CS 544: Computer Networks
Multicast Multi-User Chat Protocol

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Abstract

Multicast Multi-User Chat is a distributed, non-reliable application-layer protocol that uses UDP at the transport layer and provides multi-user chat room creation, discovery, and the exchange of user presence information and messaging without a central server.

1 Introduction

Multicast Multi-User Chat is a distributed, non-reliable application-layer protocol that uses UDP at the transport layer and provides multi-user chat room creation, discovery, and the exchange of user presence information and messaging without a central server.

A client can join a chat room by name, which is hashed to a specific multicast channel within a given range of channels, excluding those already in use. The client then sends messages intended for that multi-user chat on the channel produced by the hashing algorithm.

The protocol is distributed and decentralized by using a classical flooding algorithm to forward non-duplicate messages.

1.1 Terminology

- **Control Channel**: a fixed port for the sending of messages, such as room creation and detection, that must reach all clients on the network
- **MUC Channel**: a dynamic port that is actively being used for chat by one or more clients, and which all clients are aware they must forward traffic for
- **MUC**: a Multi-User Chat, a shared "chat room" between multiple clients.
- **MUC Message**: a message from one client to all clients in the MUC
- **Direct Message**: a message from one client that is forwarded to all clients in the MUC but that is directed to one client in particular - MUC

software implementations may choose to not display messages not directed at the active user

2 Message Types

Protocol messages are JSON (JavaScript Object Notation) collections of name/value pairs. JSON was chosen because it is easy for both machines and humans to read and parse.

The primitive data types used in the protocol are ⟨integer⟩, a 32-bit signed two's complement integer, ⟨long-integer⟩, a 64-bit signed two's complement integer, and ⟨string⟩, a sequence of characters in the UTF-16 format.

The following compound types are also provided:

$$\begin{aligned} \langle \textit{integer-list} \rangle &\rightarrow \langle \textit{integer} \rangle | \langle \textit{integer} \rangle, \langle \textit{integer-list} \rangle \\ \langle certificate \rangle &\rightarrow \{\text{`certificate'} : \langle string \rangle, \text{`format'} : \langle string \rangle\} \\ \langle \textit{certificate-list} \rangle &\rightarrow \langle certificate \rangle | \langle certificate \rangle, \langle \textit{certificate-list} \rangle \end{aligned}$$

All messages are of the format

$$\{\text{`uid'} : \langle uid \rangle, \text{`action'} : \langle action \rangle\}$$

where an action may be:

$$\begin{aligned} \langle action \rangle \rightarrow & \langle \textit{list-rooms} \rangle | \langle \textit{use-rooms} \rangle | \langle message \rangle | \\ & \langle presence \rangle | \langle timeout \rangle | \langle preserve \rangle \end{aligned}$$

and 'uid' is an unique identifier for each message sent by a client and

$$\langle uid \rangle \rightarrow \langle \textit{long-integer} \rangle$$

'certificate' is a public key certificate, and 'format' specifies the certificate format, such as PGP or X.509. This allows the clients to use both self-signed and certificate-authority (CA) issued certificates.

2.1 Unique IDs (UIDs)

For the multicast flooding algorithm, each node must have a way of tracking of each message it has forwarded, to avoid forwarding them again. Simply requiring the clients to keep the last n messages is insufficient, as there is no method to distinguish between duplicates and messages that are new but the same as old messages (such as when a room gets re-created or a message with the same body/from fields). Thus the protocol will require unique message ID numbers; each client can generate a unique ID for each message it creates, and every other client can use this ID to determine if the message is a duplicate or not. This must be an attribute of every message and each client would have a history of message IDs seen. Clients must also store an MD5 hash of the message with the ID, so that IDs may eventually be reused. So the client receives

$$\{\text{`uid'} : \text{`}X\text{'}, \langle Y \rangle\}$$

where $\langle Y \rangle$ is a collection of key/value pairs, and only forwards it once, but would forward

$$\{\text{`uid'} : \text{'}X\text{'}, \langle Z \rangle\}$$

if Y has a different hash than Z, and so on.

From a security perspective, one can't rely on any particular behavior (globally unique ids) from a client. For a sequence of packets sent by a given client, the UIDs need to be unpredictable, or a malicious client can stop another client's packets from being forwarded. We have to assume the only uniqueness comes from the client's ability to generate a random sequence of numbers. We do not specify the ID generation algorithm for clients.

2.2 Control Messages

The *list-rooms* action is used by clients to update channel use information. If the optional collection of rooms is not included, this signals that the client wants to know about all channels in use. If a collection of rooms is provided, the client wishes to know the status of just those channels. list-rooms takes the form:

$$\langle \textit{list-rooms} \rangle \rightarrow \text{`list-rooms'}, [\text{`rooms'} : [\langle \textit{integer-list} \rangle]]$$

The *use-rooms* action is used to reply to a *list-rooms* action. Clients will either reply with a collection of all channels they know are in use or the subset of channels in use that were asked about in the original *list-rooms* action. In addition, *use-rooms* is also used to create a new room. The syntax of *use-rooms* is:

$$\langle \textit{use-rooms} \rangle \rightarrow \text{`use-rooms'}, \text{`rooms'} : [\langle \textit{integer-list} \rangle]$$

The timeout action is used by clients to find channels clients are no longer actively using to chat, and thus whose allocated resources can be freed. The timeout is used to ask the other clients which of the provided rooms they are using:

$$\langle \textit{timeout} \rangle \rightarrow \text{`timeout'}, \text{`rooms'} : [\langle \textit{integer-list} \rangle]$$

The preserve action is used to reply to a timeout action, indicating that clients should continue to forward traffic for the included rooms:

$$\langle \textit{preserve} \rangle \rightarrow \text{`preserve'}, \text{`rooms'} : [\langle \textit{integer-list} \rangle]$$

2.3 Presence Messages

$$
\begin{aligned}
\langle \textit{poll-presence} \rangle &\rightarrow \text{`poll-presence'} \\
\langle \textit{presence} \rangle &\rightarrow \text{`presence'}, \text{`from'} : \langle \textit{string} \rangle, \text{`status'} : \langle \textit{status} \rangle \\
&\quad [, \text{`keys'} : [\langle \textit{certificate-list} \rangle]] \\
\langle \textit{status} \rangle &\rightarrow \text{`online'} | \text{`offline'}
\end{aligned}
$$

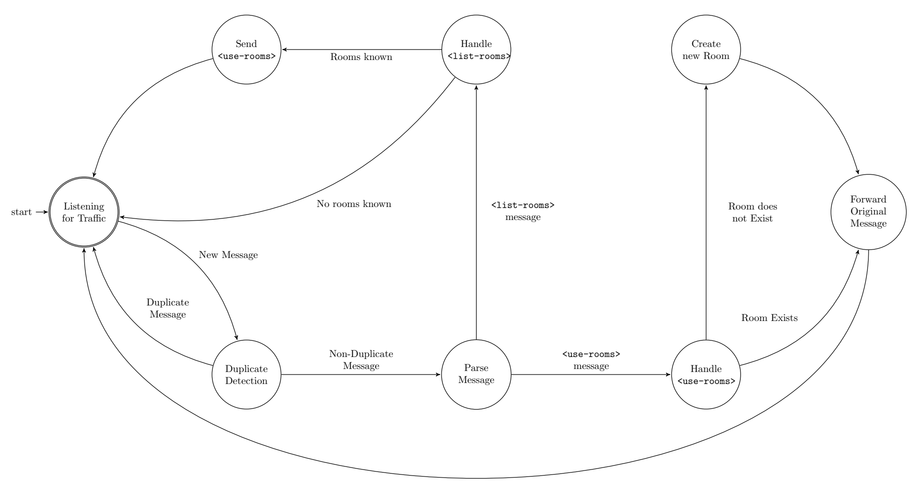
2.4 Chat Messages

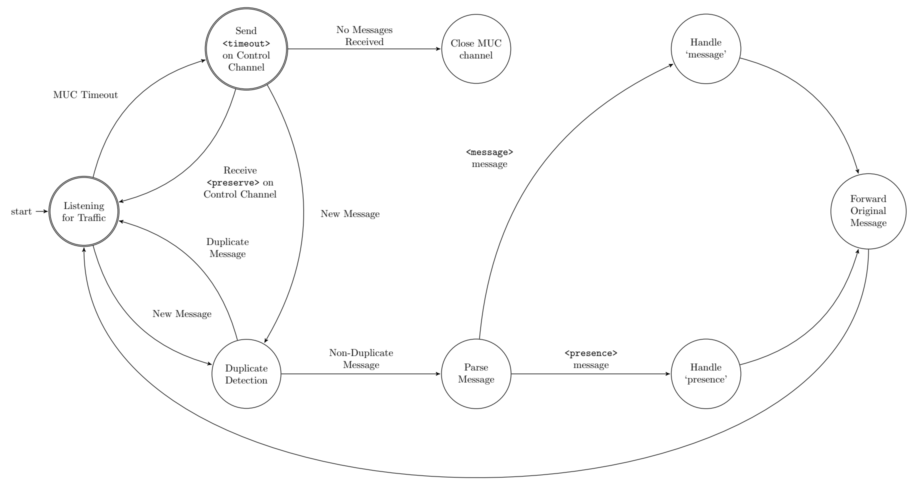
A chat room message action must carry a ‘from’ field, which is a nickname that identifies the sender, and a ‘body’ field that carries the user’s input. Messages can also optionally contain a ‘to’ value, for which clients can choose to hide from the user messages not meant for them. Messages can also be optionally encrypted with the public key certificate specified by ‘key’. Using ‘to’ and ‘key’ together allows clients to avoid checking the ‘key’ against their own keystore, as they will know the messages was not directed at them. The formal specification for message is:

$$
\begin{aligned}
\langle \textit{message} \rangle &\rightarrow \text{`message'}, \text{`from'} : \langle \textit{string} \rangle, \text{`body'} : \langle \textit{string} \rangle \\
&\quad [, \text{`to'} : \langle \textit{string} \rangle][, \text{`key'} : \langle \textit{certificate} \rangle]
\end{aligned}
$$

3 States of a Node

See included diagrams for full-size DFAs of a control channel and a MUC channel.





4 Joining a Network

4.1 Discovering Peers

A control channel on a fixed port (31941) is used to announce the creation of each new room, by specifying a new channel that clients should listen on and forward traffic. When a new client connects to the network, they send a message on the control channel announcing their existence, and its neighbors inform the client of the channels they know about. Version Negotiation

Due to the nature of Multicast IP, the protocol will indiscriminately send it's multicast messages to all clients on a LAN. Since any version of the protocol will use the same port for the control channel, and could feasibly use the same ports as MUC channels, performing actual version negotiation would not reduce or eliminate the possible receipt of messages using different versions. Therefore, it shall be the responsibility of all implementations to ignore any message which is not properly formatted or of a type described in the version it is using. Similarly, it shall be the responsibility of all future versions to offer full backwards compatibility, or fully ignore messages from incompatible versions.

5 Joining a MUC

5.1 Channel Hash Algorithm

The protocol uses a double hashing algorithm: it uses one hash value as a starting point and repeatedly steps forward an interval determined by second hash function until an unused port is found. A good hash function will map inputs evenly over the output range, as the computational cost of hashing increases with the number of collisions. Double hashing minimizes collisions more effectively than linear or quadratic probing strategies. The i-th position of given value x, in a range of size n is then

$$F(x, i) = G(x) + i * H(x) \mod n$$

Here, G and H should each produce a 32-bit signed two's complement integer (twice the range of dynamic ports) using the concatenated first four bytes of the MD5 cryptographic hash for G and SHA-1 for H.

Limiting a channel to one chat room helps scale the protocol as high amount of UDP traffic on a single port can quickly experience data loss and congestion. It does limit the number of possible rooms, but each channel will have better performance because there is less contention for bandwidth. We see this as a minor drawback, as the number of dynamic ports is large on a modern OS (16,384 in the IANA range, used by Windows, and 28,233 on some Linux kernels). Channel Announcement

To announce the creation of a new MUC room (and thus, a new MUC channel) to all peer nodes, a client should send an announcement message on the control channel Sending a MUC Message

5.2 Addressing

Addressing in this protocol is not addressing in the typical sense. Because MUC messages are delivered to all clients in the MUC, and MUC channels are restricted to their individual ports, there is no need to specifically address a message to a client or MUC. Instead, clients must specify a "from" attribute, to add organization to chat messages and support for presence messages.

Alternatively, the protocol can support direct messaging by specifying a "to" attribute. However, there is no acknowledgement for any messages, including direct messages, and mis-addressed messages will simply be ignored by all clients.

5.3 Address Collisions

Address collisions are allowed by the protocol. Although this may present an issue with presence information if two distinctly different clients attempt to use the the same address Message Text Encoding

All messages are encoded in UTF-16, a character encoding for Unicode that uses one or two 16-bit codes per character. Hard Message Size Limit

A UDP datagram has a 16-bit length field and a 8 byte header, which allows for a theoretical data length of $65,535-8 = 65,527$ bytes. However, the practical limit for the message length is imposed by the underlying IPv4 protocol, which has a 20 byte header, and is thus $65,527 - 20 = 65,507$ bytes. $65,507$ bytes can represent between $2,047$ to $4,095$ UTF-16 characters, which is considerably longer than the typical messages expected to be sent in practice, and thus the protocol will not perform fragmentation and reassembly.

5.4 Peer-to-peer Message Delivery

The flooding algorithm is simple, forwarding all non-duplicate messages to all single-hop neighbors.

5.5 MUC Maintenance

5.5.1 Timeout/Shutdown

Each client sets random timer for between 5-10 minutes after receiving a message on port N. When a client doesn't see any further traffic on port N before the timer expires, and it isn't in the room for Port N itself, it sends out a 'timeout' action on the control channel. Any client that see the 'timeout' action stops its own timer. If any client responds to the 'timeout' poll before a timeout period of 60 seconds, all clients keep port N open and reset their timers. If no clients respond, all clients shut down on port N.

6 Reliability Considerations

Since the protocol uses UDP, which makes no promise of reliability, the reliability of the protocol is a function of the number of peers. Clients forward messages even for rooms they're not in and thus adding or removing peers from the network can alter the reliability of any given chat room.

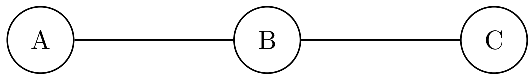
7 Security Considerations

Messages sent over MUC will not be secure by default. This creates the risk that a man-in-the-middle attack could read message intended for someone else. We will allow clients to send their certificate if they have one, allowing for others to send messages encrypted with the public key they get from the certificate. The certificates could be authorized by Certificate Authorities or they could be issued by one of the web of trust organizations (e.g. PGP, GnuPG, OpenPGP, etc.). Certificates can also be used to authenticate messages coming from the owner of the public key are actually being sent by the owner of the certificate, which could be useful in the context of MUC. (We considered using the symmetric key encryption and encrypting the entire channel, but this seems to be too complicated to implement for this project.)

Another security vulnerability is the possibility that a client could try opening a large number of rooms or sending a large number of messages, with the aim of using up connected clients' resources, or the MUC network's bandwidth. This could be prevented by limiting each client to creating no more than x number of rooms in a 24-hour period, and preventing the client from sending out y number of messages in a 60-second period. This could add a lot of complexity because it would require adding timers to the client for both actions (creating rooms and sending messages) and it wouldn't prevent someone who had figured out the MUC message protocol from sending their own messages without these limitations.

8 Detailed Examples

Sample network configuration for these examples is as follows:



8.1 Control Messages

8.1.1 Room Discovery

In this example, Client A knows about no rooms, and Client B responds with the rooms it knows about:

Client A :{ 'action' : 'list-rooms' }
Client B :{ 'action' : 'use-rooms', 'rooms' : [51200, 45235, 656] }

or, in this example, Client A knows about two rooms. Client B is using these two rooms, plus a third that Client A did not know about:

Client A :{ 'uid' : 'X', 'action' : 'list-rooms', 'rooms' : [51200, 45235] }
Client B :{ 'uid' : 'Y', 'action' : 'use-rooms', 'rooms' : [51200, 45235, 60056] }

8.1.2 MUC Room Creation

In this example, Client A creates a room. The 'use-rooms' message then propagates through the network as it is repeated by clients B and C:

Client A : { 'uid' : 'X', 'action' : 'use-rooms', 'rooms' : [51200] }
Client B : { 'uid' : 'X', 'action' : 'use-rooms', 'rooms' : [51200] }
Client C : { 'uid' : 'X', 'action' : 'use-rooms', 'rooms' : [51200] }

8.1.3 Room Cleanup

In this example, Client A's timeout period has expired for three rooms. Client B responds with a room that it is using, and forwards the timeout message to

Client C, which also responds with a room that it is using.

Client A :{ ‘uid’ : ‘W’, ‘action’ : ‘timeout’, ‘rooms’ : [51200, 45235, 60056] }
Client B :{ ‘uid’ : ‘X’, ‘action’ : ‘preserve’, ‘rooms’ : [51200] }
Client C :{ ‘uid’ : ‘X’, ‘action’ : ‘preserve’, ‘rooms’ : [51200] }
Client A :{ ‘uid’ : ‘X’, ‘action’ : ‘preserve’, ‘rooms’ : [51200] }
Client B :{ ‘uid’ : ‘Y’, ‘action’ : ‘timeout’, ‘rooms’ : [45235, 60056] }
Client C :{ ‘uid’ : ‘Z’, ‘action’ : ‘preserve’, ‘rooms’ : [45235] }
Client B :{ ‘uid’ : ‘Z’, ‘action’ : ‘preserve’, ‘rooms’ : [45235] }
Client A :{ ‘uid’ : ‘Z’, ‘action’ : ‘preserve’, ‘rooms’ : [45235] }

8.2 MUC Messages

8.2.1 Presence

In this example Client A checks to see who else is online, Client B and C respond that they are both online.

Client A :{ ‘uid’ : ‘X’, ‘action’ : ‘poll-presence’, ‘from’ : ‘dsi23’ , ‘status’ : ‘online’ }
Client B :{ ‘uid’ : ‘Y’, ‘action’ : ‘presence’ , ‘from’ : ‘bjs83’ , ‘status’ : ‘online’ }
Client C :{ ‘uid’ : ‘Z’, ‘action’ : ‘presence’ , ‘from’ : ‘bb482’ , ‘status’ : ‘online’ }

8.2.2 MUC Messaging

The first two messages are sent to the room, the second two are private messages, the second of which is encrypted.

Client A :{ ‘uid’ : ‘W’, ‘action’ : ‘message’, ‘from’ : ‘bjs83’,
‘body’ : ’First message sent to the room’ }
Client A :{ ‘uid’ : ‘X’, ‘action’ : ‘message’, ‘from’ : ‘bjs83’,
‘body’ : ’Second message sent to the room.’ }
Client A :{ ‘uid’ : ‘Y’, ‘action’ : ‘message’, ‘from’ : ‘bb482’, ‘to’ : ‘bb482’,
‘body’ : ’First direct message sent.’ }
Client A :{ ‘uid’ : ‘Z’, ‘action’ : ‘message’, ‘from’ : ‘bb482’, ‘to’ : ‘bb482’,
‘body’ : ⟨ encrypted: First encrypted direct message sent⟩ ,
‘key’ : ⟨ certificate⟩ }

9 Technology Reuse

9.1 IP Multicast

IP Multicast is a way to send a message from one client to many other clients on the network, without requiring knowledge of the identities or number of receivers, and only requiring the source to send a single message. Multicast is built into the infrastructure of IP and is efficient in that the network entities forward the datagrams in such a way that each datagram is sent over each link once. Multicast messages are coordinated through the use of groups, where the message originator uses the group address as the IP destination address in their datagram and each receiver uses the group address to register their interest in receiving packets sent to that group. As receivers join a group, a distribution tree is built up using a protocol such as Protocol Independent Multicast (PIM). The Internet Group Management Protocol (IGMP) is used to register to a group. In IPv4, addresses 224.0.0.0 through 239.255.255.255 are reserved for multicast.

9.2 UDP

User Datagram Protocol or UDP is a transport layer service that will carry the messages of the application protocol. UDP was chosen because it is a lightweight and connectionless protocol, providing only checksumming of the data, port numbers for distinguishing different user requests and multiplexing, minimizing total network traffic. The MUC protocol will take advantage of the port numbers for establishing individual chat rooms. All the other necessary services, such as encryption, will be handled by the application level protocol. The MUC protocol will use a classical flooding algorithm to distribute messages to all clients on the network. Thus the non-reliability of UDP can be countered by a network topology that results in a client receiving a message from multiple neighbors. The more inter-connected the clients are, the less likely that a given message will be lost (e.g., transmitted across a single link but delivered unsuccessfully).

9.3 JSON

JavaScript Object Notation or JSON is a lightweight, and convenient standard for data exchange through the passing of objects that are simple data structures (treated as name value pairs) or associative arrays (a comma separated list of values). JSON objects are unordered collections of name value pairs. The objects start and end with curly braces and the name value pairs are separated by a colon. The basic data types within a JSON object are: Number, String, Boolean, Array, Object and Null. JSON is easily machine and human readable and there are existing parsers for many programming languages. XML was also considered as the message container for the protocol but since JSON messages tend to be much simpler and smaller than XML, bandwidth and storage are conserved and there is less processing overhead. The fact that it uses less bandwidth is particularly important with this type of protocol where network traffic could get quite large. It is also important to note that since the message sizes are smaller there will be an increase in performance during parsing, therefore not bogging down the client if it was to receive many chat messages simultaneously.

9.4 Encryption

The protocol allows users to optionally include their public key(s) and associated encryption scheme with their presence information. This allows the clients to support private messages between users, which sent by broadcast flooding but unreadable for anyone but the intended recipient. One well-known and outstanding problem with public keys is verifying that a public key truly belongs to the person you think it does. The initial version of the protocol does not attempt to solve this, but future versions and extensions could, through either certificate authorities or web of trust (a la PGP), while remaining backwards compatible.