CS 544: Computer Networks
Term Paper I – XMPP Protocol Analysis

Dustin Ingram

April 23, 2012

1 Background

The Extensible Messaging and Presence Protocol (XMPP) is a stateful application layer protocol primarily used for instant-messaging (IM). XMPP was initially conceived as the open-source Jabber messaging protocol by Jeremie Miller in 1998 [1], after which it was extensively developed the open-source developer community which surrounded it. In 2002, the Internet Engineering Task Force (IETF) approved the creation of the XMPP Working Group to focus on refining the protocol into an IETF standard.[2]

1.1 XMPP and related IETF RFCs

The IETF's XMPP Working Group and it's successor, the XMPP Standards Foundation, have produced a number of RFCs related to XMPP.[3]

1.1.1 RFC 2778 and RFC 2779

The informational RFCs *"A Model for Presence and Instant Messaging"* (RFC 2778) and *"Instant Messaging / Presence Protocol Requirements"* (RFC 2779) were published in 2000 by the IETF Instant Messaging and Presence Protocol (IMPP) Working Group. These were produced in parallel with the work being done by the Jabber community at the time, and pre-date the existence of the XMPP Working Group.

1.2 RFC 3920 and RFC 3921

These RFCs, *"XMPP: Core"* and *"XMPP: Instant Messaging and Presence"*, were the first RFCs produced by the XMPP Working Group which were accepted by the IETF in 2004 as conforming to the standards set by RFC 2778 and RFC 2779, and essentially defined XMPP v1.0.

1.3 RFC 6120 and RFC 6121

These RFCs obsolete RFC 3920 and RFC 3921, respectively, and are based on over six years of feedback between RFCs from the XMPP developer community, and the XMPP Standards Foundation (XSF). A number of important issues that existed in the previous iteration of these RFCs are addressed in the latest versions.

[1] `http://xmpp.org/about-xmpp/xsf/xsf-people/#bdfl`
[2] `http://xmpp.org/about-xmpp/history/`
[3] `http://xmpp.org/xmpp-protocols/rfcs/`

1.4 Other RFCs

- **RFC 3922** – Mapping the Extensible Messaging and Presence Protocol (XMPP) to Common Presence and Instant Messaging (CPIM)
- **RFC 3923** – End-to-End Signing and Object Encryption for the Extensible Messaging and Presence Protocol (XMPP)
- **RFC 4854** – A Uniform Resource Name (URN) Namespace for Extensions to the Extensible Messaging and Presence Protocol (XMPP)
- **RFC 4979** – IANA Registration for Enumservice 'XMPP'
- **RFC 5122** – Internationalized Resource Identifiers (IRIs) and Uniform Resource Identifiers (URIs) for the Extensible Messaging and Presence Protocol (XMPP)
- **RFC 6122** – Extensible Messaging and Presence Protocol (XMPP): Address Format

1.5 Scope of this Analysis

Since the XMPP protocol consists of a number of related RFCs which provide different areas of functionality, this paper will focus solely on the core of the protocol, RFC 6120, *"XMPP: Core"*. Furthermore, since RFC 6120 provides information for Client-to-Server as well as Server-to-Server implementations of the XMPP protocol, the focus of this analysis will additionally restrict itself to only the Client-to-Server portion of the protocol, as it is arguably more widely used.

2 Services Provided by the XMPP Protocol

The core of the XMPP Protocol seeks to provide asynchronous application-layer instant-messaging (IM) and information exchange. This mainly involves the transfer of transfer of small, text-only (non-binary) messages, although extensions exist for file transfers, amongst other things. The typical implementation and use of the XMPP protocol is in a Client-to-Server scenario, however, RFC 6120 also provides a reference for Server-to-Server communication, in the case of server federation and inter-communication. The combination of these two typical scenarios produces a "distributed client-server architecture", where multiple clients can interoperate through a network of multiple servers.

3 Overview of XMPP Communication Architecture

3.1 Messaging Architecture

In a general sense, XMPP uses a structured message format similar to XML, which the protocol calls "XML stanzas" or just "stanzas", for all information exchange. The main difference between a "stanza" and an XML file is that stanzas may not (and often are not) complete XML documents in the typical sense, as XMPP uses the notion of these individual chunks of XML-esque information to "stream" information, starting connections with an opening tag and ending them with a closing tag, and over the course of one connection and information exchange, building a complete document.

The XMPP protocol uses three types of XMPP stanzas, essentially XML element tags, to denote different types of messaging. They include:

- "Messages", using the `<message>` tag
- "Presence Messages", using the `<presence>` tag
- "IQ Messages", using the `<iq>` tag

Each of these message types are discussed at length in subsequent sections.

3.1.1 Issues with the Messaging Architecture

The XMPP stanza structure can present problems when it comes to implementing clients or servers, as most standard libraries for XML parsing require a complete document, otherwise they are unable to parse. Since XMPP stanzas are, by definition, incomplete fragments of an XML document, this often requires the use of unique, underused or custom XML parsers to use the raw transmitted information in a meaningful way.

Furthermore, XMPP's reliance on XML-based message structure is a hallmark and indicator of it's age. While XML is useful as a human-readable markup language, that feature is not necessarily a requirement within the XMPP protocol, where messages are abstracted and hidden by client and server implementations.

As a result, XML is generally considered to be a unnecessarily verbose language format. In relation to XMPP, this may be undesirable in instances where bandwidth is constrained or the network is congested.

3.2 Addressing Scheme

Addressing is inherent to the XMPP protocol – so much so, in fact, that there is an entire published RFC specifically for the XMPP address format. However, the addressing scheme necessary to understand the XMPP Core Protocol is simple enough to be described succinctly.

XMPP addresses, also known as "Jabber IDs" or "JIDs", have the following general structure:

$$\underbrace{\texttt{client}}_{\text{local part}}\,@\,\underbrace{\texttt{chat.example.com}}_{\text{domain part}}\,/\,\underbrace{\texttt{nickname}}_{\text{resource part}}$$

The XMPP protocol is designed to use these addresses to route messages to any globally accessible server, as the "domain part" will represent a globally unique address based on the DNS standard. The "local part" represents an individual user's account at any given domain – which may or may not represent a single server, as domains may be spread between multiple servers. The "resource part" simply identifies a "nickname" or "alias" for the user in instances where one might be necessary, such as multi-user chat.

3.2.1 Issues with the Addressing Scheme

This addressing scheme works well on the Internet, where domains are regulated and unique, but such a reliance on DNS can pose issues on a network without a need for domains or the DNS protocol. Often, in a situation where the network is isolated from the Internet, this would require a custom DNS solution or manual hostname organization.

Furthermore, dependence on DNS for the resolution of domain names simply means that the XMPP protocol depends directly on the DNS protocol, and therefore inherits and possesses all the issues and hardships that come with it.

4 Overview of XMPP Communication Primitives

As mentioned in the previous section, the XMPP protocol defines the basic communication primitive of the protocol to be the XMPP stanzas. There are three individual first-level elements which are considered proper XMPP stanzas.

4.1 Messaging

The "Message" primitive provides a simple 'push' mechanism, whereby a <message> stanza is sent with a payload between the start and end tags of the stanza. Here, the payload can be nearly anything, as specified by the various possible extensions to the protocol, but is most often a plain-text message, or more recently common, an HTML message.

4.2 Network Availability ('Presence')

The "Presence" primitive provides a Broadcast or Publish/Subscribe service for a XMPP client to advertise it's "network availability". This is identical to the notion of online/offline status many IM networks employ, however XMPP Presence is particularly extendable as it can describe virtually any type of status or presence message by design.

The XMPP protocol further provides a specification to give servers the ability to support presence subscriptions, whereby one client can 'subscribe' to the presence of another client. This is further defined in RFC 6121.

4.3 Request-Response Interactions ('IQ')

The "IQ" or Info/Query communication primitive provides a simple request & response mechanism. The RFC accurately relates this to the Hypertext Transfer Protocol (HTTP) as it has similar query 'types'; the XMPP protocol uses `GET`, `SET`, `RESULT`, and `ERROR` as it's IQ ID types.

4.3.1 Alternatives to XMPP IQ for Info/Query

The RFC portrays XMPP's IQ primitive as a similar, yet distinctly different protocol compared to HTTP. However, this RFC was written at a time when HTTP was not being used nearly as much as a stateful protocol as it is today. With the advent of RESTful API's and REST styled HTTP architectures, it may be possible to replace the IQ stanza entirely with a more adaptive and descriptive primitive.

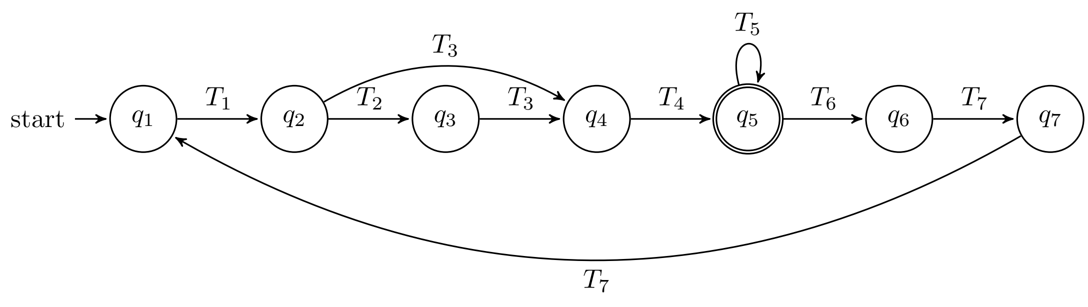
4.4 Other First-Level Elements

There are a number of first-level elements which may occur in an XMPP stream which are not considered XMPP stanzas. These may include self-closing stanza elements, elements without a qualified Jabber namespace, or feature negotiation elements.

5 States of the Protocol

A simple state diagram, showing basic connection and initialization of the XMPP protocol. Here, $q5$ is the only state in which the protocol accepts and transmits messages. However, this is most likely the state the protocol spends the most time in, and this this state alone contains the bulk of the additional portions of the protocol.

Producing an error in any state always results in a transition to the disconnected state, $q7$, so these transitions are not shown.



- start – Open a TCP connection
- T_1 – Open an XML Stream over TCP

- T_2 – Negotiate TLS for channel encryption (optional)
- T_3 – Authenticate using a SASL mechanism
- T_4 – Bind a resource to a stream
- T_5 – Exchange an unbounded amount of XML stanzas
- T_6 – Close the XML Stream (with a `</stanza>`)
- T_7 – Close the TCP connection
- T_8 – Open a new TCP connection

5.1 Connection Initialization

The XMPP protocol uses a pair of persistent TCP connections for each Client-to-Server or Server-to-Server to provide what the RFC describes as an "always-on" stream which allows any entity to immediately push data to any other connected entity.

5.1.1 Reconnection and Reliability

The XMPP protocol provides an interesting feature to avoid massive synchronized reconnection. Essentially, in the case of a server disconnection (thus severing the TCP connection), to avoid what may be a large number of clients from immediately trying to re-connect to the server at once, the protocol specifies that clients should wait to reconnect for an "unpredictable number between 0 and 60" seconds, and then "back off increasingly between subsequent reconnection attempts".

This essentially manages congestion of the server by reducing the load at any given second to one sixtieth of the load it would have been previously handling, and is a simple and elegant solution to the problem.

The RFC addresses reliability of "long-lived TCP connections in XMPP" as being inherently unreliable, as they "might not discover a connectivity disruption in a timely manner". The reasons for this are beyond the scope of this analysis, but the protocol attempts to overcome this by introducing an extension outside the core protocol.

5.1.2 Issues with TCP as the UTM

While using TCP as the underlying transport mechanism is clearly necessary to enable immediate routing and provide truly *instantaneous* messaging, there are a few known issues that might manifest themselves in certain use cases.

As previously mentioned with the issues with XML, TCP is also a verbose protocol, and may be non-ideal or even unacceptable for constrained networks. Also as previously mentioned, long-lived TCP connections lend themselves to being unreliable, a condition which is not immediately repairable by either protocol.

Furthermore, in certain situations, the XMPP protocol may be using TCP too heavily in cases where other protocols may be optimal. For example, when a number of clients are communicating in a multi-user chat (MUC) room, each individual client maintains a TCP connection to the server, and vice versa. The server, then, takes on the responsibility of routing and distributing messages through each TCP connection to the intended client. In most cases, though, all clients in the MUC are the intended clients, and the extra bandwidth (sending the same TCP message over a different connection for every client) can be avoided.

6 Authentication

The XMPP protocol uses the Simple Authentication and Security Layer (SASL) exclusively to provide "a reliable mechanism for peer entity authentication". Therefore, every client and server implementation *must* implement SASL. SASL is a protocol within it's own right, and likely doesn't need further description within the context of the XMPP protocol, as XMPP core uses it in a relatively standard way.

7 Security (Channel Encryption)

The XMPP protocol uses a specific extension of the Transport Layer Security (TLS) protocol and certification to encrypt and secure the stream and to establish trust by verifying trusted entities. Similar to SASL, the protocol requires that all client and server implementations support TLS – however, actual use of TLS is left to the user to decide, and thus is not mandatory.

8 XMPP Extension Protocols

XMPP is inherently extendable – after all, it's in the name. Within the XMPP protocol lies a number of XMPP Extension Protocols, otherwise known as XEPs, which provide additional functionality across a wide range of applications on top of the core protocol. For example, XEP-0045 defines an extension for multi-user chat, which builds upon this RFC in the same way that this RFC builds upon other standards.

9 Conclusion

To conclude, I find that XMPP is a robust and highly extendable protocol. It is specifically designed to be adaptable and have a multitude of swappable sub-protocols to make it applicable for a variety of scenarios, through the existence of the XEPs to the XMPP Standards Foundation itself.

The protocol has few weaknesses, if any. Specifically, the protocol is designed to operate on a high-bandwidth enterprise network, and likely will not perform well on a mobile, high-latency, low-bandwith network without significant modification.

Furthermore, certain components, such as the IQ stanzas, may be better served by relatively young technologies emerging from the evolution of the Internet since the protocols first inception.