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EVM Session Intent for HTTP Payment Authentication

Abstract

This document defines the "evm" payment method implementation of the "session" intent for the Payment HTTP Authentication Scheme. It specifies unidirectional streaming payment channels for incremental, voucher-based payments on any EVM-compatible blockchain, suitable for metered services such as LLM inference.

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1. Introduction

This document is published as Informational but contains normative requirements using BCP 14 keywords [[RFC2119](#)] [[RFC8174](#)] to ensure interoperability between implementations.

This document defines the "evm" payment method implementation of the "session" intent registered by [[I-D.payment-intent-session](#)].

The session intent establishes a unidirectional streaming payment channel using on-chain escrow and off-chain [[EIP-712](#)] vouchers. This enables high-frequency, low-cost payments by batching many off-chain voucher signatures into periodic on-chain settlements.

Unlike the charge intent which requires the full payment amount upfront, the session intent allows clients to pay incrementally as they consume services, paying exactly for resources received.

This specification adapts the streaming payment channel mechanism defined in [I-D.temp-session]: on-chain escrow holds deposited funds; the client signs cumulative EIP-712 vouchers authorizing increasing payment amounts off-chain; the server settles periodically or at session close. This document extends the mechanism for any EVM-compatible chain, with EVM-specific transaction formats, gas models, and domain separators.

1.1. Use Case: LLM Token Streaming

Consider an LLM inference API that charges per output token:

1. Client requests a streaming completion (SSE response)
2. Server returns 402 with a session challenge
3. Client opens a payment channel on-chain, depositing funds
4. Server begins streaming response
5. As response streams, or over incremental requests, client signs vouchers with increasing amounts
6. Server settles periodically or at stream completion

The client pays exactly for tokens received, with no worst-case reservation.

2. Requirements Language

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

3. Terminology

Streaming Payment Channel A unidirectional off-chain payment mechanism where the payer deposits funds into an escrow contract and signs cumulative vouchers authorizing increasing amounts.

Voucher An [EIP-712] signed message authorizing a cumulative payment amount for a specific channel. Vouchers are monotonically increasing in amount.

Channel A payment relationship between a payer and payee, identified by a unique channelId. The channel holds deposited funds and tracks cumulative settlements.

Settlement The on-chain [ERC-20] transfer that converts off-chain voucher authorizations into actual token movement.

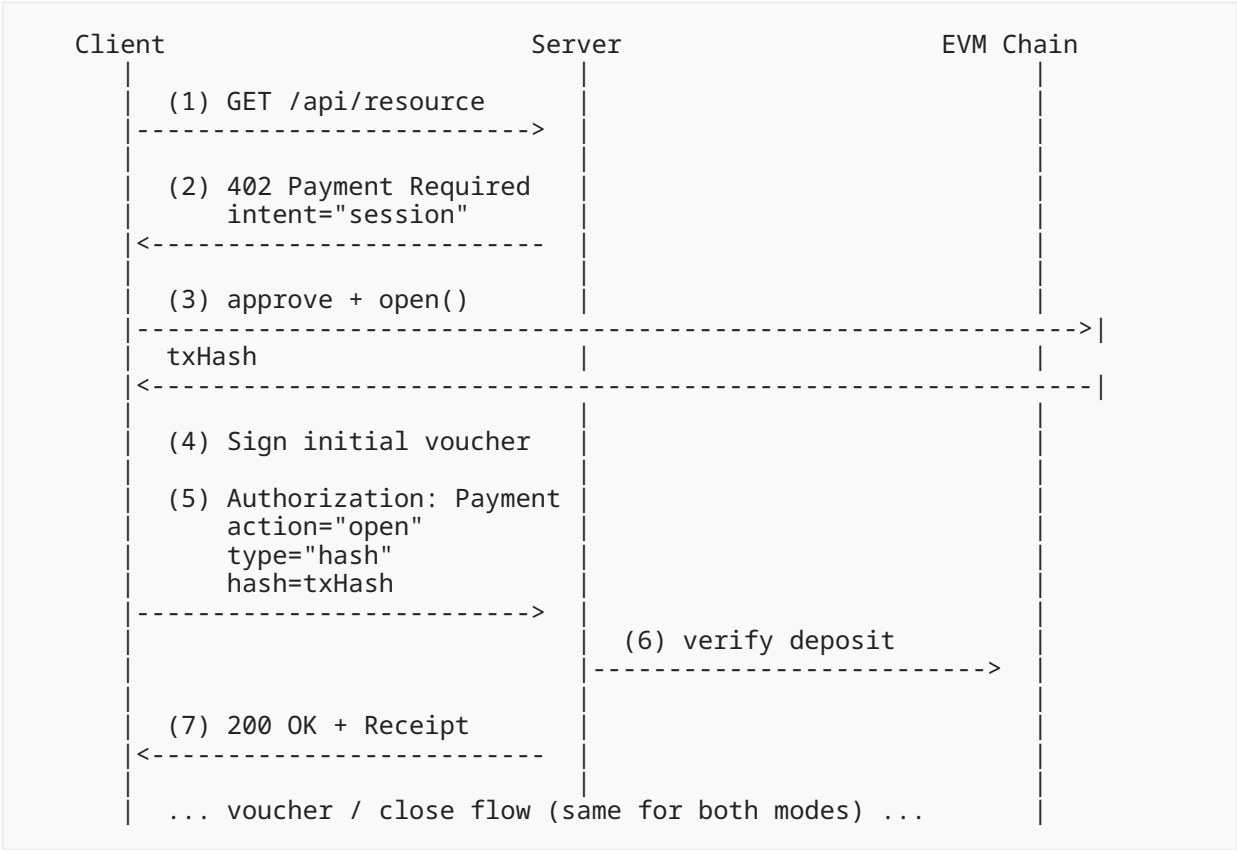
Authorized Signer An address delegated to sign vouchers on behalf of the payer. Defaults to the payer if not specified. In this specification, voucher signatures are verified either as ECDSA secp256k1 signatures (for EOA signers) or via ERC-1271 isValidSignature (for smart-contract wallets such as Safe or ERC-4337 accounts). The authorizedSigner field **MAY** be an EOA or an ERC-1271-compliant contract wallet.

Base Units The smallest indivisible unit of an ERC-20 token, determined by the token's decimal precision. For example, USDC (6 decimals) uses 1,000,000 base units per 1 USDC.

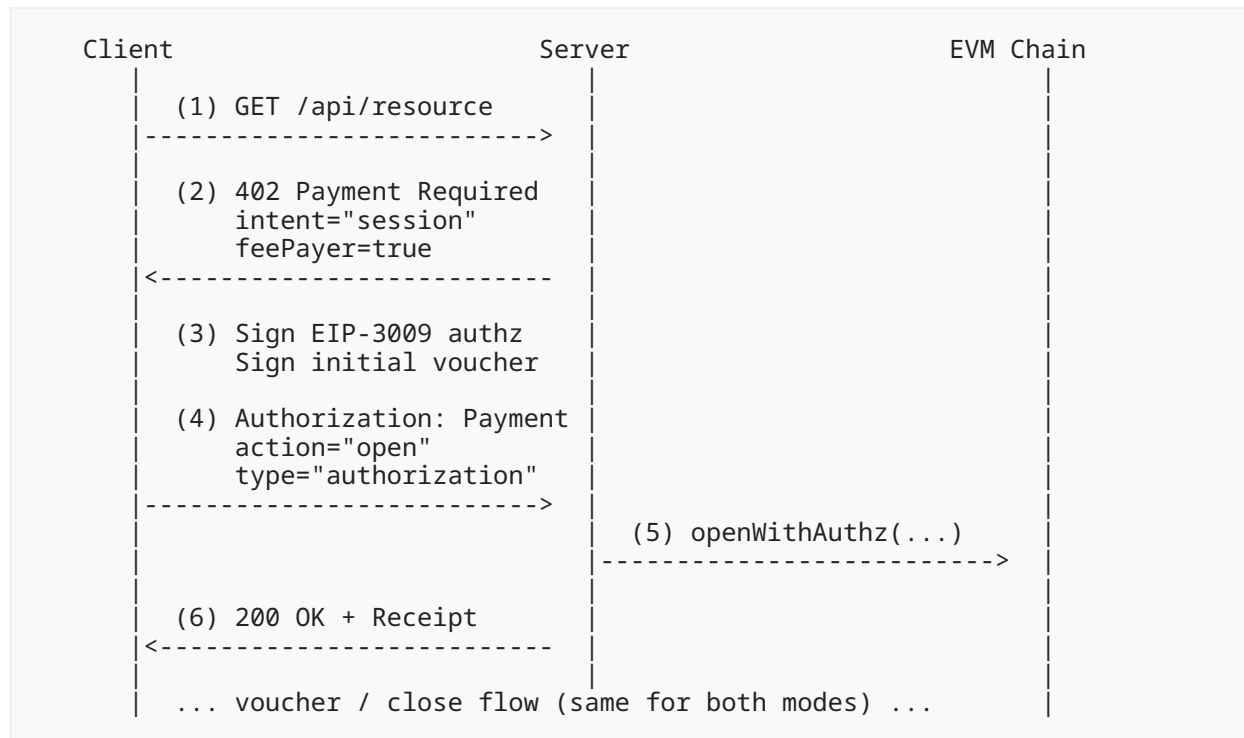
4. Session Flow

The following diagrams illustrate the two open modes.

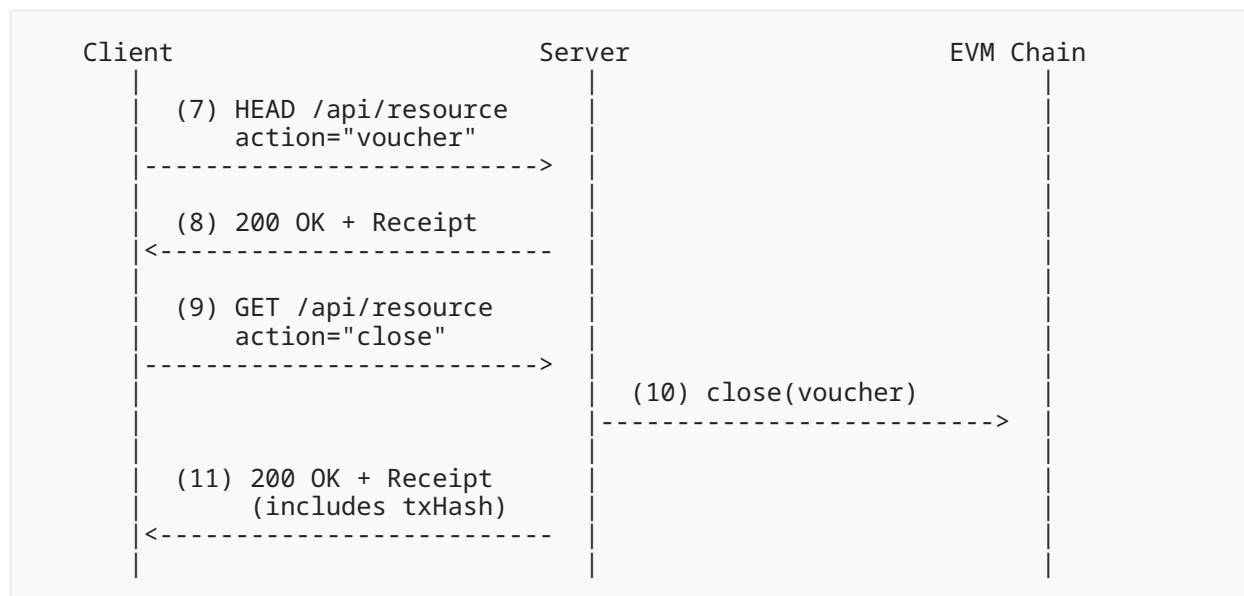
Client-broadcast open (feePayer: false):



Server-submitted open (feePayer: true):



Voucher and close flow (common to both modes):



Voucher updates and close requests are submitted to the **same resource URI** that requires payment. Servers **SHOULD** support voucher updates via any HTTP method [\[RFC9110\]](#); clients **MAY** use HEAD for pure voucher top-ups when no response body is needed.

5. Concurrency Model

A channel supports one active session at a time. The cumulative voucher semantics ensure correctness — each voucher advances a single monotonic counter. The channel is the unit of concurrency; no additional session locking is required.

When a client sends a new streaming request on a channel that already has an active session, servers **SHOULD** terminate the previous session and start a new one. Voucher updates **MAY** arrive on separate HTTP connections (including HTTP/2 streams) and **MUST** be processed atomically with respect to balance updates.

Servers **MUST** ensure that voucher acceptance and balance deduction are serialized per channel to prevent race conditions.

6. Encoding Conventions

This section defines normative encoding rules for interoperability.

6.1. Hexadecimal Values

All byte arrays (addresses, hashes, signatures, channelId) use:

- Lowercase hexadecimal encoding
- 0x prefix
- No padding or truncation

Type	Length	Example
address	42 chars (0x + 40 hex)	0x742d35cc6634c0532925a3b844bc9e7595f8fe00
bytes32	66 chars (0x + 64 hex)	0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f
signature (bytes)	132 chars (0x + 130 hex)	65-byte ECDSA signature

Table 1

All signatures in this specification are 65 bytes, encoded as `r (32 bytes) || s (32 bytes) || v (1 byte)` and passed as a single bytes parameter. Implementations **MUST NOT** produce EIP-2098 compact 64-byte signatures [EIP-2098]. Implementations **MAY** accept them (e.g., when using a standard signature-verification library such as OpenZeppelin SignatureChecker that transparently handles both formats), but **MUST NOT** require clients to produce them.

Implementations **MUST** use lowercase hex for channelId, signatures, and hashes. Address fields in the request schema (currency, recipient, escrowContract) **SHOULD** use [EIP-55] mixed-case encoding for display but **MUST** be compared by decoded 20-byte value, not string form.

6.2. Numeric Values

Integer values (amounts, timestamps) are encoded as decimal strings in JSON to avoid precision loss with large numbers:

Field	Encoding	Example	Rationale
cumulativeAmount	Decimal string	"250000"	May exceed Number.MAX_SAFE_INTEGER
validAfter, validBefore	Decimal string	"1743523500"	uint256 on-chain; string for consistency
chainId	JSON number	196	Small values; no precision risk

Table 2

The chainId uses JSON number encoding because EVM chain IDs are small enough to avoid precision issues. All other large integers use decimal strings. In EIP-712 typed data, chainId is a uint256 — implementations **MUST** convert the JSON number to uint256 when constructing the domain separator.

6.3. Timestamp Format

HTTP headers and receipt fields use [RFC3339] formatted timestamps. Timestamps in EIP-712 signed data use Unix seconds as decimal strings.

7. Channel Escrow Contract

Streaming payment channels require an on-chain escrow contract that holds user deposits and enforces voucher-based withdrawals.

The escrow's deposit accounting assumes the currency token transfers exactly the requested amount. Implementations **MUST** restrict the escrow to well-behaved ERC-20 tokens and **MUST NOT** use it with fee-on-transfer or rebasing tokens: those would make channel.deposit over-record the balance actually held, letting a payee settle more than was escrowed.

7.1. Channel State

Each channel is identified by a unique `channelId` and stores:

Field	Type	Description
<code>payer</code>	<code>address</code>	User who deposited funds
<code>payee</code>	<code>address</code>	Server authorized to withdraw
<code>token</code>	<code>address</code>	[ERC-20] token address
<code>authorizedSigner</code>	<code>address</code>	Authorized signer (0 = payer)
<code>deposit</code>	<code>uint128</code>	Total amount deposited
<code>settled</code>	<code>uint128</code>	Cumulative amount already withdrawn by payee
<code>closeRequestedAt</code>	<code>uint64</code>	Timestamp when close was requested (0 if not)
<code>finalized</code>	<code>bool</code>	Whether channel is closed. Sticky: set once and never cleared; the record is never deleted (see Section 15.2)

Table 3

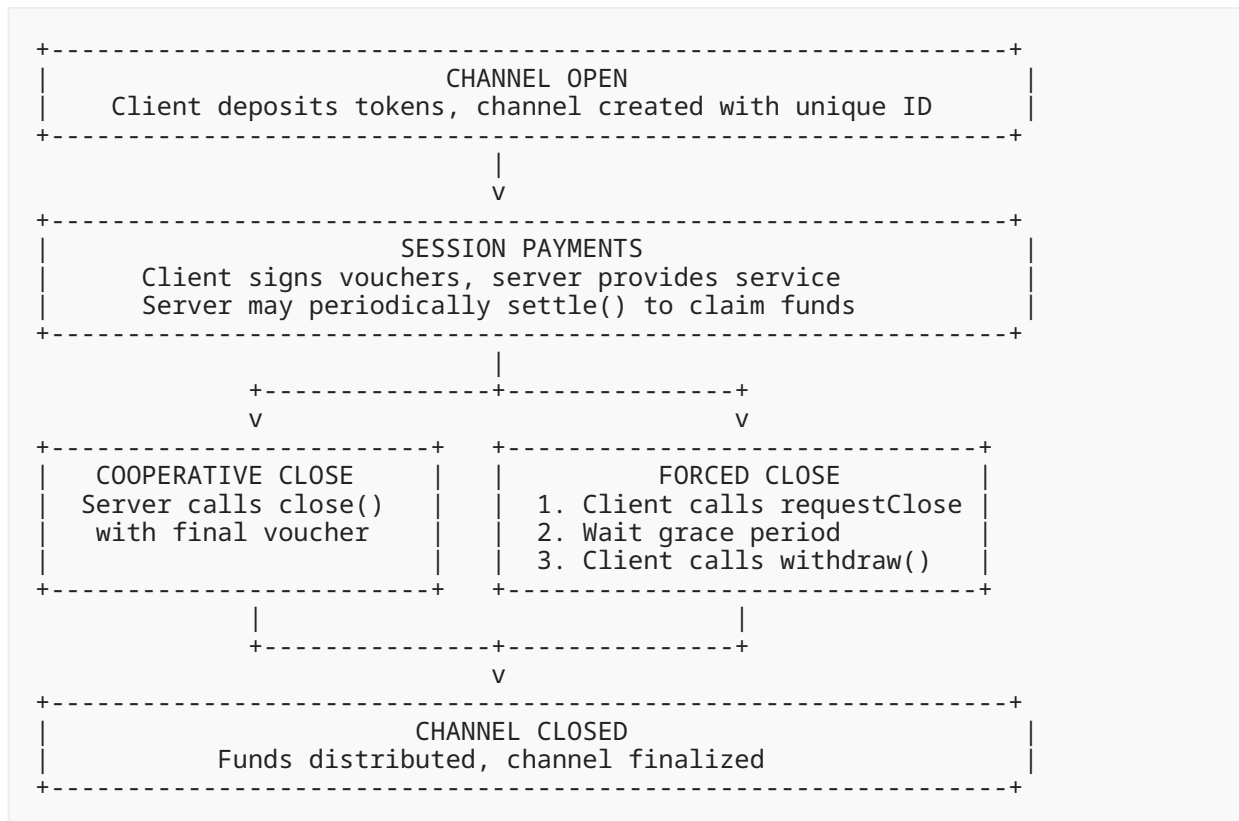
The `channelId` **MUST** be computed deterministically using the escrow contract's `computeChannelId()` function or equivalent logic:

```
channelId = keccak256(abi.encode(  
    payer,  
    payee,  
    token,  
    salt,  
    authorizedSigner,  
    address(this),  
    block.chainid  
))
```

Note: The `channelId` includes `address(this)` (the escrow contract address) and `block.chainid`, explicitly binding the channel to a specific contract deployment and chain. This computation is identical to the Tempo escrow specification. For the relayed open functions (`openWithAuthorization`, `openWithPermit2`), `payer` in this computation is the `from` argument (the depositor), not the relayer that submits the transaction.

7.2. Channel Lifecycle

Channels have no expiry — they remain open until explicitly closed.



7.3. Contract Functions

The escrow surface is split into a **mandatory core** that every compliant contract **MUST** implement, and an **optional Relayed / Gasless Operations profile** ([Section 9.4](#)) that an implementation **MAY** omit in whole.

Mandatory core:

- `open`, `settle`, `topUp`, `close`, `requestClose`, `withdraw`

Optional Relayed / Gasless Operations profile ([Section 9.4](#)):

- Payer-funded via EIP-3009, relayer-submitted: `openWithAuthorization`, `topUpWithAuthorization`
- Payer-funded via Permit2, relayer-submitted: `openWithPermit2`, `topUpWithPermit2`
- Payee-initiated via EIP-712 payee authorization, relayer-submitted: `settleWithAuthorization`, `closeWithAuthorization`

The two payer-funded paths are alternatives, not both required: EIP-3009 suits tokens that ship `receiveWithAuthorization` (e.g. USDC), while Permit2 covers any ERC-20 the payer has approved to the Permit2 contract. An implementation **MAY** offer either or both.

All six relayed functions share one shape: an off-chain authorization (EIP-3009 or Permit2 from the payer, or an EIP-712 payee authorization from the seller) plus submission by any relay that pays gas. An implementation **MAY** support any subset, but a server **MUST NOT** advertise a capability (`feePayer: true`, or `relayed settle/close`) whose underlying function its escrow does not implement. Each function below that belongs to the profile is tagged accordingly; all others are mandatory.

7.3.1. open

Opens a new channel with escrowed funds. The caller becomes the payer. Requires prior `approve(escrow, deposit)` on the ERC-20 token; the contract pulls funds via `transferFrom`. The contract **MUST** revert if a channel with the computed `channelId` already exists.

Channel records **MUST** be retained permanently: the `finalized` flag is sticky (set once at `close/withdraw` and never cleared) and the channel record **MUST NOT** be deleted. Because `channelId` is derived only from stable inputs (`payer`, `payee`, `token`, `salt`, `authorizedSigner`, `contract`, `chain`) with no epoch component, deleting a finalized record would let the same inputs re-derive an identical `channelId` and EIP-712 voucher digest, replaying old-epoch vouchers against a freshly funded channel. Retaining the record makes the "already exists" check above reject any re-open. See [Section 15.2](#).

Parameter	Type	Description
<code>payee</code>	<code>address</code>	Server's address authorized to withdraw
<code>token</code>	<code>address</code>	ERC-20 token contract address
<code>deposit</code>	<code>uint128</code>	Amount to deposit in base units
<code>salt</code>	<code>bytes32</code>	Random value for <code>channelId</code> computation
<code>authorizedSigner</code>	<code>address</code>	Delegated signer; <code>address(0)</code> = payer

Table 4

```
function open(
    address payee,
    address token,
    uint128 deposit,
    bytes32 salt,
    address authorizedSigner
) external returns (bytes32 channelId);
```

7.3.2. openWithAuthorization

Part of the optional *Relayed / Gasless Operations* profile ([Section 9.4](#)).

Opens a channel using EIP-3009 [EIP-3009] authorization. The server (or any relay) submits the transaction, pulling funds from the payer via `receiveWithAuthorization` inside the contract.

Note: The escrow contract **MUST** use `receiveWithAuthorization` (not `transferWithAuthorization`) to pull funds from the token. `receiveWithAuthorization` enforces `msg.sender == to`, preventing front-running attacks where an attacker extracts the EIP-3009 signature from the mempool and calls the token directly (see [Section 15.13](#)). This specification targets tokens that support the USDC v2.2 `bytes` signature overload of `receiveWithAuthorization` and calls it directly with the packed 65-byte signature. Tokens that only expose the canonical (`uint8 v`, `bytes32 r`, `bytes32 s`) interface are NOT supported by this escrow design.

Parameter	Type	Description
payee	address	Server's address
token	address	ERC-20 token contract
deposit	uint128	Amount to deposit
salt	bytes32	Random value
authorizedSigner	address	Delegated signer; <code>address(0)</code> = payer
from	address	Payer address (EIP-3009 from)
validAfter	uint256	EIP-3009 validity start
validBefore	uint256	EIP-3009 validity end
nonce	bytes32	EIP-3009 nonce; MUST equal the value derived per Section 15.13
signature	bytes	Packed EIP-3009 authorization signature (65 bytes)

Table 5

```
function openWithAuthorization(
    address payee,
    address token,
    uint128 deposit,
    bytes32 salt,
    address authorizedSigner,
    address from,
    uint256 validAfter,
    uint256 validBefore,
    bytes32 nonce,
    bytes calldata signature
) external returns (bytes32 channelId);
```

The nonce parameter is supplied by the caller for transparency, but the contract **MUST** recompute the expected nonce as `keccak256(abi.encode(from, payee, token, salt, authorizedSigner))` and revert if the supplied value does not match. Compliant implementations **SHOULD** revert with a dedicated error such as `NonceMismatch()` so callers can distinguish this failure mode. See [Section 15.13](#) for the threat model.

7.3.3. `openWithPermit2`

Part of the optional Relayed / Gasless Operations profile ([Section 9.4](#)).

Opens a channel using [\[Permit2\]](#) `SignatureTransfer` with a witness. The server (or any relayer) submits the transaction, pulling funds from the payer via the canonical Permit2 contract. This path supports any ERC-20 token that the payer has previously approved for the Permit2 contract (typically a one-time, unlimited approval).

Note: The escrow contract **MUST** use `permitWitnessTransferFrom` (not `permitTransferFrom`) to bind the channel intent (`payee`, `salt`, `authorizedSigner`) into the EIP-712 signature as a named witness struct. This serves two purposes: (1) wallets that render EIP-712 typed data display the channel parameters as labeled fields at signing time, instead of leaving them to be hashed opaquely into the nonce; (2) the contract enforces channel-parameter integrity via the Permit2 signature itself, so an attacker cannot front-run with a different payee. The Permit2 spender is fixed to `msg.sender` by the contract, so only the escrow can spend the signature.

Parameter	Type	Description
<code>payee</code>	address	Server's address
<code>token</code>	address	ERC-20 token contract
<code>deposit</code>	uint128	Amount to deposit
<code>salt</code>	bytes32	Random value
<code>authorizedSigner</code>	address	Delegated signer; <code>address(0)</code> = payer
<code>from</code>	address	Payer address (Permit2 owner)
<code>nonce</code>	uint256	Permit2 nonce (any unused value; bitmap-based replay protection)
<code>deadline</code>	uint256	Permit2 signature deadline (Unix seconds)
<code>signature</code>	bytes	Permit2 EIP-712 signature (65 bytes)

Table 6

```
function openWithPermit2(
    address payee,
    address token,
    uint128 deposit,
    bytes32 salt,
    address authorizedSigner,
    address from,
    uint256 nonce,
    uint256 deadline,
    bytes calldata signature
) external returns (bytes32 channelId);
```

The escrow contract **MUST** construct the Permit2 `PermitTransferFrom` struct, `SignatureTransferDetails`, and the `ChannelOpenWitness` witness struct from these parameters with `permitted.token = token`, `permitted.amount = deposit`, `transferDetails.to = address(this)`, `transferDetails.requestedAmount = deposit`, and witness fields (`payee`, `salt`, `authorizedSigner`). It then computes `witnessHash = keccak256(abi.encode(CHANNEL_OPEN_WITNESS_TYPEHASH, payee, salt, authorizedSigner))` and calls `IPermit2(PERMIT2).permitWitnessTransferFrom(permit, transferDetails, from, witnessHash, WITNESS_TYPE_STRING, signature)` on the canonical Permit2 deployment. If the payer signed a different `payee`, `salt`, or `authorizedSigner` than the function arguments, the Permit2 signature verification reverts.

7.3.4. settle

Server withdraws funds using a signed voucher without closing the channel. The contract **MUST** revert if `msg.sender != channel.payee`.

Parameter	Type	Description
<code>channelId</code>	<code>bytes32</code>	Unique channel identifier
<code>cumulativeAmount</code>	<code>uint128</code>	Cumulative total authorized
<code>signature</code>	<code>bytes</code>	EIP-712 signature from authorized signer

Table 7

The contract **MUST** revert (e.g., with `AmountNotIncreasing()`) if `cumulativeAmount <= channel.settled`, and (e.g., with `AmountExceedsDeposit()`) if `cumulativeAmount > channel.deposit`; only a strictly increasing cumulative amount within the deposited balance advances settlement. Otherwise the contract computes `delta = cumulativeAmount - channel.settled`, sets `channel.settled = cumulativeAmount`, and transfers `delta` to the payee. This on-chain check is the last line of defense for the rollback prevention described in [Section 15.5](#); a server-side check alone does not constrain a payee calling the contract directly.

```
function settle(
    bytes32 channelId,
    uint128 cumulativeAmount,
    bytes calldata signature
) external;
```

7.3.5. topUp

User adds more funds to an existing channel. Requires prior `approve(escrow, additionalDeposit)`. The contract **MUST** revert if `msg.sender != channel.payer`. If a close request is pending (`channel.closeRequestedAt != 0`), calling `topUp()` **MUST** reset `closeRequestedAt` to 0, cancelling the pending close.

Parameter	Type	Description
channelId	bytes32	Existing channel identifier
additionalDeposit	uint128	Additional amount in base units

Table 8

```
function topUp(
    bytes32 channelId,
    uint128 additionalDeposit
) external;
```

7.3.6. topUpWithAuthorization

Part of the optional *Relayed / Gasless Operations* profile ([Section 9.4](#)).

Adds funds using EIP-3009 authorization. The server calls this on behalf of the payer.

Parameter	Type	Description
channelId	bytes32	Existing channel identifier
additionalDeposit	uint128	Additional amount
from	address	Payer address
topUpSalt	bytes32	Random value for nonce derivation
validAfter	uint256	EIP-3009 validity start
validBefore	uint256	EIP-3009 validity end
nonce	bytes32	EIP-3009 nonce; MUST equal the value derived per Section 15.13

Parameter	Type	Description
signature	bytes	Packed EIP-3009 authorization signature (65 bytes)

Table 9

```
function topUpWithAuthorization(
    bytes32 channelId,
    uint128 additionalDeposit,
    address from,
    bytes32 topUpSalt,
    uint256 validAfter,
    uint256 validBefore,
    bytes32 nonce,
    bytes calldata signature
) external;
```

As with `openWithAuthorization`, the contract **MUST** recompute the expected nonce as `keccak256(abi.encode(channelId, additionalDeposit, from, topUpSalt))` and revert (e.g., with `NonceMismatch()`) if the supplied nonce does not match. Clients **MUST** use the same derivation when signing.

7.3.7. topUpWithPermit2

Part of the optional *Relayed / Gasless Operations* profile ([Section 9.4](#)).

Adds funds using [\[Permit2\]](#) `SignatureTransfer` with a witness. Mirrors `openWithPermit2` for an existing channel. The escrow **MUST** call `permitWitnessTransferFrom` with a `ChannelTopUpWitness` binding `channelId`, so the payer's wallet shows the target channel and the contract enforces that the signature cannot be redirected to a different channel. Unlike the EIP-3009 path, no `topUpSalt` is required: Permit2's unordered nonce already provides replay protection for repeated top-ups, and `channelId` alone binds the deposit to the channel. Because this function takes no token argument, the escrow sets `permitted.token = channel.token` from the existing channel record when reconstructing the Permit2 permit.

Parameter	Type	Description
channelId	bytes32	Existing channel identifier
additionalDeposit	uint128	Additional amount
from	address	Payer address
nonce	uint256	Permit2 nonce (any unused value; bitmap-based replay protection)
deadline	uint256	Permit2 signature deadline (Unix seconds)

Parameter	Type	Description
signature	bytes	Permit2 EIP-712 signature (65 bytes)

Table 10

```
function topUpWithPermit2(
    bytes32 channelId,
    uint128 additionalDeposit,
    address from,
    uint256 nonce,
    uint256 deadline,
    bytes calldata signature
) external;
```

7.3.8. close

Server closes the channel, settling outstanding voucher and refunding remainder to payer. The contract **MUST** revert if `msg.sender != channel.payee`.

If `cumulativeAmount <= channel.settled`, the payee is forfeiting any uncollected amount (e.g., to cleanly close an exhausted or abandoned channel). In this case the contract **MAY** skip voucher signature verification and signature **MAY** be empty.

Parameter	Type	Description
channelId	bytes32	Channel to close
cumulativeAmount	uint128	Final cumulative amount
signature	bytes	EIP-712 voucher signature; MAY be empty when <code>cumulativeAmount <= channel.settled</code> (forfeit path)

Table 11

```
function close(
    bytes32 channelId,
    uint128 cumulativeAmount,
    bytes calldata signature
) external;
```

7.3.9. requestClose

User requests channel closure, starting a grace period. The contract **MUST** revert if `msg.sender != channel.payer`, if no channel exists for `channelId`, or if the channel is already finalized.

Parameter	Type	Description
channelId	bytes32	Channel to request closure

Table 12

```
function requestClose(bytes32 channelId) external;
```

7.3.10. withdraw

User withdraws the unsettled remainder after the forced-close grace period expires. The contract **MUST** revert if `msg.sender != channel.payer`, if the channel is already finalized, if no close has been requested (`channel.closeRequestedAt == 0`), or if the grace period has not elapsed (`block.timestamp < channel.closeRequestedAt + CLOSE_GRACE_PERIOD`). On success it transfers `channel.deposit - channel.settled` to the payer and sets `finalized` atomically with the payout.

The `closeRequestedAt == 0` check is essential: without it, `block.timestamp >= 0 + CLOSE_GRACE_PERIOD` is trivially true, so a payer could call `withdraw` without ever calling `requestClose`, draining the channel before the payee settles outstanding vouchers and bypassing the grace period entirely. The `finalized` check prevents a second payout (a cooperative close followed by `requestClose + withdraw`) from drawing on the contract's pooled balance.

Parameter	Type	Description
channelId	bytes32	Channel to withdraw from

Table 13

```
function withdraw(bytes32 channelId) external;
```

7.4. Access Control

Function	Caller	Description
open	Anyone	Creates channel; caller becomes payer
openWithAuthorization	Anyone (typically server)	Creates channel via EIP-3009; from becomes payer
openWithPermit2	Anyone (typically server)	Creates channel via Permit2 SignatureTransfer; from becomes payer

Function	Caller	Description
settle	Payee only	Withdraws funds using voucher
topUp	Payer only	Adds funds (approve + pull)
topUpWithAuthorization	Anyone (typically server)	Adds funds via EIP-3009; no caller restriction because the EIP-3009 signature provides authorization
topUpWithPermit2	Anyone (typically server)	Adds funds via Permit2; no caller restriction because the Permit2 signature provides authorization
close	Payee only	Closes with final voucher
settleWithAuthorization	Anyone (typically relayer)	Settles via payee EIP-712 authorization; payee signature, not msg.sender, authorizes
closeWithAuthorization	Anyone (typically relayer)	Closes via payee EIP-712 authorization; payee signature, not msg.sender, authorizes
requestClose	Payer only	Initiates forced close
withdraw	Payer only	Withdraws after grace period

Table 14

7.5. Signature Verification

The escrow contract **MUST** perform the following verification for all functions that accept voucher signatures (settle, close):

1. **Canonical signatures:** The contract **MUST** reject ECDSA signatures with non-canonical (high- s) values. Signatures **MUST** have $s \leq \text{secp256k1_order} / 2$ where the half-order is `0x7FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF5D576E7357A4501DDFE92F46681B20A0`. See [Section 15.9](#) for rationale.
2. **Authorized signer verification:** The contract **MUST** recover the signer address from the EIP-712 signature and verify it matches:
 - `channel.authorizedSigner` if non-zero
 - Otherwise `channel.payer` The signer may be an EOA (verified via ECDSA) or an ERC-1271 contract wallet (verified via `isValidSignature`).
3. **Domain binding:** The contract **MUST** use its own address as `verifyingContract` in the EIP-712 domain separator, ensuring vouchers cannot be replayed across different escrow deployments.

Failure to enforce these requirements on-chain would allow attackers to bypass server-side validation by submitting transactions directly to the contract.

7.6. Contract Errors

This subsection is informative. The normative requirement is that the escrow reverts under each condition below, as stated in the relevant function and security sections; the error names are a **RECOMMENDED** common vocabulary for implementers, tooling, and diagnostics.

Implementations **MAY** use different names or revert representations. On-the-wire, a reverted transaction is reported to clients as the transaction-reverted problem type ([Section 12.7](#)), not as a raw Solidity selector.

Suggested error	Revert condition	Functions
ChannelAlreadyExists	A channel with the computed channelId already exists, including a finalized one (Section 15.2)	open, openWithAuthorization, openWithPermit2
ChannelNotFound	No channel for the given channelId	settle, topUp*, close*, requestClose, withdraw
ChannelFinalized	Channel is already finalized	settle, topUp*, close*, requestClose, withdraw
NotPayee	msg.sender != channel.payee	settle, close
NotPayer	msg.sender != channel.payer	topUp, requestClose, withdraw
AmountNotIncreasing	cumulativeAmount <= channel.settled on a non-forfeit path (Section 15.5)	settle*, close*
AmountExceedsDeposit	cumulativeAmount > channel.deposit	settle*, close*
InvalidSignature	Voucher or payee signature fails recovery, signer mismatch, or non-canonical high-s (Section 7.5)	settle*, close*
NonceMismatch	Supplied EIP-3009 nonce != value derived from channel parameters (Section 15.13)	openWithAuthorization, topUpWithAuthorization

Suggested error	Revert condition	Functions
NonceAlreadyUsed	(channel.payee, channelId, nonce) already consumed (Section 9.4.2)	settleWithAuthorization, closeWithAuthorization
AuthorizationExpired	block.timestamp > deadline on a payee authorization (Section 9.4.2)	settleWithAuthorization, closeWithAuthorization
CloseNotReady	withdraw called with no pending close (closeRequestedAt == 0) or before the close grace period elapsed	withdraw
ZeroDeposit	Deposit amount is 0	open*, topUp*
DepositOverflow	Deposit would exceed the uint128 bound	open*, topUp*

Table 15

In the table, a trailing * denotes the base function plus its WithAuthorization and WithPermit2 variants where they exist.

8. Request Schema

The request parameter in the WWW-Authenticate challenge contains a JSON [[RFC8259](#)] object, serialized using JCS [[RFC8785](#)] and then base64url-encoded [[RFC4648](#)].

8.1. Fields

Field	Type	Required	Description
amount	string	REQUIRED	Price per unit of service in base units (not total charge)
unitType	string	OPTIONAL	Unit being priced (e.g., "llm_token", "byte", "request")
suggestedDeposit	string	OPTIONAL	Suggested channel deposit amount in base units
currency	string	REQUIRED	ERC-20 token contract address (EIP-55 checksummed)
recipient	string	REQUIRED	Payee address (server's withdrawal address)

Field	Type	Required	Description
description	string	OPTIONAL	Human-readable payment description
externalId	string	OPTIONAL	Merchant's reference (order ID, invoice number, etc.)

Table 16

For the session intent, amount specifies the price per unit of service in base units, not a total charge. The total cost depends on consumption: $\text{total} = \text{amount} * \text{units_consumed}$.

8.2. Method Details

Field	Type	Required	Description
methodDetails.chainId	number	REQUIRED	EVM chain ID
methodDetails.escrowContract	string	REQUIRED	Address of the channel escrow contract
methodDetails.channelId	string	OPTIONAL	Channel ID if resuming an existing channel
methodDetails.minVoucherDelta	string	OPTIONAL	Minimum amount increase between vouchers (base units). Default: "0" (any positive increment accepted). See Section 15.8
methodDetails.feePayer	boolean	OPTIONAL	If true, server pays gas for open/topUp (default: false)
methodDetails.credentialTypes	array	OPTIONAL	Credential formats the server accepts, as an ordered list of top-level payload.type values. EVM session uses the shared EVM values "permit2", "authorization", and "hash"; it omits the charge-only full signed transaction path. Order expresses server preference

Field	Type	Required	Description
<code>methodDetails.permit2Contract</code>	string	OPTIONAL	Permit2 contract address used as the EIP-712 <code>verifyingContract</code> on the permit2 authorization path. Defaults to the canonical deterministic Permit2 deployment; REQUIRED when the target chain's Permit2 is not at the canonical address. The client MUST use this value (or the canonical default when omitted) as <code>verifyingContract</code> when signing, and it MUST match the escrow's configured Permit2 address

Table 17

Servers **MAY** advertise `credentialTypes` listing every credential format they accept for this challenge. The list uses the same ordered preference semantics as the EVM charge intent: clients select the first listed type they can produce unless local policy chooses otherwise, and **MUST NOT** submit a format absent from the list. If `credentialTypes` is omitted, it defaults to `["hash"]`.

When `feePayer` is `true`, servers that want clients to use a server-submitted open/topUp format **MUST** include at least one such type backed by the escrow (`openWithAuthorization` deployed $\Rightarrow$ include `"authorization"`; `openWithPermit2` deployed $\Rightarrow$ include `"permit2"`). They **MAY** also include `"hash"` as a client-broadcast fallback. This makes the supported paths discoverable in-band rather than relying on out-of-band documentation. A contract **MAY** additionally expose its relayed-path support on-chain (e.g. via an introspection view) for clients that verify the escrow directly, but the challenge field is the authoritative signal for the session flow.

Channel reuse is **OPTIONAL**. Servers **MAY** include `channelId` to suggest resuming an existing channel:

- **New channel** (no `channelId`): Client generates a random salt, computes `channelId` using the formula in [Section 7.1](#), opens the channel on-chain, and returns the `channelId` in the credential.
- **Existing channel** (`channelId` provided): Client **MUST** verify `channel.deposit - channel.settled >= amount` before resuming.

Example (new channel):

```
{
  "amount": "100",
  "unitType": "llm_token",
  "suggestedDeposit": "5000000",
  "currency": "0x74b7F16337b8972027F6196A17a631ac6dE26d22",
  "recipient": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
  "methodDetails": {
    "escrowContract": "0x1234567890abcdef1234567890abcdef12345678",
    "chainId": 196,
    "minVoucherDelta": "10000"
  }
}
```

This requests a price of 0.0001 USDC per LLM token on X Layer, with a suggested deposit of 5.00 USDC (approximately 50,000 tokens). The minVoucherDelta of 10,000 base units (0.01 USDC) means vouchers cover at least 100 tokens each.

Example (existing channel):

```
{
  "amount": "25",
  "unitType": "llm_token",
  "currency": "0xA8CE8aee21bC2A48a5EF670afCc9274C7bbbC035",
  "recipient": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
  "methodDetails": {
    "escrowContract": "0x1234567890abcdef1234567890abcdef12345678",
    "channelId":
"0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "chainId": 196
  }
}
```

9. Fee Payment

The `feePayer` field affects only the client-originated channel funding transactions (open and topUp). Settlement and close are always server-initiated and server-funded.

9.1. Server-Paid Fees (`feePayer: true`)

When `feePayer: true`, the client submits a token-pull authorization signature instead of broadcasting an on-chain transaction. The server submits the on-chain transaction and pays gas from its own balance.

This specification supports two authorization formats, distinguished by the credential's top-level `payload.type`:

- **EIP-3009** ([EIP-3009], `type="authorization"`): the token itself implements `receiveWithAuthorization`. Suitable for stablecoins such as USDC and EURC that ship EIP-3009. No prior approval is required from the payer.

- **Permit2** ([[Permit2](#)], type="permit2"): the canonical Permit2 contract (deployed at the same deterministic address on most major EVM chains) brokers the transfer via `permitWitnessTransferFrom`, with the channel parameters carried as a named EIP-712 witness so they appear as labeled fields in the payer's wallet at signing time. Suitable for any ERC-20 token, including tokens without native EIP-3009 support. The payer **MUST** have previously approved the Permit2 contract for the token (typically a one-time, unlimited approval).

Selection rules:

1. The server advertises accepted credential formats in the challenge's `methodDetails.credentialTypes`, or defaults to "hash" when that field is omitted. For `feePayer: true`, the client selects one advertised server-submitted format ("authorization" or "permit2") that it can produce; the credential's top-level `payload.type` is the on-the-wire discriminator for the choice.
2. **EIP-3009 path**: The client signs the EIP-712 typed data for `receiveWithAuthorization`. The server calls `openWithAuthorization()` or `topUpWithAuthorization()`. The escrow contract internally calls `receiveWithAuthorization` on the token.
3. **Permit2 path**: The client signs the EIP-712 typed data for Permit2 `PermitWitnessTransferFrom` with a channel-parameter witness (`ChannelOpenWitness` for open, `ChannelTopUpWitness` for topUp). The server calls `openWithPermit2()` or `topUpWithPermit2()`. The escrow contract internally calls `permitWitnessTransferFrom` on the canonical Permit2 contract, which verifies the witness against the function arguments and pulls tokens via the prior Permit2 approval.

When `feePayer` is true, the currency token **MUST** support at least one of the two server-submitted paths advertised by the server. Servers **MUST NOT** advertise `feePayer: true` for tokens whose authorization paths they cannot service.

9.2. Client-Paid Fees (`feePayer: false`)

When `feePayer: false` or omitted:

- **EOA clients**: Client calls `approve(escrow, deposit)` and then `open()` on the escrow contract, paying gas from their own balance.
- **Smart Wallet clients**: Client batches `approve + open` in a `UserOperation` (ERC-4337 [[ERC-4337](#)]). A Paymaster **MAY** sponsor gas for this client-submitted transaction path.

Servers that accept this client-broadcast path either omit `methodDetails.credentialTypes` (defaulting to "hash") or include "hash" in the list; clients **MUST NOT** submit type="hash" when `credentialTypes` is present and omits "hash".

9.3. Server-Initiated Operations

`settle` and `close` are server-originated on-chain transactions. The server pays gas for these regardless of the `feePayer` setting.

By default the payee (merchant) holds the native token of the target chain to pay gas for `settle()` and `close()`. Merchants that prefer not to maintain a native-token gas balance **MAY** instead use the relayed payee-side functions defined in the Relayed / Gasless Operations profile (Section 9.4): `settleWithAuthorization` and `closeWithAuthorization`. These let the payee sign an EIP-712 authorization off-chain and have any relayer submit and pay gas.

9.4. Relayed / Gasless Operations Profile

This profile is **OPTIONAL**. An implementation **MAY** omit it entirely, or implement any subset of its functions. The mandatory core (Section 7.3) is sufficient to operate a channel when the party initiating each transaction pays its own gas. The profile exists only to let a relayer submit and fund a transaction on behalf of a party that authorized it off-chain.

A server **MUST NOT** advertise a capability whose backing function its escrow does not implement: `feePayer: true` requires at least one of the payer-funded functions for the offered top-level type, and relayed settlement requires the corresponding payee-side function.

9.4.1. Payer-funded functions

`openWithAuthorization`, `openWithPermit2`, `topUpWithAuthorization`, and `topUpWithPermit2` are specified in Section 7.3. They are callable by anyone; the payer's funds move only under the payer's own EIP-3009 or Permit2 signature, and the channel parameters the contract trusts are bound into that signature as required by Section 15.13 (deterministic nonce for EIP-3009, named witness for Permit2). On the top-up paths the funding from need not equal `channel.payer`: the contract credits the existing channel, and any refund on close or withdraw is still paid to `channel.payer`, so a third-party top-up can only add funds, never redirect them.

9.4.2. Payee-initiated functions

`settleWithAuthorization` and `closeWithAuthorization` let the payee authorize a settlement or close off-chain and have any relayer submit it. Each requires **two** signatures: the payer/authorizedSigner Voucher (Section 11) that authorizes the amount, and an EIP-712 authorization from `channel.payee` that authorizes this specific relayed call.

Parameter	Type	Description
<code>channelId</code>	bytes32	Channel identifier
<code>cumulativeAmount</code>	uint128	Cumulative amount to settle/finalize
<code>nonce</code>	uint256	Payee-chosen, unused value in the (<code>payee</code> , <code>channelId</code>) scope
<code>deadline</code>	uint256	Unix seconds; contract MUST revert after this
<code>payeeSignature</code>	bytes	EIP-712 payee authorization (65 bytes)

Parameter	Type	Description
voucherSignature	bytes	EIP-712 Voucher signature; MAY be empty on the close forfeit path (<code>cumulativeAmount <= channel.settled</code>)

Table 18

```

function settleWithAuthorization(
    bytes32 channelId,
    uint128 cumulativeAmount,
    uint256 nonce,
    uint256 deadline,
    bytes calldata payeeSignature,
    bytes calldata voucherSignature
) external;

function closeWithAuthorization(
    bytes32 channelId,
    uint128 cumulativeAmount,
    uint256 nonce,
    uint256 deadline,
    bytes calldata payeeSignature,
    bytes calldata voucherSignature
) external;

```

The payee authorization uses these EIP-712 types under the same domain separator as the Voucher ([Section 11](#)):

```

SettleAuthorization(bytes32 channelId,uint128 cumulativeAmount,uint256
nonce,uint256 deadline)
CloseAuthorization(bytes32 channelId,uint128 cumulativeAmount,uint256
nonce,uint256 deadline)

```

Requirements for these functions:

1. The contract **MUST** recover the `payeeSignature` signer and verify it equals `channel.payee` (EOA via ECDSA, contract wallet via ERC-1271).
2. The contract **MUST** verify the Voucher signature exactly as `settle` / `close` do ([Section 7.5](#)), including the strictly increasing rule ([Section 15.5](#)); the `close` forfeit path (`cumulativeAmount <= channel.settled`) **MAY** omit `voucherSignature`.
3. Replay protection: the contract **MUST** maintain a used-set keyed by `(channel.payee, channelId, nonce)` and revert (e.g., `NonceAlreadyUsed()`) if the nonce was already consumed; `settle` and `close` authorizations **MUST** share the same used-set so a nonce cannot be reused across the two. Any caller **MAY** submit; the payee signature — not `msg.sender` — provides authorization.
4. The contract **MUST** revert (e.g., `AuthorizationExpired()`) when `block.timestamp > deadline`.

The nonce is an arbitrary unused uint256 (no ordering requirement), mirroring the Permit2 unordered-nonce model rather than a sequential counter. Payees **SHOULD** set a short deadline to bound the lifetime of an unsubmitted authorization.

10. Credential Schema

The credential in the Authorization header contains a base64url-encoded JSON object per [I-D.httpauth-payment].

10.1. Credential Structure

Field	Type	Required	Description
challenge	object	REQUIRED	Echo of the challenge parameters
payload	object	REQUIRED	Session-specific payload object
source	string	CONDITIONAL	Payer identifier as a DID. REQUIRED when payload type="hash"; NOT REQUIRED when type="authorization" or type="permit2"

Table 19

The source field **SHOULD** use the did:pkh method [DID-PKH] with the chain ID from the challenge and the payer's Ethereum address (e.g., did:pkh:eip155:196:0xConsumer...). When type="authorization" or type="permit2", the payer is identified via authorization.from.

10.2. Payload Actions

The payload object uses an action discriminator:

Field	Type	Required	Description
action	string	REQUIRED	One of "open", "topUp", "voucher", "close"

Table 20

Action	Description
open	Confirms channel open; begins streaming
topUp	Adds funds to an existing channel
voucher	Submits an updated cumulative voucher
close	Requests server to close the channel

Table 21

10.2.1. Open Payload (feePayer: false)

When `feePayer` is `false`, the client broadcasts the `open()` or `approve + open()` transaction themselves and submits the `txHash`. For smart wallets, this **MAY** be an ERC-4337 `UserOperation` whose outer transaction targets an `EntryPoint` while the inner execution opens the escrow channel.

Field	Type	Required	Description
<code>action</code>	string	REQUIRED	"open"
<code>type</code>	string	REQUIRED	"hash"
<code>channelId</code>	string	REQUIRED	Channel identifier (hex bytes32)
<code>hash</code>	string	REQUIRED	Tx hash of the on-chain open, direct or via ERC-4337 <code>EntryPoint</code>
<code>cumulativeAmount</code>	string	REQUIRED	Initial cumulative amount (typically "0")
<code>signature</code>	string	REQUIRED	EIP-712 voucher signature for the initial amount
<code>authorizedSigner</code>	string	OPTIONAL	Address delegated to sign vouchers (defaults to payer if omitted)
<code>salt</code>	string	REQUIRED	Random bytes32 hex for <code>channelId</code> computation

Table 22

The initial voucher (with `cumulativeAmount` typically "0") is **REQUIRED** so that the server holds a signed voucher from the start of the session. This ensures the server can call `settle()` or `close()` at any time, even if the client disconnects immediately after opening.

When `type="hash"`, the `source` field in the credential structure is **REQUIRED**. The server needs the payer identity to verify the on-chain deposit. This is consistent with the charge intent's requirement for hash credentials.

Example:

```
{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "source": "did:pkh:eip155:196:0xaabbccdde11223344556677889900aabbccdde",
  "payload": {
    "action": "open",
    "type": "hash",
    "channelId":
    "0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "hash":
    "0x9f8e7d6c5b4a39281700abcdef1234567890abcdef1234567890abcdef123456",
    "cumulativeAmount": "0",
    "signature": "0xabcdef1234567890...",
    "authorizedSigner": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
    "salt":
    "0xaaaa1234bbbb5678cccc9012dddd3456eeee7890ffff1234aaaa5678bbbb9012"
  }
}
```

10.2.2. Open Payload (feePayer: true)

When `feePayer` is `true`, the client submits a token-pull authorization for the server to call the corresponding `openWith...` function on the escrow contract. The top-level `type` field selects the format.

Field	Type	Required	Description
<code>action</code>	string	REQUIRED	"open"
<code>type</code>	string	REQUIRED	"authorization" for EIP-3009, or "permit2" for Permit2
<code>channelId</code>	string	REQUIRED	Channel identifier (hex bytes32)
<code>authorization</code>	object	REQUIRED	Token-pull authorization parameters; shape determined by the top-level type
<code>signature</code>	string	REQUIRED	Authorization signature (65 bytes hex). EIP-3009 signature if type="authorization"; Permit2 EIP-712 signature if type="permit2"
<code>cumulativeAmount</code>	string	REQUIRED	Initial cumulative amount (typically "0")
<code>voucherSignature</code>	string	REQUIRED	EIP-712 voucher signature for the initial amount

Field	Type	Required	Description
authorizedSigner	string	OPTIONAL	Address delegated to sign vouchers (defaults to payer if omitted)
salt	string	REQUIRED	Random bytes32 hex for channelId computation

Table 23

The authorization object takes one of two shapes.

EIP-3009 shape (type="authorization"):

Field	Type	Required	Description
from	string	REQUIRED	Payer address
to	string	REQUIRED	Escrow contract address (= <code>methodDetails.escrowContract</code>)
value	string	REQUIRED	Deposit amount in base units
validAfter	string	REQUIRED	Unix timestamp, valid from. "0" = immediately
validBefore	string	REQUIRED	Unix timestamp, expires
nonce	string	REQUIRED	bytes32 hex. EIP-3009 nonce; MUST be derived from channel parameters per Section 15.13

Table 24

The nonce **MUST** be derived from the surrounding payload's channel parameters: for `action="open"`, `nonce = keccak256(abi.encode(from, payee, token, salt, authorizedSigner))`; for `action="topUp"`, `nonce = keccak256(abi.encode(channelId, additionalDeposit, from, topUpSalt))`. The client **MUST** sign the EIP-3009 typed data with this derived nonce and **MUST** transmit it in the credential. The escrow contract recomputes the expected nonce from its own function arguments and reverts if the caller-supplied value does not match.

Permit2 shape (type="permit2"):

Field	Type	Required	Description
from	string	REQUIRED	Payer address (Permit2 owner); the Permit2 signature is verified against this address

Field	Type	Required	Description
permitted	object	REQUIRED	Permit2 TokenPermissions: { "token": <ERC-20 address = request.currency>, "amount": <deposit in base units> }
nonce	string	REQUIRED	Decimal string. uint256 Permit2 unordered nonce (any unused value)
deadline	string	REQUIRED	Decimal string. Unix timestamp after which the signature is invalid
witness	object	REQUIRED	Channel-parameter witness. For open: { "payee", "salt", "authorizedSigner" }. For topUp: { "channelId" }

Table 25

The authorization object carries every field the Permit2 signature covers, so the signed digest is reconstructable from the object alone (plus the domain below). This mirrors the EIP-3009 shape, whose fields are likewise exactly what that scheme signs.

The spender is the one signed field deliberately omitted: Permit2 fixes `spender = msg.sender` inside `permitWitnessTransferFrom`, so it is always the escrow contract. Clients **MUST** set `spender = methodDetails.escrowContract` when constructing the EIP-712 hash; the escrow supplies it implicitly on-chain.

The witness object **MUST** carry the channel parameters:

- For open: `payee`, `salt`, `authorizedSigner`. `payee` **MUST** equal the challenge `request.recipient`; `salt` and `authorizedSigner` **MUST** equal the corresponding open-payload fields (an omitted `authorizedSigner` is the zero address).
- For topUp: `channelId`, which **MUST** equal the payload `channelId`.

The channel parameters the server passes to the escrow are authoritative: the escrow reconstructs the witness from them and the Permit2 verification reverts on any mismatch. A server **MUST** reject the credential if `authorization.witness` disagrees with those authoritative values rather than forwarding a signature that will revert on-chain.

The Permit2 EIP-712 domain and struct types are:

```
EIP712Domain(string name,uint256 chainId,address verifyingContract)
    name           = "Permit2"
    chainId        = methodDetails.chainId
    verifyingContract = canonical Permit2 contract address

// For open (action="open"):
PermitWitnessTransferFrom(TokenPermissions permitted,address spender,uint256
nonce,uint256 deadline,ChannelOpenWitness witness)
ChannelOpenWitness(address payee,bytes32 salt,address authorizedSigner)
TokenPermissions(address token,uint256 amount)

// For topUp (action="topUp"):
PermitWitnessTransferFrom(TokenPermissions permitted,address spender,uint256
nonce,uint256 deadline,ChannelTopUpWitness witness)
ChannelTopUpWitness(bytes32 channelId)
TokenPermissions(address token,uint256 amount)
```

The witnessTypeString passed to permitWitnessTransferFrom is the suffix beginning at ChannelOpenWitness witness) (or ChannelTopUpWitness witness)) followed by the witness struct definition and the TokenPermissions definition, per the Permit2 encoding rules.

Note that the Permit2 domain omits the version field. The canonical Permit2 contract is deployed at the same deterministic address on most major EVM chains. The client uses methodDetails.permit2Contract when present, and otherwise the canonical deterministic address, as verifyingContract. The escrow's configured Permit2 address **MUST** be the same one the client signed against; a mismatch makes the Permit2 signature fail verification on-chain. Servers **MUST** advertise methodDetails.permit2Contract on any chain whose Permit2 is not at the canonical address.

Example (EIP-3009):

```
{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "payload": {
    "action": "open",
    "type": "authorization",
    "channelId":
    "0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "authorization": {
      "from": "0xaabbccdde11223344556677889900aabbccdde",
      "to": "0x1234567890abcdef1234567890abcdef12345678",
      "value": "10000000",
      "validAfter": "0",
      "validBefore": "1743523500",
      "nonce": "0xaaaa...aaaa"
    },
    "signature": "0xabcdef...eip3009sig",
    "cumulativeAmount": "0",
    "voucherSignature": "0x123456...vouchersig",
    "authorizedSigner": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
    "salt":
    "0xaaaa1234bbbb5678cccc9012dddd3456eeee7890ffff1234aaaa5678bbbb9012"
  }
}
```

Example (Permit2):

```

{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "payload": {
    "action": "open",
    "type": "permit2",
    "channelId":
    "0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "authorization": {
      "from": "0xaabbccdde11223344556677889900aabbccdde",
      "permitted": {
        "token": "0x74b7F16337b8972027F6196A17a631ac6dE26d22",
        "amount": "10000000"
      },
      "nonce": "1",
      "deadline": "1743523500",
      "witness": {
        "payee": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
        "salt":
        "0xaaaa1234bbbb5678cccc9012dddd3456eeee7890ffff1234aaaa5678bbbb9012",
        "authorizedSigner": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00"
      }
    },
    "signature": "0xfedcba...permit2sig",
    "cumulativeAmount": "0",
    "voucherSignature": "0x123456...vouchersig",
    "authorizedSigner": "0x742d35cc6634c0532925a3b844bc9e7595f8fe00",
    "salt":
    "0xaaaa1234bbbb5678cccc9012dddd3456eeee7890ffff1234aaaa5678bbbb9012"
  }
}

```

The `authorization.witness.payee` equals the `challenge.request.recipient`, and `witness.salt / witness.authorizedSigner` equal the top-level `salt / authorizedSigner` (they appear in both places because the witness is a faithful copy of what was signed, while the top-level fields are what the server passes to the escrow). The server treats the top-level channel parameters as authoritative when calling `openWithPermit2`; the `Permit2` signature reverts on-chain if the witness it reconstructs disagrees. `spender` is not shown because `Permit2` fixes it to the escrow (`msg.sender`).

10.2.3. TopUp Payload

The `topUp` action adds funds to an existing channel. It resets any pending close timer.

When `feePayer: false` (client broadcasts):

Field	Type	Required	Description
action	string	REQUIRED	"topUp"
type	string	REQUIRED	"hash"
channelId	string	REQUIRED	Channel ID
hash	string	REQUIRED	Tx hash of the on-chain topUp, direct or via ERC-4337 EntryPoint
additionalDeposit	string	REQUIRED	Additional amount deposited

Table 26

When type="hash", the credential-level source field is **REQUIRED**, as described in the Credential Structure section.

When feePayer: true (server submits via EIP-3009 or Permit2):

Field	Type	Required	Description
action	string	REQUIRED	"topUp"
type	string	REQUIRED	"authorization" for EIP-3009, or "permit2" for Permit2
channelId	string	REQUIRED	Channel ID
salt	string	CONDITIONAL	Random bytes32 hex; passed as topUpSalt for EIP-3009 nonce derivation. REQUIRED when type="authorization"; omitted for "permit2" (the Permit2 path uses no topUpSalt)
authorization	object	REQUIRED	Token-pull authorization parameters; shape determined by the top-level type, using the same shapes defined in Section 10.2.2
signature	string	REQUIRED	Authorization signature

Field	Type	Required	Description
additionalDeposit	string	REQUIRED	Additional amount to deposit. MUST equal the authorization amount (authorization.value for "authorization", authorization.permitted.amount for "permit2")

Table 27

The top-level additionalDeposit and the authorization amount **MUST** be equal: the server passes this value as the additionalDeposit argument to topUpWithAuthorization / topUpWithPermit2, and the escrow binds it into the token-pull signature (EIP-3009 value, or Permit2 permitted.amount). A server **MUST** reject the credential if the two disagree.

10.2.4. Voucher Payload

The voucher action submits an updated cumulative voucher. For action="voucher" and action="close", the source field is **OPTIONAL**; the server identifies the payer from the established channel state.

Field	Type	Required	Description
action	string	REQUIRED	"voucher"
channelId	string	REQUIRED	Channel identifier
cumulativeAmount	string	REQUIRED	Cumulative amount authorized
signature	string	REQUIRED	EIP-712 voucher signature

Table 28

Vouchers **MAY** carry an optional deposit field to merge a deposit authorization with the voucher update in a single round-trip. This allows the server to process both the funding and the new voucher atomically.

Field	Type	Required	Description
deposit	object	OPTIONAL	Deposit extension
deposit.action	string	REQUIRED	"open" or "topUp"
deposit.type	string	REQUIRED	"authorization" for EIP-3009, or "permit2" for Permit2

Field	Type	Required	Description
<code>deposit.authorization</code>	object	REQUIRED	Token-pull authorization parameters; shape determined by <code>deposit.type</code> , using the same shapes defined in Section 10.2.2
<code>deposit.signature</code>	string	REQUIRED	Authorization signature (65 bytes, hex-encoded)
<code>deposit.salt</code>	string	CONDITIONAL	Random bytes32 hex. Used for <code>channelId</code> computation when <code>deposit.action</code> is "open" (REQUIRED). When <code>deposit.action</code> is "topUp", passed as <code>topUpSalt</code> for EIP-3009 nonce derivation (REQUIRED for <code>type="authorization"</code> ; unused by "permit2")
<code>deposit.authorizedSigner</code>	string	OPTIONAL	Address delegated to sign vouchers. Omitted $\Rightarrow$ the zero address, which the contract treats as the payer; clients MUST use the zero address (not <code>authorization.from</code>) when deriving the EIP-3009 nonce or constructing the Permit2 witness. Only applicable when <code>deposit.action</code> is "open"

Table 29

When `deposit` is present, the server processes the deposit first by calling the matching escrow function (`openWithAuthorization` / `topUpWithAuthorization` for `deposit.type="authorization"`, or `openWithPermit2` / `topUpWithPermit2` for `deposit.type="permit2"`), then validates and accepts the voucher. If the deposit fails, the server **MUST** reject the entire credential.

`deposit.action`: "open" is an optimization pattern that allows the client to pre-compute the `channelId` deterministically (per the formula in the Channel State section) and bundle channel creation with the initial voucher in a single round-trip. Despite using `action="voucher"` in the payload, the server creates the channel as part of processing. The server **MUST** process the deposit first (calling `openWithAuthorization` or `openWithPermit2`), then validate the voucher against the newly created channel. For already-existing channels, `deposit.action` **MUST** be "topUp". The escrow contract will revert if `open` is called on an existing `channelId`.

Example (voucher only):

```
{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "payload": {
    "action": "voucher",
    "channelId":
    "0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "cumulativeAmount": "250000",
    "signature": "0xabcdef1234567890..."
  }
}
```

Example (voucher + deposit merge):

```
{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "payload": {
    "action": "voucher",
    "channelId":
    "0x6d0f4fdf1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "cumulativeAmount": "15000000",
    "signature": "0xabcdef...vouchersig",
    "deposit": {
      "action": "topUp",
      "type": "authorization",
      "salt":
      "0xcccc5678dddd9012eeee3456ffff7890aaaa1234bbbb5678cccc9012dddd3456",
      "authorization": {
        "from": "0xaabbccdde11223344556677889900aabbccdde",
        "to": "0x1234567890abcdef1234567890abcdef12345678",
        "value": "5000000",
        "validAfter": "0",
        "validBefore": "1743523500",
        "nonce": "0xbbbb...bbbb"
      },
      "signature": "0x789abc...eip3009sig"
    }
  }
}
```

10.2.5. Close Payload

The `close` action requests the server to close the channel and settle on-chain.

Field	Type	Required	Description
action	string	REQUIRED	"close"
channelId	string	REQUIRED	Channel identifier
cumulativeAmount	string	REQUIRED	Final cumulative amount
signature	string	REQUIRED	EIP-712 voucher signature

Table 30

The server calls `close(channelId, cumulativeAmount, signature)` on the escrow contract.

Example:

```
{
  "challenge": {
    "id": "kM9xPqWvT2nJrHsY4aDfEb",
    "realm": "api.llm-service.com",
    "method": "evm",
    "intent": "session",
    "request": "eyJ...",
    "expires": "2026-04-01T12:05:00Z"
  },
  "payload": {
    "action": "close",
    "channelId":
"0x6d0f4fd1f2f6a1f6c1b0fbd6a7d5c2c0a8d3d7b1f6a9c1b3e2d4a5b6c7d8e9f",
    "cumulativeAmount": "500000",
    "signature": "0xabcdef1234567890..."
  }
}
```

11. Voucher Signing Format

Vouchers use [\[EIP-712\]](#) typed structured data signing.

11.1. Type Definitions

```
{
  "Voucher": [
    { "name": "channelId", "type": "bytes32" },
    { "name": "cumulativeAmount", "type": "uint128" }
  ]
}
```

11.2. Domain Separator

Field	Type	Value
name	string	"EVM Payment Channel"
version	string	"1"
chainId	uint256	EVM chain ID (e.g., 196)
verifyingContract	string	Escrow contract address

Table 31

Note: The domain name differs from Tempo's "Tempo Stream Channel". This is the only semantic difference in the voucher signing scheme.

11.3. Signing Procedure

1. Construct the domain separator hash:

```
domainSeparator = keccak256(
  abi.encode(
    keccak256("EIP712Domain(string name,string version,uint256
chainId,address verifyingContract)"),
    keccak256(bytes("EVM Payment Channel")),
    keccak256(bytes("1")),
    chainId,
    verifyingContract
  )
)
```

2. Construct the struct hash:

```
structHash = keccak256(  
  abi.encode(  
    keccak256("Voucher(bytes32 channelId,uint128 cumulativeAmount)",  
      channelId,  
      cumulativeAmount  
    )  
  )  
)
```

3. Compute the signing hash:

```
signingHash = keccak256(  
  "\x19\x01" || domainSeparator || structHash  
)
```

4. Sign with ECDSA using secp256k1 curve

5. Encode as a 65-byte bytes value: `r (32) || s (32) || v (1)`, where `v` is 27 or 28

11.4. Cumulative Semantics

Vouchers specify cumulative totals, not incremental deltas:

- Voucher #1: `cumulativeAmount = 100` (authorizes 100 total)
- Voucher #2: `cumulativeAmount = 250` (authorizes 250 total)
- Voucher #3: `cumulativeAmount = 400` (authorizes 400 total)

When settling, the contract computes: `delta = cumulativeAmount - settled`

Server **MUST** verify `cumulativeAmount <= 2^128 - 1` (uint128 upper bound). Vouchers exceeding this **MUST** be rejected.

12. Verification Procedure

12.1. Common Verification

For all actions, servers **MUST** perform the following steps before action-specific verification:

1. Decode the `base64url` credential and parse the JSON object
2. Verify `payload.action` is a recognized action
3. Look up the stored challenge using `credential.challenge.id`
4. Verify all fields in `credential.challenge` exactly match the stored challenge parameters
5. Verify the challenge has not expired

12.2. Transaction Outcome Checks

Whenever a server relies on an on-chain transaction — verifying a client-submitted txHash (type="hash") or submitting one itself (type="authorization", type="permit2", settle, close) — it **MUST** read the receipt's status field and **MUST NOT** treat the transaction as effective on status alone being present.

- status == 0x1 (success): the call's on-chain effects occurred; proceed to verify channel state.
- status == 0x0 (reverted): the transaction was mined but **no state changed** (e.g. NonceMismatch, AmountNotIncreasing, ChannelAlreadyExists, or a failed token pull). The server **MUST** fail fast with a typed error and **MUST NOT** keep polling for a state change that will never come.
- No receipt yet (not mined): distinct from a revert; the server **MAY** await or retry up to a bounded timeout.

A reverted status == 0x0 is a definitive negative outcome, not a pending one; conflating the two is what causes close/settlement paths to hang on a spinner.

12.3. Open Verification

On action="open", servers **MUST**:

When type="hash":

1. Verify the txHash via eth_getTransactionReceipt, checking receipt.status per [Section 12.2](#) (a reverted 0x0 **MUST** be rejected immediately, not awaited)
2. Verify the transaction successfully caused open() to be executed on the expected escrow, either directly or through an ERC-4337 EntryPoint-mediated UserOperation
3. Verify that this execution created or initialized the specific payload.channelId
4. Query the escrow contract to verify channel state:
 - Channel exists with the provided channelId
 - channel.payee matches server's address
 - channel.token matches request.currency
 - channel.deposit - channel.settled >= amount
 - Channel is not finalized
 - channel.closeRequestedAt == 0 (no pending close)
5. Verify the initial voucher signature (see [Section 12.5](#))
6. Initialize server-side accounting state

When type="authorization" or type="permit2":

1. Verify the authorization parameters according to the top-level type:
 - "authorization": validate EIP-3009 fields and signature
 - "permit2": validate Permit2 fields and signature
2. Call the matching escrow function:
 - "authorization": `openWithAuthorization()`
 - "permit2": `openWithPermit2()`
3. Verify channel state as above
4. Verify the initial voucher signature
5. Initialize server-side accounting state

12.4. TopUp Verification

On action="topUp", servers **MUST**:

When type="hash":

1. Verify the txHash shows a successful `topUp()` execution on the expected escrow (check `receipt.status` per [Section 12.2](#); reject a reverted `0x0` immediately), either directly or through an ERC-4337 EntryPoint-mediated UserOperation
2. Verify that this execution affected the specific `payload.channelId`
3. Query updated channel state
4. Verify the channel deposit increased by exactly `payload.additionalDeposit`
5. Update server-side balance

When type="authorization" or type="permit2":

1. Verify the authorization parameters according to the top-level type:
 - "authorization": validate EIP-3009 fields and signature
 - "permit2": validate Permit2 fields and signature
2. Call the matching escrow function:
 - "authorization": `topUpWithAuthorization()`
 - "permit2": `topUpWithPermit2()`
3. Verify updated channel state
4. Update server-side balance

12.5. Voucher Verification

On `action="voucher"`, servers **MUST**:

1. Verify `channel.closeRequestedAt == 0` (no pending close). Reject vouchers on channels with a pending forced close.
2. If `deposit` field is present, process deposit first:
 - For `deposit.type="authorization"`, call `openWithAuthorization` or `topUpWithAuthorization`
 - For `deposit.type="permit2"`, call `openWithPermit2` or `topUpWithPermit2`
 - Verify updated channel state
3. Verify voucher signature using EIP-712 recovery
4. Verify signature uses canonical low-s values
5. Recover signer and verify it matches the expected signer from on-chain state (`channel.authorizedSigner` if non-zero, otherwise `channel.payer`). For ERC-1271 contract wallets, verify via `isValidSignature`.
6. If `cumulativeAmount <= highestVoucherAmount`, return `200 OK` without changing state (idempotent replay).
7. Verify monotonicity:
 - `(cumulativeAmount - highestVoucherAmount) >= minVoucherDelta`
8. Verify `cumulativeAmount <= channel.deposit` (ensures the settlement delta `cumulativeAmount - channel.settled` does not exceed available funds `channel.deposit - channel.settled`)
9. Persist voucher to durable storage before providing service
10. Update `highestVoucherAmount = cumulativeAmount`

Signature and signer verification (steps 3-5) **MUST** be performed before the idempotency short-circuit in step 6. Because voucher and close credentials **MAY** omit the source field and identify the payer from channel state, returning `200 OK` for a stale `cumulativeAmount` before verifying the signature would let any party that knows a `channelId` trigger successful-looking responses, and — when the voucher is submitted alongside a service request — consume already-authorized balance on the payer's behalf.

Implementations **MAY** cache successfully-verified voucher signatures keyed by `(channelId, cumulativeAmount, signature)` and short-circuit on an exact bit-for-bit replay before re-running `ecrecover`. This optimization is safe because the cache hit itself proves the signature was previously verified.

12.6. Idempotency

Servers **MUST** treat voucher submissions idempotently **only after the voucher signature and signer have been verified** per steps 3-5 of [Section 12.5](#):

- If signature verification fails, the server **MUST** return an error response per [Section 12.7](#), regardless of how `cumulativeAmount` compares to `highestVoucherAmount`.
- After successful signature and signer verification:
 - If `cumulativeAmount == highestVoucherAmount`, the server **MUST** return `200 OK` without changing state.
 - If `cumulativeAmount < highestVoucherAmount`, the server **MUST** return `200 OK` without changing state.
 - Only vouchers with `cumulativeAmount > highestVoucherAmount` proceed to the monotonicity and balance checks in [Section 12.5](#).

12.7. Error Responses

Status	When
400 Bad Request	Malformed payload or missing fields
402 Payment Required	Invalid signature or signer mismatch
409 Conflict	A submitted/verified on-chain transaction reverted (<code>receipt.status == 0x0</code> , see Section 12.2)
410 Gone	Channel finalized or not found

Table 32

Error responses use Problem Details [[RFC9457](#)]. Problem type URIs:

Type URI	Description
https://paymentauth.org/problems/session/invalid-signature	Voucher signature invalid
https://paymentauth.org/problems/session/signer-mismatch	Signer not authorized
https://paymentauth.org/problems/session/amount-exceeds-deposit	Exceeds channel deposit
https://paymentauth.org/problems/session/delta-too-small	Below <code>minVoucherDelta</code>

Type URI	Description
https://paymentauth.org/problems/session/channel-not-found	No channel with this ID
https://paymentauth.org/problems/session/channel-finalized	Channel closed
https://paymentauth.org/problems/session/challenge-not-found	Challenge unknown or expired
https://paymentauth.org/problems/session/insufficient-balance	Insufficient authorized balance
https://paymentauth.org/problems/session/transaction-reverted	An on-chain open/topUp/settle/close transaction reverted

Table 33

These problem types are the **interoperable error surface**: they are what a client consumes, and they **MUST** be uniform across deployments regardless of how each escrow names its internal reverts (Section 7.6). Accordingly, when a server-submitted transaction reverts (Section 12.2) — a feePayer: true open/topUp, a relayed settle/close — or when an action fails server-side validation, the server **MUST** report the failure using the most specific applicable problem type, falling back to transaction-reverted when none is more specific. Servers **MUST NOT** surface a raw on-chain revert selector or an implementation-specific error string as the problem type.

Recommended mapping from on-chain revert condition (Section 7.6) to problem type:

Revert condition	Problem type
AmountExceedsDeposit	amount-exceeds-deposit
ChannelNotFound	channel-not-found
ChannelFinalized	channel-finalized
InvalidSignature	invalid-signature
Insufficient on-chain balance / token pull failed	insufficient-balance
NonceMismatch, NonceAlreadyUsed, AuthorizationExpired, AmountNotIncreasing, ChannelAlreadyExists, or any other	transaction-reverted

Table 34

For `feePayer: false`, where the client broadcasts its own `open / topUp`, the client determines the outcome by querying channel state (`Open/TopUp Verification`, [Section 12.2](#)) rather than decoding the `revert`, so it likewise does not depend on the escrow's internal error encoding.

Example error response:

```
{
  "type": "https://paymentauth.org/problems/session/invalid-signature",
  "title": "Invalid Signature",
  "status": 402,
  "detail": "Voucher signature could not be verified",
  "channelId": "0x6d0f4fdf..."
}
```

13. Server-Side Accounting

Servers **MUST** maintain per-session accounting state:

Field	Type	Description
<code>acceptedCumulative</code>	<code>uint128</code>	Highest valid voucher amount accepted (monotonically increasing). Also referred to as <code>highestVoucherAmount</code> in the verification procedure
<code>spent</code>	<code>uint128</code>	Cumulative amount charged for delivered service (monotonically increasing)
<code>settledOnChain</code>	<code>uint128</code>	Last cumulative amount settled on-chain

Table 35

Available balance: `available = acceptedCumulative - spent`

13.1. Per-Request Processing

1. **Voucher acceptance:** Verify and persist new `acceptedCumulative`
2. **Balance check:** If `available < cost`, return 402
3. **Charge and deliver:** Persist `spent := spent + cost` BEFORE delivering service
4. **Receipt generation:** Include balance state

13.2. Crash Safety

- Persist `spent` increments BEFORE delivering service
- Persist `acceptedCumulative` BEFORE relying on new balance
- Use transactional storage or write-ahead logging

13.3. Insufficient Balance During Streaming

When balance is exhausted during a streaming response:

1. Server **MUST** stop delivering additional metered content
2. Server **MUST** emit a payment-need-voucher [SSE] event:

```
event: payment-need-voucher
data: {"channelId": "0x6d0f...",
      "requiredCumulative": "250025",
      "acceptedCumulative": "250000",
      "deposit": "500000"}
```

The payment-need-voucher event data:

Field	Type	Required	Description
channelId	string	REQUIRED	Channel identifier
requiredCumulative	string	REQUIRED	Minimum next voucher amount
acceptedCumulative	string	REQUIRED	Current highest accepted
deposit	string	REQUIRED	Current on-chain deposit

Table 36

When `requiredCumulative > deposit`, the client **MUST** submit a `topUp` before sending a new voucher.

Note: The SSE event types `payment-need-voucher` and `payment-receipt` are defined by this specification. They are not registered in any external event type registry.

13.4. Request Idempotency

To prevent double-charging on retries:

- Clients **SHOULD** include an `Idempotency-Key` header on paid requests
- Servers **SHOULD** track (`challengeId`, `idempotencyKey`) pairs and return cached responses for duplicates
- Servers **MUST NOT** increment `spent` for duplicate idempotent requests

13.5. Cost Calculation

Servers **MUST** support at least one of:

- **Fixed cost:** A predetermined amount per request

- **Usage-based:** Proportional to resource consumption (e.g., tokens generated, bytes transferred)

For streaming responses (SSE), servers **SHOULD**:

1. Reserve an estimated cost before starting delivery
2. Adjust spent as actual consumption is measured
3. Pause delivery if available is exhausted

14. Settlement Procedure

14.1. Settlement Timing

Servers **MAY** settle at any time:

- Periodically (every N seconds or M base units)
- When `action="close"` is received
- When unsettled amount exceeds a threshold
- Based on gas cost optimization

For every server-submitted `settle()` or `close()`, the server **MUST** check `receipt.status` per [Section 12.2](#) and treat a reverted `0x0` as a definitive failure to settle (surface a typed error and retry as appropriate), never as a pending result to be polled to timeout.

14.2. Cooperative Close

When the client sends `action="close"`:

1. Server **MUST** verify `cumulativeAmount >= spent` (the client's final voucher covers all delivered service). If the client's voucher is insufficient, the server **SHOULD** settle using the highest previously accepted voucher instead of the close voucher
2. Server calls `close(channelId, cumulativeAmount, signature)`
3. Server **MUST** check the resulting `receipt.status` per [Section 12.2](#). On a reverted `0x0`, the server **MUST NOT** report the channel as closed or block the client on a spinner; it **MUST** surface a typed error and **MAY** retry (e.g. re-submit with the highest accepted voucher, or after diagnosing the revert reason)
4. On `status == 0x1`, the contract has settled the delta and refunded the remainder to the payer; the server returns a receipt with the transaction hash

14.3. Forced Close

If the server does not respond:

1. Client calls `requestClose(channelId)` on-chain

2. Grace period begins (defined by the contract's `CLOSE_GRACE_PERIOD` constant; the reference value is 15 minutes. Compliant implementations **MUST NOT** use a grace period shorter than 10 minutes to ensure the server has reasonable time to settle outstanding vouchers. Servers **MUST** verify the contract's grace period meets this minimum before accepting channels on that contract)
3. Server can still `settle()` or `close()` during grace period
4. After grace period, client calls `withdraw(channelId)`
5. Client receives remaining (unsettled) funds

14.4. Sequential Sessions

A single channel supports sequential sessions. Each session uses the same cumulative voucher counter. The channel's `highestVoucherAmount` is the source of truth for the next voucher's minimum value.

14.5. Voucher Submission Transport

Vouchers are submitted via HTTP requests to the **same resource URI** that requires payment. There is no separate session endpoint. Clients **SHOULD** use HTTP/2 multiplexing or maintain separate connections for voucher updates and content streaming.

For voucher-only updates (no response body needed), clients **MAY** use HEAD requests.

14.6. Receipt Generation

Servers **MUST** return a `Payment-Receipt` header on **every successful paid request**. For streaming responses (SSE), servers **MUST** include the receipt in the initial response headers AND as a final SSE event:

```
event: payment-receipt
data: {"method": "evm", "intent": "session", "status": "success", ...}
```

For chunked responses, the final receipt **MAY** be delivered as an HTTP trailer if the client advertises `TE: trailers`.

Field	Type	Required	Description
method	string	REQUIRED	"evm"
intent	string	REQUIRED	"session"
status	string	REQUIRED	"success"
timestamp	string	REQUIRED	[RFC3339] response time

Field	Type	Required	Description
reference	string	REQUIRED	Stable session reference; equal to channelId
challengeId	string	REQUIRED	Challenge identifier
channelId	string	REQUIRED	Channel identifier
acceptedCumulative	string	REQUIRED	Highest voucher accepted
spent	string	REQUIRED	Total amount charged
chainId	number	REQUIRED	EVM chain ID where settlement occurs
units	number	OPTIONAL	Units consumed this request
txHash	string	OPTIONAL	On-chain transaction hash (present on settlement/close)
confirmations	number	OPTIONAL	Block confirmations at receipt time

Table 37

The `reference` field is the core spec's stable receipt reference and **MUST** equal `channelId`. The `txHash` field is optional settlement evidence because not every response involves an on-chain settlement; voucher updates are off-chain. When present, `txHash` can also serve as a method-specific settlement reference.

Example receipt (per-request):

```
{
  "method": "evm",
  "intent": "session",
  "status": "success",
  "timestamp": "2026-04-01T12:08:30Z",
  "challengeId": "kM9xPqWvT2nJrHsY4aDfEb",
  "reference": "0x6d0f4fdf...",
  "channelId": "0x6d0f4fdf...",
  "chainId": 196,
  "acceptedCumulative": "250000",
  "spent": "237500",
  "units": 500
}
```

Example receipt (on close):

```
{
  "method": "evm",
  "intent": "session",
  "status": "success",
  "timestamp": "2026-04-01T12:10:00Z",
  "challengeId": "kM9xPqWvT2nJrHsY4aDfEb",
  "reference": "0x6d0f4fdf...",
  "channelId": "0x6d0f4fdf...",
  "chainId": 196,
  "acceptedCumulative": "250000",
  "spent": "250000",
  "txHash":
  "0x1a2b3c4d5e6f7890abcdef1234567890abcdef1234567890abcdef1234567890"
}
```

15. Security Considerations

15.1. Replay Prevention

Vouchers are bound to a specific channel and contract via:

- `channelId` in the voucher message
- `verifyingContract` in EIP-712 domain
- `chainId` in EIP-712 domain
- Cumulative amount semantics (can only increase)

EIP-3009 nonces prevent replay of deposit authorizations at the contract level. Because the nonce is derived deterministically from the channel parameters (see [Section 15.13](#)), each unique (payee, salt, authorizedSigner) open or (channelId, additionalDeposit, topUpSalt) top-up produces a distinct nonce and the token contract rejects any reuse for the same from.

15.2. Channel Re-Use / Cross-Epoch Replay

`channelId` is derived from stable inputs only — (payer, payee, token, salt, authorizedSigner, address(this), chainId) — with no epoch or open-nonce. After a channel is closed, the same inputs (notably the same salt) re-derive a byte-identical `channelId`, and because the EIP-712 domain and Voucher struct are unchanged, an old voucher's digest is also byte-identical. If the contract permitted re-opening that `channelId`, the payee could replay a stale high-water voucher against the new deposit.

The escrow **MUST** prevent this by retaining finalized channel records permanently (sticky finalized flag, no struct deletion) so the open "already exists" check rejects every re-open of a used `channelId`. This matches the Tempo reference design, which likewise carries a persistent finalized flag and folds no epoch into `channelId`. Clients that want a fresh channel after close **MUST** choose a new salt.

15.3. Cross-Chain Replay

The EIP-712 domain separator includes `chainId`, making signatures invalid on other chains.

15.4. Voucher Tampering

EIP-712 signatures bind all voucher fields. Any modification invalidates the signature.

15.5. Rollback Prevention

Server **MUST** only accept strictly increasing `cumulativeAmount`, and the escrow contract **MUST** enforce the same on-chain in `settle` (reverting when `cumulativeAmount <= channel.settled`). Old vouchers are automatically superseded.

15.6. Overflow Protection

Server **MUST** verify `cumulativeAmount <= 2^128 - 1`. The escrow contract enforces the same constraint.

15.7. Deposit Cap

Server **MUST** verify `cumulativeAmount <= channel.deposit`. The escrow contract enforces this on-chain as well.

15.8. Denial of Service

- Rate limit voucher submissions (**SHOULD** limit to 10/second/session)
- Enforce `minVoucherDelta` to prevent tiny increments
- Enforce minimum deposit thresholds
- Perform format validation before signature recovery
- When `feePayer` is `true`, servers **SHOULD** enforce minimum deposit amounts to prevent gas griefing. A malicious client could sign many small EIP-3009 authorizations, forcing the server to spend gas on economically unprofitable `openWithAuthorization` calls.

15.9. Signature Malleability

ECDSA signatures have an inherent malleability: given a valid 65-byte signature containing components (r, s, v) , the value $(r, \text{secp256k1_order} - s, 55 - v)$ is also valid for the same message. (Note: $55 - v$ maps 27→28 and 28→27, which is the correct v -flip for EIP-712 signatures where $v \in \{27, 28\}$.) This could allow an attacker to submit a modified signature that passes `ecrecover` but references a different transaction hash.

The escrow contract **MUST** enforce canonical (low- s) signatures to prevent this. See the signature verification requirements in the Contract Functions section.

15.10. Reentrancy

Functions that transfer tokens out — `settle`, `close`, `withdraw`, and their relayed variants — **MUST** follow the checks-effects-interactions pattern: all state changes (`channel.settled`, `channel.finalized`, and the payee-relayed nonce used-set) **MUST** be committed before the external token transfer. The core functions are additionally protected by their `msg.sender` access checks (a re-entrant call from a malicious token carries `msg.sender == token` and fails the payer/payee check), but `settleWithAuthorization` and `closeWithAuthorization` are callable by any relayer, so implementations **MUST** apply a reentrancy guard or rely strictly on checks-effects-interactions for those paths. Restricting the escrow to well-behaved tokens without transfer callbacks (e.g. USDC) further reduces this surface.

15.11. No Voucher Expiry

Vouchers have no `validUntil` field. Channels have no expiry — they are closed explicitly. Vouchers remain valid until the channel closes. The close grace period protects against clients disappearing.

Operational guidance: Servers **SHOULD** settle and close channels that have been inactive for extended periods (e.g., 30+ days).

15.12. Chain Reorganization

If a chain reorganization removes a confirmed `open()` or `topUp()` transaction, the server loses its escrow guarantee. Mitigations:

- Servers **SHOULD** use sufficient confirmation depth before accepting `open/topUp` (e.g., 1 block for L2 rollups with fast finality, 12+ blocks for Ethereum mainnet)
- For L2 rollups, consider L1 settlement finality for high-value channels
- Voucher-based payments are not affected (off-chain)
- Settlement transactions should use appropriate gas pricing

15.13. Front-Running Protection

The escrow contract's `channelId` is deterministic. An attacker who observes a pending `open()` transaction could front-run it. However, the `channelId` includes the payer address (the `msg.sender` of `open()`), so a front-runner calling `open()` with identical parameters would produce a different `channelId` because their address differs. The `salt` parameter (chosen by the client) provides additional protection by making the `channelId` unpredictable before the transaction appears in the mempool.

When `feePayer` is true, the token-pull authorization signature is visible in the pending `openWith...` transaction. The same direct-call attack is mitigated at the token-transfer layer by both supported authorization formats:

- **EIP-3009**: The escrow contract **MUST** use `receiveWithAuthorization` (not `transferWithAuthorization`) when calling the token. This enforces `msg.sender == to`, so only the escrow contract can execute the transfer. The `authorization.to` field **MUST** be the escrow contract address.
- **Permit2**: The Permit2 contract fixes `spender = msg.sender` inside `permitWitnessTransferFrom`, so only the caller of `permitWitnessTransferFrom` (the escrow contract) can spend the signature. The `transferDetails.to` is also constrained to the escrow contract address. The channel parameters (`payee`, `salt`, `authorizedSigner` for open; `channelId` for topUp) are bound into the signature as a named EIP-712 witness, so an attacker who substitutes any of those values when calling the escrow causes the Permit2 signature verification to revert.

The two paths achieve channel-parameter integrity by different mechanisms:

- Permit2 signs `permitted.token`, `permitted.amount`, `spender`, `nonce`, `deadline`, **and** the witness struct, which carries the channel parameters explicitly. No nonce derivation is required: any unused Permit2 nonce is acceptable, and clients **MAY** use random or sequential nonces.
- EIP-3009 signs only `from`, `to`, `value`, `validAfter`, `validBefore`, `nonce`. It has no witness mechanism, so the channel parameters (`payee`, `salt`, `authorizedSigner` for open; `channelId`, `topUpSalt` for topUp) are not covered by the underlying signature. An attacker could front-run `openWithAuthorization` with a different payee (their own address), and the underlying transfer signature would remain valid.

To close this gap on the EIP-3009 path, compliant escrow contracts **MUST** derive the EIP-3009 nonce deterministically from the channel parameters and **MUST** validate the caller-supplied nonce argument against the derived value, reverting (e.g., with `NonceMismatch()`) on any mismatch:

```
// openWithAuthorization (EIP-3009 nonce, bytes32)
nonce = keccak256(abi.encode(from, payee, token, salt, authorizedSigner))

// topUpWithAuthorization (EIP-3009 nonce, bytes32)
nonce = keccak256(abi.encode(channelId, additionalDeposit, from, topUpSalt))
```

The contract passes the validated nonce to `receiveWithAuthorization`. If an attacker calls the escrow with a substituted payee, salt, authorizedSigner, channelId, additionalDeposit, or topUpSalt, the derived nonce differs from the one the payer signed; the contract **MUST** reject the call before invoking the token, and even if it did not, the underlying signature verification at the token contract would revert.

The nonce is exposed as an explicit function parameter (rather than derived silently) so that callers and indexers can observe the value the payer signed; the on-chain check is what makes the binding non-bypassable. Implementations **MUST NOT** skip this check, and **MUST NOT** fall back to using the caller-supplied value unchanged.

Clients **MUST** use the same derivation formula when signing the EIP-3009 authorization and **MUST** transmit the derived nonce in the credential. Including from ensures the nonce is bound to the depositor identity, even though the underlying signature already covers from directly.

Trade-off note: The deterministic-nonce approach for EIP-3009 trades signing-time UX (the nonce appears as an opaque hash in wallet displays) for protocol simplicity. The Permit2 witness approach trades a slightly longer EIP-712 type string for intent-visible UX — wallets that render typed data show payee, salt, and authorizedSigner as labeled fields the user can review.

15.14. ERC-20 Approval Front-Running

When `feePayer` is false, the client calls `approve(escrow, deposit)` followed by `open()`. The classic ERC-20 approval front-running attack (where a spender races to spend both the old and new allowance) does not apply here because the escrow contract is trusted code with deterministic behavior. However, clients **SHOULD** batch `approve` and `open` in a single transaction when possible (e.g., via ERC-4337 `UserOperations` or `multicall`) to minimize the window between approval and channel creation.

When `feePayer` is true and `type="permit2"`, the payer must have previously approved the canonical Permit2 contract for the token (typically a one-time, unlimited approval). The same reasoning applies: Permit2 is trusted code with deterministic behavior, and each Permit2 `SignatureTransfer` is gated by a single-use unordered nonce.

15.15. Contract Wallet Signer Mutability

When `authorizedSigner` is an ERC-1271 contract wallet (e.g., Safe, ERC-4337 account), voucher validity depends on the wallet's current signer state at verification time, not at signing time. If the wallet's owner set, signing key, or signature-validation policy changes after a voucher is signed, `isValidSignature` **MAY** return failure for previously-signed vouchers, rendering them unredeemable on-chain.

This creates an asymmetric risk:

- **Payee risk:** If the payer rotates keys on their contract wallet after signing vouchers but before the payee calls `settle()`, the payee loses the ability to redeem accumulated off-chain authorizations.
- **Payer mitigation:** Payers using contract wallets as `authorizedSigner` **SHOULD** avoid key rotation during active sessions, or coordinate rotation with settlement.
- **Payee mitigation:** Payees **SHOULD** settle more frequently when the `authorizedSigner` is a contract wallet, reducing the value at risk from signer-state changes. Payees **MAY** inspect the signer address to determine whether it is a contract (via `EXTCODESIZE`) and adjust settlement cadence accordingly.

EOA signers are not affected: ECDSA recovery is stateless and depends only on the signature and message.

Recommended pattern: When the payer is a contract wallet, the payer **SHOULD** delegate voucher signing to an ephemeral EOA session key by setting `authorizedSigner` to that EOA's address, rather than leaving `authorizedSigner` unset (which defaults to the payer contract wallet). This preserves the AA benefits for the escrowed funds — the contract wallet still controls `open()`, `topUp()`, and `close()` calls — while eliminating the signer-mutability risk for off-chain vouchers. The session key **SHOULD** be scoped to the lifetime of the channel and discarded after `close()`.

Contract-wallet `authorizedSigner` remains permitted for cases where EOA delegation is not acceptable (e.g., enterprise multi-sig policies that require every signed artifact to carry a quorum signature). In such cases, the mitigations above apply.

15.16. Escrow Guarantees

The escrow contract provides the following security properties:

- **Payer protection:** Funds can only be withdrawn with a valid voucher signature. Forced `close` + grace period ensures payer can always recover uncommitted funds.
- **Payee protection:** A valid voucher is an irrevocable on-chain claim. The payee can call `settle()` at any time.
- **Atomicity:** `close()` settles and refunds in a single transaction.

15.17. Disconnection Handling

Scenario	Handling
Client disappears	Server holds last voucher, can <code>settle()</code> unilaterally
Server crashes	Server persists vouchers, can <code>settle()</code> on restart
Session idle timeout	Server settles and closes after configured threshold

Table 38

16. IANA Considerations

16.1. Payment Method Registration

The `evm` payment method is registered by [\[I-D. evm-charge\]](#). This document does not create a separate registration.

16.2. Payment Intent Registration

The session intent is registered by [I-D.payment-intent-session]. This document does not register a new payment intent; it defines how the evm payment method implements the registered session intent.

16.3. Problem Type Registration

This document registers the following problem types:

Type URI	Title	Status
.../session/invalid-signature	Invalid Signature	402
.../session/signer-mismatch	Signer Mismatch	402
.../session/amount-exceeds-deposit	Amount Exceeds Deposit	402
.../session/delta-too-small	Delta Too Small	402
.../session/channel-not-found	Channel Not Found	410
.../session/channel-finalized	Channel Finalized	410
.../session/challenge-not-found	Challenge Not Found	402
.../session/insufficient-balance	Insufficient Balance	402
.../session/transaction-reverted	Transaction Reverted	409

Table 39

Base URI: <https://paymentauth.org/problems>

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Appendix A. Scenario Walkthroughs

A.1. LLM Token Billing (Escrow + High-Frequency Voucher)

Agent A calls Provider P's LLM inference API, per-token billing on X Layer with USDC.

Parameters:

- Unit price: 100 base units per token = 0.0001 USDC (6 decimals)
- Suggested deposit: 5,000,000 = 5.0 USDC (~50,000 tokens)
- minVoucherDelta: 10,000 = 0.01 USDC (100 tokens per voucher)

Client	Server	X Layer
POST /v1/chat		
----->		
402 + WWW-Authenticate method="evm" intent="session"		
<-----		
approve(escrow, 5M)		
----->		
open(payee, USDC, 5000000, salt, A)		
----->		
txHash=0xabc...		
<-----		
Credential: action="open" type="hash" hash="0xabc..."		
----->		
Receipt: channelId	verify deposit	
<-----		
POST /v1/chat (800 tk) voucher: cum=80000		
----->		
200 + response + Receipt{spent:80000}		
<-----		
... repeat ... cumulative = 3750000		
402 + Need-Voucher required: 3750100		
<-----		
action="close" cum=3750100		
----->		
	close(ch, 3750100)	
	----->	
Receipt{closed, ref}	Provider: 3.7501 USDC Agent: 1.2499 USDC	
<-----		

Key numbers:

- Total consumed: 3,750,100 base units = 3.7501 USDC
- Refunded: 5,000,000 - 3,750,100 = 1,249,900 = 1.2499 USDC

- On-chain transactions: only 2 (open + close), all intermediate vouchers are off-chain

A.2. LLM Token Billing (Deposit Merge Mode)

Same setup as Scenario 1, but using feePayer: true + deposit merge mode. Consumer pays zero gas.



Key advantages:

- Consumer needs no native token for gas
- Voucher + deposit merged into single HTTP round-trip

- Server batches on-chain operations for gas optimization

Appendix B. Acknowledgements

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