

arf - Another RPC Framework

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Abstract

The Another RPC Framework (stylized `arf`) defines an interface description language (IDL), a compact binary serialization format, and a request/response protocol for service-oriented communication.

arf aims to provide a simple, evolvable, and highly efficient system for defining structs, services, and RPC methods while eliminating the need for field numeric identifiers in IDL source files. arf emphasizes readability, forward compatibility, and minimal over-the-wire footprint.

1 Status of This Memo

This document is an Internet-Draft and is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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3 Introduction

arf (Another RPC Framework) is a compact, binary, schema-first RPC mechanism designed for service-oriented systems. arf provides:

- A simple IDL with packages, imports, structs, and services.
- Efficient binary encoding without field tags on the wire.
- Optional types without nested “option” wrappers.
- Evolvability through package-level versioning.
- Re-openable service definitions for modular organization.

arf draws inspiration from Protobuf, Cap’n Proto, and Thrift while focusing on ergonomics and avoiding field-ID management clutter.

4 Conventions and Terminology

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 [RFC2119] and [RFC8174] when, and only when, they appear in all capitals.

4.0.1 Terms

Client The endpoint that initiates an RPC by sending an `INVOK` frame.

Server The endpoint that receives an `INVOK` frame and executes the corresponding method.

Endpoint Either the client or the server participating in an RPC.

RPC A single remote procedure call identified by one **CorrelationID** and consisting of an `INVOK` frame and any subsequent frames that share that identifier.

Frame A discrete protocol message sent over the underlying transport representing an invocation, stream element, or control signal, as defined in Section 7.1.

CorrelationID The identifier that associates all frames belonging to the same RPC on a given connection.

Active RPC An RPC for which an `INVOK` frame has been sent and for which the RPC completion conditions defined in Section 7.6.1 have not yet been satisfied.

Unary A non-streaming RPC parameter or result, serialized as a single value rather than as a sequence.

Stream A potentially unbounded sequence of values of a given type, carried using `IN_STREAM/IN_CLOSE` or `OUT_STREAM/OUT_CLOSE` frames.

Input stream A stream of values flowing from client to server as part of an RPC.

Output stream A stream of values flowing from server to client as part of an RPC.

Form One of the sixteen method signature combinations defined in Section 7.6, derived from the presence or absence of unary input, unary output, input stream, and output stream.

Struct A user-defined composite type consisting of a fixed sequence of named fields.

Field A named component of a struct, identified for serialization by its ordinal position within the struct declaration.

Optional field A struct field whose type is `optional<T>`, whose presence or absence is indicated by the struct's presence bitmap.

Package A named collection of type and service declarations that forms a versioned namespace boundary, as defined in Section 5.4.

Service A named collection of RPC methods defined within a package.

Method A single RPC operation defined within a service, identified by its name and method form.

VarUInt The variable-length unsigned integer encoding used for lengths and similar quantities, as defined in Section 6.2.

5 The arf Language

5.1 Packages

An arf source file MUST begin with a `package` declaration:

```
1 package v1beta1.myservice;
```

Package names establish namespace boundaries and versioning domains. A package name uniquely identifies all types and services defined within the file. Each type defined in a package is assigned a fully-qualified name of the form:

```
<package-name> "<type-name>"
```

Example:

```
v1beta1.mypackage.OtherName
```

5.2 Imports

A source file MAY include one or more `import` directives that logically incorporate definitions from other arf source files:

```
1 import ".../common/v1beta1/common";
```

Each imported file MUST contain a `package` declaration. The package name of the imported file determines the fully-qualified names of the types it defines.

An import MAY specify an explicit local alias using the `as` keyword. If no alias is provided, the compiler MUST derive an implicit alias from the final component of the imported package name.

All aliases within a single source file MUST be unique. If two imports would produce the same implicit alias, or if an implicit alias collides with an explicit alias, the compiler MUST reject the source file.

Referenced types of the form `<alias>.<Type Name>` MUST resolve unambiguously to exactly one imported package. Fully-qualified names MAY be used instead of aliases and MUST NOT depend on import aliasing.

5.3 Types

arf provides a set of builtin types that form the foundation of the serialization model. These types MAY appear as struct fields, unary method parameters and results, and stream element types. The builtin types are:

- `bool`: a boolean value.

- `int8, int16, int32, int64`: signed integers of the specified width.
- `uint8, uint16, uint32, uint64`: unsigned integers of the specified width.
- `float32, float64`: IEEE 754 binary floating-point values.
- `string`: a sequence of UTF-8 encoded Unicode scalar values.
- `timestamp`: Represents a moment in time encoded as an UTC Unix epoch with millisecond precision.
- `bytes`: an arbitrary sequence of octets.
- `array<T>`: an ordered, variable-length sequence of values of type `T`.
- `map<K, V>`: an unordered, variable-length association between keys of type `K` and values of type `V`.
- `optional<T>`: a value of type `T` that MAY be present or absent.

User-defined `struct` types MAY also be declared within a package. All types, whether builtin or user-defined, participate uniformly in the serialization rules described in Section 6. Additionally, map keys are restricted to primitive types, Structures and Enums. Other types are forbidden.

5.4 Struct Declarations

Structs define a sequence of fields, each consisting of a name and a type, in the order in which they are written:

```

1 struct TeamNameRequest {
2     name string;
3 }
```

Field numbers MUST NOT appear in arf source files. Instead, each field is assigned an implicit ordinal index based solely on its position in the declaration, beginning at zero for the first field. Ordinal indices MUST remain stable within a package version, as they are referenced by the binary serialization rules defined in Section 6.

Struct declarations MAY include nested struct definitions. Nested structs are assigned fully-qualified names in the same manner as top-level structs.

5.5 Service Declarations

Services define RPC methods:

```

1 service NameService {
2     check_name(req CheckNameRequest) -> common.
3         CheckNameResponse;
3 }
```

Each method name MUST be unique within a service unless the service is re-opened as described below.

5.5.1 Re-Openable Services

A service MAY be declared in multiple **service** blocks within the same package:

```

1 service NameService {
2     check_name(req CheckNameRequest) -> common.
3         CheckNameResponse;
3 }
4
5 service NameService {
6     check_slug(req CheckSlugRequest) -> common.
7         CheckSlugResponse;
7 }
```

All **service** blocks with the same service name MUST be merged into a single logical service definition during compilation. If a method name appears in more than one block, the compiler MUST determine whether the corresponding method signatures are identical.

Two method declarations are considered to have *identical signatures* if and only if all of the following hold:

- They declare the same method name.
- They declare the same ordered sequence of unary input parameters.
- They declare the same input stream type (or both omit it).
- They declare the same ordered sequence of unary output values.
- They declare the same output stream type (or both omit it).

If any of these conditions is violated, the signatures are divergent, and the compiler MUST reject the program.

5.5.2 Methods

An arf method signature consists of zero or more unary input parameters, zero or more unary output parameters, and at most one input stream and one output stream. The presence or absence of each of these components determines a *method form*. Four independent boolean dimensions are defined:

- **HasInput**: whether the method declares at least one unary input parameter.
- **HasOutput**: whether the method declares at least one unary output value.
- **HasInputStream**: whether the method declares a single input stream parameter.
- **HasOutputStream**: whether the method declares a single output stream.

The combination of these four booleans yields sixteen method forms. Each form has a well-defined set of legal frame sequences, as specified in Section 7.6.

Unary inputs and outputs, and streams MUST use either structures or enums instead of primitive or composite types. This limitation was deliberately created to ensure all data transmitted through RPC methods are part of structures, enforcing all messages to be explicitly defined.

5.5.3 IDL Syntax for Streams

Streams are declared using the `stream` keyword in either the input parameter list or the output tuple. A method MAY declare at most one input stream and at most one output stream.

Examples:

```

1 NNYN(stream T);
2 NYNY() -> (0, stream U);
3 YYYY(i I, stream T) -> (0, stream U);

```

A streaming parameter is written as `stream <Type>`. Unary parameters are written as standard name-type bindings. Streams MUST NOT appear more than once on either side of the signature.

5.6 Fully-Qualified Names

Every type and service defined within a package is assigned a fully-qualified name of the form:

```
<package-name> ".<identifier>
```

Fully-qualified names uniquely identify declarations across all packages. Two declarations with distinct fully-qualified names are considered distinct, even if their unqualified names are identical or their definitions are structurally equivalent.

Within a source file, references to types defined in other packages MAY appear in either of the following forms:

- **Aliased form:** `<alias>.<TypeName>`, where `<alias>` is the explicit or implicit import alias established by an `import` directive; or
- **Fully-qualified form:** `<package-name>.<TypeName>`.

Aliased references MUST resolve unambiguously to exactly one imported package. Fully-qualified references MUST NOT depend on import aliasing and MUST resolve solely based on the declared package name.

Fully-qualified names MUST remain stable across all files belonging to the same package version. Changing the package name of any declaration constitutes a breaking change and therefore requires introducing a new package version.

6 Serialization

6.1 Overview

arf defines a compact binary serialization format for values of all builtin and user-defined types. Serialization is deterministic and does not depend on field names or field numbers appearing in the IDL. Struct fields are serialized in declaration order using implicit ordinal indices as described in Section 5.4.

Unless otherwise noted, all integers are encoded in little-endian byte order. Variable-length entities (such as strings, byte sequences, arrays, and maps) are prefixed with a length encoded using the variable-length integer scheme described in Section 6.2.

All serialized representations are self-delimiting and do not require out-of-band framing. The RPC protocol defines its own framing mechanism for transporting serialized values.

6.2 Length Encoding

arf uses an unsigned variable-length integer format (referred to in this document as *VarUInt*) for encoding lengths of variable-sized objects. VarUInt uses a base-128 continuation-bit scheme:

- Each byte contributes seven bits of payload and one continuation bit.
- For all but the final byte, the most-significant bit (MSB) MUST be set to 1.
- The final byte MUST have its MSB set to 0.

This format allows lengths to be encoded using between one and ten bytes, depending on magnitude. An implementation MUST NOT accept lengths that exceed the representational capacity of a 64-bit unsigned integer.

Unless explicitly stated, all length-prefixed types in this section use VarUInt for length encoding.

6.3 Primitive Types

The serialization of primitive types is defined as follows:

- **bool**: encoded as a single byte. The value 0x00 represents **false**; the value 0x01 represents **true**. No other values are permitted.
- **int8, uint8**: encoded as a single byte.
- **int16, uint16**: encoded as 2 bytes in little-endian order.
- **int32, uint32**: encoded as 4 bytes in little-endian order.
- **int64, uint64**: encoded as 8 bytes in little-endian order.
- **float32, float64**: encoded in IEEE 754 binary32 or binary64 format respectively, using little-endian byte order.
- **string**: encoded as `VarUInt(length)` followed by `length` bytes containing UTF-8 encoded scalar values. Invalid UTF-8 byte sequences MUST cause deserialization to fail.
- **bytes**: encoded as `VarUInt(length)` followed by `length` raw octets.

These encodings are used uniformly whether a primitive appears as a struct field. However, primitives cannot be used as unary method parameters, unary method results, or a stream elements. For methods, structs must be used, as specified in Section 5.5.2.

6.4 Composite Types

Composite types define container-like structures with their own encoding rules.

6.4.1 Arrays

An `array<T>` value is encoded as:

1. `VarUInt(n)`, where n is the number of elements.
2. The concatenation of the serialized representations of the n elements in order.

An array MAY be empty. Empty arrays are encoded as `VarUInt(0)` followed by zero bytes.

6.4.2 Maps

A `map<K, V>` value is encoded as:

1. `VarUInt(n)`, where n is the number of key-value pairs.
2. For each pair, the serialized key immediately followed by the serialized value.

A map MAY be empty. Map iteration order MUST be the order chosen by the encoder and MUST be preserved by the decoder without implying semantic ordering or sorting.

Keys MUST be unique according to the equality semantics of type `K`. Deserializers MUST reject maps that contain duplicate keys.

6.4.3 Structs

Structs are serialized field-by-field in the order declared in the IDL. No field numbers or tag identifiers appear on the wire; fields are identified solely by their ordinal position within the struct.

Let a struct contain m fields. Struct serialization proceeds as follows:

1. Emit a presence bitmap with *exactly m bits*, encoded in whole bytes, least-significant bit first. The i th bit corresponds to the i th field in declaration order.
 - For a non-optional field, the bit *MUST* be set to 1.
 - For an `optional<T>` field, the bit is set to 1 if the value is present and to 0 if the value is absent.
2. For each field i in declaration order:
 - If the presence bit for field i is 1, serialize the value according to the rules for its type.

- If the presence bit for field i is 0, no bytes are emitted for that field; this case is only legal for `optional<T>` fields.

Decoders *MUST* ignore bitmap bits beyond the set of fields they recognize. When encountering a set bit corresponding to an unknown field, the decoder *MUST* skip the value by applying the serialization rules of the field's declared type.

Because field ordinals define the on-wire layout, implementations *MUST NOT* reorder fields within a package version.

6.5 Optional Fields

An `optional<T>` value MAY be present or absent. Optional fields in structs use the presence bitmap described above. Any other type or composite type may be used as T.

6.6 Error Handling

A deserializer MUST reject any of the following:

- malformed VarUInt encodings,
- lengths that exceed the remaining buffer,
- invalid UTF-8 in `string` values,
- duplicate keys in a `map<K,V>`,
- unexpected trailing bytes after a serialized value,
- any violation of the structural constraints defined in this section.

Unless explicitly specified, deserialization errors MUST be treated as fatal to the enclosing RPC invocation.

7 RPC Protocol

arf defines a bidirectional message-oriented protocol used to transport serialized request and response values between a client and a server. This section defines the framing model, identifier space, message semantics, and the legal frame sequences for each method form defined in Section 7.6.

Unless otherwise noted, all multi-byte integer fields are encoded in little-endian byte order. All frames are self-contained and do not rely on lower-layer segmentation semantics.

7.1 Frame Format

Each message exchanged between a client and server is encoded as an arf *frame*. Frames MUST NOT be fragmented or interleaved at the byte level. The format of a frame is:

Field	Description
Magic[2]	Fixed value 0xAF 0x01 identifying arf framing.
Version[1]	Protocol version. This document specifies version 1.
MessageKind[1]	Indicates the semantic type of the frame.
Flags[1]	Reserved for future use; MUST be zero for version 1.
PackageID[4]	Identifier for the package containing the service.
ServiceID[4]	Identifier for the service.
MethodID[4]	Identifier for the method.
CorrelationID[8]	Opaque identifier linking frames belonging to the same RPC.
PayloadLength (var)	Length of the payload using VarUInt encoding.
Payload (var)	Serialized value according to Section 6.

All frames MUST begin with the 2-byte magic value. Receivers MUST treat a mismatched magic value as a framing error and close the connection.

7.1.0.1 MessageKind The `MessageKind` byte MUST be one of the following:

Value	Meaning
0x01	INVOKE: initiates an RPC call.
0x02	IN_STREAM: element of an input stream.
0x03	IN_CLOSE: signals end of input stream.
0x04	OUT_STREAM: element of an output stream.
0x05	OUT_CLOSE: signals end of output stream.
0x06	RESPONSE: unary output payload.
0x07	ERROR: terminal error.
0x08	CANCEL: client cancellation of the RPC.

7.2 Transport Assumptions

arf is designed to run over a reliable, ordered, bidirectional transport. The transport MUST preserve byte order and MUST NOT duplicate or reorder bytes. Examples of suitable transports include TCP connections, QUIC streams, and Unix domain sockets.

arf frames, as defined in Section 7.1, are logical protocol units and do not necessarily correspond to transport-level segments. Endpoints MUST be able to reconstruct frames from an arbitrary segmentation of the underlying byte stream.

Datagram-oriented transports (such as bare UDP) do not satisfy these requirements without additional reliability and ordering mechanisms. Such mechanisms are out of scope for this specification.

7.3 Connection Model and Multiplexing

arf is designed to support multiplexing of multiple RPCs over a single transport connection. A connection is viewed as a bidirectional stream of frames as defined in Section 7.1.

7.3.1 Correlation Identifiers

The `CorrelationID` field in each frame identifies the logical RPC to which the frame belongs. The following rules apply:

- For a given connection, the client MUST choose a `CorrelationID` that is not currently active when initiating a new RPC.
- An RPC becomes active when its `INVOKE` frame is sent. It remains active until the RPC completion conditions defined in Section 7.6.1 are satisfied.
- Once an RPC has completed, its `CorrelationID` MAY be reused for a subsequent RPC on the same connection.

Implementations MUST treat the receipt of frames for an unknown or inactive `CorrelationID` (that is, a `CorrelationID` for which no active RPC exists) as a protocol error.

7.3.2 Concurrent RPCs

Clients MAY initiate multiple RPCs concurrently over the same connection by sending multiple `INVOKE` frames with distinct `CorrelationID` values. Similarly, servers MAY process multiple RPCs concurrently and interleave frames for those RPCs arbitrarily.

For each individual `CorrelationID`, the following invariants MUST hold:

- Exactly one `INVOKE` frame MUST appear, and it MUST be the first frame for that `CorrelationID`.
- All subsequent frames with that `CorrelationID` MUST conform to the method form and sequencing rules defined in Section 7.6.
- Once the RPC completion conditions defined in Section 7.6.1 have been satisfied, endpoints MUST treat the `CorrelationID` as inactive and MUST NOT send further frames for that `CorrelationID`.

Frames belonging to different `CorrelationID` values MAY be arbitrarily interleaved in both directions, subject to any flow-control or prioritization policies implemented by the endpoints.

7.3.3 Ordering Guarantees

The transport MUST preserve byte order, and endpoints MUST preserve the frame order in which data is received. As a consequence:

- For a given **CorrelationID**, the sequence of frames is strictly ordered and can be processed in order.
- No ordering guarantees are provided between frames belonging to different **CorrelationID** values beyond those implied by the underlying transport.

arf does not define fairness or prioritization between concurrent RPCs. Such policies are implementation-specific and MAY be influenced by application-level considerations.

7.4 Identifiers

PackageID, ServiceID, and MethodID are 32-bit unsigned integers derived from stable hashing of fully-qualified names. The hashing algorithm MUST be deterministic and MUST produce identical identifiers across all conforming implementations.

The identifier derivation scheme is intentionally opaque in arf source files and MUST NOT be user-configurable. Identifiers MUST remain stable for the lifetime of a package version. Changing any identifier constitutes a breaking change requiring a new package version.

7.5 Requests

An RPC request is initiated by the client sending an **INVOK**E frame. The payload of the **INVOK**E frame depends on the method form:

- If **HasInput** is true, the payload MUST contain the serialization of the unary input struct.
- If **HasInput** is false, the payload MUST be empty.
- If **HasInputStream** is true, the input stream is considered open immediately after the **INVOK**E frame. The client MAY send zero or more **IN_STREAM** frames, followed by exactly one **IN_CLOSE**.

A client MUST NOT send additional **INVOK**E frames with the same **CorrelationID**. Doing so constitutes a protocol error.

7.6 Method Forms and Allowed Frame Sequences

arf defines sixteen distinct *method forms*, derived from the presence or absence of: (1) unary input parameters, (2) unary output values, (3) an input stream, and (4) an output stream. The four-letter form label encodes the booleans `HasInput`, `HasOutput`, `HasInputStream`, and `HasOutputStream`, respectively, using Y for “present” and N for “absent”.

Table 1 specifies, for each form, whether the client and server MAY send the streaming frame kinds defined in Section 7.1. Frames belonging to different `CorrelationID` values MAY be arbitrarily interleaved on the same connection, as described in Section 7.3.

Table 1: arf Method Forms and Permitted Streaming Frames (per `CorrelationID`)

Form	HasIn	HasOut	HasInS	HasOutS	C:IS	C:IC	S:OS	S:OC
NNNN	N	N	N	N	N	N	N	N
NNNY	N	N	N	Y	N	N	Y	Y
NNYN	N	N	Y	N	Y	Y	N	N
NNYY	N	N	Y	Y	Y	Y	Y	Y
NYNN	N	Y	N	N	N	N	N	N
NYNY	N	Y	N	Y	N	N	Y	Y
NYYN	N	Y	Y	N	Y	Y	N	N
NYYY	N	Y	Y	Y	Y	Y	Y	Y
YNNN	Y	N	N	N	N	N	N	N
YNNY	Y	N	N	Y	N	N	Y	Y
YNYN	Y	N	Y	N	Y	Y	N	N
YNYY	Y	N	Y	Y	Y	Y	Y	Y
YYNN	Y	Y	N	N	N	N	N	N
YYNY	Y	Y	N	Y	N	N	Y	Y
YYYN	Y	Y	Y	N	Y	Y	N	N
YYYY	Y	Y	Y	Y	Y	Y	Y	Y

Legend:

- HasIn = `HasInput`
- HasOut = `HasOutput`
- HasInS = `HasInputStream`
- HasOutS = `HasOutputStream`
- C:IS = client MAY send `IN_STREAM`
- C:IC = client MAY send `IN_CLOSE`

- S:OS = server MAY send `OUT_STREAM`
- S:OC = server MAY send `OUT_CLOSE`

For each form, the following additional constraints apply, per `CorrelationID`:

- Exactly one `INVOKE` frame MUST be sent, and it MUST be the first frame.
- If `HasInS` is Y, the client MAY send zero or more `IN_STREAM` frames followed by exactly one `IN_CLOSE`. If `HasInS` is N, the client MUST NOT send `IN_STREAM` or `IN_CLOSE`.
- If `HasOutS` is Y, the server MAY send zero or more `OUT_STREAM` frames followed by exactly one `OUT_CLOSE`. If `HasOutS` is N, the server MUST NOT send `OUT_STREAM` or `OUT_CLOSE`.

7.6.1 RPC Completion

For a given `CorrelationID`, an RPC is considered complete when one of the following conditions holds:

- An `ERROR` frame has been received, or
- A `CANCEL` frame has been received, or
- A `RESPONSE` frame has been received and all streams declared by the method form have been closed:
 - if `HasInputStream` is true, an `IN_CLOSE` frame has been received; and
 - if `HasOutputStream` is true, an `OUT_CLOSE` frame has been received.

Once any of the above conditions is satisfied, endpoints MUST treat the `CorrelationID` as inactive and MUST NOT send further frames with that `CorrelationID`.

7.7 Interleaving of Input and Output Streams

For method forms that declare both an input stream and an output stream (i.e., `HasInputStream` = true and `HasOutputStream` = true), the client and server MAY send `IN_STREAM` and `OUT_STREAM` frames in any order, including arbitrarily interleaved. Neither endpoint is required to await stream activity from the peer before sending additional elements.

Stream directions are independent: the client MAY continue sending input elements regardless of whether the server is actively sending output elements, and vice versa.

7.8 Unary vs Streaming Semantics

7.8.1 Unary Input

If **HasInput** is true, the INVOKE payload MUST contain a serialized unary input struct. If false, the payload MUST be empty.

7.8.2 Input Stream

If **HasInputStream** is true:

- The client MAY send zero or more IN_STREAM frames.
- Each IN_STREAM frame MUST contain exactly one serialized element of the declared input stream type.
- The client MUST send exactly one IN_CLOSE.
- After IN_CLOSE, no further inbound stream frames are permitted.

7.8.3 Unary Output

For every RPC that completes successfully (that is, does not terminate with an ERROR frame), the server MUST send exactly one RESPONSE frame for the corresponding CorrelationID, regardless of whether the method declares no unary outputs, one or more unary outputs, an output stream, or any combination thereof.

The RESPONSE frame MUST be the first application-level frame sent by the server for that CorrelationID. In particular, the server MUST NOT send any OUT_STREAM or OUT_CLOSE frames before the RESPONSE frame.

If **HasOutput** is true, the payload of the RESPONSE frame MUST contain the serialized unary output struct or tuple. If **HasOutput** is false, the payload of the RESPONSE frame MUST be empty.

7.8.4 Unary Output Ordering

For all method forms in which **HasOutput** is true, the server MUST send the RESPONSE frame before transmitting any OUT_STREAM frames. Once RESPONSE has been sent, the server MAY interleave OUT_STREAM frames with incoming IN_STREAM frames arbitrarily.

7.8.5 Output Stream

If **HasOutputStream** is true, the server MAY produce an output stream after sending the RESPONSE frame.

In that case, the following rules apply for the given CorrelationID:

- The server MAY send zero or more OUT_STREAM frames.

- Each `OUT_STREAM` frame MUST contain exactly one serialized element of the declared output stream type.
- The server MUST send exactly one `OUT_CLOSE` frame to indicate the end of the output stream.
- The server MUST NOT send any `OUT_STREAM` or `OUT_CLOSE` frames before the `RESPONSE` frame.
- After sending `OUT_CLOSE`, the server MUST NOT send any further `OUT_STREAM` or `OUT_CLOSE` frames for that `CorrelationID`.

Thus, for methods with `HasOutputStream` set to `true`, the canonical successful server-side sequence (ignoring input frames) is:

```
RESPONSE
OUT_STREAM*    // zero or more times
OUT_CLOSE
```

7.9 Per-form Examples

This subsection provides illustrative but non-normative examples of legal frame sequences for selected method forms. Let `CID` be a `CorrelationID`.

7.9.1 Form: NNNN (no input, no output, no streams)

```
INVOKE(CID)
RESPONSE(CID)
```

7.9.2 Form: NNNY (server-streaming only)

```
INVOKE(CID)
RESPONSE(CID)
OUT_STREAM(CID)
OUT_STREAM(CID)
OUT_CLOSE(CID)
```

7.9.3 Form: YNYN (unary input, input stream, no unary output)

```
INVOKE(CID, unary-input)
RESPONSE(CID)    // empty response
IN_STREAM(CID, T)
IN_STREAM(CID, T)
IN_CLOSE(CID)
```

7.9.4 Form: YYYY (full bidirectional streaming + unary input/output)

```
INVOKE(CID, unary-input)
IN_STREAM(CID, T)
IN_STREAM(CID, T)
IN_CLOSE(CID)

RESPONSE(CID, unary-output)

OUT_STREAM(CID, U)
OUT_STREAM(CID, U)
OUT_CLOSE(CID)
```

7.10 Cancellation and Error Semantics

A client MAY abort an ongoing RPC using a `CANCEL` frame with the same `CorrelationID` as the active call. Upon receiving `CANCEL`, the server:

- MUST cease sending further frames for that `CorrelationID`,
- MAY release any associated resources immediately,
- MAY send an `ERROR` frame if additional diagnostic information is available.

A server MAY emit an `ERROR` frame at any time to signal an irrecoverable condition. Upon receiving `ERROR`, the client MUST treat the RPC as terminated and MUST NOT send additional frames for that `CorrelationID`.

7.11 Backpressure

arf does not define a mandatory flow-control mechanism. Implementations SHOULD apply backpressure using transport-level or application-level means. Implementations MUST remain robust in the presence of senders that produce data more rapidly than the receiver can process.

Extensions to provide explicit credit-based flow control MAY be defined in future versions of this specification.

8 Evolution and Compatibility

arf is designed to permit incremental schema evolution without requiring explicit field identifiers in source files. The rules in this section govern how types may change across package versions while maintaining compatibility at the binary level.

8.1 Adding Fields

New fields MAY be appended to the end of an existing struct. Because field ordinal indices are defined by declaration order, appending a field assigns it the next available ordinal. Existing fields MUST NOT change ordinal indices.

Receivers MUST ignore trailing fields they do not recognize. Senders MAY omit trailing fields during serialization. These rules allow new fields to be introduced in a backward-compatible and forward-compatible manner.

New fields SHOULD be declared as `optional<T>` unless the type definition clearly requires the field to be present for semantic correctness. Optional fields preserve maximal flexibility for evolution.

8.2 Removing Fields

Fields MUST NOT be removed from a struct in a way that changes existing ordinal indices. Instead, a field that is no longer used SHOULD be marked with the `@deprecated` attribute and retained with its original ordinal.

Senders SHOULD omit deprecated fields. Receivers MUST ignore deprecated fields if they appear.

If a field must be fully removed, its removal MUST occur only in a new, distinct package version (see Section 8.4). Cross-version compatibility between packages is not required.

8.3 Changing Types

A field's type MUST NOT change within the same package version. Any change in type—including widening (e.g., `int32` to `int64`), narrowing, or structural changes—MUST be treated as a backward-incompatible modification.

Type changes MUST be performed only within a new package version boundary.

Changing a field from a concrete type to `optional<T>` MAY be performed only if the wire encoding remains identical when the value is present and if receivers can safely interpret the absence of the field as the “not present” state.

Changing a field from `optional<T>` to a non-optional type is not compatible and MUST NOT be performed within the same package version.

8.4 Versioning Through Packages

arf relies on the package namespace as the primary unit of versioning. A change that violates any of the compatibility rules in this section MUST be introduced under a new package name.

Package names SHOULD include a stability level (e.g., `v1beta1`, `v1`, `v2`) to provide clear evolution points. Implementations MAY simultaneously support multiple package versions.

No cross-package binary compatibility is required or implied. Changes within a package version MUST adhere to the evolution rules above.

9 ABNF Grammar

This section provides the normative syntax of the arf source language, expressed using Augmented Backus–Naur Form (ABNF) as defined in RFC 5234 and RFC 7405. ABNF rules specify the lexical and syntactic structure of valid arf source files. The grammar below is complete for this specification.

```

arf-source      = *c-nl source-root *c-nl
;
; COMMON DEFINITIONS

CRLF          = (CR LF) / LF
ident          = ALPHA *(ALPHA / DIGIT / "_")
semi           = ";" *WSP *c-nl
c-nl           = comment / CRLF ; comment line or a bare newline
comment        = "#" *(WSP / VCHAR) CRLF
snake-ident    = (%x61-7A / "_") *(%x61-7A / "_" / DIGIT)
screaming-snake-ident =
                  (%x41-5A / "_") *(%x41-5A / "_" / DIGIT)

```

```

camel-ident      = %x41-5A *(ALPHA / DIGIT)

; TYPES

type            = composite-type / plain-type
plain-type      = snake-ident / camel-ident
composite-type  = optional-type / array-type / map-type
optional-type   = "optional<" *WSP type *WSP ">"
array-type      = "array<" *WSP type *WSP ">"
map-type        = "map<" *WSP type *WSP "," *WSP type *WSP ">"
stream          = "stream" 1*WSP type

; SOURCE ROOT

source-root     = package *c-nl imports *c-nl definitions *c-nl
definitions    = *(*c-nl definition *c-nl)
definition     = struct / enum / service

; PACKAGE

package          = "package" 1*WSP package-name *WSP semi
package-name    = snake-ident *(." snake-ident)

; IMPORTS

imports          = *c-nl *("import" 1*WSP import-path [import-alias] semi)
import-path      = *WSP DQUOTE import-components DQUOTE *WSP
import-components = 1*(ALPHA / DIGIT / "-" / "_" / "/" / ".")
import-alias     = 1*WSP "as" 1*WSP snake-ident

; ANNOTATIONS

annotations     = *(annotation)
annotation       = "@" snake-ident *WSP

```

```

[ "(" *annotation-params ")"
  *WSP *c-nl

annotation-params = annotation-param *(," annotation-param)
annotation-param = DQUOTE *VCHAR DQUOTE

; STRUCT

struct          = annotations struct-def struct-body *c-nl
struct-def      = "struct" 1*WSP camel-ident *WSP
struct-body     = "{" *struct-elements "}" *WSP *c-nl
struct-elements = *(c-nl / struct-field / struct)
struct-field    = annotations *CRLF *WSP
                 snake-ident 1*WSP type semi

; ENUM

enum            = annotations enum-def enum-body *c-nl
enum-def        = "enum" 1*WSP camel-ident *WSP
enum-body       = "{" *enum-elements "}" *WSP *c-nl
enum-elements  = *(c-nl / WSP / enum-value)
enum-value      = annotations *CRLF *WSP
                 screaming-snake-ident *WSP
                 "=" *WSP 1*DIGIT semi

; SERVICE

service         = annotations service-def service-body *c-nl
service-def     = "service" 1*WSP camel-ident *WSP
service-body    = "{" *service-elements "}" *WSP *c-nl
service-elements = *(c-nl / WSP / service-rpc)
service-rpc     = service-rpc-prelude
                 service-rpc-params
                 [ service-rpc-returns ]

```

```

semi

service-rpc-prelude =
    annotations *CRLF *WSP camel-ident *WSP

service-rpc-params =
    "(" *service-rpc-input ")" *WSP

service-rpc-input =
    stream /
    (snake-ident 1*WSP type
     (*WSP "," *WSP snake-ident 1*WSP type)
     [*WSP "," stream])

service-rpc-returns =
    ">->" (
        (*WSP type *WSP) /
        ("(" *WSP type *WSP
         *(," *WSP type *WSP)
         [*WSP stream] *WSP ")") /
        (*WSP stream *WSP)
    )

```

10 Security Considerations

arf describes a serialization format and an RPC protocol but does not mandate any particular transport security mechanism. When deployed over an untrusted network, implementations MUST provide confidentiality, integrity, and endpoint authentication using a transport such as TLS [RFC8446], QUIC [RFC9000] with TLS 1.3 [RFC9001], or an equivalent secure channel.

Endpoints MUST validate that incoming frames conform to the arf framing rules, including length fields, frame ordering constraints, and stream termination semantics. Malformed or truncated frames MUST result in termination of the associated `CorrelationID` and SHOULD result in connection closure.

Implementations MUST impose limits on:

- maximum frame length,
- maximum number of concurrent `CorrelationID` streams,
- maximum nesting depth for type decoding,
- maximum aggregate memory per connection.

These limits prevent resource exhaustion attacks.

Optional fields and variable-length structures (arrays, maps, byte sequences) MUST be validated before allocation. Implementations MUST reject encodings that imply unreasonable memory commitments.

Method names, package names, and type names are not security boundaries. Applications MAY impose authorization checks based on method identity, but such checks are outside the scope of this specification.

Applications that embed sensitive data in arf messages MUST consider application-level encryption or tokenization if end-to-end confidentiality is required beyond the transport layer.

11 IANA Considerations

This document makes no requests of the IANA.

Future versions of arf MAY define frame-type registries or well-known package namespaces. Such extensions MUST define their own IANA interactions as appropriate.

12 References

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