Generic Web HSM Signing Protocol - Specification v1.0

Version: 1.0.2 **Date:** January 23, 2026

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1. Introduction

1.1 Purpose

This document defines the **Generic Web HSM Signing Protocol v1.0**, a standardized communication protocol enabling web applications to request digital signatures from a Chrome browser extension, which in turn communicates with a native host application connected to hardware security modules (HSMs).

1.2 Scope

This protocol covers:

- Message formats between Web App ↔ Extension ↔ Native Host
- Content representation for various data types
- Delivery mechanisms for signed content
- Error handling and status reporting

1.3 Design Principles

1. **No Business Logic in Signing Stack**: The extension and native host are generic signing utilities. All business logic (what to sign, where to send) is defined by the calling web application.
2. **No Inline Binary**: PDF and binary content is NEVER transmitted inline. The native host fetches content from URLs provided by the caller.

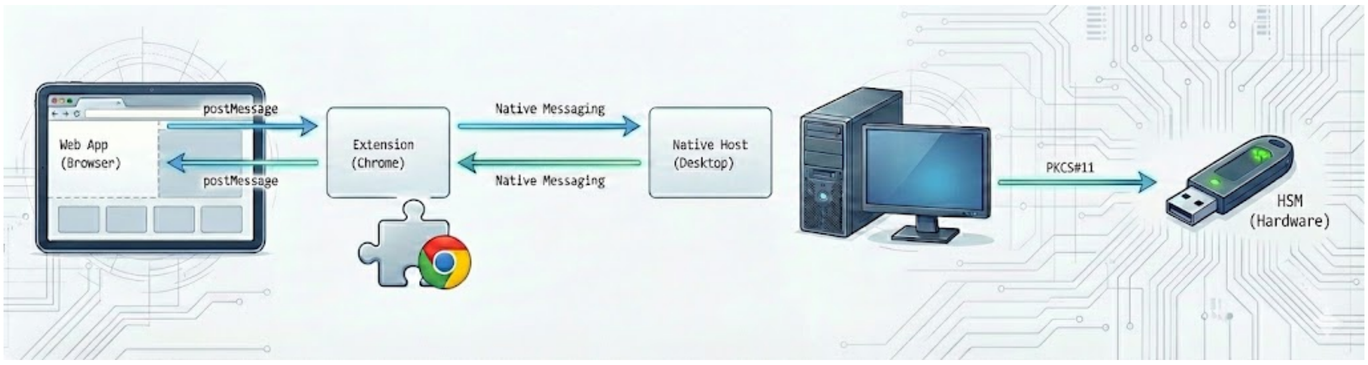
3. **Callback-Based Delivery**: Signed content is uploaded directly by the native host to endpoints specified by the caller. No signed content is returned through the message chain.
4. **Hardware-Only Signing**: Only PKCS#11 hardware tokens are supported. No software certificates.

1.4 Roles

Role	Description
Web Application	The calling application (e.g., a grades management system). Constructs signing requests and provides all URLs for content retrieval and result delivery.
Chrome Extension	Browser bridge. Receives requests via `window.postMessage`, validates origin, and forwards to native host via Chrome Native Messaging.
Native Host	Desktop application. Downloads content, performs HSM signing via PKCS#11, uploads results, and reports status.
HSM	Hardware Security Module containing the signing certificate and private key.

2. Architecture Overview

2.1 Transport Mechanisms



2.2 Transport Details

Leg	Transport	Format
Web App → Extension	`window.postMessage()`	JSON
Extension → Web App	`window.postMessage()`	JSON
Extension → Native Host	Chrome Native Messaging (stdin)	JSON
Native Host → Extension	Chrome Native Messaging (stdout)	JSON
Native Host → Content Server	HTTPS GET	Binary/Text
Native Host → Upload Server	HTTPS POST (raw bytes)	Binary/Text
Native Host → Callback Server	HTTPS POST	JSON

2.3 What Each Component Does

Web Application Responsibilities:

- Generate unique `requestId` (UUID)
- Construct complete signing request with all URLs
- Provide authentication headers for all external endpoints
- Handle final response from extension
- Implement callbacks endpoints (onSuccess, onError, progress)

Extension Responsibilities:

- Validate sender origin against allowlist
- Validate request schema
- Forward request to native host
- Forward response to web app
- **Does NOT**: Download content, modify payloads, or perform signing

Native Host Responsibilities:

- Download content from provided each `downloadUrl`
- Perform cryptographic signing via PKCS#11
- Upload signed content to provided `uploadUrl`
- POST status updates to callbacks endpoints
- Return completion status to extension

---

3. Protocol Versioning

3.1 Version Field

Every request and response MUST include a `protocolVersion` field at the root level.

```
{
  "protocolVersion": "1.0",
  ...
}
```

3.2 Version Format

- Format: `MAJOR.MINOR` (e.g., `"1.0"`, `"1.1"`, `"2.0"`)
- MAJOR: Incremented for breaking changes
- MINOR: Incremented for backward-compatible additions

3.3 Compatibility Rules

- Extension/Native Host MUST reject requests with unsupported `protocolVersion`
- Response MUST echo the same `protocolVersion` from the request

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4. Data Types

4.1 Supported Types

The `dataType` field specifies the type of content being signed.

dataType	Description	Content-Type	Allowed Modes
`text`	Plain UTF-8 text string	text/plain	`inline`*, `remote`
`xml`	UTF-8 XML document	application/xml	`inline`*, `remote`
`json`	UTF-8 JSON string	application/json	`inline`*, `remote`
`pdf`	PDF document (binary)	application/pdf	`remote` **ONLY**
`binary`	Opaque binary data	application/octet-stream	`remote` **ONLY**

* only if the data to sign + JSON wrapper is under 1MB

4.2 Critical Rule: No Inline Binary

PDF and binary content MUST use `mode: "remote"` exclusively.

Inline Base64 encoding is **FORBIDDEN** because:

1. Base64 adds 33% overhead
2. Large payloads can exceed Chrome Native Messaging limits (~1MB)
3. `window.postMessage` with large payloads degrades browser performance

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5. Content Representation

> **Note**: This section describes the `content` object structure used in the **non-grouped `objects` array** (Section 6). For **grouped requests** using `objectGroups`, see Section 7 where `mode` is defined at the group level.

5.1 The `content` Object

When using the `objects` array (not `objectGroups`), every signable item has a `content` object describing how to access its data.

5.2 Inline Mode (Text/XML/JSON Only)

Use for small text content that can be embedded directly in the request.

```json
{
  "mode": "inline",
  "encoding": "utf8",
  "content": "<the actual text content here>"
}
```

Field	Type	Required	Description
`mode`	string	YES	Must be `"inline"`
`encoding`	string	YES	Must be `"utf8"`
`content`	string	YES	The actual text content

Example - Inline Text:

```
{
  "mode": "inline",
  "encoding": "utf8",
  "content": "185632|1500|2000|8|false|false"
}
```

Example - Inline XML:

```
{
  "mode": "inline",
  "encoding": "utf8",
  "content": "<?xml version=\"1.0\"?><root><data>value</data></root>"
}
```

5.3 Remote Mode (Required for PDF/Binary, Optional for Text)

Use for binary content or large text content fetched from a URL.

```
{
  "mode": "remote",
  "downloadUrl": "https://api.example.com/documents/123",
  "httpMethod": "GET",
  "headers": {
    "X-API-Key": "abc123",
    "Authorization": "Bearer token..."
  }
}
```

Field	Type	Required	Description
`mode`	string	YES	Must be `"remote"`
`downloadUrl`	string	YES	Full HTTPS URL to fetch content
`httpMethod`	string	NO	HTTP method (default: `"GET"`)
`headers`	object	NO	HTTP headers for authentication

5.4 Download URL Requirements

CRITICAL: The `downloadUrl` endpoint MUST:

1. Return **raw bytes** directly (not wrapped in JSON)
2. Set appropriate `Content-Type` header (e.g., `application/pdf`)
3. Support the specified `httpMethod` (usually GET)

CORRECT Implementation:

```
GET /api/documents/123
Authorization: Bearer token...

Response:
HTTP/1.1 200 OK
Content-Type: application/pdf
Content-Length: 45678

%PDF-1.4
... (raw PDF bytes)
```

INCORRECT Implementation (FORBIDDEN):

```
GET /api/documents/123

Response:
HTTP/1.1 200 OK
Content-Type: application/json

{
  "id": 123,
  "value": "JVBERi0xLjQK..."  <-- Base64 encoded - WRONG!
}
```

---

6. Object Structure

6.1 Single Object Format

Each item to be signed is represented as an "object" with the following structure:

```
{
  "id": "unique-identifier",
  "dataType": "...",
  "content": { ... },
  "pdfOptions": { ... },
  "xmlOptions": { ... },
  "upload": { ... },
  "callbacks": { ... }
}
```

6.2 Object Fields Reference

Field	Type	Required	Description
`id`	string	YES	Unique identifier for this object within the request
`dataType`	string	YES	One of: `text`, `xml`, `json`, `pdf`, `binary`
`content`	object	YES	Content definition (see Section 5)
`pdfOptions`	object	IF pdf	Required if `dataType` is `"pdf"`
`xmlOptions`	object	IF xml	Required if `dataType` is `"xml"`
`upload`	object	YES	Where to send signed content
`callbacks`	object	YES	Status notification endpoints

6.3 PDF Options

Required when `dataType` is `"pdf"`. Omit entirely for other types.

```
{
  "pdfOptions": {
    "label": "Student Grade Report"
  }
}
```

Field	Type	Required	Description
`label`	string	YES	Visible label text in the PDF signature

6.4 XML Options

Required when `dataType` is `"xml"`. Omit entirely for other types.

```
{
  "xmlOptions": {
    "xpath": "//Document/Signature",
    "idAttribute": "Id"
  }
}
```

Field	Type	Required	Description
`xpath`	string	YES	XPath to the signature location

Field	Type	Required	Description
`idAttribute`	string	NO	ID attribute name for reference

7. Object Grouping

7.1 When to Use Grouping

MANDATORY when multiple objects share the same:

- `dataType`
- `callbacks` configuration
- `upload` configuration

Purpose: Reduce request size and enforce consistency.

7.2 Group Structure

7.2.1 Inline Mode (for text/xml/json)

When `mode` is `"inline"`, each object provides its own `content`:

```
{
  "objectGroups": [
    {
      "dataType": "text",
      "mode": "inline",
      "callbacks": { ... },
      "upload": { ... },
      "objects": [
        { "id": "grade-001", "content": { "encoding": "utf8", "value": "..." } },
        { "id": "grade-002", "content": { "encoding": "utf8", "value": "..." } }
      ]
    }
  ]
}
```

7.2.2 Remote Mode (REQUIRED for pdf/binary)

When `mode` is `"remote"`, the `downloadUrl` is defined **once at the group level** with a **mandatory `<objectId>` placeholder**. Each object provides **only its `id`** — the native host constructs the final URL by substituting `<objectId>`.

```
{
  "objectGroups": [
    {
      "dataType": "pdf",
      "mode": "remote",
      "downloadUrl": "https://api.example.com/documents?id=<objectId>",
      "downloadHeaders": {
        "X-API-Key": "abc123"
      },
      "pdfOptions": { "label": "Official Document" },
      "callbacks": { ... },
      "upload": { ... },
      "objects": [
        { "id": "doc-001" },
        { "id": "doc-002" },
        { "id": "doc-003" }
      ]
    }
  ]
}
```

URL Construction Rule:

- The `<objectId>` placeholder in `downloadUrl` is **MANDATORY** when `mode` is `"remote"`
- The native host replaces `<objectId>` with each object's `id` value
- Example: `downloadUrl: "https://api.example.com/documents?id=<objectId>"` with `id: "doc-001"` becomes `https://api.example.com/documents?id=doc-001`

Why this design:

- Signing 500 PDFs no longer requires 500 separate URL definitions
- Reduces request payload size dramatically
- Enforces consistent URL patterns across a batch

7.3 Group Fields Reference

Field	Type	Required	Description
`dataType`	string	YES	Shared data type for all objects in group
`mode`	string	YES	`"inline"` or `"remote"` — determines how content is accessed
`downloadUrl`	string	IF remote	URL template with `<objectId>` placeholder (required when mode is remote)
`downloadHeaders`	object	NO	HTTP headers for download requests (used when mode is remote)
`pdfOptions`	object	IF pdf	Shared PDF options (if dataType is pdf)
`xmlOptions`	object	IF xml	Shared XML options (if dataType is xml)
`callbacks`	object	YES	Shared callbacks configuration
`upload`	object	YES	Shared upload configuration
`objects`	array	YES	Array of objects (structure depends on mode — see 7.4)

7.4 Object Within Group

The structure of each object depends on the group's `mode`:

When `mode: "inline"` (text/xml/json)

Each object provides `id` and `content`:

```
{
  "id": "grade-001",
  "content": {
    "encoding": "utf8",
    "value": "185632|1500|2000|8|false|false"
  }
}
```

Field	Type	Required	Description
`id`	string	YES	Unique identifier for this object
`content.encoding`	string	YES	Must be `"utf8"`
`content.value`	string	YES	The actual text content to sign

When `mode: "remote"` (pdf/binary, or large text)

Each object provides **only** `id` — the URL is constructed from the group's `downloadUrl` template:

```
{
  "id": "doc-001"
}
```

Field	Type	Required	Description
`id`	string	YES	Unique identifier — substituted into `<objectId>` placeholder

7.5 Critical Rules

Rule 1: objects XOR objectGroups

A request MUST contain **either** `objects` OR `objectGroups`, **never both**.

Scenario	Use
Single item	`objects` array with one element
Multiple items, different configs	`objects` array
Multiple items, same config	`objectGroups` array

Scenario	Use
Mixed configs	Multiple groups in `objectGroups`

Rule 2: mode Determines Object Structure

Group Mode	Object Contains	downloadUrl Location
`"inline"`	`id` + `content`	N/A
`"remote"`	`id` only	Group level (with `<objectId>` placeholder)

Rule 3: PDF/Binary MUST Use Remote Mode

When `dataType` is `"pdf"` or `"binary"`, `mode` MUST be `"remote"`. Inline binary is forbidden.

---

8. Delivery and Callbacks

8.1 Upload Configuration

Defines where the native host sends signed content.

```
{
  "upload": {
    "uploadUrl": "https://api.example.com/signed-document?id=<objectId>",
    "httpMethod": "POST",
    "headers": {
      "X-API-Key": "abc123"
    },
    "signedContentType": "pdf"
  }
}
```

Field	Type	Required	Description
`uploadUrl`	string	YES	Full HTTPS URL for upload (with `<objectId>` placeholder)
`httpMethod`	string	NO	HTTP method (default: `"POST"`)
`headers`	object	NO	HTTP headers for authentication
`signedContentType`	string	YES	Type of signed content (see below)

URL Construction Rule:

- The `<objectId>` placeholder in `uploadUrl` is **MANDATORY**
- The native host replaces `<objectId>` with each object's `id` value
- Example: `uploadUrl: "https://api.example.com/signed-document?id=<objectId>"` with `id: "report-001"` becomes `https://api.example.com/signed-document?id=report-001`

8.2 Signed Content Types

signedContentType	Description
`"string"`	Signed hash/digest of text content
`"pdf"`	Signed PDF document bytes
`"xml"`	XML document with embedded signature
`"binary"`	Signed binary bytes

8.3 Upload Request Format

The native host sends a **raw bytes POST** to the constructed URL:

```
POST /signed-document?id=report-001 HTTP/1.1
Host: api.example.com
Content-Type: application/pdf
X-API-Key: abc123
Content-Length: 125432

%PDF-1.4
... (signed PDF bytes)
```

Content-Type is determined by `signedContentType`:

signedContentType	Content-Type Header
`"string"`	`text/plain`
`"pdf"`	`application/pdf`
`"xml"`	`application/xml`
`"binary"`	`application/octet-stream`

Backend Requirement: Your upload endpoint MUST:

- Accept the `id` query parameter to identify which object is being uploaded
- Accept raw bytes in the request body (not multipart)
- Return HTTP 2xx on success

8.4 Callback Configuration

Defines endpoints for status notifications.

```
{
  "callbacks": {
    "onSuccess": "https://api.example.com/status/success",
    "onError": "https://api.example.com/status/error",
    "progress": "https://api.example.com/status/progress",
    "headers": {
      "X-API-Key": "abc123"
    }
  }
}
```

Field	Type	Required	Description
`onSuccess`	string	YES	URL called after successful signing + upload
`onError`	string	YES	URL called on any failure
`progress`	string	NO	URL for progress updates during signing
`headers`	object	NO	HTTP headers for callback requests

> **Note**: The request-level `metadata` object (see Section 9.4) is automatically echoed in all callback payloads. There is no separate metadata field in the callbacks configuration.

8.5 Callback Payloads

Progress Callback (Native Host → Server)

```
POST /status/progress
Content-Type: application/json
X-API-Key: abc123

{
  "objectId": "report-001",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "signing",
  "percentComplete": 50,
  "message": "Signing document...",
  "metadata": {
    "businessId": 12345,
    "courseCode": "CS101"
  }
}
```

Field	Type	Description
`objectId`	string	ID of the object being processed
`requestId`	string	Request ID from original request
`status`	string	`"signing"` or `"uploading"`
`percentComplete`	number	0-100
`message`	string	Optional status message

Field	Type	Description
`metadata`	object	Echoed from request-level `metadata` (Section 9.4)

Success Callback (Native Host → Server)

```
POST /status/success
Content-Type: application/json
X-API-Key: abc123

{
  "objectId": "report-001",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "completed",
  "uploadResult": {
    "statusCode": 200,
    "responseBody": "{\"message\":\"OK\"}"
  },
  "timestamp": "2026-01-20T10:30:00Z",
  "metadata": {
    "businessId": 12345,
    "courseCode": "CS101"
  }
}
```

Field	Type	Description
`objectId`	string	ID of the object that was signed
`requestId`	string	Request ID from original request
`status`	string	Always `"completed"` for success callbacks
`uploadResult`	object	Result from the upload endpoint (see below)
`timestamp`	string	ISO 8601 timestamp of completion
`metadata`	object	Echoed from request-level `metadata` (Section 9.4)

`uploadResult` Object: The native host constructs this object by capturing the HTTP response from the upload endpoint.

Field	Type	Description
`statusCode`	number	HTTP status code returned by upload endpoint (e.g., 200, 201)
`responseBody`	string	Raw response body as string (JSON-stringified if the endpoint returned JSON)

Error Callback (Native Host → Server)

```
POST /status/error
Content-Type: application/json
X-API-Key: abc123

{
  "objectId": "report-001",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "failed",
  "error": {
    "code": "SIGN_FAILED",
    "message": "HSM communication timeout"
  },
  "timestamp": "2026-01-20T10:30:00Z",
  "metadata": {
    "businessId": 12345,
    "courseCode": "CS101"
  }
}
```

Field	Type	Description
`objectId`	string	ID of the object that failed
`requestId`	string	Request ID from original request
`status`	string	Always `"failed"` for error callbacks
`error`	object	Error details (see below)
`timestamp`	string	ISO 8601 timestamp of failure
`metadata`	object	Echoed from request-level `metadata` (Section 9.4)

`error` Object: The native host constructs this object with details about what went wrong.

Field	Type	Description
`code`	string	Error code from Section 13.1 (e.g., `SIGN_FAILED`, `DOWNLOAD_FAILED`, `UPLOAD_FAILED`)
`message`	string	Human-readable description of the error

8.6 Callback Response Requirements

The callbacks endpoints MUST return HTTP 2xx. If the progress endpoint returns non-2xx, the native host:

1. Cancels signing for that object
2. Reports error with code `PROGRESS_ENDPOINT_FAILED`
3. Calls `onError` endpoint

---

9. Complete Request Schema

9.1 Request Structure (Web App → Extension)

```
{
  "protocolVersion": "1.0",
  "requestId": "<uuid>",
  "correlationId": "<optional-tracing-id>",
  "appId": "<caller-app-identifier>",
  "cert": {
    "certId": "<certificate-serial-or-thumbprint>",
    "label": "<optional-display-label>"
  },
  "metadata": {
    "<any>": "<caller-defined-context>"
  },
  "objects": [ ... ]
}
```

OR with grouping:

```
{
  "protocolVersion": "1.0",
  "requestId": "<uuid>",
  "correlationId": "<optional-tracing-id>",
  "appId": "<caller-app-identifier>",
  "cert": {
    "certId": "<certificate-serial-or-thumbprint>",
    "label": "<optional-display-label>"
  },
  "metadata": {
    "<any>": "<caller-defined-context>"
  },
  "objectGroups": [ ... ]
}
```

9.2 Root Fields Reference

Field	Type	Required	Description
`protocolVersion`	string	YES	Must be `"1.0"`
`requestId`	string	YES	UUID generated by caller
`correlationId`	string	NO	Optional cross-system tracing ID
`appId`	string	YES	Identifier of the calling application
`cert`	object	YES	Certificate selection criteria
`metadata`	object	YES	Caller-defined context (can be empty `{}`)

Field	Type	Required	Description
`objects`	array	*	Array of objects (mutually exclusive with objectGroups)
`objectGroups`	array	*	Array of object groups (mutually exclusive with objects)

* One of `objects` or `objectGroups` is required, but not both.

9.3 Certificate Selection

```
{
  "cert": {
    "certId": "ABC123456789",
    "label": "My Signing Certificate"
  }
}
```

Field	Type	Required	Description
`certId`	string	YES	Certificate serial number or thumbprint
`label`	string	NO	Display label for user prompts

9.4 Metadata

Opaque object echoed in responses. Use for caller-specific context.

```
{
  "metadata": {
    "batchId": "batch-2026-001",
    "userId": "user@example.com",
    "department": "Engineering"
  }
}
```

---

10. Complete Response Schema

10.1 Response Structure (Extension → Web App)

```
{
  "protocolVersion": "1.0",
  "requestId": "<uuid-from-request>",
  "status": "ok" | "error" | "partial",
  "results": [ ... ],
  "errors": [ ... ],
  "metadata": { ... },
  "metrics": {
    "totalMs": 1234
  }
}
```

10.2 Root Fields Reference

Field	Type	Required	Description
`protocolVersion`	string	YES	Echoed from request
`requestId`	string	YES	Echoed from request
`status`	string	YES	Overall status (see below)
`results`	array	YES	Per-object results
`errors`	array	NO	Array of errors (if any)
`metadata`	object	YES	Echoed from request
`metrics`	object	NO	Performance metrics

10.3 Status Values

Status	Meaning
`"ok"`	All objects signed and uploaded successfully
`"partial"`	Some objects succeeded, some failed
`"error"`	All objects failed or request-level error

10.4 Result Object

```
  {
    "id": "report-001",
    "status": "ok",
    "uploadResult": {
      "statusCode": 200,
      "responseBody": "{\"message\":\"Uploaded successfully\"}"
    },
    "callbackResult": {
      "status": "sent",
      "endpoint": "onSuccess",
      "timestamp": "2026-01-20T10:30:00Z"
    }
  }
```

Field	Type	Description
`id`	string	Object ID from request

Field	Type	Description
`status`	string	`"ok"` or `"error"`
`uploadResult`	object	Upload endpoint response
`callbackResult`	object	Callback delivery status

10.5 Error Object

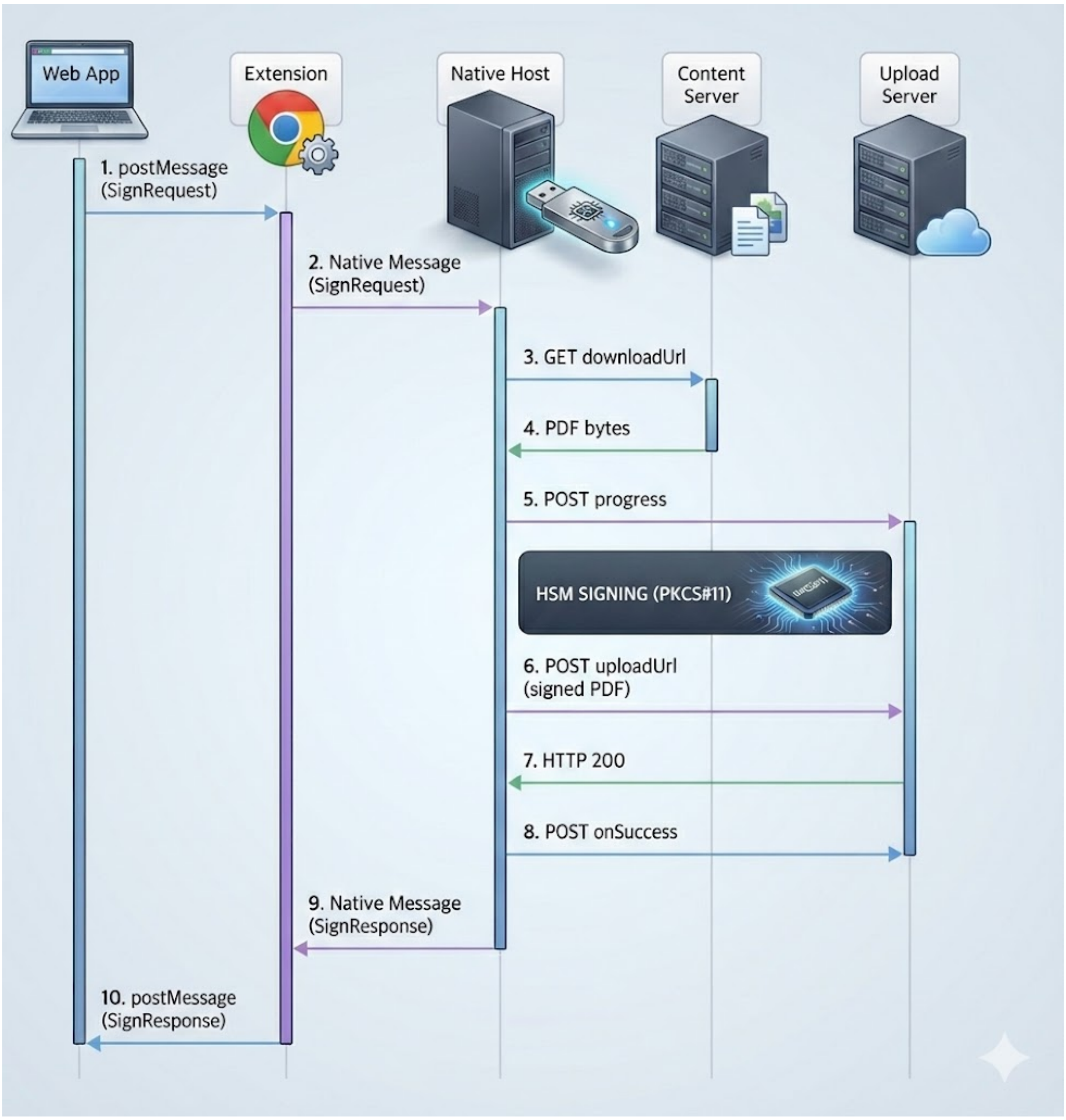
```json
{
  "id": "report-002",
  "code": "DOWNLOAD_FAILED",
  "message": "HTTP 404 from downloadUrl"
}
```

Field	Type	Description
`id`	string	Object ID (omit for request-level errors)
`code`	string	Error code (see Section 13)
`message`	string	Human-readable description

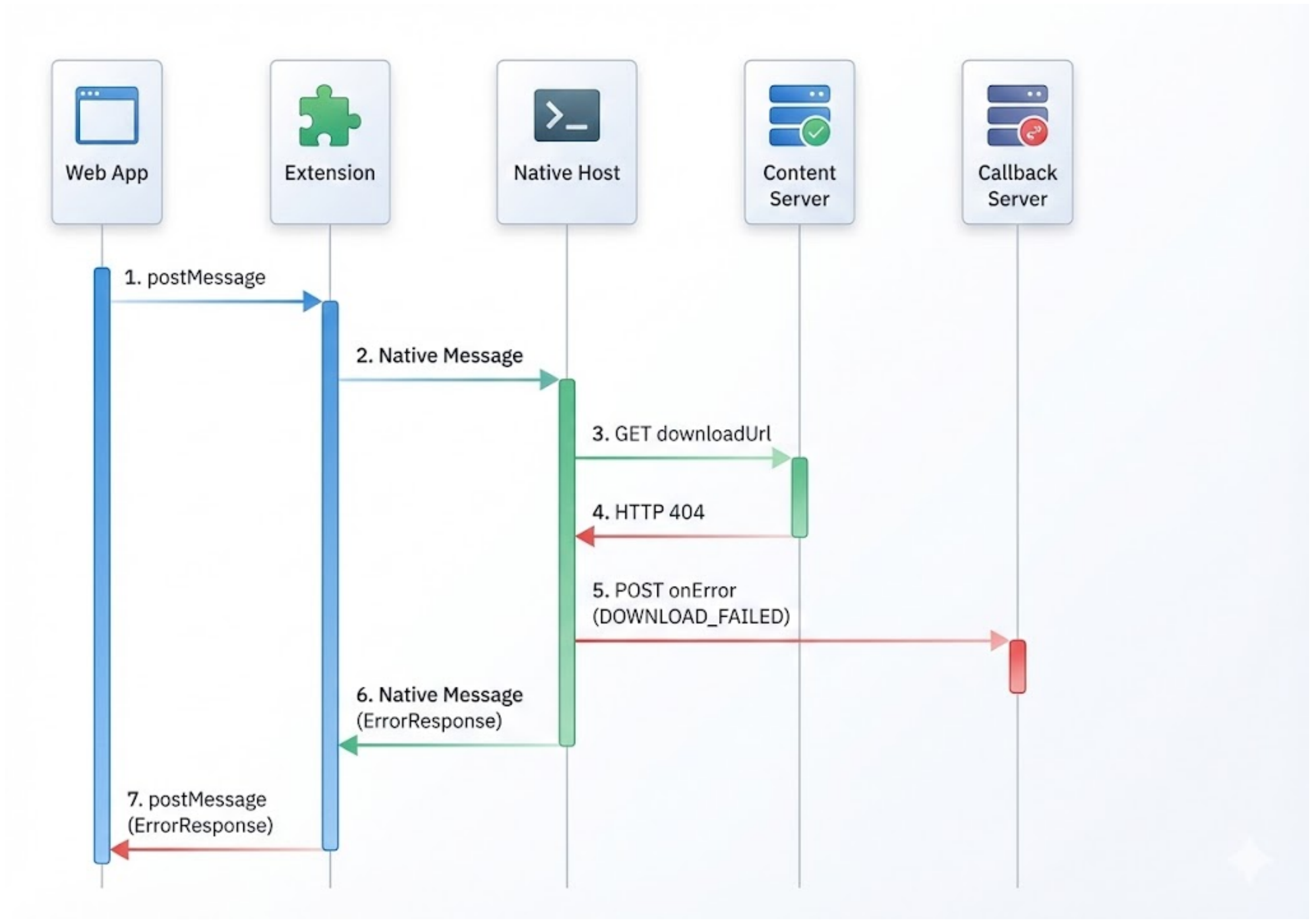
---

11. Message Flow Diagrams

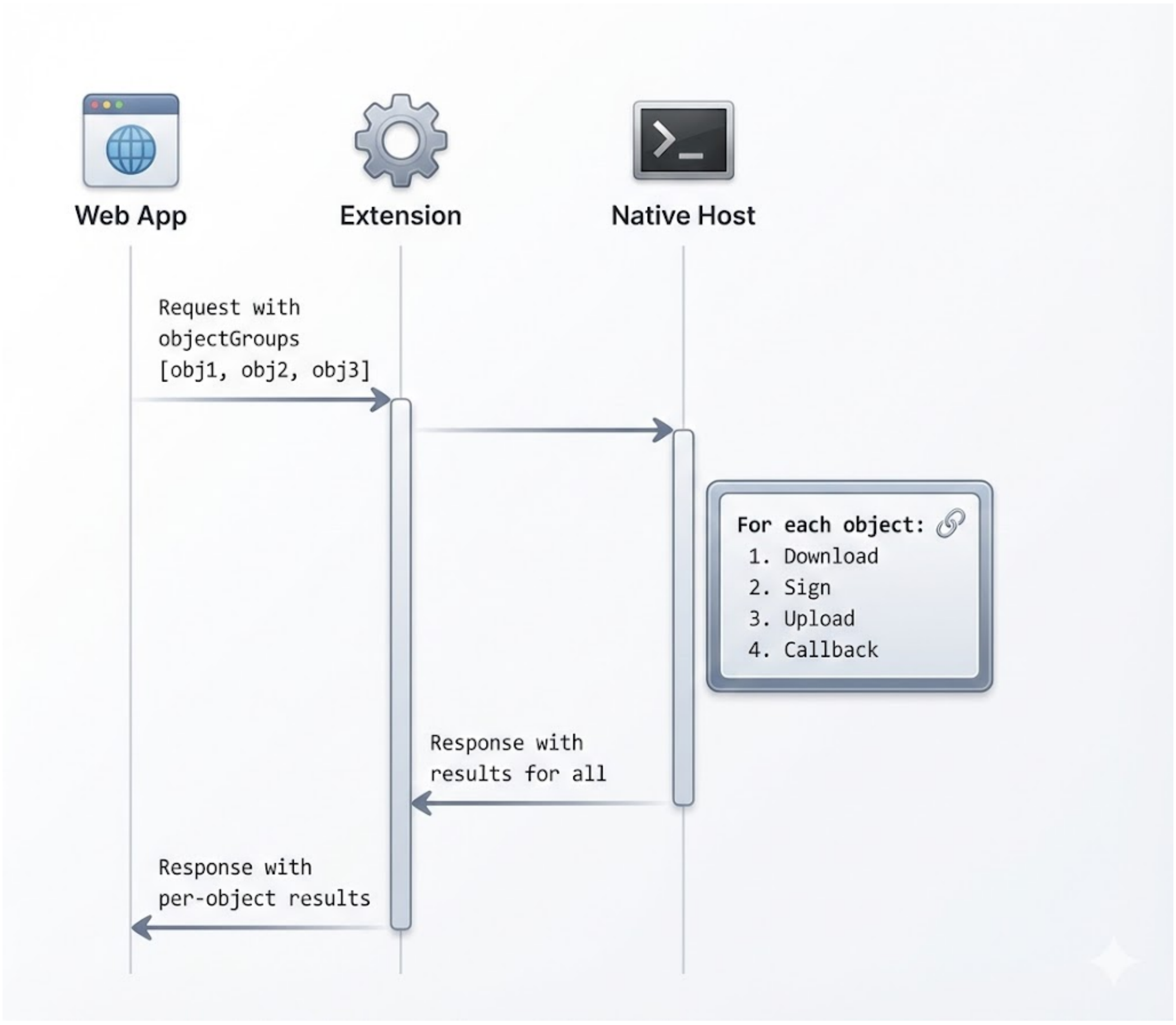
11.1 Successful Single PDF Signing Flow


Web App
Extension
Native Host
Content Server
Upload Server
1. postMessage (SignRequest)
2. Native Message (SignRequest)
3. GET downloadUrl
4. PDF bytes
5. POST progress
HSM SIGNING (PKCS#11)
6. POST uploadUrl (signed PDF)
7. HTTP 200
8. POST onSuccess
9. Native Message (SignResponse)
10. postMessage (SignResponse)

11.2 Error Flow (Download Failed)



11.3 Batch Signing Flow (Multiple Objects)


Web App
Extension
Native Host
Request with objectGroups [obj1, obj2, obj3]
For each object:
1. Download
2. Sign
3. Upload
4. Callback
Response with results for all
Response with per-object results

---

12. Full Worked Examples

12.1 Example A: Sign a Single PDF Document

Scenario: A web application needs to sign a student report PDF.

Step 1: Web App Sends Request

```
// Web Application Code
const request = {
  protocolVersion: "1.0",
  requestId: "550e8400-e29b-41d4-a716-446655440000",
  appId: "student-portal",
  cert: {
    certId: "ABC123456789",
    label: "University Signing Certificate"
  },
  metadata: {
    studentId: "STU-2026-001",
    documentType: "grade-report"
  },
  objects: [
    {
      id: "report-001",
      dataType: "pdf",
      content: {
        mode: "remote",
        downloadUrl: "https://api.university.edu/reports/2026/STU-001/download",
        httpMethod: "GET",
        headers: {
          "X-API-Key": "university-api-key-12345",
          "Authorization": "Bearer eyJhbGciOiJIUzI1NiIs..."
        }
      },
      pdfOptions: {
        label: "Official Grade Report - University of Example"
      },
      upload: {
        uploadUrl: "https://api.university.edu/signed-document?id=<objectId>",
        httpMethod: "POST",
        headers: {
          "X-API-Key": "university-api-key-12345"
        },
        signedContentType: "pdf"
      },
      callbacks: {
        onSuccess: "https://api.university.edu/signing/status/success",
        onError: "https://api.university.edu/signing/status/error",
        progress: "https://api.university.edu/signing/status/progress",
        headers: {
          "X-API-Key": "university-api-key-12345"
        }
      }
    }
  ]
};

// Send to extension
window.postMessage({
  type: "HSM_SIGN_REQUEST",
  data: request
}, "*");
```

Step 2: Extension Validates and Forwards

The extension:

1. Checks `event.origin` against allowlist
2. Validates request schema
3. Forwards unchanged to native host via Chrome Native Messaging

```
// Message sent to Native Host (stdin)
{
  "protocolVersion": "1.0",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "appId": "student-portal",
  "cert": {
    "certId": "ABC123456789",
    "label": "University Signing Certificate"
  },
  "metadata": {
    "studentId": "STU-2026-001",
    "documentType": "grade-report"
  },
  "objects": [
    {
      "id": "report-001",
      "dataType": "pdf",
      "content": {
        "mode": "remote",
        "downloadUrl": "https://api.university.edu/reports/2026/STU-001/download",
        "httpMethod": "GET",
        "headers": {
          "X-API-Key": "university-api-key-12345",
          "Authorization": "Bearer eyJhbGciOiJIUzI1NiIs..."
        }
      },
      "pdfOptions": {
        "label": "Official Grade Report - University of Example"
      },
      "upload": {
        "uploadUrl": "https://api.university.edu/signed-document?id=<objectId>",
        "httpMethod": "POST",
        "headers": {
          "X-API-Key": "university-api-key-12345"
        },
        "signedContentType": "pdf"
      },
      "callbacks": {
        "onSuccess": "https://api.university.edu/signing/status/success",
        "onError": "https://api.university.edu/signing/status/error",
        "progress": "https://api.university.edu/signing/status/progress",
        "headers": {
          "X-API-Key": "university-api-key-12345"
        }
      }
    }
  ]
}
```

Step 3: Native Host Downloads Content

```
GET /reports/2026/STU-001/download HTTP/1.1
Host: api.university.edu
X-API-Key: university-api-key-12345
Authorization: Bearer eyJhbGciOiJIUzI1NiIs...

---

HTTP/1.1 200 OK
Content-Type: application/pdf
Content-Length: 125432

%PDF-1.4
... (raw PDF bytes)
```

Step 4: Native Host Reports Progress

```
POST /signing/status/progress HTTP/1.1
Host: api.university.edu
Content-Type: application/json
X-API-Key: university-api-key-12345

{
  "objectId": "report-001",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "signing",
  "percentComplete": 0,
  "message": "Starting signature process",
  "metadata": {
    "studentId": "STU-2026-001",
    "documentType": "grade-report"
  }
}

---

HTTP/1.1 200 OK
```

Step 5: Native Host Signs via PKCS#11

(Internal HSM operation - no network traffic)

Step 6: Native Host Uploads Signed Document

```
POST /signed-document?id=report-001 HTTP/1.1
Host: api.university.edu
Content-Type: application/pdf
X-API-Key: university-api-key-12345
```

```
Content-Length: 125432

%PDF-1.4
... (signed PDF bytes with embedded digital signature)

---

HTTP/1.1 200 OK
Content-Type: application/json

{"status": "received", "documentId": "DOC-2026-00123"}
```

Step 7: Native Host Calls Success Callback

```
POST /signing/status/success HTTP/1.1
Host: api.university.edu
Content-Type: application/json
X-API-Key: university-api-key-12345

{
  "objectId": "report-001",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "completed",
  "uploadResult": {
    "statusCode": 200,
    "responseBody": "{\"status\": \"received\", \"documentId\": \"DOC-2026-
00123\"}"
  },
  "timestamp": "2026-01-20T10:30:45Z",
  "metadata": {
    "studentId": "STU-2026-001",
    "documentType": "grade-report"
  }
}
```

Step 8: Native Host Returns Response to Extension

```
{
  "protocolVersion": "1.0",
  "requestId": "550e8400-e29b-41d4-a716-446655440000",
  "status": "ok",
  "results": [
    {
      "id": "report-001",
      "status": "ok",
      "uploadResult": {
        "statusCode": 200,
        "responseBody": "{\"status\": \"received\", \"documentId\": \"DOC-2026-
00123\"}"
      },
      "callbackResult": {
        "status": "sent",
        "endpoint": "onSuccess",
        "timestamp": "2026-01-20T10:30:45Z"
      }
    }
  ],
  "metadata": {
    "studentId": "STU-2026-001",
    "documentType": "grade-report"
  },
  "metrics": {
    "totalMs": 2345
  }
}
```

Step 9: Extension Returns Response to Web App

```
// Web App receives via postMessage listener
window.addEventListener("message", (event) => {
  if (event.data.type === "HSM_SIGN_RESPONSE") {
    const response = event.data.data;
    // response contains the exact JSON from Step 8

    if (response.status === "ok") {
      console.log("All documents signed successfully!");
      // The signed document is already uploaded to the server
      // The callback has already notified our backend
    }
  }
});
```

12.2 Example B: Sign Multiple Text Items (Grades Batch)

Scenario: Sign 3 student grade strings in a single request.

Request (Web App → Extension)

```
{
  "protocolVersion": "1.0",
  "requestId": "661f9511-f3a0-42e5-b817-557766550001",
  "appId": "grades-system",
  "cert": {
    "certId": "CERT-GRADES-2026"
  },
  "metadata": {
    "batchId": "BATCH-2026-CS101-FINAL",
    "courseCode": "CS101",
    "semester": "2025-2026-S1",
    "professorId": "PROF-001"
  },
  "objectGroups": [
    {
      "dataType": "text",
      "mode": "inline",
      "callbacks": {
        "onSuccess": "https://api.grades.edu/batches/BATCH-2026-CS101-FINAL/item-
success",
        "onError": "https://api.grades.edu/batches/BATCH-2026-CS101-FINAL/item-
error",
        "progress": "https://api.grades.edu/batches/BATCH-2026-CS101-FINAL/item-
progress",
        "headers": {
          "X-API-Key": "grades-api-key-67890",
          "X-Batch-Token": "batch-auth-token-xyz"
        }
      },
      "upload": {
        "uploadUrl": "https://api.grades.edu/signed-grade?id=<objectId>",
        "httpMethod": "POST",
        "headers": {
          "X-API-Key": "grades-api-key-67890",
          "X-Batch-Token": "batch-auth-token-xyz"
        },
        "signedContentType": "string"
      },
      "objects": [
        {
          "id": "grade-STU001",
          "content": {
            "encoding": "utf8",
            "value": "STU001|CS101|2026-S1|A|95|PROF-001|2026-01-15"
          }
        },
        {
          "id": "grade-STU002",
          "content": {
            "encoding": "utf8",
            "value": "STU002|CS101|2026-S1|B+|87|PROF-001|2026-01-15"
          }
        },
        {
          "id": "grade-STU003",
          "content": {
            "encoding": "utf8",
            "value": "STU003|CS101|2026-S1|A-|91|PROF-001|2026-01-15"
          }
        }
      ]
    }
  ]
}
```

Key Points:

- `mode: "inline"` at group level — objects contain `id` + `content`
- All 3 grades share the same `callbacks` and `upload` configuration
- `uploadUrl` uses `<objectId>` placeholder — native host uploads to `https://api.grades.edu/signed-grade?id=grade-STU001`
- `signedContentType: "string"` indicates the upload will be a signature hash

Native Host Upload (Per Grade)

For grade-STU001:

```
POST /signed-grade?id=grade-STU001 HTTP/1.1
Host: api.grades.edu
Content-Type: text/plain
X-API-Key: grades-api-key-67890
X-Batch-Token: batch-auth-token-xyz

SHA256:a1b2c3d4e5f6...BASE64_SIGNATURE_HERE...
```

Response (Extension → Web App)

```
{
  "protocolVersion": "1.0",
  "requestId": "661f9511-f3a0-42e5-b817-557766550001",
  "status": "ok",
  "results": [
    {
      "id": "grade-STU001",
      "status": "ok",
      "uploadResult": { "statusCode": 200, "responseBody": "{\"gradeId\":\"grade-STU001\",\"status\":\"signed\"}" },
      "callbackResult": { "status": "sent", "endpoint": "onSuccess", "timestamp": "2026-01-20T11:00:01Z" }
    },
    {
      "id": "grade-STU002",
      "status": "ok",
      "uploadResult": { "statusCode": 200, "responseBody": "{\"gradeId\":\"grade-STU002\",\"status\":\"signed\"}" },
      "callbackResult": { "status": "sent", "endpoint": "onSuccess", "timestamp": "2026-01-20T11:00:02Z" }
    },
    {
      "id": "grade-STU003",
      "status": "ok",
      "uploadResult": { "statusCode": 200, "responseBody": "{\"gradeId\":\"grade-
STU003\",\"status\":\"signed\"}" },
      "callbackResult": { "status": "sent", "endpoint": "onSuccess", "timestamp":
"2026-01-20T11:00:03Z" }
    }
  ],
  "metadata": {
    "batchId": "BATCH-2026-CS101-FINAL",
    "courseCode": "CS101",
    "semester": "2025-2026-S1",
    "professorId": "PROF-001"
  },
  "metrics": {
    "totalMs": 4521
  }
}
```

12.3 Example C: Mixed Batch (PDFs + Text)

Scenario: Sign 2 PDF certificates and 3 text honor strings in one request.

```
{
  "protocolVersion": "1.0",
  "requestId": "772f0622-g4b1-53f6-c928-668877660002",
  "appId": "graduation-system",
  "cert": {
    "certId": "CERT-GRADUATION-2026"
  },
  "metadata": {
    "ceremony": "GRAD-2026-SPRING",
    "department": "Computer Science"
  },
  "objectGroups": [
    {
      "dataType": "pdf",
      "mode": "remote",
      "downloadUrl": "https://api.graduation.edu/certs/pdf?id=<objectId>",
      "downloadHeaders": {
        "X-API-Key": "grad-key-111"
      },
      "pdfOptions": {
        "label": "Official Graduation Certificate"
      },
      "callbacks": {
        "onSuccess": "https://api.graduation.edu/certs/signed",
        "onError": "https://api.graduation.edu/certs/error",
        "headers": { "X-API-Key": "grad-key-111" }
      },
      "upload": {
        "uploadUrl": "https://api.graduation.edu/signed-cert?id=<objectId>",
        "httpMethod": "POST",
        "headers": { "X-API-Key": "grad-key-111" },
        "signedContentType": "pdf"
      },
      "objects": [
        { "id": "cert-STU001" },
        { "id": "cert-STU002" }
      ]
    },
    {
      "dataType": "text",
      "mode": "inline",
      "callbacks": {
        "onSuccess": "https://api.graduation.edu/honors/signed",
        "onError": "https://api.graduation.edu/honors/error",
        "headers": { "X-API-Key": "grad-key-111" }
      },
      "upload": {
        "uploadUrl": "https://api.graduation.edu/signed-honors?id=<objectId>",
        "httpMethod": "POST",
        "headers": { "X-API-Key": "grad-key-111" },
        "signedContentType": "string"
      },
      "objects": [
        { "id": "honors-STU001", "content": { "encoding": "utf8", "value":
"STU001|SUMMA_CUM_LAUDE|3.95|2026" } },
        { "id": "honors-STU002", "content": { "encoding": "utf8", "value":
"STU002|MAGNA_CUM_LAUDE|3.82|2026" } },
        { "id": "honors-STU003", "content": { "encoding": "utf8", "value":
"STU003|CUM_LAUDE|3.65|2026" } }
      ]
    }
  ]
}
```

Key Points:

- **PDF Group** (`mode: "remote"`):
  - `downloadUrl` at group level with `<objectId>` placeholder
  - Objects contain **only** `id` — no content definition needed
  - Native host constructs download URL: `https://api.graduation.edu/certs/pdf?id=cert-STU001`
  - Native host constructs upload URL: `https://api.graduation.edu/signed-cert?id=cert-STU001`
- **Text Group** (`mode: "inline"`):
  - Objects contain `id` + `content` with actual data
  - Native host constructs upload URL: `https://api.graduation.edu/signed-honors?id=honors-STU001`
- Each group has different `callbacks` and `upload` configurations

- `pdfOptions` only appears in the PDF group
- Request-level `metadata` (ceremony, department) is echoed in all callbacks

---

12.4 Example D: Error Response (Partial Failure)

Scenario: 3 documents requested, 1 fails to download.

Response (Extension → Web App)

```
{
  "protocolVersion": "1.0",
  "requestId": "883g1733-h5c2-64g7-d039-779988770003",
  "status": "partial",
  "results": [
    {
      "id": "doc-001",
      "status": "ok",
      "uploadResult": { "statusCode": 200, "responseBody": "OK" },
      "callbackResult": { "status": "sent", "endpoint": "onSuccess", "timestamp":
"2026-01-20T12:00:01Z" }
    },
    {
      "id": "doc-003",
      "status": "ok",
      "uploadResult": { "statusCode": 200, "responseBody": "OK" },
      "callbackResult": { "status": "sent", "endpoint": "onSuccess", "timestamp":
"2026-01-20T12:00:03Z" }
    }
  ],
  "errors": [
    {
      "id": "doc-002",
      "code": "DOWNLOAD_FAILED",
      "message": "HTTP 404: Document not found at downloadUrl"
    }
  ],
  "metadata": { "batchId": "batch-123" },
  "metrics": { "totalMs": 3456 }
}
```

Note: The native host also called `onError` for `doc-002`:

```
POST /callback/error
{
  "objectId": "doc-002",
  "requestId": "883g1733-h5c2-64g7-d039-779988770003",
  "status": "failed",
  "error": {
    "code": "DOWNLOAD_FAILED",
    "message": "HTTP 404: Document not found at downloadUrl"
  },
  "timestamp": "2026-01-20T12:00:02Z",
  "metadata": { "batchId": "batch-123" }
}
```

12.5 Example E: Bulk PDF Signing (500 Documents)

Scenario: Sign 500 student report PDFs in a single efficient request.

```
{
  "protocolVersion": "1.0",
  "requestId": "994h2844-i6d3-75h8-e140-880099880004",
  "appId": "report-system",
  "cert": { "certId": "CERT-REPORTS-2026" },
  "metadata": {
    "batchId": "REPORTS-2026-SEMESTER1",
    "totalDocuments": 500
  },
  "objectGroups": [
    {
      "dataType": "pdf",
      "mode": "remote",
      "downloadUrl": "https://api.reports.edu/documents/download?id=<objectId>",
      "downloadHeaders": {
        "X-API-Key": "reports-api-key-99999",
        "Authorization": "Bearer batch-token-xyz"
      },
      "pdfOptions": {
        "label": "Official Student Report"
      },
      "callbacks": {
        "onSuccess": "https://api.reports.edu/batch/REPORTS-2026-
SEMESTER1/success",
        "onError": "https://api.reports.edu/batch/REPORTS-2026-SEMESTER1/error",
        "progress": "https://api.reports.edu/batch/REPORTS-2026-
SEMESTER1/progress",
        "headers": { "X-API-Key": "reports-api-key-99999" }
      },
      "upload": {
        "uploadUrl": "https://api.reports.edu/signed-document?id=<objectId>",
        "httpMethod": "POST",
        "headers": { "X-API-Key": "reports-api-key-99999" },
        "signedContentType": "pdf"
      },
      "objects": [
        { "id": "report-STU001" },
        { "id": "report-STU002" },
        { "id": "report-STU003" },
        { "id": "report-STU004" },
        { "id": "report-STU005" }
      ]
    }
  ]
}
```

Native Host Processing: For each object, the native host:

1. Constructs download URL: `https://api.reports.edu/documents/download?id=report-STU001`
2. Sends GET with `downloadHeaders`
3. Receives raw PDF bytes
4. Signs via PKCS#11
5. Constructs upload URL: `https://api.reports.edu/signed-document?id=report-STU001`
6. POSTs raw signed bytes with `Content-Type: application/pdf`
7. Calls appropriate callback

Backend API Requirements:

Your `/documents/download` endpoint MUST:

- Accept query parameter `id`
- Return raw PDF bytes (not JSON-wrapped)
- Set `Content-Type: application/pdf`

Your `/signed-document` endpoint MUST:

- Accept query parameter `id` to identify the document
- Accept POST with raw bytes in body (not multipart/form-data)
- Handle `Content-Type: application/pdf`

---

13. Error Handling

13.1 Error Codes Reference

Code	HTTP Analog	Description	Recovery
`BAD_REQUEST`	400	Invalid request schema	Fix request and retry
`UNSUPPORTED_VERSION`	400	Unknown protocolVersion	Use supported version
`UNSUPPORTED_TYPE`	400	Unknown dataType	Use valid dataType
`CERT_NOT_FOUND`	404	Certificate not available	Check certId
`DOWNLOAD_FAILED`	502	Failed to fetch content	Check downloadUrl
`SIGN_FAILED`	500	HSM signing operation failed	Check HSM status
`UPLOAD_FAILED`	502	Failed to upload signed content	Check uploadUrl

Code	HTTP Analog	Description	Recovery
`CALLBACK_FAILED`	502	Failed to notify callback	Check callback URLs
`PROGRESS_ENDPOINT_FAILED`	502	Progress endpoint returned error	Check progress URL
`TIMEOUT`	504	Operation timed out	Retry or increase timeout
`CANCELLED_BY_USER`	499	User cancelled the operation	User action required
`INTERNAL_ERROR`	500	Unexpected internal error	Contact support

13.2 Error Response Structure

```
{
  "protocolVersion": "1.0",
  "requestId": "...",
  "status": "error",
  "results": [],
  "errors": [
    {
      "id": "object-id-if-applicable",
      "code": "ERROR_CODE",
      "message": "Human readable description"
    }
  ],
  "metadata": { ... }
}
```

13.3 Request-Level vs Object-Level Errors

Request-Level Error (entire request fails):

```
{
  "status": "error",
  "results": [],
  "errors": [
    {
      "code": "BAD_REQUEST",
      "message": "Missing required field: protocolVersion"
    }
  ]
}
```

Object-Level Error (some objects fail):

```
{
  "status": "partial",
  "results": [ { "id": "obj-1", "status": "ok", ... } ],
  "errors": [
    {
      "id": "obj-2",
      "code": "DOWNLOAD_FAILED",
      "message": "HTTP 404 from downloadUrl"
    }
  ]
}
```

---

14. Security Requirements

14.1 Transport Security

- **TLS Required**: All URLs (`downloadUrl`, `uploadUrl`, callbacks) MUST use HTTPS
- **Certificate Validation**: Native host MUST validate TLS certificates
- **No HTTP Fallback**: HTTP URLs MUST be rejected

14.2 Origin Validation

The extension MUST validate the sender origin:

```
// Extension content script
window.addEventListener("message", (event) => {
  const ALLOWED_ORIGINS = [
    "https://app.university.edu",
    "https://grades.university.edu"
  ];

  if (!ALLOWED_ORIGINS.includes(event.origin)) {
    console.error("Rejected request from unauthorized origin:", event.origin);
    return;
  }

  // Process request...
});
```

14.3 API Keys in Requests

Sending API keys via `postMessage` to the extension is **SAFE** because:

1. Chrome extension sandboxing isolates extension code
2. Malicious web content cannot intercept messages to extension background
3. Only the extension receives messages sent via `postMessage`

However, API keys MUST NOT be logged or included in error messages returned to the web app.

14.4 Content Integrity

- Content integrity is the **caller's responsibility**
- The native host does NOT verify content hashes
- If content integrity is critical, use signed URLs or implement application-level verification

14.5 Error Message Security

- Error messages returned to web app should be minimal
- Detailed errors should be logged locally by native host
- Never include secrets, tokens, or full URLs in error responses

---

15. Glossary

Term	Definition
HSM	Hardware Security Module - physical device storing cryptographic keys
PKCS#11	Cryptographic Token Interface Standard - API for HSM communication
Native Host	Desktop application communicating with Chrome via Native Messaging
Native Messaging	Chrome API for extensions to communicate with native applications
postMessage	Browser API for cross-origin communication between windows
Object	A single item to be signed (document, text string, etc.)
Object Group	Collection of objects sharing the same configuration
Callback	HTTP endpoint called by native host to report status
Upload	HTTP endpoint where native host sends signed content
Content	The actual data to be signed (accessed inline or via URL)
Remote Mode	Content is fetched from a URL by the native host
Inline Mode	Content is embedded directly in the request JSON

Document History

Version	Date	Author	Changes
1.0	2026-01-20	Zeek Liviu	Initial release
1.0.1	2026-01-22	Zeek Liviu	Clarified Section 7: `mode` and `downloadUrl` at group level with `<objectId>` placeholder for efficient bulk PDF signing. Added Example E for 500-document batch.

Version	Date	Author	Changes
1.0.2	2026-01-23	Zeek Liviu	Simplified Section 8: removed `fieldName`/`fileName` from upload, introduced `<objectId>` placeholder in `uploadUrl`, changed to raw bytes POST. Removed `metadata` from callbacks config (request-level `metadata` is now echoed in all callbacks). Added `uploadResult` and `error` object documentation. Removed redundant `mimeType`/`fileName` from content. Updated all examples.

END OF SPECIFICATION