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V. Birk  
H. Marques  
Shelburn  
pEp Foundation  
S. Koechli  
pEp Security  
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pretty Easy privacy (pEp): Privacy by Default  
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Abstract

Building on already available security formats and message transports (like PGP/MIME for email), and with the intention to stay interoperable to systems widely deployed, pretty Easy privacy (pEp) describes protocols to automatize operations (key management, key discovery, private key handling including peer-to-peer synchronization of private keys and other user data across devices) that have been seen to be barriers to deployment of end-to-end secure interpersonal messaging. pEp also introduces "Trustwords" (instead of fingerprints) to verify communication peers and proposes a trust rating system to denote secure types of communications and signal the privacy level available on a per-user and per-message level. In this document, the general design choices and principles of pEp are outlined.

Status of This Memo

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## 1. Introduction

[[At this stage it is not year clear to us how many of our implementation details should be part of new RFCs and at which places we can safely refer to already existing RFCs to make clear on which RFCs we are already relying.]]

The pretty Easy privacy (pEp) protocols are propositions to the Internet community to create software for peers to automatically encrypt, anonymize (where possible, depending on the message transport used) and verify their daily written digital communications -- this is done by building upon already existing standards and tools and automatizing all steps a user would need to carry out to engage in secure end-to-end encrypted communciations without depending on centralized infrastructures.

To mitigate for Man-In-The-Middle Attacks (MITM) and as the only manual step users may carry out, Trustwords as natural language representations of two peers' fingerprints are proposed, for peers to put trust on their communication channel.

Particularly, pEp proposes to automatize key management, key discovery and also synchronization of secret key material by an in-band peer-to-peer approach.

[[The pEp initiators had to learn from the CryptoParty movement, from which the project emerged, that step-by-step guides can be helpful to a particiular set of users to engage in secure end-to-end communications, but that for a much major fraction of users it would be more convenient to have the step-by-step procedures put into actual code (as such, following a protocol) and thus automatizing the initial configuration and whole usage of cryptographic tools.]]

The Privacy by Default principles that pretty Easy privacy (pEp) introduces, are in accordance with the perspective outlined in [RFC7435] to bring Opportunistic Security in the sense of "some protection most of the time", with the subtle, but important difference that when privacy is weighted against security, the choice falls to privacy, which is why in pEp data minimization is a primary goal (e.g., omitting unnecessary email headers or encrypting the subject line).

The pEp propositions are focused on written digital communications, but not limited to asynchronous (offline) types of communications like email, but can also be implemented for message transports, which support synchronous (online) communications (e.g., for peer-to-peer networks like GUNet). pEp's goal is to bridge the different standardized and/or widely spread communications channels, such that users can reach their peers in the most privacy-enhancing way possible using differing IRIs/URIs.

## 2. Terms

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

Terms like "TOFU" or "MITM" are used as defined in [RFC4949].

- o Handshake: The process when Alice -- e.g. in-person or via phone -- contacts Bob to verify Trustwords (or by fallback: fingerprints) is called handshake.
- o Trustwords: A scalar-to-word representation of 16-bit numbers (0 to 65535) to natural language words. When doing a handshake, peers are shown combined Trustwords of both public keys involved to ease the comparison. [pEpTrustwords]

## 3. Protocol's core design principles

### 3.1. Compatibility

- o Be conservative (strict) in requirements for pEp implementations and how they behave between each other.
- o Be liberal (accepting) in what comes in from non-pEp implementations (e.g., do not send, but support to decipher PGP/INLINE formats).
- o Where pEp requires diverging from an RFC for privacy reasons (e.g., from OpenPGP propositions as defined in [RFC4880]), options SHOULD be implemented to empower the user to comply to practices already (widespreadly) used, either at contact level or globally.

### 3.2. Peer-to-Peer (P2P)

All communications and verifications in pEp implementations for pursuing secure and establishing trusted communications between peers MUST be Peer-to-Peer (P2P) in nature.

This means, there SHALL NOT be any pEp-specific central services whatsoever needed for implementers of pEp to rely on, neither for verification of peers nor for the actual encryption.

Still, implementers of pEp MAY provide options to interoperate with providers of centralized infrastructures as users MAY NOT be stopped from being able to communicate with their peers on platforms with vendor lock-in.

Trust provided by global Certificate Authorities (e.g., commercial X.509 CAs) SHALL NOT be signaled (cf. [pEpTrustRating]) as trustworthy to users of pEp (e.g., when interoperating with peers using S/MIME) by default.

### 3.3. User Experience (UX)

[[We are aware of the fact that usually UX requirements are not part of RFCs. However, to have massively more people engaged in secure end-to-end encryption and at the same time to avoid putting users at risk, we believe requiring certain straightforward signaling for the users to be a good idea -- in a similar way as this happens to be the case for already popular Instant Messaging services.]]

Implementers of pEp MUST take special care to not confuse users with technical terms, especially those of cryptography (e.g., "keys", "certificates" or "fingerprints") if they do not explicitly ask for them. Advanced settings MAY be available, in some cases further options MUST be available, but they SHALL NOT be unnecessarily exposed to users of pEp implementations at the first sight when using clients implementing the pEp propositions.

The authors believe widespread adoption of end-to-end cryptography is much less of an issue if the users are not hassled and visibly forced in any way to use cryptography. That is, if they can just rely on the principles of Privacy by Default.

By consequence, this means that users MUST NOT wait for cryptographic tasks (e.g., key generation or public key retrieval) to finish before being able to have their respective message clients ready to communicate. This finally means, pEp implementers MUST make sure that the ability to draft, send and receive messages is always preserved -- even if that means a message is sent out unencrypted, thus being in accordance with the Opportunistic Security approach outlined in [RFC7435].

In turn, pEp implementers MUST make sure a Privacy Status is clearly visible to the user on both contact and message level, such that

users easily understand with what level of privacy messages are about to be sent or were received, respectively.

#### 4. Identities in pEp

With pEp users MUST have the possibility to have different identities, which MUST not correlate to each other by default. On the other hand, binding of different identities MUST be supported (being for support of aliases).

[[This is the reason why in current pEp implementations for each email account a different key pair is created, which allows a user to retain different identities.]]

In particular, with pEp users MUST NOT be bound to a specific IRI/URI, but SHALL be free to choose which identity they want to expose to certain peers -- this includes support for pseudonymity and anonymity, which the authors consider to be vital for users to control their privacy.

[[It might be necessary to introduce further addressing schemes through IETF contributions or IANA registrations.]]

In the reference implementation of the pEp Engine (cf. src/pEpEngine.h), a pEp identity is defined like the following (C99):

```
typedef struct _pEp_identity {
    char *address;           // C string with address UTF-8 encoded
    char *fpr;              // C string with fingerprint UTF-8 encoded
    char *user_id;          // C string with user ID UTF-8 encoded
    char *username;         // C string with user name UTF-8 encoded
    PEP_comm_type comm_type; // type of communication with this ID
    char lang[3];           // language of conversation
                            // ISO 639-1 ALPHA-2, last byte is 0
    bool me;                // if this is the local user herself/himself
    identity_flags_t flags; // identity_flag1 | identity_flag2 | ...
} pEp_identity;
```

A relational example (in SQL) used in current pEp implementations:

```

CREATE TABLE pgp_keypair (
    fpr text primary key,
    created integer,
    expires integer,
    comment text,
    flags integer default 0
);

CREATE TABLE person (
    id text primary key,
    username text not null,
    main_key_id text
        references pgp_keypair (fpr)
        on delete set null,
    lang text,
    comment text,
    device_group text
);

CREATE TABLE identity (
    address text,
    user_id text
        references person (id)
        on delete cascade,
    main_key_id text
        references pgp_keypair (fpr)
        on delete set null,
    comment text,
    flags integer default 0, primary key (address, user_id)
);

```

The public key's fingerprint (denoted as fpr) as part of a pEp identity MUST always be the full fingerprint.

Notable differences of how terms and concepts used differ between pEp and OpenPGP:

pEp	OpenPGP	Comments
user_id	(no concept)	ID for a person, i.e. a contact
username + address	uid	comparable only for email
fpr	fingerprint	used as key ID in pEp
(no concept)	Key ID	does not exist in pEp

## 5. Key Management

Key management in pEp MUST be automatized in order to achieve the goal of widespread adoption of secure communications.

A pEp implementation MUST make sure cryptographic keys for end-to-end cryptography are generated for every identity configured (or instantly upon its configuration) if no secure cryptographic setup can be found. Users SHALL NOT be stopped from communicating -- this also applies for initial situations where cryptographic keys are not generated fast enough. This process MUST be carried out in the background so the user is not stopped from communicating.

There is the pEp Trust Rating system in [pEpTrustRating] describing which kind of encryption MUST be considered reliable and is thus secure enough for usage in pEp implementations. This also applies for keys already available for the given identity. If the available keys are considered unsecure (e.g, insufficient key length), pEp implementers are REQUIRED to generate new keys for use with the respective identity.

As example for the rating of communication types, the definition of the data structure by the pEp Engine reference implementation (cf. src/pEpEngine.h) is provided:

```
typedef enum _PEP_comm_type {
    PEP_ct_unknown = 0,

    // range 0x01 to 0x09: no encryption, 0x0a to 0x0e: nothing reasonable

    PEP_ct_no_encryption = 0x01, // generic
    PEP_ct_no_encrypted_channel = 0x02,
    PEP_ct_key_not_found = 0x03,
    PEP_ct_key_expired = 0x04,
    PEP_ct_key_revoked = 0x05,
    PEP_ct_key_b0rken = 0x06,
    PEP_ct_my_key_not_included = 0x09,

    PEP_ct_security_by_obscurity = 0x0a,
    PEP_ct_b0rken_crypto = 0x0b,
    PEP_ct_key_too_short = 0x0c,

    PEP_ct_compromized = 0x0e, // known compromised connection
    PEP_ct_mistrusted = 0x0f, // known mistrusted key

    // range 0x10 to 0x3f: unconfirmed encryption

    PEP_ct_unconfirmed_encryption = 0x10, // generic
```



```
PEP_ct_OpenPGP_weak_unconfirmed = 0x11, // RSA 1024 is weak

PEP_ct_to_be_checked = 0x20, // generic
PEP_ct_SMIME_unconfirmed = 0x21,
PEP_ct_CMS_unconfirmed = 0x22,

PEP_ct_strong_but_unconfirmed = 0x30, // generic
PEP_ct_OpenPGP_unconfirmed = 0x38, // key at least 2048 bit RSA or EC
PEP_ct_OTR_unconfirmed = 0x3a,

// range 0x40 to 0x7f: unconfirmed encryption and anonymization

PEP_ct_unconfirmed_enc_anon = 0x40, // generic
PEP_ct_pEp_unconfirmed = 0x7f,

PEP_ct_confirmed = 0x80, // this bit decides if trust is confirmed

// range 0x81 to 0x8f: reserved
// range 0x90 to 0xbf: confirmed encryption

PEP_ct_confirmed_encryption = 0x90, // generic
PEP_ct_OpenPGP_weak = 0x91, // RSA 1024 is weak (unused)

PEP_ct_to_be_checked_confirmed = 0xa0, //generic
PEP_ct_SMIME = 0xa1,
PEP_ct_CMS = 0xa2,

PEP_ct_strong_encryption = 0xb0, // generic
PEP_ct_OpenPGP = 0xb8, // key at least 2048 bit RSA or EC
PEP_ct_OTR = 0xba,

// range 0xc0 to 0xff: confirmed encryption and anonymization

PEP_ct_confirmed_enc_anon = 0xc0, // generic
PEP_ct_pEp = 0xff
} PEP_comm_type;
```

#### 5.1. Private Keys

Private keys in pEp implementations MUST always be held on the end user's device(s): pEp implementers SHALL NOT rely on private keys stored in centralized remote locations. This also applies for key storages where the private keys are protected with sufficiently long passphrases. It MUST be considered a violation of pEp's P2P design principle to rely on centralized infrastructures. This also applies for pEp implementations created for applications not residing on a user's device (e.g., web-based MUAs). In such cases, pEp

implementations MUST be done in a way the locally-held private key can neither be directly accessed nor leaked to the outside world.

[[It is particularly important that browser add-ons implementing pEp functionality do not obtain their cryptographic code from a centralized (cloud) service, as this must be considered a centralized attack vector allowing for backdoors, negatively impacting privacy.]]

As a decentralized proposition, there is a pEp Key Synchronization protocol. [pEpKeySync] It outlines how pEp implementers can distribute their private keys in a secure and trusted manner: this allows Internet users to read their messages across their different devices, when sharing a common address (e.g., the same email account).

## 5.2. Key Distribution

Implementers of pEp are REQUIRED to attach the identity's public key to any outgoing message. However, this MAY be omitted if you previously received a message encrypted with the public key of the receiver.

The sender's public key MUST be sent encrypted whenever possible, i.e. when a public key of the receiving peer is available.

If no encryption key is available for the recipient, the sender's public key MUST be sent unencrypted. In either case, this approach ensures that message clients (e.g., MUAs which at least implement OpenPGP) do not need to have pEp implemented to see a user's public key. Such peers thus have the chance to (automatically) import the sender's public key.

If there is already a known public key from the sender of a message and it is still valid and not expired, new keys SHALL not be used for future communication to avoid a MITM attack unless they are signed by the previous key. Messages SHALL always be encrypted with the receiving peer's oldest public key, as long as it is valid and not expired.

Implementers of pEp SHALL make sure that public keys attached to messages (e.g, in email) are not displayed to the user. This ensures, they do not get confused by a file they cannot potentially deal with.

Metadata (e.g., email headers) SHALL NOT be made to announce a user's public key by the Privacy by Default principles. This must be considered unnecessary information leakage, potentially affecting privacy -- also depending on a country's data retention laws.

Furtherly, this affects interoperability to existing users (e.g., in the OpenPGP field) which have no notion of such header fields and thus lose the ability to import any such keys distributed this way. It SHOULD, though, be supported to obtain other users' public keys by extracting them from respective header fields, in case such approaches get widespread.

Keyservers or generally intermediate approaches to obtain a peer's public key SHALL NOT be used by default. On the other hand, the user MAY be given the option to opt-in for remote locations to obtain keys, considering the widespread adoption of such approaches for key distribution.

Keys generated or obtained by implementations SHALL NOT be uploaded to any (intermediate) keystore locations without the user's explicit will.

### 5.3. Passphrases

Passphrases to protect an user's private key MUST be supported by pEp implementations, but SHALL NOT be enforced by default. That is, if a pEp implementation finds a suitable (i.e., secure enough) cryptographic setup, which uses passphrases, pEp implementations MUST provide a way to unlock the key. However, if a new key pair is generated for a given identity no passphrase SHALL be put in place. The authors assume that the enforcement of secure (i.e., unique and long enough) passphrases would massively reduce the users of pEp (by hassling them) -- and in turn provide little to no additional privacy for the common cases of passive monitoring being carried out by corporations and state-level actors.

## 6. Privacy Status

For end-users, the most important component of pEp, which MUST be made visible on a per-recipient and per-message level, is the Privacy Status.

By colors, symbols and texts a user SHALL immediately understand how private

- o a communication channel with a given peer was or ought to be and
- o a given message was or ought to be.

The Privacy Status in its most general form MUST be expressed with traffic lights semantics (and respective symbols and texts), whereas the three colors yellow, green and red can be applied for any peer or message -- like this immediately indicating how secure and

trustworthy (and thus private) a communication was or ought to be considered. In cases no (special) Privacy Status can be inferred for peers or messages, no color (or the gray color) MUST be shown and respective texts -- being "unknown" or "unreliable" -- MUST be shown.

The detailed Privacy Status as an end-user element of the pEp Trust Rating system with all its states and respective representations to be followed is outlined in [pEpTrustRating].

## 7. Options in pEp

[[Just a selection; not yet complete.]]

### 7.1. Option "Passive Mode"

For situations where it might not be desirable to attach the sender's public key for outgoing messages (which is the default), a "Passive Mode" option MUST be made available to avoid this.

### 7.2. Option "Disable Protection"

#### 7.2.1. For all communications

Implementers of pEp MUST provide an option "Disable Protection" for the user's will to disable any outgoing encryption and signing. This option SHALL not affect the user's ability to decipher already received or sent messages.

#### 7.2.2. For some communications

For users to disable protection for some situations, i.e. at contact or message level, pEp implementers MUST provide an option. This allows users to disable outgoing encryption and signing for peers or individual messages.

### 7.3. Option "Extra Keys"

For environments where there is the need to send messages to further locations, pEp implementers MAY provide an "Extra Keys" option where further recipients (by public key) can be specified. With the user's will, each outgoing message MUST then be sent encrypted to any of those extra (implicit) recipients. Message clients SHOULD save and show only one message as sent to the explicit recipient(s), so as to not confuse users.

#### 7.4. Option "Blacklist Keys"

An option "Blacklist Keys" MUST be provided for an advanced user to be able to disable keys which the user does not want to be used anymore for any new communications. However, the keys SHALL NOT be deleted. It MUST still be possible to verify and decipher past communications.

#### 7.5. Establishing trust between peers

In pEp, Trustwords [pEpTrustwords] are used for users to compare the authenticity of peers in order to mitigate for MITM attacks.

By default, Trustwords MUST be used to represent two peers' fingerprints of their public keys in pEp implementations.

In order to retain compatibility with peers not using pEp implementations (e.g., Mail User Agents (MUAs) with OpenPGP implementations without Trustwords), it is REQUIRED that pEp implementers give the user the choice to show both peers' fingerprints instead of just their common Trustwords.

### 8. Security Considerations

By attaching the sender's public key to outgoing messages, Trust on First Use (TOFU) is established, which can lead for MITM attacks to succeed. Cryptographic key subversion is considered Pervasive Monitoring (PM) according to [RFC7258]. Those attacks can be mitigated by having the involved users comparing their common Trustwords. This possibility MUST be made easily accessible to pEp users in the user interface implementation. If for compatibility reasons (e.g., with OpenPGP users) no Trustwords can be used, then an comparably easy way to verify the respective public key fingerprints MUST be implemented.

Devices themselves SHOULD be made encrypted, as the use of passphrases for private keys is not advised.

### 9. Implementation Status

#### 9.1. Introduction

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation

here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC7942], "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

## 9.2. Reference implementation of pEp's core

The pEp Foundation provides a reference implementation of pEp's core principles and functionalities, which go beyond the documentation status of this Internet-Draft. [pEpCore]

pEp's reference implementation is composed of pEp Engine and pEp Adapters (or bindings), alongside with some libraries which pEp Engine relies on to function on certain platforms (like a NetPGP fork we maintain for the iOS platform).

The pEp engine is a Free Software library encapsulating implementations of:

- o Key Management
  - \* Key Management in pEp engine is based on GnuPG key chains (NetPGP on iOS). Keys are stored in an OpenPGP compatible format and can be used for different crypto implementations.
- o Trust Rating
  - \* pEp engine is sporting a two phase trust rating system. In phase one there is a rating based on channel, crypto and key security named "comm\_types". In phase 2 these are mapped to user representable values which have attached colors to present them in traffic light semantics.
- o Abstract Crypto API
  - \* The Abstract Crypto API is providing functions to encrypt and decrypt data or full messages without requiring an application programmer to understand the different formats and standards.

- o Message Transports

- \* pEp engine will support a growing list of Message Transports to support any widespread text messaging system including email, SMS, XMPP and many more.

pEp engine is written in C99. It is not meant to be used in application code directly. Instead, pEp engine is coming together with a list of software adapters for a variety of programming languages and development environments, which are:

- o pEp COM Server Adapter
- o pEp JNI Adapter
- o pEp JSON Adapter
- o pEp ObjC (and Swift) Adapter
- o pEp Python Adapter
- o pEp Qt Adapter

### 9.3. Abstract Crypto API examples

[[Just a selection; more functionality available.]]

The following code excerpts are from the pEp Engine reference implementation, to be found in src/message\_api.h.

#### 9.3.1. Encrypting a message

```
// encrypt_message() - encrypt message in memory
//
// parameters:
//   session (in)      session handle
//   src (in)         message to encrypt
//   extra (in)       extra keys for encryption
//   dst (out)        pointer to new encrypted message or NULL on failure
//   enc_format (in)  encrypted format
//   flags (in)       flags to set special encryption features
//
// return value:
//   PEP_STATUS_OK           on success
//   PEP_KEY_NOT_FOUND      at least one of the receiptent keys
//                           could not be found
//   PEP_KEY_HAS_AMBIG_NAME at least one of the receiptent keys has
//                           an ambiguous name
//   PEP_GET_KEY_FAILED     cannot retrieve key
//   PEP_UNENCRYPTED        no recipients with usable key,
//                           message is left unencrypted,
//                           and key is attached to it
//
// caveat:
//   the ownership of src remains with the caller
//   the ownership of dst goes to the caller
DYNAMIC_API PEP_STATUS encrypt_message(
    PEP_SESSION session,
    message *src,
    stringlist_t *extra,
    message **dst,
    PEP_enc_format enc_format,
    PEP_encrypt_flags_t flags
);
```

### 9.3.2. Decrypting a message



```
// decrypt_message() - decrypt message in memory
//
// parameters:
//   session (in)   session handle
//   src (in)      message to decrypt
//   dst (out)     pointer to new decrypted message or NULL on failure
//   keylist (out) stringlist with keyids
//   rating (out)  rating for the message
//   flags (out)   flags to signal special decryption features
//
// return value:
//   error status
//   or PEP_DECRYPTED if message decrypted but not verified
//   or PEP_STATUS_OK on success
//
// caveat:
//   the ownership of src remains with the caller
//   the ownership of dst goes to the caller
//   the ownership of keylist goes to the caller
//   if src is unencrypted this function returns PEP_UNENCRYPTED and sets
//   dst to NULL
DYNAMIC_API PEP_STATUS decrypt_message(
    PEP_SESSION session,
    message *src,
    message **dst,
    stringlist_t **keylist,
    PEP_rating *rating,
    PEP_decrypt_flags_t *flags
);
```

### 9.3.3. Obtaining common Trustwords

```
// get_trustwords() - get full trustwords string for a *pair* of identities
//
// parameters:
// session (in) session handle
// id1 (in) identity of first party in communication - fpr can't be NULL
// id2 (in) identity of second party in communication - fpr can't be NULL
// lang (in) C string with ISO 639-1 language code
// words (out) pointer to C string with all trustwords UTF-8 encoded,
// separated by a blank each
// NULL if language is not supported or trustword
// wordlist is damaged or unavailable
// wsize (out) length of full trustwords string
// full (in) if true, generate ALL trustwords for these identities.
// else, generate a fixed-size subset. (TODO: fixed-minimum-entropy
// subset in next version)
//
// return value:
// PEP_STATUS_OK trustwords retrieved
// PEP_OUT_OF_MEMORY out of memory
// PEP_TRUSTWORD_NOT_FOUND at least one trustword not found
//
// caveat:
// the word pointer goes to the ownership of the caller
// the caller is responsible to free() it (on Windows use pEp_free())
//
DYNAMIC_API PEP_STATUS get_trustwords(
    PEP_SESSION session, const pEp_identity* id1, const pEp_identity* id2,
    const char* lang, char **words, size_t *wsize, bool full
);
```

#### 9.4. Current software implementing pEp

The following software implementing the pEp protocols (to varying degrees) already exists; it does not yet go beyond implementing pEp for email, which is to be described nearer in [pEpEmail]:

- o pEp for Outlook as add-on for Microsoft Outlook, production [pEpForOutlookSrc]
- o pEp for Android (based on a fork of the K9 MUA), beta [pEpForAndroidSrc]
- o Enigmail/pEp as add-on for Mozilla Thunderbird, early beta [EnigmailpEpSrc]
- o pEp for iOS (implemented in a new MUA), alpha [pEpForiOSSrc]

pEp for Android, iOS and Outlook are provided by pEp Security, a commercial entity specializing in end-user software implementing pEp while Enigmail/pEp is pursued as community project, supported by the pEp Foundation.

## 10. Notes

The pEp logo and "pretty Easy privacy" are registered trademarks owned by pEp Foundation in Switzerland, a tax-free, non-commercial entity.

Primarily, we want to ensure the following:

- o Software using the trademarks MUST be backdoor-free.
- o Software using the trademarks MUST be accompanied by a serious (detailed) code audit carried out by a reputable third-party, for any proper release.

The pEp Foundation will help to support any community-run (non-commercial) project with the latter, be it organizationally or financially.

Through this, the foundation wants to make sure that software using the pEp trademarks is as safe as possible from a security and privacy point of view.

## 11. Acknowledgements

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[[Much more general acknowledgements to follow.]]

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Authors' Addresses

Volker Birk  
pEp Foundation

Email: [vb@pep-project.org](mailto:vb@pep-project.org)

Hernani Marques  
pEp Foundation

Email: [hernani.marques@pep.foundation](mailto:hernani.marques@pep.foundation)

Shelburn  
pEp Foundation

Email: [shelburn@pep.foundation](mailto:shelburn@pep.foundation)

Sandro Koechli  
pEp Security

Email: [sandro@pep-security.net](mailto:sandro@pep-security.net)

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V. Birk  
H. Marques  
B. Hoeneisen  
pEp Foundation  
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pretty Easy privacy (pEp): Privacy by Default  
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Abstract

The pretty Easy privacy (pEp) model and protocols describe a set of conventions for the automation of operations traditionally seen as barriers to the use and deployment of secure, privacy-preserving end-to-end interpersonal messaging. These include, but are not limited to, key management, key discovery, and private key handling (including peer-to-peer synchronization of private keys and other user data across devices). Human Rights-enabling principles like Data Minimization, End-to-End and Interoperability are explicit design goals. For the goal of usable privacy, pEp introduces means to verify communication between peers and proposes a trust-rating system to denote secure types of communications and signal the privacy level available on a per-user and per-message level. Significantly, the pEp protocols build on already available security formats and message transports (e.g., PGP/MIME with email), and are written with the intent to be interoperable with already widely-deployed systems in order to ease adoption and implementation. This document outlines the general design choices and principles of pEp.

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## 1. Introduction

Secure and private communications are vital for many different reasons, and there are particular properties that privacy-preserving protocols need to fulfill in order to best serve users. In particular, [RFC8280] has identified and documented important principles such as data minimization, the end-to-end principle, and interoperability as integral properties which enable access to Human Rights. Today's applications widely lack privacy support that ordinary users can easily adapt. The pretty Easy privacy (pEp)



protocols generally conform to the principles outlined in [RFC8280], and, as such, can facilitate the adoption and correct usage of secure and private communications technology.

The pretty Easy privacy (pEp) protocols are propositions to the Internet community to create software for peers to automatically encrypt, anonymize (where possible), and verify their daily written digital communications. This is achieved by building upon already existing standards and tools and automating each step a user needs to carry out in order to engage in secure end-to-end encrypted communications. Significantly, the pEp protocols describe how do to this without dependence on centralized infrastructures.

The pEp project emerged from the CryptoParty movement. During that time, the initiators learned that while step-by-step guides can help some users engage in secure end-to-end communications, it is both more effective and convenient for the vast majority of users if these step-by-step guides are put into running code (following a protocol), which automates the initial configuration and general usage of cryptographic tools. To facilitate this goal, pEp proposes the automation of key management, key discovery, and key synchronization through an in-band approach which follows the end-to-end principle.

To mitigate man-in-the-middle attacks (MITM) by an active adversary, and as the only manual step users carry out in the course of the protocols, the proposed Trustwords [I-D.birk-pep-trustwords] mechanism uses natural language representations of two peers' fingerprints for users to verify their trust in a paired communication channel.

The privacy-by-default principles that pEp introduces are in accordance with the perspective outlined in [RFC7435], aiming to provide opportunistic security in the sense of "some protection most of the time". This is done, however, with the subtle but important difference that when privacy is weighed against security, the choice defaults to privacy. Therefore, data minimization is a primary goal in pEp (e.g., hiding subject lines and headers unnecessary for email transport inside the encrypted payload of a message).

The pEp propositions are focused on (but not limited to) written digital communications and cover asynchronous (offline) types of communications like email as well as synchronous (online) types such as chat.

pEp's goal is to bridge different standardized and widely-used communications channels such that users can reach communications partners in the most privacy-enhancing way possible.

### 1.1. Relationship to other pEp documents

While this document outlines the general design choices and principles of pEp, other related documents specialize in more particular aspects of the model, or the application of pEp on a specific protocol like as follows:

1. pEp-enabled applications (e.g., pEp email [I-D.pep-email]).
2. Helper functions for peer interaction, which facilitate understanding and handling of the cryptographic aspects of pEp implementation for users (e.g., pEp Handshake [I-D.marques-pep-handshake]).
3. Helper functions for interactions between a user's own devices, which give the user the ability to run pEp applications on different devices at the same time, such as a computer, mobile phone, or tablets (e.g., pEp KeySync [I-D.hoeneisen-pep-keysync]).

In addition, there are documents that do not directly depend on this one, but provide generic functions needed in pEp, e.g., IANA Registration of Trustword Lists [I-D.birk-pep-trustwords].

[ [ Note: At this stage it is not yet clear to us how many of our implementation details should be part of new RFCs and where we can safely refer to already existing RFCs to clarify which RFCs we rely on. ] ]

### 1.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

### 1.3. Terms

The following terms are defined for the scope of this document:

- o pEp Handshake: The process of one user contacting another over an independent channel in order to verify Trustwords (or fingerprints as a fallback). This can be done in-person or through established verbal communication channels, like a phone call. [I-D.marques-pep-handshake]

- o Trustwords: A scalar-to-word representation of 16-bit numbers (0 to 65535) to natural language words. When doing a Handshake, peers are shown combined Trustwords of both public keys involved to ease the comparison. [I-D.birk-pep-trustwords]
  
- o Trust On First Use (TOFU): cf. [RFC7435], which states: "In a protocol, TOFU calls for accepting and storing a public key or credential associated with an asserted identity, without authenticating that assertion. Subsequent communication that is authenticated using the cached key or credential is secure against an MiTM attack, if such an attack did not succeed during the vulnerable initial communication."
  
- o Man-in-the-middle (MITM) attack: cf. [RFC4949], which states: "A form of active wiretapping attack in which the attacker intercepts and selectively modifies communicated data to masquerade as one or more of the entities involved in a communication association."

Note: Historically, MITM has stood for 'Man-in-the-middle'. However, to indicate that the entity in the middle is not always a human attacker, MITM can also stand for 'Machine-in-the-middle' or 'Meddler-in-the-middle'.

## 2. Protocol's Core Design Principles

### 2.1. Privacy by Default

pEp's most important goal is to ensure privacy above all else. To clarify, pEp's protocol defaults are designed to maximize both security and privacy, but in the few cases where achieving both more privacy and more security are in conflict, pEp chooses more privacy.

In contrast to pEp's prioritization of user privacy, OpenPGP's Web-of-Trust (WoT) releases user and trust level relationships to the public. In addition, queries to OpenPGP key servers dynamically disclose the social graph, indicating a user's intent to communicate with specific peers. Similar issues exist in other security protocols that rely upon a centralized trust model, such as the certificate revocation protocols used in XPKI (S/MIME).

[[\*TODO\*: Fix the wording and reference to XPKI, S/MIME]].

In pEp messaging (e.g., when using HTML) content and information SHALL NOT be obtained from remote locations as this constitutes a privacy breach.

Because of the inherent privacy risks in using remote or centralized infrastructures, implementations of pEp messaging, by default, SHALL NOT obtain content and information from remote or centralized locations, as this constitutes a privacy breach. In email this issue exists with HTML mails.

## 2.2. Data Minimization

Data minimization keeps data spare and hides all technically concealable information whenever possible. It is an important design goal of pEp.

## 2.3. Interoperability

The proposed pEp protocols seek interoperability with established message formats, as well as cryptographic security protocols and their widespread implementations.

To achieve this interoperability, pEp MUST follow Postel's Robustness Principle outlined in [RFC1122]: "Be liberal in what you accept, and conservative in what you send."

Particularly, pEp applies Postel's principle as follows:

- o pEp is conservative (strict) in requirements for pEp implementations and how they interact with pEp or other compatible implementations.
- o pEp liberally accepts input from non-pEp implementations. For example, in email, pEp will not produce outgoing messages, but will transparently support decryption of incoming PGP/INLINE messages.
- o Finally, where pEp requires divergence from established RFCs due to privacy concerns (e.g., from OpenPGP propositions as defined in [OpenPGP], options SHOULD be implemented which empower the user to override pEp's defaults.

## 2.4. Peer-to-Peer

Messaging and verification processes in pEp are designed to work in a peer-to-peer (P2P) manner, without the involvement of intermediaries.

This means there MUST NOT be any pEp-specific central services whatsoever needed for pEp implementations, both in the case of verification of peers and for the actual encryption.

However, implementers of pEp MAY provide options for interoperation with providers of centralized infrastructures (e.g., to enable users to communicate with their peers on platforms with vendor lock-in).

Trust provided by global Certificate Authorities (e.g., commercial X.509 CAs) SHALL NOT be signaled as trustworthy (cf. [I-D.marques-pep-rating]) to users of pEp (e.g., when interoperating with peers using S/MIME) by default.

## 2.5. User Interaction

Implementers of pEp MUST NOT expose users to technical terms and views, especially those specific to cryptography, like "keys", "certificates", or "fingerprints". Users may explicitly opt-in to see such terms wanting seeking for more options; i.e., advanced settings MAY be available, and in some cases, these options may be required.

The authors believe that widespread adoption of end-to-end cryptography is possible if users are not required to understand cryptography and key management. This belief forms the central goal of pEp, which is that users can simply rely on the principles of Privacy by Default.

On the other hand, to preserve usability, users MUST NOT be required to wait for cryptographic tasks such as key generation to complete before being able to use their respective message client for its default purpose. In short, pEp implementers MUST ensure that the ability to draft, send, and receive messages is always preserved, even if that means a message is sent unencrypted, in accordance with the Opportunistic Security approach outlined in [RFC7435].

In turn, pEp implementers MUST ensure that a distinguishable privacy status is clearly visible to the user, both on a per-contact as well as per-message level. This allows users to assess both the privacy level for the message and the trust level of its intended recipients before choosing to send it.

[[ \*NOTE\*: We are aware of the fact that usually UX requirements are not part of RFCs. However, in order to encourage massive adoption of secure end-to-end encryption while at the same time avoiding putting users at risk, we believe certain straightforward signaling requirements for users to be a good idea, just as it is currently done for already-popular instant messaging services. ]]

### 3. Identity System

Everyone has the right to choose how to reveal themselves to the world, both offline and online. This is an important element to maintain psychological, physical, and digital privacy. As such, pEp users MUST have the option to choose their identity, and they MUST have the ability to maintain multiple identities.

These different identities MUST NOT be externally correlatable with each other by default. On the other hand, combining different identities when such information is known MUST be supported (alias support).

#### 3.1. User

A user is a real world human being or a group of human beings. If it is a single human being, it can be called person.

A user is identified by a user ID (`user_id`). The `user_id` SHOULD be a UUID, it MAY be an arbitrary unique string.

The own user can have a `user_id` like all other users. If the own user does not have a `user_id`, then it is assigned a "`pEp_own_userId`" instead.

A user can have a default key. [[ TODO: Provide ref explaining this. ]]

#### 3.2. Address

A pEp address is a network address, e.g., an SMTP address or another Universal Resource Identifier (URI).

[[ Note: It might be necessary to introduce further addressing schemes through IETF contributions or IANA registrations, e.g., implementing pEp to bridge to popular messaging services with no URIs defined. ]]

#### 3.3. Key

A key is an OpenPGP-compatible asymmetric cryptographic key pair.

Keys in pEp are identified by the full fingerprint (`fpr`) of the public key. The fingerprint is to be obtained from the specific cryptographic service used to handle the keys. The canonical representation in pEp is upper-case hexadecimal with zero-padding and no separators or spaces.

### 3.4. Identity

An identity is a representation of a user, encapsulating how this user appears within the network of a messaging system. This representation may or may not be pseudonymous in nature.

An identity is defined by mapping a `user_id` to an address. If no `user_id` is known, it is guessed by mapping a username to an address.

An identity can have a temporary `user_id` as a placeholder until a real `user_id` is known.

In pEp a different key pair for each (e.g., email) account **MUST** be created. This allows a user to retain different identities, which are not correlated by the usage of the same key for all of those. This is beneficial in terms of privacy.

A user **MAY** have a default key; each identity a user has **MAY** have a default key (of its own). When both an Identity and the related User have a default key set, the Identity's default key **MUST** override the User's default key.

[[ TODO: Provide ref explaining this. ]]

In Appendix A.1, the definition of a pEp identity can be found according to the reference implementation by the pEp engine.

## 4. Key Management

In order to achieve the goal of widespread adoption of secure communications, key management in pEp **MUST** be automated.

### 4.1. Key Generation

A pEp implementation **MUST** ensure that cryptographic keys for every configured identity are available. If a corresponding key pair for the identity of a user is found and said identity fulfills the requirements (e.g., for email, as set out in [I-D.pep-email]), said key pair **MUST** be reused. Otherwise a new key pair **MUST** be generated. This may be carried out instantly upon its configuration.

On devices with limited processing power (e.g., mobile devices) the key generation may take more time than a user is willing to wait. If this is the case, users **SHOULD NOT** be stopped from communicating, i.e., the key generation process **SHOULD** be carried out in the background.

## 4.2. Private Keys

### 4.2.1. Storage

Private keys in pEp implementations MUST always be held on the end user's device(s): pEp implementers MUST NOT rely on private keys stored in centralized remote locations. This applies even for key storages where the private keys are protected with sufficiently long passphrases. It is considered a violation of pEp's P2P design principle to rely on centralized infrastructures (cf. Section 2.4). This also applies for pEp implementations created for applications not residing on a user's device (e.g., web-based MUAs). In such cases, pEp implementations MUST be done in a way such that the locally-held private key can neither be directly accessed nor leaked to the outside world.

[[ Note: It is particularly important that browser add-ons implementing pEp functionality do not obtain their cryptographic code from a centralized (cloud) service, as this must be considered a centralized attack vector allowing for backdoors, negatively impacting privacy. ]]

Cf. Section 6.1 for a means to synchronize private keys among different devices of the same network address in a secure manner.

### 4.2.2. Passphrase

Passphrases to protect a user's private key MUST be supported by pEp implementations, but MUST NOT be enforced by default. That is, if a pEp implementation finds a suitable (i.e., secure enough) cryptographic setup, which uses passphrases, pEp implementations MUST provide a way to unlock the key. However, if a new key pair is generated for a given identity, no passphrase MUST be put in place. The authors assume that the enforcement of secure (i.e., unique and long enough) passphrases would massively reduce the number of pEp users (by hassling them), while providing little to no additional privacy for the common cases of passive monitoring being carried out by corporations or state-level actors.

## 4.3. Key Reset

### 4.4. Public Key Distribution

As the key is available (cf. Section 4.1) implementers of pEp are REQUIRED to ensure that the identity's public key is attached to every outgoing message. However, this MAY be omitted if the peer has previously received a message encrypted with the public key of the sender.



The sender's public key SHOULD be sent encrypted whenever possible, i.e., when a public key of the receiving peer is available. If no encryption key of the recipient is available, the sender's public key MAY be sent unencrypted. In either case, this approach ensures that messaging clients (e.g., MUAs that at least implement OpenPGP) do not need to have pEp implemented to see a user's public key. Such peers thus have the chance to (automatically) import the sender's public key.

If there is already a known public key from the sender of a message and it is still valid and not expired, new keys MUST NOT be used for future communication unless they are signed by the previous key (to avoid a MITM attack). Messages MUST always be encrypted with the receiving peer's oldest public key, as long as it is valid and not expired.

#### 4.4.1. UX Considerations

Implementers of pEp SHALL prevent the display of public keys attached to messages (e.g, in email) to the user in order to prevent user confusion by files they are potentially unaware of how to handle.

#### 4.4.2. No addition of unnecessary metadata

Metadata, such as email headers, MUST NOT be added in order to announce a user's public key. This is considered unnecessary information leakage, may affect user privacy, and may be subject to a country's data retention laws (cf. Section 2.2). Furthermore, this may affect interoperability to existing users that have no knowledge of such header fields, such as users of OpenPGP in email, and lose the ability to import any keys distributed in this way as a result. The ability to extract and receive public keys from such metadata SHOULD be supported, however, in the event these approaches become widespread.

#### 4.4.3. No centralized public key storage or retrieval by default

Keyservers or generally intermediate approaches to obtain a peer's public key SHALL NOT be used by default. On the other hand, the user MAY be provided with the option to opt-in for remote locations to obtain keys, considering the widespread adoption of such approaches for key distribution.

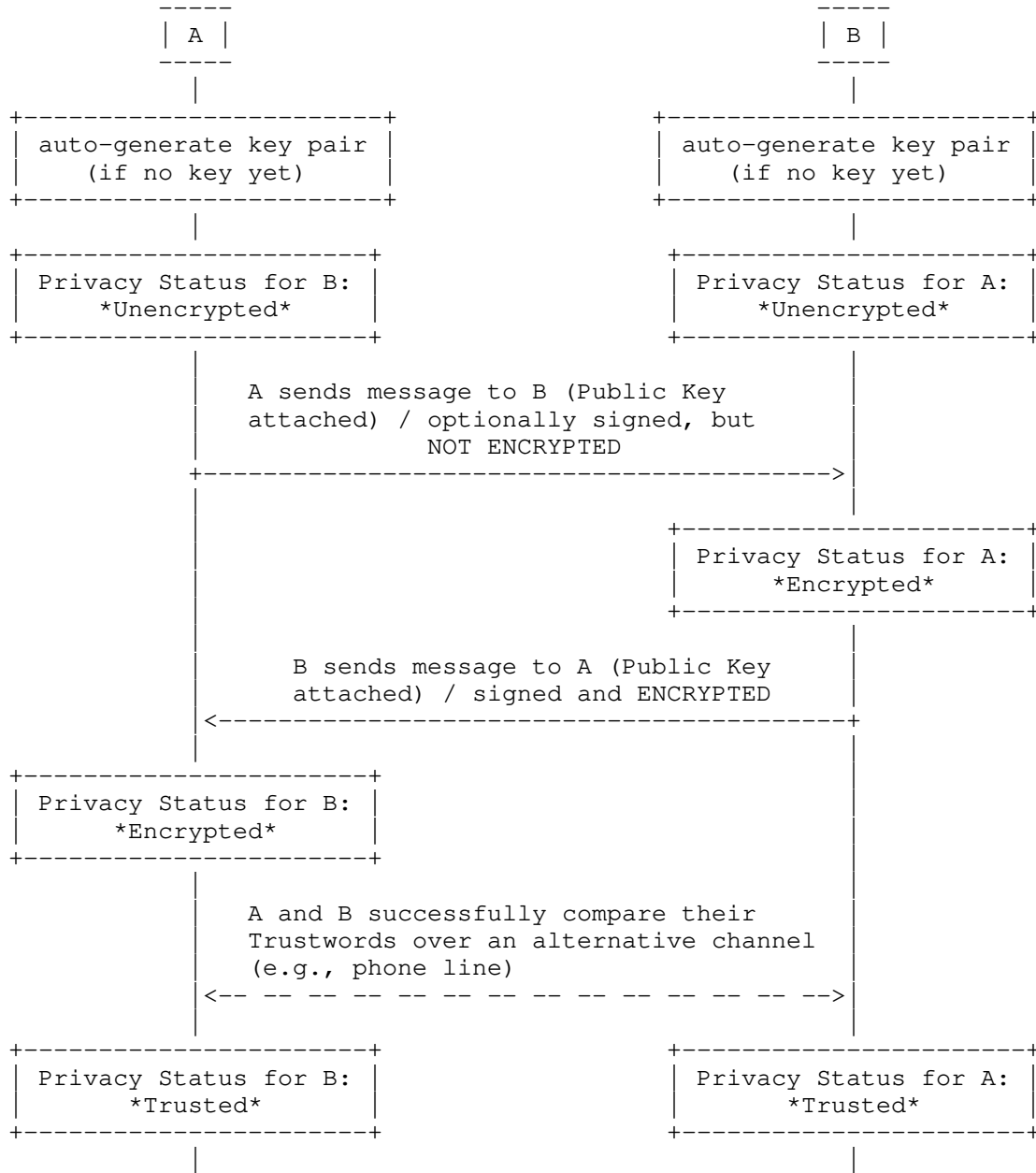
Keys generated or obtained by pEp clients MUST NOT be uploaded to any (intermediate) keystore locations without the user's explicit consent.

#### 4.4.4. Example message flow

The following example roughly describes a pEp scenario with a typical initial message flow to demonstrate key exchange and basic trust management:

The following example describes a pEp scenario between two users - Alice and Bob - in order to demonstrate the message flow that occurs when exchanging keys and determining basic trust management for the first time:

1. Alice - knowing nothing of Bob - sends a message to Bob. As Alice has no public key from Bob, this message is sent out unencrypted. However, Alice's public key is automatically attached.
2. Bob receives Alice's message and her public key. He is able to reply to her and encrypt the message. His public key is automatically attached to the message. Because he has her public key now, Alice's rating in his message client changes to 'encrypted'. From a UX perspective, this status is displayed in yellow (cf. Section 5.3).
3. Alice receives Bob's key. As of now Alice is also able to send secure messages to Bob. The rating for Bob changes to "encrypted" (with yellow color) in Alice's messaging client (cf. Section 5.3).
4. Alice receives Bob's reply with his public key attached. Now, Alice can send secure messages to Bob as well. The rating for Bob changes to yellow, or 'encrypted', in Alice's messaging client Section 5.3.
5. If Alice and Bob want to prevent man-in-the-middle (MITM) attacks, they can engage in a pEp Handshake comparing their so-called Trustwords (cf. Section 5.2) and confirm this process if those match. After doing so, their identity rating changes to "encrypted and authenticated" (cf. Section 5.3), which (UX-wise) can be displayed using a green color. See also Section 5.
6. Alice and Bob can encrypt now, but they are not yet authenticated, leaving them vulnerable to man-in-the-middle (MitM) attacks. To prevent this from occurring, Alice and Bob can engage in a pEp Handshake to compare their Trustwords (cf. Section 5.2) and confirm if they match. After this step is performed, their respective identity ratings change to "encrypted and authenticated", which is represented by a green color (cf. Section 5).



#### 4.5. Key Reset

[[ TODO: This section will explain how to deal with invalid keys, e.g., if expired or (potentially) leaked. ]]

### 5. Trust Management

[[ TODO: Intro ]]

#### 5.1. Privacy Status

The trust status for an identity can change due to a number of factors. These shifts will cause the color code assigned to this identity to change accordingly, and is applied to future communications with this identity.

For end-users, the most important component of pEp, which MUST be made visible on a per-recipient and per-message level, is the Privacy Status.

By colors, symbols and texts a user SHALL immediately understand how private

- o a communication channel with a given peer was or ought to be and
- o a given message was or ought to be.

#### 5.2. Handshake

To establishing trust between peers and to upgrade Privacy Status, pEp defines a handshake, which is specified in [I-D.marques-pep-handshake].

In pEp, Trustwords [I-D.birk-pep-trustwords] are used for users to compare the authenticity of peers in order to mitigate MITM attacks.

By default, Trustwords MUST be used to represent two peers' fingerprints of their public keys in pEp implementations.

In order to retain compatibility with peers not using pEp implementations (e.g., Mail User Agents (MUAs) with OpenPGP implementations without Trustwords), it is REQUIRED that pEp implementers give the user the choice to show both peers' fingerprints instead of just their common Trustwords.

### 5.3. Trust Rating

pEp includes a Trust Rating system defining Rating and Color Codes to express the Privacy Status of a peer or message [I-D.marques-pep-rating]. The ratings are labeled, e.g., as "Unencrypted", "Encrypted", "Trusted", "Under Attack", etc. The Privacy Status in its most general form is expressed with traffic lights semantics (and respective symbols and texts), whereas the three colors yellow, green and red can be applied for any peer or message - like this immediately indicating how secure and trustworthy (and thus private) a communication was or ought to be considered.

The pEp Trust Rating system with all its states and respective representations to be followed is outlined in [I-D.marques-pep-rating].

Note: An example for the rating of communication types, the definition of the data structure by the pEp Engine reference implementation is provided in Appendix A.2.

### 5.4. Trust Revoke

[[ TODO: This section will explain how to deal with the situation when a peer can no longer be trusted, e.g., if a peer's device is compromised. ]]

## 6. Synchronization

An important feature of pEp is to assist the user to run pEp applications on different devices, such as personal computers, mobile phones and tablets, at the same time. Therefore, state needs to be synchronized among the different devices.

### 6.1. Private Key Synchronization

The pEp KeySync protocol (cf. [I-D.hoeneisen-pep-keysync]) is a decentralized proposition which defines how pEp users can distribute their private keys among their different devices in a user-authenticated manner. This allows users to read their messages across their various devices, as long as they share a common address, such as an email account.

### 6.2. Trust Synchronization

[[ TODO: This section will explain how trust and other related state is synchronized among different devices in a user-authenticated manner. ]]

## 7. Interoperability

pEp aims to be interoperable with existing applications designed to enable privacy, e.g., OpenPGP and S/MIME in email.

## 8. Options in pEp

In this section a non-exhaustive selection of options is provided.

### 8.1. Option "Passive Mode"

By default, the sender attaches its public key to any outgoing message (cf. Section 4.4). For situations where a sender wants to ensure that it only attaches a public key to an Internet user which has a pEp implementation, a Passive Mode MUST be made available.

### 8.2. Option "Disable Protection"

Using this option, protection can be disabled generally or selectively. Implementers of pEp MUST provide an option "Disable Protection" to allow a user to disable encryption and signing for:

1. all communication
2. specific contacts
3. specific messages

The public key still attached, unless the option "Passive Mode" (cf. Section 8.1) is activated at the same time.

### 8.3. Option "Extra Keys"

#### 8.3.1. Use Case for Organizations

For internal or enterprise environments, authorized personnel may need to centrally decrypt user messages for archival or other legal purposes. Therefore, pEp implementers MAY provide an "Extra Keys" option in which a message is encrypted with at least one additional public key. The corresponding secret key(s) are intended to be secured by CISO staff or other authorized personnel for the organization.

However, it is crucial that the "Extra Keys" feature MUST NOT be activated by default for any network address, and is intended to be an option used only for organization-specific identities, as well as their corresponding network addresses and accounts. The "Extra Keys"

feature SHOULD NOT be applied to the private identities, addresses, or accounts a user might possess once it is activated.

#### 8.3.2. Use Case for Key Synchronization

The "Extra Keys" feature also plays a role during pEp's KeySync protocols, where the additional keys are used to decipher message transactions by both parties involved during the negotiation process for private key synchronization. During the encrypted (but untrusted) transactions, KeySync messages are not just encrypted with the sending device's default key, but also with the default keys of both parties involved in the synchronization process.

#### 8.4. Option "Blacklist Keys"

A "Blacklist Keys" option MAY be provided for an advanced user, allowing them to disable keys of peers that they no longer want to use in new communications. However, the keys SHALL NOT be deleted. It MUST still be possible to verify and decipher past communications that used these keys.

### 9. Security Considerations

By attaching the sender's public key to outgoing messages, Trust on First Use (TOFU) is established. However, this is prone to MITM attacks. Cryptographic key subversion is considered Pervasive Monitoring (PM) according to [RFC7258]. Those attacks can be mitigated, if the involved users compare their common Trustwords. This possibility MUST be made easily accessible to pEp users in the user interface implementation. If for compatibility reasons (e.g., with OpenPGP users) no Trustwords can be used, then a comparatively easy way to verify the respective public key fingerprints MUST be implemented.

As the use of passphrases for private keys is not advised, devices themselves SHOULD use encryption.

### 10. Privacy Considerations

[[ TODO ]]

### 11. IANA Considerations

This document has no actions for IANA.

## 12. Implementation Status

### 12.1. Introduction

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC7942], "[...] this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit."

### 12.2. Current software implementations of pEp

The following software implementations of the pEp protocols (to varying degrees) already exists:

- o pEp for Outlook as add-on for Microsoft Outlook, release [SRC.pepforoutlook]
- o pEp for iOS (implemented in a new MUA), release [SRC.pepforios]
- o pEp for Android (based on a fork of the K9 MUA), release [SRC.pepforandroid]
- o pEp for Thunderbird as a new add-on for Thunderbird, beta [SRC.pepforthunderbird]
- o Enigmail/pEp as add-on for Mozilla Thunderbird, release (will be discontinued late 2020/early 2021) [SRC.enigmailpep]

pEp for Android, iOS, Outlook and Thunderbird are provided by pEp Security, a commercial entity specializing in end-user pEp implementations while Enigmail/pEp is pursued as community project, supported by the pEp Foundation.



All software is available as Free and Open Source Software and published also in source form.

### 12.3. Reference implementation of pEp's core

The pEp Foundation provides a reference implementation of pEp's core principles and functionalities, which go beyond the documentation status of this Internet-Draft. [SRC.pepcore]

pEp's reference implementation is composed of pEp Engine and pEp Adapters (or bindings), alongside with some libraries which pEp Engine relies on to function on certain platforms (like a NetPGP fork we maintain for the iOS platform).

The pEp engine is a Free Software library encapsulating implementations of:

- o Key Management

Key Management in pEp engine is based on GnuPG key chains (NetPGP on iOS). Keys are stored in an OpenPGP compatible format and can be used for different crypto implementations.

- o Trust Rating

pEp engine is sporting a two phase trust rating system. In phase one there is a rating based on channel, crypto and key security named "comm\_types". In phase 2 these are mapped to user representable values which have attached colors to present them in traffic light semantics.

- o Abstract Crypto API

The Abstract Crypto API is providing functions to encrypt and decrypt data or full messages without requiring an application programmer to understand the different formats and standards.

- o Message Transports

pEp engine will support a growing list of Message Transports to support any widespread text messaging system including email, SMS, XMPP and many more.

pEp engine is written in C99 programming language. It is not meant to be used in application code directly. Instead, pEp engine is coming together with a list of software adapters for a variety of programming languages and development environments, which are:

- o pEp COM Server Adapter
- o pEp JNI Adapter
- o pEp JSON Adapter
- o pEp ObjC (and Swift) Adapter
- o pEp Python Adapter
- o pEp Qt Adapter

#### 12.4. Abstract Crypto API examples

A selection of code excerpts from the pEp Engine reference implementation (encrypt message, decrypt message, and obtain trustwords) can be found in Appendix A.3.

#### 13. Notes

The pEp logo and "pretty Easy privacy" are registered trademarks owned by the non-profit pEp Foundation based in Switzerland.

Primarily, we want to ensure the following:

- o Software using the trademarks MUST be backdoor-free.
- o Software using the trademarks MUST be accompanied by a serious (detailed) code audit carried out by a reputable third-party, for any proper release.

The pEp Foundation will help to support any community-run (non-commercial) project with the latter, be it organizationally or financially.

Through this, the foundation wants to make sure that software using the pEp trademarks is as safe as possible from a security and privacy point of view.

#### 14. Acknowledgments

The authors would like to thank the following people who provided substantial contributions, helpful comments or suggestions for this document: Alexey Melnikov, Athena Schumacher, Ben Campbell, Brian Trammell, Bron Gondwana, Claudio Luck, Daniel Kahn Gillmor, Enrico Tomae, Eric Rescorla, Gabriele Lenzini, Hans-Peter Dittler, Iraklis Symeonidis, Kelly Bristol, Krista Bennett, Mirja Kuehlewind, Nana

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This work was initially created by pEp Foundation, and then reviewed and extended with funding by the Internet Society's Beyond the Net Programme on standardizing pEp. [ISOC.bnet]

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## [ISOC.bnet]

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[RFC1122] Braden, R., Ed., "Requirements for Internet Hosts - Communication Layers", STD 3, RFC 1122, DOI 10.17487/RFC1122, October 1989, <<https://www.rfc-editor.org/info/rfc1122>>.

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## [SRC.enigmailpep]

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## [SRC.pepcore]

"Core source code and reference implementation of pEp (engine and adapters)", July 2018, <<https://pep.foundation/dev/>>.

## [SRC.pepforandroid]

"Source code for pEp for Android", November 2020, <<https://pep-security.lu/gitlab/android/pep>>.

```
[SRC.pepforios]
    "Source code for pEp for iOS", November 2020,
    <https://pep-security.ch/dev/repos/pEp\_for\_iOS/>.

[Src.pepforoutlook]
    "Source code for pEp for Outlook", November 2020,
    <https://pep-security.lu/dev/repos/pEp\_for\_Outlook/>.

[Src.pepforthunderbird]
    "Source code for pEp for Thunderbird", November 2020,
    <https://pep-security.lu/dev/repos/pEp\_for\_Thunderbird/>.
```

## Appendix A. Code Excerpts

This section provides excerpts of the running code from the pEp reference implementation pEp engine (C99 programming language).

### A.1. pEp Identity

How the pEp identity is defined in the data structure (cf. `src/pEpEngine.h`):

```
typedef struct _pEp_identity {
    char *address;           // C string with address UTF-8 encoded
    char *fpr;              // C string with fingerprint UTF-8
                           // encoded
    char *user_id;          // C string with user ID UTF-8 encoded
    char *username;         // C string with user name UTF-8
                           // encoded
    PEP_comm_type comm_type; // type of communication with this ID
    char lang[3];           // language of conversation
                           // ISO 639-1 ALPHA-2, last byte is 0
    bool me;                // if this is the local user
                           // herself/himself
    identity_flags_t flags; // identity_flag1 | identity_flag2
                           // | ...
} pEp_identity;
```

#### A.1.1. Corresponding SQL

Relational table scheme excerpts (in SQL) used in current pEp implementations, held locally for every pEp installation in a SQLite database:

```
CREATE TABLE person (  
  id text primary key,  
  username text not null,  
  main_key_id text  
    references pgp_keypair (fpr)  
    on delete set null,  
  lang text,  
  comment text,  
  device_group text,  
  is_pep_user integer default 0  
);  
  
CREATE TABLE identity (  
  address text,  
  user_id text  
    references person (id)  
    on delete cascade on update cascade,  
  main_key_id text  
    references pgp_keypair (fpr)  
    on delete set null,  
  comment text,  
  flags integer default 0,  
  is_own integer default 0,  
  timestamp integer default (datetime('now')),  
  primary key (address, user_id)  
);  
  
CREATE TABLE pgp_keypair (  
  fpr text primary key,  
  created integer,  
  expires integer,  
  comment text,  
  flags integer default 0  
);  
CREATE INDEX pgp_keypair_expires on pgp_keypair (  
  expires  
);
```

## A.2. pEp Communication Type

In the following, is an example for the rating of communication types as defined by a data structure (cf. `src/pEpEngine.h` [`SRC.pepcore`]):

```
typedef enum _PEP_comm_type {  
  PEP_ct_unknown = 0,  
  
  // range 0x01 to 0x09: no encryption, 0x0a to 0x0e:  
  // nothing reasonable
```

```
PEP_ct_no_encryption = 0x01, // generic
PEP_ct_no_encrypted_channel = 0x02,
PEP_ct_key_not_found = 0x03,
PEP_ct_key_expired = 0x04,
PEP_ct_key_revoked = 0x05,
PEP_ct_key_b0rken = 0x06,
PEP_ct_my_key_not_included = 0x09,

PEP_ct_security_by_obscurity = 0x0a,
PEP_ct_b0rken_crypto = 0x0b,
PEP_ct_key_too_short = 0x0c,

PEP_ct_compromized = 0x0e, // known compromised connection
PEP_ct_mistrusted = 0x0f, // known mistrusted key

// range 0x10 to 0x3f: unconfirmed encryption

PEP_ct_unconfirmed_encryption = 0x10, // generic
PEP_ct_OpenPGP_weak_unconfirmed = 0x11, // RSA 1024 is weak

PEP_ct_to_be_checked = 0x20, // generic
PEP_ct_SMIME_unconfirmed = 0x21,
PEP_ct_CMS_unconfirmed = 0x22,

PEP_ct_strong_but_unconfirmed = 0x30, // generic
PEP_ct_OpenPGP_unconfirmed = 0x38, // key at least 2048 bit
                                // RSA or EC
PEP_ct_OTR_unconfirmed = 0x3a,

// range 0x40 to 0x7f: unconfirmed encryption and anonymization

PEP_ct_unconfirmed_enc_anon = 0x40, // generic
PEP_ct_pEp_unconfirmed = 0x7f,

PEP_ct_confirmed = 0x80, // this bit decides if trust
                        // is confirmed

// range 0x81 to 0x8f: reserved
// range 0x90 to 0xbf: confirmed encryption

PEP_ct_confirmed_encryption = 0x90, // generic
PEP_ct_OpenPGP_weak = 0x91, // RSA 1024 is weak (unused)

PEP_ct_to_be_checked_confirmed = 0xa0, //generic
PEP_ct_SMIME = 0xa1,
PEP_ct_CMS = 0xa2,

PEP_ct_strong_encryption = 0xb0, // generic
```

```
PEP_ct_OpenPGP = 0xb8, // key at least 2048 bit RSA or EC
PEP_ct_OTR = 0xba,

// range 0xc0 to 0xff: confirmed encryption and anonymization

PEP_ct_confirmed_enc_anon = 0xc0, // generic
PEP_ct_pEp = 0xff
} PEP_comm_type;
```

### A.3. Abstract Crypto API examples

The following code excerpts are from the pEp Engine reference implementation, to be found in `src/message_api.h`.

```
[[ Note: Just a selection; more functionality is available. ]]
```

#### A.3.1. Encrypting a Message

Cf. `src/message_api.h` [SRC.pepcore]:



```
// encrypt_message() - encrypt message in memory
//
// parameters:
//   session (in)    session handle
//   src (in)       message to encrypt
//   extra (in)     extra keys for encryption
//   dst (out)      pointer to new encrypted message or NULL if
//                 no encryption could take place
//   enc_format (in) encrypted format
//   flags (in)     flags to set special encryption features
//
// return value:
//   PEP_STATUS_OK           on success
//   PEP_KEY_HAS_AMBIG_NAME at least one of the recipient
//                           keys has an ambiguous name
//   PEP_UNENCRYPTED        no recipients with usable key,
//                           message is left unencrypted,
//                           and key is attached to it
//
// caveat:
//   the ownership of src remains with the caller
//   the ownership of dst goes to the caller
DYNAMIC_API PEP_STATUS encrypt_message(
    PEP_SESSION session,
    message *src,
    stringlist_t *extra,
    message **dst,
    PEP_enc_format enc_format,
    PEP_encrypt_flags_t flags
);
```

Cf. src/message\_api.h [SRC.pepcore]:

### A.3.2. Decrypting a Message

Cf. src/message\_api.h [SRC.pepcore]:

```
// decrypt_message() - decrypt message in memory
//
// parameters:
//   session (in)    session handle
//   src (in)       message to decrypt
//   dst (out)      pointer to new decrypted message
//                 or NULL on failure
//   keylist (out)  stringlist with keyids
//   rating (out)   rating for the message
//   flags (out)    flags to signal special decryption features
//
```

```
// return value:
//   error status
//   or PEP_DECRYPTED if message decrypted but not verified
//   or PEP_CANNOT_REENCRYPT if message was decrypted (and
//   possibly verified) but a reencryption operation is
//   expected by the caller and failed
//   or PEP_STATUS_OK on success
//
// flag values:
//   in:
//     PEP_decrypt_flag_untrusted_server
//       used to signal that decrypt function should engage in
//       behaviour specified for when the server storing the
//       source is untrusted
//   out:
//     PEP_decrypt_flag_own_private_key
//       private key was imported for one of our addresses
//       (NOT trusted or set to be used - handshake/trust is
//       required for that)
//     PEP_decrypt_flag_src_modified
//       indicates that the src object has been modified. At
//       the moment, this is always as a direct result of the
//       behaviour driven by the input flags. This flag is the
//       ONLY value that should be relied upon to see if such
//       changes have taken place.
//     PEP_decrypt_flag_consume
//       used by sync
//     PEP_decrypt_flag_ignore
//       used by sync
//
// caveat:
//   the ownership of src remains with the caller - however, the
//   contents might be modified (strings freed and allocated anew
//   or set to NULL, etc) intentionally; when this happens,
//   PEP_decrypt_flag_src_modified is set.
//   the ownership of dst goes to the caller
//   the ownership of keylist goes to the caller
//   if src is unencrypted this function returns PEP_UNENCRYPTED
//   and sets
//   dst to NULL
DYNAMIC_API PEP_STATUS decrypt_message(
    PEP_SESSION session,
    message *src,
    message **dst,
    stringlist_t **keylist,
    PEP_rating *rating,
    PEP_decrypt_flags_t *flags
```

```
);
```

### A.3.3. Obtain Common Trustwords

Cf. `src/message_api.h` [SRC.pepcore]:

```
// get_trustwords() - get full trustwords string
//                    for a *pair* of identities
//
// parameters:
//   session (in)  session handle
//   id1 (in)     identity of first party in communication
//                - fpr can't be NULL
//   id2 (in)     identity of second party in communication
//                - fpr can't be NULL
//   lang (in)    C string with ISO 639-1 language code
//   words (out)  pointer to C string with all trustwords
//                UTF-8 encoded, separated by a blank each
//                NULL if language is not supported or
//                trustword wordlist is damaged or unavailable
//   wsize (out)  length of full trustwords string
//   full (in)    if true, generate ALL trustwords for these
//                identities.
//                else, generate a fixed-size subset.
//                (TODO: fixed-minimum-entropy subset
//                in next version)
//
// return value:
//   PEP_STATUS_OK           trustwords retrieved
//   PEP_OUT_OF_MEMORY      out of memory
//   PEP_TRUSTWORD_NOT_FOUND at least one trustword not found
//
// caveat:
//   the word pointer goes to the ownership of the caller
//   the caller is responsible to free() it
//   (on Windoze use pEp_free())
//
DYNAMIC_API PEP_STATUS get_trustwords(
    PEP_SESSION session, const pEp_identity* id1,
    const pEp_identity* id2, const char* lang,
    char **words, size_t *wsize, bool full
);
```

## Appendix B. Document Changelog

[[ RFC Editor: This section is to be removed before publication ]]

- o draft-birk-pep-06:

- \* Minor changes
- o draft-birk-pep-05:
  - \* Change authors
  - \* Minor changes, especially in identity system
- o draft-birk-pep-04:
  - \* Fix internal reference
  - \* Add IANA Considerations section
  - \* Add other use case of Extra Keys
  - \* Add Claudio Luck as author
  - \* Incorporate review changes by Kelly Bristol and Nana Karlstetter
- o draft-birk-pep-03:
  - \* Major restructure of the document
  - \* Adapt authors to the actual authors and extend Acknowledgments section
  - \* Added several new sections, e.g., Key Reset, Trust Revoke, Trust Synchronization, Private Key Export / Import, Privacy Considerations (content yet mostly TODO)
  - \* Added reference to HRPC work / RFC8280
    - + Added text and figure to better explain pEp's automated Key Exchange and Trust management (basic message flow)
  - \* Lots of improvement in text and editorial changes
- o draft-birk-pep-02:
  - \* Move (updated) code to Appendix
  - \* Add Changelog to Appendix
  - \* Add Open Issue section to Appendix
  - \* Fix description of what Extra Keys are

- \* Fix Passive Mode description
- \* Better explain pEp's identity system
- o draft-birk-pep-01:
  - \* Mostly editorial
- o draft-birk-pep-00:
  - \* Initial version

#### Appendix C. Open Issues

[[ RFC Editor: This section should be empty and is to be removed before publication ]]

- o Shorten Introduction and Abstract
- o References to RFC6973 (Privacy Considerations)
- o Add references to prior work, and what differs here - PEM (cf. RFC1421-1424)
- o Better explain Passive Mode
- o Better explain / illustrate pEp's identity system
- o Explain Concept of Key Mapping (e.g. to S/MIME, which is to be refined in pEp application docs such as pEp email [I-D.pep-email])
- o Add more information to deal with organizational requirements
- o Add text to Key Reset (Section 4.3) as well as reference as soon as available
- o Add text to Trust Revoke (Section 5.4) as well as reference as soon as available
- o Add text to Trust Synchronization (Section 6.2) as well as reference as soon as available
- o Add text to Privacy Considerations (Section 10)
- o Scan for leftovers of email-specific stuff and move it to pEp email I-D [I-D.pep-email], while replacing it herein with generic descriptions.

Authors' Addresses

Volker Birk  
pEp Foundation  
Oberer Graben 4  
CH-8400 Winterthur  
Switzerland

Email: [volker.birk@pep.foundation](mailto:volker.birk@pep.foundation)  
URI: <https://pep.foundation/>

Hernani Marques  
pEp Foundation  
Oberer Graben 4  
CH-8400 Winterthur  
Switzerland

Email: [hernani.marques@pep.foundation](mailto:hernani.marques@pep.foundation)  
URI: <https://pep.foundation/>

Bernie Hoeneisen  
pEp Foundation  
Oberer Graben 4  
CH-8400 Winterthur  
Switzerland

Email: [bernie.hoeneisen@pep.foundation](mailto:bernie.hoeneisen@pep.foundation)  
URI: <https://pep.foundation/>

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V. Birk  
H. Marques  
pEp Foundation  
B. Hoeneisen  
Ucom.ch  
Feb 22, 2018

pretty Easy privacy (pEp): Trustwords concept  
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## Abstract

In public-key cryptography comparing the public keys' fingerprints of the communication partners involved is vital to ensure that there is no man-in-the-middle (MITM) attack on the communication channel. Fingerprints normally consist of a chain of hexadecimal chars. However, comparing hexadecimal strings is often impractical for regular users and prone to misunderstandings.

To mitigate these challenges, this memo proposes the comparison of trustwords as opposed to hexadecimal strings. Trustwords are common words in a natural language (e.g., English) to which the hexadecimal strings are mapped to. This makes the verification process more natural.

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1. Introduction

In public-key cryptography comparing the public keys’ fingerprints of the communication partners involved is vital to ensure that there is no man-in-the-middle (MITM) attack on the communication channel. Fingerprints normally consist of a chain of hexadecimal chars. However, comparing hexadecimal strings is often impractical for regular users and prone to misunderstandings.

To mitigate these challenges, this memo proposes the comparison of trustwords as opposed to hexadecimal strings. Trustwords are common words in a natural language (e.g., English) to which the hexadecimal strings are mapped to. This makes the verification process more natural.

Trustwords are used to achieve easy contact verification in pEp’s proposition of Privacy by Default [pEp] for end-to-end encryption situations after the peers have exchanged public keys opportunistically.

Trustwords may also be used for purposes other than contact verification.



## 2. Terms

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

## 3. The Concept of Trustword Mapping

## 4. Example

A fingerprint typically looks like:

```
F482 E952 2F48 618B 01BC 31DC 5428 D7FA ACDC 3F13
```

Its mapping to trustwords looks like:

```
dog house brother town fat bath school banana kite task
```

[[Actual mapping for English should be used here and perhaps an example for another language.]]

Instead of the former hexadecimal string, users can compare ten common words of their language.

## 5. Previous work

The basic concept of trustwork mapping has been already documented in the past, e.g. for use in One-Time Passwords (OTP) [RFC2289] or the PGP Word List ("Pretty Good Privacy word list" [PGPwordlist], also called a biometric word list, to compare fingerprints.

## 6. Number of Trustwords for a language

Previous proposals have the shortcoming of a limited number of trustwords and they are usually only available in English. If the number of trustwords is low, a lot of trustworks need to be compared, which make a comparison somewhat cumbersome for users, i.e. leads to degraded usability. To reduce the number of trustwords to compare, 16-bit scalars are mapped to natural language words. Therefore, the size (by number of key--value pairs) of any key--value pair structure MUST be 65536, the keys being the enumeration of the Trustwords (starting at 0) and the values being individual natural language words in the respective language.

However, the number of unique values to be used in a language may be less than 65536. This can be addressed e.g. by using the same value (trustword) for more than one key. However, the entropy of the representation is slightly reduced.

Example. A Trustwords list of just 42000 words still allows for an entropy of  $\log_2(42000) \approx 15.36$  bits in 16-bit mappings.

It is for further study, what minimal number of words (or entropy) should be required.

#### 7. The nature of the words

Every Trustwords list SHOULD be cleared from swearwords in order to not offend users. This is a task to be carried out by speakers of the respective natural language.

#### 8. IANA Considerations

Each natural language requires a different set of trustwords. To allow implementors for identical trustword lists, a IANA registry is to be established. The IANA registration policy according to [RFC8126] will likely be "Expert Review" and "Specification Required".

An IANA registration will contain:

- o language code according to ISO 639-3
- o version number
- o list of up to 65536 trustwords

The details of the IANA registry and requirements for the expert to assess the specification are for further study.

#### 9. Security Considerations

There are no special security considerations.

#### 10. Acknowledgements

This work was initially created by pEp Foundation, and then reviewed and extended with funding by the Internet Society's Beyond the Net Programme on standardizing pEp. [bnet]

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Authors' Addresses

Volker Birk  
pEp Foundation

Email: [vb@peg-project.org](mailto:vb@peg-project.org)

Hernani Marques  
pEp Foundation

Email: [hernani.marques@peg.foundation](mailto:hernani.marques@peg.foundation)

Bernie Hoeneisen  
Ucom Standards Track Solutions GmbH

Email: [bernie@ietf.hoeneisen.ch](mailto:bernie@ietf.hoeneisen.ch) (bernhard.hoeneisen AT ucom.ch)  
URI: <http://www.ucom.ch/>

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B. Hoeneisen  
H. Marques  
pEp Foundation  
January 09, 2020

IANA Registration of Trustword Lists: Guide, Template and IANA  
Considerations  
draft-birk-peg-trustwords-05

Abstract

This document specifies the IANA Registration Guidelines for Trustwords, describes corresponding registration procedures, and provides a guideline for creating Trustword list specifications.

Trustwords are common words in a natural language (e.g., English), which hexadecimal strings are mapped to. Such a mapping makes verification processes like fingerprint comparisons more practical, and less prone to misunderstandings.

Status of This Memo

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## 1. Introduction

In public-key cryptography, comparing the respective public key fingerprints for each of the communication partners involved is vital to ensure that there is no Man-in-the-Middle (MITM) attack on the communication channel. These fingerprints normally consist of a chain of hexadecimal characters, which are often impractical, cumbersome, and prone to misunderstandings for end-users.

To mitigate these challenges, several systems offer Trustword comparison as an alternative to these hexadecimal strings. Trustwords are common words in a natural language (e.g., English), which these hexadecimal strings are mapped to. Using Trustwords makes verification processes like fingerprint comparisons more natural for users.

For example, in pEp's Privacy by Default proposition [I-D.birk-pep] Trustwords are used to facilitate easy contact verification for end-to-end encryption. Trustword comparison is offered after the peers have opportunistically exchanged public keys. Examples of Trustword lists used by current pEp implementations can be found here in CSV format: <https://pep.foundation/dev/repos/pEpEngine/file/tip/db>.

In addition to contact verification, Trustwords are also used for other purposes, such as Human-Readable 128-bit Keys [RFC1751], One Time Passwords (OTP) [RFC1760] [RFC2289], SSH host-key verification, VPN server certificate verification, deriving private keys in blockchain applications for cryptocurrencies, and to import or synchronize secret keys across multiple devices owned by a single user [I-D.pep-keysync]. Further ideas include the use of Trustwords for private key recovery in case of loss, contact verification in Extensible Messaging and Presence Protocol (XMPP) [RFC6120], or for X.509 certificate verification in browsers [RFC3647].

### 1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

### 1.2. Terms

The following terms are defined for the scope of this document:

- o pEp Handshake: The process of one user contacting another over an independent channel in order to verify Trustwords (or fingerprints as a fallback). This can be done in-person or through established verbal communication channels, like a phone call.  
[I-D.marques-pep-handshake]
- o Man-in-the-middle (MITM) attack: cf. [RFC4949], which states: "A form of active wiretapping attack in which the attacker intercepts and selectively modifies communicated data to masquerade as one or more of the entities involved in a communication association."

## 2. The Concept of Trustword Mapping

### 2.1. Example

As already discussed, fingerprints normally consist of a string of hexadecimal characters. A typical fingerprint looks like this:

```
F482 E952 2F48 618B 01BC 31DC 5428 D7FA ACDC 3F13
```

Instead of the hexadecimal string, Trustwords allow users to compare ten common words of a language of their choosing. For example, the above fingerprint, mapped to English Trustwords, might appear as:

```
dog house brother town fat bath school banana kite task
```

The same fingerprint might appear in German Trustwords as:

```
klima gelb lappen weg trinken alles kaputt rasen rucksack durch
```

Note: These examples are for illustration purposes only, and are not derived from any published Trustword list.

### 2.2. Previous work

The basic concept of Trustword mapping - also known as a biometric word list - for fingerprint comparison is well-documented. Examples of this concept are used with One-Time Passwords (OTP) [RFC1751] [RFC1760] [RFC2289], as well as the PGP Word List ("Pretty Good Privacy word list" [PGP.wl]). Furthermore, cryptocurrencies use a similar concept for deriving private keys [bitcoin.wl].

[[ TODO: Explain each previous usage a bit further and synchronize with section Section 1. ]]

Regarding today's needs, previous proposals have the following shortcomings:

- o Small/limited word lists, which generally result in more words to compare
- o Existing word lists are usually only available in English, which limits their usefulness for non-English speakers

Furthermore, there are differences in the basic concept:

- o The Trustword concept suggested herein intends to improve usability and security for all users, instead of only the technically-savvy.



- o In many use cases, Trustwords are only read (aloud) during the comparison process, rather than being written or typed. For example, two users might compare their respective Trustwords during a phone call. Verbal comparison reduces the need to keep the actual Trustwords short. The use of longer Trustwords increases the entropy within the system, as it allows for a larger dictionary, and thus reduces the likelihood of phonetic collisions.

### 2.3. Number of Trustwords for a language

If the number of Trustwords in a dictionary is low, shorter parts of the original string (e.g., fingerprint) can be mapped to a single Trustword. Thus, many Trustwords will need to be compared, which results in a potentially cumbersome process for users, and lead to reduced usability.

To reduce the number of Trustwords that need to be compared, pEp's Privacy by Default proposition [I-D.birk-pep] calls for 16-bit scalars to be mapped to natural language words. Therefore, the size (by number of key-value pairs) of any key-value pair structure is 65536. However, the number of unique values to be used in a language may be smaller than this number. This discrepancy can be addressed by using the same value, or Trustword, for more than one key. In such cases, the entropy of the representation is slightly reduced. For example, a Trustword list of 42000 words still allows for an entropy of  $\log_2(42000)$ , which is roughly 15.36 bits in 16-bit mappings. As a consequence such Trustword lists are not bijective.

On the other hand, small Trustword lists allow for Trustwords consisting of words with shorter strings (number of short words per natural language is normally limited), which are easier to use in implementations where Trustwords have to be typed or written, such as in OTP applications.

Note: This specification allows for registration of variable numbers of Trustwords per dictionary.

### 2.4. Language

Although English is used around the world, the vast majority of the global population is not English-speaking. For an application to be useful to as wide of a user base as possible, localization is essential. Therefore, this specification allows for registration of Trustword lists in different languages.

In applications where two humans are attempting to establish secure communications, it is likely that they share a common language. At

this time, no real-world use cases for Trustword list translation capability have been identified. Because the translation process inherently - and drastically - increases complexity from an IANA registration standpoint, the topic of Trustword translation is beyond the scope of this document.

## 2.5. The nature of the words

Every Trustword list SHOULD be clear of offensive language (i.e., swear/curse words, slurs, derogatory language, etc.). This process SHOULD be performed by native speakers of each respective language.

## 3. Security Considerations

There are no specific security considerations.

## 4. Privacy Considerations

[[ TODO ]]

## 5. IANA Considerations

Each natural language requires a different set of Trustwords. To allow implementers for identical Trustword lists, a IANA registry is to be established. The IANA registration policy according to [RFC8126] is "Expert Review" and "Specification Required".

[[ Note: Further details of the IANA registry and requirements for the expert to assess the specification are for further study. A similar approach as used in [RFC6117] is likely followed. ]]

### 5.1. Registration Template (XML chunk)

```
<record>
  <languagecode>
    <!-- ISO 639-3 (e.g. eng, deu, ...) -->
  </languagecode>
  <bitsize>
    <!-- How many bits can be mapped with this list
         (e.g. 8, 16, ...) -->
  </bitsize>
  <numberofuniquewords>
    <!-- number of unique words registered
         (e.g. 256, 65536, ...) -->
  </numberofuniquewords>
  <bijjective>
    <!-- whether or not the list allows for a two-way-mapping
         (e.g. yes, no) -->
  </bijjective>
</record>
```

```
</bijective>
<version>
  <!-- version number within language
        (e.g. b.1.2, n.0.1, ...) -->
</version>
<registrationdocs>
  <!-- Change accordingly -->
  <xref type="rfc" data="rfc2551"/>
</registrationdocs>
<requesters>
  <!-- Change accordingly -->
  <xref type="person" data="John_Doe"/>
  <xref type="person" data="Jane_Dale"/>
</requesters>
<additionalinfo>
  <paragraph>
    <!-- Text with additional information about
          the Wordlist to be registered -->
  </paragraph>
  <artwork>
    <!-- There can be artwork sections, too -->
  </artwork>
</additionalinfo>
<wordlist>
  <!-- Change accordingly -->
  <w0>first</w0>
  <w1>second</w1>
  [...]
  <w65535>last</w65535>
</wordlist>
</record>

<people>
  <person id="John_Doe">
    <name> <!-- Firstname Lastname --> </name>
    <org> <!-- Organization Name --> </org>
    <uri> <!-- mailto: or http: URI --> </uri>
    <updated> <!-- date format YYYY-MM-DD --> </updated>
  </person>
  <!-- repeat person section for each person -->
</people>
```

Authors of a Wordlist are encouraged to use these XML chunks as a template to create the IANA Registration Template.

## 5.2. IANA Registration

An IANA registration will contain the following elements:

### 5.2.1. Language Code (<languagecode>)

The language code follows the ISO 639-3 specification [ISO639], e.g., eng, deu.

[[ Note: It is for further study, which of the ISO 639 Specifications is most suitable to address the Trustwords' challenge. ]]

Example usage for German:

e.g. <languagecode>deu</languagecode>

### 5.2.2. Bit Size (<bitsize>)

The bit size is the number of bits that can be mapped with the Wordlist. The number of registered words in a word list MUST be  $2^{bitsize}$ .

Example usage for 16-bit Wordlist:

e.g. <bitsize>16</bitsize>

### 5.2.3. Number Of Unique Words (<numberofuniquewords>)

The number of unique words that are registered.

e.g. <numberofuniquewords>65536</numberofuniquewords>

### 5.2.4. Bijectivity (<bijjective>)

Whether the registered Wordlist has a one-to-one mapping, meaning the number of unique words registered equals  $2^{bitsize}$ .

Valid content: ( yes | no )

e.g. <bijjective>yes</bijjective>

### 5.2.5. Version (<version>)

The version of the Wordlist MUST be unique within a language code.

[[ Note: Requirements to a "smart" composition of the version number are for further study ]]

e.g. `<version>b.1.2</version>`

#### 5.2.6. Registration Document(s) (`<registrationdocs>`)

Reference(s) to the Document(s) containing the Wordlist

e.g. `<registrationdocs>  
 <xref type="rfc" data="rfc4979"/>  
</registrationdocs>`

e.g. `<registrationdocs>  
 <xref type="rfc" data="rfc8888"/> (obsoleted by RFC 9999)  
 <xref type="rfc" data="rfc9999"/>  
</registrationdocs>`

e.g. `<registrationdocs>  
 [International Telecommunications Union,  
 "Wordlist for Foobar application",  
 ITU-F Recommendation B.193, Release 73, Mar 2009.]  
</registrationdocs>`

#### 5.2.7. Requesters (`<requesters>`)

The persons requesting the registration of the Wordlist. Usually these are the authors of the Wordlist.

e.g. `<requesters>  
 <xref type="person" data="John_Doe"/>  
</requesters>`

```
<people>  
  <person id="John_Doe">  
    <name>John Doe</name>  
    <org>Example Inc.</org>  
    <uri>mailto:john.doe@example.com</uri>  
    <updated>2018-06-20</updated>  
  </person>  
</people>
```

Note: If there is more than one requester, there must be one `<xref>` element per requester in the `<requesters>` element, and one `<person>` chunk per requester in the `<people>` element.

#### 5.2.8. Further Information (`<additionalinfo>`)

Any other information the authors deem interesting.

e.g. `<additionalinfo>`  
    `<paragraph>more info goes here</paragraph>`  
    `</additionalinfo>`

Note: If there is no such additional information, then the `<additionalinfo>` element is omitted.

#### 5.2.9. Wordlist (`<wordlist>`)

The full Wordlist to be registered. The number of words MUST be a power of 2 as specified above. The element names serve as key used for enumeration of the Trustwords (starting at 0) and the elements contains the values being individual natural language words in the respective language.

e.g. `<wordlist>`  
    `<w0>first</w0>`  
    `<w1>second</w1>`  
    `[...]`  
    `<w65535>last</w65535>`  
    `</wordlist>`

] ]>

[[ Note: The exact representation of the Wordlist is for further study. ]]

## 6. Acknowledgments

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#### Appendix A. IANA XML Template Example

This section contains a non-normative example of the IANA Registration Template XML chunk.



```
<record>
  <languagecode>lat</languagecode>
  <bitsize>16</bitsize>
  <numberofuniquewords>57337</numberofuniquewords>
  <bijective>no</bijective>
  <version>n.0.1</version>
  <registrationdocs>
    <xref type="rfc" data="rfc2551"/>
  </registrationdocs>
  <requesters>
    <xref type="person" data="Julius_Caesar"/>
  </requesters>
  <additionalinfo>
    <paragraph>
      This Wordlist has been optimized for
      the Roman Standards Process.
    </paragraph>
  </additionalinfo>
  <wordlist>
    <w0>errare</w0>
    <w1>humanum</w1>
    [...]
    <w65535>est</w65535>
  </wordlist>
</record>

<people>
  <person id="Julius_Caesar">
    <name>Julius Caesar</name>
    <org>Curia Romana</org>
    <uri>mailto:julius.cesar@example.com</uri>
    <updated>1999-12-31</updated>
  </person>
</people>
```

#### Appendix B. Document Changelog

[[ RFC Editor: This section is to be removed before publication ]]

- o draft-birk-pep-trustwords-05:
  - \* Update terms and references
- o draft-birk-pep-trustwords-04:
  - \* Add Privacy Considerations section
  - \* Swapped Security and IANA Consideration Sections

- \* Corrected typo in ISO references
- \* Updated Introduction, Terms and concept Sections
- o draft-birk-pep-trustwords-03:
  - \* Update references
  - \* Minor edits
- o draft-birk-pep-trustwords-02:
  - \* Minor editorial changes and bug fixes
  - \* Added more items to Open Issues
  - \* Add usage example
- o draft-birk-pep-trustwords-01:
  - \* Included feedback from mailing list and IETF-101 SECDISPATCH WG, e.g.
    - + Added more explanatory text / less focused on the main use case
    - + Bit size as parameter
  - \* Explicitly stated translations are out-of-scope for this document
  - \* Added draft IANA XML Registration template, considerations, explanation and examples
  - \* Added Changelog to Appendix
  - \* Added Open Issue section to Appendix

#### Appendix C. Open Issues

[[ RFC Editor: This section should be empty and is to be removed before publication. ]]

- o Better explain previous work on Trustwords
- o More explanatory text for Trustword use cases, properties and requirements

- o Further details of the IANA registry and requirements for the expert to assess the specification
- o Decide which ISO language code either 639-1 or 639-3 to use, i.e., ISO-639-1 (e.g., ca, de, en, ...) as currently used in pEp implementations (running code) or ISO-639-3 (eng, deu, ita, ...)
- o Adjust exact representation of wordlists
  - \* e.g. XML, CSV, ...
  - \* Syntax for non-ASCII letters or language symbols (UTF-8) in Wordlists
- o Need for optional entropy value assigned to words, to account for similar phonetics among words in the same wordlist?
- o Need for an additional field, to define what a wordlist is optimized for, e.g., "entropy", "minimize word lengths", ...?
- o Work out (requirements for) "smart" composition of the version number
- o Decide whether in non-bijective Wordlists the redundant words need to be repeated in the IANA Registration
- o Register only a hash over the wordlist with IANA?
- o Does it make sense to open registrations for other patterns than just words, e.g., images?

#### Authors' Addresses

Bernie Hoeneisen  
pEp Foundation  
Oberer Graben 4  
CH-8400 Winterthur  
Switzerland

Email: [bernie.hoeneisen@pep.foundation](mailto:bernie.hoeneisen@pep.foundation)  
URI: <https://pep.foundation/>

Hernani Marques  
pEp Foundation  
Oberer Graben 4  
CH-8400 Winterthur  
Switzerland

Email: [hernani.marques@pep.foundation](mailto:hernani.marques@pep.foundation)  
URI: <https://pep.foundation/>

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C. Jennings  
Cisco  
March 5, 2018

New Media Stack  
draft-jennings-dispatch-new-media-00

Abstract

A sketch of a proposal for a new media stack for interactive communications.

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

This draft proposes a new media stack to replace the existing stack RTP, DTLS-SRTP, and SDP Offer Answer. The key parts of this stack are connectivity layer, the transport layer, the media layer, a control API, and the signaling layer.

The connectivity layer uses a simplified version of ICE, called snowflake [I-D.jennings-dispatch-snowflake], to find connectivity between endpoints and change the connectivity from one address to another as different networks become available or disappear. It is based on ideas from [I-D.jennings-mmusic-ice-fix].

The transport layer uses QUIC to provide a hop by hop encrypted, congestion controlled transport of media. Although QUIC does not currently have all of the partial reliability mechanisms to make this work, this draft assumes that they will be added to QUIC.

The media layer uses existing codecs and packages them along with extra header information to provide information about, when the sequence needs to be played back, which camera it came from, and media streams to be synchronized.

The control API is an abstract API that provides a way for the media stack to report its capabilities and features and a way for the application to tell the media stack how it should be configured. Configuration includes what codec to use, size and frame rate of video, and where to send the media.

The signaling layer is based on an advertisement and proposal model. Each endpoint can create an advertisement that describes what it supports including things like supported codecs and maximum bitrates. A proposal can be sent to an endpoint that tells the endpoint exactly what media to send and receive and where to send it. The endpoint can accept or reject this proposal in total but cannot change any part of it.

## 2. Terminology

- o media stream: Stream of information from a single sensor. For example, a video stream from a single camera. A stream may have multiple encodings for example video at different resolutions.
- o encoding: A encoded version of a stream. A given stream may have several encodings at different resolutions. One encoding may depend on other encodings such as forward error corrections or in the case of scalable video codecs.
- o flow: A logical transport between two computers. Many media streams can be transported over a single flow. The actual IP address and ports used to transport data in the flow may change over time as connectivity changes.
- o message: some data or media that to be sent across the network along with metadata about it. Similar to an RTP packet.

- o media source: a camera, microphone or other source of data on an endpoint
- o media sink: a speaker, screen, or other destination for data on an endpoint
- o TLV: Tag Length Value. When used in the draft, the Tag, Length, and any integer values are coded as variable length integers similar to how this is done in CBOR.

### 3. Connectivity Layer

#### 3.1. Snowflake - New ICE

All that is needed to discover the connectivity is way to:

- o Gather some IP/ports that may work using TURN2 relay, STUN2, and local addresses.
- o A controller, which might be running in the cloud, to inform a client to send a STUN2 packet from a given source IP/port to a given destination IP/port.
- o The receiver notifies the controller about information on received STUN2 packets.
- o The controller can tell the sender the secret that was in the packet to prove consent of the receiver to receive data then the sending client can allow media to flow over that connection.

The actually algorithm used to decide on what pairs of addresses are tested and in what order does not need to be agreed on by both the sides of the call - only the controller needs to know it. This allows the controller to use machine learning, past history, and heuristics to find an optimal connection much faster than something like ICE.

The details of this approach are described in [I-D.jennings-dispatch-snowflake].

#### 3.2. STUN2

The speed of setting up a new media flow is often determined by how many STUN2 checks need to be done. If the STUN2 packets are smaller, then the stun checks can be done faster without risk of causing congestion. The STUN2 server and client share a secret that they use for authentication and encryption. When talking to a public STUN2 server this secret is the empty string.



### 3.2.1. STUN2 Request

A STUN2 request consists of the following TLVs:

- o a magic number that uniquely identifies this as a STUN2 request packet with minimal risk of collision when multiplexing.
- o a transaction ID that uniquely identifies this request and does not change in retransmissions of the same request.
- o an optional sender secret that can be used by the receiver to prove that it received the request. In WebRTC the browser would create the secret but the JavaScript on the sending side would know the value.

The packet is encrypted by using the secret and an AEAD crypto to create a STUN2 packet where the first two fields are the magic number and transaction ID which are only authenticated followed by the rest of the fields that are authenticated and encrypted followed by the AEAD authentication data.

The STUN2 requests are transmitted with the same retransmission and congestion algorithms as STUN2 in WebRTC 1.0

### 3.2.2. STUN2 Response

A STUN2 response consists of the following TLVs:

- o a magic number that uniquely identifies this as a STUN2 response packet with minimal risk of collision when multiplexing.
- o the transaction ID from the request.
- o the IP address and port the request was received from.

The packet is encrypted where the first two fields are the magic number and transaction ID which are only authenticated followed by the rest of the fields that are authenticated and encrypted followed by the AEAD authentication data.

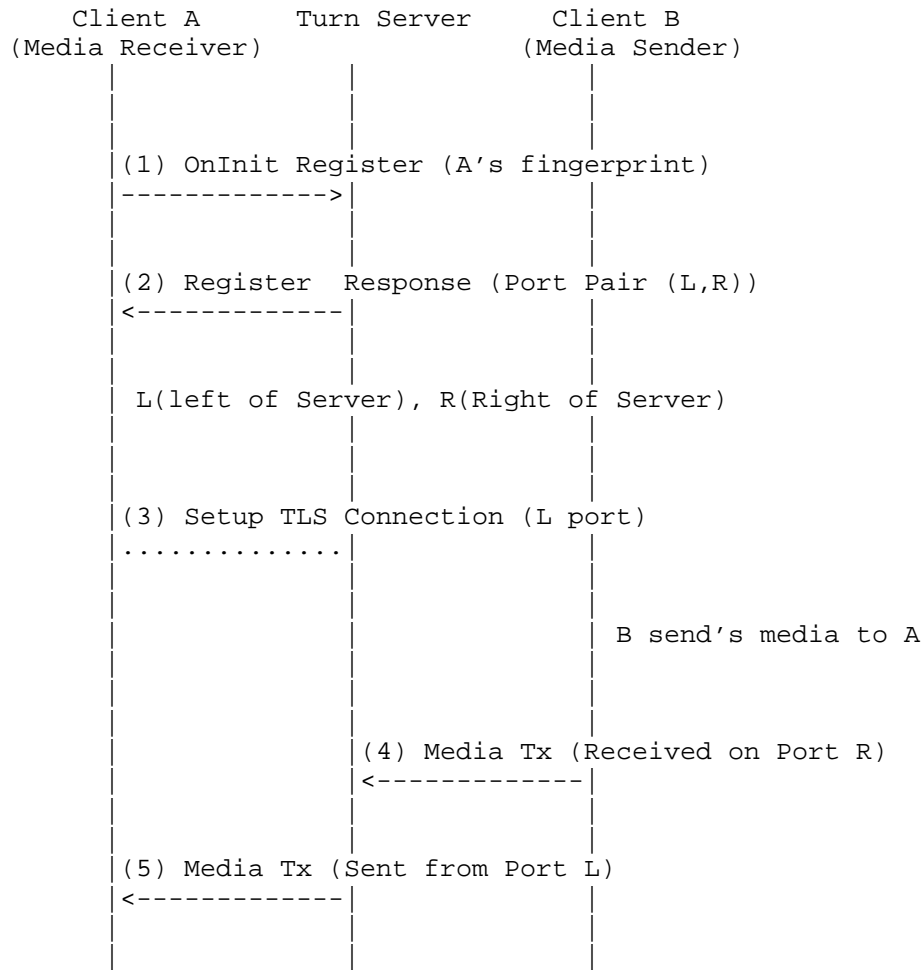
### 3.3. TURN2

Out of band, the client tells the TURN2 server the fingerprint of the cert it uses to authenticate with and the TURN2 server gives the client two public IP:port address pairs. One is called inbound and other called outbound. The client connects to the outbound port and authenticates to TURN2 server using the TLS domain name of server. The TURN2 server authenticates the client using mutual TLS with

fingerprint of cert provided by the client. Any time a message or stun packet is received on the matched inbound port, the TURN2 server forwards it to the client(s) connected to the outbound port.

A single TURN2 connection can be used for multiple different calls or session at the same time and a client could choose to allocate the TURN2 connection at the time that it started up. It does not need to be done on a per session basis.

The client can not send from the TURN2 server.



#### 4. Transport Layer

The responsibility of the transport layer is to provide an end to end crypto layer equivalent to DTLS and they must ensure adequate congestion control. The transport layer brings up a flow between two computers. This flow can be used by multiple media streams.

The MTI transport layer is QUIC with packets sent in an unreliable mode.

This is secured by checking the fingerprints of the DTLS connection match the fingerprints provided at the control layer or by checking the names of the certificates match what was provided at control layer.

The transport layer needs to be able to set the DSCP values in transmitting packets as specified by the control layer.

The transport MAY provide a compression mode to remove the redundancy of the non-encrypted portion of the media messages such as GlobalEncodingID. For example, a GlobalEncodingID could be mapped to a QUIC channel and then it could be removed before sending the message and added back on the receiving side.

The transport need to be able to ensure that it has a very small chance of being confused with the STUN2 traffic it will be multiplexed with.

#### 5. Media Layer - RTP3

Each message consist of a set of TLV headers with metadata about the packet, followed by payload data such as the output of audio or video codec.

There are several message headers that help the receiver understand what to do with the media. The TLV header are the follow:

- o Conference ID: Integer that will be globally unique identifier for the for all applications using a common call signaling system. This is set by the proposal.
- o Endpoint ID: Integer to uniquely identify the endpoint with within scope of conference ID. This is set by the proposal.
- o Source ID: integer to uniquely identify the input source within the scope a endpoint ID. A source could be a specific camera or a microphone. This is set by the endpoint and included in the advertisement.

- o Sink ID: integer to uniquely identify the sink within the scope a endpoint ID. A sink could be a speaker or screen. This is set by the endpoint and included in the advertisement.
- o Encoding ID: integer to uniquely identify the encoding of the stream within the scope of the stream ID. Note there may be multiple encodings of data from the same source. This is set by the proposal.
- o Salt : salt to use for forming the initialization vector for AEAD. The salt shall be sent as part of the packet and need not be sent in all the packets. This is created by the endpoint sending the message.
- o GlobalEncodingID: 64 bit hash of concatenation of conference ID, endpoint ID, stream ID, encoding ID
- o Capture time: Time when the first sample in the message was captured. It is a NTP time in ms with the high order bits discarded. The number of bits in the capture time needs to be large enough that it does not wrap in for the lifetime of this stream. This is set by the endpoint sending the message.
- o Sequence ID: When the data captured for a single point in time is too large to fit in a single message, it can be split into multiple chunks which are sequentially numbered starting at 0 corresponding to the first chunk of the message. This is set by the endpoint sending the message.
- o GlobalMessageID: 64 bit hash of concatenation of conference ID, endpoint ID, encoding ID, sequence ID
- o Active level: this is a number from 0 to 100 indicates the level that the sender of this media wishes it to be considered active media. For example if it was voice, it would be 100 if the person was clearly speaking, and 0 if not, and perhaps a value in the middle if it was uncertain. This allows an media switch to select the active speaker in the in a conference call.
- o Location in room: relative location in room enumerated starting at front left and moving around clockwise. This helps get the correct content on left and right screens for video and helps with for spatial audio
- o Reference Frame : bool to indicate if this message is part of a reference frame

- o DSCP : DSCP to use on transmissions of this message and future messages on this GlobalEncodingID
- o Layer ID : Integer indicating which layer is for scalable video codecs. SFU may use this to selectively drop a frame.

The keys used for the AEAD are unique to a given conference ID and endpoint ID.

If the message has any of the following headers, they must occur in the following order followed by all other headers:

1. GlobalEncodingID,
2. GlobalMessageID,
3. conference ID,
4. endpoint ID,
5. encoding ID,
6. sequence ID,
7. active level,
8. DSCP

Every second there must be at least one message in each encoding that contains:

- o conference ID,
- o endpoint ID,
- o encoding ID,
- o salt,
- o and sequence ID headers

but they are not needed in every packet.

The sequence ID or GlobalMessageID is required in every message and periodically there should be message with the capture time.

### 5.1. Securing the messages

The whole message is end to end secured with AEAD. The headers are authenticated while the payload data is authenticated and encrypted. Similar to how the IV for AES-GCM is calculated in SRTP, in this case the IV is computed by xor'ing the salt with the concatenation of the GlobalEncodingID and low 64 bits of sequence ID. The message consists of the authenticated data, followed by the encrypted data , then the authentication tag.

### 5.2. Sender requests

The control layer supports requesting retransmission of a particular media message identified by IDs and capture time it would contain.

The control layer supports requesting a maximum rate for each given encoding ID.

### 5.3. Data Codecs

Data messages including raw bytes, xml, senml can all be sent just like media by selecting an appropriate codec and a software based source or sink. An additional parameter to the codec can indicate if reliably delivery is needed and if in order delivery is needed.

### 5.4. Forward Error Correction

A new Reed-Solomon based FEC scheme based on [I-D.ietf-payload-flexible-fec-scheme] that provides FEC over messages needs to be defined.

### 5.5. MTI Codecs

Implementation MUST support at least G711, Opus, H.264 and AV1

Video codecs use square pixels.

Video codecs MUST support any aspect ratio within the limits of their max width and height.

Video codecs MUST support a min width and min height of 1.

All video on the wire is oriented such that the first scan line in the frame is up and first pixel in the scan line is on the left.

T.38 fax and DTMF are not supported. Fax can be sent as a TIFF imager over a data channel and DTFM can be done as an application specific information over a data channel.

## 5.6. Message Key Agreement

The secret for encrypting messages can be provided in the proposal by value or by a reference. The reference approach allows the client to get it from a messaging system where the server creating the proposal may not have access to the the secret. For example, it might come from a system like [I-D.barnes-mls-protocol].

## 6. Control Layer

The control layer needs an API to find out what the capabilities of the device are, and then a way to set up sending and receiving stream. All media flow are only in one direction. The control is broken into control of connectivity and transports, and control of media streams.

### 6.1. Transport Capabilities API

An API to get information for remote connectivity including:

- o set the IP, port, and credential for each TURN2 server
- o can return the IP, port tuple for the remote side to send to TURN2 server
- o gather local IP, port, protocol tuples for receiving media
- o report SHA256 fingerprint of local TLS certificate
- o encryption algorithms supported
- o report an error for a bad TURN2 credential

### 6.2. Media Capabilities API

Send and receive codecs are consider separate codecs and can have separate capabilities though the default to the same if not specified separately.

For each send or receive audio codec, an API to learn:

- o codec name
- o the max sample rate
- o the max sample size
- o the max bitrate

For each send or receive video codec, an API to learn:

- o codec name
- o the max width
- o the max height
- o the max frame rate
- o the max pixel depth
- o the max bitrate
- o the max pixel rate ( pixels / second )

### 6.3. Transport Configuration API

To create a new flow, the information that can be configured is:

- o turn server to use
- o list of IP, Port, Protocol tuples to try connecting to
- o encryption algorithm to use
- o TLS fingerprint of far side

An api to allow modification of the follow attributes of a flow:

- o total max bandwidth for flow
- o forward error correction scheme for flow
- o FEC time window
- o retransmission scheme for flow
- o addition IP, Port, Protocol pairs to send to that may improve connectivity

### 6.4. Media Configuration API

For all streams:

- o set conference ID
- o set endpoint ID



- o set encoding ID
- o salt and secret for AEAD
- o flag to pause transition

For each transmitted audio stream, a way to set the:

- o audio codec to use
- o media source to connect
- o max encoded bitrate
- o sample rate
- o sample size
- o number of channels to encode
- o packetization time
- o process as one of : automatically set, raw, speech, music
- o DSCP value to use
- o flag to indicating to use constant bit rate

For each transmitted video stream, a way to set

- o video codec to use
- o media source to connect to
- o max width and max height
- o max encoded bitrate
- o max pixel rate
- o sample rate
- o sample size
- o process as one of : automatically set, rapidly changing video,  
fine detail video
- o DSCP value to use

- o for layered codec, a layer ID and set of layers IDs this depends on

For each transmitted video stream, a way to tell it to:

- o encode the next frame as an intra frame

For each transmitted data stream:

- o a way to send a data message and indicate reliable or unreliable transmission

For each received audio stream:

- o audio codec to use
- o media sink to connect to
- o lip sync flag

For each received video stream:

- o video codec to use
- o media sink to connect to
- o lip sync flag

For each received data stream:

- o notification of received data messages

Note on lip sync: For any streams that have the lip sync flag set to true, the render attempts to synchronize their play back.

#### 6.5. Transport Metrics

- o report gathering state and completion

#### 6.6. Flow Metrics API

For each flow, report:

- o report connectivity state
- o report bits sent
- o report packets lost

- o report estimated RTT
- o report SHA256 fingerprint for certificate of far side
- o current 5 tuple in use

#### 6.7. Stream Metrics API

For sending streams:

- o Bits sent
- o packets lost

For receiving streams:

- o capture time of most recently receives packet
- o endpoint ID of more recently received packet
- o bits received
- o packets lost

For video streams (send & receive):

- o current encoded width and height
- o current encoded frame rate

#### 7. Call Signaling

Call signaling is out of scope for usages like WebRTC but other usages may want a common REST API they can use.

Call signaling works by having the client connect to a server when it starts up and send its current advertisement and open a web socket or to receive proposals from the server. A client can make a rest call indicating the parties(s) it wishes to connect to and the server will then send proposals to all clients that connect them. The proposal tell each client exactly how to configure it's media stack and MUST be either completely accepted, or completely rejected.

The signaling is based on the the advertisement proposal ideas from [I-D.peterson-sipcore-advprop].

We define one round trip of signaling to be a message going from a client up to a server in the cloud, then down to another client which

returns a response along the reverse path. With this definition SIP is takes 1.5 round trips or more if TURN is needed to set up a call while this takes 0.5 round trips.

## 8. Signaling Examples

### 8.1. Simple Audio Example

#### 8.1.1. simple audio advertisement

```
{
  "receiveAt":[
    {
      "relay":"2001:db8::10:443",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    },
    {
      "stun":"203.0.113.10:43210",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    },
    {
      "local":"192.168.0.2:443",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    }
  ],
  "sources":[
    {
      "sourceID":1,
      "sourceType":"audio",
      "codecs":[
        {
          "codecName":"opus",
          "maxBitrate":128000
        },
        {
          "codecName":"g711"
        }
      ]
    }
  ],
  "sinks":[
    {
      "sinkID":1,
      "sourceType":"audio",
      "codecs":[]
    }
  ]
}
```

```

        {
          "codecName": "opus",
          "maxBitrate": 256000
        },
        {
          "codecName": "g711"
        }
      ]
    }
  ]
}

```

#### 8.1.2. simple audio proposal

```

{
  "receiveAt": [
    {
      "relay": "2001:db8::10:443",
      "stunSecret": "s8i739dk8"
    },
    {
      "stun": "203.0.113.10:43210",
      "stunSecret": "s8i739dk8"
    },
    {
      "local": "192.168.0.10:443",
      "stunSecret": "s8i739dk8"
    }
  ],
  "sendTo": [
    {
      "relay": "2001:db8::20:443",
      "stunSecret": "20kdiu83kd8",
      "tlsFingerprintSHA256": "9389739"
    },
    {
      "stun": "203.0.113.20:43210",
      "stunSecret": "20kdiu83kd8",
      "tlsFingerprintSHA256": "9389739"
    },
    {
      "local": "192.168.0.20:443",
      "stunSecret": "20kdiu83kd8",
      "tlsFingerprintSHA256": "9389739"
    }
  ],
  "sendStreams": [
    {

```

```

        "conferenceID":4638572387,
        "endpointID":23,
        "sourceID":1,
        "encodingID":1,
        "codecName":"opus",
        "AEAD":"AES128-GCM",
        "secret":"xy34",
        "maxBitrate":24000,
        "packetTime":20
    }
],
"receiveStreams":[
    {
        "conferenceID":4638572387,
        "endpointID":23,
        "sinkID":1,
        "encodingID":1,
        "codecName":"opus",
        "AEAD":"AES128-GCM",
        "secret":"xy34"
    }
]
}

```

## 8.2. Simple Video Example

Advertisement for simple send only camera with no audio

```

{
  "sources":[
    {
      "sourceID":1,
      "sourceType":"video",
      "codecs":[
        {
          "codecName":"av1",
          "maxBitrate":20000000,
          "maxWidth":3840,
          "maxHeight":2160,
          "maxFrameRate":120,
          "maxPixelRate":248832000,
          "maxPixelDepth":8
        }
      ]
    }
  ]
}

```

## 8.2.1. Proposal sent to camera

```
{
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    }
  ],
  "sendStreams":[
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":0,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":640,
      "height":480,
      "frameRate":30
    }
  ]
}
```

## 8.3. Simulcast Video Example

Advertisement same as simple camera above but proposal has two streams with different encodingID.

```
{
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    }
  ],
  "sendStreams":[
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":1,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":1920,
      "height":1080,
      "frameRate":30
    },
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":2,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":240,
      "height":240,
      "frameRate":15
    }
  ]
}
```

#### 8.4. FEC Example

##### 8.4.1. Advertisement includes a FEC codec.



```
{
  "sources": [
    {
      "sourceID": 1,
      "sourceType": "video",
      "codecs": [
        {
          "codecName": "av1",
          "maxBitrate": 20000000,
          "maxWidth": 3840,
          "maxHeight": 2160,
          "maxFrameRate": 120,
          "maxPixelRate": 248832000,
          "maxPixelDepth": 8
        },
        {
          "codecName": "flex-fec-rs"
        }
      ]
    }
  ]
}
```

8.4.2. Proposal sent to camera

```

{
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    }
  ],
  "sendStreams":[
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":1,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":640,
      "height":480,
      "frameRate":30
    },
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":2,
      "AEAD":"NULL",
      "codecName":"flex-fec-rs",
      "fecRepairWindow":200,
      "fecRepairEncodingIDs":[
        1
      ]
    }
  ]
}

```

## 9. Switched Forwarding Unit (SFU)

When several clients are in conference call, the SFU can forward packets based on looking at which clients needs a given GlobalEncodingID. By looking at the "active level", the SFU can figure out which endpoints are the active speaker and forward only those. The SFU never changes anything in the message.

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## Author's Address

Cullen Jennings  
Cisco

Email: fluffy@iii.ca

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C. Jennings  
Cisco  
March 18, 2018

Modular Media Stack  
draft-jennings-dispatch-new-media-01

Abstract

A sketch of a proposal for a modular media stack for interactive communications.

Status of This Memo

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## 1. Introduction

This draft is an accumulation of various ideas some people are thinking about. Most of them are fairly separable and could be morphed into existing protocols though this draft takes a blank sheet of paper approach to considering what would be the best think if we were starting from scratch. With that in place, it is possible to ask which of these ideas makes sense to back patch into existing protocols.

## 2. Goals

- o Better connectivity by enable situation where asymmetric media is possible.
- o Design for SFU ( Switch Forwarding Units). Design for multiparty calls first then consider two party calls as a specialized subcase of that.
- o Designed for client servers with server based control of clients
- o Faster setup
- o Pluggable congestion control
- o much much simpler
- o end to end security
- o remove ability to use STUN / TURN in DDOS reflection attacks
- o ability for receiver of video to tell the sender about size changes of display window such that the sender can match
- o Eliminate the problems with ROC in SRTP
- o address reasons people have not used from SDES to DTLS-SRTP
- o separation of call setup and ongoing call / conference control

- o make codec negotiation more generic so that it works for future codecs
- o remove ICE's need for global pacing which is more or less impossible on general purpose devices like PCs

### 3. Overview

This draft proposes a new media stack to replace the existing stack RTP, DTLS-SRTP, and SDP Offer Answer. The key parts of this stack are connectivity layer, the transport layer, the media layer, a control API, and the singling layer.

The connectivity layer uses a simplified version of ICE, called snowflake [I-D.jennings-dispatch-snowflake], to find connectivity between endpoints and change the connectivity from one address to another as different networks become available or disappear. It is based on ideas from [I-D.jennings-mmusic-ice-fix].

The transport layer uses QUIC to provide a hop by hop encrypted, congestion controlled transport of media. Although QUIC does not currently have all of the partial reliability mechanisms to make this work, this draft assumes that they will be added to QUIC.

The media layer uses existing codecs and packages them along with extra header information to provide information about, when the sequence needs to be played back, which camera it came from, and media streams to be synchronized.

The control API is an abstract API that provides a way for the media stack to report its capabilities and features and a way for the application to tell the media stack how it should be configured. Configuration includes what codec to use, size and frame rate of video, and where to send the media.

The singling layer is based on an advertisement and proposal model. Each endpoint can create an advertisement that describes what it supports including things like supported codecs and maximum bitrates. A proposal can be sent to an endpoint that tells the endpoint exactly what media to send and receive and where to send it. The endpoint can accept or reject this proposal in total but cannot change any part of it.

### 4. Terminology

- o media stream: Stream of information from a single sensor. For example, a video stream from a single camera. A stream may have multiple encodings for example video at different resolutions.

- o encoding: A encoded version of a stream. A given stream may have several encodings at different resolutions. One encoding may depend on other encodings such as forward error corrections or in the case of scalable video codecs.
- o flow: A logical transport between two computers. Many media streams can be transported over a single flow. The actually IP address and ports used to transport data in the flow may change over time as connectivity changes.
- o message: some data or media that to be sent across the network along with metadata about it. Similar to an RTP packet.
- o media source: a camera, microphone or other source of data on an endpoint
- o media sink: a speaker, screen, or other destination for data on an endpoint
- o TLV: Tag Length Value. When used in the draft, the Tag, Length, and any integer values are coded as variable length integers similar to how this is done in CBOR.

## 5. Architecture

Much of the deployments architecture of IETF media designs are based on a distributed controller for the media stack that is running peer to peer in each client. Nearly all deployments, by they a cloud based conferencing systems or an enterprise PBX, use a central controller that acts as an SBC to try and controll each client. The goal here would be an deployment architecture that

- o support a single controller that controlled all the device in a given conference or call. The controller could be in the cloud or running on one of the endpoints.
- o design for multi party conference calls first and treat 2 party calls as a speialed sub case of that
- o design with the assumption that an light weight SFU (Switched Forwarding Unit) was used to distribute media for conference calls.

## 6. Connectivity Layer



### 6.1. Snowflake - New ICE

All that is needed to discover the connectivity is way to:

- o Gather some IP/ports that may work using TURN2 relay, STUN2, and local addresses.
- o A controller, which might be running in the cloud, to inform a client to send a STUN2 packet from a given source IP/port to a given destination IP/port.
- o The receiver notifies the controller about information on received STUN2 packets.
- o The controller can tell the sender the secret that was in the packet to prove consent of the receiver to receive data then the sending client can allow media to flow over that connection.

The actually algorithm used to decide on what pairs of addresses are tested and in what order does not need to be agreed on by both the sides of the call - only the controller needs to know it. This allows the controller to use machine learning, past history, and heuristics to find an optimal connection much faster than something like ICE.

The details of this approach are described in [I-D.jennings-dispatch-snowflake]. Many of ideas in this can be traced back to [I-D.kaufman-rtcweb-traversal].

### 6.2. STUN2

The speed of setting up a new media flow is often determined by how many STUN2 checks need to be done. If the STUN2 packets are smaller, then the stun checks can be done faster without risk of causing congestion.

#### 6.2.1. STUN2 Request

A STUN2 request consists of, well, really nothing. The STUN client just opens a QUIC connection to the STUN server.

#### 6.2.2. STUN2 Response

When the STUN2 sever receives a new QUIC connection, it responds with the IP address and port that the connection came from.

The client can check it is talking to the correct STUN server by checking the fingerprint of the certificate. Protocols like ICE

would need to exchange these fingerprints instead of all the crazy stun attributes.

Thanks to Peter Thatcher for proposing STUN over QUIC.

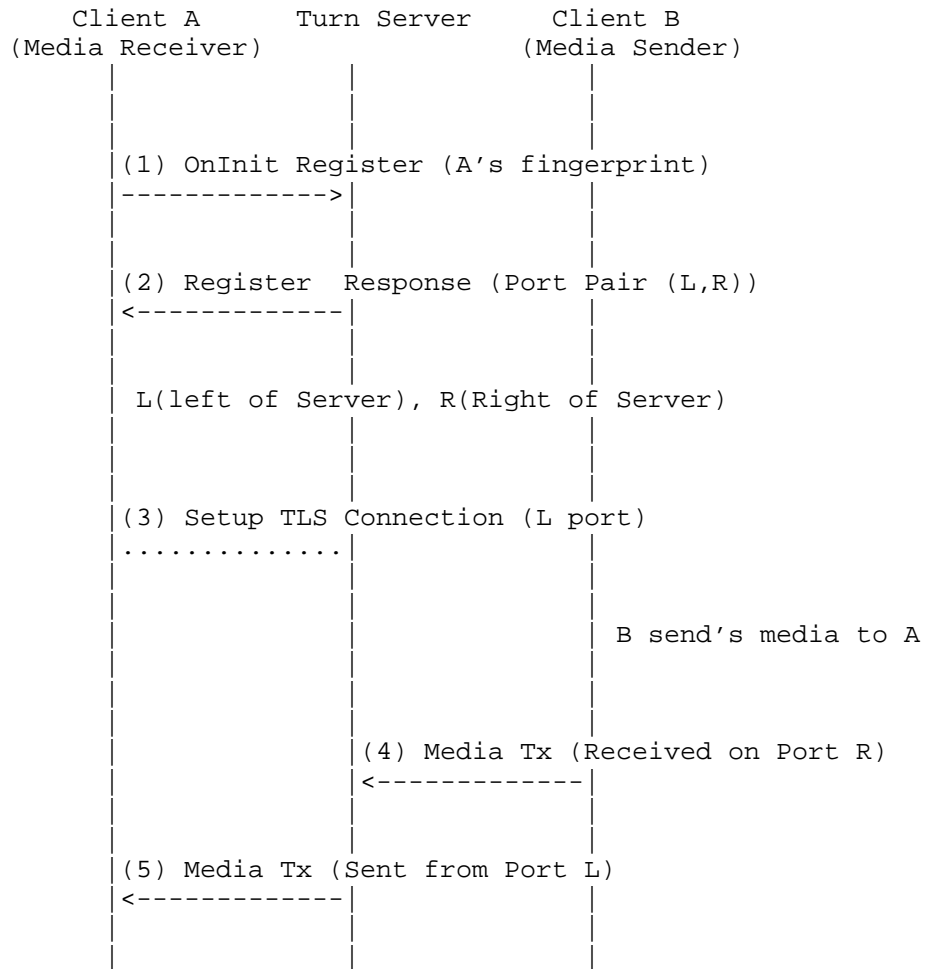
### 6.3. TURN2

TODO: make TURN2 run over QUIC

Out of band, the client tells the TURN2 server the fingerprint of the cert it uses to authenticate with. The TURN2 server gives the client two public IP:port address pairs. One is called inbound and other called outbound. The client connects to the outbound port and authenticates to TURN2 server using the TLS domain name of server. The TURN2 server authenticates the client using mutual TLS with fingerprint of cert provided by the client. Any time a message or stun packet is received on the matched inbound port, the TURN2 server forwards it to the client(s) connected to the outbound port.

A single TURN2 connection can be used for multiple different calls or session at the same time and a client could choose to allocate the TURN2 connection at the time that it started up. It does not need to be done on a per session basis.

The client can not send from the TURN2 server.



7. Transport Layer

The responsibility of the transport layer is to provide an end to end crypto layer equivalent to DTLS and they must ensure adequate congestion control. The transport layer brings up a flow between two computers. This flow can be used by multiple media streams.

The MTI transport layer is QUIC with packets. It assumes that QUIC has a way to delivers the packets in an effecent unreliable mode as wells as an optional way to deliver important metadata packets in a reliable mode. It assumes that QUIC can report up to the rate adaptation layer a current max target bandwidth that QUIC can transmit at. It's possible these are all unrealistic characteristics

of QUIC in which case a new transport protocol should be developed that provides these and is layered on top of DTLS for security.

This is secured by checking the fingerprints of the DTLS connection match the fingerprints provided at the control layer or by checking the names of the certificates match what was provided at control layer.

The transport layer needs to be able to set the DSCP values in transmitting packets as specified by the control layer.

The transport MAY provide a compression mode to remove the redundancy of the non-encrypted portion of the media messages such as GlobalEncodingID. For example, a GlobalEncodingID could be mapped to a QUIC channel and then it could be removed before sending the message and added back on the receiving side.

The transport need to be able to ensure that it has a very small chance of being confused with the STUN2 traffic it will be multiplexed with. (Open issue - if the STUN2 runs on top of same transport, this becomes less of issue )

The transport crypto needs to be able to export server state that can be passed out of band to the client to enable the client to make a zero RTT connection to the server.

#### 8. Media Layer - RTP3

Each message consist of a set of TLV headers with metadata about the packet, followed by payload data such as the output of audio or video codec.

There are several message headers that help the receiver understand what to do with the media. The TLV header are the follow:

- o Conference ID: Integer that will be globally unique identifier for the for all applications using a common call singling system. This is set by the proposal.
- o Endpoint ID: Integer to uniquely identify the endpoint with within scope of conference ID. This is set by the proposal.
- o Source ID: integer to uniquely identify the input source within the scope a endpoint ID. A source could be a specific camera or a microphone. This is set by the endpoint and included in the advertisement.

- o Sink ID: integer to uniquely identify the sink within the scope a endpoint ID. A sink could be a speaker or screen. This is set by the endpoint and included in the advertisement. An endpoint sending media can have this set. If it is set it should transmit it for 3 frames any time it changes and once every 5 second. An SFU can add, modify, or delete this from any media packet. TODO - How to use this for SFU controlled layout - for example, if have 100 users in conference and want to put the 10 most recent speakers in thumbnails. Do we need this at all ?
- o Encoding ID: integer to uniquely identify the encoding of the stream within the scope of the source ID. Note there may be multiple encodings of data from the same source. This is set by the proposal.
- o Salt : salt to use for forming the initialization vector for AEAD. The salt shall be sent as part of the packet and need not be sent in all the packets. This is created by the endpoint sending the message.
- o GlobalEncodingID: 64 bit hash of concatenation of conference ID, endpoint ID, source ID, encoding ID
- o Capture time: Time when the first sample in the message was captured. It is a NTP time in ms with the high order bits discarded. The number of bits in the capture time needs to be large enough that it does not wrap in for the lifetime of this stream. This is set by the endpoint sending the message.
- o Sequence ID: When the data captured for a single point in time is too large to fit in a single message, it can be split into multiple chunks which are sequentially numbered starting at 0 corresponding to the first chunk of the message. This is set by the endpoint sending the message.
- o GlobalMessageID: 64 bit hash of concatenation of conference ID, endpoint ID, encoding ID, sequence ID
- o Active level: this is a number from 0 to 100 indicates the probability that the sender of this media wishes it to be considered active media. For example if it was voice, it would be 100 if the person was clearly speaking, and 0 if not, and perhaps a value in the middle if it was uncertain. This allows an media switch to select the active speaker in the in a conference call.
- o Location: relative or absolute location, direction of view, and field view. With video coming from drones, 360 cameras, VR light field cameras, and complex video conferencing rooms, this provides

the information about the camera or microphone that the receiver can use to render the correct view. This is end to end encrypted.

- o Reference Frame : bool to indicate if this message is part of a reference frame. Typically, a SFU will switch to the new video stream at the start of a reference frame.
- o DSCP : DSCP to use on transmissions of this message and future messages on this GlobalEncodingID
- o Layer ID : Integer indicating which layer is for scalable video codecs. SFU may use this to selectively drop a frame.

The keys used for the AEAD are unique to a given conference ID and endpoint ID.

If the message has any of the following headers, they must occur in the following order followed by all other headers:

1. GlobalEncodingID,
2. GlobalMessageID,
3. conference ID,
4. endpoint ID,
5. encoding ID,
6. sequence ID,
7. active level,
8. DSCP

Every second there must be at least one message in each encoding that contains:

- o conference ID,
- o endpoint ID,
- o encoding ID,
- o salt,
- o and sequence ID headers

but they are not needed in every packet.

The sequence ID or GlobalMessageID is required in every message and periodically there should be message with the capture time.

### 8.1. RTP Meta Data

We tend to end up with a few categories of data associated with the media:

- o Stuff you need at the same time you get the media. For example, this is a reference frame.
- o Stuff you need soon but not instantly. For example the name of the speaker in a given rectangle of a video stream

And it tends to change at different rates:

- o Stuff that you need to process the media and may change but does not change quickly and you don't need it with every frame. For example, salt for encryption
- o Stuff that you need to join the media but may never change. For example, resolution of the video is

TODO - think about how to optimize design for each type of meta data

### 8.2. Securing the messages

The whole message is end to end secured with AEAD. The headers are authenticated while the payload data is authenticated and encrypted. Similar to how the IV for AES-GCM is calculated in SRTP, in this case the IV is computed by xor'ing the salt with the concatenation of the GlobalEncodingID and low 64 bits of sequence ID. The message consists of the authenticated data, followed by the encrypted data, then the authentication tag.

### 8.3. Sender requests

The control layer supports requesting retransmission of a particular media message identified by IDs and capture time it would contain.

The control layer supports requesting a maximum rate for each given encoding ID.

#### 8.4. Data Codecs

Data messages including raw bytes, xml, senml can all be sent just like media by selecting an appropriate codec and a software based source or sink. An additional parameter to the codec can indicate if reliably delivery is needed and if in order delivery is needed.

#### 8.5. Media Keep Alive

Provided by transport.

#### 8.6. Forward Error Correction

A new Reed-Solomon based FEC scheme based on [I-D.ietf-payload-flexible-fec-scheme] that provides FEC over messages needs to be defined.

#### 8.7. MTI Codecs

##### 8.7.1. Audio

Implementation MUST support at least G711 and Opus

##### 8.7.2. Video

Implementation MUST support at least H.264 and AV1

Video codecs use square pixels.

Video codecs MUST support any aspect ratio within the limits of their max width and height.

Video codecs can specify a maximum pixel rate, maximum frame rate, maximum images size. They can also specify a list of binary flags of supported features which are defined by the codec and may be supported by the codec for encode, decode, or neither where each feature can be independently controlled. They can not impose constraints beyond that. Some existing codecs like vp8 may easily fit into that while some codec like H264 may need some suspects defined as new codecs to meet the requirements for this. It is not expected that all the nuances that could be negotiated with SDP for 264 would be supported in this new media.

Video codecs MUST support a min width and min height of 1.

All video on the wire is oriented such that the first scan line in the frame is up and first pixel in the scan line is on the left.



T.38 fax and DTMF are not supported. Fax can be sent as a TIFF imager over a data channel and DTFM can be done as an application specific information over a data channel.

TODO: Capture the list of what metadata video encoders produce \* if it is a reference frame or not \* resolution \* frame-rate ? \* capture time of frame

TODO: Capture the list of what metadata video encoders needs. \* capture timestamp \* source and target resolution \* source and target frame-rate \* target bitrate \* max bitrate \* max pixel rate

#### 8.7.3. Annotation

Optional support for annotation based overlay using vector graphics such as a subset of SVG.

#### 8.7.4. Application Data Channels

Need support for application defined data in both a reliable and unreliable datagram mode.

#### 8.7.5. Reverse Requests & Stats

The hope is that this is not needed.

Much of what goes in the reverse direction of the media in RTCP is either used for congestion control, diagnostics, or control of the codec such as requesting to resent a frame or sending a new intra codec frame for video. The design reduces the need for this.

The congestion control information which is needed quickly is all handled at QUIC layer.

The diagnostic type information can be reported from the endpoint to the controller and does not need to flow at the media level.

Information that needs to be delivered reliably can be sent that way at the QUIC level remove the need for retransmit type request. System that use selective retransmission to recover from packet loss of media do not tend to work as well for interactive medias as forward error correction schemes because of the large latency they introduce.

Information like requesting a new intra codec frame for video often needs to come from the controller and can be sent over the signalling and control layer.

### 8.8. Message Key Agreement

The secret for encrypting messages can be provided in the proposal by value or by a reference. The reference approach allows the client to get it from a messaging system where the server creating the proposal may not have access to the the secret. For example, it might come from a system like [I-D.barnes-mls-protocol].

## 9. Control Layer

The control layer needs an API to find out what the capabilities of the device are, and then a way to set up sending and receiving stream. All media flow are only in one direction. The control is broken into control of connectivity and transports, and control of media streams.

### 9.1. Transport Capabilities API

An API to get information for remote connectivity including:

- o set the IP, port, and credential for each TURN2 server
- o can return the IP, port tuple for the remote side to send to TURN2 server
- o gather local IP, port, protocol tuples for receiving media
- o report SHA256 fingerprint of local TLS certificate
- o encryption algorithms supported
- o report an error for a bad TURN2 credential

### 9.2. Media Capabilities API

Send and receive codecs are consider separate codecs and can have separate capabilities though the default to the same if not specified separately.

For each send or receive audio codec, an API to learn:

- o codec name
- o the max sample rate
- o the max sample size
- o the max bitrate

For each send or receive video codec, an API to learn:

- o codec name
- o the max width
- o the max height
- o the max frame rate
- o the max pixel depth
- o the max bitrate
- o the max pixel rate ( pixels / second )

### 9.3. Transport Configuration API

To create a new flow, the information that can be configured is:

- o turn server to use
- o list of IP, Port, Protocol tuples to try connecting to
- o encryption algorithm to use
- o TLS fingerprint of far side

An api to allow modification of the follow attributes of a flow:

- o total max bandwidth for flow
- o forward error correction scheme for flow
- o FEC time window
- o retransmission scheme for flow
- o addition IP, Port, Protocol pairs to send to that may improve connectivity

### 9.4. Media Configuration API

For all streams:

- o set conference ID
- o set endpoint ID

- o set encoding ID
- o salt and secret for AEAD
- o flag to pause transition

For each transmitted audio stream, a way to set the:

- o audio codec to use
- o media source to connect
- o max encoded bitrate
- o sample rate
- o sample size
- o number of channels to encode
- o packetization time
- o process as one of : automatically set, raw, speech, music
- o DSCP value to use
- o flag to indicating to use constant bit rate
- o optionally set a sinkID to periodically include in the media

For each transmitted video stream, a way to set

- o video codec to use
- o media source to connect to
- o max width and max height
- o max encoded bitrate
- o max pixel rate
- o sample rate
- o sample size
- o process as one of : automatically set, rapidly changing video, fine detail video

- o DSCP value to use
- o for layered codec, a layer ID and set of layers IDs this depends on
- o optionally set a sinkID to periodically include in the media

For each transmitted video stream, a way to tell it to:

- o encode the next frame as an intra frame

For each transmitted data stream:

- o a way to send a data message and indicate reliable or unreliable transmission

For each received audio stream:

- o audio codec to use
- o media sink to connect to
- o lip sync flag

For each received video stream:

- o video codec to use
- o media sink to connect to
- o lip sync flag

For each received data stream:

- o notification of received data messages

Note on lip sync: For any streams that have the lip sync flag set to true, the render attempts to synchronize their play back.

#### 9.5. Transport Metrics

- o report gathering state and completion

#### 9.6. Flow Metrics API

For each flow, report:

- o report connectivity state

- o report bits sent
- o report packets lost
- o report estimated RTT
- o report SHA256 fingerprint for certificate of far side
- o current 5 tuple in use

#### 9.7. Stream Metrics API

For sending streams:

- o Bits sent
- o packets lost

For receiving streams:

- o capture time of most recently receives packet
- o endpoint ID of more recently received packet
- o bits received
- o packets lost

For video streams (send & receive):

- o current encoded width and height
- o current encoded frame rate

#### 10. Call Signalling - JABBER2

Call signalling is out of scope for usages like WebRTC but other usages may want a common REST API they can use.

Call signalling works by having the client connect to a server when it starts up and send its current advertisement and open a web socket or to receive proposals from the server. A client can make a rest call indicating the parties(s) it wishes to connect to and the server will then send proposals to all clients that connect them. The proposal tell each client exactly how to configure it's media stack and MUST be either completely accepted, or completely rejected.

The signalling is based on the the advertisement proposal ideas from [I-D.peterson-sipcore-advprop].

We define one round trip of signalling to be a message going from a client up to a server in the cloud, then down to another client which returns a response along the reverse path. With this definition SIP is takes 1.5 round trips or more if TURN is needed to set up a call while this takes 0.5 round trips.

## 11. Signalling Examples

### 11.1. Simple Audio Example

#### 11.1.1. simple audio advertisement

```
{
  "receiveAt":[
    {
      "relay":"2001:db8::10:443",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    },
    {
      "stun":"203.0.113.10:43210",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    },
    {
      "local":"192.168.0.2:443",
      "stunSecret":"s8i739dk8",
      "tlsFingerprintSHA256":"1283938"
    }
  ],
  "sources":[
    {
      "sourceID":1,
      "sourceType":"audio",
      "codecs":[
        {
          "codecName":"opus",
          "maxBitrate":128000
        },
        {
          "codecName":"g711"
        }
      ]
    }
  ]
},
```

```
"sinks":[
  {
    "sinkID":1,
    "sourceType":"audio",
    "codecs":[
      {
        "codecName":"opus",
        "maxBitrate":256000
      },
      {
        "codecName":"g711"
      }
    ]
  }
]
```

#### 11.1.2. simple audio proposal

```
{
  "receiveAt":[
    {
      "relay":"2001:db8::10:443",
      "stunSecret":"s8i739dk8"
    },
    {
      "stun":"203.0.113.10:43210",
      "stunSecret":"s8i739dk8"
    },
    {
      "local":"192.168.0.10:443",
      "stunSecret":"s8i739dk8"
    }
  ],
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    },
    {
      "stun":"203.0.113.20:43210",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    },
    {
      "local":"192.168.0.20:443",
      "stunSecret":"20kdiu83kd8",

```



```
        "tlsFingerprintSHA256":"9389739"
      }
    ],
    "sendStreams":[
      {
        "conferenceID":4638572387,
        "endpointID":23,
        "sourceID":1,
        "encodingID":1,
        "codecName":"opus",
        "AEAD":"AES128-GCM",
        "secret":"xy34",
        "maxBitrate":24000,
        "packetTime":20
      }
    ],
    "receiveStreams":[
      {
        "conferenceID":4638572387,
        "endpointID":23,
        "sinkID":1,
        "encodingID":1,
        "codecName":"opus",
        "AEAD":"AES128-GCM",
        "secret":"xy34"
      }
    ]
  }
}
```

## 11.2. Simple Video Example

Advertisement for simple send only camera with no audio

```
{
  "sources": [
    {
      "sourceID": 1,
      "sourceType": "video",
      "codecs": [
        {
          "codecName": "av1",
          "maxBitrate": 20000000,
          "maxWidth": 3840,
          "maxHeight": 2160,
          "maxFrameRate": 120,
          "maxPixelRate": 248832000,
          "maxPixelDepth": 8
        }
      ]
    }
  ]
}
```

#### 11.2.1.1. Proposal sent to camera

```
{
  "sendTo": [
    {
      "relay": "2001:db8::20:443",
      "stunSecret": "20kdiu83kd8",
      "tlsFingerprintSHA256": "9389739"
    }
  ],
  "sendStreams": [
    {
      "conferenceID": 0,
      "endpointID": 0,
      "sourceID": 0,
      "encodingID": 0,
      "codecName": "av1",
      "AEAD": "NULL",
      "width": 640,
      "height": 480,
      "frameRate": 30
    }
  ]
}
```

### 11.3. Simulcast Video Example

Advertisement same as simple camera above but proposal has two streams with different encodingID.

```
{
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    }
  ],
  "sendStreams":[
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":1,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":1920,
      "height":1080,
      "frameRate":30
    },
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":2,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":240,
      "height":240,
      "frameRate":15
    }
  ]
}
```

### 11.4. FEC Example

#### 11.4.1. Advertisement includes a FEC codec.

```
{
  "sources": [
    {
      "sourceID": 1,
      "sourceType": "video",
      "codecs": [
        {
          "codecName": "av1",
          "maxBitrate": 20000000,
          "maxWidth": 3840,
          "maxHeight": 2160,
          "maxFrameRate": 120,
          "maxPixelRate": 248832000,
          "maxPixelDepth": 8
        },
        {
          "codecName": "flex-fec-rs"
        }
      ]
    }
  ]
}
```

11.4.2. Proposal sent to camera

```

{
  "sendTo":[
    {
      "relay":"2001:db8::20:443",
      "stunSecret":"20kdiu83kd8",
      "tlsFingerprintSHA256":"9389739"
    }
  ],
  "sendStreams":[
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":1,
      "codecName":"av1",
      "AEAD":"NULL",
      "width":640,
      "height":480,
      "frameRate":30
    },
    {
      "conferenceID":0,
      "endpointID":0,
      "sourceID":0,
      "encodingID":2,
      "AEAD":"NULL",
      "codecName":"flex-fec-rs",
      "fecRepairWindow":200,
      "fecRepairEncodingIDs":[
        1
      ]
    }
  ]
}

```

## 12. Switched Forwarding Unit (SFU)

When several clients are in conference call, the SFU can forward packets based on looking at which clients needs a given GlobalEncodingID. By looking at the "active level", the SFU can figure out which endpoints are the active speaker and forward only those. The SFU never changes anything in the message.

### 12.1. Software Defined Networking

Is it possible to use the packet recycling concepts in SDN to forward a single packet to multiple endpoints? Can the way SDN forwarding would work be adapted to use a SDN router as a SFU?

## 12.2. Vector Packet Processors

Can we use fast VPP systems like fd.io to create a SFU?

## 12.3. Information Centric Networking

What changes would be needed to map RTP2 into the prefix and suffix of hICN?

## 13. Acknowledgements

Thank you for input from: Harald Alvestrand, Espen Berger, Matthew Kaufman, Patrick Linskey, Eric Rescorla, Peter Thatcher, Malcolm Walters Martin Thomson

## 14. Other Work

rfc7016

draft-kaufman-rtcweb-traversal

Consider using terminology from rfc7656

[docs.google.com/presentation/  
d/1Sg\\_1TVCcKJvZ8Egz5oa0CP01TC2rNdv9HVu7W38Y4zA/  
edit#slide=id.g29a8672e18\\_22\\_120](https://docs.google.com/presentation/d/1Sg_1TVCcKJvZ8Egz5oa0CP01TC2rNdv9HVu7W38Y4zA/edit#slide=id.g29a8672e18_22_120)

[docs.google.com/presentation/d/1o-  
o5jZBLw3Py1OuenzWDkxDG6NigSmLHvGw5KemKWLw/  
edit#slide=id.g2f8f4acff1\\_1\\_249](https://docs.google.com/presentation/d/1o-o5jZBLw3Py1OuenzWDkxDG6NigSmLHvGw5KemKWLw/edit#slide=id.g2f8f4acff1_1_249)

[cs.chromium.org/chromium/src/third\\_party/webrtc/common\\_video/include/  
video\\_frame.h](https://cs.chromium.org/chromium/src/third_party/webrtc/common_video/include/video_frame.h)

## 15. Style of specification

Fundamental driven by experiments. The proposal is to have a high level overview document where we document some of the design - this document could be a start of that. Then write a spec for each one of the separable protocol parts such as STUN2, TURN2, etc.

The protocol specs would contain a high level overview like you might find on a wikipedia page and the details of the protocol encoding would be provided in an open source reference implementation. The test code for the references implementation helps test the spec. The implementation is not optimized for performance but instead is simply trying to clearly illustrate the protocol. Particular version of the draft would be bound to a tagged version of the source code. All the

source code would be under normal IETF IPR rules just like it was included directly in the draft.

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## Author's Address

Cullen Jennings  
Cisco

Email: fluffy@iii.ca

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A. Newton  
ARIN  
P. Cordell  
Codalogic  
September 28, 2017

A Language for Rules Describing JSON Content  
draft-newton-json-content-rules-09

Abstract

This document describes a language for specifying and testing the expected content of JSON structures found in JSON-using protocols, software, and processes.

Status of This Memo

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## 1. Introduction

This document describes JSON Content Rules (JCR), a language for specifying and testing the interchange of data in JSON [RFC7159] format used by computer protocols and processes. The syntax of JCR is not JSON but is "JSON-like", possessing the conciseness and utility that has made JSON popular.

### 1.1. A First Example: Specifying Content

The following JSON data describes a JSON object with two members, "line-count" and "word-count", each containing an integer.

```
{ "line-count" : 3426, "word-count" : 27886 }
```

Figure 1

This is also JCR that describes a JSON object with a member named "line-count" that is an integer that is exactly 3426 and a member named "word-count" that is an integer that is exactly 27886.

For a protocol specification, it is probably more useful to specify that each member is any integer and not specific, exact integers:

```
{ "line-count" : integer, "word-count" : integer }
```

Figure 2

Since line counts and word counts should be either zero or a positive integer, the specification may be further narrowed:

```
{ "line-count" : 0.. , "word-count" : 0.. }
```

Figure 3

### 1.2. A Second Example: Testing Content

Building on the first example, this second example describes the same object but with the addition of another member, "file-name".

```
{
  "file-name" : "rfc7159.txt",
  "line-count" : 3426,
  "word-count" : 27886
}
```

Figure 4

The following JCR describes objects like it.

```
{
  "file-name" : string,
  "line-count" : 0..,
  "word-count" : 0..
}
```

Figure 5

For the purposes of writing a protocol specification, JCR may be broken down into named rules to reduce complexity and to enable reuse. The following example takes the JCR from above and rewrites the members as named rules.

```
{
  $fn,
  $lc,
  $wc
}

$fn = "file-name" : string
$lc = "line-count" : 0..
$wc = "word-count" : 0..
```

Figure 6

With each member specified as a named rule, software testers can override them locally for specific test cases. In the following example, the named rules are locally overridden for the test case where the file name is "rfc4627.txt".

```
$fn = "file-name" : "rfc4627.txt"
$lc = "line-count" : 2102
$wc = "word-count" : 16714
```

Figure 7

In this example, the protocol specification describes the JSON object in general and an implementation overrides the rules for testing specific cases.

All figures used in this specification are available here [1].

## 2. Overview of the Language

JCR is composed of rules (as the name suggests). A collection of rules that is processed together is a ruleset. Rulesets may also contain comments, blank lines, and directives that apply to the processing of a ruleset.

Rules are composed of two parts, an optional rule name and a rule specification. A rule specification can be either a type specification or a member specification. A member specification consists of a member name specification and a type specification.

A type specification is used to specify constraints on a superset of a JSON value (e.g. number / string / object / array etc.). In addition to defining primitive types (such as string or integer), array types, and object types, type specifications may define the JCR specific concept of group types.

Type specifications corresponding to arrays, objects and groups may be composed of other rule specifications.

A member specification is used to specify constraints on a JSON member (i.e. members of a JSON object).

Rules with rule name assignments may be referenced in place of type specifications and member specifications.

Rules may be defined across line boundaries and there is no line continuation syntax.

Any rule consisting only of a type specification is considered a root rule. Unless otherwise specified, all the root rules of a ruleset are evaluated against a JSON instance or document.

Putting it all together, Figure 9 describes the JSON in Figure 8.

Example JSON shamelessly lifted from RFC 4627

```
{
  "Image": {
    "Width": 800,
    "Height": 600,
    "Title": "View from 15th Floor",
    "Thumbnail": {
      "Url": "http://www.example.com/image/481989943",
      "Height": 125,
      "Width": 100
    },
    "IDs": [116, 943, 234, 38793]
  }
}
```

Figure 8

## Rules describing Figure 8

```
; the root of the JSON instance is an object
; this root rule describes that object
{

; the object specification contains
; one member specification
"Image" : {

; $width and $height are defined below
$width,
$height,

; "Title" member specification
"Title" :string,

; "Thumbnail" member specification, which
; defines an object
"Thumbnail": {

; $width and $height are re-used again
$width, $height,

"Url" :uri
},

; "IDs" member that is an array of
; one ore more integers
"IDs" : [ integer * ]

}
}

; The definitions of the rules $width and $height
$width = "Width" : 0..1280
$height = "Height" : 0..1024
```

Figure 9

## 3. Lines and Comments

There is no statement terminator and therefore no need for a line continuation syntax. Rules may be defined across line boundaries. Blank lines are allowed.

Comments are the same as comments in ABNF [RFC4234]. They start with a semi-colon (';') and continue to the end of the line.

#### 4. Rules

Rules have two main components, an optional rule name assignment and a type or member specification.

Type specifications define arrays, objects, etc... of JSON and may reference other rules using rule names. Most type specifications can be defined with repetitions for specifying the frequency of the type being defined. In addition to the type specifications describing JSON types, there is an additional group specification for grouping types.

Member specifications define members of JSON objects, and are composed of a member name specification and either a type specification or a rule name referencing a type specification.

Rules may also contain annotations which may affect the evaluation of all or part of a rule. Rules without a rule name assignment are considered root rules, though rules with a rule name assignment can be considered a root rule with the appropriate annotation.

Type specifications, depending on their type, can contain zero or more other specifications or rule names. For example, an object specification might contain multiple member specifications or rule names that resolve to member specifications or a mixture of member specifications and rule names. For the purposes of this document, specifications and rule names composing other specifications are called subordinate components.

##### 4.1. Rule Names and Assignments

Rule names are signified with the dollar character ('\$'), which is not part of the rule name itself. Rule names have two components, an optional ruleset identifier alias and a local rule name.

Local rule names must start with an alphabetic character (a-z,A-Z) and must contain only alphabetic characters, numeric characters, the hyphen character ('-') and the underscore character ('\_'). Local rule names are case sensitive, and must be unique within a ruleset (that is, no two rule name assignments may use the same local rule name).

Ruleset identifier aliases enable referencing rules from another ruleset. They are not allowed in rule name assignments, and only found in rule names referencing other rules. Ruleset identifiers

must start with an alphabetic character and contain no whitespace. Ruleset identifiers are case sensitive. Simple use cases of JCR will most likely not use ruleset identifiers.

In Figure 10 below, "http://ietf.org/rfcYYYY.JCR" and "http://ietf.org/rfcXXXX.JCR" are ruleset identifiers and "rfcXXXX" is a ruleset identifier alias.

```
# ruleset-id http://ietf.org/rfcYYYY.JCR
# import http://ietf.org/rfcXXXX.JCR as rfcXXXX
$my_encodings = ( "mythic" | "magic" )
$all_encodings = ( $rfcXXXX.encodings | $my_encodings )
```

Figure 10

There are two forms of rule name assignments: assignments of primitive types and assignments of all other types. Rule name assignments to primitive type specifications separate the rule name from the type specification with the character sequence '=', whereas rule name assignments for all other type specifications only require the separation using the '=' character.

```
;rule name assignments for primitive types
$foo      =: "foo"
$some_string =: string

;rule name assignments for arrays
$bar = [ integer, integer, integer ]

;rule name assignment for objects
$bob = { "bar" : $bar, "foo" : $foo }
```

Figure 11

This is the one little "gotcha" in JCR. This syntax is necessary so that JCR parsers may readily distinguish between rule name assignments involving string and regular expressions primitive types and member names of member specifications.

#### 4.2. Annotations

Annotations may appear before a rule name assignment, before a type or member specification, or before a rule name contained within a type specification. In each place, there may be zero or more annotations. Each annotation begins with the character sequence "@{" and ends with "}". The following is an example of a type specification with the not annotation (explained in Section 4.14):



```
@{not} [ "fruits", "vegatables" ]
```

Figure 12

This specification defines the annotations "root", "not", and "unordered", but other annotations may be defined for other purposes.

#### 4.3. Starting Points and Root Rules

Evaluation of a JSON instance or document against a ruleset begins with the evaluation of a root rule or set of root rules. If no root rule (or rules) is specified locally at runtime, the set of root rules specified in the ruleset are evaluated. The order of evaluation is undefined.

The set of root rules specified in a ruleset is composed of all rules without a rule name assignment and all rules annotated with the "@{root}" annotation.

The "@{root}" annotation may either appear before a rule name assignment or before a type definition. It is ignored if present before referenced rule name inside of a type specification.

#### 4.4. Type Specifications

The syntax of each type of type specifications varies depending on the type:

```
; primitive types can be string
; or number literals
; or number ranges
"foo"
2
1..10

; primitive types can also be more generalized types
string
integer

; primitive type rules may be named
$my_int =: 12

; member specifications consist of a member name
; followed by a colon and then followed by another
; type specification or a rule name
; (example shown with a rule name assignment)
$mem1 = "bar" : "baz"
$mem2 = "fizz" : $my_int

; member names may either be quoted strings
; or regular expressions
; (example shown with a rule name assignment)
$mem3 = /^dev[0-9]$/ : 0..4096

; object specifications start and end with "curly braces"
; object specifications contain zero
; or more member specifications
; or rule names which reference a member specification
{ $mem1, "foo" : "fuzz", "fizz" : $my_int }

; array specifications start and end with square brackets
; array specifications contain zero
; or more non-member type specifications
[ 1, 2, 3, $my_int ]

; finally, group specifications start and end with parenthesis
; groups contain other type specifications
( [ integer, integer], $rule1 )
$rule1 = [ string, string ]
```

Figure 13

#### 4.5. Primitive Specifications

Primitive type specifications define content for JSON numbers, booleans, strings, and null.

##### 4.5.1. Numbers, Booleans and Null

The rules for booleans and null are the simplest and take the following forms:

```
true
false
boolean
null
```

Figure 14

Rules for numbers can specify the number be either an integer or floating point number:

```
integer
float
double
```

Figure 15

The keyword 'float' represents a single precision IEEE-754 floating point number represented in decimal. The keyword 'double' represents a double precision IEEE-754 floating point number represented in decimal format.

Numbers may also be specified as an absolute value or a range of possible values, where a range may be specified using a minimum, maximum, or both:

```
n
n..m
..m
n..
n.f
n.f..m.f
..m.f
n.f..
```

Figure 16

When specifying a minimum and a maximum, both must either be an integer or a floating point number. Thus to specify a floating point

number between zero and ten a definition of the following form is used:

```
0.0..10.0
```

Figure 17

Integers may also be specified as ranges using bit lengths preceded by the 'int' or 'uint' words (i.e. 'int8', 'uint16'). The 'int' prefix specifies the integer as being signed whereas the 'uint' prefix specifies the integer as being unsigned.

```
; 0..255
uint8

; -32768..32767
int16

; 0..65535
uint16

; -9223372036854775808..9223372036854775807
int64

; 0..18446744073709551615
uint64
```

Figure 18

#### 4.5.2. Strings

JCR provides a large number of data types to define the contents of JSON strings. Generically, a string may be specified using the word 'string'. String literals may be specified using a double quote character followed by the literal content followed by another double quote. And regular expressions may be specified by enclosing a regular expression within the forward slash ( '/') character.

```
; any string
string

; a string literal
"she sells sea shells"

; a regular expression
/^she sells .*/
```

Figure 19

Regular expressions are not implicitly anchored and therefore must be explicitly anchored if necessary.

A string can be specified as a URI [RFC3986] using the word 'uri', but also may be more narrowly scoped to a URI of a specific scheme. Specific URI schemes are specified with the word 'uri' followed by two period characters ('..') followed by the URI scheme.

```
; any URI
uri

;a URI narrowed for an HTTPS uri
uri..https
```

Figure 20

IP addresses may be specified with either the word 'ipv4' for IPv4 addresses [RFC1166] or the word 'ipv6' for IPv6 addresses [RFC5952]. Fully qualified A-label and U-label domain names may be specified with the words 'fqdn' and 'idn'.

Dates and time can be specified as formats found in RFC 3339 [RFC3339]. The word 'date' corresponds to the full-date ABNF rule, the word 'time' corresponds to the full-time ABNF rule, and the word 'datetime' corresponds to the 'date-time' ABNF rule.

Email addresses formatted according to RFC 5322 [RFC5322] may be specified using the 'email' word, and E.123 phone numbers may be specified using the word 'phone'.

```
;IP addresses
ipv4
ipv6
ipaddr

;domain names
fqdn
idn

; RFC 3339 full-date
date
; RFC 3339 full-time
time
; RFC 3339 date-time
datetime

; RFC 5322 email address
email

; phone number
phone
```

Figure 21

Binary data can be specified in string form using the encodings specified in RFC 4648 [RFC4648]. The word 'hex' corresponds to base16, while 'base32', 'base32hex', 'base64', and 'base64url' correspond with their RFC 4648 counterparts accordingly.

```
; RFC 4648 base16
hex

; RFC 4648 base32
base32

; RFC 4648 base32hex
base32hex

; RFC 4648 base64
base64

; RFC 4648 base64url
base64url
```

Figure 22

#### 4.6. Any Type

It is possible to specify that a value can be of any type allowable by JSON using the word 'any'. The 'any' type specifies any primitive type, array, or object.

#### 4.7. Member Specifications

Member specifications define members of JSON objects. Unlike other type specifications, member specifications cannot be root rules and must be part of an object specification or preceded by a rule name assignment.

Member specifications consist of a member name specification followed by a colon character (':') followed by either a subordinate component, which is either a rule name or a primitive, object, array, or group specification. Member name specifications can be given either as a quoted string using double quotes or as a regular expression using forward slash ('/') characters. Regular expressions are not implicitly anchored and therefore must have explicit anchors if needed.

```
;member name will exactly match "locationURI"  
$location_uri = "locationURI" : uri  
  
;member name will match "eth0", "eth1", ... "eth9"  
$iface_mappings = /^eth[0-9]$/ : ipv4
```

Figure 23

#### 4.8. Object Specifications

Object specifications define JSON objects and are composed of zero or more subordinate components, each of which can be either a rule name, member specification, or group specification. The subordinate components are enclosed at the start with a left curly brace character ('{') and at the end with a right curly brace character ('}').

Evaluation of the subordinate components of object specifications is as follows:

- o No order is implied for the members of the object being evaluated.
- o Subordinate components of the object specification are evaluated in the order they appear.

- o Each member of the object being evaluated can only match one subordinate component.
- o Any members not matched against a subordinate component are ignored.

The following examples illustrate matching of JSON objects to JCR object specifications.

As order is not implied for the members of objects under evaluation, the following rule will match the JSON in Figure 25 and Figure 26.

```
{ "locationUri" : uri, "statusCode" : integer }
```

Figure 24

```
{ "locationUri" : "http://example.com", "statusCode" : 200 }
```

Figure 25

```
{ "statusCode" : 200, "locationUri" : "http://example.com" }
```

Figure 26



Because subordinate components of an object specification are evaluated in the order in which they are specified (i.e. left to right, top to bottom) and object members can only match one subordinate component of an object specification, the rule o1 below will not match against the JSON in Figure 28 but the rule o2 below will match it.

```

; zero or more members that match "p0", "p1", etc
; and a member that matches "p1"
$o1 = { /^p\d+$/ : integer *, "p1" : integer }

; a member that matches "p1" and
; zero or more members that match "p0", "p1", etc
$o2 = { "p1" : integer, /^p\d+$/ : integer * }

```

The first subordinate of rule o1 specifies that an object can have zero or more members (that is the meaning of "\*", see Section 4.13) where the member name is the letter 'p' followed by a number (e.g. "p0", "p1", "p2"), and the second rule specifies a member with the exact member name of "p1". Rule o2 has the exact same member specifications but in the opposite order. Figure 28 does not match rule o1 because all of the members match the first subordinate rule leaving none to match the second subordinate rule. However, rule o2 does match because the first subordinate rule matches only one member of the JSON object allowing the second subordinate rule to match the other member of the JSON object.

Figure 27

```
{ "p0" : 1, "p1" : 2 }
```

Figure 28

As stated above, members of objects which do not match a rule are ignored. The reason for this validation model is due to the nature of the typical access model to JSON objects in many programming languages, where members of the object are obtained by referencing the member name. Therefore extra members may exist without harm.

However, some specifications may need to restrict the members of a JSON object to a known set. To construct a rule specifying that no extra members are expected, the @*{not}* annotation (see Section 4.14) may be used with a "match-all" regular expression as the last subordinate component of the object specification.

The following rule will match the JSON object in Figure 30 but will not match the JSON object in Figure 31.

```
{ "foo" : 1, "bar" : 2, @{not} // : any + }
```

Figure 29

```
{ "foo" : 1, "bar" : 2 }
```

Figure 30

```
{ "foo" : 1, "bar" : 2, "baz" : 3 }
```

Figure 31

This works because subordinate components are evaluated in the order they appear in the object rule, and the last component accepts any member with any type but fails to validate if one or more of those components are found due to the `@{not}` annotation.

#### 4.9. Array Specifications

Array specifications define JSON arrays and are composed of zero or more subordinate components, each of which can either be a rule name or a primitive, array, object or group specification. The subordinate components are enclosed at the start with a left square brace character (`'['`) and at the end with a right square brace character (`']'`).

Evaluation of the subordinate components of array specifications is as follows:

- o The order of array items is implied unless the `@{unordered}` annotation is present.
- o Subordinate components of the array specification are evaluated in the order they appear.
- o Each item of the array being evaluated can only match one subordinate component of the array specification.
- o If any items of the array are not matched, then the array does not match the array specification.

These rules are further explained in the examples below.

```
[ 0..1024, 0..980 ]
```

Figure 32

Unlike object specifications, order is implied in array specifications by default. That is, the first subordinate component will match the first element of the array, the second subordinate component will match the second element of the array, and so on.

Take for example the following ruleset:

```
; the first element of the array is to be a string
; the second element of the array is to be an integer
$a1 = [ string, integer ]

; the first element of the array is to be an integer
; the second element of the array is to be a string
$a2 = [ integer, string ]
```

Figure 33

It defines two rules, a1 and a2. The array in the following JSON will not match a1, but will match a2.

```
[ 24, "Bob Smurd" ]
```

Figure 34

If an array has more elements than can be matched from the array specification, the array does not match the array specification. Or stated differently, an array with unmatched elements does not validate. Using the example array rule a2 from above, the following array does not match because the last element of the array does not match any subordinate component:

```
[ 24, "Bob Smurd", "http://example.com/bob_smurd" ]
```

Figure 35

To allow an array to contain any value after guaranteeing that it contains the necessary items, the last subordinate component of the array specification should accept any item:

```
; the first element of the array is to be an integer
; the second element of the array is to be a string
; anything else can follow
$a3 = [ integer, string, any * ]
```

The JSON array in Figure 35 will validate against the a3 rule in this example.

Figure 36

#### 4.9.1. Unordered Array Specifications

Array specifications can be made to behave in a similar fashion to object specifications with regard to the order of matching with the `@{unordered}` annotation.

In the ruleset below, a1 and a2 have the same subordinate components given in the same order. a2 is annotated with the `@{unordered}` annotation.

```
$a1 = [ string, integer ]
$a2 = @{unordered} [ string, integer ]
```

Figure 37

The JSON array below does not match a1 but does match a2.

```
[ 24, "Bob Smurd" ]
```

Figure 38

Like ordered array specifications, the subordinate components in an unordered array specification are evaluated in the order they are specified. The difference is that they need not match an element of the array in the same position as given in the array specification.

Finally, like ordered array specifications, unordered array specifications also require that all elements of the array be matched by a subordinate component. If the array has more elements than can be matched, the array does not match the array specification.

#### 4.10. Group Specifications

Unlike the other type specifications, group specifications have no direct tie with JSON syntax. Group specifications simply group together their subordinate components. Group specifications enclose one or more subordinate components with the parenthesis characters.

Group specifications and any nesting of group specifications, must conform to the allowable set of type specifications of the type specifications in which they are contained. For example, a group specification inside of an array specification may not contain a member specification since member specifications are not allowed as direct subordinates of array specifications (arrays contain values, not object members in JSON). Likewise, a group specification referenced inside an object specification must only contain member specifications (JSON objects may only contain object members).

The following is an example of a group specification:

```
$the_bradys = [ $parents, $children ]  
  
$children = ( "Greg", "Marsha", "Bobby", "Jan" )  
  
$parents = ( "Mike", "Carol" )
```

Figure 39

Like the subordinate components of array and object specifications, the subordinate components of a group specification are evaluated in the order they appear.

#### 4.11. Ordered and Unordered Groups in Arrays

Section 4.9.1 specifies that arrays can be evaluated by the order of the items in the array or can be evaluated without order. Section 4.10 specifies that arrays may have group rules as subordinate components.

The evaluation of a group specification inside an array specification inherits the ordering property of the array specification. If the array specification is unordered, then the items of the group specification are also considered to be unordered. And if the array specification is ordered, then the items of the group specification are also considered to be ordered.

#### 4.12. Sequence and Choice Combinations in Array, Object, and Group Specifications

Combinations of subordinate components in array, object, and group specifications can be specified as either a sequence ("and") or a choice ("or"). A sequence is a subordinate component followed by the comma character (','), followed by another subordinate component. A choice is a subordinate component followed by a pipe character ('|') followed by another subordinate component.

```
; sequence ("and")
[ "this" , "that" ]

; choice ("or")
[ "this" | "that" ]
```

Figure 40

Sequence and choice combinations cannot be mixed, and group specifications must be used to explicitly declare precedence between a sequence and a choice. Therefore, the following is illegal:

```
[ "this", "that" | "the_other" ]
```

Figure 41

The example above should be expressed as:

```
[ "this", ( "that" | "the_other" ) ]
```

Figure 42

NOTE: A future specification will clarify the choice ('|') operation as inclusive or, exclusive or ("xor") or otherwise. At present readers should assume the choice ('|') operator is an inclusive or. However, for objects and unordered arrays that is not ideal, nor is xor. We are in the process of defining an algorithm to "rewrite" choices of rules for use with inclusive or which is more suitable for the data model of JSON.

#### 4.13. Repetition in Array, Object, and Group Specifications

Evaluation of subordinate components in array, object, and group specifications may be succeeded by a repetition expression denoting how many times the subordinate component should be evaluated. Repetition expressions are specified using a Kleene symbol ('?', '+', or '\*') or with the '\*' symbol succeeded by specific minimum and/or maximum values, each being non-negative integers. Repetition expressions may also be appended with a step expression, which is the '%' symbol followed by a positive integer.

When no repetition expression is present, both the minimum and maximum are 1.

A minimum and maximum can be expressed by giving the minimum followed by two period characters ('..') followed by the maximum, with either the minimum or maximum being optional. When the minimum is not

explicitly specified, it is assumed to be zero. When the maximum is not explicitly specified, it is assumed to be positive infinity.

```

; exactly 2 octets
$word = [ $octet *2 ]
$octet =: int8

; 1 to 13 name servers
[ $name_servers *1..13 ]
$name_servers =: fqdn

; 0 to 99 ethernet addresses
{ /^eth.* / : $mac_addr *..99 }
$mac_addr =: hex

; four or more bytes
[ $octet *4.. ]

```

Figure 43

The allowable Kleene operators are the question mark character ('?') which specifies zero or one (i.e. optional), the plus character ('+') which specifies one or more, and the asterisk character ('\*') which specifies zero or more.

```

; age is optional
{ "name" : string, "age" : integer ? }

; zero or more errors
$error_set = ( string * )

; 1 or more integer values
[ integer + ]

```

Figure 44

A repetition step expression may follow a minimum to maximum expression or the zero or more Kleene operator or the one or more Kleene operator.

- o When the repetition step follows a minimum to maximum expression or the zero or more Kleene operator ('\*'), it specifies that the total number of repetitions present in the JSON instance being validated minus the minimum repetition value must be a multiple of the repetition step (e.g. the total repetitions minus the minimum repetition value must be divisible by the step value with a remainder of zero).

- o When the repetition step follows a one or more Kleene operator ('+'), the minimum repetition value is set equal to the repetition step value and the total number of repetitions minus the step value must be a multiple of the repetition step value.

The following is an example for repetition steps in repetition expressions.

```

; there must be at least 2 name servers
; there may be no more than 12 name servers
; there must be an even number of name servers
; e.g. 2,4,6,8,10,12
[ $name_servers *2..12%2 ]
$name_servers =: fqdn

; minimum is zero
; maximum is 100
; must be an even number
{ /^eth.* / : $mac_addr *..100%2 }
$mac_addr =: hex

; at least 32 octets
; must be in groups of 16
; e.g. 32, 48, 64 etc
[ $octet *32..%16 ]
$octet =: int8

; if there are to be error sets,
; their number must be divisible by 4
; e.g. 0, 4, 8, 12 etc
$error_set = ( string *%4 )

; Throws of a pair of dice must be divisible by 2
; e.g. 2, 4, 6 etc
$dice_throws = ( 1..6 +%2 )

```

Figure 45

#### 4.14. Negating Evaluation

The evaluation of a rule can be changed with the `@{not}` annotation. With this annotation, a rule that would otherwise match does not, and a rule that would not have matched does.



```

; match anything that isn't the integer 2
$not_two = [ @not 2 ]

; error if one of the status values is "fail"
$status = @not @unordered [ "fail", string * ]

```

Figure 46

## 5. Directives

Directives modify the processing of a ruleset. There are two forms of the directive, the single line directive and the multi-line directive.

Single line directives appear on their own line in a ruleset, begin with a hash character ('#') and are terminated by the end of the line. They take the following form:

```
# directive_name parameter_1 parameter_2 ...
```

Figure 47

Multi-line directives also appear on their own lines, but may span multiple lines. They begin with the character sequence "#{" and end with "}". They take the following form:

```
#{ directive_name
   parameter_1 parameter_2
   parameter_3
   ...
}
```

Figure 48

This specification defines the directives "jcr-version", "ruleset-id", and "import", but other directives may be defined.

### 5.1. jcr-version

This directive declares that the ruleset complies with a specific version of this standard. The version is expressed as a major integer followed by a period followed by a minor integer.

```
# jcr-version 0.7
```

Figure 49

The major.minor number signifying compliance with this document is "0.7". Upon publication of this specification as an IETF proposed standard, it will be "1.0".

```
# jcr-version 1.0
```

Figure 50

Ruleset authors are advised to place this directive as the first line of a ruleset.

This directive may have optional extension identifiers following the version number. Each extension identifier is preceded by the plus ('+') character and separated by white space. The format of extension identifiers is specific to the extension, but it is recommended that they are terminated by a version number.

```
# jcr-version 1.0 +co-constraints-1.2 +jcr-doc-1.0
```

Figure 51

## 5.2. ruleset-id

This directive identifies a ruleset to rule processors. It takes the form:

```
# ruleset-id identifier
```

Figure 52

An identifier can be a URL (e.g. `http://example.com/foo`), an inverted domain name (e.g. `com.example.foo`) or any other form that conforms to the JCR ABNF syntax that a ruleset author deems appropriate. To a JCR processor the identifier is treated as an opaque, case-sensitive string.

## 5.3. import

The `import` directive specifies that another ruleset is to have its rules evaluated in addition to the ruleset where the directive appears.

The following is an example:

```
# import http://example.com/rfc9999 as rfc9999
```

Figure 53

The rule names of the ruleset to be imported may be referenced by prepending the alias followed by a period character ('.') followed by the rule name (i.e. "alias.name"). To continue the example above, if the ruleset at <http://example.com/rfc9999> were to have a rule named 'encoding', rules in the ruleset importing it can refer to that rule as 'rfc9999.encoding'.

## 6. Tips and Tricks

### 6.1. Any Member with Any Value

Because member names may be specified with regular expressions, it is possible to construct a member rule that matches any member name. As an example, the following defines an object with a member with any name that has a value that is a string:

```
{ // : string }
```

Figure 54

The JSON below matches the above rule.

```
{ "foo" : "bar" }
```

Figure 55

Likewise, the JSON below also matches the same rule.

```
{ "fuzz" : "bazz" }
```

Figure 56

Constructing an object with a member of any name with any type would therefore take the form:

```
{ // : any }
```

Figure 57

The above rule matches not only the two JSON objects above, but the JSON object below.

```
{ "fuzz" : 1234 }
```

Figure 58

## 6.2. Lists of Values

Group specifications may be used to create enumerated lists of primitive data types, because primitive specifications may contain a group specification, which may have multiple primitive specifications. Because a primitive specification must resolve to a single data type, the group specification must only contain choice combinations.

Consider the following examples:

```
; either an IPv4 or IPv6 address
$address =: ( ipv4 | ipv6 )

; allowable fruits
$fruits =: ( "apple" | "banana" | "pear" )
```

Figure 59

## 6.3. Groups in Arrays

Groups may be a subordinate component of array specifications:

```
[ ( ipv4 | ipv6 ), integer ]
```

Figure 60

Unlike primitive specifications, subordinate group specifications in array specifications may have sequence combinations and contain any type specification.

```
; a group in an array
[ ( $first_name, $middle_name ?, $last_name ), $age ]

; a group referenced from an array
[ $name, $age ]
$name = ( $first_name, $middle_name ?, $last_name )

$first_name =: string
$middle_name =: string
$last_name =: string
$age =: 0..
```

Figure 61

#### 6.4. Groups in Objects

Groups may be a subordinate component of object specifications: Subordinate group specifications in object specifications may have sequence combinations but must only contain member specifications.

```

; a group in an object
{ ( $title, $date, $author ), $paragraph + }

; a group referenced from an object
{ $front_matter, $paragraph + }
$front_matter = ( $title, $date, $author )

$title = "title" : string
$date = "date" : date
$author = "author" : [ string * ]
$paragraph = /p[0-9]*/ : string

```

Figure 62

NOTE: A future specification will clarify the choice ('|') operation as inclusive or, exclusive or ("xor") or otherwise. At present readers should assume the choice ('|') operator is an inclusive or. We are in the process of defining an algorithm to "rewrite" choices of rules for use with inclusive or which is more suitable for the data model of JSON. Such a change will impact the guidance given below.

When using groups to use both sequences and choices of member specifications, consideration must be given to the processing of object specifications where by unmatched member specifications are ignored (see Figure 23).

A casual reading of this rule might lead a reader to believe that the JSON object in Figure 64 would not match, however it does because the extra member (either "foo" or "baz") is not matched but is ignored.

```
{ "bar":string, ( "foo":integer | "baz":string ) }
```

Figure 63

```
{ "bar":"thing", "foo":2, "baz": "thingy" }
```

Figure 64

The rule in Figure 63 must be modified to either match all extra rules, as in Figure 65, or the logic of the rules must be rewritten

to explicitly negate the presence of the unwanted members, as in Figure 66.

```
{ "bar":string, ( "foo":integer | "baz":string ), @not //:any + }
```

Figure 65

```
{ "bar":string,
  ( ( "foo":integer , @not "baz":string ) |
    ( "baz":string , @not "foo":integer )
  ) }
```

Figure 66

#### 6.5. Group Rules as Macros

The syntax for group specifications accommodates one or more subordinate components and a repetition expression for each. Other than grouping multiple rules, a group specification can be used as a macro definition for a single rule.

```
$paragraphs = ( /p[0-9]*/ : string + )
```

Figure 67

#### 6.6. Object Mixins

Group rules can be used to create object mixins, a pattern for writing data models similar in style to object derivation in some programming languages. In the example in below, both obj1 and obj2 have a members "foo" and "fob" with obj1 having the additional member "bar" and obj2 having the additional member "baz".

```
$mixin_group = ( "foo" : integer, "fob" : uri )
$obj1 = { $mixin_group, "bar" : string }
$obj2 = { $mixin_group, "baz" : string }
```

Figure 68

#### 6.7. Subordinate Dependencies

In object and array specifications, there may be situations in which it is necessary to condition the existence of a subordinate component on the existence of a sibling subordinate component. In other words, `example_two` should only be evaluated if `example_one` evaluates positively. Or put another way, a member of an object or an item of

an array may be present only on the condition that another member or item is present.

In the following example, the `referrer_uri` member can only be present if the `location_uri` member is present.

```
    ; $referrer_uri can only be present if
    ; $location_uri is present
    { ( $location_uri, $referrer_uri? )? }

    $location_uri = "locationURI" : uri
    $referrer_uri = "referrerURI" : uri
```

Figure 69

## 7. Implementation Status

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7492] . The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC7492] , "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

### 7.1. JCR Validator

The JCR Validator, written in Ruby, currently implements all portions of this specification, and has been used extensively to prototype various aspects of JCR under consideration. It's development has gone hand-in-hand with this specification.

This software is primarily produced by the American Registry for Internet Numbers (ARIN) and freely distributable under the ISC license.

Source code for this software is available on GitHub at <https://github.com/arineng/jcrvalidator>. This software is also easily obtained as a Ruby Gem through the Ruby Gem system.

## 7.2. Codalogic JCR Parser

The Codalogic JCR Parser is a C++ implementation of a JCR parsing engine, and is a work in progress. It is targeted for the Windows platform.

This software is produced by Codalogic Ltd and freely distributable under the Gnu LGPL v3 license.

Source code is available on GitHub at <https://github.com/codalogic/cl-jcr-parser>.

## 7.3. JCR Java

JCR Java is a work in progress and currently only implements the parsing of JCR rulesets according to the ABNF using a custom parsing framework.

This software is produced by the American Registry for Internet Numbers (ARIN) and freely distributable under the MIT license.

Source code is available on BitBucket at [https://bitbucket.org/aneaton\\_1998/jcr\\_java](https://bitbucket.org/aneaton_1998/jcr_java).

## 8. ABNF Syntax

The following ABNF describes the syntax for JSON Content Rules. A text file containing these ABNF rules can be downloaded from [JCR\_ABNF].

```

jcr           = *( sp-cmt / directive / root-rule / rule )

sp-cmt       = spaces / comment
spaces       = 1*( WSP / CR / LF )
DSPs        = ; Directive spaces
             1*WSP /           ; When in one-line directive
             1*sp-cmt   ; When in muti-line directive
comment     = ";" *comment-char comment-end-char
comment-char = HTAB / %x20-10FFFF
             ; Any char other than CR / LF
comment-end-char = CR / LF

directive    = "#" (one-line-directive / multi-line-directive)
one-line-directive = [ DSPs ]

```



```

        (directive-def / one-line-tbd-directive-d)
        *WSP eol
multi-line-directive = "{" *sp-cmt
                    ( directive-def /
                      multi-line-tbd-directive-d )
                    *sp-cmt "}"
directive-def       = jcr-version-d / ruleset-id-d / import-d
jcr-version-d      = jcr-version-kw DSPs major-version
                    "." minor-version
                    *( DSPs "+" [ DSPs ] extension-id )
major-version      = non-neg-integer
minor-version      = non-neg-integer
extension-id       = ALPHA *not-space
ruleset-id-d       = ruleset-id-kw DSPs ruleset-id
import-d           = import-kw DSPs ruleset-id
                    [ DSPs as-kw DSPs ruleset-id-alias ]
ruleset-id         = ALPHA *not-space
not-space          = %x21-10FFFF
ruleset-id-alias  = name
one-line-tbd-directive-d = directive-name
                    [ WSP one-line-directive-parameters ]
directive-name     = name
one-line-directive-parameters = *not-eol
not-eol           = HTAB / %x20-10FFFF
eol              = CR / LF
multi-line-tbd-directive-d = directive-name
                    [ 1*sp-cmt multi-line-directive-parameters ]
multi-line-directive-parameters = multi-line-parameters
multi-line-parameters = *(comment / q-string / regex /
                          not-multi-line-special)
not-multi-line-special = spaces / %x21 / %x23-2E / %x30-3A /
                        %x3C-7C / %x7E-10FFFF ; not " , / , ; or }

root-rule         = value-rule / group-rule

rule              = annotations "$" rule-name *sp-cmt
                    "=" *sp-cmt rule-def

rule-name         = name
target-rule-name = annotations "$"
                    [ ruleset-id-alias "." ]
                    rule-name
name              = ALPHA *( ALPHA / DIGIT / "-" / "-" )

rule-def          = member-rule / type-designator rule-def-type-rule /
                    array-rule / object-rule / group-rule /
                    target-rule-name
type-designator   = type-kw 1*sp-cmt / ":" *sp-cmt

```

```

rule-def-type-rule = value-rule / type-choice
value-rule         = primitive-rule / array-rule / object-rule
member-rule       = annotations
                   member-name-spec *sp-cmt ":" *sp-cmt type-rule
member-name-spec  = regex / q-string
type-rule         = value-rule / type-choice / target-rule-name
type-choice       = annotations "(" type-choice-items
                   *( choice-combiner type-choice-items ) ")"
explicit-type-choice = type-designator type-choice
type-choice-items = *sp-cmt ( type-choice / type-rule ) *sp-cmt

annotations       = *( "@{" *sp-cmt annotation-set *sp-cmt "}"
                   *sp-cmt )
annotation-set    = not-annotation / unordered-annotation /
                   root-annotation / tbd-annotation
not-annotation    = not-kw
unordered-annotation = unordered-kw
root-annotation   = root-kw
tbd-annotation    = annotation-name [ spaces annotation-parameters ]
annotation-name   = name
annotation-parameters = multi-line-parameters

primitive-rule    = annotations primitive-def
primitive-def     = string-type / string-range / string-value /
                   null-type / boolean-type / true-value /
                   false-value / double-type / float-type /
                   float-range / float-value /
                   integer-type / integer-range / integer-value /
                   sized-int-type / sized-uint-type / ipv4-type /
                   ipv6-type / ipaddr-type / fqdn-type / idn-type /
                   uri-type / phone-type / email-type /
                   datetime-type / date-type / time-type /
                   hex-type / base32hex-type / base32-type /
                   base64url-type / base64-type / any
null-type         = null-kw
boolean-type      = boolean-kw
true-value        = true-kw
false-value       = false-kw
string-type       = string-kw
string-value      = q-string
string-range      = regex
double-type       = double-kw
float-type        = float-kw
float-range       = float-min ".." [ float-max ] / ".." float-max
float-min         = float
float-max         = float
float-value       = float
integer-type      = integer-kw

```

```

integer-range      = integer-min ".." [ integer-max ] /
                    ".." integer-max
integer-min        = integer
integer-max        = integer
integer-value      = integer
sized-int-type     = int-kw pos-integer
sized-uint-type    = uint-kw pos-integer
ipv4-type          = ipv4-kw
ipv6-type          = ipv6-kw
ipaddr-type        = ipaddr-kw
fqdn-type          = fqdn-kw
idn-type           = idn-kw
uri-type           = uri-kw [ ".." uri-scheme ]
phone-type         = phone-kw
email-type         = email-kw
datetime-type      = datetime-kw
date-type          = date-kw
time-type          = time-kw
hex-type           = hex-kw
base32hex-type     = base32hex-kw
base32-type        = base32-kw
base64url-type     = base64url-kw
base64-type        = base64-kw
any                = any-kw

object-rule        = annotations "{" *sp-cmt
                    [ object-items *sp-cmt ] }"
object-items       = object-item [ 1*( sequence-combiner object-item ) /
                    1*( choice-combiner object-item ) ]
object-item        = object-item-types *sp-cmt [ repetition *sp-cmt ]
object-item-types  = object-group / member-rule / target-rule-name
object-group       = annotations "(" *sp-cmt [ object-items *sp-cmt ] ")"

array-rule         = annotations "[" *sp-cmt [ array-items *sp-cmt ] "]"
array-items        = array-item [ 1*( sequence-combiner array-item ) /
                    1*( choice-combiner array-item ) ]
array-item         = array-item-types *sp-cmt [ repetition *sp-cmt ]
array-item-types   = array-group / type-rule / explicit-type-choice
array-group        = annotations "(" *sp-cmt [ array-items *sp-cmt ] ")"

group-rule         = annotations "(" *sp-cmt [ group-items *sp-cmt ] ")"
group-items        = group-item [ 1*( sequence-combiner group-item ) /
                    1*( choice-combiner group-item ) ]
group-item         = group-item-types *sp-cmt [ repetition *sp-cmt ]
group-item-types   = group-group / member-rule /
                    type-rule / explicit-type-choice
group-group        = group-rule

```

```

sequence-combiner = "," *sp-cmt
choice-combiner   = "|" *sp-cmt

repetition        = optional / one-or-more /
                   repetition-range / zero-or-more
optional           = "?"
one-or-more       = "+" [ repetition-step ]
zero-or-more      = "*" [ repetition-step ]
repetition-range  = "*" *sp-cmt (
                   min-max-repetition / min-repetition /
                   max-repetition / specific-repetition )
min-max-repetition = min-repeat ".." max-repeat
                   [ repetition-step ]
min-repetition    = min-repeat ".." [ repetition-step ]
max-repetition    = ".." max-repeat [ repetition-step ]
min-repeat        = non-neg-integer
max-repeat        = non-neg-integer
specific-repetition = non-neg-integer
repetition-step  = "%" step-size
step-size         = non-neg-integer

integer           = "0" / ["-"] pos-integer
non-neg-integer  = "0" / pos-integer
pos-integer       = digit1-9 *DIGIT

float             = [ minus ] int frac [ exp ]
                   ; From RFC 7159 except 'frac' required
minus            = %x2D ; -
plus             = %x2B ; +
int              = zero / ( digit1-9 *DIGIT )
digit1-9         = %x31-39 ; 1-9
frac             = decimal-point 1*DIGIT
decimal-point    = %x2E ; .
exp              = e [ minus / plus ] 1*DIGIT
e                = %x65 / %x45 ; e E
zero            = %x30 ; 0

q-string         = quotation-mark *char quotation-mark
                   ; From RFC 7159
char             = unescaped /
                   escape (
                   %x22 / ; " quotation mark U+0022
                   %x5C / ; \ reverse solidus U+005C
                   %x2F / ; / solidus U+002F
                   %x62 / ; b backspace U+0008
                   %x66 / ; f form feed U+000C
                   %x6E / ; n line feed U+000A
                   %x72 / ; r carriage return U+000D

```

```

        %x74 /           ; t   tab           U+0009
        %x75 4HEXDIG ) ; uXXXX           U+XXXX
escape      = %x5C           ; \
quotation-mark = %x22           ; "
unescaped   = %x20-21 / %x23-5B / %x5D-10FFFF

regex       = "/" *( escape "/" / not-slash ) "/"
              [ regex-modifiers ]
not-slash   = HTAB / CR / LF / %x20-2E / %x30-10FFFF
              ; Any char except "/"
regex-modifiers = *( "i" / "s" / "x" )

uri-scheme  = 1*ALPHA

;; Keywords
any-kw      = %x61.6E.79           ; "any"
as-kw       = %x61.73             ; "as"
base32-kw   = %x62.61.73.65.33.32 ; "base32"
base32hex-kw = %x62.61.73.65.33.32.68.65.78 ; "base32hex"
base64-kw   = %x62.61.73.65.36.34 ; "base64"
base64url-kw = %x62.61.73.65.36.34.75.72.6C ; "base64url"
boolean-kw  = %x62.6F.6F.6C.65.61.6E ; "boolean"
date-kw     = %x64.61.74.65       ; "date"
datetime-kw = %x64.61.74.65.74.69.6D.65 ; "datetime"
double-kw   = %x64.6F.75.62.6C.65 ; "double"
email-kw    = %x65.6D.61.69.6C     ; "email"
false-kw    = %x66.61.6C.73.65     ; "false"
float-kw    = %x66.6C.6F.61.74     ; "float"
fqdn-kw     = %x66.71.64.6E        ; "fqdn"
hex-kw      = %x68.65.78           ; "hex"
idn-kw      = %x69.64.6E           ; "idn"
import-kw   = %x69.6D.70.6F.72.74 ; "import"
int-kw      = %x69.6E.74           ; "int"
integer-kw  = %x69.6E.74.65.67.65.72 ; "integer"
ipaddr-kw   = %x69.70.61.64.64.72 ; "ipaddr"
ipv4-kw     = %x69.70.76.34        ; "ipv4"
ipv6-kw     = %x69.70.76.36        ; "ipv6"
jcr-version-kw = %x6A.63.72.2D.76.65.72.73.69.6F.6E ; "jcr-version"
not-kw      = %x6E.6F.74           ; "not"
null-kw     = %x6E.75.6C.6C        ; "null"
phone-kw    = %x70.68.6F.6E.65     ; "phone"
root-kw     = %x72.6F.6F.74        ; "root"
ruleset-id-kw = %x72.75.6C.65.73.65.74.2D.69.64 ; "ruleset-id"
string-kw   = %x73.74.72.69.6E.67 ; "string"
time-kw     = %x74.69.6D.65        ; "time"
true-kw     = %x74.72.75.65        ; "true"
type-kw     = %x74.79.70.65        ; "type"
uint-kw     = %x75.69.6E.74        ; "uint"

```

```

unordered-kw    = %x75.6E.6F.72.64.65.72.65.64    ; "unordered"
uri-kw         = %x75.72.69                        ; "uri"

;; Referenced RFC 5234 Core Rules
ALPHA          = %x41-5A / %x61-7A    ; A-Z / a-z
CR             = %x0D                ; carriage return
DIGIT         = %x30-39              ; 0-9
HEXDIG        = DIGIT / "A" / "B" / "C" / "D" / "E" / "F"
HTAB          = %x09                ; horizontal tab
LF            = %x0A                ; linefeed
SP            = %x20                ; space
WSP           = SP / HTAB           ; white space

```

Figure 70: ABNF for JSON Content Rules

## 9. Acknowledgements

John Cowan, Andrew Biggs, Paul Kyzivat and Paul Jones provided feedback and suggestions which led to many changes in the syntax.

## 10. References

### 10.1. Normative References

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## 10.2. Infomative References

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- [RFC7492] Bhatia, M., Zhang, D., and M. Jethanandani, "Analysis of Bidirectional Forwarding Detection (BFD) Security According to the Keying and Authentication for Routing Protocols (KARP) Design Guidelines", RFC 7492, DOI 10.17487/RFC7492, March 2015, <<https://www.rfc-editor.org/info/rfc7492>>.

## 10.3. URIs

- [1] <https://github.com/arineng/jcr/tree/master/figs>

## Appendix A. Co-Constraints

This specification defines a small set of annotations and directives for JCR, yet the syntax is extensible allowing for other annotations and directives. [I-D.cordell-jcr-co-constraints] ("Co-Constraints for JCR") defines further annotations and directives which define more detailed constraints on JSON messages, including co-constraints (constraining parts of JSON message based on another part of a JSON message).

## Appendix B. Testing Against JSON Content Rules

One aspect of JCR that differentiates it from other format schema languages are the mechanisms helpful to developers for taking a formal specification, such as that found in an RFC, and evolving it into unit tests, which are essential to producing quality protocol implementations.

## B.1. Locally Overriding Rules

As mentioned in the introduction, one tool for testing would be the ability to locally override named rules. As an example, consider the following rule which defines an array of strings.

```
$statuses = [ string * ]
```

Figure 71

Consider the specification where this rule is found does not define the values but references an extensible list of possible values updated independently of the specification, such as in an IANA registry.

If a software developer desired to test a specific situation in which the array must at least contain the status "accepted", the rules from the specification could be used and the statuses rule could be explicitly overridden locally as:

This rule will evaluate positively with the JSON in Figure 73

```
$statuses = @{\unordered} [ "accepted", string * ]
```

Figure 72

```
[ "submitted", "validated", "accepted" ]
```

Figure 73

Alternatively, the developer may need to ensure that the status "denied" should not be present in the array:

This rule will fail to evaluate the JSON in Figure 75 thus signaling a problem.

```
$statuses = @{\unordered} @{\not} [ "denied" + , string * ]
```

Figure 74



```
[ "submitted", "validated", "denied" ]
```

Figure 75

## B.2. Rule Callbacks

In many testing scenarios, the evaluation of rules may become more complex than that which can be expressed in JCR, sometimes involving variables and interdependencies which can only be expressed in a programming language.

A JCR processor may provide a mechanism for the execution of local functions or methods based on the name of a rule being evaluated. Such a mechanism could pass to the function the data to be evaluated, and that function could return to the processor the result of evaluating the data in the function.

## Appendix C. Changes from -07 and -08

This revision of the document makes no substantive changes to any parts of the specification. Some of the ABNF has been updated to more correctly allow group rules, and other small change have been made to the ABNF to make it simpler.

## Authors' Addresses

Andrew Lee Newton  
American Registry for Internet Numbers  
PO Box 232290  
Centreville, VA 20120  
US

Email: [andy@arin.net](mailto:andy@arin.net)  
URI: <http://www.arin.net>

Pete Cordell  
Codalogic  
PO Box 30  
Ipswich IP5 2WY  
UK

Email: [pete.cordell@codalogic.com](mailto:pete.cordell@codalogic.com)  
URI: <http://www.codalogic.com>

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M. Nottingham  
April 8, 2019

Well-Known Uniform Resource Identifiers (URIs)  
draft-nottingham-rfc5785bis-11

Abstract

This memo defines a path prefix for "well-known locations", `"/.well-known/"`, in selected Uniform Resource Identifier (URI) schemes.

In doing so, it obsoletes RFC 5785, and updates the URI schemes defined in RFC 7230 to reserve that space. It also updates RFC 7595 to track URI schemes that support well-known URIs in their registry.

Note to Readers

`_RFC EDITOR: please remove this section before publication_`

This draft is a proposed revision of RFC5875.

The issues list for this draft can be found at <https://github.com/mnot/I-D/labels/rfc5785bis> [1].

The most recent (often, unpublished) draft is at <https://mnot.github.io/I-D/rfc5785bis/> [2].

Recent changes are listed at <https://github.com/mnot/I-D/commits/gh-pages/rfc5785bis> [3].

See also the draft's current status in the IETF datatracker, at <https://datatracker.ietf.org/doc/draft-nottingham-rfc5785bis/> [4].

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

Some applications on the Web require the discovery of information about an origin [RFC6454] (sometimes called "site-wide metadata") before making a request. For example, the Robots Exclusion Protocol (<http://www.robotstxt.org/> [5]) specifies a way for automated processes to obtain permission to access resources; likewise, the Platform for Privacy Preferences [P3P] tells user-agents how to discover privacy policy before interacting with an origin server.

While there are several ways to access per-resource metadata (e.g., HTTP header fields, WebDAV's PROPFIND [RFC4918]), the perceived overhead (either in terms of client-perceived latency and/or deployment difficulties) associated with them often precludes their use in these scenarios.

At the same time, it has become more popular to use HTTP as a substrate for non-Web protocols. Sometimes, such protocols need a way to locate one or more resources on a given host.

When this happens, one solution is to designate a "well-known location" for data or services related to the origin overall, so that it can be easily located. However, this approach has the drawback of risking collisions, both with other such designated "well-known locations" and with resources that the origin has created (or wishes to create). Furthermore, defining well-known locations usurp's the origin's control over its own URI space [RFC7320].

To address these uses, this memo reserves a path prefix in HTTP, HTTPS, WS and WSS URIs for these "well-known locations", `/.well-known/`. Future specifications that need to define a resource for such metadata can register their use to avoid collisions and minimise impingement upon origins' URI space.

Well-known URIs can also be used with other URI schemes, but only when those schemes' definitions explicitly allow it.

## 2. Notational Conventions

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.

### 3. Well-Known URIs

A well-known URI is a URI [RFC3986] whose path component begins with the characters `"/.well-known/"`, provided that the scheme is explicitly defined to support well-known URIs.

For example, if an application registers the name `'example'`, the corresponding well-known URI on `'http://www.example.com/'` would be `'http://www.example.com/.well-known/example'`.

This specification updates the `"http"` [RFC7230] and `"https"` [RFC7230] schemes to support well-known URIs. Other existing schemes can use the appropriate process for updating their definitions; for example, [RFC8307] does so for the `"ws"` and `"wss"` schemes. The Uniform Resource Identifier (URI) Schemes Registry tracks which schemes support well-known URIs; see Section 5.2.

Applications that wish to mint new well-known URIs **MUST** register them, following the procedures in Section 5.1, subject to the following requirements.

Registered names **MUST** conform to the segment-nz production in [RFC3986]. This means they cannot contain the `"/"` character.

Registered names for a specific application **SHOULD** be correspondingly precise; "squatting" on generic terms is not encouraged. For example, if the Example application wants a well-known location for metadata, an appropriate registered name might be `"example-metadata"` or even `"example.com-metadata"`, not `"metadata"`.

At a minimum, a registration will reference a specification that defines the format and associated media type(s) to be obtained by dereferencing the well-known URI, along with the URI scheme(s) that the well-known URI can be used with. If no URI schemes are explicitly specified, `"http"` and `"https"` are assumed.

Typically, applications will use the default port for the given scheme; if an alternative port is used, it **MUST** be explicitly specified by the application in question.

Registrations **MAY** also contain additional information, such as the syntax of additional path components, query strings and/or fragment identifiers to be appended to the well-known URI, or protocol-specific details (e.g., HTTP [RFC7231] method handling).

Note that this specification defines neither how to determine the hostname to use to find the well-known URI for a particular application, nor the scope of the metadata discovered by

dereferencing the well-known URI; both should be defined by the application itself.

Also, this specification does not define a format or media-type for the resource located at `"/.well-known/"` and clients should not expect a resource to exist at that location.

Well-known URIs are rooted in the top of the path's hierarchy; they are not well-known by definition in other parts of the path. For example, `"/.well-known/example"` is a well-known URI, whereas `"/foo/.well-known/example"` is not.

See also Section 4 for Security Considerations regarding well-known locations.

### 3.1. Registering Well-Known URIs

The "Well-Known URIs" registry is located at `"https://www.iana.org/assignments/well-known-uris/"`. Registration requests can be made by following the instructions located there or by sending an email to the `"wellknown-uri-review@ietf.org"` mailing list.

Registration requests consist of at least the following information:

URI suffix: The name requested for the well-known URI, relative to `"/.well-known/"`; e.g., `"example"`.

Change controller: For Standards-Track RFCs, state `"IETF"`. For others, give the name of the responsible party. Other details (e.g., e-mail address, home page URI) may also be included.

Specification document(s): Reference to the document that specifies the field, preferably including a URI that can be used to retrieve a copy of the document. An indication of the relevant sections may also be included, but is not required.

Status: One of `"permanent"` or `"provisional"`. See guidance below.

Related information: Optionally, citations to additional documents containing further relevant information.

General requirements for registered values are described in Section 3.

Values defined by standards-track RFCs and other open standards (in the sense of [RFC2026], Section 7.1.1) have a status of `"permanent"`. Other values can also be registered as permanent, if the Experts find

that they are in use, in consultation with the community. Other values should be registered as "provisional".

Provisional entries can be removed by the Experts if - in consultation with the community - the Experts find that they are not in use. The Experts can change a provisional entry's status to permanent; in doing so, the Experts should consider how widely used a value is, and consult the community beforehand.

Note that "consult with the community" above refers to those responsible for the URI scheme(s) in question. Generally, this would take place on the mailing list(s) of the appropriate Working Group(s) (possibly historical), or on [art@ietf.org](mailto:art@ietf.org) if no such list exists.

Well-known URIs can be registered by third parties (including the expert(s)), if the expert(s) determine that an unregistered well-known URI is widely deployed and not likely to be registered in a timely manner otherwise. Such registrations still are subject to the requirements defined, including the need to reference a specification.

#### 4. Security Considerations

Applications minting new well-known URIs, as well as administrators deploying them, will need to consider several security-related issues, including (but not limited to) exposure of sensitive data, denial-of-service attacks (in addition to normal load issues), server and client authentication, vulnerability to DNS rebinding attacks, and attacks where limited access to a server grants the ability to affect how well-known URIs are served.

[RFC3552] contains some examples of potential security considerations that may be relevant to application protocols and administrators deploying them.

##### 4.1. Protecting Well-Known Resources

Because well-known locations effectively represent the entire origin, server operators should appropriately control the ability to write to them. This is especially true when more than one entity is co-located on the same origin. Even for origins that are controlled by and represent a single entity, due care should be taken to assure that write access to well-known locations is not granted unwittingly, either externally through server configuration, or locally through implementation permissions (e.g., on a filesystem).

#### 4.2. Interaction with Web Browsing

Applications using well-known URIs for "http" or "https" URLs need to be aware that well-known resources will be accessible to Web browsers, and therefore are able to be manipulated by content obtained from other parts of that origin. If an attacker is able to inject content (e.g., through a Cross-Site Scripting vulnerability), they will be able to make potentially arbitrary requests to the well-known resource.

HTTP and HTTPS also use origins as a security boundary for many other mechanisms, including (but not limited to) Cookies [RFC6265], Web Storage [WEBSTORAGE] and many capabilities.

Applications defining well-known locations should not assume that they have sole access to these mechanisms, or that they are the only application using the origin. Depending on the nature of the application, mitigations can include:

- o Encrypting sensitive information
- o Allowing flexibility in the use of identifiers (e.g., Cookie names) to avoid collisions with other applications
- o Using the 'HttpOnly' flag on Cookies to assure that cookies are not exposed to browser scripting languages [RFC6265]
- o Using the 'Path' parameter on Cookies to assure that they are not available to other parts of the origin [RFC6265]
- o Using X-Content-Type-Options: nosniff [FETCH] to assure that content under attacker control can't be coaxed into a form that is interpreted as active content by a Web browser

Other good practices include:

- o Using an application-specific media type in the Content-Type header field, and requiring clients to fail if it is not used
- o Using Content-Security-Policy [CSP] to constrain the capabilities of active content (such as HTML [HTML5]), thereby mitigating Cross-Site Scripting attacks
- o Using Referrer-Policy [REFERRER-POLICY] to prevent sensitive data in URLs from being leaked in the Referer request header field
- o Avoiding use of compression on any sensitive information (e.g., authentication tokens, passwords), as the scripting environment



offered by Web browsers allows an attacker to repeatedly probe the compression space; if the attacker has access to the path of the communication, they can use this capability to recover that information.

#### 4.3. Scoping Applications

This memo does not specify the scope of applicability for the information obtained from a well-known URI, and does not specify how to discover a well-known URI for a particular application.

Individual applications using this mechanism must define both aspects; if this is not specified, security issues can arise from implementation deviations and confusion about boundaries between applications.

Applying metadata discovered in a well-known URI to resources other than those co-located on the same origin risks administrative as well as security issues. For example, allowing "https://example.com/.well-known/example" to apply policy to "https://department.example.com", "https://www.example.com" or even "https://www.example.com:8000" assumes a relationship between hosts where there might be none, giving control to a potential attacker.

Likewise, specifying that a well-known URI on a particular hostname is to be used to bootstrap a protocol can cause a large number of undesired requests. For example, if a well-known HTTPS URI is used to find policy about a separate service such as e-mail, it can result in a flood of requests to Web servers, even if they don't implement the well-known URI. Such undesired requests can resemble a denial-of-services attack.

#### 4.4. Hidden Capabilities

Applications using well-known locations should consider that some server administrators might be unaware of its existence (especially on operating systems that hide directories whose names begin with "."). This means that if an attacker has write access to the .well-known directory, they would be able to control its contents, possibly without the administrator realising it.

### 5. IANA Considerations

#### 5.1. The Well-Known URI Registry

This specification updates the registration procedures for the "Well-Known URI" registry, first defined in [RFC5785]; see Section 3.1.

Well-known URIs are registered on the advice of one or more Experts, with a Specification Required (using terminology from [RFC8126]).

The Experts' primary considerations in evaluating registration requests are:

- o Conformance to the requirements in Section 3
- o The availability and stability of the specifying document
- o The considerations outlined in Section 4

IANA will direct any incoming requests regarding the registry to this document and, if defined, the processes established by the expert(s); typically, this will mean referring them to the registry Web page.

Upon publication, IANA should:

- o Update the status of all existing registrations to "permanent".

## 5.2. The Uniform Resource Identifier (URI) Schemes Registry

This specification adds a field to the registration template of the Uniform Resource Identifier (URI) Schemes Registry, with the name "Well-Known URI Support" and a default value of "-".

If a URI scheme explicitly has been specified to use well-known URIs as per Section 3, the value changes to a reference to that specification. Initial values not equal to "-" are given in Table 1.

URI Scheme	Well-Known URI Support
coap	[RFC7252]
coap+tcp	[RFC8323]
coap+ws	[RFC8323]
coaps	[RFC7252]
coaps+tcp	[RFC8323]
coaps+ws	[RFC8323]
http	[this document]
https	[this document]
ws	[RFC8307]
wss	[RFC8307]

Table 1: Rows in URI scheme registry with nonempty new column

## 6. References

### 6.1. Normative References

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### 6.3. URIs

- [1] <https://github.com/mnot/I-D/labels/rfc5785bis>
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- [3] <https://github.com/mnot/I-D/commits/gh-pages/rfc5785bis>
- [4] <https://datatracker.ietf.org/doc/draft-nottingham-rfc5785bis/>
- [5] <http://www.robotstxt.org/>

### Appendix A. Frequently Asked Questions

Aren't well-known locations bad for the Web? They are, but for various reasons - both technical and social - they are sometimes necessary. This memo defines a "sandbox" for them, to reduce the risks of collision and to minimise the impact upon pre-existing URIs on sites.

Why /.well-known? It's short, descriptive, and according to search indices, not widely used.

What impact does this have on existing mechanisms, such as P3P and robots.txt?

None, until they choose to use this mechanism.

Why aren't per-directory well-known locations defined? Allowing every URI path segment to have a well-known location (e.g., "/images/.well-known/") would increase the risks of colliding with a pre-existing URI on a site, and generally these solutions are found not to scale well, because they're too "chatty".

### Appendix B. Changes from RFC5785

- o Allow non-Web well-known locations
- o Adjust IANA instructions
- o Update references
- o Various other clarifications
- o Track supporting schemes in the URI Scheme registry

Author's Address

Mark Nottingham

Email: [mnot@mnot.net](mailto:mnot@mnot.net)

URI: <https://www.mnot.net/>