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Extensible Authentication Protocol (EAP)
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Abstract

This document defines the Extensible Authentication Protocol (EAP), an authentication framework which supports multiple authentication methods. EAP typically runs directly over data link layers such as PPP or IEEE 802, without requiring IP. EAP provides its own support for duplicate elimination and retransmission, but is reliant on lower

layer ordering guarantees. Fragmentation is not supported within EAP itself; however, individual EAP methods may support this.

This document obsoletes RFC 2284. A summary of the changes between this document and RFC 2284 is available in Appendix A.

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1. Introduction

This document defines the Extensible Authentication Protocol (EAP), an authentication framework which supports multiple authentication methods. EAP typically runs directly over data link layers such as PPP or IEEE 802, without requiring IP. EAP provides its own support for duplicate elimination and retransmission, but is reliant on lower layer ordering guarantees. Fragmentation is not supported within EAP itself; however, individual EAP methods may support this.

EAP may be used on dedicated links as well as switched circuits, and wired as well as wireless links. To date, EAP has been implemented with hosts and routers that connect via switched circuits or dial-up lines using PPP [RFC1661]. It has also been implemented with switches and access points using IEEE 802 [IEEE-802]. EAP encapsulation on IEEE 802 wired media is described in [IEEE-802.1X], and encapsulation on IEEE wireless LANs in [IEEE-802.11i].

One of the advantages of the EAP architecture is its flexibility. EAP is used to select a specific authentication mechanism, typically after the authenticator requests more information in order to determine the specific authentication method to be used. Rather than requiring the authenticator to be updated to support each new authentication method, EAP permits the use of a backend authentication server which may implement some or all authentication methods, with the authenticator acting as a pass-through for some or all methods and peers.

Within this document, authenticator requirements apply regardless of whether the authenticator is operating as a pass-through or not. Where the requirement is meant to apply to either the authenticator or backend authentication server, depending on where the EAP authentication is terminated, the term "EAP server" will be used.

1.1 Specification of Requirements

In this document, several words are used to signify the requirements of the specification. These words are often capitalized. 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 Terminology

This document frequently uses the following terms:

authenticator
: The end of the link initiating EAP authentication. The term Authenticator is used in [IEEE-802.1X], and authenticator has the same meaning in this document.

peer
: The end of the link that responds to the authenticator. In [IEEE-802.1X], this end is known as the Supplicant.

backend authentication server
: A backend authentication server is an entity that provides an authentication service to an authenticator. When used, this server typically executes EAP methods for the authenticator. This terminology is also used in [IEEE-802.1X].

AAA
: Authentication, Authorization and Accounting. AAA protocols with EAP support include RADIUS [RFC3579] and Diameter [DIAM-EAP]. In this document, the terms "AAA server" and "backend authentication server" are used interchangeably.

Displayable Message
: This is interpreted to be a human readable string of characters. The message encoding MUST follow the UTF-8 transformation format [RFC2279].

EAP server
: The entity that terminates the EAP authentication method with the peer. In the case where no backend authentication server is used, the EAP server is part of the authenticator. In the case where the authenticator operates in pass-through mode, the EAP server is located on the backend authentication server.

Silently Discard
: This means the implementation discards the packet without further processing. The implementation SHOULD provide the capability of logging the event, including the contents of the silently discarded packet, and SHOULD record the event in a statistics counter.

Successful authentication
: In the context of this document, "successful authentication" is an exchange of EAP messages, as a result of which the authenticator decides to allow access by the peer, and the peer decides to use this access. The

authenticator's decision typically involves both authentication and authorization aspects; the peer may successfully authenticate to the authenticator but access may be denied by the authenticator due to policy reasons.

Message Integrity Check (MIC)
: A keyed hash function used for authentication and integrity protection of data. This is usually called a Message Authentication Code (MAC), but IEEE 802 specifications (and this document) use the acronym MIC to avoid confusion with Medium Access Control.

Cryptographic separation
: Two keys (x and y) are "cryptographically separate" if an adversary that knows all messages exchanged in the protocol cannot compute x from y or y from x without "breaking" some cryptographic assumption. In particular, this definition allows that the adversary has the knowledge of all nonces sent in cleartext as well as all predictable counter values used in the protocol. Breaking a cryptographic assumption would typically require inverting a one-way function or predicting the outcome of a cryptographic pseudo-random number generator without knowledge of the secret state. In other words, if the keys are cryptographically separate, there is no shortcut to compute x from y or y from x, but the work an adversary must do to perform this computation is equivalent to performing exhaustive search for the secret state value.

Master Session Key (MSK)
: Keying material that is derived between the EAP peer and server and exported by the EAP method. The MSK is at least 64 octets in length. In existing implementations a AAA server acting as an EAP server transports the MSK to the authenticator.

Extended Master Session Key (EMSK)
: Additional keying material derived between the EAP client and server that is exported by the EAP method. The EMSK is at least 64 octets in length. The EMSK is reserved for future uses that are not defined yet and is not provided to a third party.

1.3 Applicability

EAP is an authentication framework primarily for use in situations such as network access, in which IP layer connectivity may not be

available.

Since the goal of EAP is to support authentication without requiring IP connectivity, it provides just enough support for the reliable transport of authentication protocols, and no more. EAP is a lock-step protocol and does not support an efficient reliable transport service as in TCP [RFC793] or SCTP [RFC2960]. While EAP provides support for retransmission, it assumes ordering guarantees provided by the lower layer, so that out of order reception is not supported.

As noted in Section 3.1, EAP does not support fragmentation and reassembly as in IP, although EAP methods may provide support for this. As a result, authentication protocols generating payloads larger than the EAP MTU will need to be modified in order to provide fragmentation support.

EAP authentication is initiated by the authenticator, whereas many authentication protocols are initiated by the client (peer). As a result, it may be necessary for an algorithm to add 0.5 - 1 additional roundtrips between the client and authenticator in order to run over EAP.

As a result, an authentication algorithm will typically require more round-trips when run over EAP than when run directly over IP. Additionally, certificate-based authentication algorithms using long certificate chains can result in many round-trips due to fragmentation.

Where EAP runs over a lower layer in which significant packet loss is experienced, or where the connection between the authenticator and authentication server experiences significant packet loss, EAP methods requiring many round-trips may experience difficulties. In these situations, use of EAP methods with fewer round trips is advisable.

Where transport efficiency is a consideration, and IP transport is available, it may be preferable to expose an artificially high EAP MTU to EAP and allow fragmentation to take place in IP. Alternatively, it is possible to choose other security mechanisms such as TLS [RFC2246] or IKE [RFC2409] or an alternative authentication framework such as SASL [RFC2222] or GSS-API [RFC2743].

2. Extensible Authentication Protocol (EAP)

The EAP authentication exchange proceeds as follows:

[1] The authenticator sends a Request to authenticate the peer. The Request has a Type field to indicate what is being requested. Examples of Request Types include Identity, MD5-challenge, etc. The MD5-challenge Type corresponds closely to the CHAP authentication protocol [RFC1994]. Typically, the authenticator will send an initial Identity Request; however, an initial Identity Request is not required, and MAY be bypassed. For example, the identity may not be required where it is determined by the port to which the peer has connected (leased lines, dedicated switch or dial-up ports); or where the identity is obtained in another fashion (via calling station identity or MAC address, in the Name field of the MD5-Challenge Response, etc.).

[2] The peer sends a Response packet in reply to a valid Request. As with the Request packet the Response packet contains a Type field, which corresponds to the Type field of the Request.

[3] The authenticator sends an additional Request packet, and the peer replies with a Response. The sequence of Requests and Responses continues as long as needed. EAP is a 'lock step' protocol, so that other than the initial Request, a new Request cannot be sent prior to receiving a valid Response. The authenticator is responsible for retransmitting requests as described in Section 4.1. After a suitable number of retransmissions, the authenticator SHOULD end the EAP conversation. The authenticator MUST NOT send a Success or Failure packet when retransmitting or when it fails to get a response from the peer.

[4] The conversation continues until the authenticator cannot authenticate the peer (unacceptable Responses to one or more Requests), in which case the authenticator implementation MUST transmit an EAP Failure (Code 4). Alternatively, the authentication conversation can continue until the authenticator determines that successful authentication has occurred, in which case the authenticator MUST transmit an EAP Success (Code 3).

Advantages:

- The EAP protocol can support multiple authentication mechanisms without having to pre-negotiate a particular one.

- Network Access Server (NAS) devices (e.g., a switch or access point) do not have to understand each authentication method and MAY act as a pass-through agent for a backend authentication server. Support for pass-through is optional. An authenticator MAY authenticate local peers while at the same time acting as a pass-through for non-local peers and authentication methods it

does not implement locally.

- Separation of the authenticator from the backend authentication server simplifies credentials management and policy decision making.

Disadvantages:

- For use in PPP, EAP does require the addition of a new authentication Type to PPP LCP and thus PPP implementations will need to be modified to use it. It also strays from the previous PPP authentication model of negotiating a specific authentication mechanism during LCP. Similarly, switch or access point implementations need to support [IEEE-802.1X] in order to use EAP.

- Where the authenticator is separate from the backend authentication server, this complicates the security analysis and, if needed, key distribution.

2.1 Support for sequences

An EAP conversation MAY utilize a sequence of methods. A common example of this is an Identity request followed by a single EAP authentication method such as an MD5-Challenge. However the peer and authenticator MUST utilize only one authentication method (Type 4 or greater) within an EAP conversation, after which the authenticator MUST send a Success or Failure packet.

Once a peer has sent a Response of the same Type as the initial Request, an authenticator MUST NOT send a Request of a different Type prior to completion of the final round of a given method (with the exception of a Notification-Request) and MUST NOT send a Request for an additional method of any Type after completion of the initial authentication method; a peer receiving such Requests MUST treat them as invalid, and silently discard them. As a result, Identity Requery is not supported.

A peer MUST NOT send a Nak (legacy or expanded) in reply to a Request, after an initial non-Nak Response has been sent. Since spoofed EAP Request packets may be sent by an attacker, an authenticator receiving an unexpected Nak SHOULD discard it and log the event.

Multiple authentication methods within an EAP conversation are not supported due to their vulnerability to man-in-the-middle attacks (see Section 7.4) and incompatibility with existing implementations.

Where a single EAP authentication method is utilized, but other methods are run within it (a "tunneled" method) the prohibition against multiple authentication methods does not apply. Such "tunneled" methods appear as a single authentication method to EAP. Backward compatibility can be provided, since a peer not supporting a "tunneled" method can reply to the initial EAP-Request with a Nak (legacy or expanded). To address security vulnerabilities, "tunneled" methods MUST support protection against man-in-the-middle attacks.

2.2 EAP multiplexing model

Conceptually, EAP implementations consist of the following components:

[a] Lower layer. The lower layer is responsible for transmitting and receiving EAP frames between the peer and authenticator. EAP has been run over a variety of lower layers including PPP; wired IEEE 802 LANs [IEEE-802.1X] ; IEEE 802.11 wireless LANs [IEEE-802.11]; UDP (L2TP [RFC2661] and IKEv2 [IKEv2]); and TCP [PIC]. Lower layer behavior is discussed in Section 3.

[b] EAP layer. The EAP layer receives and transmits EAP packets via the lower layer, implements duplicate detection and retransmission, and delivers and receives EAP messages to and from the EAP peer and authenticator layers.

[c] EAP peer and authenticator layers. Based on the Code field, the EAP layer demultiplexes incoming EAP packets to the EAP peer and authenticator layers. Typically an EAP implementation on a given host will support either peer or authenticator functionality, but it is possible for a host to act as both an EAP peer and authenticator. In such an implementation both EAP peer and authenticator layers will be present.

[d] EAP method layers. EAP methods implement the authentication algorithms and receive and transmit EAP messages via the EAP peer and authenticator layers. Since fragmentation support is not provided by EAP itself, this is the responsibility of EAP methods, which are discussed in Section 5.

The EAP multiplexing model is illustrated in Figure 1 below. Note that there is no requirement that an implementation conform to this model, as long as the on-the-wire behavior is consistent with it.

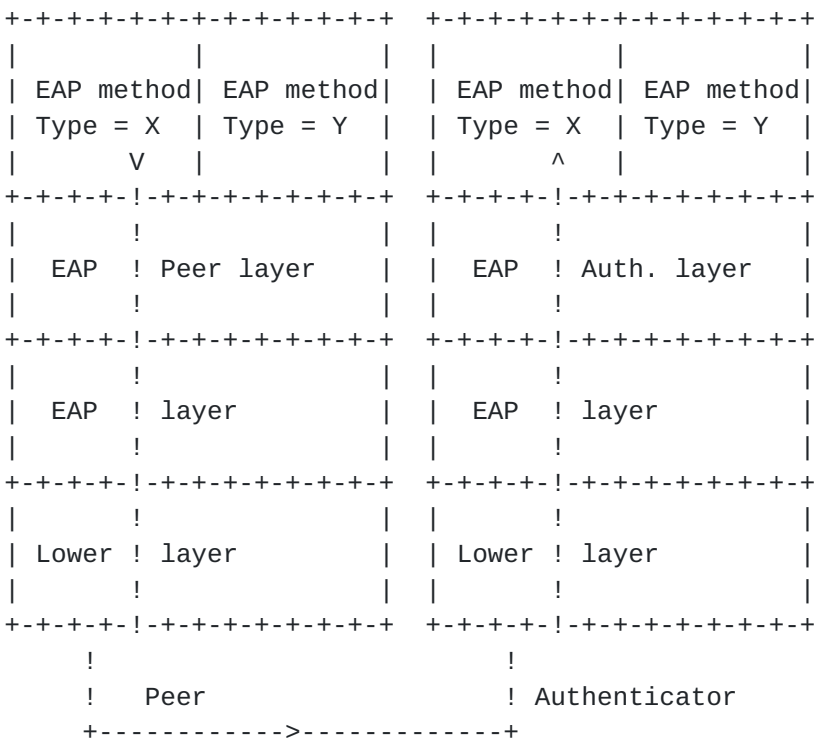


Figure 1: EAP Multiplexing Model

Within EAP, the Code field functions much like a protocol number in IP. It is assumed that the EAP layer demultiplexes incoming EAP packets according to the Code field. Received EAP packets with Code=1 (Request), 3 (Success) and 4 (Failure) are delivered by the EAP layer to the EAP peer layer, if implemented. EAP packets with Code=2 (Response) are delivered to the EAP authenticator layer, if implemented.

Within EAP, the Type field functions much like a port number in UDP or TCP. It is assumed that the EAP peer and authenticator layers demultiplex incoming EAP packets according to their Type, and deliver them only to the EAP method corresponding to that Type. An EAP method implementation on a host may register to receive packets from the peer or authenticator layers, or both, depending on which role(s) it supports.

Since EAP authentication methods may wish to access the Identity, implementations SHOULD make the Identity Request and Response accessible to authentication methods (Types 4 or greater) in addition to the Identity method. The Identity Type is discussed in Section 5.1.

A Notification Response is only used as confirmation that the peer received the Notification Request, not that it has processed it, or

displayed the message to the user. It cannot be assumed that the contents of the Notification Request or Response is available to another method. The Notification Type is discussed in Section 5.2.

Nak (Type 3) or Expanded Nak (Type 254) are utilized for the purposes of method negotiation. Peers respond to an initial EAP Request for an unacceptable Type with a Nak Response (Type 3) or Expanded Nak Response (Type 254). It cannot be assumed that the contents of the Nak Response(s) are available to another method. The Nak Type(s) are discussed in Section 5.3.

EAP packets with Codes of Success or Failure do not include a Type field, and are not delivered to an EAP method. Success and Failure are discussed in Section 4.2.

Given these considerations, the Success, Failure, Nak Response(s) and Notification Request/Response messages MUST NOT be used to carry data destined for delivery to other EAP methods.

2.3 Pass-through behavior

When operating as a "pass-through authenticator", an authenticator performs checks on the Code, Identifier and Length fields as described in Section 4.1. It forwards EAP packets received from the peer and destined to its authenticator layer to the backend authentication server; packets received from the backend authentication server destined to the peer are forwarded to it.

A host receiving an EAP packet may only do one of three things with it: act on it, drop it, or forward it. The forwarding decision is typically based only on examination of the Code, Identifier and Length fields. A pass-through authenticator implementation MUST be capable of forwarding to the backend authentication server EAP packets received from the peer with Code=2 (Response). It also MUST be capable of receiving EAP packets from the backend authentication server and forwarding EAP packets of Code=1 (Request), Code=3 (Success), and Code=4 (Failure) to the peer.

Unless the authenticator implements one or more authentication methods locally which support the authenticator role, the EAP method layer header fields (Type, Type-Data) are not examined as part of the forwarding decision. Where the authenticator supports local authentication methods, it MAY examine the Type field to determine whether to act on the packet itself or forward it. Compliant pass-through authenticator implementations MUST by default forward EAP packets of any Type.

EAP packets received with Code=1 (Request), Code=3 (Success), and

Code=4 (Failure) are demultiplexed by the EAP layer and delivered to the peer layer. Therefore unless a host implements an EAP peer layer, these packets will be silently discarded. Similarly, EAP packets received with Code=2 (Response) are demultiplexed by the EAP layer and delivered to the authenticator layer. Therefore unless a host implements an EAP authenticator layer, these packets will be silently discarded. The behavior of a "pass-through peer" is undefined within this specification, and is unsupported by AAA protocols such as RADIUS [RFC3579] and Diameter [DIAM-EAP].

The forwarding model is illustrated in Figure 2.

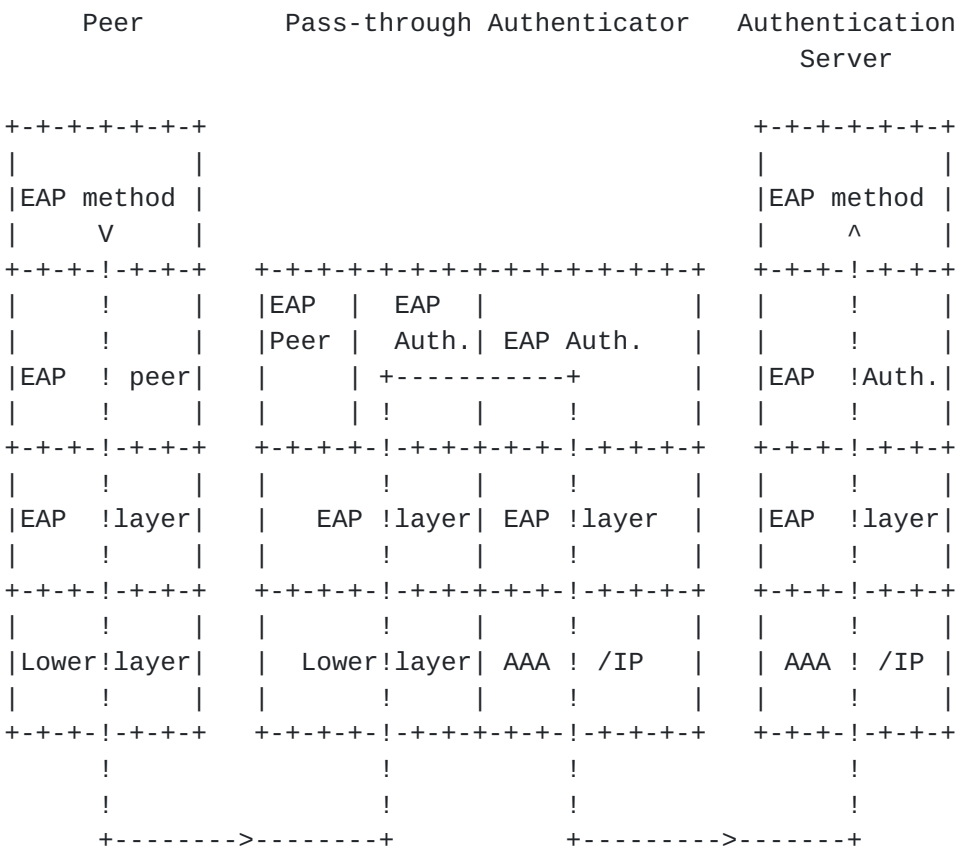


Figure 2: Pass-through Authenticator

For sessions in which the authenticator acts as a pass-through, it MUST determine the outcome of the authentication solely based on the Accept/Reject indication sent by the backend authentication server; the outcome MUST NOT be determined by the contents of an EAP packet sent along with the Accept/Reject indication, or the absence of such an encapsulated EAP packet.

2.4 Peer-to-Peer Operation

Since EAP is a peer-to-peer protocol, an independent and simultaneous authentication may take place in the reverse direction (depending on the capabilities of the lower layer). Both peers may act as authenticators and authenticatees at the same time, in which case it is necessary for both peers to implement EAP authenticator and peer layers. In addition, the EAP method implementations on both peers must support both authenticator and peer functionality.

Although EAP supports peer-to-peer operation, some EAP implementations, methods, AAA protocols and link layers may not support this. Some EAP methods may support asymmetric authentication, with one type of credential being required for the peer and another type for the authenticator. Hosts supporting peer-to-peer operation with such a method would need to be provisioned with both types of credentials.

For example, EAP-TLS [RFC2716] is a client-server protocol with a different certificate profile for the client and server. This implies that a host supporting peer-to-peer authentication with EAP-TLS would need to implement both the EAP peer and authenticator layers; support both peer and authenticator roles in the EAP-TLS implementation; and provision two distinct certificates, one appropriate for each role.

AAA protocols such as RADIUS/EAP [RFC3579] and Diameter EAP [DIAM-EAP] only support "passthrough authenticator" operation. As noted in [RFC3579] Section 2.6.2, a RADIUS server responds to an Access-Request encapsulating an EAP-Request, Success or Failure packet with an Access-Reject. There is therefore no support for "passthrough peer" operation.

Even where a method is used which supports mutual authentication and protected result indications, several considerations may dictate that two EAP authentications, (one in each direction) are required. These include:

[1] Support for bi-directional session key derivation in the lower layer. Lower layers such as IEEE 802.11 may only support uni-directional derivation and transport of transient session keys. For example, the group-key handshake defined in [IEEE-802.11i] is uni-directional, since in IEEE 802.11 infrastructure mode only the Access Point (AP) sends multicast/ broadcast traffic. In IEEE 802.11 ad-hoc mode where either peer may send multicast/broadcast traffic, two uni-directional group-key exchanges are required. Due to limitations of the design, this also implies the need for unicast key derivations

and EAP method exchanges to occur in each direction.

[2] Support for tie-breaking in the lower layer. Lower layers such as IEEE 802.11 adhoc do not support "tie breaking" wherein two hosts initiating authentication with each other will only go forward with a single authentication. This implies that even if 802.11 were to support a bi-directional group-key handshake, then two authentications, one in each direction, might still occur.

[3] Peer policy satisfaction. EAP methods may support protected result indications, enabling the peer to indicate to the EAP server that it successfully authenticated the EAP server. However, a pass-through authenticator will not be aware that the peer has accepted the credentials offered by the EAP server, unless this information is provided to the authenticator via the AAA protocol. As a result, two authentications, one in each direction, may still be needed.

It is also possible that the EAP peer's access policy was not satisfied during the EAP method exchange. For example, the authenticator may not have successfully authenticated to the peer, or may not have demonstrated authorization to act in both peer and server roles. For example, in EAP-TLS [RFC2716], the authenticator may have authenticated using a valid TLS server certificate, but not using a valid TLS client certificate. As a result, the peer may require an additional authentication in the reverse direction, even if the peer provided a protected result indication to the EAP server indicating that the server had successfully authenticated to it.

3. Lower layer behavior

3.1 Lower layer requirements

EAP makes the following assumptions about lower layers:

[1] Unreliable transport. In EAP, the authenticator retransmits Requests that have not yet received Responses, so that EAP does not assume that lower layers are reliable. Since EAP defines its own retransmission behavior, it is possible (though undesirable) for retransmission to occur both in the lower layer and the EAP layer when EAP is run over a reliable lower layer.

Note that EAP Success and Failure packets are not retransmitted. Without a reliable lower layer, and a non-negligible error rate, these packets can be lost, resulting in timeouts. It is therefore desirable for implementations to improve their resilience to loss

of EAP Success or Failure packets, as described in Section 4.2.

[2] Lower layer error detection. While EAP does not assume that the lower layer is reliable, it does rely on lower layer error detection (e.g., CRC, Checksum, MIC, etc.). EAP methods may not include a MIC, or if they do, it may not be computed over all the fields in the EAP packet, such as the Code, Identifier, Length or Type fields. As a result, without lower layer error detection, undetected errors could creep into the EAP layer or EAP method layer header fields, resulting in authentication failures.

For example, EAP TLS [RFC2716], which computes its MIC over the Type-Data field only, regards MIC validation failures as a fatal error. Without lower layer error detection, this method and others like it will not perform reliably.

[3] Lower layer security. EAP assumes that lower layers either provide physical security (e.g., wired PPP or IEEE 802 links) or support per-packet authentication, integrity and replay protection. EAP SHOULD NOT be used on physically insecure links (e.g., wireless or the Internet) where subsequent data is not protected by per-packet authentication, integrity and replay protection.

[4] Minimum MTU. EAP is capable of functioning on lower layers that provide an EAP MTU size of 1020 octets or greater.

EAP does not support path MTU discovery, and fragmentation and reassembly is not supported by EAP, nor by the methods defined in this specification: the Identity (1), Notification (2), Nak Response (3), MD5-Challenge (4), One Time Password (5), Generic Token Card (6) and expanded Nak Response (254) Types.

Typically, the EAP peer obtains information on the EAP MTU from the lower layers and sets the EAP frame size to an appropriate value. Where the authenticator operates in pass-through mode, the authentication server does not have a direct way of determining the EAP MTU, and therefore relies on the authenticator to provide it with this information, such as via the Framed-MTU attribute, as described in [RFC3579], Section 2.4.

While methods such as EAP-TLS [RFC2716] support fragmentation and reassembly, EAP methods originally designed for use within PPP where a 1500 octet MTU is guaranteed for control frames (see [RFC1661], Section 6.1) may lack fragmentation and reassembly features.

EAP methods can assume a minimum EAP MTU of 1020 octets, in the

absence of other information. EAP methods SHOULD include support for fragmentation and reassembly if their payloads can be larger than this minimum EAP MTU.

EAP is a lock-step protocol, which implies a certain inefficiency when handling fragmentation and reassembly. Therefore if the lower layer supports fragmentation and reassembly (such as where EAP is transported over IP), it may be preferable for fragmentation and reassembly to occur in the lower layer rather than in EAP. This can be accomplished by providing an artificially large EAP MTU to EAP, causing fragmentation and reassembly to be handled within the lower layer.

[5] Possible duplication. Where the lower layer is reliable, it will provide the EAP layer with a non-duplicated stream of packets. However, while it is desirable that lower layers provide for non-duplication, this is not a requirement. The Identifier field provides both the peer and authenticator with the ability to detect duplicates.

[6] Ordering guarantees. EAP does not require the Identifier to be monotonically increasing, and so is reliant on lower layer ordering guarantees for correct operation. EAP was originally defined to run on PPP, and [RFC1661] Section 1 has an ordering requirement:

> "The Point-to-Point Protocol is designed for simple links which transport packets between two peers. These links provide full-duplex simultaneous bi-directional operation, and are assumed to deliver packets in order."

Lower layer transports for EAP MUST preserve ordering between a source and destination, at a given priority level (the ordering guarantee provided by [IEEE-802]).

Reordering, if it occurs, will typically result in an EAP authentication failure, causing EAP authentication to be rerun. In an environment in which reordering is likely, it is therefore expected that EAP authentication failures will be common. It is RECOMMENDED that EAP only be run over lower layers that provide ordering guarantees; running EAP over raw IP or UDP transport is NOT RECOMMENDED. Encapsulation of EAP within RADIUS [RFC3579] satisfies ordering requirements, since RADIUS is a "lockstep" protocol that delivers packets in order.

3.2 EAP usage within PPP

In order to establish communications over a point-to-point link, each end of the PPP link must first send LCP packets to configure the data link during Link Establishment phase. After the link has been established, PPP provides for an optional Authentication phase before proceeding to the Network-Layer Protocol phase.

By default, authentication is not mandatory. If authentication of the link is desired, an implementation MUST specify the Authentication Protocol Configuration Option during Link Establishment phase.

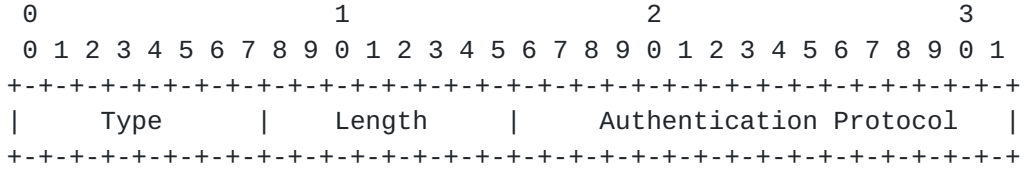
If the identity of the peer has been established in the Authentication phase, the server can use that identity in the selection of options for the following network layer negotiations.

When implemented within PPP, EAP does not select a specific authentication mechanism at PPP Link Control Phase, but rather postpones this until the Authentication Phase. This allows the authenticator to request more information before determining the specific authentication mechanism. This also permits the use of a "backend" server which actually implements the various mechanisms while the PPP authenticator merely passes through the authentication exchange. The PPP Link Establishment and Authentication phases, and the Authentication Protocol Configuration Option, are defined in The Point-to-Point Protocol (PPP) [RFC1661].

3.2.1 PPP Configuration Option Format

A summary of the PPP Authentication Protocol Configuration Option format to negotiate EAP is shown below. The fields are transmitted from left to right.

Exactly one EAP packet is encapsulated in the Information field of a PPP Data Link Layer frame where the protocol field indicates type hex C227 (PPP EAP).



Type

3

Length

4

Authentication Protocol

C227 (Hex) for Extensible Authentication Protocol (EAP)

3.3 EAP usage within IEEE 802

The encapsulation of EAP over IEEE 802 is defined in [IEEE-802.1X]. The IEEE 802 encapsulation of EAP does not involve PPP, and IEEE 802.1X does not include support for link or network layer negotiations. As a result, within IEEE 802.1X it is not possible to negotiate non-EAP authentication mechanisms, such as PAP or CHAP [RFC1994].

3.4 Lower layer indications

The reliability and security of lower layer indications is dependent on the lower layer. Since EAP is media independent, the presence or absence of lower layer security is not taken into account in the processing of EAP messages.

To improve reliability, if a peer receives a lower layer success indication as defined in Section 7.2, it MAY conclude that a Success packet has been lost, and behave as if it had actually received a Success packet. This includes choosing to ignore the Success in some circumstances as described in Section 4.2.

A discussion of some reliability and security issues with lower layer indications in PPP, IEEE 802 wired networks and IEEE 802.11 wireless LANs can be found in the Security Considerations, Section 7.12.

After EAP authentication is complete, the peer will typically transmit data to the network via the authenticator. In order to provide assurance that the peer transmitting data is the same entity that successfully completed EAP authentication, the lower layer needs to bind per-packet integrity, authentication and replay protection to the original EAP authentication, using keys derived during EAP authentication. Alternatively, the lower layer needs to be physically secure. Otherwise it is possible for subsequent data traffic to be hijacked or replayed.

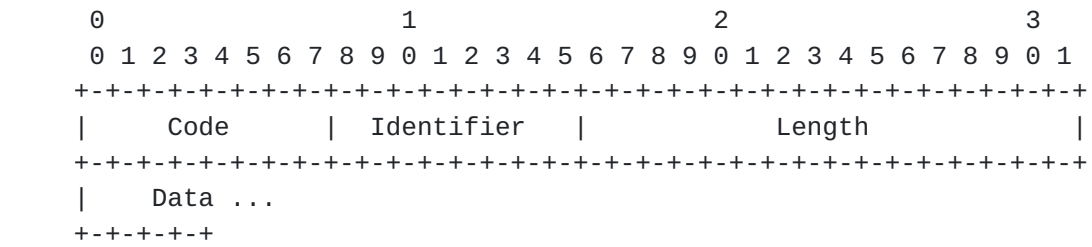
As a result of these considerations, EAP SHOULD be used only when lower layers provide physical security for data (e.g., wired PPP or IEEE 802 links), or for insecure links, where per-packet authentication, integrity and replay protection is provided.

Where keying material for the lower layer ciphersuite is itself provided by EAP, ciphersuite negotiation and key activation is controlled by the lower layer. In PPP, ciphersuites are negotiated within ECP so that it is not possible to use keys derived from EAP authentication until the completion of ECP. Therefore an initial EAP exchange cannot protected by a PPP ciphersuite, although EAP re-authentication can be protected.

In IEEE 802 media, initial key activation also typically occurs after completion of EAP authentication. Therefore an initial EAP exchange typically cannot be protected by the lower layer ciphersuite, although an EAP re-authentication or pre-authentication exchange can be protected.

4. EAP Packet format

A summary of the EAP packet format is shown below. The fields are transmitted from left to right.



Code

The Code field is one octet and identifies the Type of EAP packet. EAP Codes are assigned as follows:

1	Request
2	Response
3	Success
4	Failure

Since EAP only defines Codes 1-4, EAP packets with other codes MUST be silently discarded by both authenticators and peers.

Identifier

The Identifier field is one octet and aids in matching Responses with Requests.

Length

The Length field is two octets and indicates the length of the EAP packet including the Code, Identifier, Length and Data fields. Octets outside the range of the Length field should be treated as Data Link Layer padding and MUST be ignored on reception. A message with the Length field set to a value larger than the number of received octets MUST be silently discarded.

Data

The Data field is zero or more octets. The format of the Data field is determined by the Code field.

4.1 Request and Response

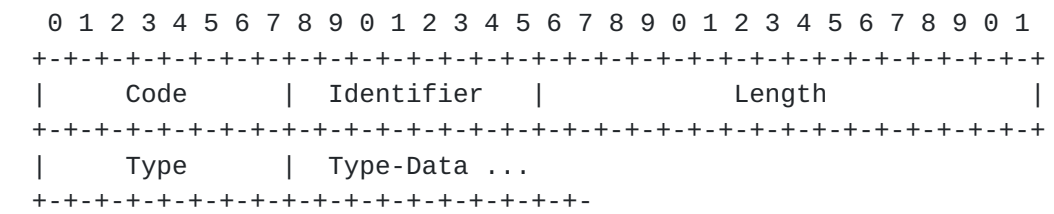
Description

The Request packet (Code field set to 1) is sent by the authenticator to the peer. Each Request has a Type field which serves to indicate what is being requested. Additional Request packets MUST be sent until a valid Response packet is received, or an optional retry counter expires.

Retransmitted Requests MUST be sent with the same Identifier value in order to distinguish them from new Requests. The content of the data field is dependent on the Request Type. The peer MUST send a Response packet in reply to a valid Request packet. Responses MUST only be sent in reply to a valid Request and never retransmitted on a timer.

If a peer receives a valid duplicate Request for which it has already sent a Response, it MUST resend its original Response without reprocessing the Request. Requests MUST be processed in the order that they are received, and MUST be processed to their completion before inspecting the next Request.

A summary of the Request and Response packet format is shown below. The fields are transmitted from left to right.



Code

1 for Request
2 for Response

Identifier

The Identifier field is one octet. The Identifier field MUST be the same if a Request packet is retransmitted due to a timeout while waiting for a Response. Any new (non-retransmission) Requests MUST modify the Identifier field.

The Identifier field of the Response MUST match that of the currently outstanding Request. An authenticator receiving a Response whose Identifier value does not match that of the currently outstanding Request MUST silently discard the Response.

In order to avoid confusion between new Requests and retransmissions, the Identifier value chosen for each new Request need only be different from the previous Request, but need not be unique within the conversation. One way to achieve this is to start the Identifier at an initial value and increment it for each new Request. Initializing the first Identifier with a random number rather than starting from zero is recommended, since it makes sequence attacks somewhat harder.

Since the Identifier space is unique to each session, authenticators are not restricted to only 256 simultaneous authentication conversations. Similarly, with re-authentication, an EAP conversation might continue over a long period of time, and is not limited to only 256 roundtrips.

Implementation Note: The authenticator is responsible for retransmitting Request messages. If the Request message is obtained from elsewhere (such as from a backend authentication server), then the authenticator will need to save a copy of the Request in order to accomplish this. The peer is responsible for detecting and handling duplicate Request messages before processing them in any way, including passing them on to an outside party. The authenticator is also responsible for discarding Response messages with a non-matching Identifier

value before acting on them in any way, including passing them on to the backend authentication server for verification. Since the authenticator can retransmit before receiving a Response from the peer, the authenticator can receive multiple Responses, each with a matching Identifier. Until a new Request is received by the authenticator, the Identifier value is not updated, so that the authenticator forwards Responses to the backend authentication server, one at a time.

Length

The Length field is two octets and indicates the length of the EAP packet including the Code, Identifier, Length, Type, and Type-Data fields. Octets outside the range of the Length field should be treated as Data Link Layer padding and MUST be ignored on reception. A message with the Length field set to a value larger than the number of received octets MUST be silently discarded.

Type

The Type field is one octet. This field indicates the Type of Request or Response. A single Type MUST be specified for each EAP Request or Response. An initial specification of Types follows in Section 5 of this document.

The Type field of a Response MUST either match that of the Request, or correspond to a legacy or Expanded Nak (see Section 5.3) indicating that a Request Type is unacceptable to the peer. A peer MUST NOT send a Nak (legacy or expanded) in response to a Request, after an initial non-Nak Response has been sent. An EAP server receiving a Response not meeting these requirements MUST silently discard it.

Type-Data

The Type-Data field varies with the Type of Request and the associated Response.

4.2 Success and Failure

The Success packet is sent by the authenticator to the peer after completion of an EAP authentication method (Type 4 or greater), to indicate that the peer has authenticated successfully to the authenticator. The authenticator MUST transmit an EAP packet with the Code field set to 3 (Success). If the authenticator cannot authenticate the peer (unacceptable Responses to one or more Requests) then after unsuccessful completion of the EAP method in

progress, the implementation MUST transmit an EAP packet with the Code field set to 4 (Failure). An authenticator MAY wish to issue multiple Requests before sending a Failure response in order to allow for human typing mistakes. Success and Failure packets MUST NOT contain additional data.

Success and Failure packets MUST NOT be sent by an EAP authenticator if the specification of the given method does not explicitly permit the method to finish at that point. A peer EAP implementation receiving a Success or Failure packet where sending one is not explicitly permitted MUST silently discard it. By default, an EAP peer MUST silently discard a "canned" Success packet (a Success packet sent immediately upon connection). This ensures that a rogue authenticator will not be able to bypass mutual authentication by sending a Success packet prior to conclusion of the EAP method conversation.

Implementation Note: Because the Success and Failure packets are not acknowledged, they are not retransmitted by the authenticator, and may be potentially lost. A peer MUST allow for this circumstance as described in this note. See also Section 3.4 for guidance on the processing of lower layer success and failure indications.

As described in Section 2.1, only a single EAP authentication method is allowed within an EAP conversation. EAP methods MAY implement protected result indications. After the authenticator sends a method-specific failure indication to the peer, regardless of the response from the peer, it MUST subsequently send a Failure packet. After the authenticator sends a method-specific success indication to the peer, and receives a method-specific success indication from the peer, it MUST subsequently send a Success packet.

On the peer, once the method completes unsuccessfully (that is, either the authenticator sends a method-specific failure indication, or the peer decides that it does want to continue the conversation, possibly after sending a method-specific failure indication), the peer MUST terminate the conversation and indicate failure to the lower layer. The peer MUST silently discard Success packets and MAY silently discard Failure packets. As a result, loss of a Failure packet need not result in a timeout.

On the peer, after protected successful result indications have been exchanged by both sides, a Failure packet MUST be silently discarded. The peer MAY, in the event that an EAP Success is not received, conclude that the EAP Success packet was lost and that authentication concluded successfully.

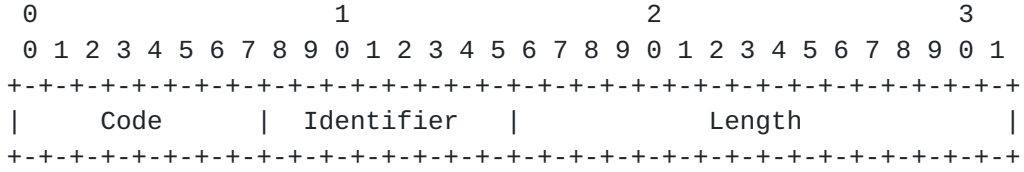
A mutually authenticating method (such as EAP-TLS [RFC2716]) that provides authorization error messages provides protected result indications for the purpose of this specification. Within EAP-TLS, the peer always authenticates the authenticator, and may send a TLS-alert message in the event of an authentication failure. An authenticator may use the "access denied" TLS alert after successfully authenticating the peer to indicate that a valid certificate was received from the peer, but when access control was applied, the authenticator decided not to proceed. If a method provides authorization error messages, the authenticator SHOULD use them so as to ensure consistency with the final access decision and avoid lengthy timeouts.

If the authenticator has not sent a method-specific result indication, and the peer is willing to continue the conversation, once the method completes the peer waits for a Success or Failure packet and MUST NOT silently discard either of them. In the event that neither a Success nor Failure packet is received, the peer SHOULD terminate the conversation to avoid lengthy timeouts in case the lost packet was an EAP Failure.

If the peer attempts to authenticate to the authenticator and fails to do so, the authenticator MUST send a Failure packet and MUST NOT grant access by sending a Success packet. However, an authenticator MAY omit having the peer authenticate to it in situations where limited access is offered (e.g., guest access). In this case the authenticator MUST send a Success packet.

Where the peer authenticates successfully to the authenticator, but the authenticator does not send a method-specific result indication the authenticator MAY deny access by sending a Failure packet where the peer is not currently authorized for network access.

A summary of the Success and Failure packet format is shown below. The fields are transmitted from left to right.



Code

3 for Success
4 for Failure

Identifier

The Identifier field is one octet and aids in matching replies to Responses. The Identifier field MUST match the Identifier field of the Response packet that it is sent in response to.

Length

4

4.3 Retransmission Behavior

Because the authentication process will often involve user input, some care must be taken when deciding upon retransmission strategies and authentication timeouts. By default, where EAP is run over an unreliable lower layer, the EAP retransmission timer SHOULD be dynamically estimated. A maximum of 3-5 retransmissions is suggested.

When run over a reliable lower layer (e.g., EAP over ISAKMP/TCP, as within [PIC]), the authenticator retransmission timer SHOULD be set to an infinite value, so that retransmissions do not occur at the EAP layer. The peer may still maintain a timeout value so as to avoid waiting indefinitely for a Request.

Where the authentication process requires user input, the measured round trip times may be determined by user responsiveness rather than network characteristics, so that dynamic RTO estimation may not be helpful. Instead, the retransmission timer SHOULD be set so as to provide sufficient time for the user to respond, with longer timeouts required in certain cases, such as where Token Cards (see Section 5.6) are involved.

In order to provide the EAP authenticator with guidance as to the appropriate timeout value, a hint can be communicated to the authenticator by the backend authentication server (such as via the RADIUS Session-Timeout attribute).

In order to dynamically estimate the EAP retransmission timer, the algorithms for estimation of SRTT, RTTVAR and RTO described in [RFC2988] are RECOMMENDED, including use of Karn's algorithm, with the following potential modifications:

[a] In order to avoid synchronization behaviors that can occur with fixed timers among distributed systems, the retransmission timer is calculated with a jitter by using the RTO value and randomly adding a value drawn between -RTOmin/2 and RTOmin/2. Alternative

calculations to create jitter MAY be used. These MUST be pseudo-random, generated by a PRNG seeded as per [RFC1750].

[b] When EAP is transported over a single link (as opposed to over the Internet), smaller values of RTOinitial, RTOmin and RTOmax MAY be used. Recommended values are RTOinitial=1 second, RTOmin=200ms, RTOmax=20 seconds.

[c] When EAP is transported over a single link (as opposed to over the Internet), estimates MAY be done on a per-authenticator basis, rather than a per-session basis. This enables the retransmission estimate to make the most use of information on link-layer behavior.

[d] An EAP implementation MAY clear SRTT and RTTVAR after backing off the timer multiple times as it is likely that the current SRTT and RTTVAR are bogus in this situation. Once SRTT and RTTVAR are cleared they should be initialized with the next RTT sample taken as described in [RFC2988] equation 2.2.

5. Initial EAP Request/Response Types

This section defines the initial set of EAP Types used in Request/ Response exchanges. More Types may be defined in follow-on documents. The Type field is one octet and identifies the structure of an EAP Request or Response packet. The first 3 Types are considered special case Types.

The remaining Types define authentication exchanges. Nak (Type 3) or Expanded Nak (Type 254) are valid only for Response packets, they MUST NOT be sent in a Request.

All EAP implementations MUST support Types 1-4, which are defined in this document, and SHOULD support Type 254. Implementations MAY support other Types defined here or in future RFCs.

1	Identity
2	Notification
3	Nak (Response only)
4	MD5-Challenge
5	One Time Password (OTP)
6	Generic Token Card (GTC)
254	Expanded Types
255	Experimental use

EAP methods MAY support authentication based on shared secrets. If

the shared secret is a passphrase entered by the user, implementations MAY support entering passphrases with non-ASCII characters. In this case, the input should be processed using an appropriate stringprep [RFC3454] profile, and encoded in octets using UTF-8 encoding [RFC2279]. A preliminary version of a possible stringprep profile is described in [SASLPREP].

5.1 Identity

Description

The Identity Type is used to query the identity of the peer. Generally, the authenticator will issue this as the initial Request. An optional displayable message MAY be included to prompt the peer in the case where there is an expectation of interaction with a user. A Response of Type 1 (Identity) SHOULD be sent in Response to a Request with a Type of 1 (Identity).

Some EAP implementations piggy-back various options into the Identity Request after a NUL-character. By default an EAP implementation SHOULD NOT assume that an Identity Request or Response can be larger than 1020 octets.

It is RECOMMENDED that the Identity Response be used primarily for routing purposes and selecting which EAP method to use. EAP Methods SHOULD include a method-specific mechanism for obtaining the identity, so that they do not have to rely on the Identity Response. Identity Requests and Responses are not protected, so from a privacy perspective it is preferable for an EAP method to include its own protected identity exchange. The Identity Response may not be the appropriate identity for the method; it may have been truncated or obfuscated so as to provide privacy; or it may have been decorated for routing purposes. Where the peer is configured to only accept authentication methods supporting protected identity exchanges, the peer MAY provide an abbreviated Identity Response (such as omitting the peer-name portion of the NAI [RFC2486]). For further discussion of identity protection, see Section 7.3.

Implementation Note: The peer MAY obtain the Identity via user input. It is suggested that the authenticator retry the Identity Request in the case of an invalid Identity or authentication failure to allow for potential typos on the part of the user. It is suggested that the Identity Request be retried a minimum of 3 times before terminating the authentication. The Notification Request MAY be used to indicate an invalid authentication attempt prior to transmitting a new Identity Request (optionally, the failure

MAY be indicated within the message of the new Identity Request itself).

Type

1

Type-Data

This field MAY contain a displayable message in the Request, containing UTF-8 encoded ISO 10646 characters [RFC2279]. Where the Request contains a null, only the portion of the field prior to the null is displayed. If the Identity is unknown, the Identity Response field should be zero bytes in length. The Identity Response field MUST NOT be null terminated. In all cases, the length of the Type-Data field is derived from the Length field of the Request/Response packet.

Security Claims (see Section 7.2):

Intended use:	Physically secure lower layers; vulnerable to attack when used with wireless or over the Internet.
Auth. mechanism:	None
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	N/A
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.2 Notification

Description

The Notification Type is optionally used to convey a displayable message from the authenticator to the peer. An authenticator MAY send a Notification Request to the peer at any time when there is no outstanding Request, prior to completion of an EAP

authentication method. The peer MUST respond to a Notification Request with a Notification Response unless the EAP authentication method specification prohibits the use of Notification message. In any case, a Nak Response MUST NOT be sent in response to a Notification Request. Note that the default maximum length of a Notification Request is 1020 octets. By default, this leaves at most 1015 octets for the human readable message.

An EAP method MAY indicate within its specification that Notification messages must not be sent during that method. In this case, the peer MUST silently discard Notification Requests from the point where an initial Request for that Type is answered with a Response of the same Type.

The peer SHOULD display this message to the user or log it if it cannot be displayed. The Notification Type is intended to provide an acknowledged notification of some imperative nature, but it is not an error indication, and therefore does not change the state of the peer. Examples include a password with an expiration time that is about to expire, an OTP sequence integer which is nearing 0, an authentication failure warning, etc. In most circumstances, Notification should not be required.

Type

2

Type-Data

The Type-Data field in the Request contains a displayable message greater than zero octets in length, containing UTF-8 encoded ISO 10646 characters [RFC2279]. The length of the message is determined by Length field of the Request packet. The message MUST NOT be null terminated. A Response MUST be sent in reply to the Request with a Type field of 2 (Notification). The Type-Data field of the Response is zero octets in length. The Response should be sent immediately (independent of how the message is displayed or logged).

Security Claims (see Section 7.2):

Intended use:	Physically secure lower layers; vulnerable to attack when used with wireless or over the Internet.
Auth. mechanism:	None
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	N/A
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.3 Nak

5.3.1 Legacy Nak

Description

The legacy Nak Type is valid only in Response messages. It is sent in reply to a Request where the desired authentication Type is unacceptable. Authentication Types are numbered 4 and above. The Response contains one or more authentication Types desired by the Peer. Type zero (0) is used to indicate that the sender has no viable alternatives, and therefore the authenticator SHOULD NOT send another Request after receiving a Nak Response containing a zero value.

Since the legacy Nak Type is valid only in Responses and has very limited functionality, it MUST NOT be used as a general purpose error indication, such as for communication of error messages, or negotiation of parameters specific to a particular EAP method.

Code

2 for Response.

Identifier

The Identifier field is one octet and aids in matching Responses with Requests. The Identifier field of a legacy Nak Response MUST match the Identifier field of the Request packet that it is sent in response to.

Length

>=6

Type

3

Type-Data

Where a peer receives a Request for an unacceptable authentication Type (4-253,255), or a peer lacking support for Expanded Types receives a Request for Type 254, a Nak Response (Type 3) MUST be sent. The Type-Data field of the Nak Response (Type 3) MUST contain one or more octets indicating the desired authentication Type(s), one octet per Type, or the value zero (0) to indicate no proposed alternative. A peer supporting Expanded Types that receives a Request for an unacceptable authentication Type (4-253, 255) MAY include the value 254 in the Nak Response (Type 3) in order to indicate the desire for an Expanded authentication Type. If the authenticator can accommodate this preference, it will respond with an Expanded Type Request (Type 254).

Security Claims (see Section 7.2):

Intended use:	Physically secure lower layers; vulnerable to attack when used with wireless or over the Internet.
Auth. mechanism:	None
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	N/A
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A

Fragmentation:	No
Channel binding:	No

5.3.2 Expanded Nak

Description

The Expanded Nak Type is valid only in Response messages. It MUST be sent only in reply to a Request of Type 254 (Expanded Type) where the authentication Type is unacceptable. The Expanded Nak Type uses the Expanded Type format itself, and the Response contains one or more authentication Types desired by the peer, all in Expanded Type format. Type zero (0) is used to indicate that the sender has no viable alternatives. The general format of the Expanded Type is described in Section 5.7.

Since the Expanded Nak Type is valid only in Responses and has very limited functionality, it MUST NOT be used as a general purpose error indication, such as for communication of error messages, or negotiation of parameters specific to a particular EAP method.

Code

2 for Response.

Identifier

The Identifier field is one octet and aids in matching Responses with Requests. The Identifier field of an Expanded Nak Response MUST match the Identifier field of the Request packet that it is sent in response to.

Length

>=20

Type

254

Vendor-Id

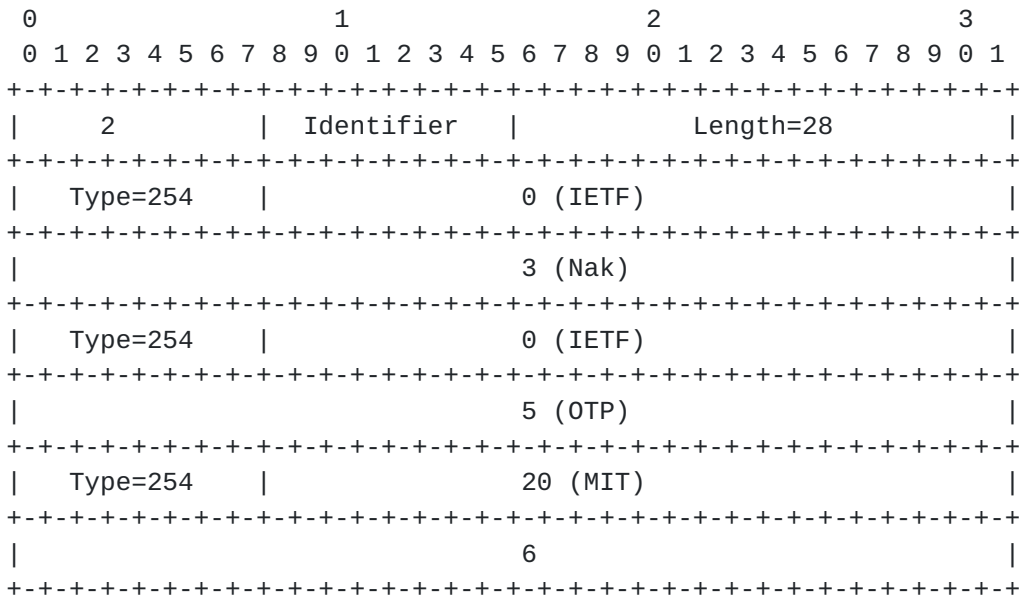
0 (IETF)

Vendor-Type

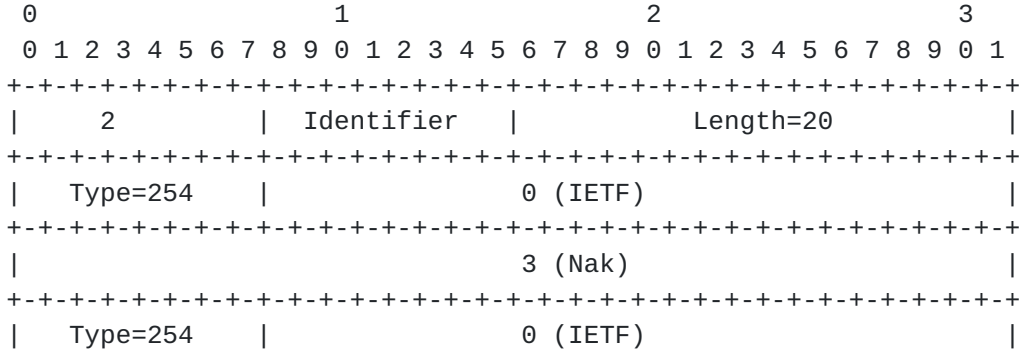
3 (Nak)

Vendor-Data

The Expanded Nak Type is only sent when the Request contains an Expanded Type (254) as defined in Section 5.7. The Vendor-Data field of the Nak Response MUST contain one or more authentication Types (4 or greater), all in expanded format, 8 octets per Type, or the value zero (0), also in Expanded Type format, to indicate no proposed alternative. The desired authentication Types may include a mixture of Vendor-Specific and IETF Types. For example, an Expanded Nak Response indicating a preference for OTP (Type 5), and an MIT (Vendor-Id=20) Expanded Type of 6 would appear as follows:



An Expanded Nak Response indicating a no desired alternative would appear as follows:



```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               0 (No alternative)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Security Claims (see Section 7.2):

Intended use:	Physically secure lower layers; vulnerable to attack when used with wireless or over the Internet.
Auth. mechanism:	None
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	N/A
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.4 MD5-Challenge

Description

The MD5-Challenge Type is analogous to the PPP CHAP protocol [RFC1994] (with MD5 as the specified algorithm). The Request contains a "challenge" message to the peer. A Response MUST be sent in reply to the Request. The Response MAY be either of Type 4 (MD5-Challenge), Nak (Type 3) or Expanded Nak (Type 254). The Nak reply indicates the peer's desired authentication Type(s). EAP peer and EAP server implementations MUST support the MD5-Challenge mechanism. An authenticator that supports only pass-through MUST allow communication with a backend authentication server that is capable of supporting MD5-Challenge, although the EAP authenticator implementation need not support MD5-Challenge itself. However, if the EAP authenticator can be configured to authenticate peers locally (e.g., not operate in pass-through), then the requirement for support of the MD5-Challenge mechanism applies.

Note that the use of the Identifier field in the MD5-Challenge Type is different from that described in [RFC1994]. EAP allows for retransmission of MD5-Challenge Request packets while [RFC1994] states that both the Identifier and Challenge fields MUST change each time a Challenge (the CHAP equivalent of the MD5-Challenge Request packet) is sent.

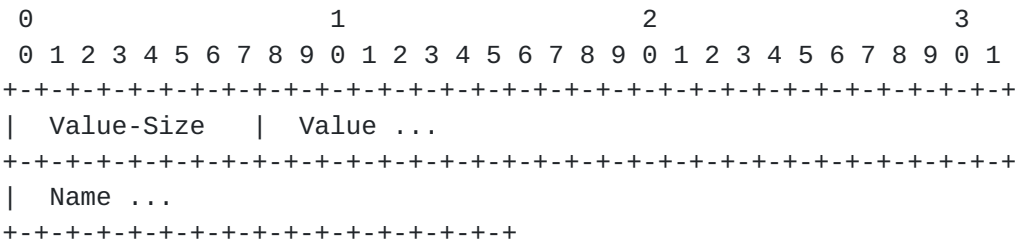
Note: [RFC1994] treats the shared secret as an octet string, and does not specify how it is entered into the system (or if it is handled by the user at all). EAP MD5-Challenge implementations MAY support entering passphrases with non-ASCII characters. See Section 5 for instructions how the input should be processed and encoded into octets.

Type

4

Type-Data

The contents of the Type-Data field is summarized below. For reference on the use of these fields see the PPP Challenge Handshake Authentication Protocol [RFC1994].



Security Claims (see Section 7.2):

Intended use:	Wired networks, including PPP, PPPOE, and IEEE 802 wired media. Use over the Internet or with wireless media only when protected.
Auth. mechanism:	Password or pre-shared key.
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	No
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.5 One-Time Password (OTP)

Description

The One-Time Password system is defined in "A One-Time Password System" [RFC2289] and "OTP Extended Responses" [RFC2243]. The Request contains an OTP challenge in the format described in [RFC2289]. A Response MUST be sent in reply to the Request. The Response MUST be of Type 5 (OTP), Nak (Type 3) or Expanded Nak (Type 254). The Nak Response indicates the peer's desired authentication Type(s). The EAP OTP method is intended for use with the One-Time Password system only, and MUST NOT be used to provide support for cleartext passwords.

Type

5

Type-Data

The Type-Data field contains the OTP "challenge" as a displayable message in the Request. In the Response, this field is used for the 6 words from the OTP dictionary [RFC2289]. The messages MUST NOT be null terminated. The length of the field is derived from the Length field of the Request/Reply packet.

Note: [RFC2289] does not specify how the secret pass-phrase is entered by the user, or how the pass-phrase is converted into octets. EAP OTP implementations MAY support entering passphrases with non-ASCII characters. See Section 5 for instructions how the input should be processed and encoded into octets.

Security Claims (see Section 7.2):

Intended use:	Wired networks, including PPP, PPPOE, and IEEE 802 wired media. Use over the Internet or with wireless media only when protected.
Auth. mechanism:	One-Time Password
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	Yes
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	No
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.6 Generic Token Card (GTC)

Description

The Generic Token Card Type is defined for use with various Token Card implementations which require user input. The Request contains a displayable message and the Response contains the Token Card information necessary for authentication. Typically, this would be information read by a user from the Token card device and entered as ASCII text. A Response MUST be sent in reply to the Request. The Response MUST be of Type 6 (GTC), Nak (Type 3) or Expanded Nak (Type 254). The Nak Response indicates the peer's desired authentication Type(s). The EAP GTC method is intended for use with the Token Cards supporting challenge/response authentication and MUST NOT be used to provide support for cleartext passwords in the absence of a protected tunnel with server authentication.

Type

6

Type-Data

The Type-Data field in the Request contains a displayable message greater than zero octets in length. The length of the message is determined by the Length field of the Request packet. The message MUST NOT be null terminated. A Response MUST be sent in reply to the Request with a Type field of 6 (Generic Token Card). The Response contains data from the Token Card required for authentication. The length of the data is determined by the Length field of the Response packet.

EAP GTC implementations MAY support entering a response with non-ASCII characters. See Section 5 for instructions how the input should be processed and encoded into octets.

Security Claims (see Section 7.2):

Intended use:	Wired networks, including PPP, PPPOE, and IEEE 802 wired media. Use over the Internet or with wireless media only when protected.
Auth. mechanism:	Hardware token.
Ciphersuite negotiation:	No
Mutual authentication:	No
Integrity protection:	No
Replay protection:	No
Confidentiality:	No
Key derivation:	No
Key strength:	N/A
Dictionary attack prot.:	No
Fast reconnect:	No
Crypt. binding:	N/A
Protected success/failure:	No
Session independence:	N/A
Fragmentation:	No
Channel binding:	No

5.7 Expanded Types

Description

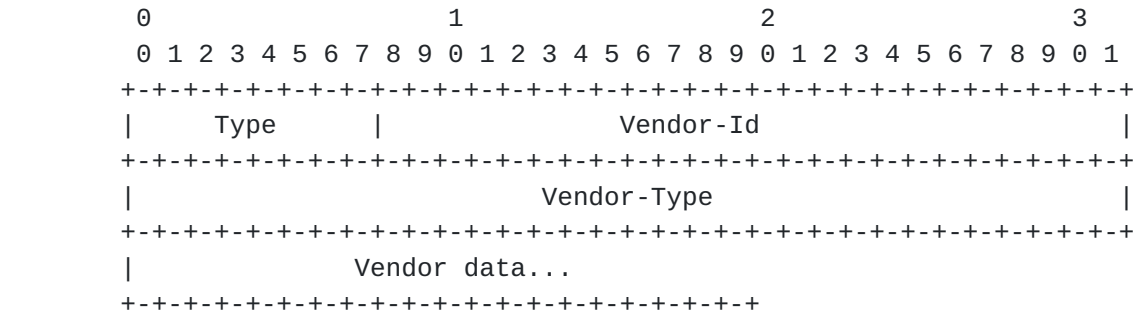
Since many of the existing uses of EAP are vendor-specific, the Expanded method Type is available to allow vendors to support

their own Expanded Types not suitable for general usage.

The Expanded Type is also used to expand the global Method Type space beyond the original 255 values. A Vendor-Id of 0 maps the original 255 possible Types onto a space of 2^32-1 possible Types. (Type 0 is only used in a Nak Response, to indicate no acceptable alternative)

An implementation that supports the Expanded attribute MUST treat EAP Types that are less than 256 equivalently whether they appear as a single octet or as the 32-bit Vendor-Type within a Expanded Type where Vendor-Id is 0. Peers not equipped to interpret the Expanded Type MUST send a Nak as described in Section 5.3.1, and negotiate a more suitable authentication method.

A summary of the Expanded Type format is shown below. The fields are transmitted from left to right.



Type

254 for Expanded Type

Vendor-Id

The Vendor-Id is 3 octets and represents the SMI Network Management Private Enterprise Code of the Vendor in network byte order, as allocated by IANA. A Vendor-Id of zero is reserved for use by the IETF in providing an expanded global EAP Type space.

Vendor-Type

The Vendor-Type field is four octets and represents the vendor-specific method Type.

If the Vendor-Id is zero, the Vendor-Type field is an extension and superset of the existing namespace for EAP Types. The first 256 Types are reserved for compatibility with single-octet EAP Types that have already been assigned or may be assigned in the

future. Thus, EAP Types from 0 through 255 are semantically identical whether they appear as single octet EAP Types or as Vendor-Types when Vendor-Id is zero. There is one exception to this rule: Expanded Nak and Legacy Nak packets share the same Type, but must be treated differently because they have a different format.

Vendor-Data

The Vendor-Data field is defined by the vendor. Where a Vendor-Id of zero is present, the Vendor-Data field will be used for transporting the contents of EAP methods of Types defined by the IETF.

5.8 Experimental

Description

The Experimental Type has no fixed format or content. It is intended for use when experimenting with new EAP Types. This Type is intended for experimental and testing purposes. No guarantee is made for interoperability between peers using this Type, as outlined in [IANA-EXP].

Type

255

Type-Data

Undefined

6. IANA Considerations

This section provides guidance to the Internet Assigned Numbers Authority (IANA) regarding registration of values related to the EAP protocol, in accordance with BCP 26, [RFC2434].

There are two name spaces in EAP that require registration: Packet Codes and method Types.

EAP is not intended as a general-purpose protocol, and allocations SHOULD NOT be made for purposes unrelated to authentication.

The following terms are used here with the meanings defined in BCP 26: "name space", "assigned value", "registration".

The following policies are used here with the meanings defined in BCP 26: "Private Use", "First Come First Served", "Expert Review", "Specification Required", "IETF Consensus", "Standards Action".

For registration requests where a Designated Expert should be consulted, the responsible IESG area director should appoint the Designated Expert. The intention is that any allocation will be accompanied by a published RFC. But in order to allow for the allocation of values prior to the RFC being approved for publication, the Designated Expert can approve allocations once it seems clear that an RFC will be published. The Designated expert will post a request to the EAP WG mailing list (or a successor designated by the Area Director) for comment and review, including an Internet-Draft. Before a period of 30 days has passed, the Designated Expert will either approve or deny the registration request and publish a notice of the decision to the EAP WG mailing list or its successor, as well as informing IANA. A denial notice must be justified by an explanation and, in the cases where it is possible, concrete suggestions on how the request can be modified so as to become acceptable.

6.1 Packet Codes

Packet Codes have a range from 1 to 255, of which 1-4 have been allocated. Because a new Packet Code has considerable impact on interoperability, a new Packet Code requires Standards Action, and should be allocated starting at 5.

6.2 Method Types

The original EAP method Type space has a range from 1 to 255, and is the scarcest resource in EAP, and thus must be allocated with care. Method Types 1-41 have been allocated, with 20 available for re-use. Method Types 42-191 may be allocated on the advice of a Designated Expert, with Specification Required.

Allocation of blocks of method Types (more than one for a given purpose) should require IETF Consensus. EAP Type Values 192-253 are reserved and allocation requires Standards Action.

Method Type 254 is allocated for the Expanded Type. Where the Vendor-Id field is non-zero, the Expanded Type is used for functions specific only to one vendor's implementation of EAP, where no interoperability is deemed useful. When used with a Vendor-Id of zero, method Type 254 can also be used to provide for an expanded IETF method Type space. Method Type values 256-4294967295 may be allocated after Type values 1-191 have been allocated.

Method Type 255 is allocated for Experimental use, such as testing of new EAP methods before a permanent Type is allocated.

7. Security Considerations

EAP was designed for use with dialup PPP [RFC1661] and was later adapted for use in wired IEEE 802 networks [IEEE-802] in [IEEE-802.1X]. On these networks, an attacker would need to gain physical access to the telephone or switch infrastructure in order to mount an attack. While such attacks have been documented, such as in [DECEPTION], they are assumed to be rare.

However, subsequently EAP has been proposed for use on wireless networks, and over the Internet, where physical security cannot be assumed. On such networks, the security vulnerabilities are greater, as are the requirements for EAP security.

This section defines the threat model and security terms and describes the security claims section required in EAP method specifications. We then discuss threat mitigation.

7.1 Threat model

On physically insecure networks, it is possible for an attacker to gain access to the physical medium. This enables a range of attacks, including the following:

[1] An attacker may try to discover user identities by snooping authentication traffic.

[2] An attacker may try to modify or spoof EAP packets.

[3] An attacker may launch denial of service attacks by spoofing lower layer indications or Success/Failure packets; by replaying EAP packets; or by generating packets with overlapping Identifiers.

[4] An attacker may attempt to recover the pass-phrase by mounting an offline dictionary attack.

[5] An attacker may attempt to convince the peer to connect to an untrusted network, by mounting a man-in-the-middle attack.

[6] An attacker may attempt to disrupt the EAP negotiation in order cause a weak authentication method to be selected.

[7] An attacker may attempt to recover keys by taking advantage of weak key derivation techniques used within EAP methods.

[8] An attacker may attempt to take advantage of weak ciphersuites subsequently used after the EAP conversation is complete.

[9] An attacker may attempt to perform downgrading attacks on lower layer ciphersuite negotiation in order to ensure that a weaker ciphersuite is used subsequently to EAP authentication.

[10] An attacker acting as an authenticator may provide incorrect information to the EAP peer and/or server via out-of-band mechanisms (such as via a AAA or lower layer protocol). This includes impersonating another authenticator, or providing inconsistent information to the peer and EAP server.

Where EAP is used over wired networks, an attacker typically requires access to the physical infrastructure in order to carry out these attacks. However, where EAP is used over wireless networks, EAP packets may be forwarded by authenticators (e.g., pre-authentication) so that the attacker need not be within the coverage area of an authenticator in order to carry out an attack on it or its peers. Where EAP is used over the Internet, attacks may be carried out at an even greater distance.

7.2 Security claims

In order to clearly articulate the security provided by an EAP method, EAP method specifications MUST include a Security Claims section including the following declarations:

[a] Intended use. This includes a statement of whether the method is intended for use over a physically secure or insecure network, as well as a statement of the applicable lower layers.

[b] Mechanism. This is a statement of the authentication technology: certificates, pre-shared keys, passwords, token cards, etc.

[c] Security claims. This is a statement of the claimed security properties of the method, using terms defined in Section 1.2: mutual authentication, integrity protection, replay protection, confidentiality, key derivation, dictionary attack resistance, fast reconnect, cryptographic binding, protected result indications. The Security Claims section of an EAP method specification SHOULD provide justification for the claims that are made. This can be accomplished by including a proof in an Appendix, or including a reference to a proof.

[d] Key strength. If the method derives keys, then the effective key strength MUST be estimated. This estimate is meant for potential users of the method to determine if the keys produced are strong enough for the intended application.

The effective key strength SHOULD be stated as number of bits, defined as follows: If the effective key strength is N bits, the best currently known methods to recover the key (with non-negligible probability) require an effort comparable to 2^N operations of a typical block cipher. The statement SHOULD be accompanied by a short rationale, explaining how this number was arrived at. This explanation SHOULD include the parameters required to achieve the stated key strength based on current knowledge of the algorithms.

(Note: Although it is difficult to define what "comparable effort" and "typical block cipher" exactly mean, reasonable approximations are sufficient here. Refer to e.g. [SILVERMAN] for more discussion.)

The key strength depends on the methods used to derive the keys. For instance, if keys are derived from a shared secret (such as a password or a long-term secret), and possibly some public information such as nonces, the effective key strength is limited by the strength of the long-term secret (assuming that the derivation procedure is computationally simple). To take another example, when using public key algorithms, the strength of the symmetric key depends on the strength of the public keys used.

[e] Description of key hierarchy. EAP methods deriving keys MUST either provide a reference to a key hierarchy specification, or describe how Master Session Keys (MSKs) and Extended Master Session Keys (EMSKs) are to be derived.

[f] Indication of vulnerabilities. In addition to the security claims that are made, the specification MUST indicate which of the security claims detailed in Section 7.2.1 are NOT being made.

7.2.1 Security claims terminology for EAP methods

These terms are used to described the security properties of EAP methods:

Protected ciphersuite negotiation
: This refers to the ability of an EAP method to negotiate the ciphersuite used to protect the EAP conversation, as well as to integrity protect the negotiation. It does not

refer to the ability to negotiate the ciphersuite used to protect data.

Mutual authentication
: This refers to an EAP method in which, within an interlocked exchange, the authenticator authenticates the peer and the peer authenticates the authenticator. Two independent one-way methods, running in opposite directions do not provide mutual authentication as defined here.

Integrity protection
: This refers to providing data origin authentication and protection against unauthorized modification of information for EAP packets (including EAP Requests and Responses). When making this claim, a method specification MUST describe the EAP packets and fields within the EAP packet that are protected.

Replay protection
: This refers to protection against replay of an EAP method or its messages, including method-specific success and failure indications.

Confidentiality
: This refers to encryption of EAP messages, including EAP Requests and Responses, and method-specific success and failure indications. A method making this claim MUST support identity protection (see Section 7.3).

Key derivation
: This refers to the ability of the EAP method to derive exportable keying material such as the Master Session Key (MSK), and Extended Master Session Key (EMSK). The MSK is used only for further key derivation, not directly for protection of the EAP conversation or subsequent data. Use of the EMSK is reserved.

Key strength
: If the effective key strength is N bits, the best currently known methods to recover the key (with non-negligible probability) require an effort comparable to 2^N operations of a typical block cipher.

Dictionary attack resistance
: Where password authentication is used, passwords are commonly selected from a small set (as compared to a set of N-bit keys), which raises a concern about dictionary attacks. A method may be said to provide protection

against dictionary attacks if, when it uses a password as a secret, the method does not allow an offline attack that has a work factor based on the number of passwords in an attacker's dictionary.

Fast reconnect
: The ability, in the case where a security association has been previously established, to create a new or refreshed security association in a smaller number of round-trips.

Cryptographic binding
: The demonstration of the EAP peer to the EAP server that a single entity has acted as the EAP peer for all methods executed within a tunnel method. Binding MAY also imply that the EAP server demonstrates to the peer that a single entity has acted as the EAP server for all methods executed within a tunnel method. If executed correctly, binding serves to mitigate man-in-the-middle vulnerabilities.

Protected result indications
: The ability within a method for the authenticator to indicate to the peer whether it has successfully authenticated to it, and for the peer to acknowledge receipt of that indication as well as indicating to the authenticator whether it has successfully authenticated to the peer. Since EAP Success and Failure packets are neither acknowledged nor integrity protected, this claim requires implementation of a method-specific result exchange that is authenticated, integrity and replay protected on a per-packet basis.

Session independence
: The demonstration that passive attacks (such as capture of the EAP conversation) or active attacks (including compromise of the MSK or EMSK) does not enable compromise of subsequent or prior MSKs or EMSKs.

Fragmentation
: This refers to whether an EAP method supports fragmentation and reassembly. As noted in Section 3.1, EAP methods should support fragmentation and reassembly if EAP packets can exceed the minimum MTU of 1020 octets.

Channel binding
: The communication within an EAP method of integrity-protected channel properties such as endpoint identifiers which can be compared to values communicated via out of band mechanisms (such as via a AAA or lower

layer protocol).

7.3 Identity protection

An Identity exchange is optional within the EAP conversation. Therefore, it is possible to omit the Identity exchange entirely, or to use a method-specific identity exchange once a protected channel has been established.

However, where roaming is supported as described in [RFC2607], it may be necessary to locate the appropriate backend authentication server before the authentication conversation can proceed. The realm portion of the Network Access Identifier (NAI) [RFC2486] is typically included within the EAP-Response/Identity in order to enable the authentication exchange to be routed to the appropriate backend authentication server. Therefore while the peer-name portion of the NAI may be omitted in the EAP-Response/Identity, where proxies or relays are present, the realm portion may be required.

It is possible for the identity in the identity response to be different from the identity authenticated by the EAP method. This may be intentional in the case of identity privacy. An EAP method SHOULD use the authenticated identity when making access control decisions.

7.4 Man-in-the-middle attacks

Where EAP is tunneled within another protocol that omits peer authentication, there exists a potential vulnerability to man-in-the-middle attack. For details, see [BINDING] and [MITM].

As noted in Section 2.1, EAP does not permit untunnelled sequences of authentication methods. Were a sequence of EAP authentication methods to be permitted, the peer might not have proof that a single entity has acted as the authenticator for all EAP methods within the sequence. For example, an authenticator might terminate one EAP method, then forward the next method in the sequence to another party without the peer's knowledge or consent. Similarly, the authenticator might not have proof that a single entity has acted as the peer for all EAP methods within the sequence.

Tunnelling EAP within another protocol enables an attack by a rogue EAP authenticator tunneling EAP to a legitimate server. Where the tunneling protocol is used for key establishment but does not require peer authentication, an attacker convincing a legitimate peer to connect to it will be able to tunnel EAP packets to a legitimate server, successfully authenticating and obtaining the key. This allows the attacker to successfully establish itself as a

man-in-the-middle, gaining access to the network, as well as the ability to decrypt data traffic between the legitimate peer and server.

This attack may be mitigated by the following measures:

[a] Requiring mutual authentication within EAP tunneling mechanisms.

[b] Requiring cryptographic binding between the EAP tunneling protocol and the tunneled EAP methods. Where cryptographic binding is supported, a mechanism is also needed to protect against downgrade attacks that would bypass it. For further details on cryptographic binding, see [BINDING].

[c] Limiting the EAP methods authorized for use without protection, based on peer and authenticator policy.

[d] Avoiding the use of tunnels when a single, strong method is available.

7.5 Packet modification attacks

While EAP methods may support per-packet data origin authentication, integrity and replay protection, support is not provided within the EAP layer.

Since the Identifier is only a single octet, it is easy to guess, allowing an attacker to successfully inject or replay EAP packets. An attacker may also modify EAP headers (Code, Identifier, Length, Type) within EAP packets where the header is unprotected. This could cause packets to be inappropriately discarded or misinterpreted.

In the case of PPP and IEEE 802 wired links, it is assumed that such attacks are restricted to attackers who can gain access to the physical link. However, where EAP is run over physically insecure lower layers such as wireless (802.11 or cellular) or the Internet (such as within protocols supporting PPP, EAP or Ethernet Tunneling), this assumption is no longer valid and the vulnerability to attack is greater.

To protect EAP messages sent over physically insecure lower layers, methods providing mutual authentication and key derivation, as well as per-packet origin authentication, integrity and replay protection SHOULD be used.

Method-specific MICs may be used to provide protection. If a per-packet MIC is employed within an EAP method, then peers,

authentication servers, and authenticators not operating in pass-through mode MUST validate the MIC. MIC validation failures SHOULD be logged. Whether a MIC validation failure is considered a fatal error or not is determined by the EAP method specification.

Since EAP messages of Types Identity, Notification, and Nak do not include their own MIC, it may be desirable for the EAP method MIC to cover information contained within these messages, as well as the header of each EAP message.

To provide protection, EAP also may be encapsulated within a protected channel created by protocols such as ISAKMP [RFC2408] as is done in [IKEv2] or within TLS [RFC2246]. However, as noted in Section 7.4, EAP tunneling may result in a man-in-the-middle vulnerability.

Existing EAP methods define message integrity checks (MICs) that cover more than one EAP packet. For example, EAP-TLS [RFC2716] defines a MIC over a TLS record that could be split into multiple fragments; within the FINISHED message, the MIC is computed over previous messages. Where the MIC covers more than one EAP packet, a MIC validation failure is typically considered a fatal error.

Within EAP-TLS [RFC2716] a MIC validation failure is treated as a fatal error, since that is what is specified in TLS [RFC2246]. However, it is also possible to develop EAP methods that support per-packet MICs, and respond to verification failures by silently discarding the offending packet.

In this document, descriptions of EAP message handling assume that per-packet MIC validation, where it occurs, is effectively performed as though it occurs before sending any responses or changing the state of the host which received the packet.

7.6 Dictionary attacks

Password authentication algorithms such as EAP-MD5, MS-CHAPv1 [RFC2433] and Kerberos V [RFC1510] are known to be vulnerable to dictionary attacks. MS-CHAPv1 vulnerabilities are documented in [PPTPv1]; Kerberos vulnerabilities are described in [KRBATTACK], [KRBLIM], and [KERB4WEAK].

In order to protect against dictionary attacks, an authentication algorithm resistant to dictionary attack (as defined in Section 7.2) SHOULD be used where EAP runs over lower layers which are not physically secure.

If an authentication algorithm is used that is known to be vulnerable

to dictionary attack, then the conversation may be tunneled within a protected channel in order to provide additional protection. However, as noted in Section 7.4, EAP tunneling may result in a man-in-the-middle vulnerability, and therefore dictionary attack resistant methods are preferred.

7.7 Connection to an untrusted network

With EAP methods supporting one-way authentication, such as EAP-MD5, the peer does not authenticate the authenticator. Where the lower layer is not physically secure (such as where EAP runs over wireless media or the Internet), the peer is vulnerable to a rogue authenticator. As a result, where the lower layer is not physically secure, a method supporting mutual authentication is RECOMMENDED.

In EAP there is no requirement that authentication be full duplex or that the same protocol be used in both directions. It is perfectly acceptable for different protocols to be used in each direction. This will, of course, depend on the specific protocols negotiated. However, in general, completing a single unitary mutual authentication is preferable to two one-way authentications, one in each direction. This is because separate authentications that are not bound cryptographically so as to demonstrate they are part of the same session are subject to man-in-the-middle attacks, as discussed in Section 7.4.

7.8 Negotiation attacks

In a negotiation attack, the attacker attempts to convince the peer and authenticator to negotiate a less secure EAP method. EAP does not provide protection for Nak Response packets, although it is possible for a method to include coverage of Nak Responses within a method-specific MIC.

Within or associated with each authenticator, it is not anticipated that a particular named peer will support a choice of methods. This would make the peer vulnerable to attacks that negotiate the least secure method from among a set. Instead, for each named peer there SHOULD be an indication of exactly one method used to authenticate that peer name. If a peer needs to make use of different authentication methods under different circumstances, then distinct identities SHOULD be employed, each of which identifies exactly one authentication method.

7.9 Implementation idiosyncrasies

The interaction of EAP with lower layers such as PPP and IEEE 802 are highly implementation dependent.

For example, upon failure of authentication, some PPP implementations do not terminate the link, instead limiting traffic in Network-Layer Protocols to a filtered subset, which in turn allows the peer the opportunity to update secrets or send mail to the network administrator indicating a problem. Similarly, while in [IEEE-802.1X] an authentication failure will result in denied access to the controlled port, limited traffic may be permitted on the uncontrolled port.

In EAP there is no provision for retries of failed authentication. However, in PPP the LCP state machine can renegotiate the authentication protocol at any time, thus allowing a new attempt. Similarly, in IEEE 802.1X the Supplicant or Authenticator can re-authenticate at any time. It is recommended that any counters used for authentication failure not be reset until after successful authentication, or subsequent termination of the failed link.

7.10 Key derivation

It is possible for the peer and EAP server to mutually authenticate and derive keys. In order to provide keying material for use in a subsequently negotiated ciphersuite, an EAP method supporting key derivation MUST export a Master Session Key (MSK) of at least 64 octets, and an Extended Master Session Key (EMSK) of at least 64 octets. EAP Methods deriving keys MUST provide for mutual authentication between the EAP peer and the EAP Server.

The MSK and EMSK MUST NOT be used directly to protect data; however, they are of sufficient size to enable derivation of a AAA-Key subsequently used to derive Transient Session Keys (TSKs) for use with the selected ciphersuite. Each ciphersuite is responsible for specifying how to derive the TSKs from the AAA-Key.

The AAA-Key is derived from the keying material exported by the EAP method (MSK and EMSK). This derivation occurs on the AAA server. In many existing protocols that use EAP, the AAA-Key and MSK are equivalent, but more complicated mechanisms are possible (see [KEYFRAME] for details).

EAP methods SHOULD ensure the freshness of the MSK and EMSK even in cases where one party may not have a high quality random number generator. A RECOMMENDED method is for each party to provide a nonce of at least 128 bits, used in the derivation of the MSK and EMSK.

EAP methods export the MSK and EMSK and not Transient Session Keys so as to allow EAP methods to be ciphersuite and media independent. Keying material exported by EAP methods MUST be independent of the ciphersuite negotiated to protect data.

Depending on the lower layer, EAP methods may run before or after ciphersuite negotiation, so that the selected ciphersuite may not be known to the EAP method. By providing keying material usable with any ciphersuite, EAP methods can used with a wide range of ciphersuites and media.

It is RECOMMENDED that methods providing integrity protection of EAP packets include coverage of all the EAP header fields, including the Code, Identifier, Length, Type and Type-Data fields.

In order to preserve algorithm independence, EAP methods deriving keys SHOULD support (and document) the protected negotiation of the ciphersuite used to protect the EAP conversation between the peer and server. This is distinct from the ciphersuite negotiated between the peer and authenticator, used to protect data.

The strength of Transient Session Keys (TSKs) used to protect data is ultimately dependent on the strength of keys generated by the EAP method. If an EAP method cannot produce keying material of sufficient strength, then the TSKs may be subject to brute force attack. In order to enable deployments requiring strong keys, EAP methods supporting key derivation SHOULD be capable of generating an MSK and EMSK, each with an effective key strength of at least 128 bits.

Methods supporting key derivation MUST demonstrate cryptographic separation between the MSK and EMSK branches of the EAP key hierarchy. Without violating a fundamental cryptographic assumption (such as the non-invertibility of a one-way function) an attacker recovering the MSK or EMSK MUST NOT be able to recover the other quantity with a level of effort less than brute force.

Non-overlapping substrings of the MSK MUST be cryptographically separate from each other, as defined in Section 7.2.1. That is, knowledge of one substring MUST NOT help in recovering some other substring without breaking some hard cryptographic assumption. This is required because some existing ciphersuites form TSKs by simply splitting the AAA-Key to pieces of appropriate length. Likewise, non-overlapping substrings of the EMSK MUST be cryptographically separate from each other, and from substrings of the MSK.

The EMSK is reserved for future use and MUST remain on the EAP peer and EAP server where it is derived; it MUST NOT be transported to, or shared with, additional parties, or used to derive any other keys. (This restriction will be relaxed in a future document that specifies how the EMSK can be used.)

Since EAP does not provide for explicit key lifetime negotiation, EAP

peers, authenticators and authentication servers MUST be prepared for situations in which one of the parties discards key state which remains valid on another party.

This specification does not provide detailed guidance on how EAP methods derive the MSK and EMSK; how the AAA-Key is derived from the MSK and/or EMSK; or how the TSKs are derived from the AAA-Key.

The development and validation of key derivation algorithms is difficult, and as a result EAP methods SHOULD reuse well established and analyzed mechanisms for key derivation (such as those specified in IKE [RFC2409] or TLS [RFC2246]), rather than inventing new ones. EAP methods SHOULD also utilize well established and analyzed mechanisms for MSK and EMSK derivation. Further details on EAP Key Derivation are provided within [KEYFRAME].

7.11 Weak ciphersuites

If after the initial EAP authentication, data packets are sent without per-packet authentication, integrity and replay protection, an attacker with access to the media can inject packets, "flip bits" within existing packets, replay packets, or even hijack the session completely. Without per-packet confidentiality, it is possible to snoop data packets.

As a result, as noted in Section 3.1, where EAP is used over a physically insecure lower layer, per-packet authentication, integrity and replay protection SHOULD be used, and per-packet confidentiality is also recommended.

Additionally, if the lower layer performs ciphersuite negotiation, it should be understood that EAP does not provide by itself integrity protection of that negotiation. Therefore, in order to avoid downgrading attacks which would lead to weaker ciphersuites being used, clients implementing lower layer ciphersuite negotiation SHOULD protect against negotiation downgrading.

This can be done by enabling users to configure which are the acceptable ciphersuites as a matter of security policy; or, the ciphersuite negotiation MAY be authenticated using keying material derived from the EAP authentication and a MIC algorithm agreed upon in advance by lower-layer peers.

7.12 Link layer

There exists a number of reliability and security issues with link layer indications in PPP, IEEE 802 wired networks and IEEE 802.11 wireless LANs:

[a] PPP. In PPP, link layer indications such as LCP-Terminate (a link failure indication) and NCP (a link success indication) are not authenticated or integrity protected. They can therefore be spoofed by an attacker with access to the physical medium.

[b] IEEE 802 wired networks. On wired networks, IEEE 802.1X messages are sent to a non-forwardable multicast MAC address. As a result, while the IEEE 802.1X EAPOL-Start and EAPOL-Logoff frames are not authenticated or integrity protected, only an attacker with access to the physical link can spoof these messages.

[c] IEEE 802.11 wireless LANs. In IEEE 802.11, link layer indications include Disassociate and Deauthenticate frames (link failure indications), and the first message of the 4-way handshake (link success indication). These messages are not authenticated or integrity protected, and although they are not forwardable, they are spoofable by an attacker within range.

In IEEE 802.11, IEEE 802.1X data frames may be sent as Class 3 unicast data frames, and are therefore forwardable. This implies that while EAPOL-Start and EAPOL-Logoff messages may be authenticated and integrity protected, they can be spoofed by an authenticated attacker far from the target when "pre-authentication" is enabled.

In IEEE 802.11 a "link down" indication is an unreliable indication of link failure, since wireless signal strength can come and go and may be influenced by radio frequency interference generated by an attacker. To avoid unnecessary resets, it is advisable to damp these indications, rather than passing them directly to the EAP. Since EAP supports retransmission, it is robust against transient connectivity losses.

7.13 Separation of authenticator and backend authentication server

It is possible for the EAP peer and EAP server to mutually authenticate and derive a AAA-Key for a ciphersuite used to protect subsequent data traffic. This does not present an issue on the peer, since the peer and EAP client reside on the same machine; all that is required is for the client to derive the AAA-Key from the MSK and EMSK exported by the EAP method, and to subsequently pass a Transient Session Key (TSK) to the ciphersuite module.

However, in the case where the authenticator and authentication server reside on different machines, there are several implications for security.

[a] Authentication will occur between the peer and the authentication server, not between the peer and the authenticator. This means that it is not possible for the peer to validate the identity of the authenticator that it is speaking to, using EAP alone.

[b] As discussed in [RFC3579], the authenticator is dependent on the AAA protocol in order to know the outcome of an authentication conversation, and does not look at the encapsulated EAP packet (if one is present) to determine the outcome. In practice this implies that the AAA protocol spoken between the authenticator and authentication server MUST support per-packet authentication, integrity and replay protection.

[c] Where EAP is used over lower layers which are not physically secure, after completion of the EAP conversation, a secure association protocol SHOULD be run between the peer and authenticator in order to provide mutual authentication; guarantee liveness of the TSKs; provide protected ciphersuite and capabilities negotiation; synchronize key usage.

[d] A AAA-Key derived from the MSK and/or EMSK negotiated between the peer and authentication server MAY be transmitted to the authenticator. Therefore a mechanism needs to be provided to transmit the AAA-Key from the authentication server to the authenticator that needs it. The specification of the AAA-key derivation, transport and wrapping mechanisms is outside the scope of this document. Further details on AAA-Key Derivation are provided within [KEYFRAME].

7.14 Cleartext Passwords

EAP does not support cleartext password authentication. This omission is intentional. Where EAP is carried over physically insecure lower layers, including wireless LANs [IEEE-802.11] or the Internet, use of cleartext passwords would allow the password to be captured by an attacker with access to the lower layer.

Since protocols encapsulating EAP, such as RADIUS [RFC3579], may not provide confidentiality, even where the lower layer is physically secure, EAP frames may be subsequently encapsulated for transport over the Internet where they may be captured by an attacker.

As a result, cleartext passwords cannot be securely used within EAP, except where encapsulated within a protected tunnel with server authentication. Some of the same risks apply to EAP methods without dictionary attack resistance, as defined in Section 7.2.1. For details, see Section 7.6.

7.15 Channel binding

It is possible for a compromised or poorly implemented EAP authenticator to communicate incorrect information to the EAP peer and/or server. This may enable an authenticator to impersonate another authenticator or communicate incorrect information via out-of-band mechanisms (such as via a AAA or lower layer protocol).

Where EAP is used in pass-through mode, the EAP peer typically does not verify the identity of the pass-through authenticator, it only verifies that the pass-through authenticator is trusted by the EAP server. This creates a potential security vulnerability.

Section 4.3.7 of [RFC3579] describes how an EAP pass-through authenticator acting as a AAA client can be detected if it attempts to impersonate another authenticator (such by sending incorrect NAS-Identifier [RFC2865], NAS-IP-Address [RFC2865] or NAS-IPv6-Address [RFC3162] attributes via the AAA protocol). However, it is possible for a pass-through authenticator acting as a AAA client to provide correct information to the AAA server while communicating misleading information to the EAP peer via a lower layer protocol.

For example, it is possible for a compromised authenticator to utilize another authenticator's Called-Station-Id or NAS-Identifier in communicating with the EAP peer via a lower layer protocol, or for a pass-through authenticator acting as a AAA client to provide an incorrect peer Calling-Station-Id [RFC2865][RFC3580] to the AAA server via the AAA protocol.

In order to address this vulnerability, EAP methods may support a protected exchange of channel properties such as endpoint identifiers, including (but not limited to): Called-Station-Id [RFC2865][RFC3580], Calling-Station-Id [RFC2865][RFC3580], NAS-Identifier [RFC2865], NAS-IP-Address [RFC2865], and NAS-IPv6-Address [RFC3162].

Using such a protected exchange, it is possible to match the channel properties provided by the authenticator via out-of-band mechanisms against those exchanged within the EAP method. Where discrepancies are found, these SHOULD be logged; additional actions MAY also be taken, such as denying access.

8. Acknowledgments

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The use of Security Claims sections for EAP methods, as required by Section 7.2 and specified for each EAP method described in this document, was inspired by Glen Zorn through [EAP-EVAL].

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Appendix A. Changes from RFC 2284

This section lists the major changes between [RFC2284] and this document. Minor changes, including style, grammar, spelling and editorial changes are not mentioned here.

- The Terminology section (Section 1.2) has been expanded, defining more concepts and giving more exact definitions.

- The two concepts Mutual authentication and Key derivation are introduced, and discussed throughout the document where appropriate.

- In Section 2, it is explicitly specified that more than one exchange of Request and Response packets may occur as part of the EAP authentication exchange. How this may and may not be used is specified in detail in Section 2.1.

- Also in Section 2, some requirements on the authenticator when acting in pass-through mode has been made explicit.

- An EAP multiplexing model (Section 2.2) has been added, to illustrate a typical implementation of EAP. There is no requirement that an implementation conforms to this model, as long as the on-the-wire behavior is consistent with it.

- As EAP is now in use with a variety of lower layers, not just PPP for which it was first designed, Section 3 on lower layer behavior has been added.

- In the description of the EAP Request and Response interaction (Section 4.1), it has been more exactly specified when packets should be silently discarded, and also the behavior on receiving duplicate requests. The implementation notes in this section has been substantially expanded.

- In Section 4.2, it has been clarified that Success and Failure packets must not contain additional data, and the implementation note has been expanded. A subsection giving requirements on processing of success and failure packets has been added.

- Section 5 on EAP Request/Response Types lists two new Type values: the Expanded Type (Section 5.7), which is used to expand the Type value number space, and the Experimental Type. In the Expanded Type number space, the new Expanded Nak (Section 5.3.2) Type has been added. Clarifications have been made in the description of most of the existing Types. Security claims summaries have been added for authentication methods.

- In Section 5, Section 5.1 and Section 5.2, requirements has been added that fields with displayable messages should contain UTF-8 encoded ISO 10646 characters.

- In Section 5.5, support for OTP Extended Responses [RFC2243] has been added to EAP OTP.

- An IANA Considerations section (Section 6) has been added, giving registration policies for the numbering spaces defined for EAP.

- The Security Considerations (Section 7) have been greatly expanded, aiming at giving a much more comprehensive coverage of possible threats and other security considerations.

- In Section 7.5, text has been added on method-specific behavior, providing guidance on how EAP method-specific integrity checks should be processed. Where possible, it is desirable for a

method-specific MIC to be computed over the entire EAP packet, including the EAP layer header (Code, Identifier, Length) and EAP method layer header (Type, Type-Data).

Appendix B. Open issues

(This section should be removed by the RFC editor before publication)

Open issues relating to this specification are tracked on the following web site:

http://www.drizzle.com/~aboba/EAP/eapissues.html

The current working documents for this draft are available at this web site:

http://www.levkowetz.com/pub/ietf/drafts/eap/rfc2284bis/

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