3.3: Architecture Container Diagram showing the web application topology with WebSockets or BOSH.

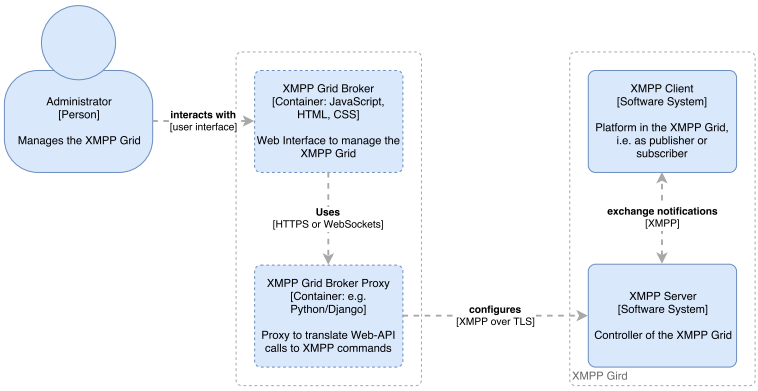

FIGURE 3.4: Architecture Container Diagram showing the WebAPI Proxy topology.

3.1.4 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 [11], that is also recommended by in the XMPP grid draft [7]. As described in the corresponding architectural decision (Appendix A.3), the main reason for SASL EXTERNAL is its higher level of security and 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].

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 out of the scope of this thesis. A detailed discussion of security concerns can be found in the XMPP specification [20] and most XEPs [15][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 prevent such corruptions best practices such as storing certificates and passwords securely must be followed.

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 has many potential security concerns, above all a modern web browser is critical for client security. Legacy browsers can not provide an adequate level of security. [10]

Most browser support extension mechanisms which have rather significant capabilities. The usage of untrusted or uncertified browser extensions is strictly discouraged. [1]

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 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. By using plain JavaScript, it's unlikely to achieve the same level of security in a reasonable timespan.

On their project website, Angular recommends the following three best practices regarding security [2].

- Keep current 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 later 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 less as possible from the standard angular setup (e.g. by not ejecting the Webpack configuration[1]).

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

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 an 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. With regards to the Angular templates, we use the

[1] https://github.com/Angular/Angular-cli/wiki/eject

offline template compiler, so that no user-generated data can influence them. 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. [2]

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 used together with BOSH or WebSockets, it is important that the XMPP server supports 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. [14][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 server side 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 out of the scope of this analysis.

In addition to these general best practices, we explicitly recommend the following security measures to maximise the 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 Stapling[2].

XMPP Server

The XMPP server security depends on the chosen implementation and the application domain. Discussing XMPP server security in detail is out of the scope of this thesis. Operators should adhere to the security recommendations of their XMPP server vendor and follow general security best practices as outlined by the XMPP-Grid draft [7].

3.4 Security Risk Mitigation

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

[2] `https://wiki.mozilla.org/Security/Server_Side_TLS`

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 expert.
3. Define explicit security requirements in the form of constraints
4. Automate build and release processes to minimise the time required to patch.
5. Stay as close to the default Angular setup to simplify further updates
6. 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 complete templates offline using the offline template compiler.
- User input is always escaped using the mechanisms provided by the framework
- XMPP-Messages are validated to contain only the specified result-types

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 Code Quality

4.2 Complexity

4.3 Testing

4.4 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*" [4]

Component

An encapsulation of software that communicates using Interfaces, that is composed of *SACM* capabilities. [4, 12]

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." [7]

control plane

"An architectural component that provides common control functions to all *SACM* components." [4]

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." [7, 4]

Data Forms

XMPP Data Forms Extension

Info/Query

XMPP Info/Query *stanza*

Jabber

Originial 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." [7]

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." [7]

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." [7]

XEP

XMPP Extension Protocol

XML

eXtensible Markup Language

XMPP

eXtensible Messaging and Presence Protocol

Appendices

A.1 Project Plan

XMPP-Grid Broker: Project Plan

Authors:
Fabian HAUSER and
Raphael ZIMMERMANN

Advisor:
Prof. Dr. Andreas STEFFEN

Spring Term 2018

Contents

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

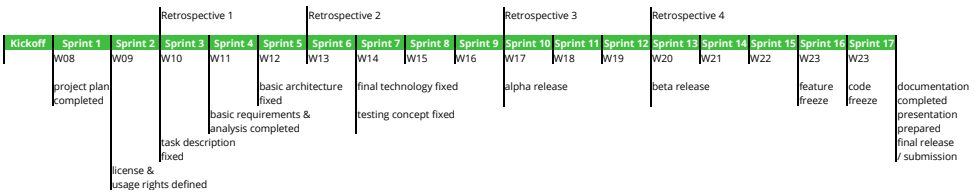

FIGURE 3.1: Overview of the 16 iterations

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 ietf draft, XEP standards etc. - compile list of open questions - begin with chapter "initial situation" - analyze existing python proof-of-concept	- collect non-functional requirements (NFRs) - compile set of user stories - draw wireframes - research frameworks and technology. Prepare architectural decisions	- extend NFRs, user stories, wireframes - make first architectural decisions - further framework and technology research - implement proof of concepts for critical components	- make big architectural decisions - implement proof of concepts for critical components
Documents / Chapters / Artefacts		- chapter "Initial Situation" completed - signed task description		

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	- implement most important user stories - make further architectural decisions	- implement most important user stories - make further architectural decisions
Documents / Artefacts		- Chapter "Our Approach" completed		

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	- implement secondary user stories - write integration tests	- implement secondary user stories - write integration tests	- implement secondary user stories - write integration tests
Documents / Artefacts	- alpha release bundle			- beta release bundle

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 remainging user stories - improve code base - write integration tests	- implement remainging user stories - improve code base - write integration tests	- implement remainging user stories - improve code base - write integration tests	- fix eventual bugs - write documentation
Documents / Artefacts				- final release bundle - poster - abstract

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
Documents / Artefacts	- personal reports - management summary - presentations - time accounting

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.

Probability \ Severity	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 thid-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.

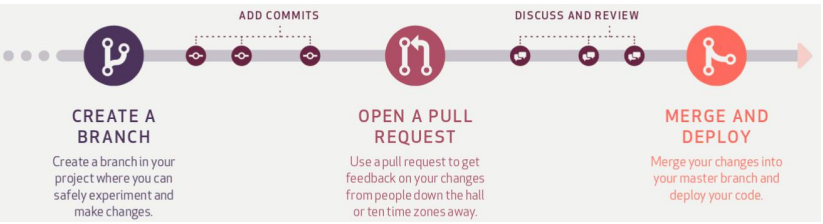

FIGURE 6.1: GitHub Flow illustrated (Source [2])

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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A.2 Development Guide

Development Guide

Tools

- Git >= 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 guidlines (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 ietf draft.
- 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 draft 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 varients [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 draft 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 draft 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 draft.

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 application 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

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

Decision Outcome

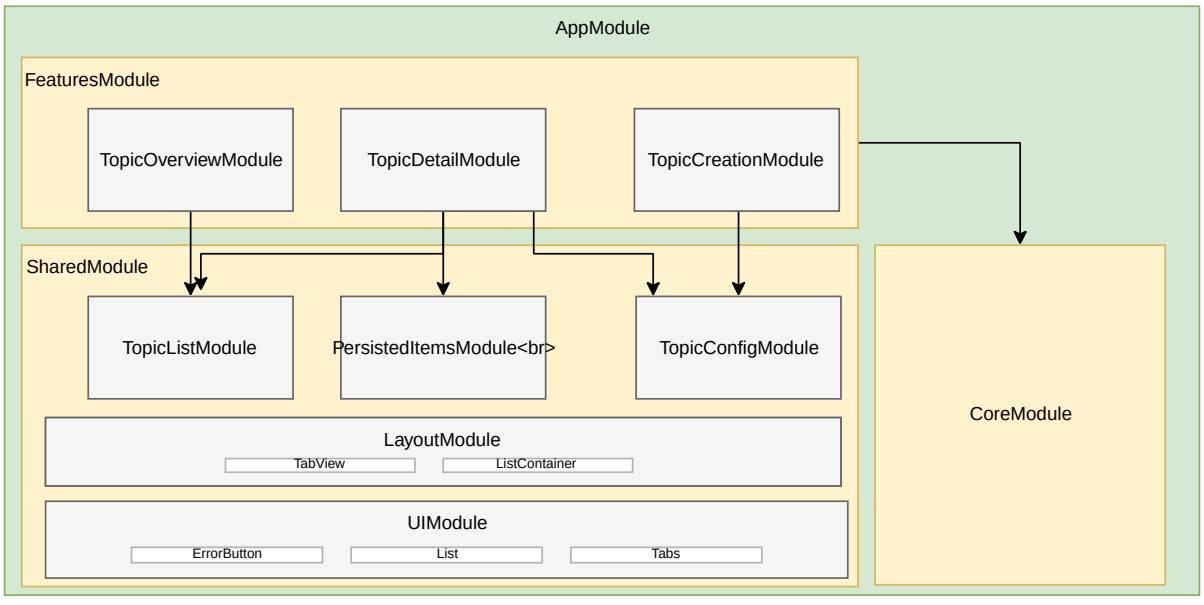
We decided on the module-based option as it follows software engineering best practices for long-lived projects. We accept a slower starting phase to benefit in the long-term from a clean architecture.

Following the Angular Style Guide, we decided on three primary modules: `core`, `shared` and `features`. Each of these modules can have submodules to refine the structure even further. While `core` and `shared` are loaded eagerly, the `features`-submodules are lazy-loaded.

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 or a list of topics.

The `features` module contains all other functionality such as topic creation.



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 continous 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 >= 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. Date and time for the next meeting

Discussions / Decisions

1. Date and time for the next meeting

Upcoming absences

A.6 Requirements

The following sections describe the primary requirements in the form of user stories [3]. Figure 1 shows an overview of the primary use stories.

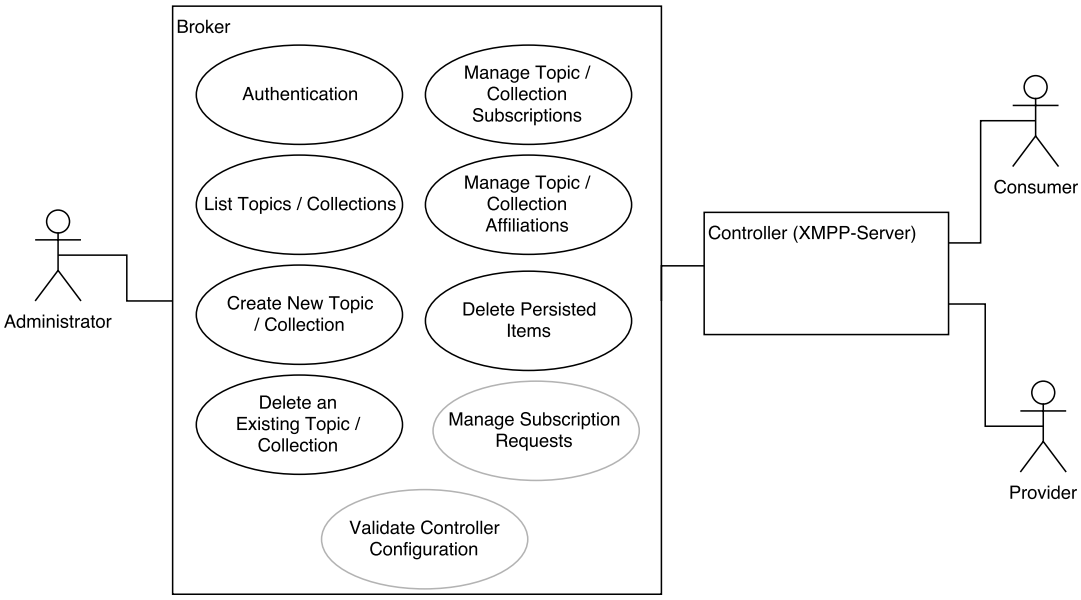


FIGURE 1: UML Use Case Diagram presenting an overview of the primary user stories.

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 draft [7].
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 draft [7].

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 Administrations

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

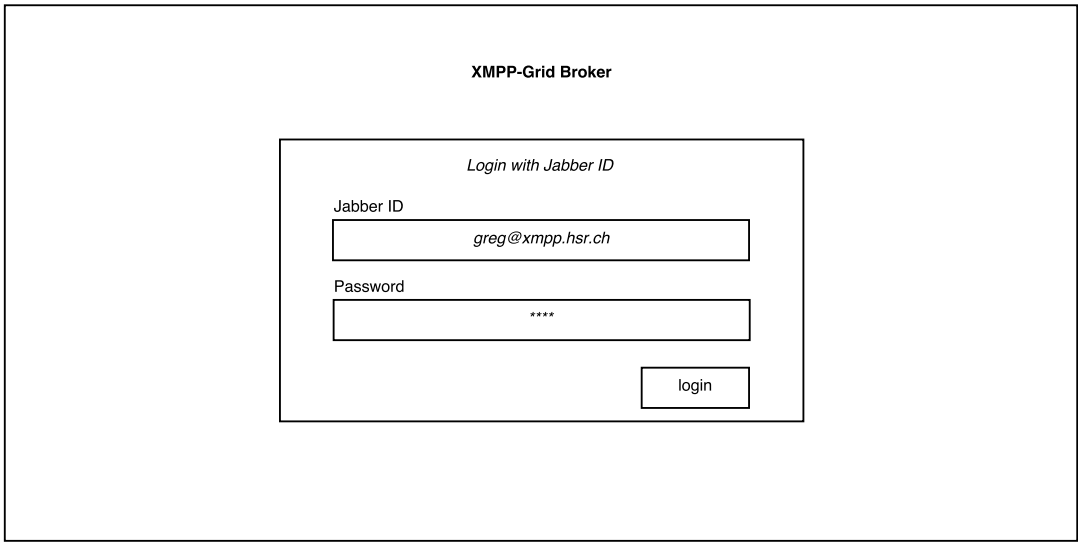


FIGURE 2: Login-Screen Wireframe

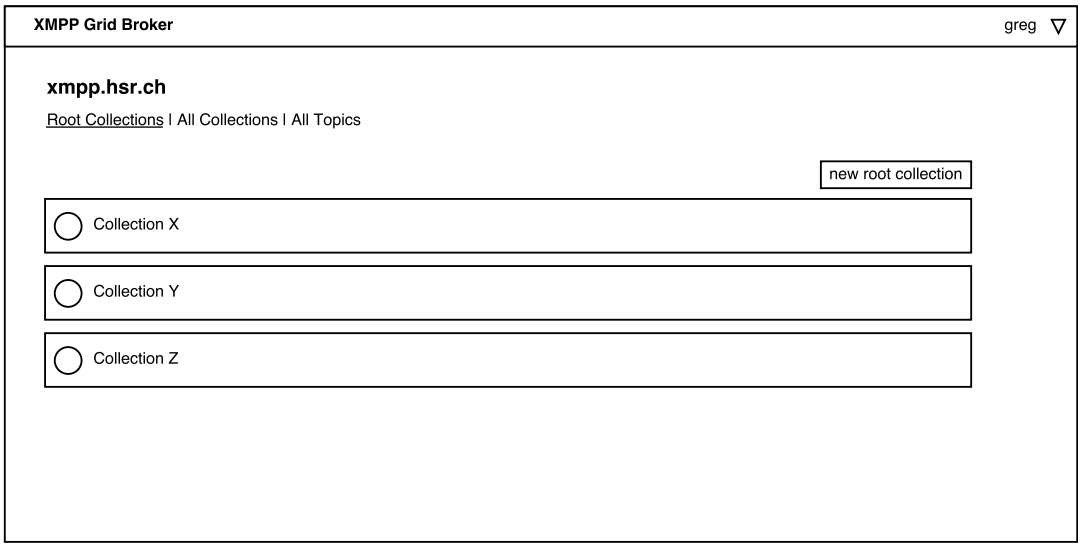


FIGURE 3: Controller Overview Wireframe

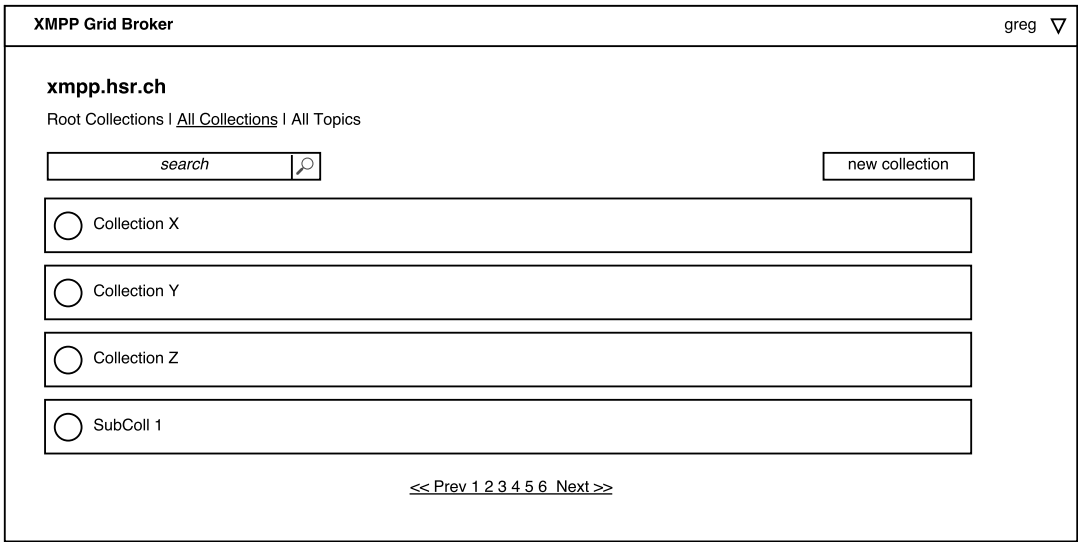


FIGURE 4: All Collections Wireframe

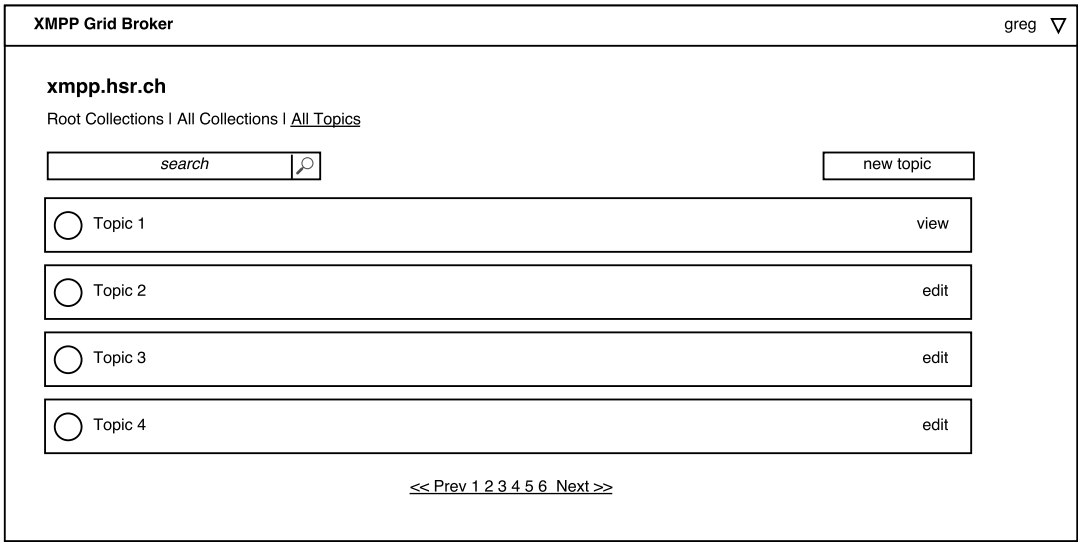


FIGURE 5: All Topics Wireframe

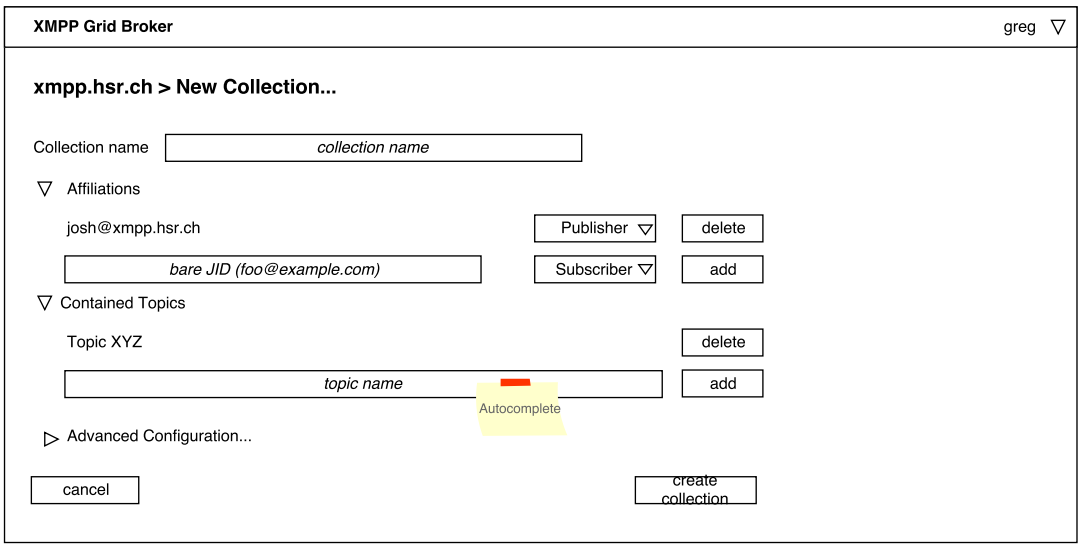


FIGURE 6: New Collection Wireframe

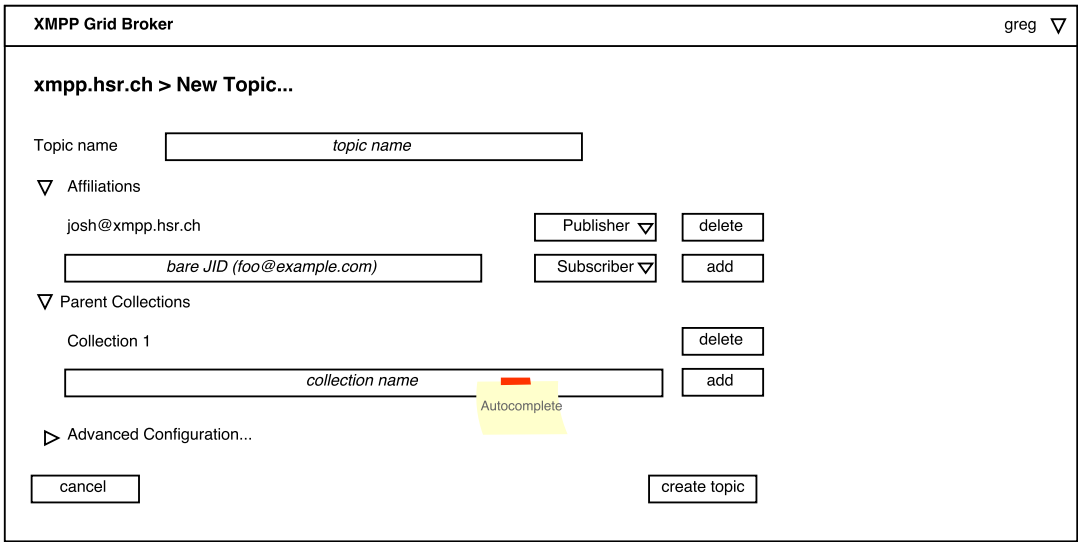


FIGURE 7: New Topic Wireframe

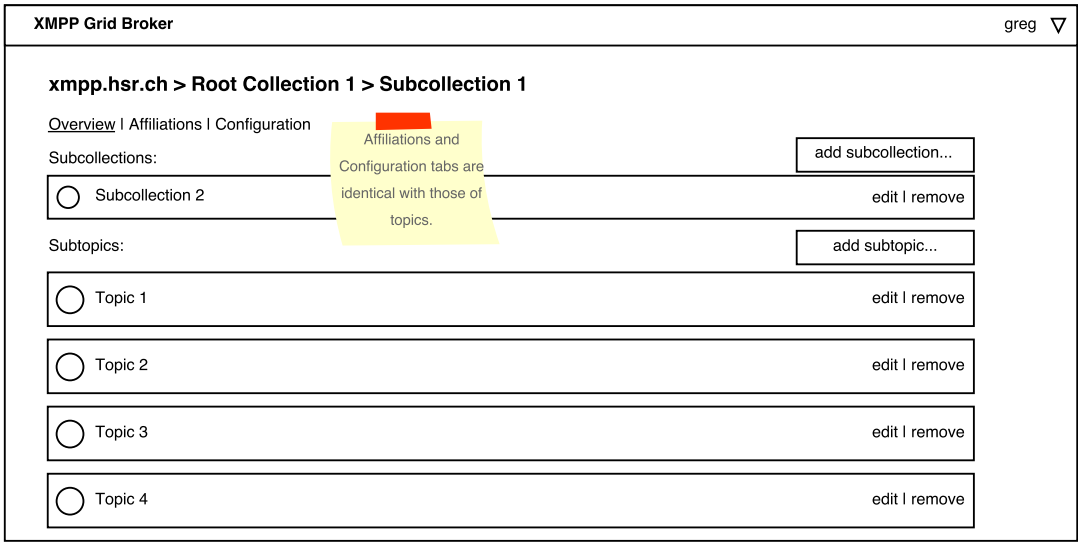


FIGURE 8: Collection Overview Wireframe

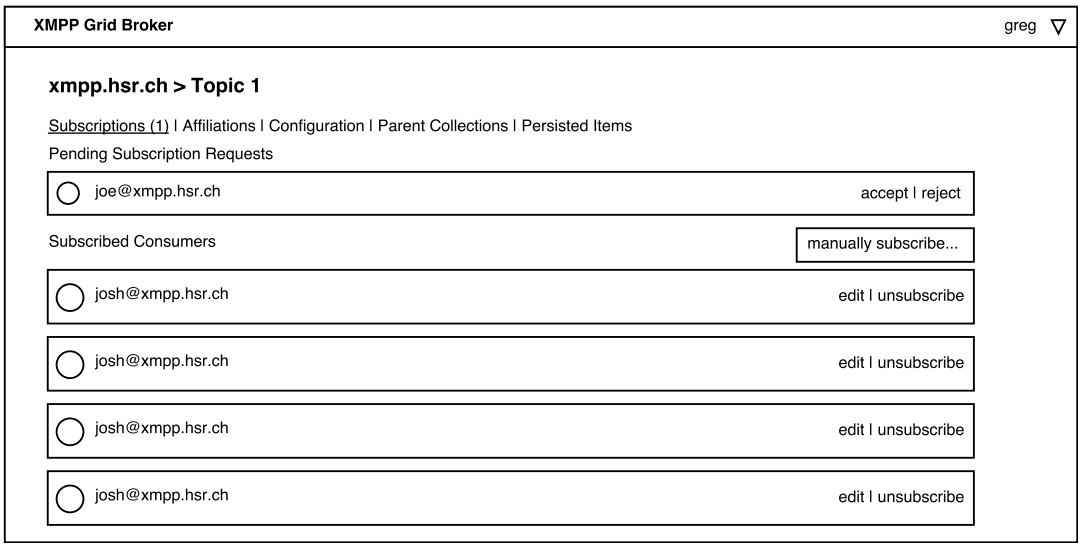


FIGURE 9: Topic Overview Wireframe

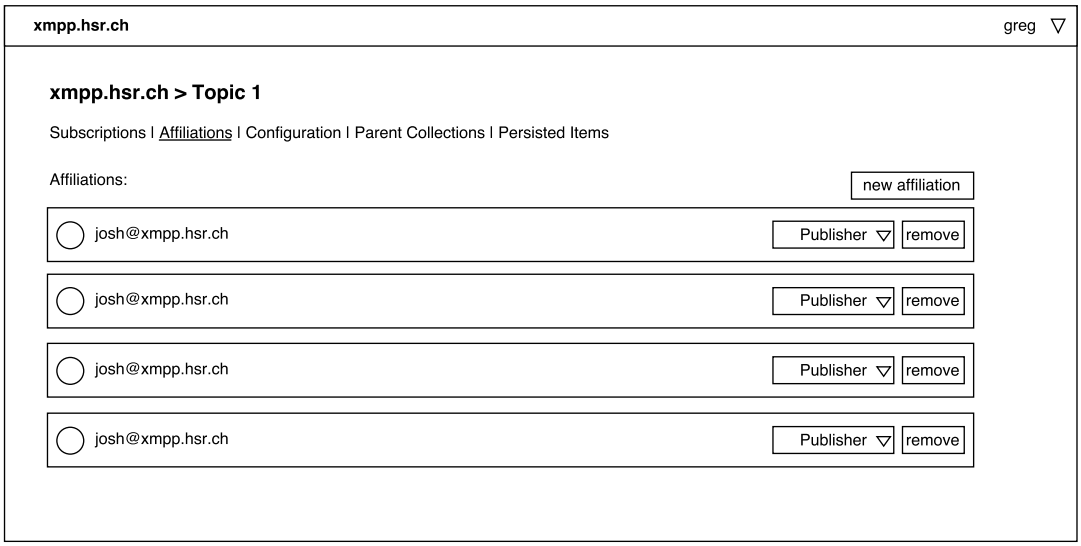


FIGURE 10: Topic/Collection Affiliations Wireframe

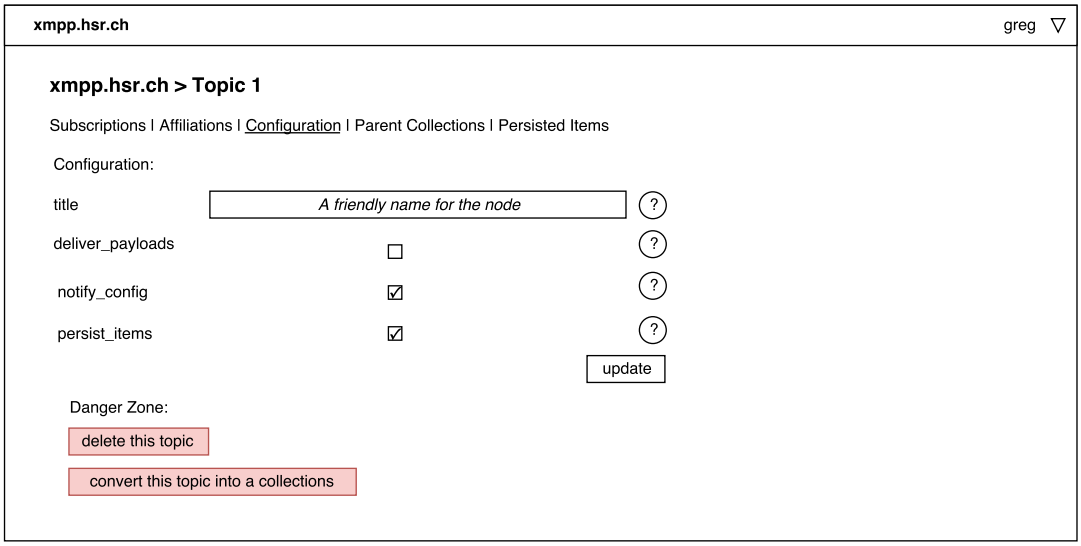


FIGURE 11: Topic/Collection Configuration Wireframe

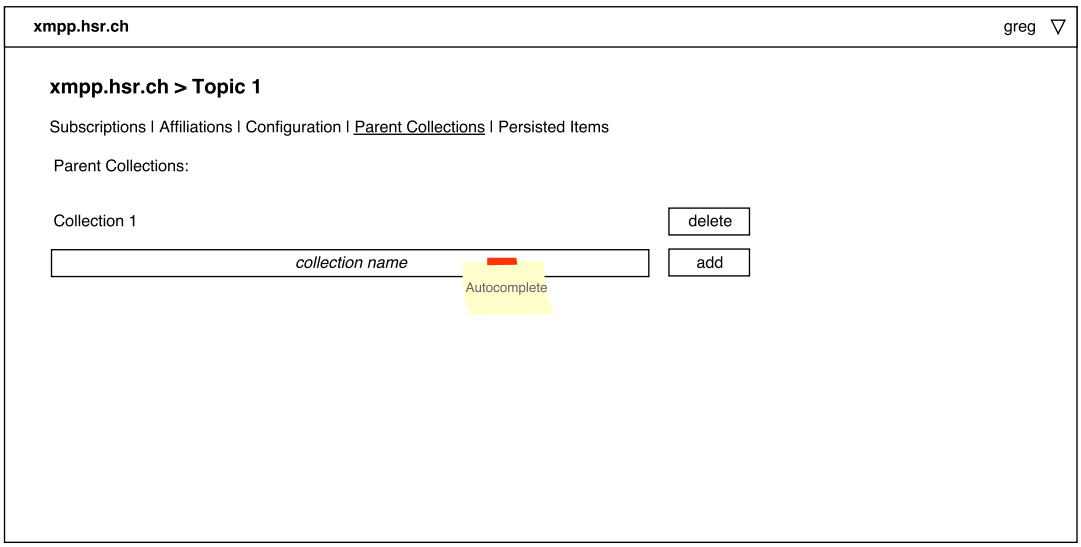


FIGURE 12: Topic Parent Collections Items Wireframe

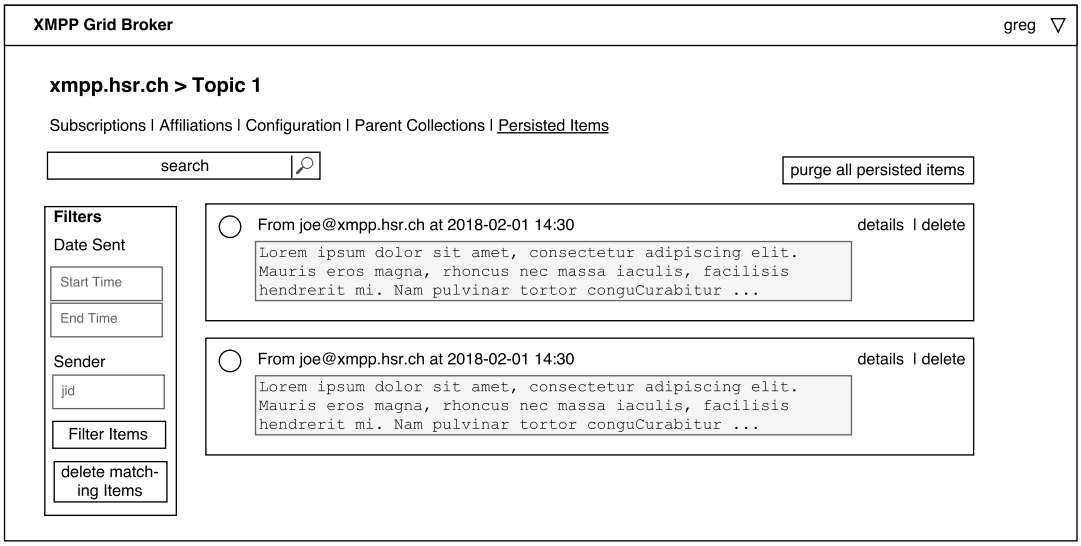


FIGURE 13: Persisted Items Wireframe

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 JAR[1]	
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/xeplist
[8] https://docs.ejabberd.im/developer/extending-ejabberd/modules/
[9] Server 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
[13] http://sleekxmpp.com/create_plugin.html
[14] Client-side only
[15] https://github.com/poezio/slixmpp/blob/master/docs/xeps.rst
[16] https://github.com/poezio/slixmpp/blob/master/docs/create_plugin.rst
[17] Client-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/
[26] https://github.com/legastero/stanza.io/blob/master/docs/Supported_XEPs.md
[27] https://github.com/legastero/stanza.io/blob/master/docs/Create_Plugin.md
[28] Not explicitly supported
[29] https://github.com/strophe/strophejs-plugins
[30] https://github.com/strophe/strophejs-plugins
[31] Not 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, April 8, 2018