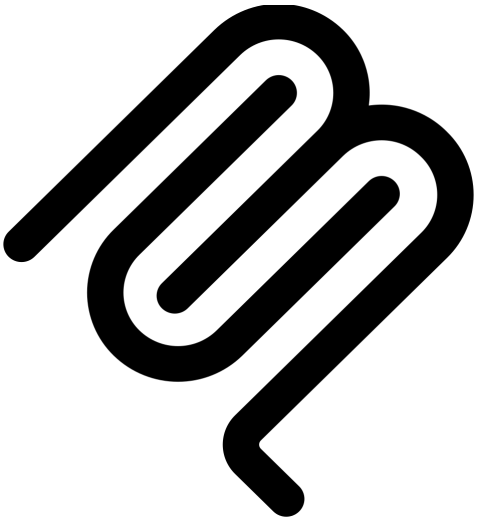
Model Context Protocol (MCP)

Specification



Protocol Revision: 2025-06-18
from https://modelcontextprotocol.io

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Specification

Model Context Protocol (MCP) is an open protocol that enables seamless integration between LLM applications and external data sources and tools. Whether you're building an AI-powered IDE, enhancing a chat interface, or creating custom AI workflows, MCP provides a standardized way to connect LLMs with the context they need.

This specification defines the authoritative protocol requirements, based on the TypeScript schema in schema.ts.

For implementation guides and examples, visit modelcontextprotocol.io.

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.

Overview

MCP provides a standardized way for applications to:

- Share contextual information with language models
- Expose tools and capabilities to AI systems
- Build composable integrations and workflows

The protocol uses JSON-RPC 2.0 messages to establish communication between:

- **Hosts**: LLM applications that initiate connections
- **Clients**: Connectors within the host application
- **Servers**: Services that provide context and capabilities

MCP takes some inspiration from the Language Server Protocol, which standardizes how to add support for programming languages across a whole ecosystem of development tools. In a similar way, MCP standardizes how to integrate additional context and tools into the ecosystem of AI applications.

Key Details

Base Protocol

- JSON-RPC message format
- Stateful connections
- Server and client capability negotiation

Features

Servers offer any of the following features to clients:

- **Resources**: Context and data, for the user or the AI model to use
- **Prompts**: Templated messages and workflows for users
- **Tools**: Functions for the AI model to execute

Clients may offer the following features to servers:

- **Sampling**: Server-initiated agentic behaviors and recursive LLM interactions
- **Roots**: Server-initiated inquiries into uri or filesystem boundaries to operate in
- **Elicitation**: Server-initiated requests for additional information from users

Additional Utilities

- Configuration
- Progress tracking
- Cancellation
- Error reporting
- Logging

Security and Trust & Safety

The Model Context Protocol enables powerful capabilities through arbitrary data access and code execution paths. With this power comes important security and trust considerations that all implementors must carefully address.

Key Principles

1. **User Consent and Control**
    - Users must explicitly consent to and understand all data access and operations
    - Users must retain control over what data is shared and what actions are taken
    - Implementors should provide clear UIs for reviewing and authorizing activities
2. **Data Privacy**
    - Hosts must obtain explicit user consent before exposing user data to servers
    - Hosts must not transmit resource data elsewhere without user consent
    - User data should be protected with appropriate access controls
3. **Tool Safety**
    - Tools represent arbitrary code execution and must be treated with appropriate caution.
        - In particular, descriptions of tool behavior such as annotations should be considered untrusted, unless obtained from a trusted server.
    - Hosts must obtain explicit user consent before invoking any tool
    - Users should understand what each tool does before authorizing its use
4. **LLM Sampling Controls**
    - Users must explicitly approve any LLM sampling requests
    - Users should control:
        - Whether sampling occurs at all
        - The actual prompt that will be sent

        - What results the server can see
    - The protocol intentionally limits server visibility into prompts

Implementation Guidelines

While MCP itself cannot enforce these security principles at the protocol level, implementors **SHOULD**:

1. Build robust consent and authorization flows into their applications
2. Provide clear documentation of security implications
3. Implement appropriate access controls and data protections
4. Follow security best practices in their integrations
5. Consider privacy implications in their feature designs

Learn More

Explore the detailed specification for each protocol component:

Key Changes

This document lists changes made to the Model Context Protocol (MCP) specification since the previous revision, 2025-03-26.

Major changes

1. Remove support for JSON-RPC **batching**
   (PR #416)
2. Add support for structured tool output
   (PR #371)
3. Classify MCP servers as OAuth Resource Servers, adding protected resource metadata to discover the corresponding Authorization server.
   (PR #338)
4. Require MCP clients to implement Resource Indicators as described in RFC 8707 to prevent malicious servers from obtaining access tokens.
   (PR #734)
5. Clarify security considerations and best practices in the authorization spec and in a new security best practices page.
6. Add support for **elicitation**, enabling servers to request additional information from users during interactions.
   (PR #382)
7. Add support for **resource links** in tool call results.
   (PR #603)
8. Require negotiated protocol version to be specified via `MCP-Protocol-Version` header in subsequent requests when using HTTP
   (PR #548).
9. Change **SHOULD** to **MUST** in Lifecycle Operation

Other schema changes

1. Add `_meta` field to additional interface types (PR #710),
   and specify proper usage.
2. Add `context` field to `CompletionRequest`, providing for completion requests to include previously-resolved variables (PR #598).
3. Add `title` field for human-friendly display names, so that `name` can be used as a programmatic identifier (PR #663)

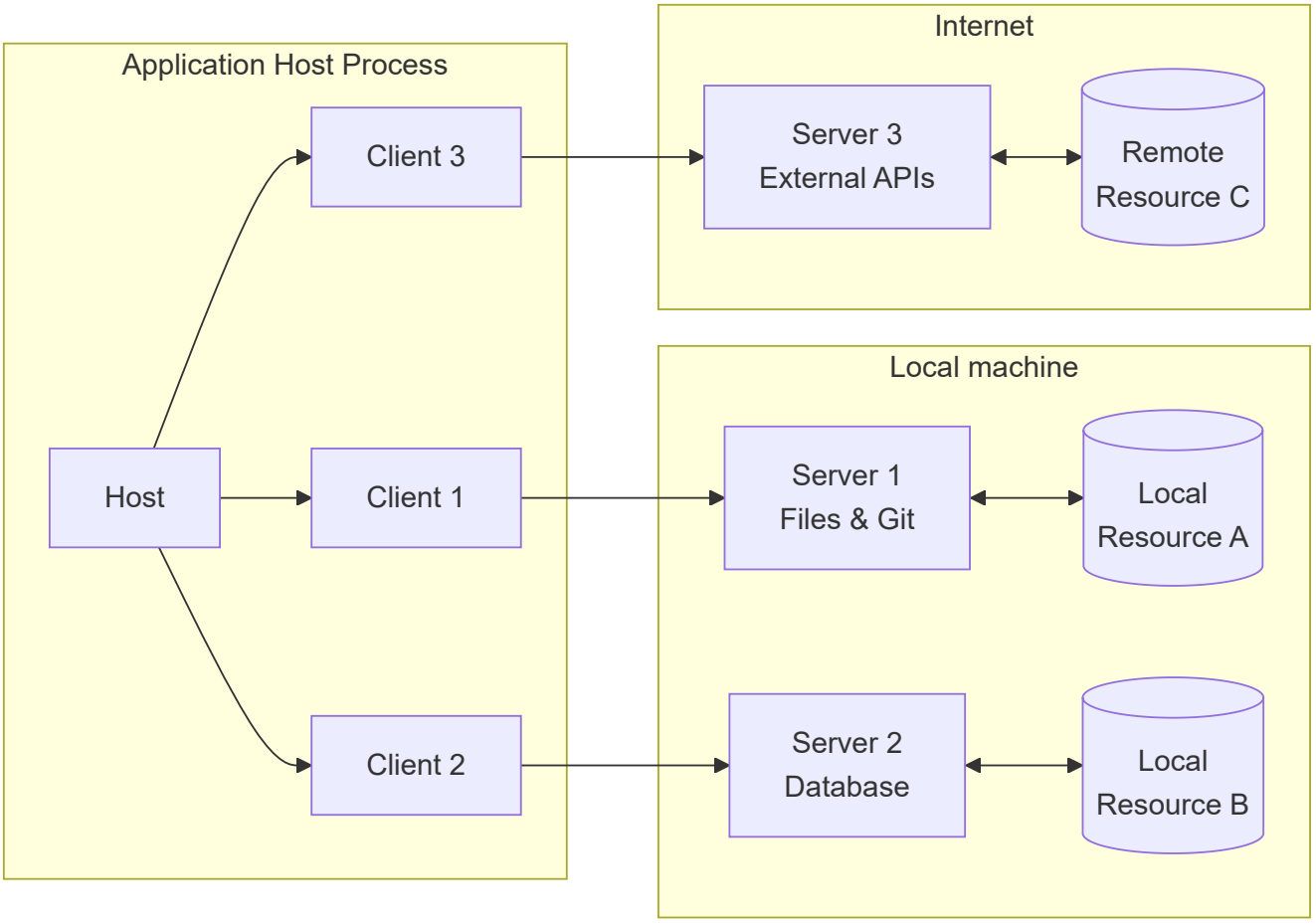
Full changelog

For a complete list of all changes that have been made since the last protocol revision, see GitHub.

Architecture

The Model Context Protocol (MCP) follows a client-host-server architecture where each host can run multiple client instances. This architecture enables users to integrate AI capabilities across applications while maintaining clear security boundaries and isolating concerns. Built on JSON-RPC, MCP provides a stateful session protocol focused on context exchange and sampling coordination between clients and servers.

Core Components



Host

The host process acts as the container and coordinator:

- Creates and manages multiple client instances
- Controls client connection permissions and lifecycle
- Enforces security policies and consent requirements
- Handles user authorization decisions
- Coordinates AI/LLM integration and sampling
- Manages context aggregation across clients

Clients

Each client is created by the host and maintains an isolated server connection:

- Establishes one stateful session per server
- Handles protocol negotiation and capability exchange
- Routes protocol messages bidirectionally
- Manages subscriptions and notifications
- Maintains security boundaries between servers

A host application creates and manages multiple clients, with each client having a 1:1 relationship with a particular server.

Servers

Servers provide specialized context and capabilities:

- Expose resources, tools and prompts via MCP primitives
- Operate independently with focused responsibilities
- Request sampling through client interfaces
- Must respect security constraints
- Can be local processes or remote services

Design Principles

MCP is built on several key design principles that inform its architecture and implementation:

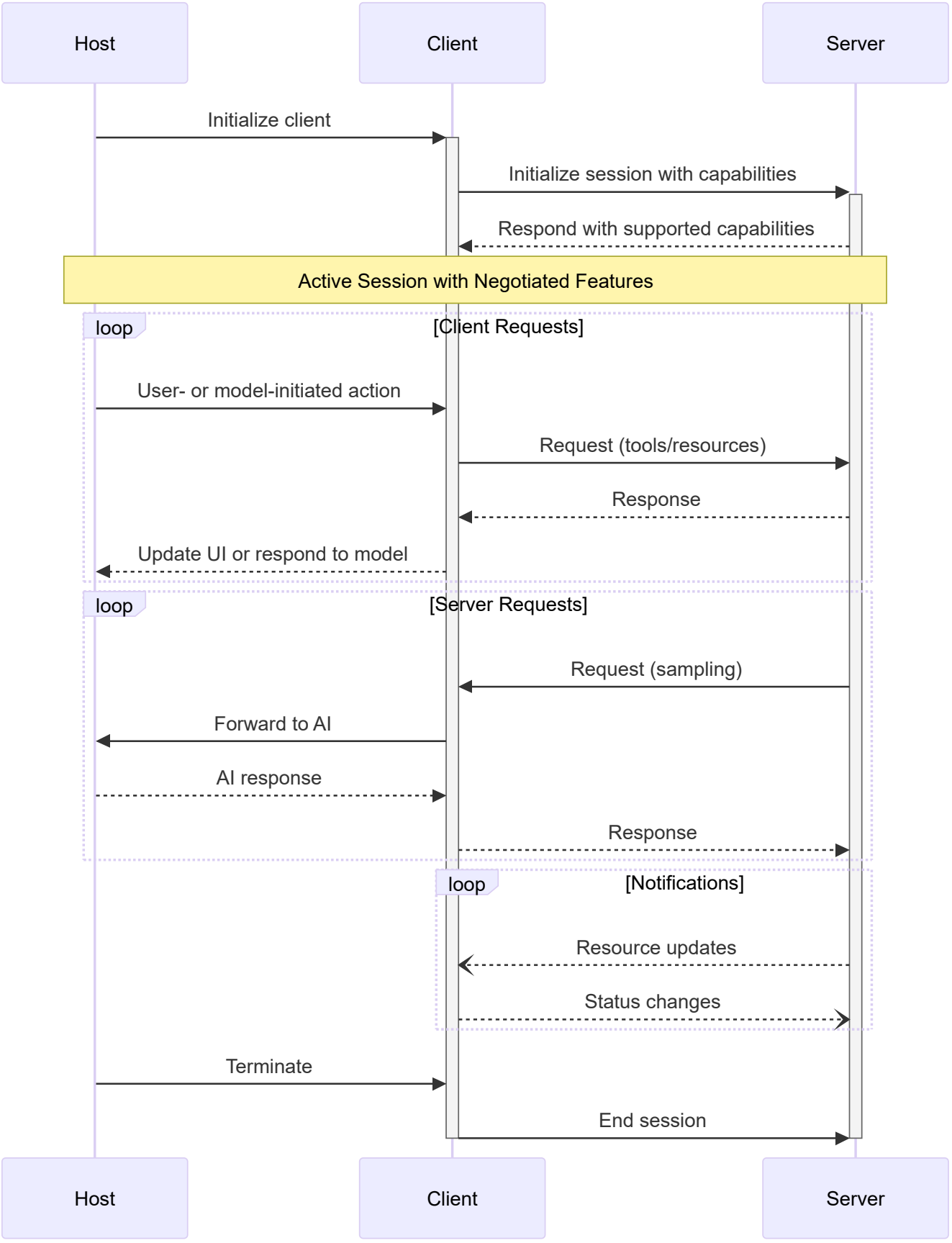
1. **Servers should be extremely easy to build**
    - Host applications handle complex orchestration responsibilities
    - Servers focus on specific, well-defined capabilities
    - Simple interfaces minimize implementation overhead
    - Clear separation enables maintainable code
2. **Servers should be highly composable**
    - Each server provides focused functionality in isolation
    - Multiple servers can be combined seamlessly
    - Shared protocol enables interoperability
    - Modular design supports extensibility
3. **Servers should not be able to read the whole conversation, nor "see into" other servers**
    - Servers receive only necessary contextual information
    - Full conversation history stays with the host
    - Each server connection maintains isolation
    - Cross-server interactions are controlled by the host

    - Host process enforces security boundaries
4. **Features can be added to servers and clients progressively**
    - Core protocol provides minimal required functionality
    - Additional capabilities can be negotiated as needed
    - Servers and clients evolve independently
    - Protocol designed for future extensibility
    - Backwards compatibility is maintained

Capability Negotiation

The Model Context Protocol uses a capability-based negotiation system where clients and servers explicitly declare their supported features during initialization. Capabilities determine which protocol features and primitives are available during a session.

- Servers declare capabilities like resource subscriptions, tool support, and prompt templates
- Clients declare capabilities like sampling support and notification handling
- Both parties must respect declared capabilities throughout the session
- Additional capabilities can be negotiated through extensions to the protocol



Each capability unlocks specific protocol features for use during the session. For example:

- Implemented server features must be advertised in the server's capabilities

- Emitting resource subscription notifications requires the server to declare subscription support
- Tool invocation requires the server to declare tool capabilities
- Sampling requires the client to declare support in its capabilities

This capability negotiation ensures clients and servers have a clear understanding of supported functionality while maintaining protocol extensibility.

Base Protocol

Overview

Protocol Revision: 2025-06-18

The Model Context Protocol consists of several key components that work together:

- **Base Protocol**: Core JSON-RPC message types
- **Lifecycle Management**: Connection initialization, capability negotiation, and session control
- **Authorization**: Authentication and authorization framework for HTTP-based transports
- **Server Features**: Resources, prompts, and tools exposed by servers
- **Client Features**: Sampling and root directory lists provided by clients
- **Utilities**: Cross-cutting concerns like logging and argument completion

All implementations **MUST** support the base protocol and lifecycle management components. Other components **MAY** be implemented based on the specific needs of the application.

These protocol layers establish clear separation of concerns while enabling rich interactions between clients and servers. The modular design allows implementations to support exactly the features they need.

Messages

All messages between MCP clients and servers **MUST** follow the JSON-RPC 2.0 specification. The protocol defines these types of messages:

Requests

Requests are sent from the client to the server or vice versa, to initiate an operation.

```
{
  jsonrpc: "2.0";
  id: string | number;
  method: string;
  params?: {
    [key: string]: unknown;
  };
}
```

- Requests **MUST** include a string or integer ID.
- Unlike base JSON-RPC, the ID **MUST NOT** be `null`.
- The request ID **MUST NOT** have been previously used by the requestor within the same session.

Responses

Responses are sent in reply to requests, containing the result or error of the operation.

```
{
  jsonrpc: "2.0";
  id: string | number;
  result?: {
    [key: string]: unknown;
  }
  error?: {
    code: number;
    message: string;
    data?: unknown;
  }
}
```

- Responses **MUST** include the same ID as the request they correspond to.
- **Responses** are further sub-categorized as either **successful results** or **errors**. Either a `result` or an `error` **MUST** be set. A response **MUST NOT** set both.
- Results **MAY** follow any JSON object structure, while errors **MUST** include an error code and message at minimum.
- Error codes **MUST** be integers.

Notifications

Notifications are sent from the client to the server or vice versa, as a one-way message.
The receiver **MUST NOT** send a response.

```
{
  jsonrpc: "2.0";
  method: string;
  params?: {
    [key: string]: unknown;
  };
}
```

- Notifications **MUST NOT** include an ID.

Auth

MCP provides an Authorization framework for use with HTTP.
Implementations using an HTTP-based transport **SHOULD** conform to this specification, whereas implementations using STDIO transport **SHOULD NOT** follow this specification, and instead retrieve credentials from the environment.

Additionally, clients and servers **MAY** negotiate their own custom authentication and authorization strategies.

For further discussions and contributions to the evolution of MCP's auth mechanisms, join us in GitHub Discussions
to help shape the future of the protocol!

Schema

The full specification of the protocol is defined as a TypeScript schema.
This is the source of truth for all protocol messages and structures.

There is also a JSON Schema, which is automatically generated from the TypeScript source of truth, for use with various automated tooling.

General fields

`_meta`

The `_meta` property/parameter is reserved by MCP to allow clients and servers to attach additional metadata to their interactions.

Certain key names are reserved by MCP for protocol-level metadata, as specified below;
implementations MUST NOT make assumptions about values at these keys.

Additionally, definitions in the schema
may reserve particular names for purpose-specific metadata, as declared in those definitions.

Key name format: valid `_meta` key names have two segments: an optional **prefix**, and a **name**.

Prefix:

- If specified, MUST be a series of labels separated by dots (`.`), followed by a slash (`/`).
  - Labels MUST start with a letter and end with a letter or digit; interior characters can be letters, digits, or hyphens (`-`).
- Any prefix beginning with zero or more valid labels, followed by `modelcontextprotocol` or `mcp`, followed by any valid label,
  is **reserved** for MCP use.
  - For example: `modelcontextprotocol.io/`, `mcp.dev/`, `api.modelcontextprotocol.org/`, and `tools.mcp.com/` are all reserved.

Name:

- Unless empty, MUST begin and end with an alphanumeric character (`[a-z0-9A-Z]`).
- MAY contain hyphens (`-`), underscores (`_`), dots (`.`), and alphanumerics in between.

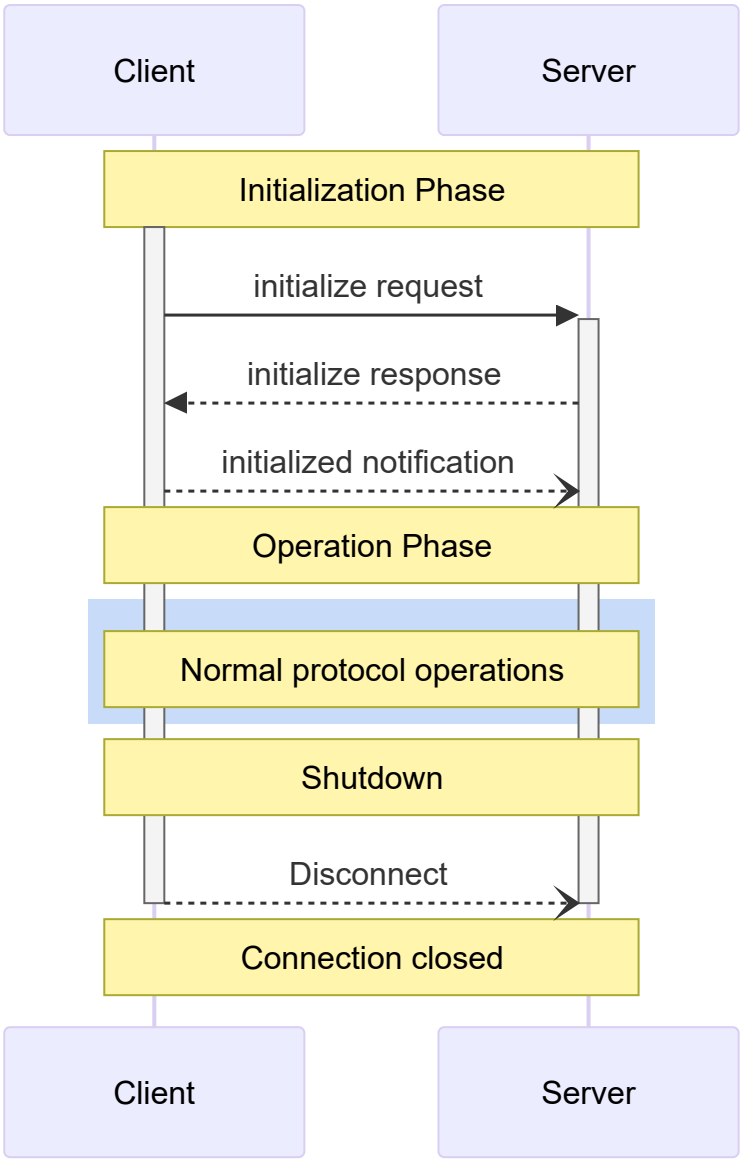
Lifecycle

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) defines a rigorous lifecycle for client-server connections that ensures proper capability negotiation and state management.

1. **Initialization**: Capability negotiation and protocol version agreement
2. **Operation**: Normal protocol communication

3. **Shutdown**: Graceful termination of the connection



Lifecycle Phases

Initialization

The initialization phase **MUST** be the first interaction between client and server.
During this phase, the client and server:

- Establish protocol version compatibility
- Exchange and negotiate capabilities
- Share implementation details

The client **MUST** initiate this phase by sending an `initialize` request containing:

- Protocol version supported
- Client capabilities
- Client implementation information

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "initialize",
  "params": {
    "protocolVersion": "2024-11-05",
    "capabilities": {
      "roots": {
        "listChanged": true
      },
      "sampling": {},
      "elicitation": {}
    },
    "clientInfo": {
      "name": "ExampleClient",
      "title": "Example Client Display Name",
      "version": "1.0.0"
    }
  }
}
```

The server **MUST** respond with its own capabilities and information:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "protocolVersion": "2024-11-05",
    "capabilities": {
      "logging": {},
      "prompts": {
        "listChanged": true
      },
      "resources": {
        "subscribe": true,
        "listChanged": true
      },
      "tools": {
        "listChanged": true
      }
    },
    "serverInfo": {
      "name": "ExampleServer",
      "title": "Example Server Display Name",
      "version": "1.0.0"
    },
    "instructions": "Optional instructions for the client"
  }
}
```

After successful initialization, the client **MUST** send an `initialized` notification to indicate it is ready to begin normal operations:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/initialized"
}
```

- The client **SHOULD NOT** send requests other than pings before the server has responded to the `initialize` request.
- The server **SHOULD NOT** send requests other than pings and logging before receiving the `initialized` notification.

Version Negotiation

In the `initialize` request, the client **MUST** send a protocol version it supports.
This **SHOULD** be the *latest* version supported by the client.

If the server supports the requested protocol version, it **MUST** respond with the same version. Otherwise, the server **MUST** respond with another protocol version it supports. This **SHOULD** be the *latest* version supported by the server.

If the client does not support the version in the server's response, it **SHOULD** disconnect.

If using HTTP, the client **MUST** include the `MCP-Protocol-Version: <protocol-version>` HTTP header on all subsequent requests to the MCP server.
For details, see the Protocol Version Header section in Transports.

Capability Negotiation

Client and server capabilities establish which optional protocol features will be available during the session.

Key capabilities include:

Category	Capability	Description
Client	`roots`	Ability to provide filesystem roots
Client	`sampling`	Support for LLM sampling requests
Client	`elicitation`	Support for server elicitation requests
Client	`experimental`	Describes support for non-standard experimental features
Server	`prompts`	Offers prompt templates
Server	`resources`	Provides readable resources
Server	`tools`	Exposes callable tools

Category	Capability	Description
Server	`logging`	Emits structured log messages
Server	`completions`	Supports argument autocompletion
Server	`experimental`	Describes support for non-standard experimental features

Capability objects can describe sub-capabilities like:

- `listChanged`: Support for list change notifications (for prompts, resources, and tools)
- `subscribe`: Support for subscribing to individual items' changes (resources only)

Operation

During the operation phase, the client and server exchange messages according to the negotiated capabilities.

Both parties **MUST**:

- Respect the negotiated protocol version
- Only use capabilities that were successfully negotiated

Shutdown

During the shutdown phase, one side (usually the client) cleanly terminates the protocol connection. No specific shutdown messages are defined—instead, the underlying transport mechanism should be used to signal connection termination:

stdio

For the stdio transport, the client **SHOULD** initiate shutdown by:

1. First, closing the input stream to the child process (the server)
2. Waiting for the server to exit, or sending `SIGTERM` if the server does not exit within a reasonable time
3. Sending `SIGKILL` if the server does not exit within a reasonable time after `SIGTERM`

The server **MAY** initiate shutdown by closing its output stream to the client and exiting.

HTTP

For HTTP transports, shutdown is indicated by closing the associated HTTP connection(s).

Timeouts

Implementations **SHOULD** establish timeouts for all sent requests, to prevent hung connections and resource exhaustion. When the request has not received a success or error response within the timeout period, the sender **SHOULD** issue a cancellation notification for that request and stop waiting for a response.

SDKs and other middleware **SHOULD** allow these timeouts to be configured on a per-request basis.

Implementations **MAY** choose to reset the timeout clock when receiving a progress notification corresponding to the request, as this implies that work is actually happening. However, implementations **SHOULD** always enforce a maximum timeout, regardless of progress notifications, to limit the impact of a misbehaving client or server.

Error Handling

Implementations **SHOULD** be prepared to handle these error cases:

- Protocol version mismatch
- Failure to negotiate required capabilities
- Request timeouts

Example initialization error:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "error": {
    "code": -32602,
    "message": "Unsupported protocol version",
    "data": {
      "supported": ["2024-11-05"],
      "requested": "1.0.0"
    }
  }
}
```

Transports

Protocol Revision: 2025-06-18

MCP uses JSON-RPC to encode messages. JSON-RPC messages **MUST** be UTF-8 encoded.

The protocol currently defines two standard transport mechanisms for client-server communication:

1. stdio, communication over standard in and standard out
2. Streamable HTTP

Clients **SHOULD** support stdio whenever possible.

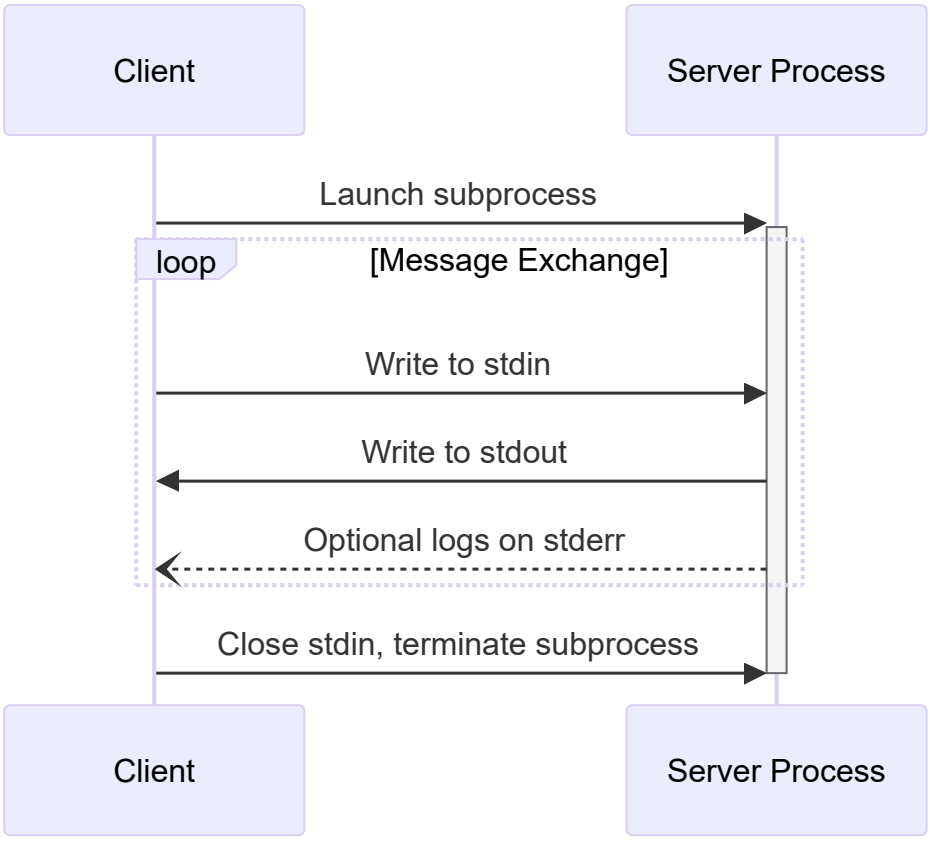
It is also possible for clients and servers to implement custom transports in a pluggable fashion.

stdio

In the **stdio** transport:

- The client launches the MCP server as a subprocess.
- The server reads JSON-RPC messages from its standard input (`stdin`) and sends messages to its standard output (`stdout`).
- Messages are individual JSON-RPC requests, notifications, or responses.
- Messages are delimited by newlines, and **MUST NOT** contain embedded newlines.

- The server **MAY** write UTF-8 strings to its standard error (`stderr`) for logging purposes. Clients **MAY** capture, forward, or ignore this logging.
- The server **MUST NOT** write anything to its `stdout` that is not a valid MCP message.
- The client **MUST NOT** write anything to the server's `stdin` that is not a valid MCP message.



Streamable HTTP

This replaces the HTTP+SSE transport from protocol version 2024-11-05. See the backwards compatibility guide below.

In the **Streamable HTTP** transport, the server operates as an independent process that can handle multiple client connections. This transport uses HTTP POST and GET requests.
Server can optionally make use of Server-Sent Events (SSE) to stream multiple server messages. This permits basic MCP servers, as well as more feature-rich servers supporting streaming and server-to-client notifications and requests.

The server **MUST** provide a single HTTP endpoint path (hereafter referred to as the **MCP endpoint**) that supports both POST and GET methods. For example, this could be a URL like `https://example.com/mcp`.

Security Warning

When implementing Streamable HTTP transport:

1. Servers **MUST** validate the `Origin` header on all incoming connections to prevent DNS rebinding attacks
2. When running locally, servers **SHOULD** bind only to localhost (127.0.0.1) rather than all network interfaces (0.0.0.0)
3. Servers **SHOULD** implement proper authentication for all connections

Without these protections, attackers could use DNS rebinding to interact with local MCP servers from remote websites.

Sending Messages to the Server

Every JSON-RPC message sent from the client **MUST** be a new HTTP POST request to the MCP endpoint.

1. The client **MUST** use HTTP POST to send JSON-RPC messages to the MCP endpoint.
2. The client **MUST** include an `Accept` header, listing both `application/json` and `text/event-stream` as supported content types.
3. The body of the POST request **MUST** be a single JSON-RPC *request*, *notification*, or *response*.
4. If the input is a JSON-RPC *response* or *notification*:
    - If the server accepts the input, the server **MUST** return HTTP status code 202 Accepted with no body.
    - If the server cannot accept the input, it **MUST** return an HTTP error status code (e.g., 400 Bad Request). The HTTP response body **MAY** comprise a JSON-RPC *error response* that has no `id`.
5. If the input is a JSON-RPC *request*, the server **MUST** either return `Content-Type: text/event-stream`, to initiate an SSE stream, or `Content-Type: application/json`, to return one JSON object. The client **MUST** support both these cases.
6. If the server initiates an SSE stream:
    - The SSE stream **SHOULD** eventually include JSON-RPC *response* for the JSON-RPC *request* sent in the POST body.
    - The server **MAY** send JSON-RPC *requests* and *notifications* before sending the JSON-RPC *response*. These messages **SHOULD** relate to the originating client *request*.
    - The server **SHOULD NOT** close the SSE stream before sending the JSON-RPC *response* for the received JSON-RPC *request*, unless the session expires.
    - After the JSON-RPC *response* has been sent, the server **SHOULD** close the SSE stream.
    - Disconnection **MAY** occur at any time (e.g., due to network conditions). Therefore:
        - Disconnection **SHOULD NOT** be interpreted as the client cancelling its request.
        - To cancel, the client **SHOULD** explicitly send an MCP `CancelledNotification`.

        - To avoid message loss due to disconnection, the server **MAY** make the stream resumable.

Listening for Messages from the Server

1. The client **MAY** issue an HTTP GET to the MCP endpoint. This can be used to open an SSE stream, allowing the server to communicate to the client, without the client first sending data via HTTP POST.
2. The client **MUST** include an `Accept` header, listing `text/event-stream` as a supported content type.
3. The server **MUST** either return `Content-Type: text/event-stream` in response to this HTTP GET, or else return HTTP 405 Method Not Allowed, indicating that the server does not offer an SSE stream at this endpoint.
4. If the server initiates an SSE stream:
    - The server **MAY** send JSON-RPC *requests* and *notifications* on the stream.
    - These messages **SHOULD** be unrelated to any concurrently-running JSON-RPC *request* from the client.
    - The server **MUST NOT** send a JSON-RPC *response* on the stream **unless** resuming a stream associated with a previous client request.
    - The server **MAY** close the SSE stream at any time.
    - The client **MAY** close the SSE stream at any time.

Multiple Connections

1. The client **MAY** remain connected to multiple SSE streams simultaneously.
2. The server **MUST** send each of its JSON-RPC messages on only one of the connected streams; that is, it **MUST NOT** broadcast the same message across multiple streams.
    - The risk of message loss **MAY** be mitigated by making the stream resumable.

Resumability and Redelivery

To support resuming broken connections, and redelivering messages that might otherwise be lost:

1. Servers **MAY** attach an `id` field to their SSE events, as described in the SSE standard.
    - If present, the ID **MUST** be globally unique across all streams within that session—or all streams with that specific client, if session management is not in use.
2. If the client wishes to resume after a broken connection, it **SHOULD** issue an HTTP GET to the MCP endpoint, and include the `Last-Event-ID` header to indicate the last event ID it received.

- The server **MAY** use this header to replay messages that would have been sent after the last event ID, *on the stream that was disconnected*, and to resume the stream from that point.
- The server **MUST NOT** replay messages that would have been delivered on a different stream.

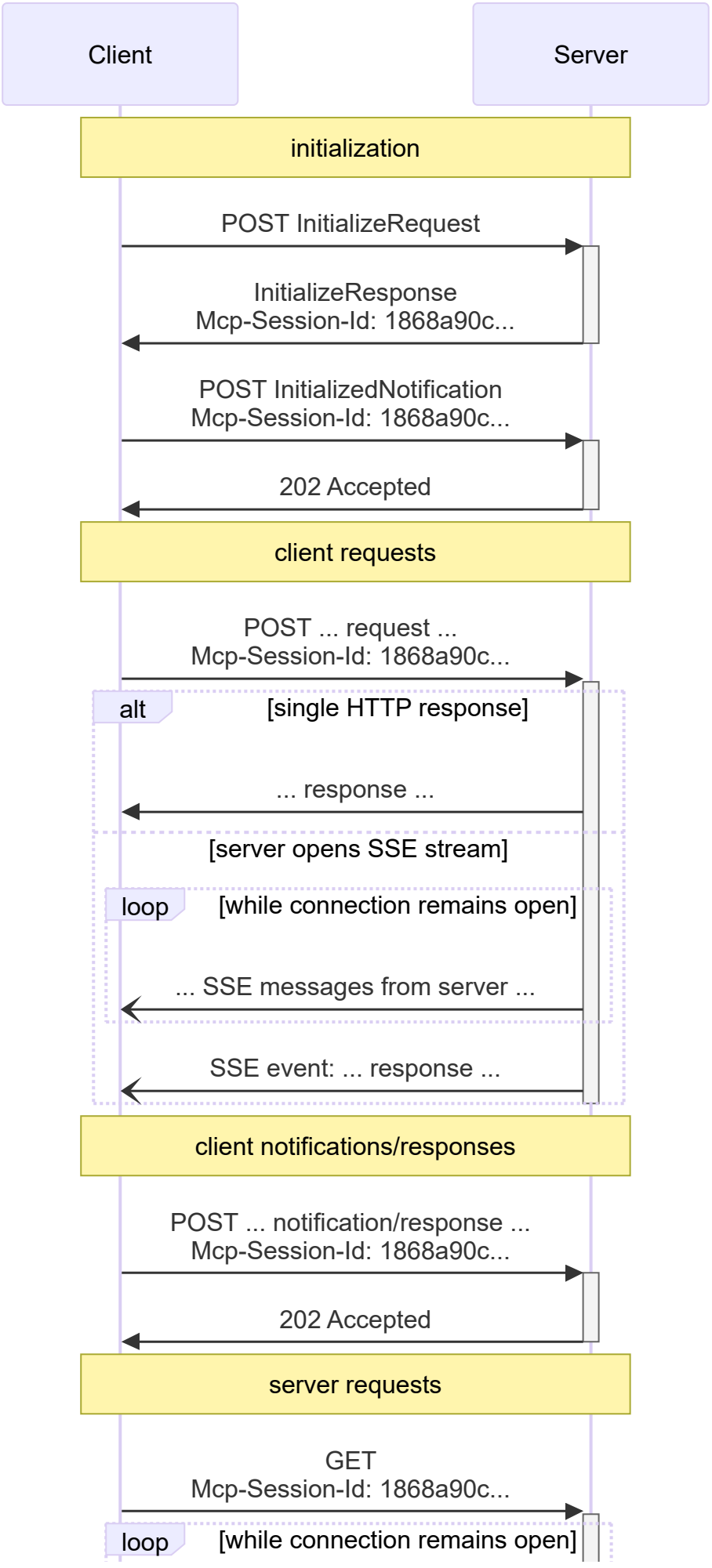
In other words, these event IDs should be assigned by servers on a *per-stream* basis, to act as a cursor within that particular stream.

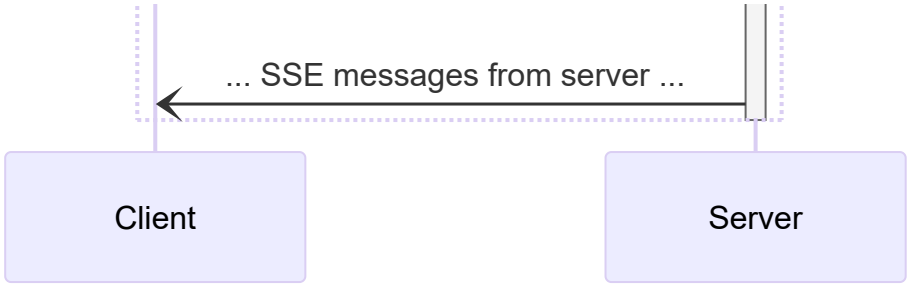
Session Management

An MCP "session" consists of logically related interactions between a client and a server, beginning with the initialization phase. To support servers which want to establish stateful sessions:

1. A server using the Streamable HTTP transport **MAY** assign a session ID at initialization time, by including it in an `Mcp-Session-Id` header on the HTTP response containing the `InitializeResult`.
   - The session ID **SHOULD** be globally unique and cryptographically secure (e.g., a securely generated UUID, a JWT, or a cryptographic hash).
   - The session ID **MUST** only contain visible ASCII characters (ranging from 0x21 to 0x7E).
2. If an `Mcp-Session-Id` is returned by the server during initialization, clients using the Streamable HTTP transport **MUST** include it in the `Mcp-Session-Id` header on all of their subsequent HTTP requests.
   - Servers that require a session ID **SHOULD** respond to requests without an `Mcp-Session-Id` header (other than initialization) with HTTP 400 Bad Request.
3. The server **MAY** terminate the session at any time, after which it **MUST** respond to requests containing that session ID with HTTP 404 Not Found.
4. When a client receives HTTP 404 in response to a request containing an `Mcp-Session-Id`, it **MUST** start a new session by sending a new `InitializeRequest` without a session ID attached.
5. Clients that no longer need a particular session (e.g., because the user is leaving the client application) **SHOULD** send an HTTP DELETE to the MCP endpoint with the `Mcp-Session-Id` header, to explicitly terminate the session.
   - The server **MAY** respond to this request with HTTP 405 Method Not Allowed, indicating that the server does not allow clients to terminate sessions.

Sequence Diagram


Client
Server
initialization
POST InitializeRequest
InitializeResponse
Mcp-Session-Id: 1868a90c...
POST InitializedNotification
Mcp-Session-Id: 1868a90c...
202 Accepted
client requests
POST ... request ...
Mcp-Session-Id: 1868a90c...
alt
[single HTTP response]
... response ...
[server opens SSE stream]
loop
[while connection remains open]
... SSE messages from server ...
SSE event: ... response ...
client notifications/responses
POST ... notification/response ...
Mcp-Session-Id: 1868a90c...
202 Accepted
server requests
GET
Mcp-Session-Id: 1868a90c...
loop
[while connection remains open]



Protocol Version Header

If using HTTP, the client **MUST** include the `MCP-Protocol-Version: <protocol-version>` HTTP header on all subsequent requests to the MCP server, allowing the MCP server to respond based on the MCP protocol version.

For example: `MCP-Protocol-Version: 2025-06-18`

The protocol version sent by the client **SHOULD** be the one negotiated during initialization.

For backwards compatibility, if the server does *not* receive an `MCP-Protocol-Version` header, and has no other way to identify the version - for example, by relying on the protocol version negotiated during initialization - the server **SHOULD** assume protocol version `2025-03-26`.

If the server receives a request with an invalid or unsupported `MCP-Protocol-Version`, it **MUST** respond with `400 Bad Request`.

Backwards Compatibility

Clients and servers can maintain backwards compatibility with the deprecated HTTP+SSE transport (from protocol version 2024-11-05) as follows:

Servers wanting to support older clients should:

- Continue to host both the SSE and POST endpoints of the old transport, alongside the new "MCP endpoint" defined for the Streamable HTTP transport.
    - It is also possible to combine the old POST endpoint and the new MCP endpoint, but this may introduce unneeded complexity.

Clients wanting to support older servers should:

1. Accept an MCP server URL from the user, which may point to either a server using the old transport or the new transport.
2. Attempt to POST an `InitializeRequest` to the server URL, with an `Accept` header as defined above:
    - If it succeeds, the client can assume this is a server supporting the new Streamable HTTP transport.
    - If it fails with an HTTP 4xx status code (e.g., 405 Method Not Allowed or 404 Not Found):
        - Issue a GET request to the server URL, expecting that this will open an SSE stream and return an `endpoint` event as the first event.

    - When the `endpoint` event arrives, the client can assume this is a server running the old HTTP+SSE transport, and should use that transport for all subsequent communication.

Custom Transports

Clients and servers **MAY** implement additional custom transport mechanisms to suit their specific needs. The protocol is transport-agnostic and can be implemented over any communication channel that supports bidirectional message exchange.

Implementers who choose to support custom transports **MUST** ensure they preserve the JSON-RPC message format and lifecycle requirements defined by MCP. Custom transports
SHOULD document their specific connection establishment and message exchange patterns to aid interoperability.

Authorization

Protocol Revision: 2025-06-18

Introduction

Purpose and Scope

The Model Context Protocol provides authorization capabilities at the transport level, enabling MCP clients to make requests to restricted MCP servers on behalf of resource owners. This specification defines the authorization flow for HTTP-based transports.

Protocol Requirements

Authorization is **OPTIONAL** for MCP implementations. When supported:

- Implementations using an HTTP-based transport **SHOULD** conform to this specification.
- Implementations using an STDIO transport **SHOULD NOT** follow this specification, and instead retrieve credentials from the environment.
- Implementations using alternative transports **MUST** follow established security best practices for their protocol.

Standards Compliance

This authorization mechanism is based on established specifications listed below, but implements a selected subset of their features to ensure security and interoperability while maintaining simplicity:

- OAuth 2.1 IETF DRAFT (draft-ietf-oauth-v2-1-13)
- OAuth 2.0 Authorization Server Metadata (RFC8414)
- OAuth 2.0 Dynamic Client Registration Protocol (RFC7591)
- OAuth 2.0 Protected Resource Metadata (RFC9728)

Authorization Flow

Roles

A protected *MCP server* acts as an OAuth 2.1 resource server, capable of accepting and responding to protected resource requests using access tokens.

An *MCP client* acts as an OAuth 2.1 client, making protected resource requests on behalf of a resource owner.

The *authorization server* is responsible for interacting with the user (if necessary) and issuing access tokens for use at the MCP server.
The implementation details of the authorization server are beyond the scope of this specification. It may be hosted with the resource server or a separate entity. The Authorization Server Discovery section specifies how an MCP server indicates the location of its corresponding authorization server to a client.

Overview

1. Authorization servers **MUST** implement OAuth 2.1 with appropriate security measures for both confidential and public clients.
2. Authorization servers and MCP clients **SHOULD** support the OAuth 2.0 Dynamic Client Registration Protocol (RFC7591).
3. MCP servers **MUST** implement OAuth 2.0 Protected Resource Metadata (RFC9728).
   MCP clients **MUST** use OAuth 2.0 Protected Resource Metadata for authorization server discovery.
4. Authorization servers **MUST** provide OAuth 2.0 Authorization Server Metadata (RFC8414).
   MCP clients **MUST** use the OAuth 2.0 Authorization Server Metadata.

Authorization Server Discovery

This section describes the mechanisms by which MCP servers advertise their associated authorization servers to MCP clients, as well as the discovery process through which MCP clients can determine authorization server endpoints and supported capabilities.

Authorization Server Location

MCP servers **MUST** implement the OAuth 2.0 Protected Resource Metadata (RFC9728) specification to indicate the locations of authorization servers. The Protected Resource Metadata document returned by the MCP server **MUST** include the `authorization_servers` field containing at least one authorization server.

The specific use of `authorization_servers` is beyond the scope of this specification; implementers should consult OAuth 2.0 Protected Resource Metadata (RFC9728) for guidance on implementation details.

Implementors should note that Protected Resource Metadata documents can define multiple authorization servers. The responsibility for selecting which authorization server to use lies with the MCP client, following the guidelines specified in RFC9728 Section 7.6 "Authorization Servers".

MCP servers **MUST** use the HTTP header `WWW-Authenticate` when returning a *401 Unauthorized* to indicate the location of the resource server metadata URL as described in RFC9728 Section 5.1 "WWW-Authenticate Response".

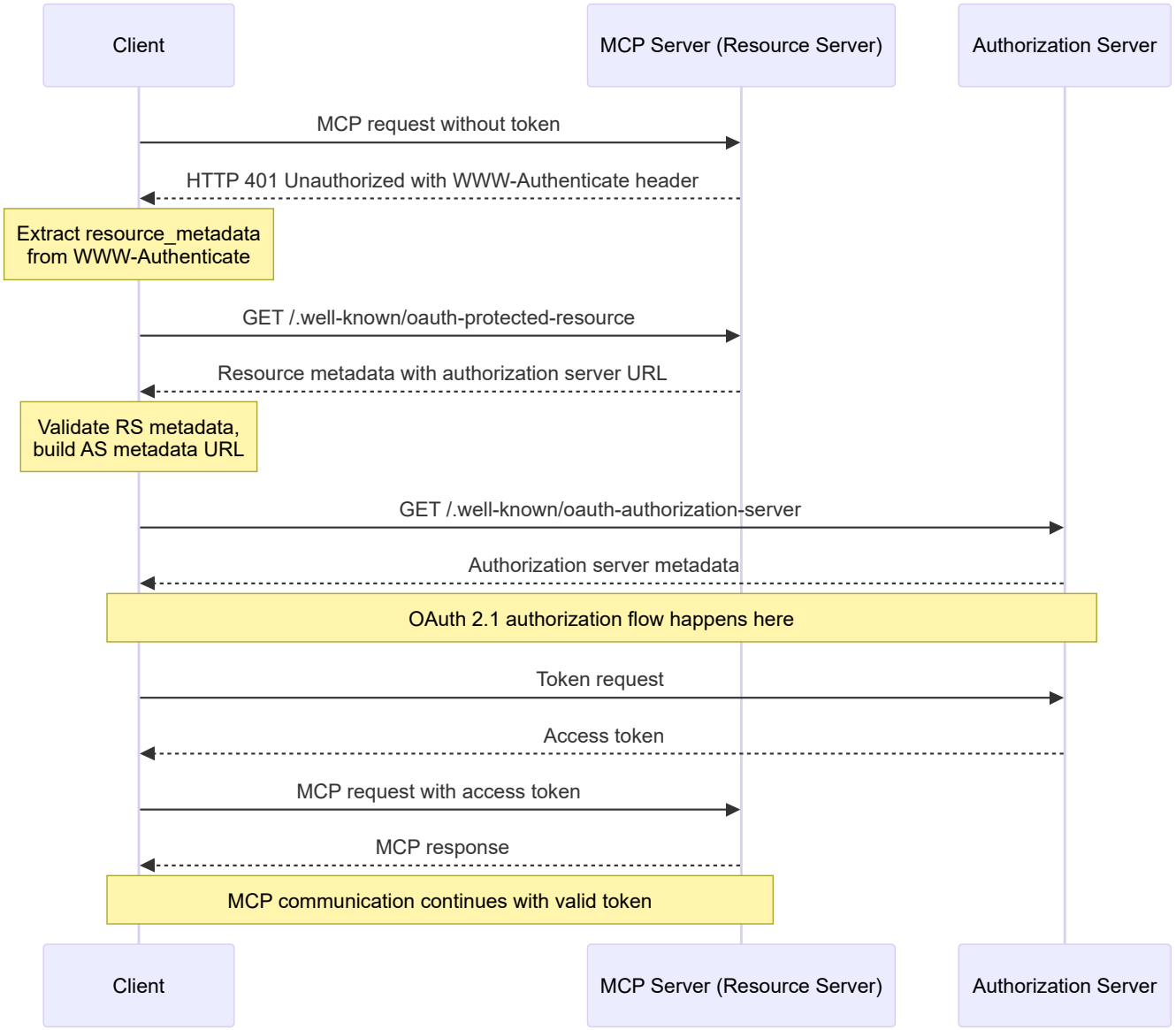
MCP clients **MUST** be able to parse `WWW-Authenticate` headers and respond appropriately to `HTTP 401 Unauthorized` responses from the MCP server.

Server Metadata Discovery

MCP clients **MUST** follow the OAuth 2.0 Authorization Server Metadata RFC8414
specification to obtain the information required to interact with the authorization server.

Sequence Diagram

The following diagram outlines an example flow:



Dynamic Client Registration

MCP clients and authorization servers **SHOULD** support the OAuth 2.0 Dynamic Client Registration Protocol RFC7591
to allow MCP clients to obtain OAuth client IDs without user interaction. This provides a standardized way for clients to automatically register with new authorization servers, which is crucial for MCP because:

- Clients may not know all possible MCP servers and their authorization servers in advance.
- Manual registration would create friction for users.

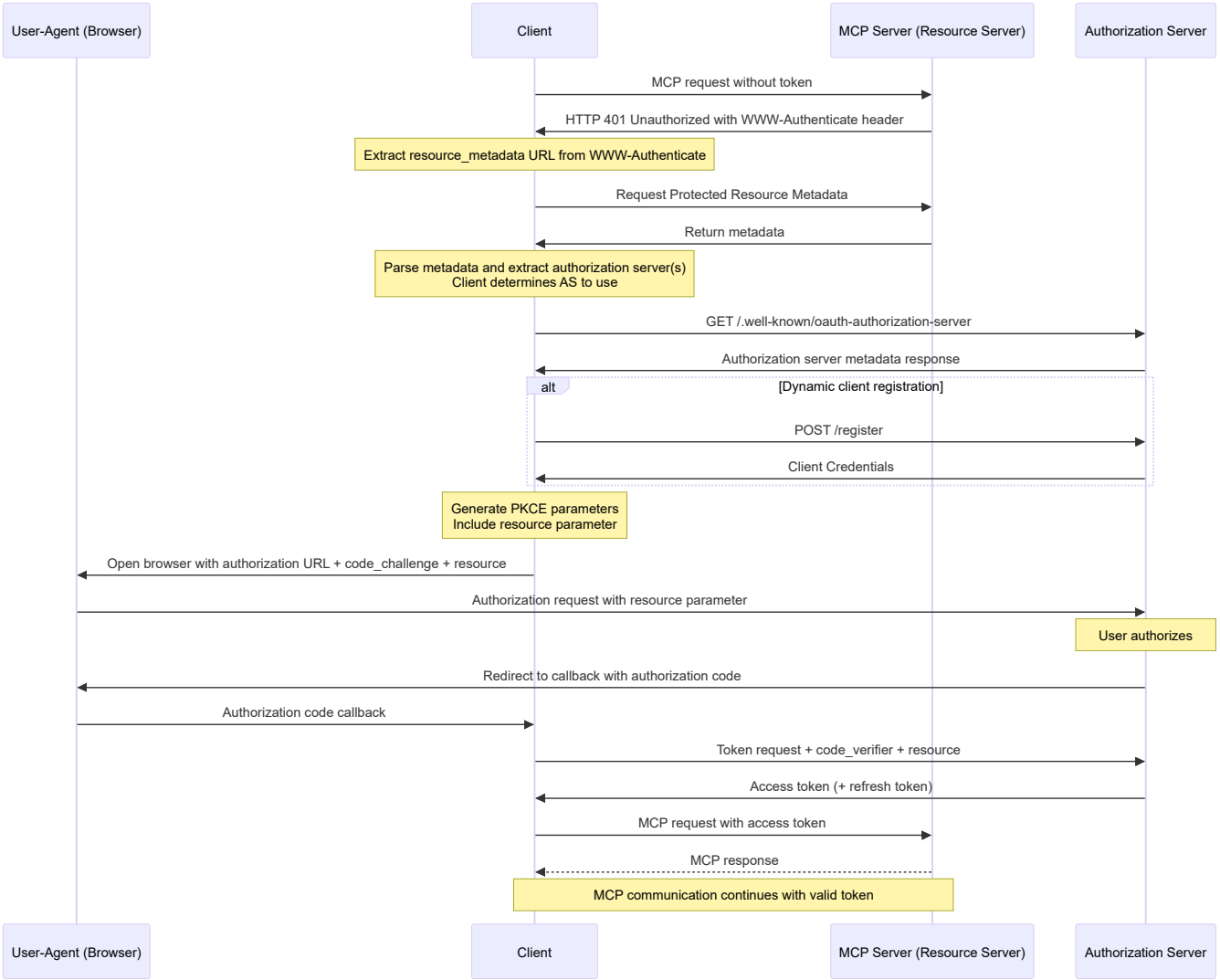
- It enables seamless connection to new MCP servers and their authorization servers.
- Authorization servers can implement their own registration policies.

Any authorization servers that *do not* support Dynamic Client Registration need to provide alternative ways to obtain a client ID (and, if applicable, client credentials). For one of these authorization servers, MCP clients will have to either:

1. Hardcode a client ID (and, if applicable, client credentials) specifically for the MCP client to use when interacting with that authorization server, or
2. Present a UI to users that allows them to enter these details, after registering an OAuth client themselves (e.g., through a configuration interface hosted by the server).

Authorization Flow Steps

The complete Authorization flow proceeds as follows:



Resource Parameter Implementation

MCP clients **MUST** implement Resource Indicators for OAuth 2.0 as defined in RFC 8707
to explicitly specify the target resource for which the token is being requested. The `resource` parameter:

1. **MUST** be included in both authorization requests and token requests.
2. **MUST** identify the MCP server that the client intends to use the token with.
3. **MUST** use the canonical URI of the MCP server as defined in RFC 8707 Section 2.

Canonical Server URI

For the purposes of this specification, the canonical URI of an MCP server is defined as the resource identifier as specified in RFC 8707 Section 2 and aligns with the `resource` parameter in RFC 9728.

MCP clients **SHOULD** provide the most specific URI that they can for the MCP server they intend to access, following the guidance in RFC 8707. While the canonical form uses lowercase scheme and host components, implementations **SHOULD** accept uppercase scheme and host components for robustness and interoperability.

Examples of valid canonical URIs:

- `https://mcp.example.com/mcp`
- `https://mcp.example.com`
- `https://mcp.example.com:8443`
- `https://mcp.example.com/server/mcp` (when path component is necessary to identify individual MCP server)

Examples of invalid canonical URIs:

- `mcp.example.com` (missing scheme)
- `https://mcp.example.com#fragment` (contains fragment)

> **Note:** While both `https://mcp.example.com/` (with trailing slash) and `https://mcp.example.com` (without trailing slash) are technically valid absolute URIs according to RFC 3986, implementations **SHOULD** consistently use the form without the trailing slash for better interoperability unless the trailing slash is semantically significant for the specific resource.

For example, if accessing an MCP server at `https://mcp.example.com`, the authorization request would include:

```
&resource=https%3A%2F%2Fmcp.example.com
```

MCP clients **MUST** send this parameter regardless of whether authorization servers support it.

Access Token Usage

Token Requirements

Access token handling when making requests to MCP servers **MUST** conform to the requirements defined in OAuth 2.1 Section 5 "Resource Requests".
Specifically:

1. MCP client **MUST** use the Authorization request header field defined in OAuth 2.1 Section 5.1.1:

```
Authorization: Bearer <access-token>
```

Note that authorization **MUST** be included in every HTTP request from client to server, even if they are part of the same logical session.

2. Access tokens **MUST NOT** be included in the URI query string

Example request:

```
GET /mcp HTTP/1.1
Host: mcp.example.com
Authorization: Bearer eyJhbGciOiJIUzI1NiIs...
```

Token Handling

MCP servers, acting in their role as an OAuth 2.1 resource server, **MUST** validate access tokens as described in OAuth 2.1 Section 5.2.
MCP servers **MUST** validate that access tokens were issued specifically for them as the intended audience, according to RFC 8707 Section 2.
If validation fails, servers **MUST** respond according to OAuth 2.1 Section 5.3 error handling requirements. Invalid or expired tokens **MUST** receive a HTTP 401 response.

MCP clients **MUST NOT** send tokens to the MCP server other than ones issued by the MCP server's authorization server.

Authorization servers **MUST** only accept tokens that are valid for use with their own resources.

MCP servers **MUST NOT** accept or transit any other tokens.

Error Handling

Servers **MUST** return appropriate HTTP status codes for authorization errors:

Status Code	Description	Usage
401	Unauthorized	Authorization required or token invalid
403	Forbidden	Invalid scopes or insufficient permissions
400	Bad Request	Malformed authorization request

Security Considerations

Implementations **MUST** follow OAuth 2.1 security best practices as laid out in OAuth 2.1 Section 7. "Security Considerations".

Token Audience Binding and Validation

RFC 8707 Resource Indicators provide critical security benefits by binding tokens to their intended audiences **when the Authorization Server supports the capability**. To enable current and future adoption:

- MCP clients **MUST** include the `resource` parameter in authorization and token requests as specified in the Resource Parameter Implementation section
- MCP servers **MUST** validate that tokens presented to them were specifically issued for their use

The Security Best Practices document
outlines why token audience validation is crucial and why token passthrough is explicitly forbidden.

Token Theft

Attackers who obtain tokens stored by the client, or tokens cached or logged on the server can access protected resources with requests that appear legitimate to resource servers.

Clients and servers **MUST** implement secure token storage and follow OAuth best practices, as outlined in OAuth 2.1, Section 7.1.

Authorization servers **SHOULD** issue short-lived access tokens to reduce the impact of leaked tokens.
For public clients, authorization servers **MUST** rotate refresh tokens as described in OAuth 2.1 Section 4.3.1 "Token Endpoint Extension".

Communication Security

Implementations **MUST** follow OAuth 2.1 Section 1.5 "Communication Security".

Specifically:

1. All authorization server endpoints **MUST** be served over HTTPS.
2. All redirect URIs **MUST** be either `localhost` or use HTTPS.

Authorization Code Protection

An attacker who has gained access to an authorization code contained in an authorization response can try to redeem the authorization code for an access token or otherwise make use of the authorization code.
(Further described in OAuth 2.1 Section 7.5)

To mitigate this, MCP clients **MUST** implement PKCE according to OAuth 2.1 Section 7.5.2.
PKCE helps prevent authorization code interception and injection attacks by requiring clients to create a secret verifier-challenge pair, ensuring that only the original requestor can exchange an authorization code for tokens.

Open Redirection

An attacker may craft malicious redirect URIs to direct users to phishing sites.

MCP clients **MUST** have redirect URIs registered with the authorization server.

Authorization servers **MUST** validate exact redirect URIs against pre-registered values to prevent redirection attacks.

MCP clients **SHOULD** use and verify state parameters in the authorization code flow and discard any results that do not include or have a mismatch with the original state.

Authorization servers **MUST** take precautions to prevent redirecting user agents to untrusted URI's, following suggestions laid out in OAuth 2.1 Section 7.12.2

Authorization servers **SHOULD** only automatically redirect the user agent if it trusts the redirection URI. If the URI is not trusted, the authorization server MAY inform the user and rely on the user to make the correct decision.

Confused Deputy Problem

Attackers can exploit MCP servers acting as intermediaries to third-party APIs, leading to confused deputy vulnerabilities.
By using stolen authorization codes, they can obtain access tokens without user consent.

MCP proxy servers using static client IDs **MUST** obtain user consent for each dynamically registered client before forwarding to third-party authorization servers (which may require additional consent).

Access Token Privilege Restriction

An attacker can gain unauthorized access or otherwise compromise a MCP server if the server accepts tokens issued for other resources.

This vulnerability has two critical dimensions:

1. **Audience validation failures.** When an MCP server doesn't verify that tokens were specifically intended for it (for example, via the audience claim, as mentioned in RFC9068), it may accept tokens originally issued for other services. This breaks a fundamental OAuth security boundary, allowing attackers to reuse legitimate tokens across different services than intended.
2. **Token passthrough.** If the MCP server not only accepts tokens with incorrect audiences but also forwards these unmodified tokens to downstream services, it can potentially cause the "confused deputy" problem, where the downstream API may incorrectly trust the token as if it came from the MCP server or assume the token was validated by the upstream API. See the Token Passthrough section of the Security Best Practices guide for additional details.

MCP servers **MUST** validate access tokens before processing the request, ensuring the access token is issued specifically for the MCP server, and take all necessary steps to ensure no data is returned to unauthorized parties.

A MCP server **MUST** follow the guidelines in OAuth 2.1 - Section 5.2 to validate inbound tokens.

MCP servers **MUST** only accept tokens specifically intended for themselves and **MUST** reject tokens that do not include them in the audience claim or otherwise verify that they are the intended recipient of the token. See the Security Best Practices Token Passthrough section for details.

If the MCP server makes requests to upstream APIs, it may act as an OAuth client to them. The access token used at the upstream API is a separate token, issued by the upstream authorization server. The MCP server **MUST NOT** pass through the token it received from the MCP client.

MCP clients **MUST** implement and use the `resource` parameter as defined in RFC 8707 - Resource Indicators for OAuth 2.0
to explicitly specify the target resource for which the token is being requested. This requirement aligns with the recommendation in RFC 9728 Section 7.4. This ensures that access tokens are bound to their intended resources and cannot be misused across different services.

Security Best Practices

Introduction

Purpose and Scope

This document provides security considerations for the Model Context Protocol (MCP), complementing the MCP Authorization specification. This document identifies security risks, attack vectors, and best practices specific to MCP implementations.

The primary audience for this document includes developers implementing MCP authorization flows, MCP server operators, and security professionals evaluating MCP-based systems. This document should be read alongside the MCP Authorization specification and OAuth 2.0 security best practices.

Attacks and Mitigations

This section gives a detailed description of attacks on MCP implementations, along with potential countermeasures.

Confused Deputy Problem

Attackers can exploit MCP servers proxying other resource servers, creating "confused deputy" vulnerabilities.

Terminology

MCP Proxy Server
: An MCP server that connects MCP clients to third-party APIs, offering MCP features while delegating operations and acting as a single OAuth client to the third-party API server.

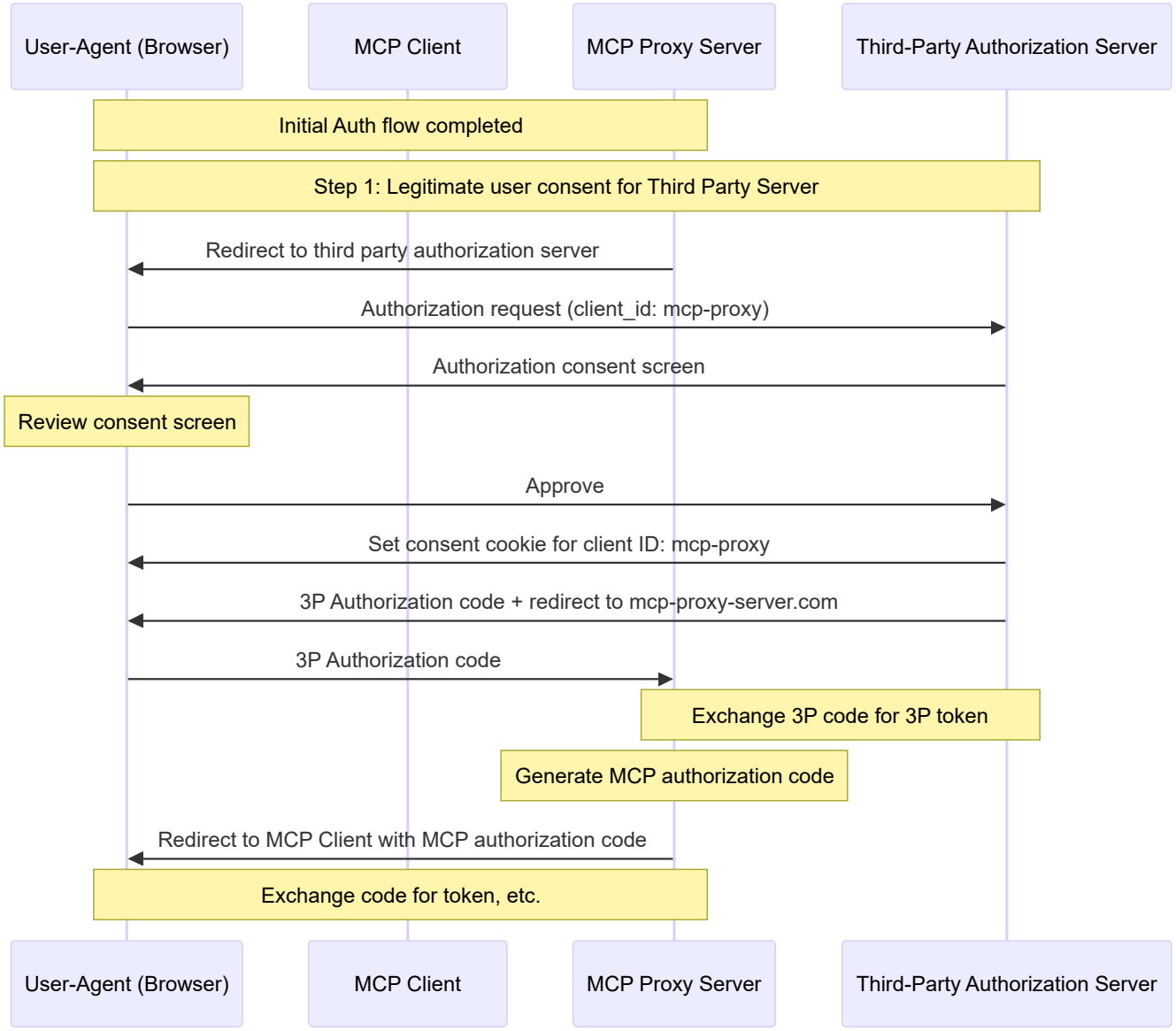
Third-Party Authorization Server
: Authorization server that protects the third-party API. It may lack dynamic client registration support, requiring MCP proxy to use a static client ID for all requests.

Third-Party API
: The protected resource server that provides the actual API functionality. Access to this API requires tokens issued by the third-party authorization server.

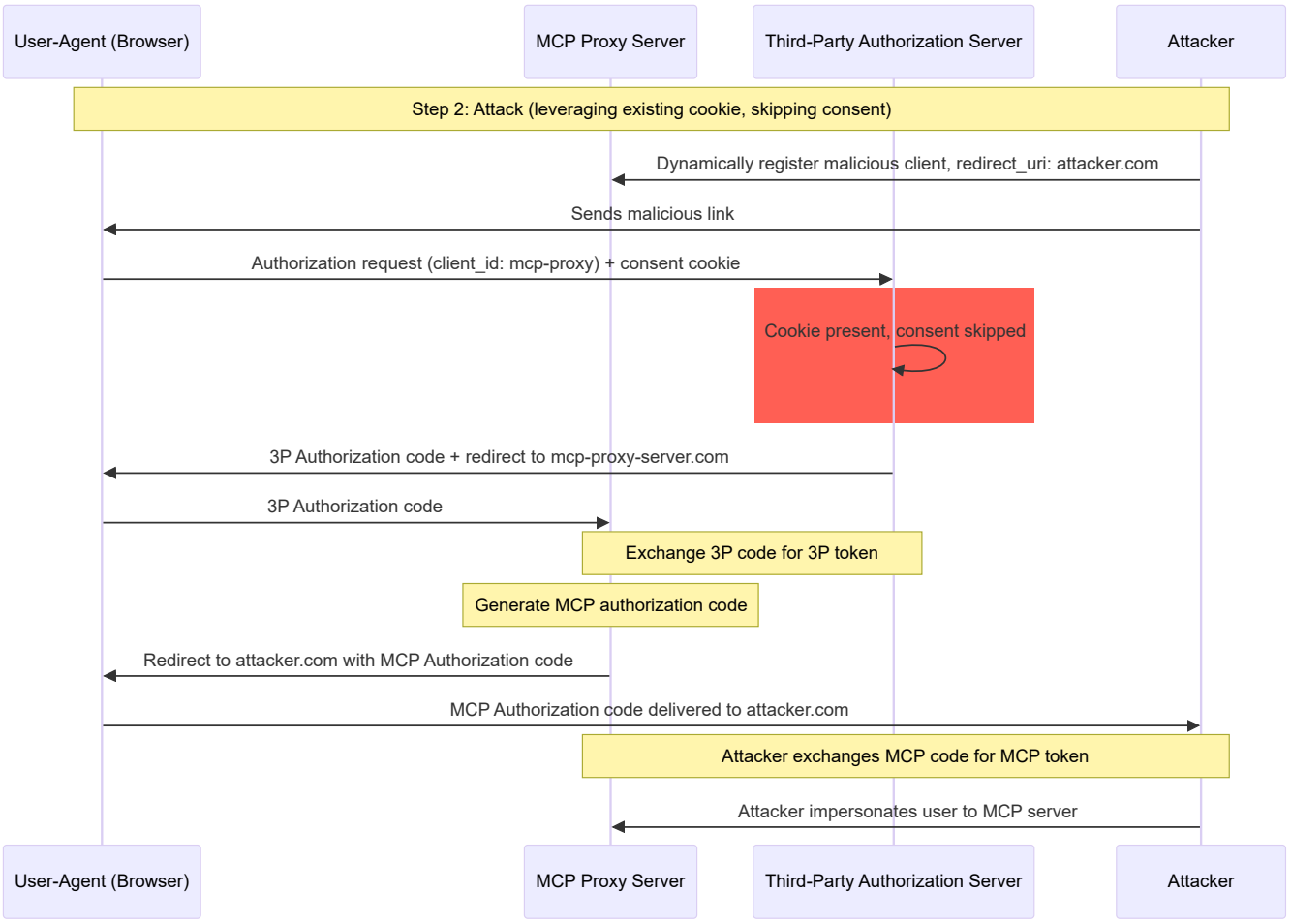
Static Client ID
: A fixed OAuth 2.0 client identifier used by the MCP proxy server when communicating with the third-party authorization server. This Client ID refers to the MCP server acting as a client to the Third-Party API. It is the same value for all MCP server to Third-Party API interactions regardless of which MCP client initiated the request.

Architecture and Attack Flows

Normal OAuth proxy usage (preserves user consent)


User-Agent (Browser)
MCP Client
MCP Proxy Server
Third-Party Authorization Server
Initial Auth flow completed
Step 1: Legitimate user consent for Third Party Server
Redirect to third party authorization server
Authorization request (client_id: mcp-proxy)
Authorization consent screen
Review consent screen
Approve
Set consent cookie for client ID: mcp-proxy
3P Authorization code + redirect to mcp-proxy-server.com
3P Authorization code
Exchange 3P code for 3P token
Generate MCP authorization code
Redirect to MCP Client with MCP authorization code
Exchange code for token, etc.
User-Agent (Browser)
MCP Client
MCP Proxy Server
Third-Party Authorization Server

Malicious OAuth proxy usage (skips user consent)



Attack Description

When an MCP proxy server uses a static client ID to authenticate with a third-party authorization server that does not support dynamic client registration, the following attack becomes possible:

1. A user authenticates normally through the MCP proxy server to access the third-party API
2. During this flow, the third-party authorization server sets a cookie on the user agent indicating consent for the static client ID
3. An attacker later sends the user a malicious link containing a crafted authorization request which contains a malicious redirect URI along with a new dynamically registered client ID
4. When the user clicks the link, their browser still has the consent cookie from the previous legitimate request
5. The third-party authorization server detects the cookie and skips the consent screen
6. The MCP authorization code is redirected to the attacker's server (specified in the crafted redirect_uri during dynamic client registration)
7. The attacker exchanges the stolen authorization code for access tokens for the MCP server without the user's explicit approval
8. Attacker now has access to the third-party API as the compromised user

Mitigation

MCP proxy servers using static client IDs **MUST** obtain user consent for each dynamically registered client before forwarding to third-party authorization servers (which may require additional consent).

Token Passthrough

"Token passthrough" is an anti-pattern where an MCP server accepts tokens from an MCP client without validating that the tokens were properly issued *to the MCP server* and "passing them through" to the downstream API.

Risks

Token passthrough is explicitly forbidden in the authorization specification as it introduces a number of security risks, that include:

- **Security Control Circumvention**
  - The MCP Server or downstream APIs might implement important security controls like rate limiting, request validation, or traffic monitoring, that depend on the token audience or other credential constraints. If clients can obtain and use tokens directly with the downstream APIs without the MCP server validating them properly or ensuring that the tokens are issued for the right service, they bypass these controls.
- **Accountability and Audit Trail Issues**
  - The MCP Server will be unable to identify or distinguish between MCP Clients when clients are calling with an upstream-issued access token which may be opaque to the MCP Server.
  - The downstream Resource Server's logs may show requests that appear to come from a different source with a different identity, rather than the MCP server that is actually forwarding the tokens.
  - Both factors make incident investigation, controls, and auditing more difficult.
  - If the MCP Server passes tokens without validating their claims (e.g., roles, privileges, or audience) or other metadata, a malicious actor in possession of a stolen token can use the server as a proxy for data exfiltration.
- **Trust Boundary Issues**
  - The downstream Resource Server grants trust to specific entities. This trust might include assumptions about origin or client behavior patterns. Breaking this trust boundary could lead to unexpected issues.
  - If the token is accepted by multiple services without proper validation, an attacker compromising one service can use the token to access other connected services.
- **Future Compatibility Risk**
  - Even if an MCP Server starts as a "pure proxy" today, it might need to add security controls later. Starting with proper token audience separation makes it easier to evolve the security model.

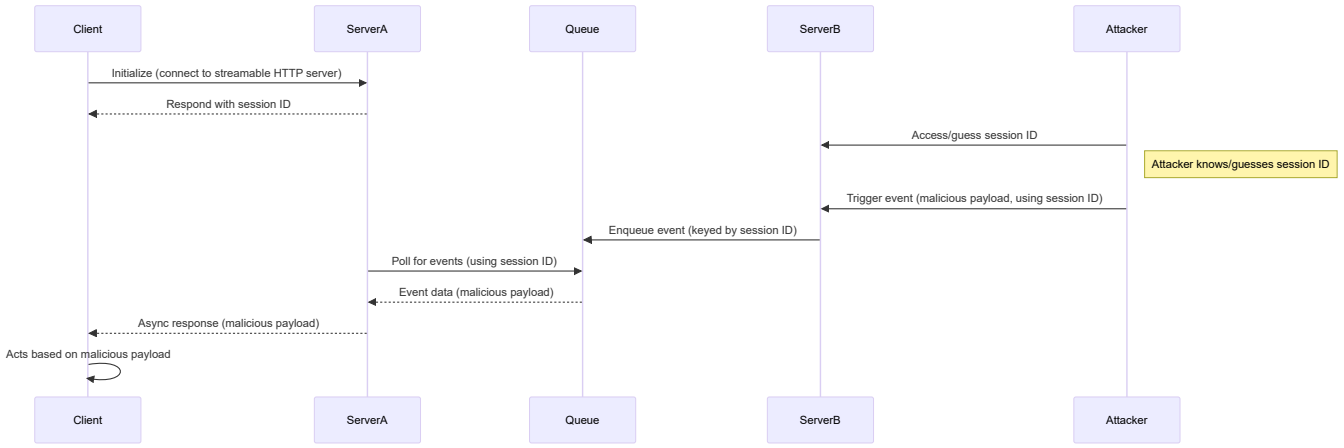
Mitigation

MCP servers **MUST NOT** accept any tokens that were not explicitly issued for the MCP server.

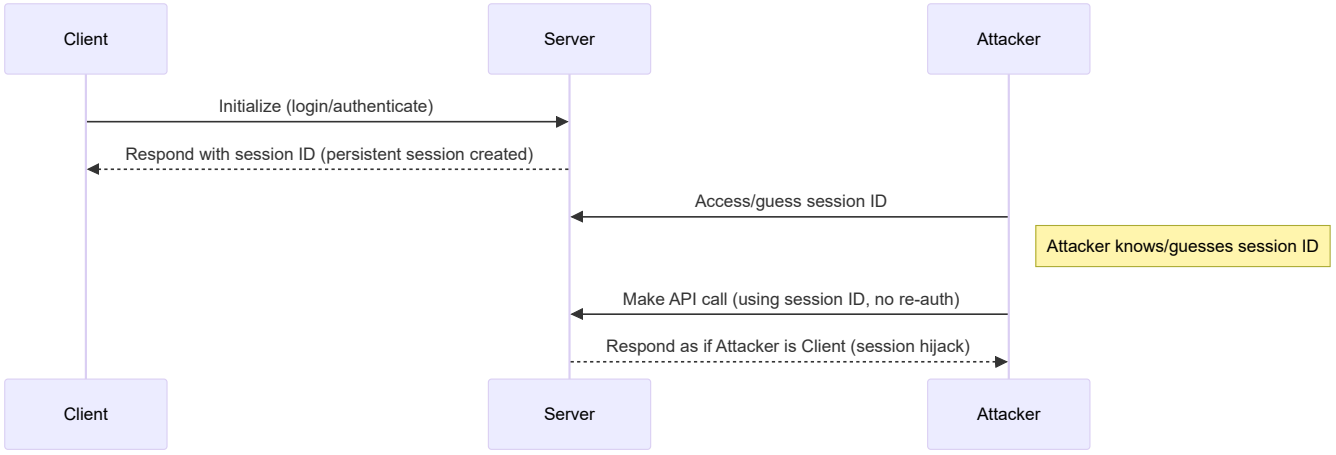
Session Hijacking

Session hijacking is an attack vector where a client is provided a session ID by the server, and an unauthorized party is able to obtain and use that same session ID to impersonate the original client and perform unauthorized actions on their behalf.

Session Hijack Prompt Injection



Session Hijack Impersonation



Attack Description

When you have multiple stateful HTTP servers that handle MCP requests, the following attack vectors are possible:

Session Hijack Prompt Injection

1. The client connects to **Server A** and receives a session ID.
2. The attacker obtains an existing session ID and sends a malicious event to **Server B** with said session ID.
    - When a server supports redelivery/resumable streams, deliberately terminating the request before receiving the response could lead to it being resumed by the original client via the GET request for server sent events.
    - If a particular server initiates server sent events as a consequence of a tool call such as a `notifications/tools/list_changed`, where it is possible to affect the tools that are offered by the server, a client could end up with tools that they were not aware were enabled.

3. **Server B** enqueues the event (associated with session ID) into a shared queue.
4. **Server A** polls the queue for events using the session ID and retrieves the malicious payload.
5. **Server A** sends the malicious payload to the client as an asynchronous or resumed response.
6. The client receives and acts on the malicious payload, leading to potential compromise.

Session Hijack Impersonation

1. The MCP client authenticates with the MCP server, creating a persistent session ID.
2. The attacker obtains the session ID.
3. The attacker makes calls to the MCP server using the session ID.
4. MCP server does not check for additional authorization and treats the attacker as a legitimate user, allowing unauthorized access or actions.

Mitigation

To prevent session hijacking and event injection attacks, the following mitigations should be implemented:

MCP servers that implement authorization **MUST** verify all inbound requests.
MCP Servers **MUST NOT** use sessions for authentication.

MCP servers **MUST** use secure, non-deterministic session IDs.
Generated session IDs (e.g., UUIDs) **SHOULD** use secure random number generators. Avoid predictable or sequential session identifiers that could be guessed by an attacker. Rotating or expiring session IDs can also reduce the risk.

MCP servers **SHOULD** bind session IDs to user-specific information.
When storing or transmitting session-related data (e.g., in a queue), combine the session ID with information unique to the authorized user, such as their internal user ID. Use a key format like `<user_id>:<session_id>`.
This ensures that even if an attacker guesses a session ID, they cannot impersonate another user as the user ID is derived from the user token and not provided by the client.

MCP servers can optionally leverage additional unique identifiers.

Utilities

Cancellation

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) supports optional cancellation of in-progress requests through notification messages. Either side can send a cancellation notification to indicate that a previously-issued request should be terminated.

Cancellation Flow

When a party wants to cancel an in-progress request, it sends a `notifications/cancelled` notification containing:

- The ID of the request to cancel
- An optional reason string that can be logged or displayed

```
{
  "jsonrpc": "2.0",
  "method": "notifications/cancelled",
  "params": {
    "requestId": "123",
    "reason": "User requested cancellation"
  }
}
```

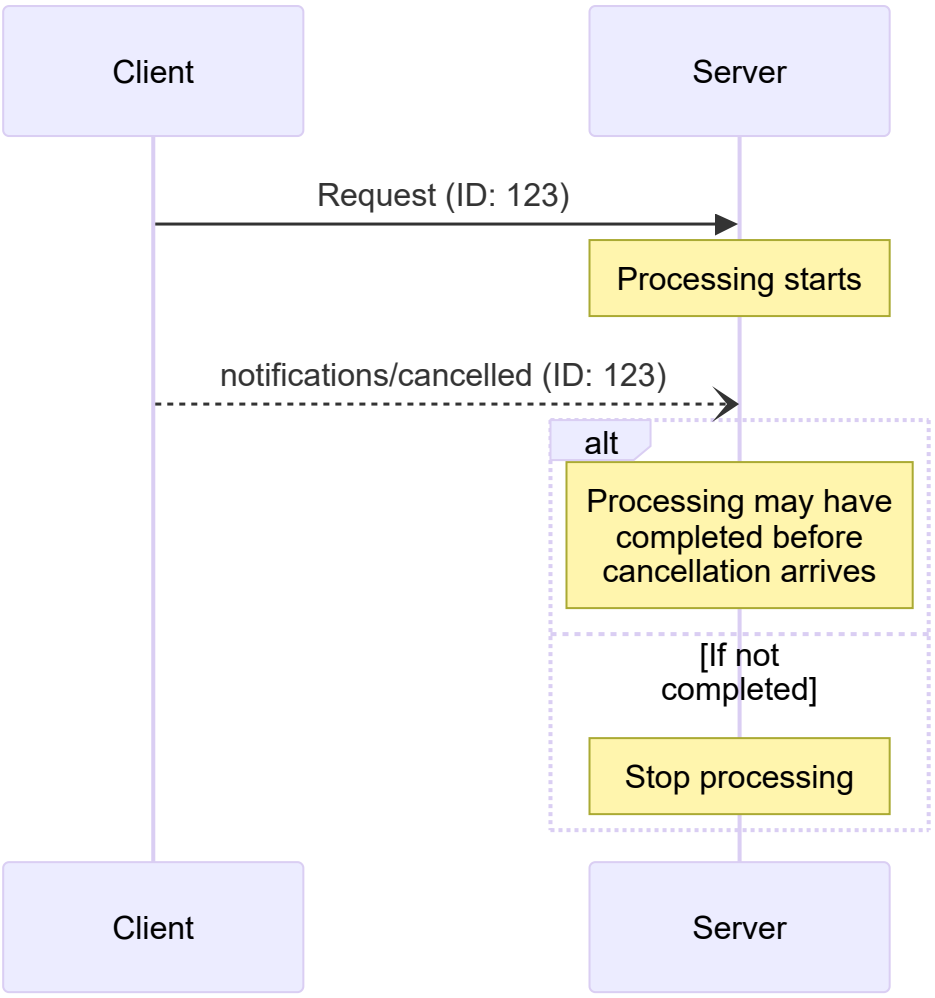
Behavior Requirements

1. Cancellation notifications **MUST** only reference requests that:
   - Were previously issued in the same direction
   - Are believed to still be in-progress
2. The `initialize` request **MUST NOT** be cancelled by clients
3. Receivers of cancellation notifications **SHOULD**:
   - Stop processing the cancelled request
   - Free associated resources
   - Not send a response for the cancelled request
4. Receivers **MAY** ignore cancellation notifications if:
   - The referenced request is unknown
   - Processing has already completed
   - The request cannot be cancelled
5. The sender of the cancellation notification **SHOULD** ignore any response to the request that arrives afterward

Timing Considerations

Due to network latency, cancellation notifications may arrive after request processing has completed, and potentially after a response has already been sent.

Both parties **MUST** handle these race conditions gracefully:



Implementation Notes

- Both parties **SHOULD** log cancellation reasons for debugging
- Application UIs **SHOULD** indicate when cancellation is requested

Error Handling

Invalid cancellation notifications **SHOULD** be ignored:

- Unknown request IDs
- Already completed requests
- Malformed notifications

This maintains the "fire and forget" nature of notifications while allowing for race conditions in asynchronous communication.

Ping

Protocol Revision: 2025-06-18

The Model Context Protocol includes an optional ping mechanism that allows either party to verify that their counterpart is still responsive and the connection is alive.

Overview

The ping functionality is implemented through a simple request/response pattern. Either the client or server can initiate a ping by sending a `ping` request.

Message Format

A ping request is a standard JSON-RPC request with no parameters:

```
{
  "jsonrpc": "2.0",
  "id": "123",
  "method": "ping"
}
```

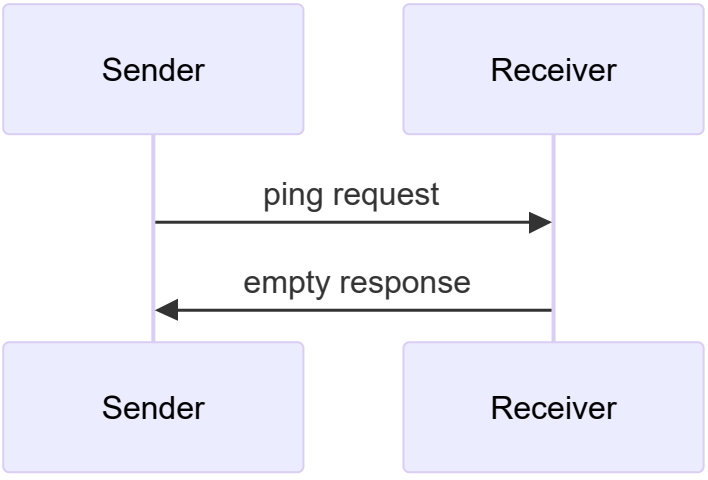
Behavior Requirements

1. The receiver **MUST** respond promptly with an empty response:

```
{
  "jsonrpc": "2.0",
  "id": "123",
  "result": {}
}
```

2. If no response is received within a reasonable timeout period, the sender **MAY**:
    - Consider the connection stale
    - Terminate the connection
    - Attempt reconnection procedures

Usage Patterns



Implementation Considerations

- Implementations **SHOULD** periodically issue pings to detect connection health
- The frequency of pings **SHOULD** be configurable
- Timeouts **SHOULD** be appropriate for the network environment
- Excessive pinging **SHOULD** be avoided to reduce network overhead

Error Handling

- Timeouts **SHOULD** be treated as connection failures
- Multiple failed pings **MAY** trigger connection reset
- Implementations **SHOULD** log ping failures for diagnostics

Progress

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) supports optional progress tracking for long-running operations through notification messages. Either side can send progress notifications to provide updates about operation status.

Progress Flow

When a party wants to *receive* progress updates for a request, it includes a `progressToken` in the request metadata.

- Progress tokens **MUST** be a string or integer value
- Progress tokens can be chosen by the sender using any means, but **MUST** be unique across all active requests.

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "some_method",
  "params": {
    "_meta": {
      "progressToken": "abc123"
    }
  }
}
```

The receiver **MAY** then send progress notifications containing:

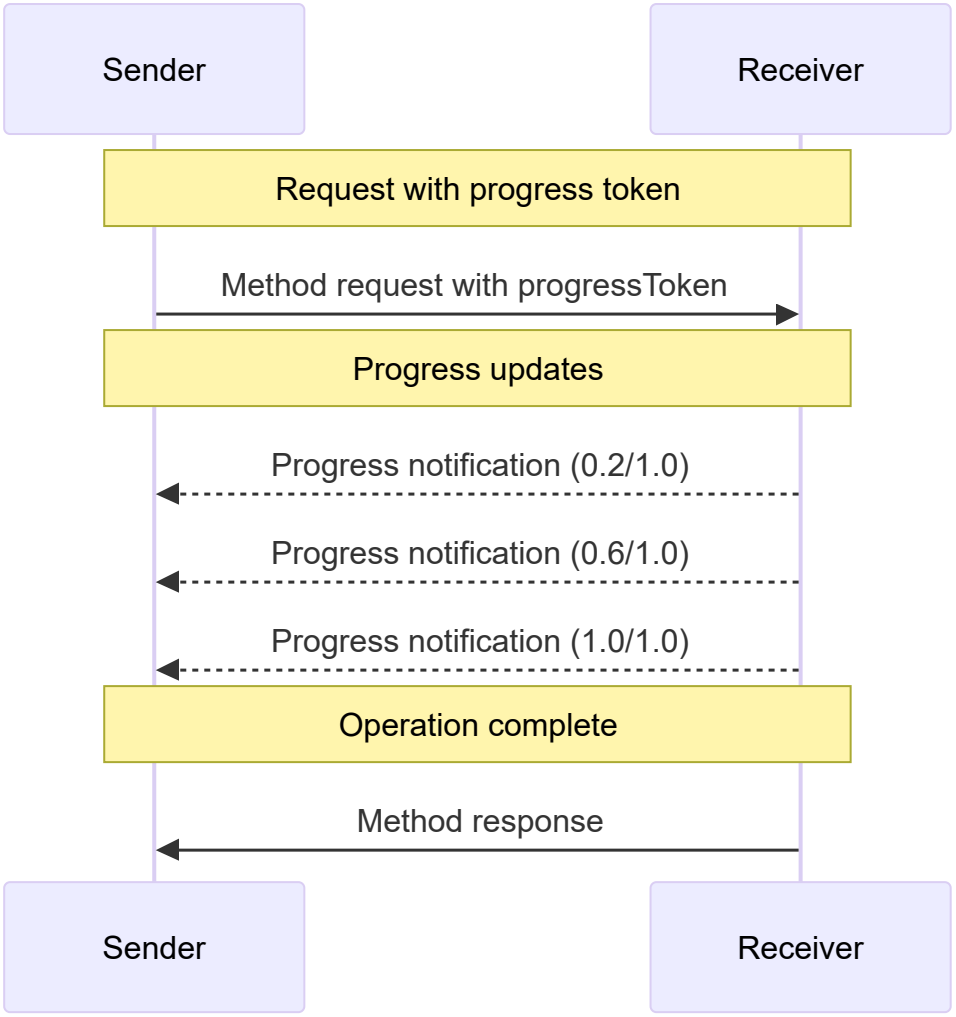
- The original progress token
- The current progress value so far
- An optional "total" value
- An optional "message" value

```
{
  "jsonrpc": "2.0",
  "method": "notifications/progress",
  "params": {
    "progressToken": "abc123",
    "progress": 50,
    "total": 100,
    "message": "Reticulating splines..."
  }
}
```

- The `progress` value **MUST** increase with each notification, even if the total is unknown.
- The `progress` and the `total` values **MAY** be floating point.
- The `message` field **SHOULD** provide relevant human readable progress information.

Behavior Requirements

1. Progress notifications **MUST** only reference tokens that:
    - Were provided in an active request
    - Are associated with an in-progress operation
2. Receivers of progress requests **MAY**:
    - Choose not to send any progress notifications
    - Send notifications at whatever frequency they deem appropriate
    - Omit the total value if unknown



Implementation Notes

- Senders and receivers **SHOULD** track active progress tokens
- Both parties **SHOULD** implement rate limiting to prevent flooding
- Progress notifications **MUST** stop after completion

Client Features

Roots

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) provides a standardized way for clients to expose filesystem "roots" to servers. Roots define the boundaries of where servers can operate within the filesystem, allowing them to understand which directories and files they have access to. Servers can request the list of roots from supporting clients and receive notifications when that list changes.

User Interaction Model

Roots in MCP are typically exposed through workspace or project configuration interfaces.

For example, implementations could offer a workspace/project picker that allows users to select directories and files the server should have access to. This can be combined with automatic workspace detection from version control systems or project files.

However, implementations are free to expose roots through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

Capabilities

Clients that support roots **MUST** declare the `roots` capability during initialization:

```
{
  "capabilities": {
    "roots": {
      "listChanged": true
    }
  }
}
```

`listChanged` indicates whether the client will emit notifications when the list of roots changes.

Protocol Messages

Listing Roots

To retrieve roots, servers send a `roots/list` request:

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "roots/list"
}
```

Response:

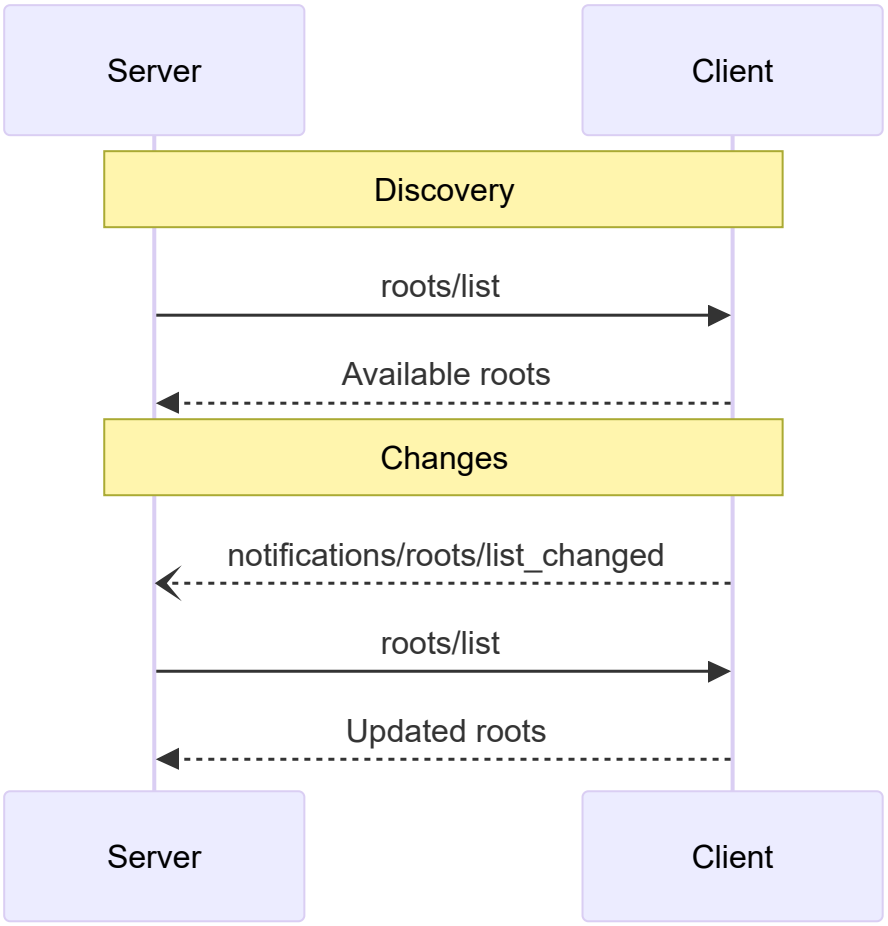
```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "roots": [
      {
        "uri": "file:///home/user/projects/myproject",
        "name": "My Project"
      }
    ]
  }
}
```

Root List Changes

When roots change, clients that support `listChanged` **MUST** send a notification:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/roots/list_changed"
}
```

Message Flow



Data Types

Root

A root definition includes:

- `uri`: Unique identifier for the root. This **MUST** be a `file://` URI in the current specification.
- `name`: Optional human-readable name for display purposes.

Example roots for different use cases:

Project Directory

```
{
  "uri": "file:///home/user/projects/myproject",
  "name": "My Project"
}
```

Multiple Repositories

```
[
  {
    "uri": "file:///home/user/repos/frontend",
    "name": "Frontend Repository"
  },
  {
    "uri": "file:///home/user/repos/backend",
    "name": "Backend Repository"
  }
]
```

Error Handling

Clients **SHOULD** return standard JSON-RPC errors for common failure cases:

- Client does not support roots: `-32601` (Method not found)
- Internal errors: `-32603`

Example error:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "error": {
    "code": -32601,
    "message": "Roots not supported",
    "data": {
      "reason": "Client does not have roots capability"
    }
  }
}
```

Security Considerations

1. Clients **MUST**:
    - Only expose roots with appropriate permissions
    - Validate all root URIs to prevent path traversal
    - Implement proper access controls
    - Monitor root accessibility
2. Servers **SHOULD**:
    - Handle cases where roots become unavailable
    - Respect root boundaries during operations
    - Validate all paths against provided roots

Implementation Guidelines

1. Clients **SHOULD**:
    - Prompt users for consent before exposing roots to servers
    - Provide clear user interfaces for root management
    - Validate root accessibility before exposing
    - Monitor for root changes
2. Servers **SHOULD**:
    - Check for roots capability before usage
    - Handle root list changes gracefully
    - Respect root boundaries in operations
    - Cache root information appropriately

Sampling

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) provides a standardized way for servers to request LLM sampling ("completions" or "generations") from language models via clients. This flow allows clients to maintain control over model access, selection, and permissions while enabling servers to leverage AI capabilities—with no server API keys necessary.
Servers can request text, audio, or image-based interactions and optionally include context from MCP servers in their prompts.

User Interaction Model

Sampling in MCP allows servers to implement agentic behaviors, by enabling LLM calls to occur *nested* inside other MCP server features.

Implementations are free to expose sampling through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

For trust & safety and security, there **SHOULD** always
be a human in the loop with the ability to deny sampling requests.

Applications **SHOULD**:

- Provide UI that makes it easy and intuitive to review sampling requests
- Allow users to view and edit prompts before sending
- Present generated responses for review before delivery

Capabilities

Clients that support sampling **MUST** declare the `sampling` capability during initialization:

```
{
  "capabilities": {
    "sampling": {}
  }
}
```

Protocol Messages

Creating Messages

To request a language model generation, servers send a `sampling/createMessage` request:

Request:

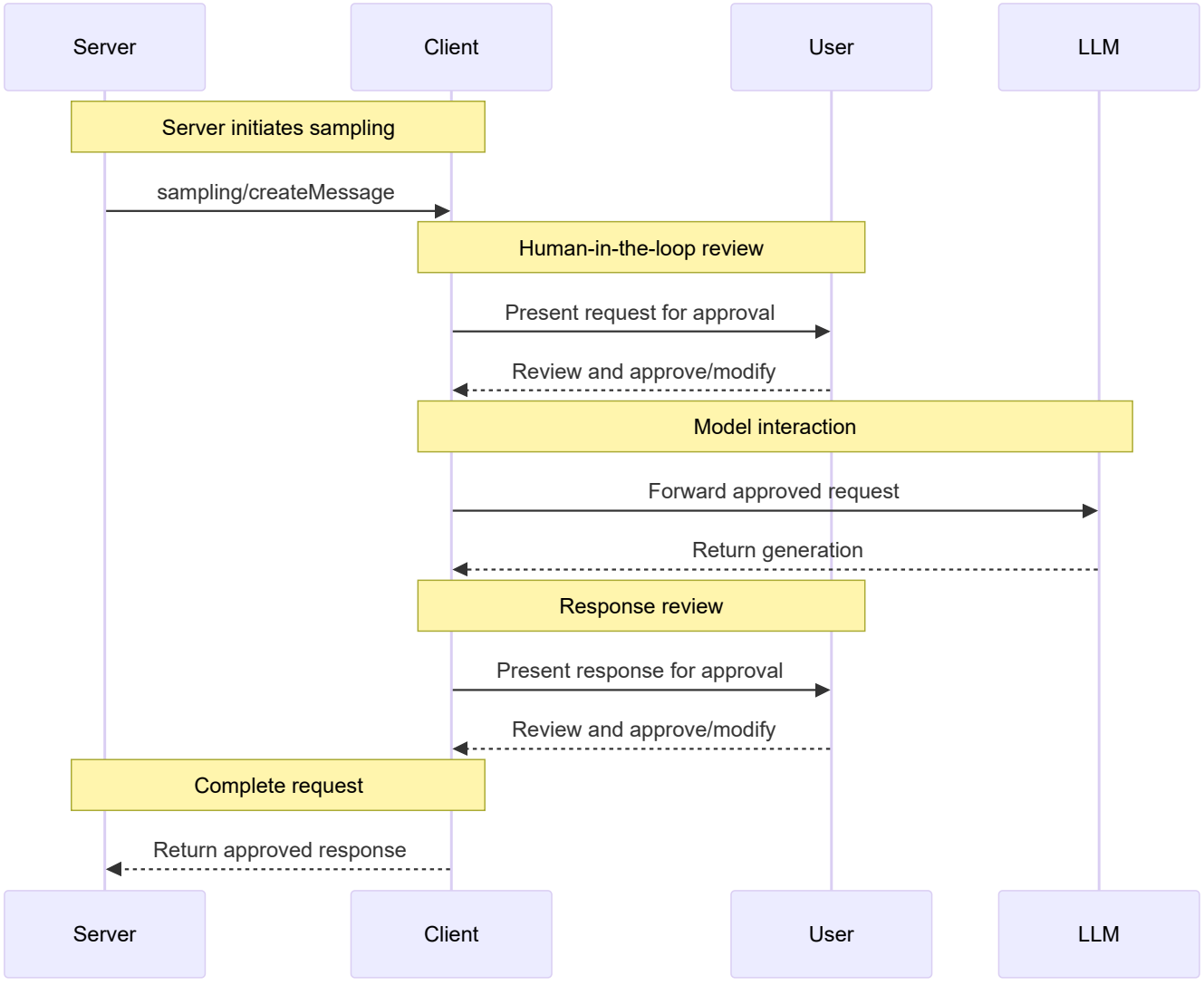
```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "sampling/createMessage",
  "params": {
    "messages": [
      {
        "role": "user",
        "content": {
          "type": "text",
          "text": "What is the capital of France?"
        }
      }
    ],
    "modelPreferences": {
      "hints": [
        {
          "name": "claude-3-sonnet"
        }
      ],
      "intelligencePriority": 0.8,
      "speedPriority": 0.5
    },
    "systemPrompt": "You are a helpful assistant.",
```

```
    "maxTokens": 100
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "role": "assistant",
    "content": {
      "type": "text",
      "text": "The capital of France is Paris."
    },
    "model": "claude-3-sonnet-20240307",
    "stopReason": "endTurn"
  }
}
```

Message Flow



Data Types

Messages

Sampling messages can contain:

Text Content

```
{
  "type": "text",
  "text": "The message content"
}
```

Image Content

```
{
  "type": "image",
  "data": "base64-encoded-image-data",
  "mimeType": "image/jpeg"
}
```

Audio Content

```
{
  "type": "audio",
  "data": "base64-encoded-audio-data",
  "mimeType": "audio/wav"
}
```

Model Preferences

Model selection in MCP requires careful abstraction since servers and clients may use different AI providers with distinct model offerings. A server cannot simply request a specific model by name since the client may not have access to that exact model or may prefer to use a different provider's equivalent model.

To solve this, MCP implements a preference system that combines abstract capability priorities with optional model hints:

Capability Priorities

Servers express their needs through three normalized priority values (0-1):

- `costPriority`: How important is minimizing costs? Higher values prefer cheaper models.
- `speedPriority`: How important is low latency? Higher values prefer faster models.
- `intelligencePriority`: How important are advanced capabilities? Higher values prefer more capable models.

Model Hints

While priorities help select models based on characteristics, `hints` allow servers to suggest specific models or model families:

- Hints are treated as substrings that can match model names flexibly
- Multiple hints are evaluated in order of preference
- Clients **MAY** map hints to equivalent models from different providers
- Hints are advisory—clients make final model selection

For example:

```
{
  "hints": [
    { "name": "claude-3-sonnet" }, // Prefer Sonnet-class models
    { "name": "claude" } // Fall back to any Claude model
  ],
  "costPriority": 0.3, // Cost is less important
  "speedPriority": 0.8, // Speed is very important
  "intelligencePriority": 0.5 // Moderate capability needs
}
```

The client processes these preferences to select an appropriate model from its available options. For instance, if the client doesn't have access to Claude models but has Gemini, it might map the sonnet hint to `gemini-1.5-pro` based on similar capabilities.

Error Handling

Clients **SHOULD** return errors for common failure cases:

Example error:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "error": {
    "code": -1,
    "message": "User rejected sampling request"
  }
}
```

Security Considerations

1. Clients **SHOULD** implement user approval controls
2. Both parties **SHOULD** validate message content
3. Clients **SHOULD** respect model preference hints
4. Clients **SHOULD** implement rate limiting
5. Both parties **MUST** handle sensitive data appropriately

Elicitation

Protocol Revision: 2025-06-18

Elicitation is newly introduced in this version of the MCP specification and its design may evolve in future protocol versions.

The Model Context Protocol (MCP) provides a standardized way for servers to request additional information from users through the client during interactions. This flow allows clients to maintain control over user interactions and data sharing while enabling servers to gather necessary information dynamically.
Servers request structured data from users with JSON schemas to validate responses.

User Interaction Model

Elicitation in MCP allows servers to implement interactive workflows by enabling user input requests to occur *nested* inside other MCP server features.

Implementations are free to expose elicitation through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

For trust & safety and security:

- Servers **MUST NOT** use elicitation to request sensitive information.

Applications **SHOULD**:

- Provide UI that makes it clear which server is requesting information
- Allow users to review and modify their responses before sending
- Respect user privacy and provide clear decline and cancel options

Capabilities

Clients that support elicitation **MUST** declare the `elicitation` capability during initialization:

```
{
  "capabilities": {
    "elicitation": {}
  }
}
```

Protocol Messages

Creating Elicitation Requests

To request information from a user, servers send an `elicitation/create` request:

Simple Text Request

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "elicitation/create",
  "params": {
    "message": "Please provide your GitHub username",
    "requestedSchema": {
      "type": "object",
      "properties": {
        "name": {
          "type": "string"
        }
      },
      "required": ["name"]
    }
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "action": "accept",
    "content": {
      "name": "octocat"
    }
  }
}
```

Structured Data Request

Request:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "method": "elicitation/create",
  "params": {
    "message": "Please provide your contact information",
    "requestedSchema": {
      "type": "object",
      "properties": {
        "name": {
          "type": "string",
          "description": "Your full name"
        },
```

```
        "email": {
          "type": "string",
          "format": "email",
          "description": "Your email address"
        },
        "age": {
          "type": "number",
          "minimum": 18,
          "description": "Your age"
        }
      },
      "required": ["name", "email"]
    }
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "action": "accept",
    "content": {
      "name": "Monalisa Octocat",
      "email": "octocat@github.com",
      "age": 30
    }
  }
}
```

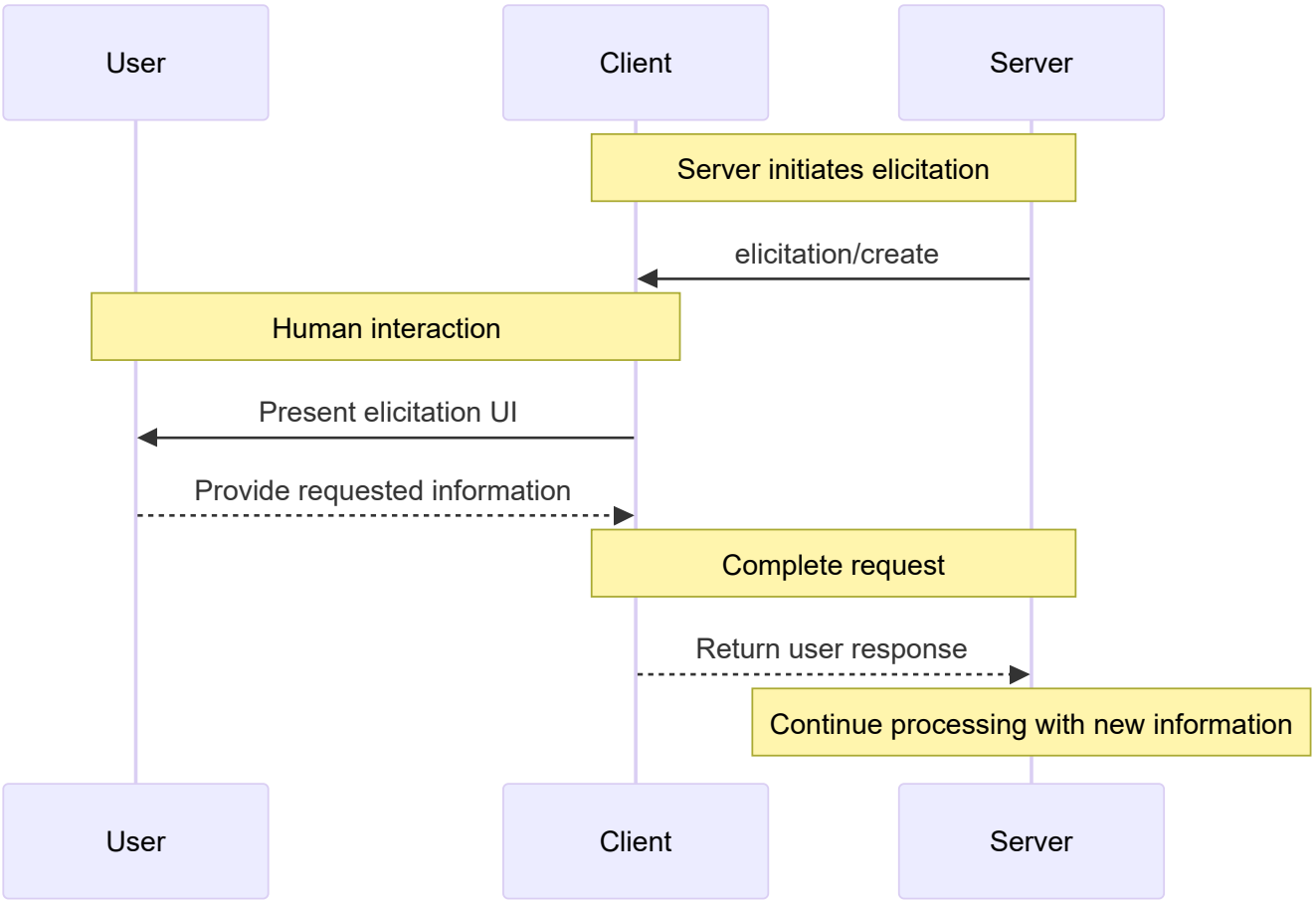
Reject Response Example:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "action": "decline"
  }
}
```

Cancel Response Example:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "action": "cancel"
  }
}
```

Message Flow



Request Schema

The `requestedSchema` field allows servers to define the structure of the expected response using a restricted subset of JSON Schema. To simplify implementation for clients, elicitation schemas are limited to flat objects with primitive properties only:

```
"requestedSchema": {
  "type": "object",
  "properties": {
    "propertyName": {
      "type": "string",
      "title": "Display Name",
      "description": "Description of the property"
    },
    "anotherProperty": {
      "type": "number",
      "minimum": 0,
      "maximum": 100
    }
  },
  "required": ["propertyName"]
}
```

Supported Schema Types

The schema is restricted to these primitive types:

1. **String Schema**

```
{
  "type": "string",
  "title": "Display Name",
  "description": "Description text",
  "minLength": 3,
  "maxLength": 50,
  "format": "email" // Supported: "email", "uri", "date", "date-time"
}
```

   Supported formats: `email`, `uri`, `date`, `date-time`

2. **Number Schema**

```
{
  "type": "number", // or "integer"
  "title": "Display Name",
  "description": "Description text",
  "minimum": 0,
  "maximum": 100
}
```

3. **Boolean Schema**

```
{
  "type": "boolean",
  "title": "Display Name",
  "description": "Description text",
  "default": false
}
```

4. **Enum Schema**

```
{
  "type": "string",
  "title": "Display Name",
  "description": "Description text",
  "enum": ["option1", "option2", "option3"],
  "enumNames": ["Option 1", "Option 2", "Option 3"]
}
```

Clients can use this schema to:

1. Generate appropriate input forms
2. Validate user input before sending
3. Provide better guidance to users

Note that complex nested structures, arrays of objects, and other advanced JSON Schema features are intentionally not supported to simplify client implementation.

Response Actions

Elicitation responses use a three-action model to clearly distinguish between different user actions:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "action": "accept", // or "decline" or "cancel"
    "content": {
      "propertyName": "value",
      "anotherProperty": 42
    }
  }
}
```

The three response actions are:

1. **Accept** (`action: "accept"`): User explicitly approved and submitted with data
    - The `content` field contains the submitted data matching the requested schema
    - Example: User clicked "Submit", "OK", "Confirm", etc.
2. **Decline** (`action: "decline"`): User explicitly declined the request
    - The `content` field is typically omitted
    - Example: User clicked "Reject", "Decline", "No", etc.
3. **Cancel** (`action: "cancel"`): User dismissed without making an explicit choice
    - The `content` field is typically omitted
    - Example: User closed the dialog, clicked outside, pressed Escape, etc.

Servers should handle each state appropriately:

- **Accept**: Process the submitted data
- **Decline**: Handle explicit decline (e.g., offer alternatives)
- **Cancel**: Handle dismissal (e.g., prompt again later)

Security Considerations

1. Servers **MUST NOT** request sensitive information through elicitation
2. Clients **SHOULD** implement user approval controls
3. Both parties **SHOULD** validate elicitation content against the provided schema
4. Clients **SHOULD** provide clear indication of which server is requesting information
5. Clients **SHOULD** allow users to decline elicitation requests at any time
6. Clients **SHOULD** implement rate limiting

7. Clients **SHOULD** present elicitation requests in a way that makes it clear what information is being requested and why

Server features

Overview

Protocol Revision: 2025-06-18

Servers provide the fundamental building blocks for adding context to language models via MCP. These primitives enable rich interactions between clients, servers, and language models:

- **Prompts**: Pre-defined templates or instructions that guide language model interactions
- **Resources**: Structured data or content that provides additional context to the model
- **Tools**: Executable functions that allow models to perform actions or retrieve information

Each primitive can be summarized in the following control hierarchy:

Primitive	Control	Description	Example
Prompts	User-controlled	Interactive templates invoked by user choice	Slash commands, menu options
Resources	Application-controlled	Contextual data attached and managed by the client	File contents, git history
Tools	Model-controlled	Functions exposed to the LLM to take actions	API POST requests, file writing

Explore these key primitives in more detail below:

Prompts

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) provides a standardized way for servers to expose prompt templates to clients. Prompts allow servers to provide structured messages and instructions for interacting with language models. Clients can discover available prompts, retrieve their contents, and provide arguments to customize them.

User Interaction Model

Prompts are designed to be **user-controlled**, meaning they are exposed from servers to clients with the intention of the user being able to explicitly select them for use.

Typically, prompts would be triggered through user-initiated commands in the user interface, which allows users to naturally discover and invoke available prompts.

For example, as slash commands:

However, implementors are free to expose prompts through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

Capabilities

Servers that support prompts **MUST** declare the `prompts` capability during initialization:

```
{
  "capabilities": {
    "prompts": {
      "listChanged": true
    }
  }
}
```

`listChanged` indicates whether the server will emit notifications when the list of available prompts changes.

Protocol Messages

Listing Prompts

To retrieve available prompts, clients send a `prompts/list` request. This operation supports pagination.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "prompts/list",
  "params": {
    "cursor": "optional-cursor-value"
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "prompts": [
      {
        "name": "code_review",
        "title": "Request Code Review",
        "description": "Asks the LLM to analyze code quality and suggest improvements",
        "arguments": [
          {
            "name": "code",
            "description": "The code to review",
            "required": true
          }
        ]
      }
    ],
    "nextCursor": "next-page-cursor"
  }
}
```

Getting a Prompt

To retrieve a specific prompt, clients send a `prompts/get` request. Arguments may be auto-completed through the completion API.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "method": "prompts/get",
  "params": {
    "name": "code_review",
    "arguments": {
      "code": "def hello():\n    print('world')"
    }
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "description": "Code review prompt",
    "messages": [
      {
        "role": "user",
        "content": {
```

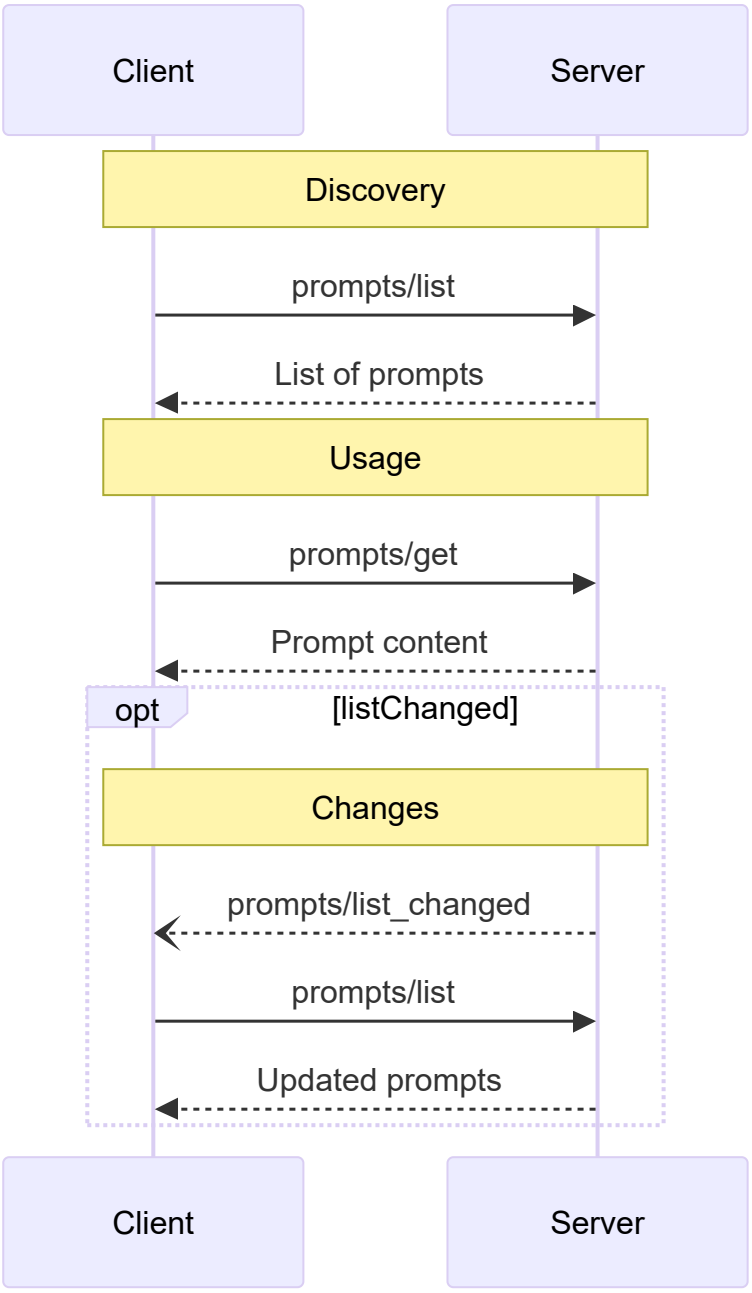
```
          "type": "text",
          "text": "Please review this Python code:\ndef hello():\n    print('world')"
        }
      }
    ]
  }
}
```

List Changed Notification

When the list of available prompts changes, servers that declared the `listChanged` capability **SHOULD** send a notification:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/prompts/list_changed"
}
```

Message Flow



Data Types

Prompt

A prompt definition includes:

- `name`: Unique identifier for the prompt
- `title`: Optional human-readable name of the prompt for display purposes.
- `description`: Optional human-readable description
- `arguments`: Optional list of arguments for customization

PromptMessage

Messages in a prompt can contain:

- `role`: Either "user" or "assistant" to indicate the speaker
- `content`: One of the following content types:

All content types in prompt messages support optional
annotations for
metadata about audience, priority, and modification times.

Text Content

Text content represents plain text messages:

```
{
  "type": "text",
  "text": "The text content of the message"
}
```

This is the most common content type used for natural language interactions.

Image Content

Image content allows including visual information in messages:

```
{
  "type": "image",
  "data": "base64-encoded-image-data",
  "mimeType": "image/png"
}
```

The image data **MUST** be base64-encoded and include a valid MIME type. This enables multi-modal interactions where visual context is important.

Audio Content

Audio content allows including audio information in messages:

```
{
  "type": "audio",
  "data": "base64-encoded-audio-data",
  "mimeType": "audio/wav"
}
```

The audio data MUST be base64-encoded and include a valid MIME type. This enables multi-modal interactions where audio context is important.

Embedded Resources

Embedded resources allow referencing server-side resources directly in messages:

```
{
  "type": "resource",
  "resource": {
    "uri": "resource://example",
    "name": "example",
    "title": "My Example Resource",
    "mimeType": "text/plain",
    "text": "Resource content"
  }
}
```

Resources can contain either text or binary (blob) data and **MUST** include:

- A valid resource URI
- The appropriate MIME type
- Either text content or base64-encoded blob data

Embedded resources enable prompts to seamlessly incorporate server-managed content like documentation, code samples, or other reference materials directly into the conversation flow.

Error Handling

Servers **SHOULD** return standard JSON-RPC errors for common failure cases:

- Invalid prompt name: `-32602` (Invalid params)
- Missing required arguments: `-32602` (Invalid params)
- Internal errors: `-32603` (Internal error)

Implementation Considerations

1. Servers **SHOULD** validate prompt arguments before processing
2. Clients **SHOULD** handle pagination for large prompt lists
3. Both parties **SHOULD** respect capability negotiation

Security

Implementations **MUST** carefully validate all prompt inputs and outputs to prevent injection attacks or unauthorized access to resources.

Resources

Protocol Revision: 2025-06-18

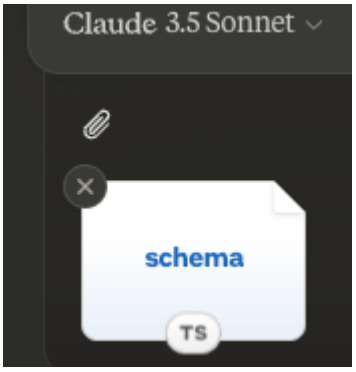
The Model Context Protocol (MCP) provides a standardized way for servers to expose resources to clients. Resources allow servers to share data that provides context to language models, such as files, database schemas, or application-specific information.
Each resource is uniquely identified by a URI.

User Interaction Model

Resources in MCP are designed to be **application-driven**, with host applications determining how to incorporate context based on their needs.

For example, applications could:

- Expose resources through UI elements for explicit selection, in a tree or list view
- Allow the user to search through and filter available resources
- Implement automatic context inclusion, based on heuristics or the AI model's selection



However, implementations are free to expose resources through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

Capabilities

Servers that support resources **MUST** declare the `resources` capability:

```
{
  "capabilities": {
    "resources": {
      "subscribe": true,
      "listChanged": true
    }
  }
}
```

The capability supports two optional features:

- `subscribe`: whether the client can subscribe to be notified of changes to individual resources.
- `listChanged`: whether the server will emit notifications when the list of available resources changes.

Both `subscribe` and `listChanged` are optional—servers can support neither, either, or both:

```
{
  "capabilities": {
    "resources": {} // Neither feature supported
  }
}
```

```
{
  "capabilities": {
    "resources": {
      "subscribe": true // Only subscriptions supported
    }
  }
}
```

```
{
  "capabilities": {
    "resources": {
      "listChanged": true // Only list change notifications supported
    }
  }
}
```

Protocol Messages

Listing Resources

To discover available resources, clients send a `resources/list` request. This operation supports pagination.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "resources/list",
  "params": {
    "cursor": "optional-cursor-value"
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "resources": [
      {
        "uri": "file:///project/src/main.rs",
        "name": "main.rs",
        "title": "Rust Software Application Main File",
        "description": "Primary application entry point",
        "mimeType": "text/x-rust"
      }
    ],
    "nextCursor": "next-page-cursor"
  }
}
```

Reading Resources

To retrieve resource contents, clients send a `resources/read` request:

Request:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "method": "resources/read",
  "params": {
    "uri": "file:///project/src/main.rs"
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "contents": [
      {
        "uri": "file:///project/src/main.rs",
        "name": "main.rs",
        "title": "Rust Software Application Main File",
        "mimeType": "text/x-rust",
        "text": "fn main() {\n    println!(\"Hello world!\");\n}"
      }
    ]
  }
}
```

Resource Templates

Resource templates allow servers to expose parameterized resources using URI templates. Arguments may be auto-completed through the completion API.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 3,
  "method": "resources/templates/list"
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 3,
  "result": {
```

```
    "resourceTemplates": [
      {
        "uriTemplate": "file:///{path}",
        "name": "Project Files",
        "title": "📁 Project Files",
        "description": "Access files in the project directory",
        "mimeType": "application/octet-stream"
      }
    ]
  }
}
```

List Changed Notification

When the list of available resources changes, servers that declared the `listChanged` capability **SHOULD** send a notification:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/resources/list_changed"
}
```

Subscriptions

The protocol supports optional subscriptions to resource changes. Clients can subscribe to specific resources and receive notifications when they change:

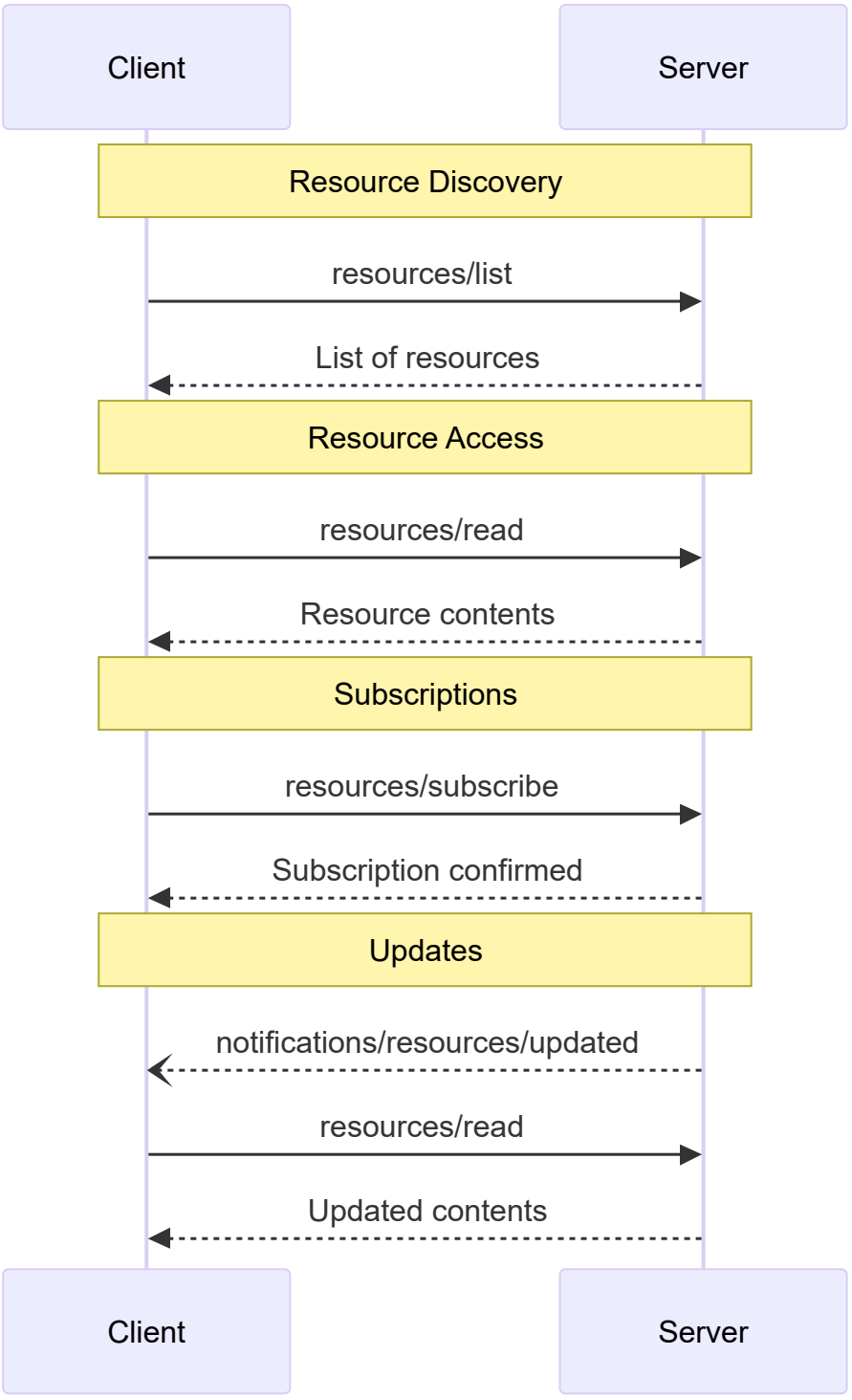
Subscribe Request:

```
{
  "jsonrpc": "2.0",
  "id": 4,
  "method": "resources/subscribe",
  "params": {
    "uri": "file:///project/src/main.rs"
  }
}
```

Update Notification:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/resources/updated",
  "params": {
    "uri": "file:///project/src/main.rs",
    "title": "Rust Software Application Main File"
  }
}
```

Message Flow



Data Types

Resource

A resource definition includes:

- `uri`: Unique identifier for the resource
- `name`: The name of the resource.
- `title`: Optional human-readable name of the resource for display purposes.

- `description`: Optional description
- `mimeType`: Optional MIME type
- `size`: Optional size in bytes

Resource Contents

Resources can contain either text or binary data:

Text Content

```
{
  "uri": "file:///example.txt",
  "name": "example.txt",
  "title": "Example Text File",
  "mimeType": "text/plain",
  "text": "Resource content"
}
```

Binary Content

```
{
  "uri": "file:///example.png",
  "name": "example.png",
  "title": "Example Image",
  "mimeType": "image/png",
  "blob": "base64-encoded-data"
}
```

Annotations

Resources, resource templates and content blocks support optional annotations that provide hints to clients about how to use or display the resource:

- `audience`: An array indicating the intended audience(s) for this resource. Valid values are `"user"` and `"assistant"`. For example, `["user", "assistant"]` indicates content useful for both.
- `priority`: A number from 0.0 to 1.0 indicating the importance of this resource. A value of 1 means "most important" (effectively required), while 0 means "least important" (entirely optional).
- `lastModified`: An ISO 8601 formatted timestamp indicating when the resource was last modified (e.g., `"2025-01-12T15:00:58Z"`).

Example resource with annotations:

```
{
  "uri": "file:///project/README.md",
  "name": "README.md",
  "title": "Project Documentation",
  "mimeType": "text/markdown",
  "annotations": {
    "audience": ["user"],
    "priority": 0.8,
    "lastModified": "2025-01-12T15:00:58Z"
  }
}
```

Clients can use these annotations to:

- Filter resources based on their intended audience
- Prioritize which resources to include in context
- Display modification times or sort by recency

Common URI Schemes

The protocol defines several standard URI schemes. This list not exhaustive—implementations are always free to use additional, custom URI schemes.

https://

Used to represent a resource available on the web.

Servers **SHOULD** use this scheme only when the client is able to fetch and load the resource directly from the web on its own—that is, it doesn't need to read the resource via the MCP server.

For other use cases, servers **SHOULD** prefer to use another URI scheme, or define a custom one, even if the server will itself be downloading resource contents over the internet.

file://

Used to identify resources that behave like a filesystem. However, the resources do not need to map to an actual physical filesystem.

MCP servers **MAY** identify file:// resources with an XDG MIME type, like `inode/directory`, to represent non-regular files (such as directories) that don't otherwise have a standard MIME type.

git://

Git version control integration.

Custom URI Schemes

Custom URI schemes **MUST** be in accordance with RFC3986, taking the above guidance in to account.

Error Handling

Servers **SHOULD** return standard JSON-RPC errors for common failure cases:

- Resource not found: `-32002`
- Internal errors: `-32603`

Example error:

```
{
  "jsonrpc": "2.0",
  "id": 5,
  "error": {
    "code": -32002,
    "message": "Resource not found",
    "data": {
      "uri": "file:///nonexistent.txt"
    }
  }
}
```

Security Considerations

1. Servers **MUST** validate all resource URIs
2. Access controls **SHOULD** be implemented for sensitive resources
3. Binary data **MUST** be properly encoded
4. Resource permissions **SHOULD** be checked before operations

Tools

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) allows servers to expose tools that can be invoked by language models. Tools enable models to interact with external systems, such as querying databases, calling APIs, or performing computations. Each tool is uniquely identified by a name and includes metadata describing its schema.

User Interaction Model

Tools in MCP are designed to be **model-controlled**, meaning that the language model can discover and invoke tools automatically based on its contextual understanding and the user's prompts.

However, implementations are free to expose tools through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

For trust & safety and security, there **SHOULD** always
be a human in the loop with the ability to deny tool invocations.

Applications **SHOULD**:

- Provide UI that makes clear which tools are being exposed to the AI model

- Insert clear visual indicators when tools are invoked
- Present confirmation prompts to the user for operations, to ensure a human is in the loop

Capabilities

Servers that support tools **MUST** declare the `tools` capability:

```
{
  "capabilities": {
    "tools": {
      "listChanged": true
    }
  }
}
```

`listChanged` indicates whether the server will emit notifications when the list of available tools changes.

Protocol Messages

Listing Tools

To discover available tools, clients send a `tools/list` request. This operation supports pagination.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "tools/list",
  "params": {
    "cursor": "optional-cursor-value"
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "tools": [
      {
        "name": "get_weather",
        "title": "Weather Information Provider",
        "description": "Get current weather information for a location",
        "inputSchema": {
          "type": "object",
          "properties": {
            "location": {
              "type": "string",
```

```
              "description": "City name or zip code"
            }
          },
          "required": ["location"]
        }
      }
    ],
    "nextCursor": "next-page-cursor"
  }
}
```

Calling Tools

To invoke a tool, clients send a `tools/call` request:

Request:

```
{
  "jsonrpc": "2.0",
  "id": 2,
  "method": "tools/call",
  "params": {
    "name": "get_weather",
    "arguments": {
      "location": "New York"
    }
  }
}
```

Response:

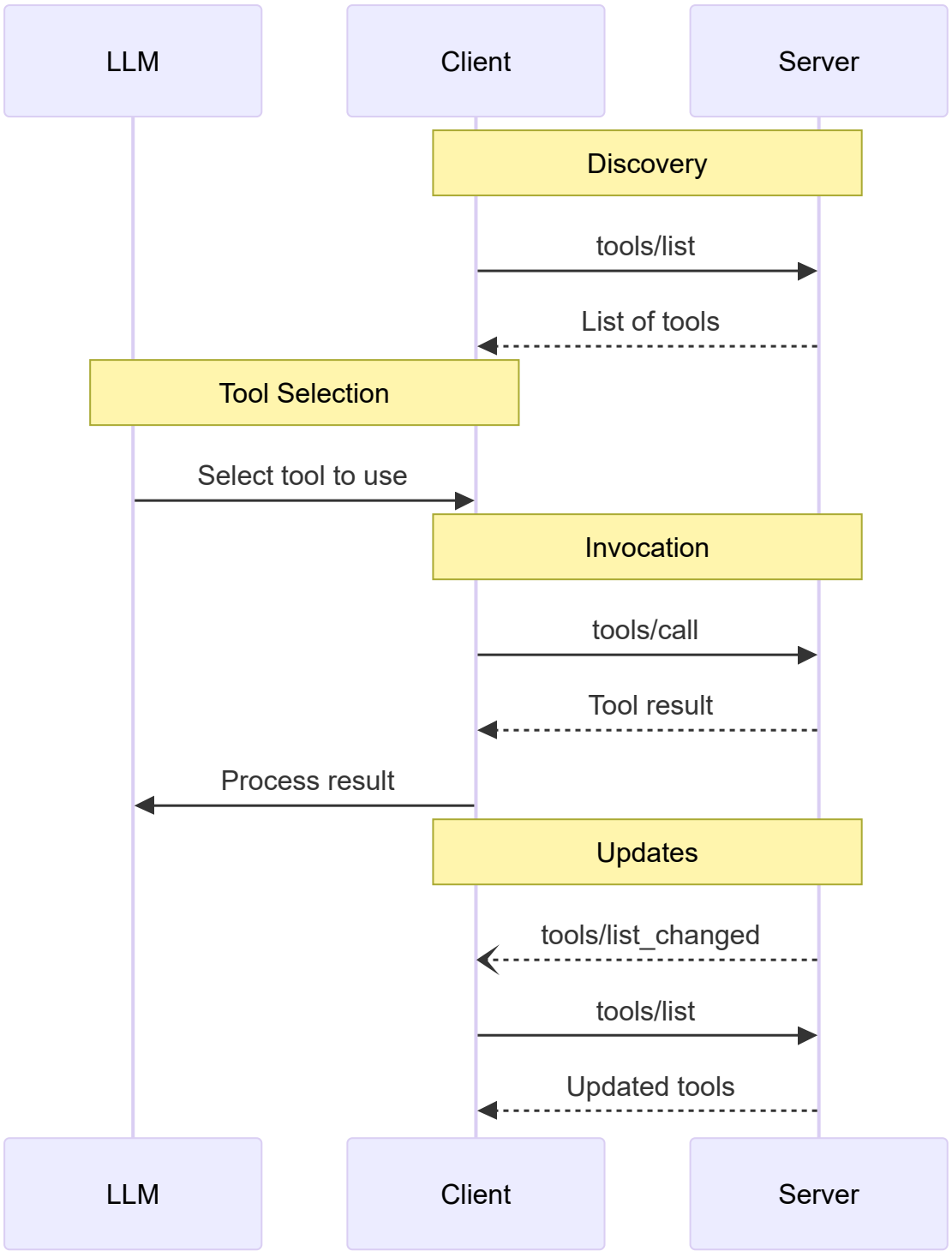
```
{
  "jsonrpc": "2.0",
  "id": 2,
  "result": {
    "content": [
      {
        "type": "text",
        "text": "Current weather in New York:\nTemperature: 72°F\nConditions: Partly cloudy"
      }
    ],
    "isError": false
  }
}
```

List Changed Notification

When the list of available tools changes, servers that declared the `listChanged` capability **SHOULD** send a notification:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/tools/list_changed"
}
```

Message Flow



Data Types

Tool

A tool definition includes:

- `name`: Unique identifier for the tool
- `title`: Optional human-readable name of the tool for display purposes.
- `description`: Human-readable description of functionality
- `inputSchema`: JSON Schema defining expected parameters
- `outputSchema`: Optional JSON Schema defining expected output structure
- `annotations`: optional properties describing tool behavior

For trust & safety and security, clients **MUST** consider
tool annotations to be untrusted unless they come from trusted servers.

Tool Result

Tool results may contain **structured** or **unstructured** content.

Unstructured content is returned in the `content` field of a result, and can contain multiple content items of different types:

All content types (text, image, audio, resource links, and embedded resources)
support optional
annotations that
provide metadata about audience, priority, and modification times. This is the
same annotation format used by resources and prompts.

Text Content

```
{
  "type": "text",
  "text": "Tool result text"
}
```

Image Content

```
{
  "type": "image",
  "data": "base64-encoded-data",
  "mimeType": "image/png"
  "annotations": {
    "audience": ["user"],
    "priority": 0.9
  }

}
```

This example demonstrates the use of an optional Annotation.

Audio Content

```
{
  "type": "audio",
  "data": "base64-encoded-audio-data",
  "mimeType": "audio/wav"
}
```

Resource Links

A tool **MAY** return links to Resources, to provide additional context or data. In this case, the tool will return a URI that can be subscribed to or fetched by the client:

```
{
  "type": "resource_link",
  "uri": "file:///project/src/main.rs",
  "name": "main.rs",
  "description": "Primary application entry point",
  "mimeType": "text/x-rust",
  "annotations": {
    "audience": ["assistant"],
    "priority": 0.9
  }
}
```

Resource links support the same Resource annotations as regular resources to help clients understand how to use them.

> Resource links returned by tools are not guaranteed to appear in the results of a `resources/list` request.

Embedded Resources

Resources **MAY** be embedded to provide additional context or data using a suitable URI scheme. Servers that use embedded resources **SHOULD** implement the `resources` capability:

```
{
  "type": "resource",
  "resource": {
    "uri": "file:///project/src/main.rs",
    "title": "Project Rust Main File",
    "mimeType": "text/x-rust",
    "text": "fn main() {\n    println!(\"Hello world!\");\n}",
    "annotations": {
      "audience": ["user", "assistant"],
      "priority": 0.7,
      "lastModified": "2025-05-03T14:30:00Z"
    }
  }
```

```
}
```

Embedded resources support the same Resource annotations as regular resources to help clients understand how to use them.

Structured Content

Structured content is returned as a JSON object in the `structuredContent` field of a result.

For backwards compatibility, a tool that returns structured content SHOULD also return the serialized JSON in a TextContent block.

Output Schema

Tools may also provide an output schema for validation of structured results.
If an output schema is provided:

- Servers **MUST** provide structured results that conform to this schema.
- Clients **SHOULD** validate structured results against this schema.

Example tool with output schema:

```
{
  "name": "get_weather_data",
  "title": "Weather Data Retriever",
  "description": "Get current weather data for a location",
  "inputSchema": {
    "type": "object",
    "properties": {
      "location": {
        "type": "string",
        "description": "City name or zip code"
      }
    },
    "required": ["location"]
  },
  "outputSchema": {
    "type": "object",
    "properties": {
      "temperature": {
        "type": "number",
        "description": "Temperature in celsius"
      },
      "conditions": {
        "type": "string",
        "description": "Weather conditions description"
      },
      "humidity": {
        "type": "number",
        "description": "Humidity percentage"
      }
    },
    "required": ["temperature", "conditions", "humidity"]
  }
```

```
}
```

Example valid response for this tool:

```
{
  "jsonrpc": "2.0",
  "id": 5,
  "result": {
    "content": [
      {
        "type": "text",
        "text": "{\"temperature\": 22.5, \"conditions\": \"Partly cloudy\", \"humidity\":
65}"
      }
    ],
    "structuredContent": {
      "temperature": 22.5,
      "conditions": "Partly cloudy",
      "humidity": 65
    }
  }
}
```

Providing an output schema helps clients and LLMs understand and properly handle structured tool outputs by:

- Enabling strict schema validation of responses
- Providing type information for better integration with programming languages
- Guiding clients and LLMs to properly parse and utilize the returned data
- Supporting better documentation and developer experience

Error Handling

Tools use two error reporting mechanisms:

1. **Protocol Errors**: Standard JSON-RPC errors for issues like:
    - Unknown tools
    - Invalid arguments
    - Server errors
2. **Tool Execution Errors**: Reported in tool results with `isError: true`:
    - API failures
    - Invalid input data
    - Business logic errors

Example protocol error:

```
{
  "jsonrpc": "2.0",
  "id": 3,
  "error": {
    "code": -32602,
    "message": "Unknown tool: invalid_tool_name"
  }
}
```

Example tool execution error:

```
{
  "jsonrpc": "2.0",
  "id": 4,
  "result": {
    "content": [
      {
        "type": "text",
        "text": "Failed to fetch weather data: API rate limit exceeded"
      }
    ],
    "isError": true
  }
}
```

Security Considerations

1. Servers **MUST**:
    - Validate all tool inputs
    - Implement proper access controls
    - Rate limit tool invocations
    - Sanitize tool outputs
2. Clients **SHOULD**:
    - Prompt for user confirmation on sensitive operations
    - Show tool inputs to the user before calling the server, to avoid malicious or accidental data exfiltration
    - Validate tool results before passing to LLM
    - Implement timeouts for tool calls
    - Log tool usage for audit purposes

Utilities

Completion

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) provides a standardized way for servers to offer argument autocompletion suggestions for prompts and resource URIs. This enables rich, IDE-like experiences where users receive contextual suggestions while entering argument values.

User Interaction Model

Completion in MCP is designed to support interactive user experiences similar to IDE code completion.

For example, applications may show completion suggestions in a dropdown or popup menu as users type, with the ability to filter and select from available options.

However, implementations are free to expose completion through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

Capabilities

Servers that support completions **MUST** declare the `completions` capability:

```
{
  "capabilities": {
    "completions": {}
  }
}
```

Protocol Messages

Requesting Completions

To get completion suggestions, clients send a `completion/complete` request specifying what is being completed through a reference type:

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "completion/complete",
  "params": {
    "ref": {
      "type": "ref/prompt",
      "name": "code_review"
    },
    "argument": {
      "name": "language",
      "value": "py"
    }
  }
```

```
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "completion": {
      "values": ["python", "pytorch", "pyside"],
      "total": 10,
      "hasMore": true
    }
  }
}
```

For prompts or URI templates with multiple arguments, clients should include previous completions in the `context.arguments` object to provide context for subsequent requests.

Request:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "completion/complete",
  "params": {
    "ref": {
      "type": "ref/prompt",
      "name": "code_review"
    },
    "argument": {
      "name": "framework",
      "value": "fla"
    },
    "context": {
      "arguments": {
        "language": "python"
      }
    }
  }
}
```

Response:

```
{
  "jsonrpc": "2.0",
  "id": 1,
  "result": {
    "completion": {
      "values": ["flask"],
      "total": 1,
      "hasMore": false
    }
  }
}
```

Reference Types

The protocol supports two types of completion references:

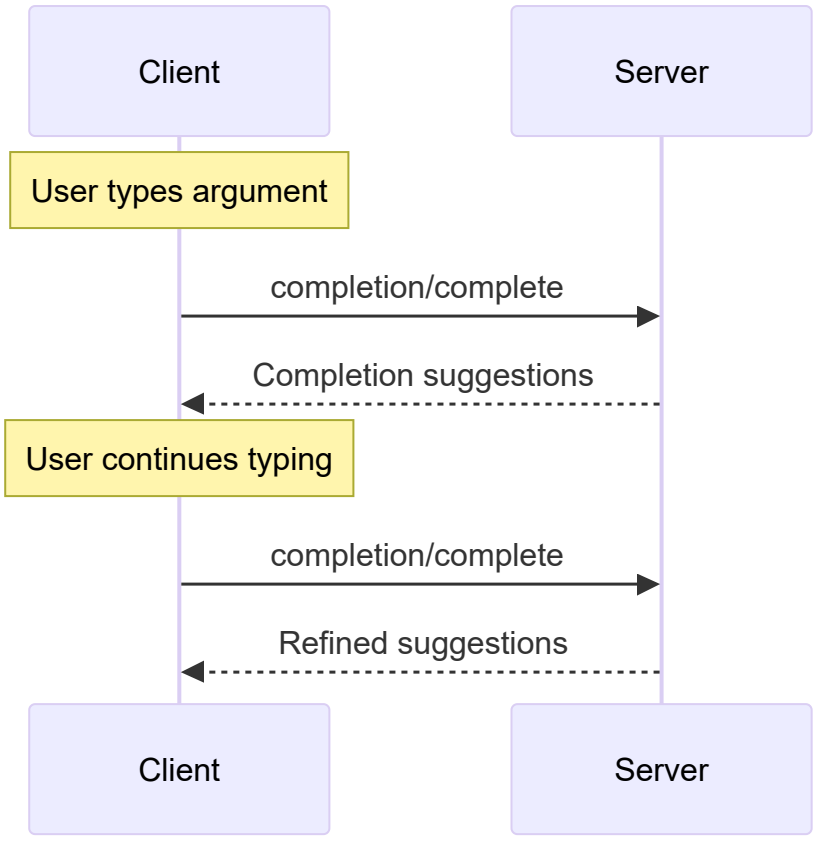
Type	Description	Example
`ref/prompt`	References a prompt by name	`{"type": "ref/prompt", "name": "code_review"}`
`ref/resource`	References a resource URI	`{"type": "ref/resource", "uri": "file:///{path}"}`

Completion Results

Servers return an array of completion values ranked by relevance, with:

- Maximum 100 items per response
- Optional total number of available matches
- Boolean indicating if additional results exist

Message Flow



Data Types

CompleteRequest

- `ref`: A `PromptReference` or `ResourceReference`
- `argument`: Object containing:
  - `name`: Argument name
  - `value`: Current value
- `context`: Object containing:
  - `arguments`: A mapping of already-resolved argument names to their values.

CompleteResult

- `completion`: Object containing:
  - `values`: Array of suggestions (max 100)
  - `total`: Optional total matches
  - `hasMore`: Additional results flag

Error Handling

Servers **SHOULD** return standard JSON-RPC errors for common failure cases:

- Method not found: `-32601` (Capability not supported)
- Invalid prompt name: `-32602` (Invalid params)
- Missing required arguments: `-32602` (Invalid params)
- Internal errors: `-32603` (Internal error)

Implementation Considerations

1. Servers **SHOULD**:
    - Return suggestions sorted by relevance
    - Implement fuzzy matching where appropriate
    - Rate limit completion requests
    - Validate all inputs
2. Clients **SHOULD**:
    - Debounce rapid completion requests
    - Cache completion results where appropriate
    - Handle missing or partial results gracefully

Security

Implementations **MUST**:

- Validate all completion inputs
- Implement appropriate rate limiting
- Control access to sensitive suggestions
- Prevent completion-based information disclosure

Logging

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) provides a standardized way for servers to send structured log messages to clients. Clients can control logging verbosity by setting minimum log levels, with servers sending notifications containing severity levels, optional logger names, and arbitrary JSON-serializable data.

User Interaction Model

Implementations are free to expose logging through any interface pattern that suits their needs—the protocol itself does not mandate any specific user interaction model.

Capabilities

Servers that emit log message notifications **MUST** declare the `logging` capability:

```
{
  "capabilities": {
    "logging": {}
  }
}
```

Log Levels

The protocol follows the standard syslog severity levels specified in RFC 5424:

Level	Description	Example Use Case
debug	Detailed debugging information	Function entry/exit points
info	General informational messages	Operation progress updates
notice	Normal but significant events	Configuration changes
warning	Warning conditions	Deprecated feature usage
error	Error conditions	Operation failures
critical	Critical conditions	System component failures
alert	Action must be taken immediately	Data corruption detected
emergency	System is unusable	Complete system failure

Protocol Messages

Setting Log Level

To configure the minimum log level, clients **MAY** send a `logging/setLevel` request:

Request:

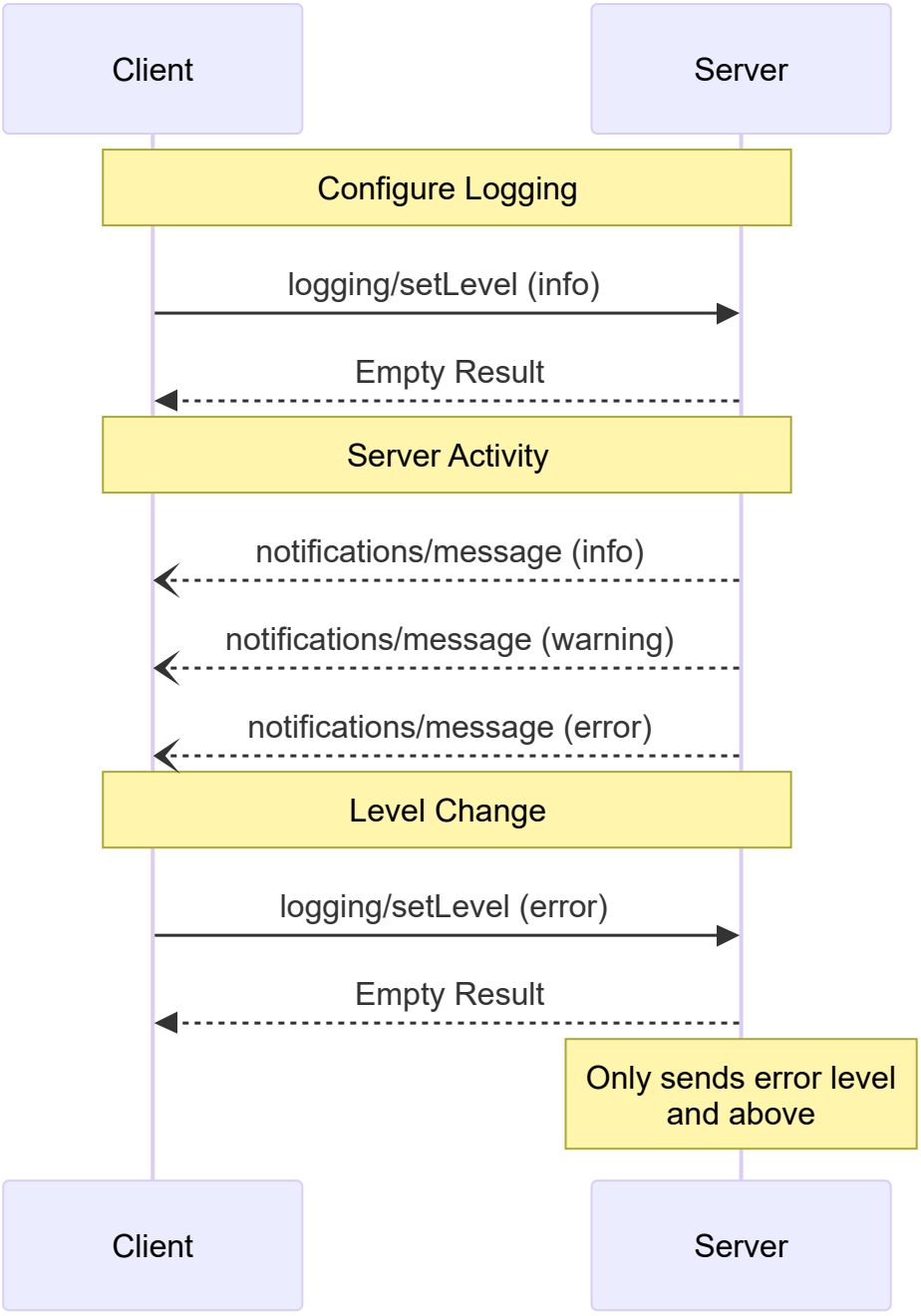
```
{
  "jsonrpc": "2.0",
  "id": 1,
  "method": "logging/setLevel",
  "params": {
    "level": "info"
  }
}
```

Log Message Notifications

Servers send log messages using `notifications/message` notifications:

```
{
  "jsonrpc": "2.0",
  "method": "notifications/message",
  "params": {
    "level": "error",
    "logger": "database",
    "data": {
      "error": "Connection failed",
      "details": {
        "host": "localhost",
        "port": 5432
      }
    }
  }
}
```

Message Flow



Error Handling

Servers **SHOULD** return standard JSON-RPC errors for common failure cases:

- Invalid log level: `-32602` (Invalid params)
- Configuration errors: `-32603` (Internal error)

Implementation Considerations

1. Servers **SHOULD**:
    - Rate limit log messages
    - Include relevant context in data field
    - Use consistent logger names

    - Remove sensitive information
2. Clients **MAY**:
    - Present log messages in the UI
    - Implement log filtering/search
    - Display severity visually
    - Persist log messages

Security

1. Log messages **MUST NOT** contain:
    - Credentials or secrets
    - Personal identifying information
    - Internal system details that could aid attacks
2. Implementations **SHOULD**:
    - Rate limit messages
    - Validate all data fields
    - Control log access
    - Monitor for sensitive content

Pagination

Protocol Revision: 2025-06-18

The Model Context Protocol (MCP) supports paginating list operations that may return large result sets. Pagination allows servers to yield results in smaller chunks rather than all at once.

Pagination is especially important when connecting to external services over the internet, but also useful for local integrations to avoid performance issues with large data sets.

Pagination Model

Pagination in MCP uses an opaque cursor-based approach, instead of numbered pages.

- The **cursor** is an opaque string token, representing a position in the result set
- **Page size** is determined by the server, and clients **MUST NOT** assume a fixed page size

Response Format

Pagination starts when the server sends a **response** that includes:

- The current page of results
- An optional `nextCursor` field if more results exist

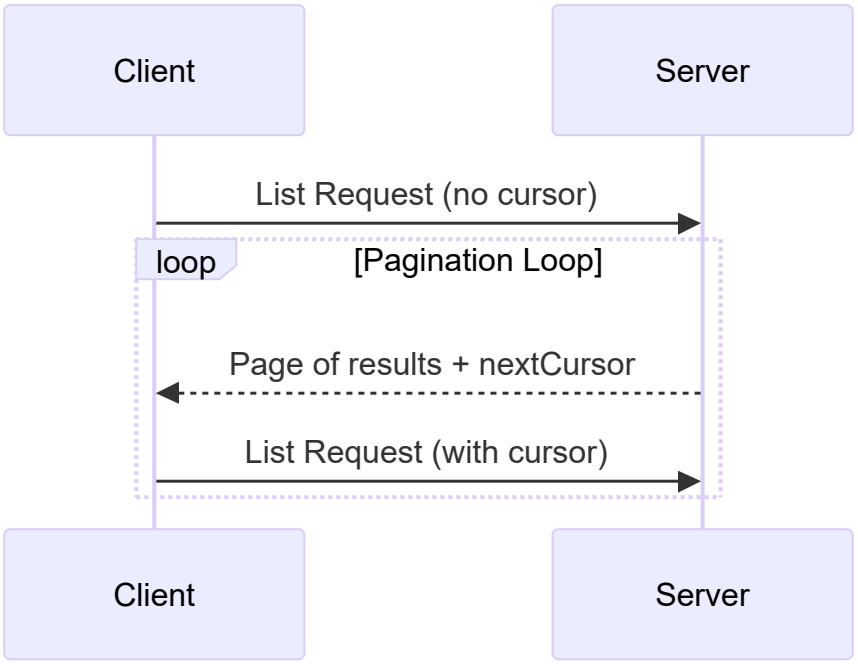
```
{
  "jsonrpc": "2.0",
  "id": "123",
  "result": {
    "resources": [...],
    "nextCursor": "eyJwYWdlIjogM30="
  }
}
```

Request Format

After receiving a cursor, the client can *continue* paginating by issuing a request including that cursor:

```
{
  "jsonrpc": "2.0",
  "method": "resources/list",
  "params": {
    "cursor": "eyJwYWdlIjogMn0="
  }
}
```

Pagination Flow



Operations Supporting Pagination

The following MCP operations support pagination:

- `resources/list` - List available resources
- `resources/templates/list` - List resource templates
- `prompts/list` - List available prompts
- `tools/list` - List available tools

Implementation Guidelines

1. Servers **SHOULD**:
   - Provide stable cursors
   - Handle invalid cursors gracefully
2. Clients **SHOULD**:
   - Treat a missing `nextCursor` as the end of results
   - Support both paginated and non-paginated flows
3. Clients **MUST** treat cursors as opaque tokens:
   - Don't make assumptions about cursor format
   - Don't attempt to parse or modify cursors
   - Don't persist cursors across sessions

Error Handling

Invalid cursors **SHOULD** result in an error with code -32602 (Invalid params).

Schema Reference

Due to formatting issues, the Schema Reference is not included in this book.
Check https://modelcontextprotocol.io for the complete reference.