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HMTFTP: HMAC-Derived TFTP with Optional AEAD Protection (v0.3)
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Abstract

HMTFTP is a lightweight UDP file transfer protocol derived from TFTP that adds a compact TLV mechanism and an optional AEAD protection mode for DATA payloads. Version v0.3 clarifies interoperability and extension governance rules so that independent implementations can evolve safely over time. The default UDP port is TBD1 and implementations MUST allow it to be configured.

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1. Introduction

The Trivial File Transfer Protocol (TFTP) [RFC1350] is extremely simple but provides no built-in security properties. HMTFTP retains the TFTP operational model (UDP, numbered blocks, ACKs) while introducing (1) a compact TLV extension mechanism and (2) an optional AEAD protection mode for DATA payloads.

The name "HMTFTP" reflects that cryptographic keys are derived using HKDF, a HMAC-based key derivation function [RFC5869]. Version v0.3 introduces an explicit compatibility profile and TLV governance rules intended to make extensions safe and deterministic.

2. Conventions and Terminology

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 BCP 14 ([RFC2119] and [RFC8174]) when, and only when, they appear in all capitals.

This document uses the following terms:

- * ***PSK***: pre-shared key
- * ***AEAD***: authenticated encryption with associated data
- * ***AAD***: additional authenticated data

3. Relationship to TFTP

HMTFTP is derived from TFTP [RFC1350] and reuses the core message types and semantics (RRQ, WRQ, DATA, ACK, ERROR). It also reuses the concept of an explicit option acknowledgment, OACK, as introduced by TFTP option extension [RFC2347]. HMTFTP replaces the key/value option encoding of RFC 2347 with a TLV encoding defined in this document.

Similar option semantics exist in TFTP, notably the blocksize option [RFC2348] and the timeout and transfer size options [RFC2349]; HMTFTP provides analogous parameters using TLVs.

HMTFTP differs from baseline TFTP primarily by:

- * using UDP port TBD1 by default (configurable), rather than 69;
- * allowing TLV extensions in RRQ, WRQ, and OACK;
- * supporting an optional AEAD security mode for DATA payloads.

4. Transport

HMTFTP runs over UDP. The default server port is TBD1, but implementations MUST allow the port to be configured.

Any future assignment of the default UDP port follows IANA procedures for service name and transport protocol port numbers [RFC6335].

As in TFTP, a transfer is conducted between a client and a server transfer address (IP, UDP port). The server MAY respond from a different UDP port than TBD1 for the remainder of the transfer, as described in [RFC1350].

5. Message Formats

All multi-octet fields are encoded in network byte order (big-endian). HMTFTP reuses the TFTP base message formats, with TLVs appended to RRQ, WRQ, and OACK. TLVs are not used in DATA, ACK, or ERROR in this version.

5.1. RRQ and WRQ

RRQ and WRQ are defined as in [RFC1350] :

RRQ/WRQ = OpCode (2) || Filename (N) || 0 || Mode (M) || 0 ||
[TLVs]

The optional TLV sequence, when present, begins immediately after the terminating zero octet of the Mode field and continues to the end of the UDP datagram. The Mode is a NUL-terminated ASCII string (e.g., "octet").

5.2. OACK

OACK is used by the server to acknowledge and/or modify the TLVs offered in RRQ/WRQ. OACK is defined by [RFC2347] as OpCode value 6. In HMTFTP, OACK contains only a TLV sequence:

OACK = OpCode (2) || TLVs

An OACK with an empty TLV sequence indicates acceptance with no negotiated parameters.

5.3. DATA and ACK

DATA and ACK are as defined in [RFC1350] :

DATA = OpCode (2) || Block (2) || Payload (0..n)

ACK = OpCode (2) || Block (2)

When AEAD protection is negotiated (Section 9), the DATA Payload is structured as: Ciphertext || Tag, where Tag is a 16-octet AES-GCM authentication tag. The ciphertext length is the datagram length minus 4 octets of header and minus 16 octets of tag.

5.4. ERROR

ERROR is as defined in [RFC1350] :

ERROR = OpCode (2) || ErrorCode (2) || ErrMsg (string) || 0

HMTFTP endpoints SHOULD use an ERROR with ErrorCode 0 ("Not defined") for extension processing failures (e.g., unsupported critical TLV).

6. TLV Encoding and Processing

HMTFTP TLVs extend RRQ, WRQ, and OACK. TLVs use a compact binary encoding:

Field	Size	Description
Type	16 bits	Type code with Critical bit in MSB
Length	16 bits	Length of Value in octets
Value	variable	Type-specific data

Table 1: TLV Format

The most significant bit (MSB) of the Type field is the Critical bit. Bits 0-14 form the 15-bit TLV code. The Critical bit is not part of the code space recorded by IANA.

Processing rules:

- * A receiver MUST ignore unknown TLVs with Critical=0.
- * A receiver that encounters an unknown TLV with Critical=1 MUST reject the message by sending an ERROR (and MUST NOT proceed with the transfer).
- * A receiver MAY accept known TLVs in any order. If a TLV appears multiple times, a receiver SHOULD treat this as an error unless the TLV definition explicitly allows repetition.

7. Defined TLVs

This specification defines the following TLVs. All multi-octet values are encoded in network byte order (big-endian).

Code	Name	Length	Description
0x0001	BLKSIZE	2	Requested maximum DATA payload size in octets (uint16). If offered by a client, the server MUST respond with BLKSIZE in OACK with the selected value, which MUST be less than or equal to the requested value.
0x0002	TIMEOUT	2	Requested retransmission timeout in seconds (uint16). If offered by a client, the server MUST respond with TIMEOUT in OACK with the selected value or reject the request.
0x0003	TSIZE	8	Transfer size in octets (uint64). In RRQ, a client MAY send TSIZE=0 to request that the server return the size. In WRQ, a client SHOULD send TSIZE with the size if known.
0x0010	ENC_REQ	0	Request to enable AEAD protection for DATA payloads (empty value). Clients that require security mode MUST set the Critical bit on ENC_REQ. Servers that accept security mode MUST echo ENC_REQ in OACK.
0x0011	CIPHER	2	Select ciphersuite (uint16). If omitted, the default ciphersuite is 0x0001 (AES-256-GCM).
0x0012	CNONCE	16	Client nonce (16 octets) generated by a CSPRNG. CNONCE MUST be present in RRQ/WRQ when ENC_REQ is present.
0x0013	SNONCE	16	Server nonce (16 octets) generated by a CSPRNG. SNONCE MUST be present in OACK when ENC_REQ is accepted.

Table 2: Defined TLVs

The ciphersuite value 0x0001 corresponds to AEAD AES-256-GCM.

8. Transfer Procedure

HMTFTP uses the following procedure, aligned with TFTP option negotiation [RFC2347] :

1. The client sends RRQ or WRQ, optionally with TLVs.
2. If the server accepts the request and any offered parameters, it replies with OACK containing the negotiated TLVs (which MAY be empty). If the server does not support a critical TLV or rejects parameters, it replies with ERROR.
3. For RRQ: the client sends ACK(0) after receiving OACK, then the server starts with DATA(1).
4. For WRQ: the client starts with DATA(1) after receiving OACK, and the server acknowledges each block with ACK(n).

Apart from the OACK exchange, block numbering, retransmissions, and EOF signaling follow [RFC1350].

9. Optional AEAD Security Mode

Security mode is negotiated using TLVs in RRQ/WRQ and OACK. When enabled, each DATA payload is protected with AEAD AES-256-GCM [RFC5116]. The AEAD key and IV base are derived using HKDF-SHA-256 [RFC5869].

9.1. Negotiation TLVs

The client requests security mode by including TLV ENC_REQ in RRQ/WRQ. When ENC_REQ is present, the client MUST include CNONCE and MAY include CIPHER. If the server accepts, it includes ENC_REQ and SNONCE in OACK and MAY include (or echo) CIPHER. If the server does not support security mode, it MUST reject a Critical ENC_REQ with ERROR.

9.2. Key Derivation

This document assumes an externally provisioned PSK (32 octets RECOMMENDED). During negotiation, the client and server exchange nonces: CNONCE and SNONCE, each 16 octets from a CSPRNG.

The AEAD key material is derived as follows:

- * IKM = PSK
- * salt = CNONCE || SNONCE (32 octets)


```
* info = "hmtftp keys v1"

* OKM = HKDF-SHA-256(IKM, salt, info, 44)

* key = OKM[0..31] (32 octets)

* iv_base = OKM[32..43] (12 octets)
```

The HKDF "info" string is a protocol constant. Implementations MUST use the exact value "hmtftp keys v1" to ensure interoperability across document revisions.

9.3. Nonce Construction and AAD

The AES-GCM nonce (12 octets) for DATA block number `_n_` is:

```
nonce = iv_base[0..7] || uint32(n)
```

where `uint32(n)` is the 32-bit big-endian encoding of the DATA block number (`n` is the 16-bit Block field widened to 32 bits).

The AEAD AAD is the 4-octet DATA header (OpCode || Block). RRQ/WRQ/OACK metadata and TLVs are not encrypted and are not included in the DATA AAD in v0.3.

Retransmissions MUST retransmit the exact same ciphertext and tag for a given block number (key, nonce).

9.4. Limits

To avoid nonce reuse, endpoints MUST NOT allow the 16-bit block number to wrap within a security context. Implementations SHOULD terminate a transfer with ERROR well before wrap if it would be reached.

10. Compatibility and TLV Governance

This section clarifies how HMTFTP remains interoperable with the operational model of TFTP while enabling extensions through TLVs. It also specifies governance rules intended to keep extensions safe, deterministic, and implementable on constrained devices.

10.1. Compatibility Profile

HMTFTP reuses the TFTP message types (RRQ, WRQ, DATA, ACK, ERROR) and the OACK concept from the TFTP option extension. Implementations MUST follow the state machine of TFTP for block numbering, retransmissions, and EOF detection, except where explicitly modified by this document.

When a peer does not send or accept TLVs, endpoints MUST fall back to baseline TFTP behavior as described in [RFC1350] and MUST NOT assume that security mode is available. A client that requires security mode MUST mark ENC_REQ as Critical so that servers that do not support it reject the request rather than silently downgrading.

10.2. TLV Code Point Governance

The TLV Type field is 16 bits on the wire. The most significant bit is the Critical bit; the remaining 15 bits are the TLV Code. New TLVs MUST be specified with clear semantics, encoding, processing rules, and interoperability expectations.

To reduce collision risks, this document reserves the TLV Code range 0x7F00-0x7FFF for Private Use. Implementations MAY use Private Use TLVs in controlled environments, but such TLVs MUST NOT be used as inputs to cryptographic processing and MUST be ignored by receivers unless explicitly configured.

Unknown TLVs with Critical=0 MUST be ignored. Unknown TLVs with Critical=1 MUST cause the request to be rejected with ERROR. This rule is the primary downgrade and interoperability safety mechanism for this specification.

11. IANA Considerations

This document requests IANA actions as described in [RFC8126].

The default UDP port is indicated as TBD1; any future assignment follows the IANA procedures for service name and transport protocol port numbers [RFC6335].

This document also defines a TLV code point space and includes guidance for private use ranges; future allocation of TLV code points may require IANA registry actions.

12. Security Considerations

Without security mode, HMTFTP provides no confidentiality or integrity beyond UDP checksums and is vulnerable to on-path modification and spoofing, as with TFTP [RFC1350].

With security mode enabled, only DATA payloads are encrypted and authenticated. RRQ/WRQ/OACK metadata and TLVs remain in cleartext. This means filenames, modes, and negotiated parameters are observable on the wire. Deployments that require metadata confidentiality MUST avoid placing sensitive data in RRQ/WRQ/OACK and SHOULD use an external secure channel or a future extension that encrypts metadata.

Nonce reuse with AES-GCM is catastrophic. Implementations MUST enforce nonce uniqueness and MUST follow the nonce construction and wrap limits described in Section 9.

Implementations should also consider UDP robustness guidelines ([RFC8085]) and rate-limiting to mitigate amplification and resource-exhaustion attacks.

13. Implementation Status

This section is provided for RFC 7942 compliance ([RFC7942]). Implementations, interop notes, and known limitations will be added in subsequent versions.

14. References

14.1. Normative References

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14.2. Informative References

- [RFC7942] Bormann, C., "Improving Awareness of Running Code: The Implementation Status Section", RFC 7942, July 2016,
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