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User-assisted Trust Establishment (EAP-UTE)  
draft-rieckers-emu-eap-ute-00

## Abstract

The Extensible Authentication Protocol (EAP) provides support for multiple authentication methods. This document defines the EAP-UTE authentication method for a User-assisted Trust Establishment between the peer and the server. The EAP method is intended for bootstrapping Internet-of-Things (IoT) devices without preconfigured authentication credentials. The trust establishment is achieved by transmitting a one-directional out-of-band (OOB) message between the peer and the server to authenticate the in-band exchange. The peer must have a secondary input or output interface, such as a display, camera, microphone, speaker, blinking light, or light sensor, so that dynamically generated messages with tens of bytes in length can be transmitted or received.

## About This Document

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

Status information for this document may be found at  
<https://datatracker.ietf.org/doc/draft-rieckers-emu-eap-ute/>.

Discussion of this document takes place on the EAP Method Update (emu) Working Group mailing list (<mailto:emu@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/emu/>.

## 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 document describes a method for registration, authentication, and key derivation for network-connected devices, especially with low computational power and small or no interaction interfaces, such as devices that are part of the Internet of Things (IoT). These devices may come without preconfigured trust anchors or have no possibility to receive a network configuration that enables them to connect securely to a network.

This document uses the basic design principle behind the EAP-N00B method described in [[RFC9140](#)] and aims to improve some key elements of the protocol to better address the needs for IoT devices. This is mainly achieved by using CBOR with numeric keys instead of JSON to encode the exchanged messages.

TODO: The EAP-UTE protocol also allows extensions, they are still TBD. Basically, the messages can just include additional fields with newly defined meanings.

The possible problems of EAP-N00B are discussed in [I-D.[draft-rieckers-emu-eap-noob-observations](#)]. This document provides a specification which aims to address these concerns.

## [2.](#) Conventions and Definitions

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

TODO frequently used terms

authenticator

peer

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server

### [3.](#) EAP-UTE protocol

This section defines the EAP-UTE method.

#### [3.1.](#) Protocol Overview

TODO: The introduction text is basically copied from [RFC9140](#). Should be reworded.

The EAP-UTE method execution spans two or more EAP conversations, called Exchanges in this specification. Each Exchange consists of several EAP request-response pairs. In order to give the user time to deliver the OOB message between the peer and the server, at least two separate EAP conversations are needed.

The overall protocol starts with a version and cryptosuite negotiation and peer detection. Depending of the current state of the peer and server, different exchanges are selected.

If the server or the peer are in the unregistered state, peer and server exchange nonces and keys for the Ephemeral Elliptic Curve Diffie-Hellman. This is called the Initial Exchange. The Initial Exchange results in an EAP-Failure, since neither the server nor the peer are authenticated.

After the Initial Exchange, the user-assisted step of trust establishment takes place. The user delivers one OOB message either

While peer and server are waiting for completion of the OOB Step, the peer MAY probe the server by reconnecting, to check for successful transmission of the OOB message. This probe request will result in a Waiting Exchange and EAP-Failure, if the server has not yet received the OOB message.

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```

Waiting
      .-----V
+-----+ +-----+
->| Unregistered (0) | Initial | Waiting for OOB (1) |
   | (ephemeral)    | -----> | (ephemeral)       |
+-----+ +-----+
      |               |
User Reset      .-----'         | OOB Input
                  | Completion     |
                  V                 V
+-----+ +-----+
-| Registered (3) | Completion | OOB Received (2) |
   | (persistent) | <----- |                   |
+-----+ +-----+

```

Figure 1: EAP-UTE Server-Peer Association State Machine

## 3.2. Messages

### 3.2.1. General Message format

All EAP-UTE messages consist of the following parts:

type: one octet to indicate the type of the message

length: two octets indicating the length of the following message payload, not including the optional MAC value

payload: the CBOR encoded message

MAC: (optional) the message authentication code

Remark from the author:

This format is just a first draft. It allows a very simple MAC calculation, since the MACs can just consist of the concatenated previous messages. This also allows an easy addition of extensions, since the extension payloads are automatically included in the MAC calculation, if they are part of the CBOR payload.

The message payloads are encoded in CBOR [[RFC8949](#)] as maps.

In Table 1 the different message fields, their assigned mapkey and the type are listed.

Mapkey	Type	Label	Description
1	Array of Integers	Versions	The versions supported by the server. For this document the version is 1
2	Integer	Version	The version selected by the peer
3	Array?	Ciphers	The ciphers supported by

			the server. TODO: Not yet sure how to define them.
4	Integer?	Cipher	The cipher selected by the peer
5	Integer	Directions	The 00B-Directions supported by the server. 0x01 for peer-to-server, 0x02 for server-to-peer, 0x03 for both
6	Integer	Direction	The 00B-Direction selected by the peer. SHOULD be either 0x01 or 0x02, but MAY be 0x03 for both directions
7	Map	ServerInfo	Information about the server, e.g. a URL for 00B-message-submission
8	Map	PeerInfo	Information about the peer, e.g. manufacturer/serial number
9	bytes	Nonce_P	Peer Nonce
10	bytes	Nonce_S	Server Nonce
11	?	Key_P	Peer's ECDHE key according to the chosen

			cipher
12	?	Key_S	Server's ECDHE key
13	null	MAC_S	Indication that Server MAC is included
14	null	MAC_P	Indication that Peer MAC

			is included
15	text	PeerId	Peer Identifier
16	bytes	OOB-Id	Identifier of the OOB message
17	int	RetryInterval	Number of seconds to wait after a failed Completion Exchange
18	Map	AdditionalServerInfo	Additional information about the server. TODO: not sure about this yet.

Table 1: Mapkeys for CBOR encoding

The inclusion of MAC\_S or MAC\_P indicate that the MAC value is appended to the message. The length of the MAC field is determined by the used cryptosuite. A message MUST NOT contain both MAC\_S and MAC\_P, only one of these values can be present in a message.

TODO: Depending on the definition of the Cipher Suites, the format for Ciphers and Cipher might change, as well as Key\_P and Key\_S. The most immediate choice would be COSE [RFC8152]. But maybe there are better choices out there.

#### 3.2.1.1. Thoughts about the message format

EAP-NOOB [RFC9140] uses JSON as encoding. Problems of using JSON are discussed in [section 2.1](#) of [I-D.[draft-rieckers-emu-eap-noob-observations](#)].

For this specification, the following encodings have been considered:

- \* Static encoding  
This allows a minimal number of bytes and requires a minimal amount of parsing, since the format and order of the message fields is specified exactly. However, this encoding severely

affects the extensibility, unless a specific extension format is



used. The specification of this protocol also has optional fields in some message types, so this would also have to be addressed.

- \* CBOR with static fields (e.g. Array)  
This approach has a slightly higher number of bytes than the static encoding, but allows an easier extensibility. The required fields can be specified, so the order of the protocol field is static and a parser has minimal effort to parse the protocol fields. However, this might be problematic in future protocol versions, when new fields are introduced. Like with static encoding, this also requires a mechanism for optional fields in the different message types.
- \* CBOR map with numeric keys  
To mitigate the problems of optional fields while keeping the parsing effort low, CBOR maps with numeric keys can be used. All protocol fields are identified by a unique identifier, specified in this document. A parser can simply loop through the CBOR map. Since CBOR maps have a canonical order, minimal implementations may rely on this fact to parse the information needed.

On the basis of this discussion, this draft will use a CBOR map as message encoding. However, this is just a first draft and suggestions for other message formats are highly welcome.

### [3.2.2.](#) Server greeting

- \* Message Type: 1
- \* Required Attributes:
  - Versions
  - Ciphers
  - ServerInfo
  - Directions
- \* Optional Attributes:
  - RetryInterval?

### [3.2.3.](#) Client greeting

- \* Message Type: 2

- \* Required Attributes:

- Version
- Cipher
- PeerInfo
- Direction
- Nonce\_P
- Key\_P

- \* Optional Attributes:

- PeerId

#### [3.2.4.](#) Server Keyshare

- \* Message Type: 3

- \* Required Attributes:

- Key\_S
- Nonce\_S
- MAC\_S

- \* Optional Attributes:

- PeerId
- AdditionalServerInfo?
- RetryInterval?

TODO: Maybe make MAC\_S optional, if used in Initial Exchange

#### [3.2.5.](#) Client Finished

- \* Message Type: 4

- \* Required Attributes:

- MAC\_P

TODO: Maybe make MAC\_P optional, if used in Initial Exchange

#### [3.2.6.](#) Client Completion Request

- \* Message Type: 5
- \* Required Attributes:
  - Nonce\_P
  - PeerId
- \* Optional Attributes:
  - OOB-Id

#### [3.2.7.](#) Server Completion Response

- \* Message Type: 6
- \* Required Attributes:
  - Nonce\_S
  - MAC\_S
- \* Optional Attributes:
  - OOB-Id

#### [3.2.8.](#) Client Keyshare

- \* Message Type: 7
- \* Required Attributes:
  - PeerId
  - Nonce\_P

- Key\_P

### [3.3.](#) Protocol Sequence

After reception of the EAP-Response/Identity packet, the server always answers with a Server Greeting packet (Type 1). This Server Greeting contains the supported protocol versions, ciphers and OOB directions along with the ServerInfo.

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Depending on the peer state, the peer chooses the next packet. If the peer is in the unregistered state and does not yet have an ephemeral or persistent state, it chooses the Client Greeting, which starts the Initial Handshake.

If the peer is in the Waiting for OOB or OOB Received state, the Initial Exchange has completed and the OOB step needs to take place. If the negotiated direction is from server to peer, the peer SHOULD NOT try to reconnect until the peer received an OOB message. If the negotiated direction is from peer to server, the peer can probe the server at regular intervals to check if the OOB message to the server has been delivered. The peer will send a Client Completion Request to initiate the Waiting/Completion Exchange.

If the peer is in the Registered state, it may choose between three different Reconnect Exchanges. If the peer wants a reconnect without new key exchanges, it will send a Client Completion Request, starting the Reconnect Exchange without ECDHE. If the peer wants to reconnect with new key exchanges, it will send a Client Key Share packet, which starts the Reconnect Exchange with new ECDHE exchange. The third option is a reconnect with a new version or cipher, this is TBD.

#### [3.3.1.](#) Initial Exchange

The Initial Exchange comprises of the following packets:

After the Server Greeting common to all exchanges, the peer sends a Client Greeting packet. The Client Greeting contains the peer's chosen protocol version, cipher and direction of the OOB message. The peer MUST only choose values for these fields offered by the server in it's Server Greeting. For Direction the peer SHOULD choose either 0x01 or 0x02 if the server offered 0x03. Additionally, the

Client Greeting contains PeerInfo, a nonce and the peer's ECDHE public key.

The server will then answer with a Server Keyshare packet. The packet contains a newly allocated PeerId, the server's nonce and ECDHE public key and the message authentication code MAC\_S.

The peer then answers with a Client Finished packet, containing the peer's message authentication code MAC\_P.

Since no authentication has yet been achieved, the server then answers with an EAP-Failure.

EAP Peer	Authenticator	EAP Server
<- EAP-Request/Identity -		
-- EAP-Response/Identity ----->		
(NAI=new@eap-ute.arpa)		
<- EAP-Request/EAP-UTE -----		
SERVER GREETING (1)		
Versions, Ciphers, ServerInfo,		
Directions		
-- EAP-Response/EAP-UTE ----->		
CLIENT GREETING (2)		
Version, Cipher, PeerInfo,		
Direction, Nonce_P, Key_P		
<- EAP-Request/EAP-UTE -----		
SERVER KEYSHARE (3)		
PeerId, Key_S, Nonce_S, MAC_S		
-- EAP-Response/EAP-UTE ----->		
CLIENT FINISHED (4)		
MAC_P		

```

|<- EAP-Failure -----|
|                               |

```

Figure 2: Initial Exchange

TODD: Do I need MACs here? What are they really for? (see [Section 3.4](#) for more thoughts on this)

### [3.3.2.](#) User-assisted out-of-band step

After the completed Initial Exchange, the peer or the server, depending on the negotiated direction, will generate an OOB message.

Details still TBD.

### [3.3.3.](#) Waiting Exchange

The Waiting Exchange is performed if neither the server nor the peer have received an OOB message yet.

The peer probes the server with a Client Completion Request. In this packet the peer omits the optional OOB-Id field. If the OOB message is delivered from the peer to the server, the server may have

received an OOB message already. To allow the server to complete the association, the peer includes a nonce, along with the allocated PeerId. The nonce MAY be repeated for all Client Completion Requests while waiting for the completion.

If the server did not receive an OOB message, it answers with an EAP-Failure.

EAP Peer	Authenticator	EAP Server
<- EAP-Request/Identity -		
-- EAP-Response/Identity ----->		
(NAI=waiting@eap-ute.arpa)		
<- EAP-Request/EAP-UTE -----		
SERVER GREETING (1)		
Versions, Ciphers, Server Info,		

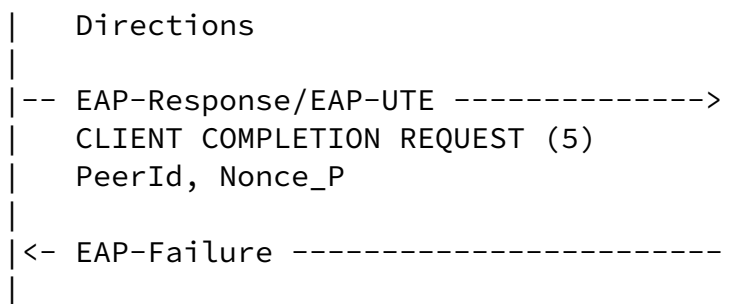


Figure 3: Waiting Exchange

#### 3.3.4. Completion Exchange

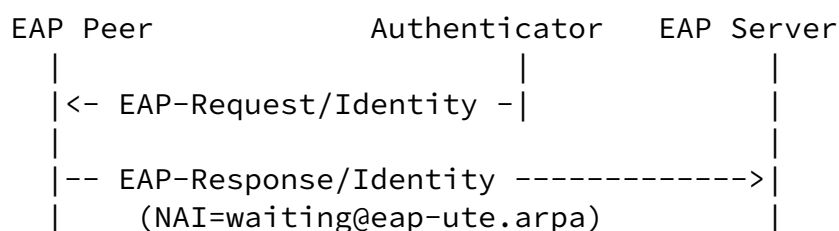
The Completion Exchange is performed to finish the mutual trust establishment.

As in the Waiting Exchange, the peer probes the server with a Client Completion Request. The nonce of the previous Client Completion Requests which did not lead to a completion MAY be repeated. If the peer has received an OOB message, the peer will include the OOB-Id in the Completion Request. If the peer did not include an OOB-Id, the server will include the OOB-Id of its received OOB message. In the unlikely case that both directions are negotiated and an OOB message is delivered from the peer to the server and from the server to the peer at the same time, as a tiebreaker, the OOB message from the server to the peer is chosen.

The server generates a new nonce, calculates MAC\_S according to [Section 3.4](#) and sends a Server Completion Response to the peer.

The peer will then calculate the MAC\_P value and send a Client Finished message to the server.

The server then answers with an EAP-Success.



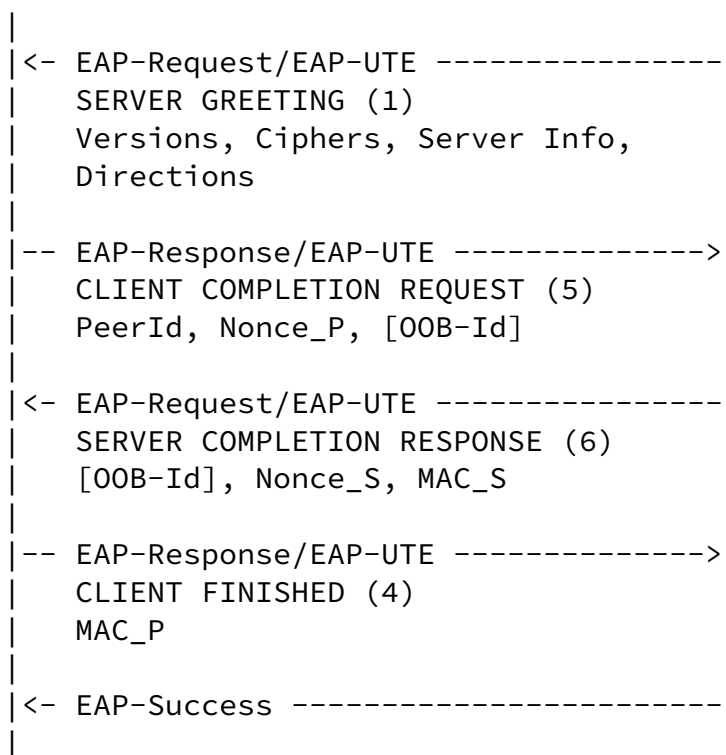


Figure 4: Completion Exchange

### 3.3.5. Reconnect Exchange

The Reconnect Exchange is performed if both the peer and the server are in the registered state.

For a reconnect without new exchanging of ECDHE keys, the peer will answer to the Server Greeting with a Client Completion Request, including the PeerId and a nonce.

To distinguish a Reconnect Exchange from a Waiting/Completion Exchange, the server will look up the saved states for the transmitted PeerId. If the server has a persistent state saved, it will choose the Reconnect Exchange, otherwise it will choose the Waiting Exchange.

The server will then generate a nonce and the MAC\_S value according to [Section 3.4](#) and send a Server Completion Response with the nonce and MAC\_S value.



The peer then sends a Client Finished message, containing the computed MAC\_P value.

The server then answers with an EAP-Success.

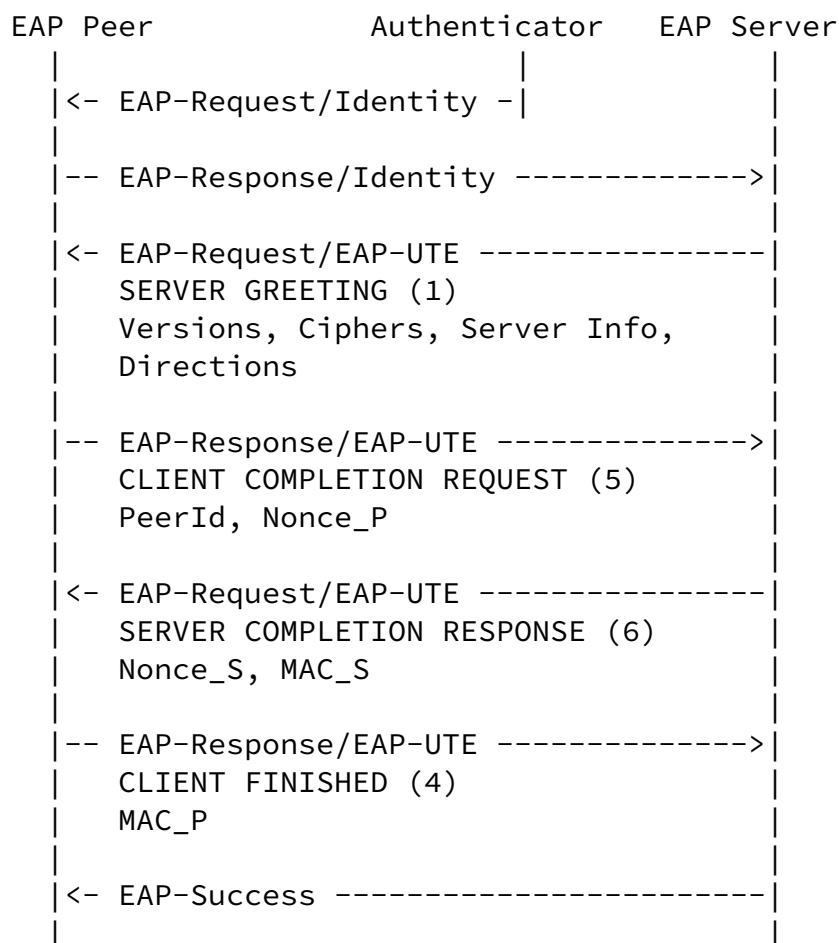


Figure 5: Reconnect Exchange without new ECDHE exchange

For a Reconnect Exchange with new ECDHE exchange, the peer will send a Client Keyshare in response to the Server Greeting. The Client Keyshare will include the PeerId, a nonce and a new ECDHE key.

The server will also generate a new ECDHE key, a nonce and compute MAC\_S according to [Section 3.4](#).

The peer will then calculate the MAC\_P value and send a Client Finished message to the server.

The server then answers with an EAP-Success.

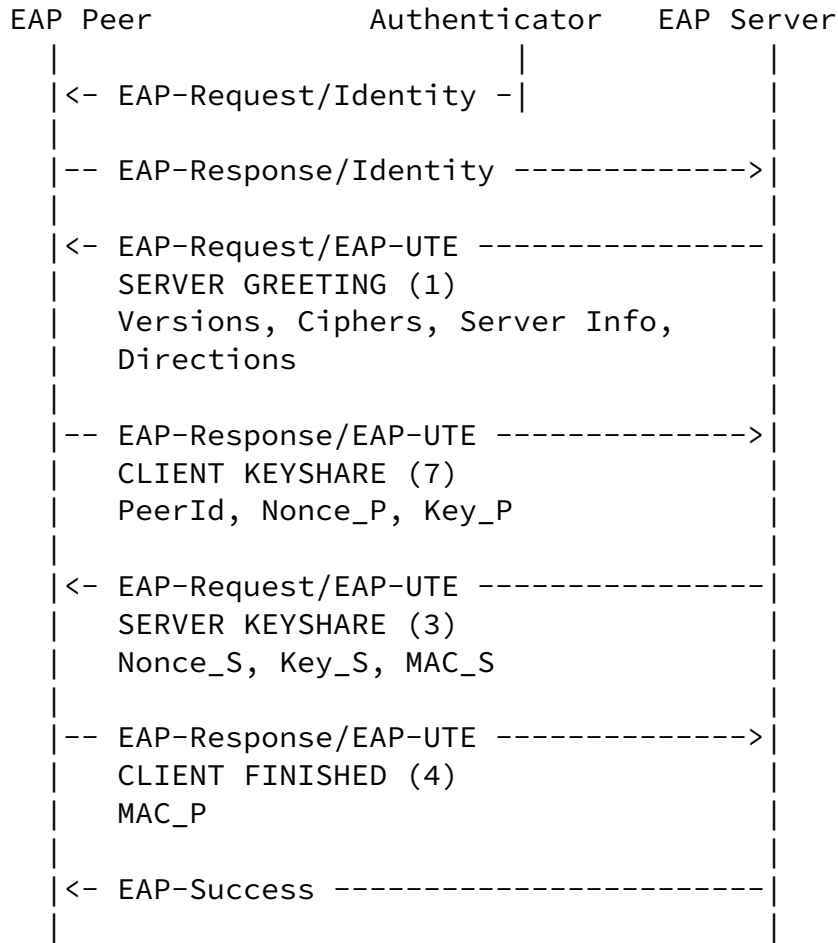


Figure 6: Reconnect Exchange with new ECDHE exchange

TOD0: Reconnect exchange with updated version or cipher suite

#### [3.4.](#) MAC and OOB calculation and Key derivation

For the MAC calculation, the exchanged messages up to the current message are concatenated into the "Messages" field. This field consists for each message of the one octet message type, the two octet encoding of the length and the CBOR encoded message payload. The optional MAC value at the end of the message is omitted for the MAC calculation. For the calculation of the MAC\_S value, the Messages field also includes the Server Keyshare/Server Completion Response message. For MAC\_P the Client Finished message is omitted, so both MAC\_P and MAC\_S have the same input.

For the following definition || denotes a concatenation.

Messages = Type\_1 || Length\_1 || Payload\_1 || ... || Type\_n ||  
Length\_n || Payload\_n

OOB-Id = H(OOB-Nonce || Messages)

TODO: Calculation of MAC\_S/MAC\_P

Idea: For initial exchange  $\text{MAC\_S/MAC\_P} = \text{HMAC}(\text{key}, \text{Messages})$ , and for completion exchange  $\text{MAC\_S/MAC\_P} = \text{HMAC}(\text{key}, \text{prev\_MAC\_S} || \text{prev\_MAC\_P} || \text{Messages})$

TODO: Key derivation. Here I have a problem. If I want to send MACs in the initial exchange, I somehow have to make a key derivation already. Maybe this is too costly. Maybe it would only be necessary to save a Hash of the previous messages during the InitialExchange and include it in the KDF to cryptographically bind the Server/PeerInfo to the connection. This way, the Initial Exchange wont have MACs, the integrity check is done completely by exchanging of MACs during the Completion Exchange. This will probably be more clear in the -01 draft version.

### [3.5.](#) Error handling

TBD

## [4.](#) Security Considerations

This document has a lot of security considerations, however they remain TBD

### [4.1.](#) EAP Security Claims

TODO. See [\[RFC3748\], section 7.2.1](#)

## [5.](#) IANA Considerations

This document has IANA actions, if approved. What they are exactly needs to be defined in detail.

The EAP Method Type number for EAP-UTE needs to be assigned. The reference implementation will use 255 (Experimental) for now.

Like EAP-N00B, this draft will probably use a .arpa domain, in this case probably eap-ute.arpa, as default NAI realm.

Additionally, the IANA should create registries for the message types and the message field mapkeys.

## 6. Implementation Status

Note to RFC Editor: Please remove this entire section before publication.

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There are no implementations yet.

## 7. Differences to [RFC 9140](#) (EAP-NOOB)

In this section the main differences between EAP-NOOB and EAP-UTE are discussed. Some problems of [[RFC9140](#)] are discussed in [I-D.[draft-rieckers-emu-eap-noob-observations](#)].

### 7.1. Different encoding

EAP-UTE uses CBOR instead of JSON. More text TBD.

### 7.2. Implicit transmission of peer state

In EAP-NOOB all EAP exchanges start with the same common handshake, which mainly serves the purpose of detecting the current peer state.

The server initiates the EAP conversation by sending a Type 1 message without any further content, to which the peer responds by sending its PeerId, if it was assigned, and its PeerState.

In EAP-UTE, this peer state transmission is done implicitly by the peer's choice of response to the Server Greeting.

This adds probably unnecessary bytes in the first packet from the server to the peer, since the peer already knows the server's supported versions, ciphers and the ServerInfo in the later exchanges, especially in the Waiting/Completion Exchange. However, this increased number of bytes is negligible in comparison to the elevated expense of an additional roundtrip, since this would significantly increase the authentication time, especially if the EAP packets are routed through a number of proxies.

### 7.3. Extensibility

The EAP-N00B standard does not specify how to deal with unexpected labels in the message, which could be used to extend the protocol. This specification will explicitly allow extensions. They are still TBD.

## 8. References

### 8.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

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- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8949] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", STD 94, [RFC 8949](#), DOI 10.17487/RFC8949, December 2020, <<https://www.rfc-editor.org/info/rfc8949>>.

### 8.2. Informative References

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TBD

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