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VCON for MIMI Messages  
draft-mahy-vcon-mimi-messages-02

## Abstract

This document describes extensions to the Virtualized Conversation (VCON) syntax for instant messaging systems using the More Instant Messaging Interoperability (MIMI) content format.

## About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at <https://rohanmahy.github.io/vcon-mimi-messages/draft-mahy-vcon-mimi-messages.html>. Status information for this document may be found at <https://datatracker.ietf.org/doc/draft-mahy-vcon-mimi-messages/>.

Discussion of this document takes place on the Virtualized Conversations Working Group mailing list (<mailto:vcon@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/vcon/>. Subscribe at <https://www.ietf.org/mailman/listinfo/vcon/>.

Source for this draft and an issue tracker can be found at <https://github.com/rohanmahy/vcon-mimi-messages>.

## Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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## 1. Introduction

VCON [I-D.ietf-vcon-vcon-container] is a format for recording and transmitting conversations. MIMI content [I-D.ietf-mimi-content] is a format for conveying Instant Messages in an interoperable way when end-to-end encrypted. This document describes a way to translate a set of MIMI messages in a conversation or part of a conversation into a VCON.

## 2. Conventions and Definitions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The examples in this document may contain base64url encoded values that have extra whitespace added for readability, and to conform with Internet-Draft formatting conventions. That whitespace should be ignored.

Some metadata about a MIMI content message is conveyed in the encryption protocol Messaging Layer Security (MLS) [RFC9420] or in the MIMI protocol [I-D.ietf-mimi-protocol].

For example, the sender, recipient, date, and message ID are not mandatory fields in a MIMI content message. The recipient is the MIMI room ID associated with the corresponding MLS group. The participants in the group are calculated from the MLS group state and MIMI participant list during the MLS "epoch" in which the message was sent. The sender is conveyed in MLS. The MIMI "Hub" received timestamp is conveyed in the MIMI protocol. The MIMI content message ID is constructed by hashing fields from the MIMI content, and the sender and room URIs (see Section 3.3 of [I-D.ietf-mimi-content]).

When message franking is enabled, as defined in Section 5.4.1 of [I-D.ietf-mimi-protocol], the franking\_tag is conveyed in the MLS message's Additional Authenticated Data (AAD) field, while the MIMI protocol conveys the Frank structure generated by the MIMI Hub.

The room metadata described in this document comes from Section 3 of [I-D.mahy-mimi-app-components], while the names of the parties comes from the participant list defined in Section 4 of the same document.

### 3. Syntax

A MIMI conversation (or portion thereof) is represented in VCON with a mandatory list of parties and dialogs, a new top-level room object, and optionally attachment objects.

#### 3.1. Room information

This document adds a mandatory, top-level room object. It contains metadata known about the room at the start of the VCON period.

- \* `id` is the MIMI room ID URL. It is mandatory.
- \* `name` is the textual name of the room. It is optional.
- \* `avatar` is a URL referencing the room image. It is optional.
- \* `subject` is the room subject. It is optional.
- \* `mood` is the room mood. It is optional.
- \* `description` is an array of `room_description` objects. It is optional. Each object can contain:
  - a `type` - a media type or an empty string. It is optional. It's default value is `text/plain; charset=UTF-8`.
  - a `lang` - a Language-tag as defined by [RFC5646]. It is optional.
  - a `content` - if the type begins with "text" or is empty, the content is the UTF-8 text description of the room. Otherwise it is the base64url encoding of whatever type is described. The content field is mandatory in a `room_description` object.

#### 3.2. Parties

The parties array MUST contain all the participants who were in the conversation at any point in time during the period represented by the VCON. The first party in the array is the MIMI room URI.

This document adds a new `party_object_type`: `im_uri`. It is mandatory. The `name` field is optional. The `role` indicates the MIMI role and is optional. The document also adds a `thumbprint` `party_object_type`, which is the JWK thumbprint of the public key of the party. If there are multiple parties (clients) with the same `im_uri` then the `thumbprint` is required, otherwise it is optional.

### 3.3. The dialog object (text type)

The following section refers to changes and additions to the dialog object when the type field is "text".

#### 3.3.1. Semantics of the existing fields for text

The dialog object consists of an array of instant messages of type "text". The start time is set to the hub received timestamp when available. The duration is zero. The originator is set to the parties index of the sender of the message.

The first MIMI message represented in a MIMI VCON should contain the complete list of parties who were participants in the room at that time. For subsequent messages, a parties array consisting of index zero, indicates the recipients of the message are the active participants of the room. Changes to the roster can be tracked if party\_history is present for those changes (see Section 3.4).

#### 3.3.2. Extensions to the dialog object for text

The parties array consist of the party indexes of those who were active participants when the message was sent.

- \* message\_id is the base64url encoding of the MIMI content message ID. It is mandatory.
- \* salt is the base64url encoding of the MIMI content salt. It is mandatory.
- \* replaces is the base64url encoding of the MIMI content message\_id of the message this message replaces. It is optional if empty.
- \* topic\_id is the base64url encoding of the MIMI topic\_id. It is optional if empty.
- \* expires is optional if empty in MIMI. It contains null or a map with the following items:
  - relative is a boolean that is true if the time is expressed relative to the recipient read time, and false if it is expressed as an absolute date/time. It is mandatory when expires is present.
  - relative\_time is an integer number of seconds. If relative is true, once the message has been read, the client is expected to delete the message after relative\_time seconds. It is mandatory if relative is true.

- `absolute_time` is the expiration date/time of the message expressed as a VCON (text) `date_type`. It is mandatory if `relative` is false and optional otherwise.
- \* `in_reply_to` is the base64url encoding of the MIMI content `message_id` of the message to which this message is replying (or reacting). It is optional if empty.
- \* `mimi_extensions` is a base64 encoding of the CBOR MIMI content extensions map or null. It is optional if not present in the MIMI content.
- \* `franking_tag` is a base64url encoding of the MIMI `franking_tag`, or null. It is optional if not present.
- \* `frank` is a base64url encoding of the MIMI protocol Frank TLS struct, or null. It is optional if not present.

VCON typically expresses message content using the `body`, `encoding`, and `mediatype` fields. In order to preserve this convention we use these fields directly for a MIMI `SinglePart` structure, but use new `MultiPart` and `ExternalPart` objects for those corresponding MIMI structures. For a `SinglePart` these two fields with the same semantics as their MIMI content counterparts could be present.

- \* `disposition` - optional if set to the default value ("render")
- \* `language` - optional if absent

If there is only a single part its `part_index` is 0, and in this case it is optional.

### 3.3.3. MultiPart objects

A `MultiPart` object is designed to carry multiple items, as with the `MultiPart` structure in MIMI content or the top level multipart media types. It contains the following fields.

- \* `part_semantics` is one of "chooseOne", "singleUnit", or "processAll". It is mandatory.
- \* `parts` is an array of `Parts`. It is mandatory in a `MultiPart` object.

### 3.3.4. Part objects

The following fields can be in a `Part` object. They have the same meaning as their MIMI content counterparts.

- \* disposition optional if set to the default value ("render")
- \* language - optional if absent
- \* part\_index is an unsigned integer. It is mandatory in a Part object.
- \* cardinality is one of "nullpart", "single", "external", or "multi". mandatory.

If cardinality is "single" or "external", then body, encoding, and mediatype fields are included directly in the Part object.

### 3.3.5. ExternalPart objects

The ExternalPart object can contain the following fields with similar meanings to those in MIMI content, with exceptions noted below.

- \* mediatype is the value of the contentType in MIMI. It is mandatory if present in the MIMI message and recommended otherwise.
- \* url is the URL of the content as a text string. It is mandatory
- \* expires is a date\_type (text) date. It is optional if not present.
- \* size is an integer number of octets. It is optional if not present.
- \* description is a text string. It is optional if not present.
- \* filename is a text string. It is optional if not present.
- \* content\_hash is the base64url encoded string of the MIMI contentHash of the ExternalPart, prefixed with the name of the hash algorithm corresponding to hashAlg and a colon (for example "sha256:"). content\_hash is mandatory if it was included in the MIMI content ExternalPart, and omitted otherwise.

In addition, the following fields are unique to MIMI VCON.

- \* cached is a boolean. It is mandatory if it is true, which means that a copy of the external content is available in a vcon attachment object (see Section 3.6). If cache is true and no content\_hash is present, a new content hash is calculated for the attachment and placed the cache\_ref field (which can only be present in this case).

ExternalPart has several fields for the decryption of the referenced content. If it is not necessary to reconstruct the original MIMI content (for example to allow later verification of the message ID), these fields can be omitted once the content has been downloaded, decrypted, verified, and included in the VCON attachments array. Otherwise they are mandatory if present in the MIMI content. All of these fields are base64url encoded strings.

- \* encAlg
- \* key
- \* nonce
- \* aad

### 3.4. Changes to the parties

The party\_history object can be interleaved with text objects in the dialog objects array. It indicates when changes have been made to the participants represented by party index zero, as well as properties of individual parties (such as their role or name).

The party\_history object contains the following fields.

- \* party is the party index of the modified party. It is mandatory.
- \* originator is the party that originated the change. It is optional.
- \* time is the time that the change was effected
- \* event is the type of change. It is mandatory and for MIMI VCONS can be one of the following new event types:
  - add: user added by someone else
  - self\_add: user added herself directly
  - leave: user leaves of their own accord
  - remove: user is removed by another user
  - ban: user is banned from the group
  - update:

- \* name is the new name of the user. It is only permitted for an update event.
- \* role is the new role assigned to the user. It is only permitted for an update event.

### 3.5. Changes to the room

Changes to the room metadata should be accompanied by a new room dialog type. The room dialog type can contain anything in the top-level room object except for the id (which cannot change). It must contain a time field to convey the time of the change, and may contain an originator field to convey who made that change.

### 3.6. Attachments

An attachment consists of the following fields:

- \* start: is the time when the attachment was downloaded. It is mandatory.
- \* party: is the party that downloaded the attachment. It is mandatory.
- \* content\_hash: is the base64url encoded hash using the hash name prefixed with a colon before the hash (ex: "sha256:"). It is mandatory.
- \* dialog\_object\_ref is a string consisting of: "mid:" (representing the message ID URI), the message\_id of the message in the dialog object, a colon, the part\_index of the Part (or "0" if the ExternalPart is at the top level), and the string "@anon.invalid"

The mediatype, filename, encoding, and body fields are as they are defined in VCON and are all mandatory.

### 3.7. Message tombstones

When a message has been deleted/retracted, or it expires, it can be valuable to present a record that such a message was previously present, by generating a dialog object with the following fields (which are all mandatory):

- \* type is "tombstone"
- \* start is the time the tombstone was generated
- \* message\_id is the message ID of the message.

- \* status is the status of the former message, either "retracted" or "expired".

## 4. Examples

### 4.1. MIMI examples as a VCON

The example vcon consists of the example messages from Section 5 of the MIMI content specification plus a party\_history object adding two new participants, and a single multipart message at the end.

```
{
  "vcon": "0.0.1",
  "room": {
    "id": "mimi://example.com/r/engineering_team",
    "name": "Engineering Team",
    "avatar": "https://example.com/images/tHMqLMakmCzNmweL",
    "subject": None,
    "mood": None,
    "description": [
      { "type": "", "lang": "en", "content": "Engineering Team Internal Chat" },
      { "type": "", "lang": "fr", "content": "Chat de l'équipe interne des ingénieurs" }
    ]
  }
}
"parties": [
  {
    "imUri": "mimi://example.com/r/engineering_team",
  },
  {
    "im_uri": "mimi://example.com/u/alice-smith",
    "name": "Alice Smith",
    "role": "moderator",
    "thumbprint": "TODOFIXDZXCog_FfQp-xLemZkd5GKB9H7Z-Y41O4jEw"
  },
  {
    "im_uri": "mimi://example.com/u/bob-jones",
    "name": "Bob Jones",
    "role": "member",
    "thumbprint": "TODOFIXYUFE7bV9pXAHZHi5bwSWzLJqjnccvs9aLKDg"
  },
  {
    "im_uri": "mimi://example.com/u/cathy-washington",
    "name": "Cathy Washington",
    "role": "member",
    "thumbprint": "TODOFIXzH3EeOGbI0-oidGTXlgKmkMzQyQ2W_Y-TB1U"
  }
]
```

```
    },
    {
      "im_uri": "mimi://example.com/u/doug-king",
      "name": "Doug King",
      "role": "member",
      "thumbprint": "TODOFIX3fdpORnHwncbdOS5XieH-z1m5r61u14WyNkj"
    },
    {
      "im_uri": "mimi://example.com/u/liz-roberts",
      "name": "Elizabeth Roberts",
      "role": "member",
      "thumbprint": "TODOFIX7qR7oFriyKfKgIJ43ZdANoObICqH0kN9g82J"
    }
  ],
  "dialog": [
    {
      "type": "text",
      "start": "2022-02-08T22:13:45.019-00:00",
      "duration": 0,
      "parties": [
        1, 2, 3
      ],
      "franking_tag": null,
      "frank": null,
      "originator": 1,
      "salt": "PC16IkqDbGRiffzjeyPKIg",
      "message_id": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ",
      "mimi_extensions": "oQGIAxgrbWltaTovL2h1Yi5leGFtcGxlL3IvU
        mwzM0ZXtENZV093eEhyWW5wV0RRZwJ4GG1pbWk6Ly9iLmV4YW1wbG
        UvdS9hbGljZQ",
      "mimetype": "text/markdown;variant=GFM",
      "encoding": "none",
      "body":
        "Hi everyone, we just shipped release 2.0. __Good work__!",
    },
    {
      "type": "text",
      "start": "2022-02-08T22:13:57.492-00:00",
      "duration": 0,
      "parties": [
        0
      ],
      "originator": 2,
      "salt": "PVeWNQrjJej4AjhqkG1Skw",
      "message_id": "Ygye96VUeBhTO6U3D0Zl1YsSwSdKB3SiRJgxAb3cdAo",
      "in_reply_to": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ",
      "mimetype": "text/markdown;variant=GFM",
    }
  ]
}
```

```
"encoding": "none"
"body": "Right on! _Congratulations_ \'all!",
},
{
  "type": "text",
  "start": "2022-02-08T22:13:57.728-00:00",
  "duration": 0,
  "parties": [
    0
  ],
  "originator": 3,
  "salt": "lV7CoeiFmX4ALPSKodrR0w"
  "message_id": "2YF0k6blW9ZbJ8sgXJgMCTJ0lofazdKwVRvf6ZUORFA",
  "in_reply_to": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ",
  "disposition": "reaction",
  "mimetype": "text/plain; charset=utf-8",
  "encoding": "none"
  "body": "笑、",
},
{
  "type": "text",
  "start": "2022-02-08T22:14:03.008-00:00",
  "duration": 0,
  "parties": [
    0
  ],
  "originator": 3,
  "salt": "pkL5Tr0pLla5EiLUOfVDJw"
  "message_id": "rF4iS5BcJ-aFfisoFDCrnTE9pZZBGCxGCoXGJ9VXnck",
  "mimetype": "text/markdown; variant=GFM",
  "encoding": "none"
  "body":
    "Kudos to [@Alice Smith](mimi://example.com/alice-smith) for
making the release happen!",
},
{
  "type": "text",
  "start": "2022-02-08T22:14:08.621-00:00",
  "duration": 0,
  "parties": [
    0
  ],
  "originator": 2,
  "salt": "26QI8adeG9TDfPvh-jlStg"
  "message_id": "-GqJXuoaJulXosu-N8nt6NWzA2RLmIRY0q9jfk_vWkM",
```

```

    "replaces": "Ygye96VUeBhTO6U3D0Zl1YsSwSdKB3SiRJgxAb3cdAo",
    "in_reply_to": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ",
    "mimetype": "text/markdown;variant=GFM",
    "encoding": "none"
    "body": "Right on! _Congratulations_ y'all"
  },
  {
    "type": "text",
    "start": "2022-02-08T22:14:08.621-00:00",
    "duration": 0,
    "parties": [
      0
    ],
    "originator": 2,
    "salt": "HbkjCnTRrh84LPT86VvYg"
    "message_id": "8cqolB9IA6nnB63oPEnmWxIqr7uk7WvQTBgVVlD_Q2c",
    "replaces": "Ygye96VUeBhTO6U3D0Zl1YsSwSdKB3SiRJgxAb3cdAo",
    "in_reply_to": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ"
  },
  {
    "party_history": [
      {
        "party": 4,
        "event": "add",
        "originator": 1,
        "time": "2022-02-08T22:14:09.277-00:00"
      },
      {
        "party": 5,
        "event": "add",
        "originator": 1,
        "time": "2022-02-08T22:14:09.277-00:00"
      }
    ]
  },
  {
    "type": "text",
    "start": "2022-02-08T22:14:10.389-00:00",
    "duration": 0,
    "parties": [
      0
    ],
    "originator": 3,
    "salt": "IrAeojgZcZGiQjjBbmQVhw"
    "message_id": "bYZ2NHaryq0WS2pq5IE9fMc4zltUyE6WrKJ7bNB5tMc",
    "replaces": "Ygye96VUeBhTO6U3D0Zl1YsSwSdKB3SiRJgxAb3cdAo",
    "in_reply_to": "yjetjodyYNLBto8YDnwLkEc89W09rOuEivbnxKGfHLQ",

```

```
    "disposition": "reaction"
  },
  {
    "type": "text",
    "start": "2022-02-08T22:49:06.227-00:00",
    "duration": 0,
    "parties": [
      0
    ],
    "originator": 1,
    "salt": "8xnQi9hjVw4N8cRGEm4X1A",
    "message_id": "GkblzkXJxyar0lTgkfcMQ0wo8qpbcU0MqtTg-gM1FiY",
    "expiring": {
      "relative": false,
      "expires": "2022-02-08T22:59:06.227-00:00"
    },
    "status": "expired"
  },
  {
    "type": "text",
    "start": "2022-02-08T22:53:41.134-00:00",
    "duration": 0,
    "parties": [
      0
    ],
    "originator": 2,
    "salt": "bqhJBqYaTyDmgTj-QtdZPA",
    "message_id": "Tdt8UCUllugSLRmuObvib_4bvU_Hz3NSwaYuy-TtET4",
    "disposition": "attachment",
    "language": "en",
    "ExternalPart": {
      "mimetype": "video/mp4",
      "url": "https://example.com/storage/8ksB4bSrrRE.mp4",
      "size": 708234961,
      "description": "2 hours of key signing video",
      "filename": "bigfile.mp4",
      "content_hash":
        "sha256:OczZYpW_L0B1DsMSLJqL2jTRJKoj7fTUJ2jhnX70-00",
      "enc_alg": 1,
      "key": "aZISOs306M7n_3csR-J1cw",
      "nonce": "5VM0QcZI3PNmnquV6CUgxxg",
      "aad": ""
    }
  },
  {
    {
```

```
"type": "text",
"start": "2022-02-08T22:54:09.972-00:00",
"duration": 0,
"parties": [
  0
],
"originator": 3,
"salt": "dPEJAGOdZGeX6_OCp0RUzA"
"message_id": "KgDTc29ZP4YyYmXtaYyxpZNRnigjvCjrCYuLTz19zWc",
"disposition": "session",
"ExternalPart": {
  "url": "https://example.com/join/12345",
  "description": "Join the Foo 118 conference"
}
},
{
  "type": "text",
  "start": "2022-02-08T22:57:14.084-00:00",
  "duration": 0,
  "parties": [
    0
  ],
  "originator": 1,
  "salt": "YSbs-8jeoXfI6Z4lQRUWQw"
  "message_id": "sD19bKRmu4mA9SHznfQOLQQzKnx1Q4mEtSNQhvvzqCZw",
  "disposition": "render",
  "part_index": 0,
  "MultiPart": {
    "part_semantics": "chooseOne",
    "parts": [
      "Part": {
        "disposition": "render",
        "language": "en",
        "part_index": 1,
        "mimetype": "text/markdown;variant=GFM",
        "encoding": "none"
        "body": "Hello!"
      },
      "Part": {
        "disposition": "render",
        "language": "fr",
        "part_index": 2,
        "mimetype": "text/markdown;variant=GFM",
        "encoding": "none"
        "body": "Bonjour!"
      }
    ]
  }
}
```

```
    },  
  ]  
}
```

#### 4.2. MIMI VCON with an Attachment

This example vcon consists of a single message in a dialog which references an attachment.

```
{  
  "vcon": "0.0.1",  
  "room": {  
    "id": "mimi://example.com/r/engineering_team",  
    "name": "Engineering Team",  
  }  
  "parties": [  
    {  
      "imUri": "mimi://example.com/r/engineering_team",  
    },  
    {  
      "im_uri": "mimi://example.com/u/alice-smith",  
      "name": "Alice Smith",  
      "role": "moderator",  
      "thumbprint": "TODOFIXDZXCog_FfQp-xLemZkd5GKB9H7Z-Y41O4jEw"  
    },  
    {  
      "im_uri": "mimi://example.com/u/bob-jones",  
      "name": "Bob Jones",  
      "role": "member",  
      "thumbprint": "TODOFIXYUFE7bV9pXAHZHi5bwSWzLJqjncevs9aLKDg"  
    },  
    {  
      "im_uri": "mimi://example.com/u/cathy-washington",  
      "name": "Cathy Washington",  
      "role": "member",  
      "thumbprint": "TODOFIXzH3EeOGbI0-oidGTXlgKmkMzQyQ2W_Y-TB1U"  
    }  
  ],  
  "dialog": [  
    {  
      "type": "text",  
      "start": "2022-02-08T22:53:41.134-00:00",  
      "duration": 0,  
      "parties": [  
        0, 1, 2, 3  
      ],  
      "originator": 1,  
      "salt": "jaPfwAWReuvBdfayWkSvtQ"  
    }  
  ]  
}
```

```
"message_id": "Tdt8UCUllugSLRmuObvib_4bvu_Hz3NSwaYuy-TtET4",
"disposition": "attachment",
"language": "en",
"ExternalPart": {
  "mimetype": "video/mp4",
  "url": "https://example.com/storage/8ksB4bSrrRE.mp4",
  "size": 708234961,
  "description": "2 hours of key signing video",
  "filename": "bigfile.mp4",
  "content_hash":
    "sha256:OczZYpW_L0B1DsMSLJqL2jTRJKoj7fTUIJ2jhnX70-00",
  "cached": true
},
],
"attachments": [
  {
    "start": "2022-02-08T22:53:41.134-00:00",
    "party": 1,
    "content_hash":
      "sha256:OczZYpW_L0B1DsMSLJqL2jTRJKoj7fTUIJ2jhnX70-00",
    "dialogObjectRef":
      "mid:Tdt8UCUllugSLRmuObvib_4bvu_Hz3NSwaYuy-TtET4:0@anon.invalid",
    "mimetype": "video/mp4",
    "filename": "bigfile.mp4",
    "encoding": "base64url",
    "body": "Ma0hHSr0f_iUk_RSShTgtY...nSQbZEip5danJYQqsvwWQ"
  }
]
```

## 5. Security Considerations

TODO Security

## 6. IANA Considerations

This document has no IANA actions.

## 7. Normative References

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## Appendix A. CDDL changes

\*TODO\*

## Appendix B. Change list

## B.1. Changes in draft-mahy-vcon-mimi-messages-02

- \* adjust to make consistent with new syntax of MIMI content (add salt, removed lastSeen, in\_reply\_to is just a message id, expires is an object to handle relative expiration, added mimi\_extensions).
- \* use a different field from content\_hash when attaching an ExternalPart that did not have a hash in the MIMI message.
- \* allow the parties list of 0 to indicate sending to every active participant in the room.
- \* added a description of using party\_history to track changes to the participant list.
- \* added room metadata, and a way to modify it
- \* added support for message "tombstones"
- \* use mediatype instead of mimetype throughout
- \* make the case of field names more consistent

## Acknowledgments

TODO acknowledge.

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