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WAMP Advanced Profile

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1. WAMP Advanced Profile

While all implementations **MUST** implement the subset of the Basic Profile necessary for the particular set of WAMP roles they provide, they **MAY** implement any subset of features from the Advanced Profile. Implementers **SHOULD** implement the maximum of features possible considering the aims of an implementation.

Note: Features listed here may be experimental or underspecified and yet unimplemented in any implementation. This part of the specification is very much a work in progress. An approximate status of each feature is given at the beginning of the feature section.

1.1. Feature Announcement

Support for advanced features must be announced by the peers which implement them. The following is a complete list of advanced features currently defined or proposed.

Advanced RPC Features

Feature	Status	P	B	S	Cr	D	Ce
Progressive Call Results	beta				X	X	X
Progressive Calls	sketch				X	X	X
Call Timeout	alpha				X	X	X
Call Canceling	alpha				X	X	X
Caller Identification	alpha				X	X	X
Call Trustlevels	alpha					X	X
Registration Meta API	beta					X	
Pattern-based Registration	beta					X	X
Shared Registration	beta					X	X
Sharded Registration	alpha					X	X
Registration Revocation	alpha					X	X
(Interface) Procedure Reflection	sketch					X	

Table 1

Advanced PubSub Features

Feature	Status	P	B	S	Cr	D	Ce
Subscriber Blackwhite Listing	stable	X	X				
Publisher Exclusion	stable	X	X				

Feature	Status	P	B	S	Cr	D	Ce
Publisher Identification	alpha	X	X	X			
Publication Trustlevels	alpha		X	X			
Subscription Meta API	beta		X				
Pattern-based Subscription	beta		X	X			
Sharded Subscription	alpha		X	X			
Event History	alpha		X	X			
(Interface) Topic Reflection	sketch		X				

Table 2

Other Advanced Features

Feature	Status
Challenge-response Authentication	beta
Ticket authentication	beta
Cryptosign authentication	beta
RawSocket transport	stable
Batched WebSocket transport	sketch
HTTP Longpoll transport	beta
Session Meta API	beta
Call Rerouting	sketch

Table 3

The status of the respective AP feature is marked as follow:

Status	Description
sketch	There is a rough description of an itch to scratch, but the feature use case isn't clear, and there is no protocol proposal at all.
alpha	The feature use case is still fuzzy and/or the feature definition is unclear, but there is at least a protocol level proposal.

Status	Description
beta	The feature use case is clearly defined and the feature definition in the spec is sufficient to write a prototype implementation. The feature definition and details may still be incomplete and change.
stable	The feature definition in the spec is complete and stable and the feature use case is field proven in real applications. There are multiple, interoperable implementations.

Table 4

1.2. Additional Messages

The Advanced Profile defines additional WAMP-level messages which are explained in detail in separate sections. The following 4 additional message types MAY be used in the Advanced Profile and their direction between peer roles. Here, "Tx" ("Rx") means the message is sent (received) by a peer of the respective role.

Code	Message	Publisher	Broker	Subscriber	Caller	Dealer	Callee
4	CHALLENGE	Rx	Tx	Rx	Rx	Tx	Rx
5	AUTHENTICATE	Tx	Rx	Tx	Tx	Rx	Tx
49	CANCEL				Tx	Rx	
69	INTERRUPT					Tx	Rx

Table 5

1.2.1. CHALLENGE

The CHALLENGE message is used with certain Authentication Methods. During authenticated session establishment, a **Router** sends a challenge message.

```
[CHALLENGE, AuthMethod|string, Extra|dict]
```

1.2.2. AUTHENTICATE

The AUTHENTICATE message is used with certain Authentication Methods. A **Client** having received a challenge is expected to respond by sending a signature or token.

```
[AUTHENTICATE, Signature|string, Extra|dict]
```

1.2.3. CANCEL

The CANCEL message is used with the Call Canceling advanced feature. A *Caller* can cancel and issued call actively by sending a cancel message to the *Dealer*.

```
[CANCEL, CALL.Request|id, Options|dict]
```

1.2.4. INTERRUPT

The INTERRUPT message is used with the Call Canceling advanced feature. Upon receiving a cancel for a pending call, a *Dealer* will issue an interrupt to the *Callee*.

```
[INTERRUPT, INVOCATION.Request|id, Options|dict]
```

2. Meta API

2.1. Session Meta API

WAMP enables the monitoring of when sessions join a realm on the router or when they leave it via **Session Meta Events**. It also allows retrieving information about currently connected sessions via **Session Meta Procedures**.

Meta events are created by the router itself. This means that the events, as well as the data received when calling a meta procedure, can be accorded the same trust level as the router.

Note that an implementation that only supports a *Broker* or *Dealer* role, not both at the same time, essentially cannot offer the **Session Meta API**, as it requires both roles to support this feature.

The following sections contain an informal, easy to digest description of the WAMP procedures and topics available in (this part of) the WAMP Meta API. A formal definition of the WAMP Meta API in terms of available WAMP procedures and topics including precise and complete type definitions of the application payloads, that is procedure arguments and results or event payloads is contained in

- Compiled Binary Schema: <WAMP API Catalog>/schema/wamp-meta.bfbs
- FlatBuffers Schema Source: <WAMP API Catalog>/src/wamp-meta.fbs

which uses FlatBuffers IDL to describe the API. The method of using FlatBuffers IDL and type definitions to formally define WAMP procedures and topics is detailed in section [WAMP IDL](#).

Feature Announcement

Support for this feature MUST be announced by **both** *Dealers* and *Brokers* via:

```
HELLO.Details.roles.<role>.features.  
  session_meta_api|bool := true
```


Here is a WELCOME message from a *Router* with support for both the *Broker* and *Dealer* role, and with support for **Session Meta API**:

```
[
  2,
  4580268554656113,
  {
    "authid": "OL3AeppwDLXiAAPbqm9IVhnw",
    "authrole": "anonymous",
    "authmethod": "anonymous",
    "roles": {
      "broker": {
        "features": {
          "session_meta_api": true
        }
      },
      "dealer": {
        "features": {
          "session_meta_api": true
        }
      }
    }
  }
]
```

Note in particular that the feature is announced on both the *Broker* and the *Dealer* roles.

2.1.1. Events

A client can subscribe to the following session meta-events, which cover the lifecycle of a session:

- `wamp.session.on_join`: Fired when a session joins a realm on the router.
- `wamp.session.on_leave`: Fired when a session leaves a realm on the router or is disconnected.

Session Meta Events MUST be dispatched by the *Router* to the same realm as the WAMP session which triggered the event.

2.1.1.1. `wamp.session.on_join`

Fired when a session joins a realm on the router. The event payload consists of a single positional argument `details|dict`:

- `session|id` - The session ID of the session that joined
- `authid|string` - The authentication ID of the session that joined
- `authrole|string` - The authentication role of the session that joined
- `authmethod|string` - The authentication method that was used for authentication the session that joined

- `authprovider|string` - The provider that performed the authentication of the session that joined
- `transport|dict` - Optional, implementation defined information about the WAMP transport the joined session is running over.

See **Authentication** for a description of the `authid`, `authrole`, `authmethod` and `authprovider` properties.

2.1.1.2. `wamp.session.on_leave`

Fired when a session leaves a realm on the router or is disconnected. The event payload consists of three positional arguments:

- `session|id` - The session ID of the session that left
- `authid|string` - The authentication ID of the session that left
- `authrole|string` - The authentication role of the session that left

2.1.2. Procedures

A client can actively retrieve information about sessions, or forcefully close sessions, via the following meta-procedures:

- `wamp.session.count`: Obtains the number of sessions currently attached to the realm.
- `wamp.session.list`: Retrieves a list of the session IDs for all sessions currently attached to the realm.
- `wamp.session.get`: Retrieves information on a specific session.
- `wamp.session.kill`: Kill a single session identified by session ID.
- `wamp.session.kill_by_authid`: Kill all currently connected sessions that have the specified `authid`.
- `wamp.session.kill_by_authrole`: Kill all currently connected sessions that have the specified `authrole`.
- `wamp.session.kill_all`: Kill all currently connected sessions in the caller's realm.

Session meta procedures **MUST** be registered by the *Router* on the same realm as the WAMP session about which information is retrieved.

2.1.2.1. `wamp.session.count`

Obtains the number of sessions currently attached to the realm.

Positional arguments

1. `filter_authroles|list[string]` - Optional filter: if provided, only count sessions with an `authrole` from this list.

Positional results

1. `count|int` - The number of sessions currently attached to the realm.

2.1.2.2. `wamp.session.list`

Retrieves a list of the session IDs for all sessions currently attached to the realm.

Positional arguments

1. `filter_authroles|list[string]` - Optional filter: if provided, only count sessions with an `authrole` from this list.

Positional results

1. `session_ids|list` - List of WAMP session IDs (order undefined).

2.1.2.3. `wamp.session.get`

Retrieves information on a specific session.

Positional arguments

1. `session|id` - The session ID of the session to retrieve details for.

Positional results

1. `details|dict` - Information on a particular session:
 - `session|id` - The session ID of the session that joined
 - `authid|string` - The authentication ID of the session that joined
 - `authrole|string` - The authentication role of the session that joined
 - `authmethod|string` - The authentication method that was used for authentication the session that joined
 - `authprovider|string` - The provider that performed the authentication of the session that joined
 - `transport|dict` - Optional, implementation defined information about the WAMP transport the joined session is running over.

See **Authentication** for a description of the `authid`, `authrole`, `authmethod` and `authprovider` properties.

Errors

- `wamp.error.no_such_session` - No session with the given ID exists on the router.

2.1.2.4. **wamp.session.kill**

Kill a single session identified by session ID.

The caller of this meta procedure may only specify session IDs other than its own session. Specifying the caller's own session will result in a `wamp.error.no_such_session` since no *other* session with that ID exists.

The keyword arguments are optional, and if not provided the reason defaults to `wamp.close.normal` and the message is omitted from the GOODBYE sent to the closed session.

Positional arguments

1. `session|id` - The session ID of the session to close.

Keyword arguments

1. `reason|uri` - reason for closing session, sent to client in GOODBYE.Reason.
2. `message|string` - additional information sent to client in GOODBYE.Details under the key "message".

Errors

- `wamp.error.no_such_session` - No session with the given ID exists on the router.
- `wamp.error.invalid_uri` - A reason keyword argument has a value that is not a valid non-empty URI.

2.1.2.5. **wamp.session.kill_by_authid**

Kill all currently connected sessions that have the specified authid.

If the caller's own session has the specified authid, the caller's session is excluded from the closed sessions.

The keyword arguments are optional, and if not provided the reason defaults to `wamp.close.normal` and the message is omitted from the GOODBYE sent to the closed session.

Positional arguments

1. `authid|string` - The authentication ID identifying sessions to close.

Keyword arguments

1. `reason|uri` - reason for closing sessions, sent to clients in GOODBYE.Reason
2. `message|string` - additional information sent to clients in GOODBYE.Details under the key "message".

Positional results

1. `sessions|list` - The list of WAMP session IDs of session that were killed.

Errors

- `wamp.error.invalid_uri` - A reason keyword argument has a value that is not a valid non-empty URI.

2.1.2.6. `wamp.session.kill_by_authrole`

Kill all currently connected sessions that have the specified `authrole`.

If the caller's own session has the specified `authrole`, the caller's session is excluded from the closed sessions.

The keyword arguments are optional, and if not provided the reason defaults to `wamp.close.normal` and the message is omitted from the GOODBYE sent to the closed session.

Positional arguments

1. `authrole|string` - The authentication role identifying sessions to close.

Keyword arguments

1. `reason|uri` - reason for closing sessions, sent to clients in GOODBYE. Reason
2. `message|string` - additional information sent to clients in GOODBYE. Details under the key "message".

Positional results

1. `count|int` - The number of sessions closed by this meta procedure.

Errors

- `wamp.error.invalid_uri` - A reason keyword argument has a value that is not a valid non-empty URI.

2.1.2.7. `wamp.session.kill_all`

Kill all currently connected sessions in the caller's realm.

The caller's own session is excluded from the closed sessions. Closing all sessions in the realm will not generate session meta events or testament events, since no subscribers would remain to receive these events.

The keyword arguments are optional, and if not provided the reason defaults to `wamp.close.normal` and the message is omitted from the GOODBYE sent to the closed session.

Keyword arguments

1. `reason|uri` - reason for closing sessions, sent to clients in GOODBYE. Reason
2. `message|string` - additional information sent to clients in GOODBYE. Details under the key "message".

Positional results

1. `count|int` - The number of sessions closed by this meta procedure.

Errors

- `wamp.error.invalid_uri` - A reason keyword argument has a value that is not a valid non-empty URI.

2.2. Registration Meta API

Registration Meta Events are fired when registrations are first created, when *Callees* are attached (removed) to (from) a registration, and when registrations are finally destroyed.

Furthermore, WAMP allows actively retrieving information about registrations via **Registration Meta Procedures**.

Meta-events are created by the router itself. This means that the events as well as the data received when calling a meta-procedure can be accorded the same trust level as the router.

Note that an implementation that only supports a *Broker* or *Dealer* role, not both at the same time, essentially cannot offer the **Registration Meta API**, as it requires both roles to support this feature.

The following sections contain an informal, easy to digest description of the WAMP procedures and topics available in (this part of) the WAMP Meta API. A formal definition of the WAMP Meta API in terms of available WAMP procedures and topics including precise and complete type definitions of the application payloads, that is procedure arguments and results or event payloads is contained in:

- Compiled Binary Schema: `<WAMP API Catalog>/schema/wamp-meta.bfbs`
- FlatBuffers Schema Source: `<WAMP API Catalog>/src/wamp-meta.fbs`

which uses FlatBuffers IDL to describe the API. The method of using FlatBuffers IDL and type definitions to formally define WAMP procedures and topics is detailed in section [WAMP IDL](#).

Feature Announcement

Support for this feature MUST be announced by a *Dealers* (`role := "dealer"`) via:

```
HELLO.Details.roles.<role>.features.  
  registration_meta_api|bool := true
```

Here is a WELCOME message from a *Router* with support for both the *Broker* and *Dealer* role, and with support for **Registration Meta API**:

```
[
  2,
  4580268554656113,
  {
    "authid": "0L3AeppwDLXiAAPbqm9IVhnw",
    "authrole": "anonymous",
    "authmethod": "anonymous",
    "roles": {
      "broker": {
        "features": {
        }
      },
      "dealer": {
        "features": {
          "registration_meta_api": true
        }
      }
    }
  }
]
```

2.2.1. Events

A client can subscribe to the following registration meta-events, which cover the lifecycle of a registration:

- `wamp.registration.on_create`: Fired when a registration is created through a registration request for a URI which was previously without a registration.
- `wamp.registration.on_register`: Fired when a *Callee* session is added to a registration.
- `wamp.registration.on_unregister`: Fired when a *Callee* session is removed from a registration.
- `wamp.registration.on_delete`: Fired when a registration is deleted after the last *Callee* session attached to it has been removed.

A `wamp.registration.on_register` event **MUST** be fired subsequent to a `wamp.registration.on_create` event, since the first registration results in both the creation of the registration and the addition of a session.

Similarly, the `wamp.registration.on_delete` event **MUST** be preceded by a `wamp.registration.on_unregister` event.

Registration Meta Events **MUST** be dispatched by the router to the same realm as the WAMP session which triggered the event.

2.2.1.1. `wamp.registration.on_create`

Fired when a registration is created through a registration request for a URI which was previously without a registration. The event payload consists of positional arguments:

- `session|id`: The session ID performing the registration request.

- `RegistrationDetails|dict`: Information on the created registration.

Object Schemas

```
RegistrationDetails :=  
{  
  "id": registration|id,  
  "created": time_created|iso_8601_string,  
  "uri": procedure|uri,  
  "match": match_policy|string,  
  "invoke": invocation_policy|string  
}
```

See [Pattern-based Registrations](#) for a description of `match_policy`.

NOTE: `invocation_policy` IS NOT YET DESCRIBED IN THE ADVANCED SPEC

2.2.1.2. `wamp.registration.on_register`

Fired when a session is added to a registration. The event payload consists of positional arguments:

- `session|id`: The ID of the session being added to a registration.
- `registration|id`: The ID of the registration to which a session is being added.

2.2.1.3. `wamp.registration.on_unregister`

Fired when a session is removed from a subscription. The event payload consists of positional arguments:

- `session|id`: The ID of the session being removed from a registration.
- `registration|id`: The ID of the registration from which a session is being removed.

2.2.1.4. `wamp.registration.on_delete`

Fired when a registration is deleted after the last session attached to it has been removed. The event payload consists of positional arguments:

- `session|id`: The ID of the last session being removed from a registration.
- `registration|id`: The ID of the registration being deleted.

2.2.2. Procedures

A client can actively retrieve information about registrations via the following meta-procedures:

- `wamp.registration.list`: Retrieves registration IDs listed according to match policies.

- `wamp.registration.lookup`: Obtains the registration (if any) managing a procedure, according to some match policy.
- `wamp.registration.match`: Obtains the registration best matching a given procedure URI.
- `wamp.registration.get`: Retrieves information on a particular registration.
- `wamp.registration.list_callees`: Retrieves a list of session IDs for sessions currently attached to the registration.
- `wamp.registration.count_callees`: Obtains the number of sessions currently attached to the registration.

2.2.2.1. `wamp.registration.list`

Retrieves registration IDs listed according to match policies.

Arguments

- None

Results

- `RegistrationLists|dict`: A dictionary with a list of registration IDs for each match policy.

Object Schemas

```
RegistrationLists :=  
{  
  "exact": registration_ids|list,  
  "prefix": registration_ids|list,  
  "wildcard": registration_ids|list  
}
```

See [Pattern-based Registrations](#) for a description of match policies.

2.2.2.2. `wamp.registration.lookup`

Obtains the registration (if any) managing a procedure, according to some match policy.

Arguments

- `procedure|uri`: The procedure to lookup the registration for.
- (Optional) `options|dict`: Same options as when registering a procedure.

Results

- (Nullable) `registration|id`: The ID of the registration managing the procedure, if found, or null.

2.2.2.3. `wamp.registration.match`

Obtains the registration best matching a given procedure URI.

Arguments

- `procedure|uri`: The procedure URI to match

Results

- (Nullable) `registration|id`: The ID of best matching registration, or null.

2.2.2.4. `wamp.registration.get`

Retrieves information on a particular registration.

Arguments

- `registration|id`: The ID of the registration to retrieve.

Results

- `RegistrationDetails|dict`: Details on the registration.

Error URIs

- `wamp.error.no_such_registration`: No registration with the given ID exists on the router.

Object Schemas

```
RegistrationDetails :=
{
  "id": registration|id,
  "created": time_created|iso_8601_string,
  "uri": procedure|uri,
  "match": match_policy|string,
  "invoke": invocation_policy|string
}
```

See [Pattern-based Registrations](#) for a description of match policies.

NOTE: invocation_policy IS NOT YET DESCRIBED IN THE ADVANCED SPEC

2.2.2.5. `wamp.registration.list_callees`

Retrieves a list of session IDs for sessions currently attached to the registration.

Arguments

- `registration|id`: The ID of the registration to get callees for.

Results

- `callee_ids|list`: A list of WAMP session IDs of callees currently attached to the registration.

Error URIs

- `wamp.error.no_such_registration`: No registration with the given ID exists on the router.

2.2.2.6. `wamp.registration.count_callees`

Obtains the number of sessions currently attached to a registration.

Arguments

- `registration|id`: The ID of the registration to get the number of callees for.

Results

- `count|int`: The number of callees currently attached to a registration.

Error URIs

- `wamp.error.no_such_registration`: No registration with the given ID exists on the router.

2.3. Subscriptions Meta API

Within an application, it may be desirable for a publisher to know whether a publication to a specific topic currently makes sense, i.e. whether there are any subscribers who would receive an event based on the publication. It may also be desirable to keep a current count of subscribers to a topic to then be able to filter out any subscribers who are not supposed to receive an event.

Subscription *meta-events* are fired when topics are first created, when clients subscribe/unsubscribe to them, and when topics are deleted. WAMP allows retrieving information about subscriptions via subscription *meta-procedures*.

Support for this feature MUST be announced by Brokers via

```
HELLO.Details.roles.broker.features.subscription_meta_api|
bool := true
```

Meta-events are created by the router itself. This means that the events as well as the data received when calling a meta-procedure can be accorded the same trust level as the router.

The following sections contain an informal, easy to digest description of the WAMP procedures and topics available in (this part of) the WAMP Meta API. A formal definition of the WAMP Meta API in terms of available WAMP procedures and topics including precise and complete type definitions of the application payloads, that is procedure arguments and results or event payloads is contained in

- Compiled Binary Schema: `<WAMP API Catalog>/schema/wamp-meta.bfbs`
- FlatBuffers Schema Source: `<WAMP API Catalog>/src/wamp-meta.fbs`

which uses FlatBuffers IDL to describe the API. The method of using FlatBuffers IDL and type definitions to formally define WAMP procedures and topics is detailed in [WAMP IDL](#).

Feature Announcement

Support for this feature **MUST** be announced by a *Brokers* (role := "nroker") via:

```
HELLO.Details.roles.<role>.features.  
  subscription_meta_api|bool := true
```

Here is a WELCOME message from a *Router* with support for both the *Broker* and *Dealer* role, and with support for **Subscription Meta API**:

```
[  
  2,  
  4580268554656113,  
  {  
    "authid": "0L3AeppwDLXiAAPbqm9IVhnw",  
    "authrole": "anonymous",  
    "authmethod": "anonymous",  
    "roles": {  
      "broker": {  
        "features": {  
          "subscription_meta_api": true  
        }  
      },  
      "dealer": {  
        "features": {  
        }  
      }  
    }  
  }  
]
```

2.3.1. Events

A client can subscribe to the following session meta-events, which cover the lifecycle of a subscription:

- `wamp.subscription.on_create`: Fired when a subscription is created through a subscription request for a topic which was previously without subscribers.
- `wamp.subscription.on_subscribe`: Fired when a session is added to a subscription.
- `wamp.subscription.on_unsubscribe`: Fired when a session is removed from a subscription.
- `wamp.subscription.on_delete`: Fired when a subscription is deleted after the last session attached to it has been removed.

A `wamp.subscription.on_subscribe` event **MUST** always be fired subsequent to a `wamp.subscription.on_create` event, since the first subscribe results in both the creation of the subscription and the addition of a session. Similarly, the `wamp.subscription.on_delete` event **MUST** always be preceded by a `wamp.subscription.on_unsubscribe` event.

The WAMP subscription meta events shall be dispatched by the router to the same realm as the WAMP session which triggered the event.

2.3.1.1. **wamp.subscription.on_create**

Fired when a subscription is created through a subscription request for a topic which was previously without subscribers. The event payload consists of positional arguments:

- `session|id`: ID of the session performing the subscription request.
- `SubscriptionDetails|dict`: Information on the created subscription.

Object Schemas

```
SubscriptionDetails :=  
{  
    "id": subscription|id,  
    "created": time_created|iso_8601_string,  
    "uri": topic|uri,  
    "match": match_policy|string  
}
```

See [Pattern-based Subscriptions](#) for a description of `match_policy`.

2.3.1.2. **wamp.subscription.on_subscribe**

Fired when a session is added to a subscription. The event payload consists of positional arguments:

- `session|id`: ID of the session being added to a subscription.
- `subscription|id`: ID of the subscription to which the session is being added.

2.3.1.3. **wamp.subscription.on_unsubscribe**

Fired when a session is removed from a subscription. The event payload consists of positional arguments:

- `session|id`: ID of the session being removed from a subscription.
- `subscription|id`: ID of the subscription from which the session is being removed.

2.3.1.4. **wamp.subscription.on_delete**

Fired when a subscription is deleted after the last session attached to it has been removed. The event payload consists of positional arguments:

- `session|id`: ID of the last session being removed from a subscription.
- `subscription|id`: ID of the subscription being deleted.

2.3.2. Procedures

A client can actively retrieve information about subscriptions via the following meta-procedures:

- `wamp.subscription.list`: Retrieves subscription IDs listed according to match policies.
- `wamp.subscription.lookup`: Obtains the subscription (if any) managing a topic, according to some match policy.
- `wamp.subscription.match`: Retrieves a list of IDs of subscriptions matching a topic URI, irrespective of match policy.
- `wamp.subscription.get`: Retrieves information on a particular subscription.
- `wamp.subscription.list_subscribers`: Retrieves a list of session IDs for sessions currently attached to the subscription.
- `wamp.subscription.count_subscribers`: Obtains the number of sessions currently attached to the subscription.

2.3.2.1. `wamp.subscription.list`

Retrieves subscription IDs listed according to match policies.

Arguments - None

Results

The result consists of one positional argument:

- `SubscriptionLists|dict`: A dictionary with a list of subscription IDs for each match policy.

Object Schemas

```
SubscriptionLists :=
{
  "exact": subscription_ids|list,
  "prefix": subscription_ids|list,
  "wildcard": subscription_ids|list
}
```

See [Pattern-based Subscriptions](#) for information on match policies.

2.3.2.2. `wamp.subscription.lookup`

Obtains the subscription (if any) managing a topic, according to some match policy.

Arguments

- `topic|uri`: The URI of the topic.
- (Optional) `options|dict`: Same options as when subscribing to a topic.

Results

The result consists of one positional argument:

- (Nullable) `subscription|id`: The ID of the subscription managing the topic, if found, or null.

2.3.2.3. **wamp.subscription.match**

Retrieves a list of IDs of subscriptions matching a topic URI, irrespective of match policy.

Arguments

- `topic|uri`: The topic to match.

Results

The result consists of positional arguments:

- (Nullable) `subscription_ids|list`: A list of all matching subscription IDs, or null.

2.3.2.4. **wamp.subscription.get**

Retrieves information on a particular subscription.

Arguments

- `subscription|id`: The ID of the subscription to retrieve.

Results

The result consists of one positional argument:

- `SubscriptionDetails|dict`: Details on the subscription.

Error URIs

- `wamp.error.no_such_subscription`: No subscription with the given ID exists on the router.

Object Schemas

```
SubscriptionDetails :=
{
  "id": subscription|id,
  "created": time_created|iso_8601_string,
  "uri": topic|uri,
  "match": match_policy|string
}
```

See [Pattern-based Subscriptions](#) for information on match policies.

2.3.2.5. **wamp.subscription.list_subscribers**

Retrieves a list of session IDs for sessions currently attached to the subscription.

Arguments - `subscription|id`: The ID of the subscription to get subscribers for.

Results

The result consists of positional arguments:

- `subscribers_ids|list`: A list of WAMP session IDs of subscribers currently attached to the subscription.

Error URIs

- `wamp.error.no_such_subscription`: No subscription with the given ID exists on the router.

2.3.2.6. `wamp.subscription.count_subscribers`

Obtains the number of sessions currently attached to a subscription.

Arguments

- `subscription|id`: The ID of the subscription to get the number of subscribers for.

Results

The result consists of one positional argument:

- `count|int`: The number of sessions currently attached to a subscription.

Error URIs

- `wamp.error.no_such_subscription`: No subscription with the given ID exists on the router.

3. Advanced RPC

3.1. Progressive Call Results

A procedure implemented by a *Callee* and registered at a *Dealer* may produce progressive results. Progressive results can e.g. be used to return partial results for long-running operations, or to chunk the transmission of larger results sets.

Feature Announcement

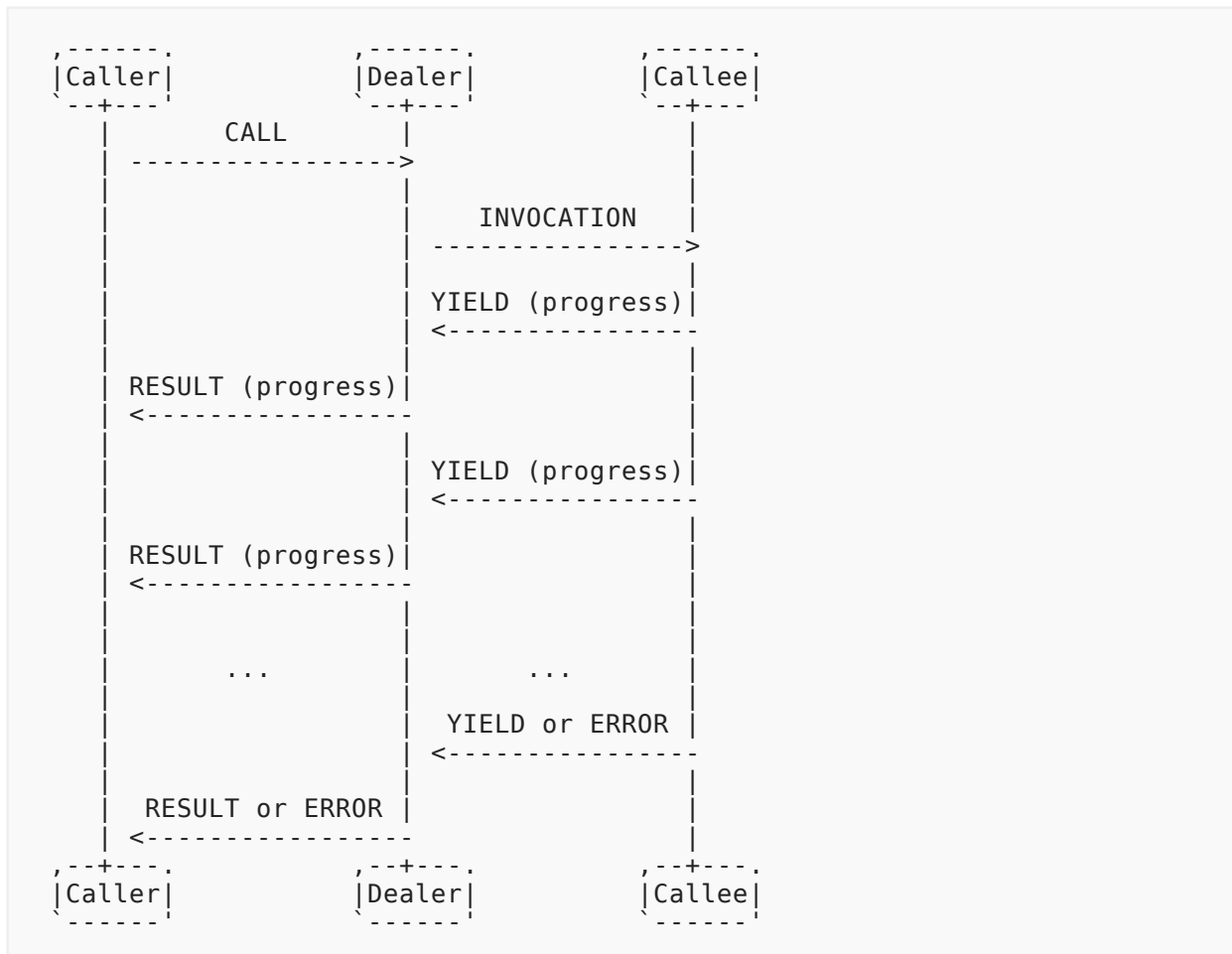
Support for this advanced feature MUST be announced by *Callers* (`role := "caller"`), *Callees* (`role := "callee"`) and *Dealers* (`role := "dealer"`) via

```
HELLO.Details.roles.<role>.features.  
    progressive_call_results|bool := true
```


Additionally, *Callees* and *Dealers* MUST support Call Canceling, which is required for canceling progressive results if the original *Caller* leaves the realm. If a *Callee* supports Progressive Call Results, but not Call Canceling, then the *Dealer* disregards the *Callees* Progressive Call Results feature.

Message Flow

The message flow for progressive results involves:



A *Caller* indicates its willingness to receive progressive results by setting

```
CALL.Options.receive_progress|bool := true
```

Example. Caller-to-Dealer CALL

```
[
  48,
  77133,
  {
    "receive_progress": true
  },
  "com.myapp.compute_revenue",
  [2010, 2011, 2012]
]
```

If the *Callee* supports progressive calls, the *Dealer* will forward the *Caller's* willingness to receive progressive results by setting

```
INVOCATION.Details.receive_progress|bool := true
```

Example. Dealer-to-Callee INVOCATION

```
[
  68,
  87683,
  324,
  {
    "receive_progress": true
  },
  [2010, 2011, 2012]
]
```

An endpoint implementing the procedure produces progressive results by sending YIELD messages to the *Dealer* with

```
YIELD.Options.progress|bool := true
```

Example. Callee-to-Dealer progressive YIELDS

```
[
  70,
  87683,
  {
    "progress": true
  },
  ["Y2010", 120]
]
```

```
[
  70,
  87683,
  {
    "progress": true
  },
  ["Y2011", 205]
]
```

Upon receiving an YIELD message from a *Callee* with `YIELD.Options.progress == true` (for a call that is still ongoing), the *Dealer* will **immediately** send a RESULT message to the original *Caller* with

```
RESULT.Details.progress|bool := true
```

Example. Dealer-to-Caller progressive RESULTS

```
[
  50,
  77133,
  {
    "progress": true
  },
  ["Y2010", 120]
]
```

```
[
  50,
  77133,
  {
    "progress": true
  },
  ["Y2011", 205]
]
```

and so on...

An invocation **MUST** *always* end in either a *normal* RESULT or ERROR message being sent by the *Callee* and received by the *Dealer*.

Example. Callee-to-Dealer final YIELD

```
[
  70,
  87683,
  {},
  ["Total", 490]
]
```

Example. Callee-to-Dealer final ERROR

```
[
  4,
  87683,
  {},
  "com.myapp.invalid_revenue_year",
  [1830]
]
```

A call *MUST always* end in either a *normal* RESULT or ERROR message being sent by the *Dealer* and received by the *Caller*.

Example. Dealer-to-Caller final RESULT

```
[
  50,
  77133,
  {},
  ["Total", 490]
]
```

Example. Dealer-to-Caller final ERROR

```
[
  4,
  77133,
  {},
  "com.myapp.invalid_revenue_year",
  [1830]
]
```

In other words: `YIELD` with `YIELD.Options.progress == true` and `RESULT` with `RESULT.Details.progress == true` messages may only be sent *during* a call or invocation is still ongoing.

The final `YIELD` and final `RESULT` may also be empty, e.g. when all actual results have already been transmitted in progressive result messages.

Example. Callee-to-Dealer `YIELDS`

```
[70, 87683, {"progress": true}, ["Y2010", 120]]
[70, 87683, {"progress": true}, ["Y2011", 205]]
...
[70, 87683, {"progress": true}, ["Total", 490]]
[70, 87683, {}]
```

Example. Dealer-to-Caller `RESULTS`

```
[50, 77133, {"progress": true}, ["Y2010", 120]]
[50, 77133, {"progress": true}, ["Y2011", 205]]
...
[50, 77133, {"progress": true}, ["Total", 490]]
[50, 77133, {}]
```

The progressive YIELD and progressive RESULT may also be empty, e.g. when those messages are only used to signal that the procedure is still running and working, and the actual result is completely delivered in the final YIELD and RESULT:

Example. Callee-to-Dealer YIELDS

```
[70, 87683, {"progress": true}]
[70, 87683, {"progress": true}]
...
[70, 87683, {}, [{"Y2010", 120}, {"Y2011", 205}, ...,
["Total", 490]]]
```

Example. Dealer-to-Caller RESULTS

```
[50, 77133, {"progress": true}]
[50, 77133, {"progress": true}]
...
[50, 77133, {}, [{"Y2010", 120}, {"Y2011", 205}, ...,
["Total", 490]]]
```

Note that intermediate, progressive results and/or the final result MAY have different structure. The WAMP peer implementation is responsible for mapping everything into a form suitable for consumption in the host language.

Example. Callee-to-Dealer YIELDS

```
[70, 87683, {"progress": true}, ["partial 1", 10]]
[70, 87683, {"progress": true}, [], {"foo": 10,
"bar": "partial 1"}]
...
[70, 87683, {}, [1, 2, 3], {"moo": "hello"}]
```

Example. Dealer-to-Caller RESULTS

```
[50, 77133, {"progress": true}, ["partial 1", 10]]
[50, 77133, {"progress": true}, [], {"foo": 10,
"bar": "partial 1"}]
...
[50, 77133, {}, [1, 2, 3], {"moo": "hello"}]
```

Even if a *Caller* has indicated its expectation to receive progressive results by setting `CALL.Options.receive_progress|bool := true`, a *Callee* is **not required** to produce progressive results. `CALL.Options.receive_progress` and `INVOCATION.Details.receive_progress` are simply indications that the *Caller* is prepared to process progressive results, should there be any produced. In other words, *Callees* are free to ignore such `receive_progress` hints at any time.

Progressive Call Result Cancellation

Upon receiving a YIELD message from a *Callee* with `YIELD.Options.progress == true` (for a call that is still ongoing), if the original *Caller* is no longer available (has left the realm), then the *Dealer* will send an INTERRUPT to the *Callee*. The INTERRUPT will have `Options.mode` set to "killnowait" to indicate to the client that no response should be sent to the INTERRUPT. This INTERRUPT is only sent in response to a progressive YIELD (`Details.progress == true`), and is not sent in response to a normal or final YIELD.

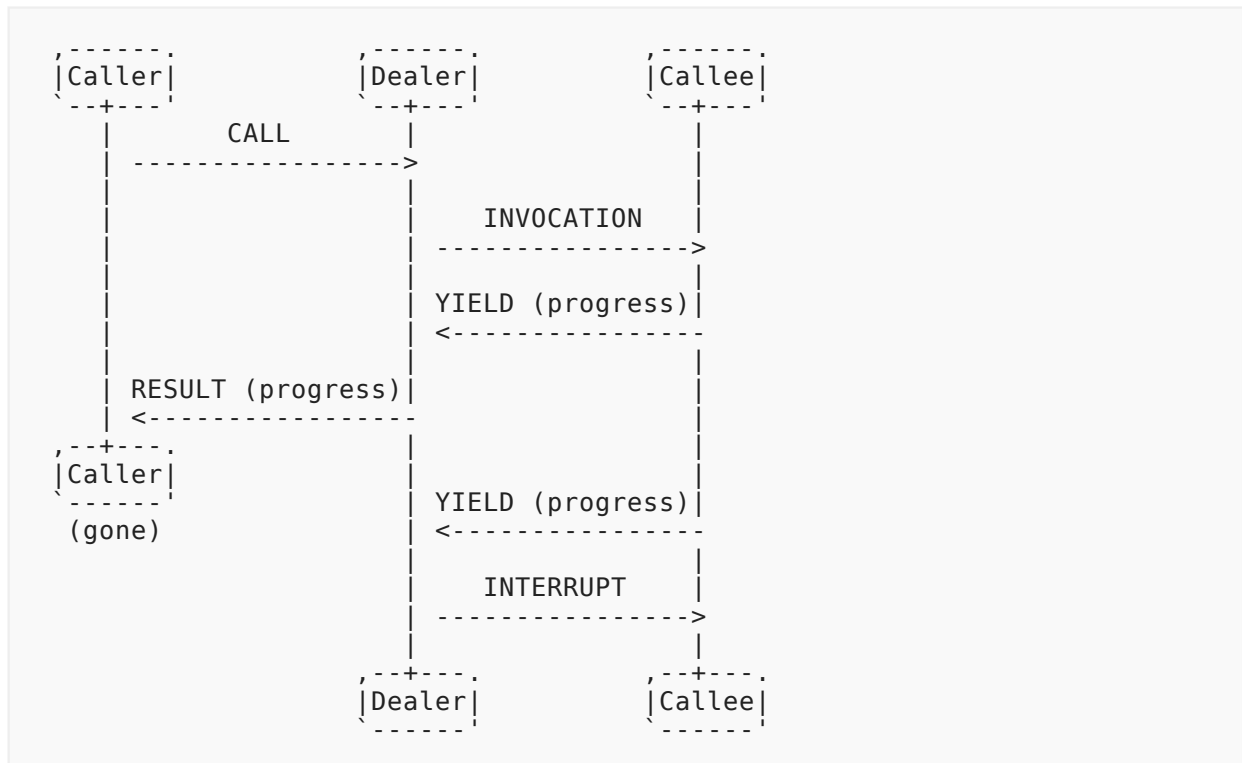
```
[INTERRUPT, INVOCATION.Request|id, Options|dict]
```

Options:

```
INTERRUPT.Options.mode|string == "killnowait"
```

Progressive call result cancellation closes an important safety gap: In cases where progressive results are used to stream data to *Callers*, and network connectivity is unreliable, *Callers* may often get disconnected in the middle of receiving progressive results. Recurring connect, call, disconnect cycles can quickly build up *Callees* streaming results to dead *Callers*. This can overload the router and further degrade network connectivity.

The message flow for progressive results cancellation involves:



Note: Any `ERROR` returned by the *Callee*, in response to the `INTERRUPT`, is ignored (same as in call canceling when `mode="killnowait"`). So, it is not necessary for the *Callee* to send an `ERROR` message.

Ignoring Progressive Call Requests

A *Callee* that does not support progressive results **SHOULD** ignore any `INVOCATION.Details.receive_progress` flag.

A *Callee* that supports progressive results, but does not support call canceling is considered by the *Dealer* to not support progressive results.

3.2. Progressive Calls

A procedure implemented by a *Callee* and registered at a *Dealer* may receive a progressive call. Progressive results can e.g. be used to start processing initial data where a larger data set may not yet have been generated or received by the *Caller*.

See this GitHub issue for more discussion: <https://github.com/wamp-proto/wamp-proto/issues/167>

3.3. Call Timeouts

A *Caller* might want to issue a call and provide a *timeout* after which the call will finish.

A *timeout* allows for **automatic** cancellation of a call after a specified time either at the *Callee* or at the *Dealer*.

A *Caller* specifies a timeout by providing

```
CALL.Options.timeout|integer
```

in ms. A timeout value of 0 deactivates automatic call timeout. This is also the default value.

The timeout option is a companion to, but slightly different from the CANCEL and INTERRUPT messages that allow a *Caller* and *Dealer* to **actively** cancel a call or invocation.

In fact, a timeout timer might run at three places:

- *Caller*
- *Dealer*
- *Callee*

Feature Announcement

Support for this feature MUST be announced by *Callers* (role := "caller"), *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.call_timeout|bool := true
```

3.4. Call Canceling

A *Caller* might want to actively cancel a call that was issued, but not has yet returned. An example where this is useful could be a user triggering a long running operation and later changing his mind or no longer willing to wait.

Feature Announcement

Support for this feature MUST be announced by *Callers* (role := "caller"), *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.call_canceling|bool := true
```

Message Flow

The message flow between *Callers*, a *Dealer* and *Callees* for canceling remote procedure calls involves the following messages:

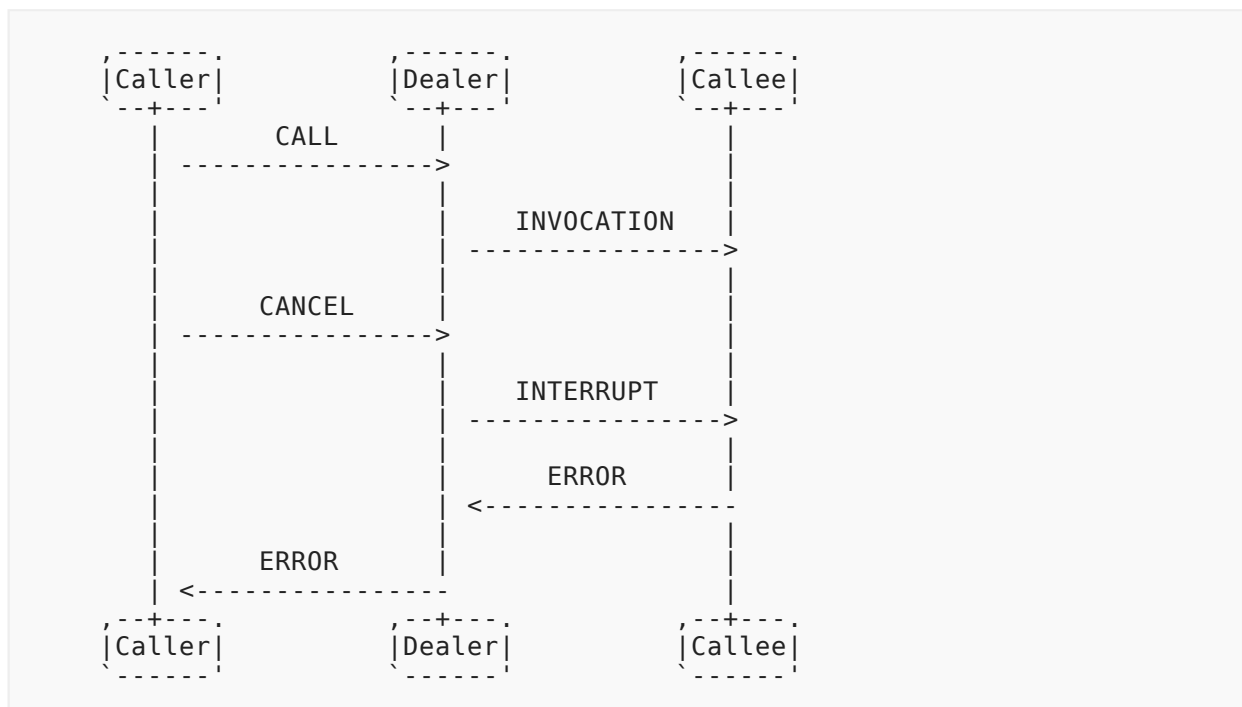
- CANCEL
- INTERRUPT
- ERROR

A call may be canceled at the *Callee* or (U+00A0)at (U+00A0)the (U+00A0)*Dealer* side. Cancellation behaves differently depending on the mode:

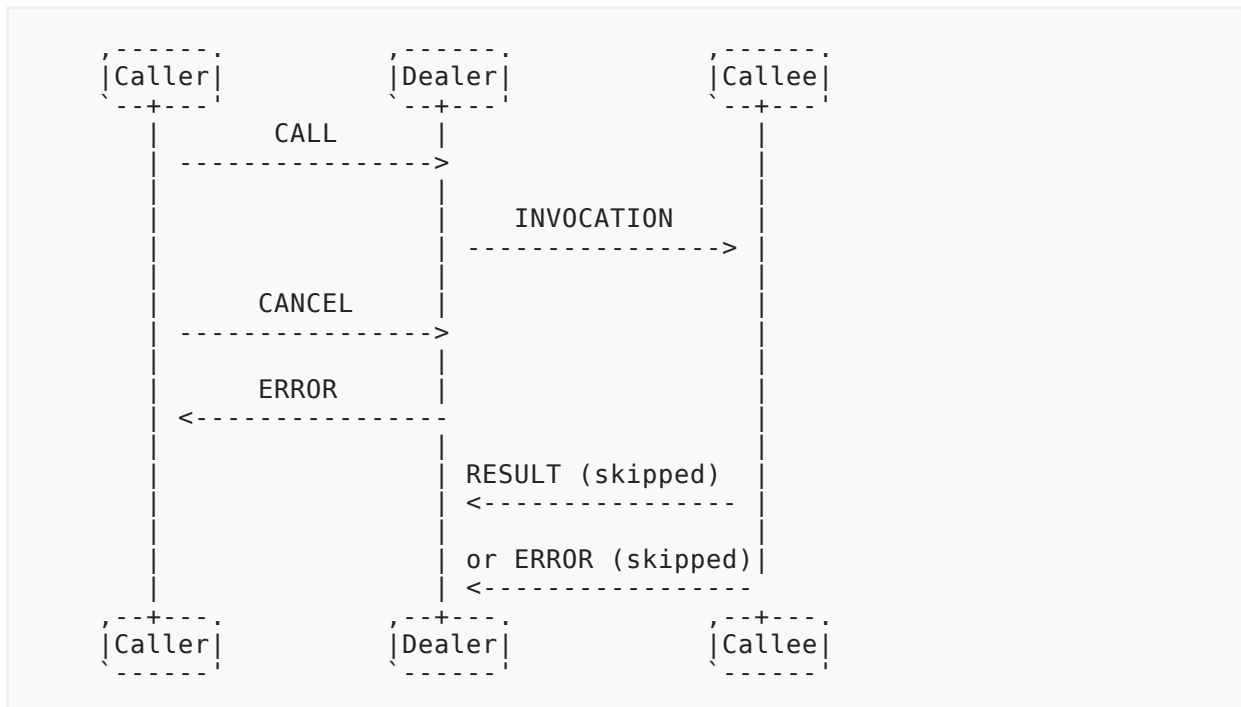
- **skip**: The pending call is canceled and ERROR is sent immediately back to the caller. No INTERRUPT is sent to the callee and the result is discarded when received.
- **kill**: INTERRUPT is sent to the callee, but ERROR is not returned to the caller until after the callee has responded to the canceled call. In this case the caller may receive RESULT or ERROR depending whether the callee finishes processing the invocation or the interrupt first.
- **killnowait**: The pending call is canceled and ERROR is sent immediately back to the caller. INTERRUPT is sent to the callee and any response to the invocation or interrupt from the callee is discarded when received.

If the callee does not support call canceling, then behavior is **skip**.

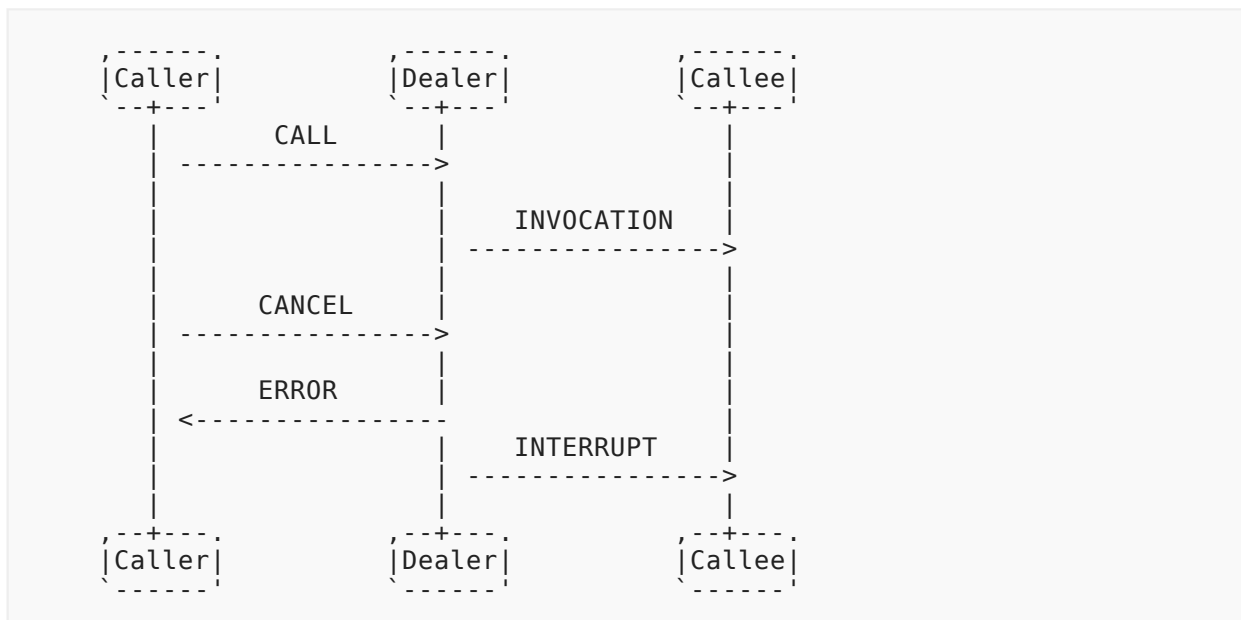
Message flow during call canceling when (U+00A0)*Callee* supports this feature and (U+00A0)mode is kill



Message flow during call canceling when (U+00A0)*Callee* does not support this feature or (U+00A0)mode is skip



Message flow during call canceling when (U+00A0)*Callee* supports this feature and (U+00A0)*mode* is *killnowait*



A *Caller* cancels a remote procedure call initiated (but not yet finished) by sending a **CANCEL** message to the *Dealer*:

```
[CANCEL, CALL.Request|id, Options|dict]
```

A *Dealer* cancels an invocation of an endpoint initiated (but not yet finished) by sending a INTERRUPT message to the *Callee*:

```
[INTERRUPT, INVOCATION.Request|id, Options|dict]
```

Options:

```
CANCEL.Options.mode|string == "skip" | "kill" | "killnowait"
```

Ignoring Results after Cancel

After the *Dealer* sends an INTERRUPT when mode="killnowait", any responses from the *Callee* are ignored. This means that it is not necessary for the *Callee* to respond with an ERROR message, when mode="killnowait", since the *Dealer* ignores it.

3.5. Call Re-Routing

A *CALLEE* might not be able to attend to a call. This may be due to a multitude of reasons including, but not limited to:

- *CALLEE* is busy handling other requests and is not able to attend
- *CALLEE* has dependency issues which prevent it from being able to fulfil the request
- In a HA environment, the *Callee* knows that it is scheduled to be taken off the HA cluster and as such should not handle the request.

A *unavailable* response allows for **automatic** reroute of a call by the *Dealer* without the *CALLER* ever having to know about it.

When such a situation occurs, the *Callee* responds to a INVOCATION message with the error uri:

```
wamp.error.unavailable
```

When the *Dealer* receives the `wamp.error.unavailable` message in response to an INVOCATION, it will reroute the CALL to another *registration* according to the rerouting rules of the `invocation_policy` of the procedure, as given below.

Feature Announcement

Support for this feature MUST be announced by *Callees* (`role := "callee"`) and *Dealers* (`role := "dealer"`) via

```
HELLO.Details.roles.<role>.features.call_reroute|bool := true
```

Rerouting Rules

The *Dealer* MUST adhere to the `invocation_policy` of the procedure when rerouting the CALL, while assuming that the unavailable registration virtually does not exist.

For different `invocation_policy` the *Dealer* MUST follow:

Invocation Policy	Operation
single	Responds with a <code>wamp.error.no_available_callee</code> error message to the <i>CALLER</i>
roundrobin	Picks the next registration from the <i>Registration Queue</i> of the <i>Procedure</i>
random	Picks another registration at random from the <i>Registration Queue</i> of the <i>Procedure</i> , as long as it is not the same registration
first	Picks the registration which was registered after the <i>called</i> registration was registered
last	Picks the registration which was registered right before the <i>called</i> registration was registered

Table 6

Failure Scenario

In case all available registrations of a *Procedure* responds with a `wamp.error.unavailable` for a *CALL*, the *Dealer* MUST respond with a `wamp.error.no_available_callee` to the *CALLER*

3.6. Caller Identification

A *Caller* MAY **request** the disclosure of its identity (its WAMP session ID) to endpoints of a routed call via

```
CALL.Options.disclose_me|bool := true
```

Example

```
[48, 7814135, {"disclose_me": true}, "com.myapp.echo",  
["Hello, world!"]]
```

If above call is issued by a *Caller* with WAMP session ID 3335656, the *Dealer* sends an INVOCATION message to *Callee* with the *Caller's* WAMP session ID in `INVOCATION.Details.caller`:

Example

```
[68, 6131533, 9823526, {"caller": 3335656}, ["Hello, world!"]]
```

Note that a *Dealer* MAY disclose the identity of a *Caller* even without the *Caller* having explicitly requested to do so when the *Dealer* configuration (for the called procedure) is setup to do so.

Feature Announcement

Support for this feature MUST be announced by *Callers* (role := "caller"), *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.  
  caller_identification|bool := true
```

Request Identification

A *Dealer* MAY deny a *Caller's* request to disclose its identity:

Example

```
[8, 7814135, "wamp.error.disclose_me.not_allowed"]
```

A *Callee* MAY **request** the disclosure of caller identity via

```
REGISTER.Options.disclose_caller|bool := true
```

Example

```
[64, 927639114088448, {"disclose_caller":true},  
  "com.maypp.add2"]
```

With the above registration, the registered procedure is called with the caller's sessionID as part of the call details object.

3.7. Call Trust Levels

A *Dealer* may be configured to automatically assign *trust levels* to calls issued by *Callers* according to the *Dealer* configuration on a per-procedure basis and/or depending on the application defined role of the (authenticated) *Caller*.

A *Dealer* supporting trust level will provide

```
INVOCATION.Details.trustlevel|integer
```

in an INVOCATION message sent to a *Callee*. The trustlevel 0 means lowest trust, and higher integers represent (application-defined) higher levels of trust.

Example

```
[68, 6131533, 9823526, {"trustlevel": 2}, ["Hello, world!"]]
```

In above event, the *Dealer* has (by configuration and/or other information) deemed the call (and hence the invocation) to be of trustlevel 2.

Feature Announcement

Support for this feature MUST be announced by *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.call_trustlevels|bool := true
```

3.8. Pattern-based Registrations

By default, *Callees* register procedures with **exact matching policy**. That is a call will only be routed to a *Callee* by the *Dealer* if the procedure called (CALL.Procedure) *exactly* matches the endpoint registered (REGISTER.Procedure).

A *Callee* might want to register procedures based on a *pattern*. This can be useful to reduce the number of individual registrations to be set up or to subscribe to a open set of topics, not known beforehand by the *Subscriber*.

If the *Dealer* and the *Callee* support **pattern-based registrations**, this matching can happen by

- **prefix-matching policy**
- **wildcard-matching policy**

Feature Announcement

Support for this feature MUST be announced by *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.  
    pattern_based_registration|bool := true
```

3.8.1. Prefix Matching

A *Callee* requests **prefix-matching policy** with a registration request by setting

```
REGISTER.Options.match|string := "prefix"
```

Example

```
[  
    64,  
    612352435,  
    {  
        "match": "prefix"  
    },  
    "com.myapp.myobject1"  
]
```

When a **prefix-matching policy** is in place, any call with a procedure that has REGISTER.Procedure as a *prefix* will match the registration, and potentially be routed to *Callees* on that registration.

In above example, the following calls with CALL . Procedure

- com.myapp.myobject1.myprocedure1
- com.myapp.myobject1-mysubobject1
- com.myapp.myobject1.mysubobject1.myprocedure1
- com.myapp.myobject1

will all apply for call routing. A call with one of the following CALL . Procedure

- com.myapp.myobject2
- com.myapp.myobject

will not apply.

3.8.2. Wildcard Matching

A *Callee* requests **wildcard-matching policy** with a registration request by setting

```
REGISTER.Options.match|string := "wildcard"
```

Wildcard-matching allows to provide wildcards for **whole** URI components.

Example

```
[
  64,
  612352435,
  {
    "match": "wildcard"
  },
  "com.myapp..myprocedure1"
]
```

In the above registration request, the 3rd URI component is empty, which signals a wildcard in that URI component position. In this example, calls with CALL . Procedure e.g.

- com.myapp.myobject1.myprocedure1
- com.myapp.myobject2.myprocedure1

will all apply for call routing. Calls with CALL . Procedure e.g.

- com.myapp.myobject1.myprocedure1.mysubprocedure1
- com.myapp.myobject1.myprocedure2
- com.myapp2.myobject1.myprocedure1

will not apply for call routing.

When a single call matches more than one of a *Callees* registrations, the call MAY be routed for invocation on multiple registrations, depending on call settings.

3.8.3. Design Aspects

No set semantics

Since each *Callee's* registrations "stands on its own", there is no *set semantics* implied by pattern-based registrations.

E.g. a *Callee* cannot register to a broad pattern, and then unregister from a subset of that broad pattern to form a more complex registration. Each registration is separate.

Calls matching multiple registrations

There can be situations, when (U+00A0)some call URI matches more than one registration. In (U+00A0)this case a call is routed to one and (U+00A0)only one best matched RPC registration, or (U+00A0)fails with `ERROR wamp.error.no_such_procedure`.

The following algorithm MUST be applied to (U+00A0)find a single RPC registration to (U+00A0)which a call is routed:

1. Check for (U+00A0)exact matching registration. If this match exists — (U+00A0 U+2014) use it.
2. If there are prefix-based registrations, (U+00A0)find the registration with the longest prefix match. Longest means it has more URI components matched, e.g. for (U+00A0)call URI `a1.b2.c3.d4` registration `a1.b2.c3` has higher priority than registration `a1.b2`. If this match exists — (U+00A0 U+2014) use it.
3. If there are wildcard-based registrations, find the registration with the longest portion of (U+00A0)URI components matched before each wildcard. E.g. for (U+00A0)call URI `a1.b2.c3.d4` registration `a1.b2..d4` has higher priority than registration `a1...d4`, see below for more complex examples. If this match exists — (U+00A0 U+2014) use it.
4. If there is no exact match, no prefix match, and no wildcard match, then *Dealer* MUST return `ERROR wamp.error.no_such_procedure`.

Examples

Registered RPCs:

1. 'a1.b2.c3.d4.e55' (exact),
2. 'a1.b2.c3' (prefix),
3. 'a1.b2.c3.d4' (prefix),
4. 'a1.b2..d4.e5',
5. 'a1.b2.c33..e5',
6. 'a1.b2..d4.e5..g7',
7. 'a1.b2..d4..f6.g7'

Call request RPC URI: 'a1.b2.c3.d4.e55' →
exact match. Use RPC 1

Call request RPC URI: 'a1.b2.c3.d98.e74' →
no exact match, single prefix match. Use RPC 2

Call request RPC URI: 'a1.b2.c3.d4.e325' →
no exact match, 2 prefix matches (2,3), select longest one.
Use RPC 3

Call request RPC URI: 'a1.b2.c55.d4.e5' →
no exact match, no prefix match, single wildcard match.
Use RPC 4

Call request RPC URI: 'a1.b2.c33.d4.e5' →
no exact match, no prefix match, 2 wildcard matches (4,5),
select longest one. Use RPC 5

Call request RPC URI: 'a1.b2.c88.d4.e5.f6.g7' →
no exact match, no prefix match, 2 wildcard matches (6,7),
both having equal first portions (a1.b2), but RPC 6 has longer
second portion (d4.e5). Use RPC 6

Call request RPC URI: 'a2.b2.c2.d2.e2' →
no exact match, no prefix match, no wildcard match.
Return wamp.error.no_such_procedure

Concrete procedure called

If an endpoint was registered with a pattern-based matching policy, a *Dealer* MUST supply the original CALL.Procedure as provided by the *Caller* in

```
INVOCATION.Details.procedure
```

to the *Callee*.

Example

```
[
  68,
  6131533,
  9823527,
  {
    "procedure": "com.myapp.procedure.proc1"
  },
  ["Hello, world!"]
]
```

3.9. Shared Registration

Feature status: **alpha**

As a default, only a single **Callee** may register a procedure for a URI.

There are use cases where more flexibility is required. As an example, for an application component with a high computing load, several instances may run, and load balancing of calls across these may be desired. As another example, in an application a second or third component providing a procedure may run, which are only to be called in case the primary component is no longer reachable (hot standby).

When shared registrations are supported, then the first **Callee** to register a procedure for a particular URI MAY determine that additional registrations for this URI are allowed, and what **Invocation Rules** to apply in case such additional registrations are made.

This is done through setting

```
REGISTER.Options.invoke|string := <invocation_policy>
```

where <invocation_policy> is one of

- 'single'
- 'roundrobin'
- 'random'
- 'first'
- 'last'

If the option is not set, 'single' is applied as a default.

With 'single', the **Dealer** MUST fail all subsequent attempts to register a procedure for the URI while the registration remains in existence.

With the other values, the **Dealer** MUST fail all subsequent attempts to register a procedure for the URI where the value for this option does not match that of the initial registration.

Feature Announcement

Support for this feature MUST be announced by *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.  
  shared_registration|bool := true
```

3.9.1. Load Balancing

For sets of registrations registered using either 'roundrobin' or 'random', load balancing is performed across calls to the URI.

For 'roundrobin', callees are picked subsequently from the list of registrations (ordered by the order of registration), with the picking looping back to the beginning of the list once the end has been reached.

For 'random' a callee is picked randomly from the list of registrations for each call.

3.9.2. Hot Stand-By

For sets of registrations registered using either 'first' or 'last', the first respectively last callee on the current list of registrations (ordered by the order of registration) is called.

3.10. Sharded Registration

Feature status: **sketch**

Sharded Registrations are intended to allow calling a procedure which is offered by a sharded database, by routing the call to a single shard.

Feature Announcement

Support for this feature MUST be announced by *Callers* (role := "caller"), *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.sharded_registration|bool := true
```

3.10.1. "All" Calls

Write me.

3.10.2. "Partitioned" Calls

If `CALL.Options.runmode == "partition"`, then `CALL.Options.rkey` MUST be present.

The call is then routed to all endpoints that were registered ..

The call is then processed as for "All" Calls.

3.11. Registration Revocation

Feature status: **alpha**

This feature allows a *Dealer* to actively revoke a previously granted registration. To achieve this, the existing UNREGISTERED message is extended as described below.

Feature Announcement

Support for this feature MUST be announced by *Callees* (role := "callee") and *Dealers* (role := "dealer") via

```
HELLO.Details.roles.<role>.features.  
  registration_revocation|bool := true
```

If the *Callee* does not support `registration_revocation`, the *Dealer* may still revoke a registration to support administrative functionality. In this case, the *Dealer* MUST NOT send an **UNREGISTERED** message to the *Callee*. The *Callee* MAY use the registration meta event `wamp.registration.on_unregister` to determine whether a session is removed from a registration.

Extending UNREGISTERED

When revoking a registration, the router has no request ID to reply to. So it's set to zero and another argument is appended to indicate which registration to revoke. Optionally, a reason why the registration was revoked is also appended.

```
[UNREGISTERED, 0, Details|dict]
```

where

- `Details.registration|bool` MUST be a previously issued registration ID.
- `Details.reason|string` MAY provide a reason as to why the registration was revoked.

Example

```
[67, 0, {"registration": 1293722, "reason": "moving endpoint to  
other callee"}]
```

4. Advanced PubSub

4.1. Subscriber Black- and Whitelisting

Subscriber Black- and Whitelisting is an advanced *Broker* feature where a *Publisher* is able to restrict the set of receivers of a published event.

Under normal Publish & Subscriber event dispatching, a *Broker* will dispatch a published event to all (authorized) *Subscribers* other than the *Publisher* itself. This set of receivers can be further reduced on a per-publication basis by the *Publisher* using **Subscriber Black- and Whitelisting**.

The *Publisher* can explicitly **exclude** *Subscribers* based on WAMP `sessionid`, `authid` or `authrole`. This is referred to as **Blacklisting**.

A *Publisher* may also explicitly define a **eligible** list of **Subscribers** based on WAMP `sessionid`, `authid` or `authrole`. This is referred to as **Whitelisting**.

Use Cases include the following.

Avoiding Callers from being self-notified

Consider an application that exposes a procedure to update a product price. The procedure might not only actually update the product price (e.g. in a backend database), but additionally publish an event with the updated product price, so that **all** application components get notified actively of the new price.

However, the application might want to exclude the originator of the product price update (the **Caller** of the price update procedure) from receiving the update event - as the originator naturally already knows the new price, and might get confused when it receives an update the **Caller** has triggered himself.

The product price update procedure can use `PUBLISH.Options.exclude|list[int]` to exclude the **Caller** of the procedure.

Note that the product price update procedure needs to know the session ID of the **Caller** to be able to exclude him. For this, please see **Caller Identification**.

A similar approach can be used for other CRUD-like procedures.

Restricting receivers of sensitive information

Consider an application with users that have different `authroles`, such as "manager" and "staff" that publishes events with updates to "customers". The topics being published to could be structured like

```
com.example.myapp.customer.<customer ID>
```

The application might want to restrict the receivers of customer updates depending on the `authrole` of the user. E.g. a user authenticated under `authrole` "manager" might be allowed to receive any kind of customer update, including personal and business sensitive information. A user under `authrole` "staff" might only be allowed to receive a subset of events.

The application can publish **all** customer updates to the **same** topic `com.example.myapp.customer.<customer ID>` and use `PUBLISH.Options.eligible_authrole|list[string]` to safely restrict the set of actual receivers as desired.

Feature Definition

A *Publisher* may restrict the actual receivers of an event from the set of *Subscribers* through the use of

- Blacklisting Options
 - `PUBLISH.Options.exclude|list[int]`
 - `PUBLISH.Options.exclude_authid|list[string]`
 - `PUBLISH.Options.exclude_authrole|list[string]`

- Whitelisting Options
 - `PUBLISH.Options.eligible|list[int]`
 - `PUBLISH.Options.eligible_authid|list[string]`
 - `PUBLISH.Options.eligible_authrole|list[string]`

`PUBLISH.Options.exclude` is a list of integers with WAMP sessionids providing an explicit list of (potential) *Subscribers* that won't receive a published event, even though they may be subscribed. In other words, `PUBLISH.Options.exclude` is a **blacklist** of (potential) *Subscribers*.

`PUBLISH.Options.eligible` is a list of integers with WAMP sessionids providing an explicit list of (potential) *Subscribers* that are allowed to receive a published event. In other words, `PUBLISH.Options.eligible` is a **whitelist** of (potential) *Subscribers*.

The `exclude_authid`, `exclude_authrole`, `eligible_authid` and `eligible_authrole` options work similar, but not on the basis of WAMP sessionid, but authid and authrole.

An (authorized) *Subscriber* to topic T will receive an event published to T if and only if all of the following statements hold true:

1. if there is an `eligible` attribute present, the *Subscriber's* sessionid is in this list
2. if there is an `eligible_authid` attribute present, the *Subscriber's* authid is in this list
3. if there is an `eligible_authrole` attribute present, the *Subscriber's* authrole is in this list
4. if there is an `exclude` attribute present, the *Subscriber's* sessionid is NOT in this list
5. if there is an `exclude_authid` attribute present, the *Subscriber's* authid is NOT in this list
6. if there is an `exclude_authrole` attribute present, the *Subscriber's* authrole is NOT in this list

For example, if both `PUBLISH.Options.exclude` and `PUBLISH.Options.eligible` are present, the *Broker* will dispatch events published only to *Subscribers* that are not explicitly excluded in `PUBLISH.Options.exclude` **and** which are explicitly eligible via `PUBLISH.Options.eligible`.

Example

```
[
  16,
  239714735,
  {
    "exclude": [
      7891255,
      1245751
    ]
  },
  "com.myapp.mytopic1",
  [
    "Hello, world!"
  ]
]
```

The above event will get dispatched to all *Subscribers* of `com.myapp.mytopic1`, but not WAMP sessions with IDs 7891255 or 1245751 (and also not the publishing session).

Example

```
[
  16,
  239714735,
  {
    "eligible": [
      7891255,
      1245751
    ]
  },
  "com.myapp.mytopic1",
  [
    "Hello, world!"
  ]
]
```

The above event will get dispatched to WAMP sessions with IDs 7891255 or 1245751 only - but only if those are actually subscribed to the topic `com.myapp.mytopic1`.

Example

```
[
  16,
  239714735,
  {
    "eligible": [
      7891255,
      1245751,
      9912315
    ],
    "exclude": [
      7891255
    ]
  },
  "com.myapp.mytopic1",
  [
    "Hello, world!"
  ]
]
```

The above event will get dispatched to WAMP sessions with IDs 1245751 or 9912315 only, since 7891255 is excluded - but only if those are actually subscribed to the topic `com.myapp.mytopic1`.

Feature Announcement

Support for this feature MUST be announced by *Publishers* (`role := "publisher"`) and *Brokers* (`role := "broker"`) via

```
HELLO.Details.roles.<role>.features.  
  subscriber_blackwhite_listing|bool := true
```

4.2. Publisher Exclusion

By default, a *Publisher* of an event will **not** itself receive an event published, even when subscribed to the Topic the *Publisher* is publishing to. This behavior can be overridden using this feature.

To override the exclusion of a publisher from its own publication, the PUBLISH message must include the following option:

```
PUBLISH.Options.exclude_me|bool
```

When publishing with `PUBLISH.Options.exclude_me := false`, the *Publisher* of the event will receive that event, if it is subscribed to the Topic published to.

Example

```
[  
  16,  
  239714735,  
  {  
    "exclude_me": false  
  },  
  "com.myapp.mytopic1",  
  ["Hello, world!"]  
]
```

In this example, the *Publisher* will receive the published event, if it is subscribed to `com.myapp.mytopic1`.

Feature Announcement

Support for this feature **MUST** be announced by *Publishers* (`role := "publisher"`) and *Brokers* (`role := "broker"`) via

```
HELLO.Details.roles.<role>.features.  
  publisher_exclusion|bool := true
```

4.3. Publisher Identification

A *Publisher* may request the disclosure of its identity (its WAMP session ID) to receivers of a published event by setting

```
PUBLISH.Options.disclose_me|bool := true
```

Example


```
[16, 239714735, {"disclose_me": true}, "com.myapp.mytopic1",
["Hello, world!"]]
```

If above event is published by a *Publisher* with WAMP session ID 3335656, the *Broker* would send an EVENT message to *Subscribers* with the *Publisher's* WAMP session ID in `EVENT.Details.publisher`:

Example

```
[36, 5512315355, 4429313566, {"publisher": 3335656},
["Hello, world!"]]
```

Note that a *Broker* may deny a *Publisher's* request to disclose its identity:

Example

```
[8, 239714735, {}, "wamp.error.option_disallowed.disclose_me"]
```

A *Broker* may also (automatically) disclose the identity of a *Publisher* even without the *Publisher* having explicitly requested to do so when the *Broker* configuration (for the publication topic) is set up to do so.

Feature Announcement

Support for this feature MUST be announced by *Publishers* (`role := "publisher"`), *Brokers* (`role := "broker"`) and *Subscribers* (`role := "subscriber"`) via

```
HELLO.Details.roles.<role>.features.
  publisher_identification|bool := true
```

4.4. Publication Trust Levels

A *Broker* may be configured to automatically assign *trust levels* to events published by *Publishers* according to the *Broker* configuration on a per-topic basis and/or depending on the application defined role of the (authenticated) *Publisher*.

A *Broker* supporting trust level will provide

```
EVENT.Details.trustlevel|integer
```

in an EVENT message sent to a *Subscriber*. The `trustlevel 0` means lowest trust, and higher integers represent (application-defined) higher levels of trust.

Example

```
[36, 5512315355, 4429313566, {"trustlevel": 2},
["Hello, world!"]]
```

In above event, the *Broker* has (by configuration and/or other information) deemed the event publication to be of trustlevel 2.

Feature Announcement

Support for this feature MUST be announced by *Subscribers* (role := "subscriber") and *Brokers* (role := "broker") via

```
HELLO.Details.roles.<role>.features.  
  publication_trustlevels|bool := true
```

4.5. Pattern-based Subscription

By default, *Subscribers* subscribe to topics with **exact matching policy**. That is an event will only be dispatched to a *Subscriber* by the *Broker* if the topic published to (PUBLISH.Topic) *exactly* matches the topic subscribed to (SUBSCRIBE.Topic).

A *Subscriber* might want to subscribe to topics based on a *pattern*. This can be useful to reduce the number of individual subscriptions to be set up and to subscribe to topics the *Subscriber* is not aware of at the time of subscription, or which do not yet exist at this time.

If the *Broker* and the *Subscriber* support **pattern-based subscriptions**, this matching can happen by

- prefix-matching policy
- wildcard-matching policy

Feature Announcement

Support for this feature MUST be announced by *Subscribers* (role := "subscriber") and *Brokers* (role := "broker") via

```
HELLO.Details.roles.<role>.features.  
  pattern_based_subscription|bool := true
```

4.5.1. Prefix Matching

A *Subscriber* requests **prefix-matching policy** with a subscription request by setting

```
SUBSCRIBE.Options.match|string := "prefix"
```

Example

```
[
  32,
  912873614,
  {
    "match": "prefix"
  },
  "com.myapp.topic.emergency"
]
```

When a **prefix-matching policy** is in place, any event with a topic that has `SUBSCRIBE.Topic` as a *prefix* will match the subscription, and potentially be delivered to *Subscribers* on the subscription.

In the above example, events with `PUBLISH.Topic`

- `com.myapp.topic.emergency.11`
- `com.myapp.topic.emergency-low`
- `com.myapp.topic.emergency.category.severe`
- `com.myapp.topic.emergency`

will all apply for dispatching. An event with `PUBLISH.Topic` e.g. `com.myapp.topic.emerge` will not apply.

4.5.2. Wildcard Matching

A *Subscriber* requests **wildcard-matching policy** with a subscription request by setting

```
SUBSCRIBE.Options.match|string := "wildcard"
```

Wildcard-matching allows to provide wildcards for **whole** URI components.

Example

```
[
  32,
  912873614,
  {
    "match": "wildcard"
  },
  "com.myapp..userevent"
]
```

In above subscription request, the 3rd URI component is empty, which signals a wildcard in that URI component position. In this example, events with `PUBLISH.Topic`

- `com.myapp.foo.userevent`
- `com.myapp.bar.userevent`
- `com.myapp.a12.userevent`

will all apply for dispatching. Events with `PUBLISH.Topic`

- `com.myapp.foo.userevent.bar`
- `com.myapp.foo.user`
- `com.myapp2.foo.userevent`

will not apply for dispatching.

4.5.3. Design Aspects

No set semantics

Since each *Subscriber*'s subscription "stands on its own", there is no *set semantics* implied by pattern-based subscriptions.

E.g. a *Subscriber* cannot subscribe to a broad pattern, and then unsubscribe from a subset of that broad pattern to form a more complex subscription. Each subscription is separate.

Events matching multiple subscriptions

When a single event matches more than one of a *Subscriber*'s subscriptions, the event will be delivered for each subscription.

The *Subscriber* can detect the delivery of that same event on multiple subscriptions via `EVENT.PUBLISHED.Publication`, which will be identical.

Concrete topic published to

If a subscription was established with a pattern-based matching policy, a *Broker* MUST supply the original `PUBLISH.Topic` as provided by the *Publisher* in

```
EVENT.Details.topic|uri
```

to the *Subscribers*.

Example

```
[
  36,
  5512315355,
  4429313566,
  {
    "topic": "com.myapp.topic.emergency.category.severe"
  },
  ["Hello, world!"]
]
```

4.6. Sharded Subscription

Feature status: **alpha**

Support for this feature MUST be announced by *Publishers* (role := "publisher"), *Subscribers* (role := "subscriber") and *Brokers* (role := "broker") via

```
HELLO.Details.roles.<role>.features.shareded_subscriptions|
  bool := true
```

Resource keys: PUBLISH.Options.rkey|string is a stable, technical **resource key**.

E.g. if your sensor has a unique serial identifier, you can use that.

Example

```
[16, 239714735, {"rkey": "sn239019"}, "com.myapp.sensor.sn239019.
  temperature", [33.9]]
```

Node keys: SUBSCRIBE.Options.nkey|string is a stable, technical **node key**.

E.g. if your backend process runs on a dedicated host, you can use its hostname.

Example

```
[32, 912873614, {"match": "wildcard", "nkey": "node23"},
  "com.myapp.sensor..temperature"]
```

4.7. Event History

Instead of complex QoS for message delivery, a *Broker* may provide *message history*. A *Subscriber* is responsible to handle overlaps (duplicates) when it wants "exactly-once" message processing across restarts.

The *Broker* may allow for configuration on a per-topic basis.

The event history may be transient or persistent message history (surviving *Broker* restarts).

A *Broker* that implements *event history* must (also) announce role HELLO.roles.callee, indicate HELLO.roles.broker.history == 1 and provide the following (builtin) procedures.

A *Caller* can request message history by calling the *Broker* procedure

```
wamp.topic.history.last
```

withArguments = [topic|uri, limit|integer] where

- topic is the topic to retrieve event history for
- limit indicates the number of last N events to retrieve

or by calling

```
wamp.topic.history.since
```

withArguments = [topic|uri, timestamp|string] where

- topic is the topic to retrieve event history for
- timestamp indicates the UTC timestamp since when to retrieve the events in the ISO-8601 format yyyy-MM-ddThh:mm:ss:SSSZ (e.g. "2013-12-21T13:43:11:000Z")

or by calling

```
wamp.topic.history.after
```

withArguments = [topic|uri, publication|id]

- topic is the topic to retrieve event history for
- publication is the id of an event which marks the start of the events to retrieve from history

FIXME

1. Should we use topic|uri or subscription|id in Arguments?
 - Since we need to be able to get history for pattern-based subscriptions as well, a subscription|id makes more sense: create pattern-based subscription, then get the event history for this.
 - The only restriction then is that we may not get event history without a current subscription covering the events. This is a minor inconvenience at worst.
2. Can wamp.topic.history.after be implemented (efficiently) at all?
3. How does that interact with pattern-based subscriptions?
4. The same question as with the subscriber lists applies where: to stay within our separation of roles, we need a broker + a separate peer which implements the callee role. Here we do not have a mechanism to get the history from the broker.
5. How are black/whitelisted sessionIDs treated? A client which requests event history will have a different sessionID than on previous connections, and may receive events for which it was excluded in the previous session, or not receive events for which it was whitelisted. - see <https://github.com/wamp-proto/wamp-proto/issues/206>

Feature Announcement

Support for this feature MUST be announced by *Subscribers* (role := "subscriber") and *Brokers* (role := "broker") via

```
HELLO.Details.roles.<role>.features.event_history|bool := true
```

4.8. Event Retention

Event Retention is where a particular topic has an event associated with it which is delivered upon an opting-in client subscribing to the topic.

It can be used for topics that generally have single or very few Publishers notifying Subscribers of a single updating piece of data -- for example, a topic where a sensor publishes changes of temperature & humidity in a data center. It may do this every time the data changes (making the time between updates potentially very far apart), which causes an issue for new Subscribers who may need the last-known value upon connection, rather than waiting an unknown period of time until it is updated. Event Retention covers this use case by allowing the Publisher to mark a event as 'retained', bound to the topic it was sent to, which can be delivered upon a new client subscription that asks for it. It is similar to Event History, but allows the publisher to decide what the most important recent event is on the topic, even if other events are being delivered.

A *Broker* that advertises support MAY provide *event retention* on topics it provides. This event retention SHOULD be provided on a best-effort basis, and MUST NOT be interpreted as permanent or reliable storage by clients. This event retention is limited to one event that all subscribers would receive, and MAY include other supplemental events that have limited distribution (for example, a event published with subscriber black/whitelisting).

A *Publisher* can request storage of a new Retained Event by setting `Publish.Options.retain|bool` to `true`. Lack of the key in `Publish.Options` MUST be interpreted as a false value. A Broker MAY decline to provide event retention on certain topics by ignoring the `Publish.Options.retain` value. Brokers that allow event retention on the given topic MUST set the topic Retained Event to this if it were eligible to be published on the topic.

Subscribers may request access to the Retained Event by setting `Subscribe.Options.get_retained|bool` to `true`. Lack of the key in `Subscribe.Options` MUST be interpreted as a false value. When they opt-in to receiving the Retained Event, the Broker MUST send the Subscriber the **most recent** Retained Event that they would have received if they were subscribing when it was published. The Broker MUST NOT send the Subscriber a Retained Event that they would not be eligible to receive if they were subscribing when it was published. The *Retained Event*, as sent to the subscribing client, MUST have `Event.Details.retained|bool` set to `true`, to inform subscribers that it is not an immediately new message.

Feature Announcement

Support for this feature MUST be announced by *Brokers* (`role := "broker"`) via

```
Welcome.Details.roles.broker.features.event_retention|bool := true
```

4.9. Subscription Revocation

Feature status: **alpha**

This feature allows a *Broker* to actively revoke a previously granted subscription. To achieve this, the existing UNSUBSCRIBED message is extended as described below.

Feature Announcement

Support for this feature MUST be announced by *Subscribers* (role := "subscriber") and *Brokers* (role := "broker") via

```
HELLO.Details.roles.<role>.features.  
  subscription_revocation|bool := true
```

If the *Subscriber* does not support subscription_revocation, the *Broker* MAY still revoke a subscription to support administrative functionality. In this case, the *Broker* MUST NOT send an **UNSUBSCRIBED** message to the *Subscriber*. The *Subscriber* MAY use the subscription meta event wamp.subscription.on_unsubscribe to determine whether a session is removed from a subscription.

Extending UNSUBSCRIBED

When revoking a subscription, the router has no request ID to reply to. So it's set to zero and another argument is appended to indicate which subscription to revoke. Optionally, a reason why the subscription was revoked is also appended.

```
[UNSUBSCRIBED, 0, Details|dict]
```

where

- Details.subscription|bool MUST be a previously issued subscription ID.
- Details.reason|string MAY provide a reason as to why the subscription was revoked.

Example

```
[35, 0, {"subscription": 1293722, "reason": "no longer authorized"}]
```

4.10. Session Testament

When a WAMP client disconnects, or the WAMP session is destroyed, it may want to notify other subscribers or publish some fixed data. Since a client may disconnect uncleanly, this can't be done reliably by them. A *Testament*, however, set on the server, can be reliably sent by the *Broker* once either the WAMP session has detached or the client connection has been lost, and allows this functionality. It can be triggered when a Session is either detached (the client has disconnected from it, or frozen it, in the case of Session Resumption) or destroyed (when the WAMP session no longer exists on the server).

This allows clients that otherwise would not be able to know when other clients disconnect get a notification (for example, by using the WAMP Session Meta API) with a format the disconnected client chose.

Feature Announcement

Support for this feature MUST be announced by *Dealers* (`role := "dealer"`) via

```
HELLO.Details.roles.dealer.features.  
testament_meta_api|bool := true
```

Testament Meta Procedures

A *Client* can call the following procedures to set/flush Testaments:

- `wamp.session.add_testament` to add a Testament which will be published on a particular topic when the Session is detached or destroyed.
- `wamp.session.flush_testaments` to remove the Testaments for that Session, either for when it is detached or destroyed.

wamp.session.add_testament

Adds a new testament:

Positional arguments

1. `topic|uri` - the topic to publish the event on
2. `args|list` - positional arguments for the event
3. `kwargs|dict` - keyword arguments for the event

Keyword arguments

1. `publish_options|dict` - options for the event when it is published -- see `Publish.Options`. Not all options may be honoured (for example, `acknowledge`). By default, there are no options.
2. `scope|string` - When the testament should be published. Valid values are `detached` (when the WAMP session is detached, for example, when using Event Retention) or `destroyed` (when the WAMP session is finalized and destroyed on the Broker). Default MUST be `destroyed`.

`wamp.session.add_testament` does not return a value.

wamp.session.flush_testaments

Removes testaments for the given scope:

Keyword arguments

1. `scope|string` - Which set of testaments to be removed. Valid values are the same as `wamp.session.add_testament`, and the default MUST be `destroyed`.

`wamp.session.flush_testaments` does not return a value.

Testaments in Use

A *Client* that wishes to send some form of data when their *Session* ends unexpectedly or their *Transport* becomes lost can set a testament using the WAMP Testament Meta API, when a *Router* supports it. For example, a client may call `add_testament` (this example uses the implicit `scope` option of `destroyed`):

```
yield self.call('wamp.session.add_testament',  
               'com.myapp.mytopic', ['Seeya!'], {'my_name': 'app1'})
```

The *Router* will then store this information on the WAMP Session, either in a detached or destroyed bucket, in the order they were added. A client MUST be able to set multiple testaments per-scope. If the *Router* does not support Session Resumption (therefore removing the distinction between a detached and destroyed session), it MUST still use these two separate buckets to allow `wamp.session.flush_testaments` to work.

When a *Session* is *detached*, the *Router* will inspect it for any Testaments in the detached scope, and publish them in the order that the Router received them, on the specified topic, with the specified arguments, keyword arguments, and publish options. The *Router* MAY ignore publish options that do not make sense for a Testament (for example, `acknowledged` publishes).

When a *Session* is going to be *destroyed*, the *Router* will inspect it for any Testaments in the destroyed scope, and publish them in the same way as it would for the detached scope, in the order that they were received.

A *Router* that does not allow Session Resumption MUST send detached-scope Testaments before destroyed-scope Testaments.

A *Client* can also clear testaments if the information is no longer relevant (for example, it is shutting down completely cleanly). For example, a client may call `wamp.session.flush_testaments`:

```
yield self.call('wamp.session.flush_testaments', scope='detached')  
yield self.call('wamp.session.flush_testaments', scope='destroyed')
```

The *Router* will then flush all Testaments stored for the given scope.

5. Authentication Methods

Authentication is a complex area. Some applications might want to leverage authentication information coming from the transport underlying WAMP, e.g. HTTP cookies or TLS certificates.

Some transports might imply trust or implicit authentication by their very nature, e.g. Unix domain sockets with appropriate file system permissions in place.

Other application might want to perform their own authentication using external mechanisms (completely outside and independent of WAMP).

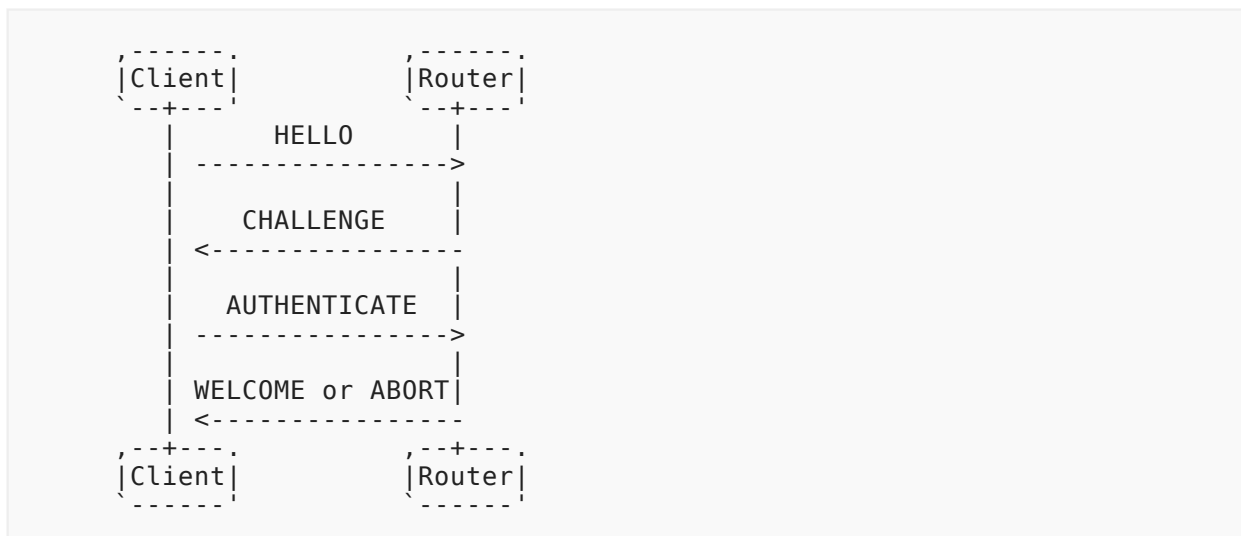
Some applications might want to perform their own authentication schemes by using basic WAMP mechanisms, e.g. by using application-defined remote procedure calls.

And some applications might want to use a transport independent scheme, nevertheless predefined by WAMP.

WAMP-level Authentication

The message flow between Clients and Routers for establishing and tearing down sessions MAY involve the following messages which authenticate a session:

1. CHALLENGE
2. AUTHENTICATE



Concrete use of CHALLENGE and AUTHENTICATE messages depends on the specific authentication method.

See [WAMP Challenge-Response Authentication](#) or [ticket authentication](#) for the use in these authentication methods.

If two-factor authentication is desired, then two subsequent rounds of CHALLENGE and RESPONSE may be employed.

CHALLENGE

An authentication MAY be required for the establishment of a session. Such requirement MAY be based on the Realm the connection is requested for.

To request authentication, the Router MUST send a CHALLENGE message to the *Endpoint*.

```
[CHALLENGE, AuthMethod|string, Extra|dict]
```

AUTHENTICATE

In response to a CHALLENGE message, the Client MUST send an AUTHENTICATE message.

```
[AUTHENTICATE, Signature|string, Extra|dict]
```

If the authentication succeeds, the Router MUST send a WELCOME message, else it MUST send an ABORT message.

Transport-level Authentication

Cookie-based Authentication

When running WAMP over WebSocket, the transport provides HTTP client cookies during the WebSocket opening handshake. The cookies can be used to authenticate one peer (the client) against the other (the server). The other authentication direction cannot be supported by cookies.

This transport-level authentication information may be forwarded to the WAMP level within `HELLO.Details.transport.auth|any` in the client-to-server direction.

TLS Certificate Authentication

When running WAMP over a TLS (either secure WebSocket or raw TCP) transport, a peer may authenticate to the other via the TLS certificate mechanism. A server might authenticate to the client, and a client may authenticate to the server (TLS client-certificate based authentication).

This transport-level authentication information may be forwarded to the WAMP level within `HELLO.Details.transport.auth|any` in both directions (if available).

5.1. Ticket-based Authentication

With *Ticket-based authentication*, the client needs to present the server an authentication "ticket" - some magic value to authenticate itself to the server.

This "ticket" could be a long-lived, pre-agreed secret (e.g. a user password) or a short-lived authentication token (like a Kerberos token). WAMP does not care or interpret the ticket presented by the client.

Caution: This scheme is extremely simple and flexible, but the resulting security may be limited. E.g., the ticket value will be sent over the wire. If the transport WAMP is running over is not encrypted, a man-in-the-middle can sniff and possibly hijack the ticket. If the ticket value is reused, that might enable replay attacks.

A typical authentication begins with the client sending a HELLO message specifying the ticket method as (one of) the authentication methods:

```
[1, "realm1",
  {
    "roles": ...,
    "authmethods": ["ticket"],
    "authid": "joe"
  }
]
```

The `HELLO.Details.authmethods|list` is used by the client to announce the authentication methods it is prepared to perform. For Ticket-based, this MUST include "ticket".

The `HELLO.Details.authid|string` is the authentication ID (e.g. username) the client wishes to authenticate as. For Ticket-based authentication, this MUST be provided.

If the server is unwilling or unable to perform Ticket-based authentication, it'll either skip forward trying other authentication methods (if the client announced any) or send an ABORT message.

If the server is willing to let the client authenticate using a ticket and the server recognizes the provided authid, it'll send a CHALLENGE message:

```
[4, "ticket", {}]
```

The client will send an AUTHENTICATE message containing a ticket:

```
[5, "secret!!!", {}]
```

The server will then check if the ticket provided is permissible (for the authid given).

If the authentication succeeds, the server will finally respond with a WELCOME message:

```
[2, 3251278072152162,
 {
  "authid": "joe",
  "authrole": "user",
  "authmethod": "ticket",
  "authprovider": "static",
  "roles": ...
 }
]
```

where

1. `authid|string`: The authentication ID the client was (actually) authenticated as.
2. `authrole|string`: The authentication role the client was authenticated for.
3. `authmethod|string`: The authentication method, here "ticket"
4. `authprovider|string`: The actual provider of authentication. For Ticket-based authentication, this can be freely chosen by the app, e.g. `static` or `dynamic`.

The `WELCOME.Details` again contain the actual authentication information active. If the authentication fails, the server will response with an `ABORT` message.

5.2. Challenge Response Authentication

WAMP Challenge-Response ("WAMP-CRA") authentication is a simple, secure authentication mechanism using a shared secret. The client and the server share a secret. The secret never travels the wire, hence WAMP-CRA can be used via non-TLS connections. The actual pre-sharing of the secret is outside the scope of the authentication mechanism.

A typical authentication begins with the client sending a `HELLO` message specifying the `wampcra` method as (one of) the authentication methods:

```
[1, "realm1",
 {
  "roles": ...,
  "authmethods": ["wampcra"],
  "authid": "peter"
 }
]
```

The `HELLO.Details.authmethods|list` is used by the client to announce the authentication methods it is prepared to perform. For WAMP-CRA, this **MUST** include "wampcra".

The `HELLO.Details.authid|string` is the authentication ID (e.g. username) the client wishes to authenticate as. For WAMP-CRA, this **MUST** be provided.

If the server is unwilling or unable to perform WAMP-CRA authentication, it **MAY** either skip forward trying other authentication methods (if the client announced any) or send an `ABORT` message.

If the server is willing to let the client authenticate using WAMP-CRA, and the server recognizes the provided authid, it MUST send a CHALLENGE message:

```
[4, "wampcra",
  {
    "challenge": "{ \"nonce\": \"LHRTC9ze0Irt_9U3\",
      \"authprovider\": \"userdb\", \"authid\": \"peter\",
      \"timestamp\": \"2014-06-22T16:36:25.448Z\",
      \"authrole\": \"user\", \"authmethod\": \"wampcra\",
      \"session\": 3251278072152162}"
  }
]
```

The CHALLENGE.Details.challenge|string is a string the client needs to create a signature for. The string MUST BE a JSON serialized object which MUST contain:

1. authid|string: The authentication ID the client will be authenticated as when the authentication succeeds.
2. authrole|string: The authentication role the client will be authenticated as when the authentication succeeds.
3. authmethod|string: The authentication methods, here "wampcra"
4. authprovider|string: The actual provider of authentication. For WAMP-CRA, this can be freely chosen by the app, e.g. userdb.
5. nonce|string: A random value.
6. timestamp|string: The UTC timestamp (ISO8601 format) the authentication was started, e.g. 2014-06-22T16:51:41.643Z.
7. session|int: The WAMP session ID that will be assigned to the session once it is authenticated successfully.

The client needs to compute the signature as follows:

```
signature := HMAC[SHA256]_{secret} (challenge)
```

That is, compute the HMAC-SHA256 using the shared secret over the challenge.

After computing the signature, the client will send an AUTHENTICATE message containing the signature, as a base64-encoded string:

```
[5, "girlmSx+deCDUV7wRM5SGIn/+R/ClqLZuH4m7FJeBVI=", {}]
```

The server will then check if

- the signature matches the one expected
- the AUTHENTICATE message was sent in due time

If the authentication succeeds, the server will finally respond with a WELCOME message:

```
[2, 3251278072152162,
  {
    "authid": "peter",
    "authrole": "user",
    "authmethod": "wampcra",
    "authprovider": "userdb",
    "roles": ...
  }
]
```

The `WELCOME.Details` again contain the actual authentication information active.

If the authentication fails, the server will response with an `ABORT` message.

Server-side Verification

The challenge sent during WAMP-CRA contains

1. random information (the `nonce`) to make WAMP-CRA robust against replay attacks
2. timestamp information (the `timestamp`) to allow WAMP-CRA timeout on authentication requests that took too long
3. session information (the `session`) to bind the authentication to a WAMP session ID
4. all the authentication information that relates to authorization like `authid` and `authrole`

Three-legged Authentication

The signing of the challenge sent by the server usually is done directly on the client. However, this is no strict requirement.

E.g. a client might forward the challenge to another party (hence the "three-legged") for creating the signature. This can be used when the client was previously already authenticated to that third party, and WAMP-CRA should run piggy backed on that authentication.

The third party would, upon receiving a signing request, simply check if the client is already authenticated, and if so, create a signature for WAMP-CRA.

In this case, the secret is actually shared between the WAMP server who wants to authenticate clients using WAMP-CRA and the third party server, who shares a secret with the WAMP server.

This scenario is also the reason the challenge sent with WAMP-CRA is not simply a random value, but a JSON serialized object containing sufficient authentication information for the third party to check.

Password Salting

WAMP-CRA operates using a shared secret. While the secret is never sent over the wire, a shared secret often requires storage of that secret on the client and the server - and storing a password verbatim (unencrypted) is not recommended in general.

WAMP-CRA allows the use of salted passwords following the [PBKDF2](#) key derivation scheme. With salted passwords, the password itself is never stored, but only a key derived from the password and a password salt. This derived key is then practically working as the new shared secret.

When the password is salted, the server will during WAMP-CRA send a CHALLENGE message containing additional information:

```
[4, "wampcra",
  {
    "challenge": "{ \"nonce\": \"LHRTC9ze0Irt_9U3\",
      \"authprovider\": \"userdb\", \"authid\": \"peter\",
      \"timestamp\": \"2014-06-22T16:36:25.448Z\",
      \"authrole\": \"user\", \"authmethod\": \"wampcra\",
      \"session\": 3251278072152162}",
    "salt": "salt123",
    "keylen": 32,
    "iterations": 1000
  }
]
```

The `CHALLENGE.Details.salt|string` is the password salt in use. The `CHALLENGE.Details.keylen|int` and `CHALLENGE.Details.iterations|int` are parameters for the PBKDF2 algorithm.

5.3. Salted Challenge Response Authentication

The WAMP Salted Challenge Response Authentication Mechanism ("WAMP-SCRAM"), is a password-based authentication method where the shared secret is neither transmitted nor stored as cleartext. WAMP-SCRAM is based on [RFC5802](#) (*Salted Challenge Response Authentication Mechanism*) and [RFC7677](#) (*SCRAM-SHA-256 and SCRAM-SHA-256-PLUS*).

WAMP-SCRAM supports the Argon2 ([draft-irtf-cfrg-argon2](#)) password-based key derivation function, a memory-hard algorithm intended to resist cracking on GPU hardware. PBKDF2 ([RFC2898](#)) is also supported for applications that are required to use primitives currently approved by cryptographic standards.

Security Considerations

With WAMP-SCRAM, if the authentication database is stolen, an attacker cannot impersonate a user unless they guess the password offline by brute force.

In the event that the server's authentication database is stolen, and the attacker either eavesdrops on one authentication exchange or impersonates a server, the attacker gains the ability to impersonate that particular user on that server. If the same salt is used on other servers, the attacker would gain the ability to impersonate that user on all servers using the same salt. That's why it's important to use a per-user random salt.

An eavesdropper that captures a user authentication exchange has enough information to mount an offline, brute-force dictionary attack for that particular user. If passwords are sufficiently strong, the cost/time needed to crack a password becomes prohibitive.

Note that when HTML/JavaScript assets are served to a web browser, WAMP-SCRAM does not safeguard against a man-in-the-middle tampering with those assets. Those assets could be tampered with in a way that captures the user's password and sends it to the attacker.

In light of the above security concerns, a secure TLS transport is therefore advised to prevent such attacks. The channel binding feature of SCRAM can be used to ensure that the TLS endpoints are the same between client and router.

Deviations from RFC5802

1. To simplify parsing, SCRAM attributes in the authentication exchange messages are encoded as members of the `Options/Details` objects without escaping the `,` and `=` characters. However, the `AuthMessage` used to compute the client and server signatures DOES use the exact syntax specified in [RFC5802, section 7](#). This makes it possible to use existing test vectors to verify WAMP-SCRAM implementations.
2. Hashing based on the weaker SHA-1 specified in [RFC5802](#) is intentionally not supported by WAMP-SCRAM, in favor of the stronger SHA-256 specified in [RFC7677](#).
3. The [Argon2](#) key derivation function MAY be used instead of PBKDF2.
4. Nonces are required to be base64-encoded, which is stricter than the printable syntax specification of [RFC5802](#).
5. The "y" channel binding flag is not used as there is currently no standard way for WAMP routers to announce channel binding capabilities.
6. The use of `authzid` for user impersonation is not supported.

authmethod Type String

"wamp - scram" SHALL be used as the authmethod type string for WAMP-SCRAM authentication. Announcement by routers of WAMP-SCRAM support is outside the scope of this document.

Base64 encoding

Base64 encoding of octet strings is restricted to canonical form with no whitespace, as defined in [RFC4648](#) (*The Base16, Base32, and Base64 Data Encodings*).

Nonces

In WAMP-SCRAM, a *nonce* (number used once) is a base64-encoded sequence of random octets. It SHOULD be of sufficient length to make a replay attack unfeasible. A length of 16 octets (128 bits) is recommended for each of the client and server-generated nonces.

See [RFC4086](#) (*Randomness Requirements for Security*) for best practices concerning randomness.

Salts

A *salt* is a base64-encoded sequence of random octets.

To prevent rainbow table attacks in the event of database theft, the salt **MUST** be generated randomly by the server **for each user**. The random salt is stored with each user record in the authentication database.

Username/Password String Normalization

Username and password strings **SHALL** be normalized according to the *SASLprep* profile described in [RFC4013](#), using the *stringprep* algorithm described in [RFC3454](#).

While SASLprep preserves the case of usernames, the server **MAY** choose to perform case insensitive comparisons when searching for a username in the authentication database.

Channel Binding

Channel binding is a feature that allows a higher layer to establish that the other end of an underlying secure channel is bound to its higher layer counterpart. See [RFC5056](#) (*On the Use of Channel Bindings*) for an in-depth discussion.

[RFC5929](#) defines binding types for use with TLS transports, of which `tls-unique` and `tls-server-end-point` are applicable for WAMP-SCRAM. For each channel binding type, there is a corresponding definition of the *channel binding data* that must be sent in response to the authentication challenge.

Negotiation and announcement of channel binding is outside the scope of this document. [RFC5929 section 6](#) recommends that application protocols use `tls-unique` exclusively, except perhaps where server-side proxies are commonly deployed.

Note that WAMP-SCRAM channel binding is not generally possible with web browser clients due to the lack of a suitable API for this purpose.

The tls-unique Channel Binding Type

The `tls-unique` channel binding type allows the WAMP layer to establish that the other peer is authenticating over the same, unique TLS connection. The channel binding data for this type corresponds to the bytes of the first TLS Finished message, as described in [RFC5929, section 3](#). [RFC5929 section 10.2](#) addresses the concern of disclosing this data over the TLS channel (in short, the TLS Finished message would already be visible to eavesdroppers).

To safeguard against the *triple handshake attack* described in [RFC7627](#), this channel binding type **MUST** be used over a TLS channel that uses the *extended master secret* extension, or over a TLS channel where session resumption is not permitted.

The tls-server-end-point Channel Binding Type

The `tls-server-end-point` channel binding type allows the WAMP layer to establish that the other peer is authenticating over a TLS connection to a server having been issued a Public Key Infrastructure Certificate. The channel binding data for this type is a hash of the TLS server's certificate, computed as described in [RFC5929, section 4.1](#). The certificate is hashed to accommodate memory-constrained implementations.

Authentication Exchange

WAMP-SCRAM uses a single round of challenge/response pairs after the client authentication request and before the authentication outcome.

The mapping of RFC5802 messages to WAMP messages is as follows:

SCRAM Message	WAMP Message
<code>client-first-message</code>	HELLO
<code>server-first-message</code>	CHALLENGE
<code>client-final-message</code>	AUTHENTICATE
<code>server-final-message with verifier</code>	WELCOME
<code>server-final-message with server-error</code>	ABORT

Table 7

Initial Client Authentication Message

WAMP-SCRAM authentication begins with the client sending a HELLO message specifying the `wamp-scram` method as (one of) the authentication methods:

```
[1, "realm1",
  {
    "roles": ...,
    "authmethods": ["wamp-scram"],
    "authid": "user",
    "authextra":
      {
        "nonce": "egVDf3DMJh0=",
        "channel_binding": null
      }
  }
]
```

where:

1. `authid|string`: The identity of the user performing authentication. This corresponds to the `username` parameter in RFC5802.

2. `authextra.nonce|string`: A base64-encoded sequence of random octets, generated by the client. See [Nonces](#).
3. `authextra.channel_binding|string`: Optional string containing the desired channel binding type. See [Channel Bindings](#).

Upon receiving the HELLO message, the server MUST terminate the authentication process by sending an ABORT message under any of the following circumstances:

- The server does not support the WAMP-SCRAM authmethods, and there are no other methods left that the server supports for this `authid`.
- The the server does not support the requested `channel_binding` type.
- (Optional) The server does not recognize the given `authid`. In this case, the server MAY proceed with a mock CHALLENGE message to avoid leaking information on the existence of usernames. This mock CHALLENGE SHOULD contain a generated `salt` value that is always the same for a given `authid`, otherwise an attacker may discover that the user doesn't actually exist.

Initial Server Authentication Message

If none of the above failure conditions apply, and the server is ready to let the client authenticate using WAMP-SCRAM, then it SHALL send a CHALLENGE message:

```
[4, "wamp-scam",
  {
    "nonce": "egVDf3DMJh0=SBmkFIh7sSo=",
    "salt": "aBc+fx0NAVA=",
    "kdf": "pbkdf2",
    "iterations": 4096,
    "memory": null
  }
]
```

where:

1. `nonce|string`: A server-generated nonce that is appended to the client-generated nonce sent in the previous HELLO message. See [Nonces](#).
2. `salt|string`: The base64-encoded salt for this user, to be passed to the key derivation function. This value is stored with each user record in the authentication database. See [Salts](#).
3. `kdf`: The key derivation function (KDF) used to hash the password. This value is stored with each user record in the authentication database. See [Key Derivation Functions](#).
4. `iterations|integer`: The execution time cost factor to use for generating the `SaltedPassword` hash. This value is stored with each user record in the authentication database.
5. `memory|integer`: The memory cost factor to use for generating the `SaltedPassword` hash. This is only used by the Argon2 key derivation function, where it is stored with each user record in the authentication database.

The client **MUST** respond with an ABORT message if `CHALLENGE.Details.nonce` does not begin with the client nonce sent in `HELLO.Details.nonce`.

The client **SHOULD** respond with an ABORT message if it detects that the cost parameters are unusually low. Such low-cost parameters could be the result of a rogue server attempting to obtain a weak password hash that can be easily cracked. What constitutes unusually low parameters is implementation-specific and is not covered by this document.

Final Client Authentication Message

Upon receiving a valid CHALLENGE message, the client **SHALL** respond with an AUTHENTICATE message:

```
[5, "dHzbZapWIk4jUhN+Ute9ytag9zjfMHgsqmmiz7AndVQ=",
  {
    "nonce": "egVDf3DMJh0=SBmkFIh7sSo=",
    "channel_binding": null,
    "cbind_data": null
  }
]
```

where:

1. `Signature|string` argument: The base64-encoded `ClientProof`, computed as described in the [SCRAM-Algorithms](#) section.
2. `nonce|string`: The concatenated client-server nonce from the previous CHALLENGE message.
3. `channel_binding|string`: Optional string containing the channel binding type that was sent in the original HELLO message.
4. `cbind_data|string`: Optional base64-encoded channel binding data. **MUST** be present if and only if `channel_binding` is not null. The format of the binding data is dependent on the binding type. See [Channel Binding](#).

Upon receiving the AUTHENTICATE message, the server **SHALL** then check that:

- The AUTHENTICATE message was received in due time.
- The `ClientProof` passed via the `Signature|string` argument is validated against the `StoredKey` and `ServerKey` stored in the authentication database. See [SCRAM Algorithms](#).
- `nonce` matches the one previously sent via CHALLENGE.
- The `channel_binding` matches the one sent in the HELLO message.
- The `cbind_data` sent by the client matches the channel binding data that the server sees on its side of the channel.

Final Server Authentication Message - Success

If the authentication succeeds, the server **SHALL** finally respond with a WELCOME message:

```
[2, 3251278072152162,
  {
    "authid": "user",
    "authrole": "frontend",
    "authmethod": "wamp-scam",
    "authprovider": "static",
    "roles": ...,
    "authextra":
      {
        "verifier":
          "v=6rriTRBi23WpRR/wtup+mMhUZUn/dB5nLTJRsjl95G4="
      }
  }
]
```

where:

1. `authid|string`: The authentication ID the client was actually authenticated as.
2. `authrole|string`: The authentication role the client was authenticated for.
3. `authmethod|string`: The authentication method, here "wamp-scam".
4. `authprovider|string`: The actual provider of authentication. For WAMP-SCRAM authentication, this can be freely chosen by the app, e.g. static or dynamic.
5. `authextra.verifier|string`: The base64-encoded `ServerSignature`, computed as described in the [SCRAM Algorithms](#) section.

The client SHOULD check the `verifier` for mutual authentication, terminating the session if invalid.

Final Server Authentication Message - Failure

If the authentication fails, the server SHALL respond with an ABORT message.

The server MAY include a SCRAM-specific error string in the ABORT message as a `Details.scram` attribute. SCRAM error strings are listed in [RFC5802, section 7](#), under `server-error-value`.

SCRAM Algorithms

This section is non-normative.

[RFC5802](#) specifies the algorithms used to compute the `ClientProof`, `ServerSignature`, `ServerKey`, and `StoredKey` values referenced by this document. Those algorithms are summarized here in pseudocode for reference.

Notation

- `"="`: The variable on the left-hand side is the result of the expression on the right-hand side.
- `"+"`: String concatenation.
- `IsNull(attribute, value, else)`: If the given `attribute` is absent or null, evaluates to the given `value`, otherwise evaluates to the given `else` value.

- `Decimal(integer)`: The decimal string representation of the given `integer`.
- `Base64(octets)`: Base64 encoding of the given octet sequence, restricted to canonical form with no whitespace, as defined in [RFC4648](#).
- `UnBase64(str)`: Decode the given Base64 string into an octet sequence.
- `Normalize(str)`: Normalize the given string using the SASLprep profile [RFC4013](#) of the "stringprep" algorithm [RFC3454](#).
- `XOR`: The exclusive-or operation applied to each octet of the left and right-hand-side octet sequences.
- `SHA256(str)`: The SHA-256 cryptographic hash function.
- `HMAC(key, str)`: Keyed-hash message authentication code, as defined in [RFC2104](#), with SHA-256 as the underlying hash function.
- `KDF(str, salt, params...)`: One of the supported key derivations function, with the output key length the same as the SHA-256 output length (32 octets). `params...` are the additional parameters that are applicable for the function: `iterations` and `memory`.
- `Escape(str)`: Replace every occurrence of `"`, `,` and `=` in the given string with `"=2C"` and `"=3D"` respectively.

Data Stored on the Server

For each user, the server needs to store:

1. A random, per-user salt.
2. The type string corresponding to the key derivation function (KDF) used to hash the password (e.g. `"argon2id13"`). This is needed to handle future revisions of the KDF, as well as allowing migration to stronger KDFs that may be added to WAMP-SCRAM in the future. This may also be needed if the KDF used during user registration is configurable or selectable on a per-user basis.
3. Parameters that are applicable to the key derivation function : `iterations` and possibly `memory`.
4. The `StoredKey`.
5. The `ServerKey`.

where `StoredKey` and `ServerKey` are computed as follows:

```
SaltedPassword = KDF(Normalize(password), salt, params...)
ClientKey      = HMAC(SaltedPassword, "Client Key")
StoredKey      = SHA256(ClientKey)
ServerKey      = HMAC(SaltedPassword, "Server Key")
```

Note that `"Client Key"` and `"Server Key"` are string literals.

The manner in which the `StoredKey` and `ServerKey` are shared with the server during user registration is outside the scope of SCRAM and this document.

AuthMessage

In SCRAM, `AuthMessage` is used for computing `ClientProof` and `ServerSignature`. `AuthMessage` is computed using attributes that were sent in the first three messages of the authentication exchange.

```
ClientFirstBare = "n=" + Escape(HELLO.Details.authid) + "," +  
                  "r=" + HELLO.Details.authextra.nonce  
  
ServerFirst = "r=" + CHALLENGE.Details.nonce + "," +  
              "s=" + CHALLENGE.Details.salt + "," +  
              "i=" + Decimal(CHALLENGE.Details.iterations)  
  
CBindName = AUTHENTICATE.Extra.channel_binding  
CBindData = AUTHENTICATE.Extra.cbind_data  
CBindFlag = IfNull(CBindName, "n", "p=" + CBindName)  
CBindInput = CBindFlag + "," +  
              IfNull(CBindData, "", UnBase64(CBindData))  
  
ClientFinalNoProof = "c=" + Base64(CBindInput) + "," +  
                     "r=" + AUTHENTICATE.Extra.nonce  
  
AuthMessage = ClientFirstBare + "," + ServerFirst + "," +  
               ClientFinalNoProof
```

ClientProof

`ClientProof` is computed by the client during the authentication exchange as follows:

```
SaltedPassword = KDF(Normalize(password), salt, params...)  
ClientKey      = HMAC(SaltedPassword, "Client Key")  
StoredKey      = SHA256(ClientKey)  
ClientSignature = HMAC(StoredKey, AuthMessage)  
ClientProof    = ClientKey XOR ClientSignature
```

The `ClientProof` is then sent to the server, base64-encoded, via the `AUTHENTICATE.Signature` argument.

The server verifies the `ClientProof` by computing the `RecoveredStoredKey` and comparing it to the actual `StoredKey`:

```
ClientSignature    = HMAC(StoredKey, AuthMessage)  
RecoveredClientKey = ClientSignature XOR ReceivedClientProof  
RecoveredStoredKey = SHA256(RecoveredClientKey)
```

Note that the client MAY cache the `ClientKey` and `StoredKey` (or just `SaltedPassword`) to avoid having to perform the expensive KDF computation for every authentication exchange. Storing these values securely on the client is outside the scope of this document.

ServerSignature

ServerSignature is computed by the server during the authentication exchange as follows:

```
ServerSignature = HMAC(ServerKey, AuthMessage)
```

The ServerSignature is then sent to the client, base64-encoded, via the `WELCOME.Details.authextra.verifier` attribute.

The client verifies the ServerSignature by computing it and comparing it with the ServerSignature sent by the server:

```
ServerKey      = HMAC(SaltedPassword, "Server Key")
ServerSignature = HMAC(ServerKey, AuthMessage)
```

Key Derivation Functions

SCRAM uses a password-based key derivation function (KDF) to hash user passwords. WAMP-SCRAM supports both [Argon2](#) and [PBKDF2](#) as the KDF. Argon2 is recommended because of its memory hardness and resistance against GPU hardware. PBKDF2, which does not feature memory hardness, is also supported for applications that are required to use primitives currently approved by cryptographic standards.

The following table maps the `CHALLENGE.Details.kdf` type string to the corresponding KDF.

KDF type string	Function
"argon2id13"	Argon2id variant of Argon2, version 1.3
"pbkdf2"	PBKDF2

Table 8

To promote interoperability, WAMP-SCRAM client/server implementations SHOULD support both of the above KDFs. During authentication, there is no "negotiation" of the KDF, and the client MUST use the same KDF than the one used to create the keys stored in the authentication database.

Which KDF is used to hash the password during user registration is up to the application and/or server implementation, and is not covered by this document. Possibilities include:

- making the KDF selectable at runtime during registration,
- making the KDF statically configurable on the server, or,
- hard-coding the KDF selection on the server.

Argon2

The Argon2 key derivation function, proposed in [draft-irtf-cfrg-argon2](#), is computed using the following parameters:

- `CHALLENGE.Details.salt` as the cryptographic salt,
- `CHALLENGE.Details.iterations` as the number of iterations,
- `CHALLENGE.Details.memory` as the memory size (in kibibytes),
- 1 as the parallelism parameter,
- Argon2id as the algorithm variant, and,
- 32 octets as the output key length.

For WAMP-SCRAM, the parallelism parameter is fixed to 1 due to the password being hashed on the client side, where it is not generally known how many cores/threads are available on the client's device.

Section 4 of the Argon2 internet draft recommends the general procedure for selecting parameters, of which the following guidelines are applicable to WAMP-SCRAM:

- A 128-bit salt is recommended, which can be reduced to 64-bit if space is limited.
- The memory parameter is to be configured to the maximum amount of memory usage that can be tolerated on client devices for computing the hash.
- The iterations parameter is to be determined experimentally so that execution time on the client reaches the maximum that can be tolerated by users during authentication. If the execution time is intolerable with `iterations = 1`, then reduce the memory parameter as needed.

PBKDF2

The PBKDF2 key derivation function, defined in [RFC2898](#), is used with SHA-256 as the pseudorandom function (PRF).

The PDBKDF2 hash is computed using the following parameters:

- `CHALLENGE.Details.salt` as the cryptographic salt,
- `CHALLENGE.Details.iterations` as the iteration count, and,
- 32 octets as the output key length (`dkLen`), which matches the SHA-256 output length.

[RFC2898 section 4.1](#) recommends at least 64 bits for the salt.

The iterations parameter SHOULD be determined experimentally so that execution time on the client reaches the maximum that can be tolerated by users during authentication. [RFC7677 section 4](#) recommends an iteration count of at least 4096, with a significantly higher value on non-mobile clients.

5.4. Cryptosign-based Authentication

Write me.

5.5. Dynamic Authentication API

Write me.

6. Advanced Transports and Serializers

The only requirements that WAMP expects from a transport are: the transport must be message-based, bidirectional, reliable and ordered. This allows WAMP to run over different transports without any impact at the application layer.

Besides the WebSocket transport, the following WAMP transports are currently specified:

- [RawSocket Transport](#)
- [Batched WebSocket Transport](#)
- [LongPoll Transport](#)
- [Multiplexed Transport](#)

Other transports such as HTTP 2.0 ("SPDY") or UDP might be defined in the future.

6.1. RawSocket Transport

WAMP-over-RawSocket is an (alternative) transport for WAMP that uses length-prefixed, binary messages - a message framing different from WebSocket.

Compared to WAMP-over-WebSocket, WAMP-over-RawSocket is simple to implement, since there is no need to implement the WebSocket protocol which has some features that make it non-trivial (like a full HTTP-based opening handshake, message fragmentation, masking and variable length integers).

WAMP-over-RawSocket has even lower overhead than WebSocket, which can be desirable in particular when running on local connections like loopback TCP or Unix domain sockets. It is also expected to allow implementations in microcontrollers in under 2KB RAM.

WAMP-over-RawSocket can run over TCP, TLS, Unix domain sockets or any reliable streaming underlying transport. When run over TLS on the standard port for secure HTTPS (443), it is also able to traverse most locked down networking environments such as enterprise or mobile networks (unless man-in-the-middle TLS intercepting proxies are in use).

However, WAMP-over-RawSocket cannot be used with Web browser clients, since browsers do not allow raw TCP connections. Browser extensions would do, but those need to be installed in a browser. WAMP-over-RawSocket also (currently) does not support transport-level compression as WebSocket does provide (permessage-deflate WebSocket extension).

Endianness

WAMP-over-RawSocket uses *network byte order* ("big-endian"). That means, given a unsigned 32 bit integer

```
0x 11 22 33 44
```

the first octet sent out to (or received from) the wire is 0x11 and the last octet sent out (or received) is 0x44.

Here is how you would convert octets received from the wire into an integer in Python:

```
import struct

octets_received = b"\x11\x22\x33\x44"
i = struct.unpack(">L", octets_received)[0]
```

The integer received has the value 287454020.

And here is how you would send out an integer to the wire in Python:

```
octets_to_be_send = struct.pack(">L", i)
```

The octets to be sent are b"\x11\x22\x33\x44".

Handshake: Client-to-Router Request

WAMP-over-RawSocket starts with a handshake where the client connecting to a router sends 4 octets:

MSB	LSB
31	0
0111 1111 LLLL SSSS RRRR RRRR RRRR RRRR	

The *first octet* is a magic octet with value 0x7F. This value is chosen to avoid any possible collision with the first octet of a valid HTTP request (see [here](#) and [here](#)). No valid HTTP request can have 0x7F as its first octet.

By using a magic first octet that cannot appear in a regular HTTP request, WAMP-over-RawSocket can be run e.g. on the same TCP listening port as WAMP-over-WebSocket or WAMP-over-LongPoll.

The *second octet* consists of a 4 bit LENGTH field and a 4 bit SERIALIZER field.

The LENGTH value is used by the *Client* to signal the **maximum message length** of messages it is willing to **receive**. When the handshake completes successfully, a *Router* MUST NOT send messages larger than this size.

The possible values for LENGTH are:

```
0: 2**9 octets
1: 2**10 octets
...
15: 2**24 octets
```

This means a *Client* can choose the maximum message length between **512** and **16M** octets.

The SERIALIZER value is used by the *Client* to request a specific serializer to be used. When the handshake completes successfully, the *Client* and *Router* will use the serializer requested by the *Client*.

The possible values for SERIALIZER are:

```
0: illegal
1: JSON
2: MessagePack
3 - 15: reserved for future serializers
```

Here is a Python program that prints all (currently) permissible values for the *second octet*:

```
SERMAP = {
    1: 'json',
    2: 'messagepack'
}

# map serializer / max. msg length to RawSocket handshake
# request or success reply (2nd octet)
for ser in SERMAP:
    for l in range(16):
        octet_2 = (l << 4) | ser
        print("serializer: {}, maxlen: {} => 0x{:02x}".format(SERMAP[ser], 2 ** (l + 9), octet_2))
```

The *third and forth octet* are **reserved** and MUST be all zeros for now.

Handshake: Router-to-Client Reply

After a *Client* has connected to a *Router*, the *Router* will first receive the 4 octets handshake request from the *Client*.

If the *first octet* differs from 0x7F, it is not a WAMP-over-RawSocket request. Unless the *Router* also supports other transports on the connecting port (such as WebSocket or LongPoll), the *Router* MUST **fail the connection**.

Here is an example of how a *Router* could parse the *second octet* in a *Clients* handshake request:

```
# map RawSocket handshake request (2nd octet) to
# serializer / max. msg length
for i in range(256):
    ser_id = i & 0x0f
    if ser_id != 0:
        ser = SERMAP.get(ser_id, 'currently undefined')
        maxlen = 2 ** ((i >> 4) + 9)
        print("{:02x} => serializer: {}, maxlen: {}".format(i, ser,
maxlen))
    else:
        print("fail the connection: illegal serializer value")
```

When the *Router* is willing to speak the serializer requested by the *Client*, it will answer with a 4 octets response of identical structure as the *Client* request:

MSB	LSB
31	0
0111 1111 LLLL SSSS RRRR RRRR RRRR RRRR	

Again, the *first octet* MUST be the value 0x7F. The *third and forth octets* are reserved and MUST be all zeros for now.

In the *second octet*, the *Router* MUST echo the serializer value in `SERIALIZER` as requested by the *Client*.

Similar to the *Client*, the *Router* sets the `LENGTH` field to request a limit on the length of messages sent by the *Client*.

During the connection, *Router* MUST NOT send messages to the *Client* longer than the `LENGTH` requested by the *Client*, and the *Client* MUST NOT send messages larger than the maximum requested by the *Router* in its handshake reply.

If a message received during a connection exceeds the limit requested, a *Peer* MUST **fail the connection**.

When the *Router* is unable to speak the serializer requested by the *Client*, or it is denying the *Client* for other reasons, the *Router* replies with an error:

MSB	LSB
31	0
0111 1111 EEEE 0000 RRRR RRRR RRRR RRRR	

An error reply has 4 octets: the *first octet* is again the magic 0x7F, and the *third and forth octet* are reserved and MUST all be zeros for now.

The *second octet* has its lower 4 bits zero'ed (which distinguishes the reply from an success/accepting reply) and the upper 4 bits encode the error:

```
0: illegal (must not be used)
1: serializer unsupported
2: maximum message length unacceptable
3: use of reserved bits (unsupported feature)
4: maximum connection count reached
5 - 15: reserved for future errors
```

Note that the error code 0 **MUST NOT** be used. This is to allow storage of error state in a host language variable, while allowing 0 to signal the current state "no error"

Here is an example of how a *Router* might create the *second octet* in an error response:

```
ERRMAP = {
    0: "illegal (must not be used)",
    1: "serializer unsupported",
    2: "maximum message length unacceptable",
    3: "use of reserved bits (unsupported feature)",
    4: "maximum connection count reached"
}

# map error to RawSocket handshake error reply (2nd octet)
for err in ERRMAP:
    octet_2 = err << 4
    print("error: {} => 0x{:02x}".format(ERRMAP[err], err))
```

The *Client* - after having sent its handshake request - will wait for the 4 octets from *Router* handshake reply.

Here is an example of how a *Client* might parse the *second octet* in a *Router* handshake reply:

```
# map RawSocket handshake reply (2nd octet)
for i in range(256):
    ser_id = i & 0x0f
    if ser_id:
        # verify the serializer is the one we requested!
        # if not, fail the connection!
        ser = SERMAP.get(ser_id, 'currently undefined')
        maxlen = 2 ** ((i >> 4) + 9)
        print("{:02x} => serializer: {}, maxlen: {}".format(i, ser,
maxlen))
    else:
        err = i >> 4
        print("error: {}".format(ERRMAP.get(err, 'currently undefined')))
```

Serialization

To send a WAMP message, the message is serialized according to the WAMP serializer agreed in the handshake (e.g. JSON or MessagePack).

The length of the serialized messages in octets MUST NOT exceed the maximum requested by the *Peer*.

If the serialized length exceed the maximum requested, the WAMP message can not be sent to the *Peer*. Handling situations like the latter is left to the implementation.

E.g. a *Router* that is to forward a WAMP EVENT to a *Client* which exceeds the maximum length requested by the *Client* when serialized might:

- drop the event (not forwarding to that specific client) and track dropped events
- prohibit publishing to the topic already
- remove the event payload, and send an event with extra information (payload_limit_exceeded = true)

Framing

The serialized octets for a message to be sent are prefixed with exactly 4 octets.

MSB	LSB
31	0
RRRR	RTTT
LLLL	LLLL
LLLL	LLLL
LLLL	LLLL
LLLL	LLLL

The *first octet* has the following structure

MSB	LSB
7	0
RRRR	RTTT

The five bits RRRRR are reserved for future use and MUST be all zeros for now.

The three bits TTT encode the type of the transport message:

0:	regular WAMP message
1:	PING
2:	PONG
3-7:	reserved

The *three remaining octets* constitute an unsigned 24 bit integer that provides the length of transport message payload following, excluding the 4 octets that constitute the prefix.

For a regular WAMP message (TTT == 0), the length is the length of the serialized WAMP message: the number of octets after serialization (excluding the 4 octets of the prefix).

For a PING message (TTT == 1), the length is the length of the arbitrary payload that follows. A *Peer* MUST reply to each PING by sending exactly one PONG immediately, and the PONG MUST echo back the payload of the PING exactly.

For receiving messages with WAMP-over-RawSocket, a *Peer* will usually read exactly 4 octets from the incoming stream, decode the transport level message type and payload length, and then receive as many octets as the length was giving.

When the transport level message type indicates a regular WAMP message, the transport level message payload is unserialized according to the serializer agreed in the handshake and the processed at the WAMP level.

6.2. Message Batching

WAMP-over-Batched-WebSocket is a variant of WAMP-over-WebSocket where multiple WAMP messages are sent in one WebSocket message.

Using WAMP message batching can increase wire level efficiency further. In particular when using TLS and the WebSocket implementation is forcing every WebSocket message into a new TLS segment.

WAMP-over-Batched-WebSocket is negotiated between Peers in the WebSocket opening handshake by agreeing on one of the following WebSocket subprotocols:

- `wamp.2.json.batched`
- `wamp.2.msgpack.batched`
- `wamp.2.cbor.batched`

Batching with JSON works by serializing each WAMP message to JSON as normally, appending the single ASCII control character `\30` ([record separator](#)) octet `0x1e` to *each* serialized messages, and packing a sequence of such serialized messages into a single WebSocket message:

```
Serialized JSON WAMP Msg 1 | 0x1e |  
Serialized JSON WAMP Msg 2 | 0x1e | ...
```

Batching with MessagePack works by serializing each WAMP message to MessagePack as normally, prepending a 32 bit unsigned integer (4 octets in big-endian byte order) with the length of the serialized MessagePack message (excluding the 4 octets for the length prefix), and packing a sequence of such serialized (length-prefixed) messages into a single WebSocket message:

```
Length of Msg 1 serialization (uint32) |  
serialized MessagePack WAMP Msg 1 | ...
```

With batched transport, even if only a single WAMP message is to be sent in a WebSocket message, the (single) WAMP message needs to be framed as described above. In other words, a single WAMP message is sent as a batch of length **1**. Sending a batch of length **0** (no WAMP message) is illegal and a *Peer* MUST fail the transport upon receiving such a transport message.

6.3. HTTP Longpoll Transport

The *Long-Poll Transport* is able to transmit a WAMP session over plain old HTTP 1.0/1.1. This is realized by the Client issuing HTTP/POSTs requests, one for sending, and one for receiving. Those latter requests are kept open at the server when there are no messages currently pending to be received.

Opening a Session

With the Long-Poll Transport, a Client opens a new WAMP session by sending a HTTP/POST request to a well-known URL, e.g.

```
http://mypp.com/longpoll/open
```

Here, `http://mypp.com/longpoll` is the base URL for the Long-Poll Transport and `/open` is a path dedicated for opening new sessions.

The HTTP/POST request SHOULD have a `Content-Type` header set to `application/json` and MUST have a request body with a JSON document that is a dictionary:

```
{
  "protocols": ["wamp.2.json"]
}
```

The (mandatory) `protocols` attribute specifies the protocols the client is willing to speak. The server will chose one from this list when establishing the session or fail the request when no protocol overlap was found.

The valid protocols are:

- `wamp.2.json.batched`
- `wamp.2.json`
- `wamp.2.msgpack.batched`
- `wamp.2.msgpack`
- `wamp.2.cbor.batched`
- `wamp.2.cbor`

The request path with this and subsequently described HTTP/POST requests MAY contain a query parameter `x` with some random or sequentially incremented value:

<http://mypp.com/longpoll/open?x=382913>

The value is ignored, but may help in certain situations to prevent intermediaries from caching the request.

Returned is a JSON document containing a transport ID and the protocol to speak:

```
{
  "protocol": "wamp.2.json",
  "transport": "kjmd3sBL0Unb3Fyr"
}
```

As an implied side-effect, two HTTP endpoints are created

```
http://mypp.com/longpoll/<transport_id>/receive
http://mypp.com/longpoll/<transport_id>/send
```

where `transport_id` is the transport ID returned from `open`, e.g.

```
http://mypp.com/longpoll/kjmd3sBL0Unb3Fyr/receive
http://mypp.com/longpoll/kjmd3sBL0Unb3Fyr/send
```

Receiving WAMP Messages

The Client will then issue HTTP/POST requests (with empty request body) to

```
http://mypp.com/longpoll/kjmd3sBL0Unb3Fyr/receive
```

When there are WAMP messages pending downstream, a request will return with a single WAMP message (unbatched modes) or a batch of serialized WAMP messages (batched mode).

The serialization format used is the one agreed during opening the session.

The batching uses the same scheme as with `wamp.2.json.batched` and `wamp.2.msgpack.batched` transport over WebSocket.

Note: In unbatched mode, when there is more than one message pending, there will be at most one message returned for each request. The other pending messages must be retrieved by new requests. With batched mode, all messages pending at request time will be returned in one batch of messages.

Sending WAMP Messages

For sending WAMP messages, the *Client* will issue HTTP/POST requests to

```
http://mypp.com/longpoll/kjmd3sBL0Unb3Fyr/send
```

with request body being a single WAMP message (unbatched modes) or a batch of serialized WAMP messages (batched mode).

The serialization format used is the one agreed during opening the session.

The batching uses the same scheme as with `wamp.2.json.batched` and `wamp.2.msgpack.batched` transport over WebSocket.

Upon success, the request will return with HTTP status code 202 ("no content"). Upon error, the request will return with HTTP status code 400 ("bad request").

Closing a Session

To orderly close a session, a Client will issue a HTTP/POST to

```
http://mypp.com/longpoll/kjmd3sBL0Unb3Fyr/close
```

with an empty request body. Upon success, the request will return with HTTP status code 202 ("no content").

7. WAMP Interfaces

WAMP was designed with the goals of being easy to approach and use for application developers. Creating a procedure to expose some custom functionality should be possible in any supported programming language using that language's native elements, with the least amount of additional effort.

Following from that, WAMP uses *dynamic typing* for the application payloads of calls, call results and error, as well as event payloads.

A WAMP router will happily forward *any* application payload on *any* procedure or topic URI as long as the client is *authorized* (has permission) to execute the respective WAMP action (call, register, publish or subscribe) on the given URI.

This approach has served WAMP well, as application developers can get started immediately, and evolve and change payloads as they need without extra steps. These advantages in flexibility of course come at a price, as nothing is free, and knowing that price is important to be aware of the tradeoffs one is accepting when using dynamic typing:

- problematic coordination of *Interfaces* within larger developer teams or between different parties
- no easy way to stabilize, freeze, document or share *Interfaces*
- no way to programmatically describe *Interfaces* ("interface reflection") at run-time

Problems such above could be avoided when WAMP supported an *option* to formally define WAMP-based *Interfaces*. This needs to answer the following questions:

1. How to specify the `args` | `List` and `kwargs` | `Dict` application payloads that are used in WAMP calls, errors and events?

2. How to specify the type and URI (patterns) for WAMP RPCs *Procedures* and WAMP PubSub *Topics* that make up an *Interface*, and how to identify an *Interface* itself as a collection of *Procedures* and *Topics*?
3. How to package, publish and share *Catalogs* as a collection of *Interfaces* plus metadata

The following sections will describe the solution to each of above questions using WAMP IDL.

Using WAMP Interfaces finally allows to support the following application developer level features:

1. router-based application payload validation and enforcement
2. WAMP interface documentation generation and autodocs Web service
3. publication and sharing of WAMP Interfaces and Catalogs
4. client binding code generation from WAMP Interfaces
5. run-time WAMP type reflection as part of the WAMP meta API

7.1. WAMP IDL

7.1.1. Application Payload Typing

To define the application payload `Arguments|list` and `ArgumentsKw|dict`, WAMP IDL reuses the [FlatBuffers IDL](#), specifically, we map a pair of `Arguments|list` and `ArgumentsKw|dict` to a FlatBuffers Table with WAMP defined FlatBuffers *Attributes*.

User defined WAMP application payloads are transmitted in `Arguments|list` and `ArgumentsKw|dict` elements of the following WAMP messages:

- PUBLISH
- EVENT
- CALL
- INVOCATION
- YIELD
- RESULT
- ERROR

A *Publisher* uses the

- `PUBLISH.Arguments|list` and `PUBLISH.ArgumentsKw|dict`

message elements to send the event payload to be published to the *Broker* in PUBLISH messages. When the event is accepted by the *Broker*, it will dispatch an EVENT message with

- `EVENT.Arguments|list` and `EVENT.ArgumentsKw|dict`

message elements to all (eligible, and not excluded) *Subscribers*.

A *Caller* uses the

- `CALL.Arguments|list` and `CALL.ArgumentsKw|dict`

message elements to send the call arguments to be used to the *Dealer* in CALL messages. When the call is accepted by the *Dealer*, it will forward

- `INVOCATION.Arguments|list` and `INVOCATION.ArgumentsKw|dict`

to the (or one of) *Callee*, and receive YIELD messages with

- `YIELD.Arguments|list` and `YIELD.ArgumentsKw|dict`

message elements, which it will return to the original *Caller* in RESULT messages with

- `RESULT.Arguments|list` and `RESULT.ArgumentsKw|dict`

In the error case, a *Callee* MAY return an ERROR message with

- `ERROR.Arguments|list` and `ERROR.ArgumentsKw|dict`

message elements, which again is returned to the original *Caller*.

It is important to note that the above messages and message elements are the only ones free for use with application and user defined payloads. In particular, even though the following WAMP messages and message element carry payloads defined by the specific WAMP authentication method used, they do *not* carry arbitrary application payloads: `HELLO.Details["authextra"]|dict`, `WELCOME.Details["authextra"]|dict`, `CHALLENGE.Extra|dict`, `AUTHENTICATE.Extra|dict`.

For example, the [Session Meta API](#) includes a procedure to [kill all sessions by authid](#) with:

Positional arguments (`args|list`)

1. `authid|string` - The authentication ID identifying sessions to close.

Keyword arguments (`kwargs|dict`)

1. `reason|uri` - reason for closing sessions, sent to clients in `GOODBYE.Reason`
2. `message|string` - additional information sent to clients in `GOODBYE.Details` under the key "message".

as arguments. When successful, this procedure will return a call result with:

Positional results (`results|list`)

1. `sessions|list` - The list of WAMP session IDs of session that were killed.

Keyword results (kwresults|dict)

1. None

To specify the call arguments in FlatBuffers IDL, we can define a FlatBuffers table for both args and kwargs:

```
/// Call args/kwargs for "wamp.session.kill_by_authid"
table SessionKillByAuthid
{
    /// The WAMP authid of the sessions to kill.
    authid: string (wampuri);

    /// A reason URI provided to the killed session(s).
    reason: string (kwarg, wampuri);

    /// A message provided to the killed session(s).
    message: string (kwarg);
}
```

The table contains the list args as table elements (in order), unless the table element has an *Attribute* kwarg, in which case the element one in kwarg.

The attributes wampid and wampuri are special markers that denote values that follow the respective WAMP identifier rules for WAMP IDs and URIs.

When successful, the procedure will return a list of WAMP session IDs of session that were killed. Again, we can map this to FlatBuffers IDL:

```
table WampIds
{
    /// List of WAMP IDs.
    value: [uint64] (wampid);
}
```

7.1.2. WAMP IDL Attributes

WAMP IDL uses *custom FlatBuffer attributes* to

- mark kwarg fields which map to WAMP keyword argument vs arg (default)
- declare fields of a scalar base type to follow (stricter) WAMP rules (for IDs and URIs)
- specify the WAMP action type, that is *Procedure* vs *Topic*, on service declarations

"Attributes may be attached to a declaration, behind a field, or after the name of a table/struct/enum/union. These may either have a value or not. Some attributes like deprecated are understood by the compiler; user defined ones need to be declared with the attribute declaration (like priority in the example above), and are available to query

if you parse the schema at runtime. This is useful if you write your own code generators/editors etc., and you wish to add additional information specific to your tool (such as a help text)." (from [source](#)).

The *Attributes* used in WAMP IDL are defined in `<WAMP API Catalog>/src/wamp.fbs`, and are described in the following sections:

- `arg`, `kwarg`
- `wampid`
- `wampname`, `wampname_s`
- `wampuri`, `wampuri_s`, `wampuri_p`, `wampuri_sp`, `wampuri_pp`, `wampuri_spp`
- `uuid`
- `ethadr`
- `type`

WAMP Positional and Keyword-based Payloads

Positional payloads `args | list` and keyword-based payloads `kwargs | dict` are table elements that have one of the following *Attributes*:

- `arg` (default)
- `kwarg`

One pair of `args` and `kwarg` types is declared by one FlatBuffer table with optional attributes on table fields, and the following rules apply or must be followed:

1. If neither `arg` nor `kwarg` attribute is provided, `arg` is assumed.
2. Only one of either `arg` or `kwarg` MUST be specified.
3. When a field has an attribute `kwarg`, all subsequent fields in the same table MUST also have attribute `kwarg`.

WAMP IDs and URIs

Integers which contain WAMP IDs use *Attribute*

1. `wampid`: WAMP ID, that is an integer `[1, 2^53]`

Strings which contain WAMP names ("URI components"), for e.g. WAMP roles or authids use *Attributes*

1. `wampname`: WAMP URI component (aka "name"), loose rules (minimum required to combine to dotted URIs), must match regular expression `^[^\s\.\#]+$`.
2. `wampname_s`: WAMP URI component (aka "name"), strict rules (can be used as identifier in most languages), must match regular expression `^[\da-z_]+$`.

Strings which contain WAMP URIs or URI patterns use *Attribute*

1. `wampuri`: WAMP URI, loose rules, no empty URI components (aka "concrete or fully qualified URI"), must match regular expression `^([\^s\.\#]+\.)*([\^s\.\#]+)$`.
2. `wampuri_s`: WAMP URI, strict rules, no empty URI components, must match regular expression `^([\da-z_]+\.)*([\da-z_]+)$`.
3. `wampuri_p`: WAMP URI or URI (prefix or wildcard) pattern, loose rules (minimum required to combine to dotted URIs), must match regular expression `^([\^s\.\#]+\.)|[\.]*([\^s\.\#]+)?$`.
4. `wampuri_sp`: WAMP URI or URI (prefix or wildcard) pattern, strict rules (can be used as identifier in most languages), must match regular expression `^([\da-z_]+\.)|[\.]*([\da-z_]+)?$`.
5. `wampuri_pp`: WAMP URI or URI prefix pattern, loose rules (minimum required to combine to dotted URIs), must match regular expression `^([\^s\.\#]+\.)*([\^s\.\#]*)$`.
6. `wampuri_spp`: WAMP URI or URI prefix pattern, strict rules (can be used as identifier in most languages), must match regular expression `^([\da-z_]+\.)*([\da-z_]*)$`.

Type/Object UUIDs

Types and generally any objects can be globally identified using UUIDs [RFC4122]. UUIDs can be used in WAMP IDL using the `uuid` *Attribute*.

```
/// UUID (canonical textual representation).
my_field1: string (uuid);

/// UUID (128 bit binary).
my_field2: uint128_t (uuid);
```

The `uint128_t` is a struct type defined as

```
/// An unsigned integer with 128 bits.
struct uint128_t {
    /// Least significand 32 bits.
    w0: uint32;

    /// 2nd significand 32 bits.
    w1: uint32;

    /// 3rd significand 32 bits.
    w2: uint32;

    /// Most significand 32 bits.
    w3: uint32;
}
```

Ethereum Addresses

Ethereum addresses can be used to globally identify types or generally any object where the global ID also needs to be conflict free, consensually shared and owned by a respective Ethereum network user. Ethereum addresses can be used in WAMP IDL using the `ethadr` *Attribute*:

```
/// Ethereum address (checksummed HEX encoded address).
my_field1: string (ethadr);

/// Ethereum address (160 bit binary).
my_field2: uint160_t (ethadr);
```

The `uint160_t` is a struct type defined as

```
/// An unsigned integer with 160 bits.
struct uint160_t {
    /// Least significand 32 bits.
    w0: uint32;

    /// 2nd significand 32 bits.
    w1: uint32;

    /// 3rd significand 32 bits.
    w2: uint32;

    /// 4th significand 32 bits.
    w3: uint32;

    /// Most significand 32 bits.
    w4: uint32;
}
```

WAMP Actions or Service Elements

The type of WAMP service element **procedure**, **topic** or **interface** is designated using the *Attribute*

1. type: one of "procedure", "topic" or "interface"

The type *Attribute* can be used to denote WAMP service interfaces, e.g. continuing with above WAMP Meta API procedure example, the `wamp.session.kill_by_authid` procedure can be declared like this:

```
rpc_service IWampMeta(type: "interface",
                      uuid: "88711231-3d95-44bc-9464-58d871dd7fd7",
                      wampuri: "wamp")
{
    session_kill_by_authid (SessionKillByAuthid): WampIds (
        type: "procedure",
        wampuri: "wamp.session.kill_by_authid"
    );
}
```

The value of attribute `type` specifies a WAMP *Procedure*, and the call arguments and result types of the procedure are given by:

- `SessionKillByAuthid`: procedure call arguments `args` (positional argument) and `kwargs` (keyword arguments) call argument follow this type
- `WampIds`: procedure call results `args` (positional results) and `kwargs` (keyword results)

The procedure will be registered under the WAMP URI `wamp.session.kill_by_authid` on the respective realm.

7.1.3. WAMP Service Declaration

WAMP services include

- *Procedures* registered by *Callees*, available for calling from *Callers*
- *Topics* published to by *Publishers*, available for subscribing by *Subscribers*

We map the two WAMP service types to FlatBuffers IDL using the *Attribute* type `== "procedure" | "topic"` as in this example:

```
rpc_service IWampMeta(type: "interface",
                      uuid: "88711231-3d95-44bc-9464-58d871dd7fd7",
                      wampuri: "wamp")
{
  session_kill_by_authid (SessionKillByAuthid): WampIds (
    type: "procedure",
    wampuri: "wamp.session.kill_by_authid"
  );

  session_on_leave (SessionInfo): Void (
    type: "topic",
    wampuri: "wamp.session.on_leave"
  );
}
```

When the procedure `wamp.session.kill_by_authid` is called to kill all sessions with a given `authid`, the procedure will return a list of WAMP session IDs of the killed sessions via `WampIds`. Independently, meta events on topic `wamp.session.on_leave` are published with detailed `SessionInfo` of the sessions left as event payload. This follows a common "do-something-and-notify-observers" pattern for a pair of a procedure and topic working together.

The *Interface* then collects a number of *Procedures* and *Topics* under one named unit of type `== "interface"` which includes a UUID in an *uuid Attribute*.

Declaring Services

Declaring services involves three element types:

- *Topics*
- *Procedures*

- *Interfaces*

The general form for declaring *Topics* is:

```
<TOPIC-METHOD> (<TOPIC-PAYLOAD-TABLE>): Void (  
    type: "topic",  
    wampuri: <TOPIC-URI>  
);
```

The application payload transmitted in EVENTS is typed via <TOPIC - PAYLOAD - TABLE>. The return type MUST always be Void, which is a dummy marker type declared in `wamp.fbs`.

Note: With *Acknowledge Event Delivery* (future), when a *Subscriber* receives an EVENT, the *Subscriber* will return an *Event-Acknowledgement* including args/ kwargs. Once we do have this feature in WAMP PubSub, the type of the *Event-Acknowledgement* can be specified using a non-Void return type.

The general form for declaring *Procedures* is:

```
<PROCEDURE-METHOD> (<CALL-PAYLOAD-TABLE>): <CALLRESULT-PAYLOAD-TABLE> (  
    type: "procedure",  
    wampuri: <PROCEDURE-URI>  
);
```

The application payload transmitted in CALLs is typed via <CALL - PAYLOAD - TABLE>. The return type of the CALL is typed via <CALLRESULT - PAYLOAD - TABLE>.

The general form for declaring *Interfaces*, which collect *Procedures* and *Topics* is:

```
rpc_service <INTERFACE> (  
    type: "interface",  
    uuid: <INTERFACE-UUID>,  
    wampuri: <INTERFACE-URI-PREFIX>  
) {  
    /// Method declarations of WAMP Procedures and Topics  
}
```

Note: We are reusing FlatBuffers IDL here, specifically the `rpc_service` service definitions which [were designed for gRPC](#). We reuse this element to declare both WAMP *Topics* and *Procedures* by using the type Attribute. Do not get confused with "rpc" in `rpc_service`.

Declaring Progressive Call Results

Write me.

Declaring Call Errors

Write me.

7.2. Interface Catalogs

Collections of types defined in FlatBuffers IDL are bundled in *Interface Catalogs* which are just ZIP files with

- one [catalog.yaml](#) file with catalog metadata
- one or more *.bfbs compiled FlatBuffer IDL schemas

and optionally

- schema source files
- image and documentation files

7.2.1. Catalog Archive File

The contents of an `example.zip` interface catalog:

```
unzip -l build/example.zip
Archive:  build/example.zip
  Length      Date    Time    Name
-----
         0  1980-00-00  00:00    schema/
    14992  1980-00-00  00:00    schema/example2.bfbs
   15088  1980-00-00  00:00    schema/example4.bfbs
   13360  1980-00-00  00:00    schema/example3.bfbs
    8932  1980-00-00  00:00    schema/example1.bfbs
    6520  1980-00-00  00:00    schema/wamp.bfbs
    1564  1980-00-00  00:00    README.md
         0  1980-00-00  00:00    img/
   13895  1980-00-00  00:00    img/logo.png
    1070  1980-00-00  00:00    LICENSE.txt
    1288  1980-00-00  00:00    catalog.yaml
-----
   76709
                        11 files
```

The bundled Catalog Interfaces in above are FlatBuffers binary schema files which are compiled using `flatc`

```
flatc -o ./schema --binary --schema --bfbs-comments --bfbs-builtins ./src
```

from FlatBuffers IDL sources, for example:

```
rpc_service IExample1 (
  type: "interface", uuid: "bf469db0-efea-425b-8de4-24b5770e6241"
) {
  my_procedure1 (TestRequest1): TestResponse1 (
    type: "procedure", wampuri: "com.example.my_procedure1"
  );

  on_something1 (TestEvent1): Void (
    type: "topic", wampuri: "com.example.on_something1"
  );
}
```

7.2.2. Catalog Metadata

The `catalog.yaml` file contains catalog metadata in [YAML Format](#):

Field	Description
name	Catalog name, which must contain only lower-case letter, numbers, hyphen and underscore so the catalog name can be used in HTTP URLs
version	Catalog version (e.g. semver or calendarver version string)
title	Catalog title for display purposes
description	Catalog description, a short text describing the API catalog
schemas	FlatBuffers schemas compiled into binary schema reflection format
author	Catalog author
publisher	Ethereum Mainnet address of publisher
license	SPDX license identifier (see https://spdx.org/licenses/) for the catalog
keywords	Catalog keywords to hint at the contents, topic, usage or similar of the catalog
homepage	Catalog home page or project page
git	Git source repository location
theme	Catalog visual theme

Table 9

Here is a complete example:

```
name: example
version: 22.6.1
title: WAMP Example API Catalog
description: An example of a WAMP API catalog.
schemas:
  - schema/example1.bfbs
  - schema/example2.bfbs
  - schema/example3.bfbs
  - schema/example4.bfbs
author: typedef int GmbH
publisher: "0x60CC48BFC44b48A53e793FE4cB50e2d625BABB27"
license: MIT
keywords:
  - wamp
  - sample
homepage: https://wamp-proto.org/
git: https://github.com/wamp-proto/wamp-proto.git
theme:
  background: "#333333"
  text: "#e0e0e0"
  highlight: "#00ccff"
  logo: img/logo.png
```

7.2.3. Catalog Sharing and Publication

Archive File Preparation

The [ZIP](#) archive format and tools, by default, include filesystem and other metadata from the host producing the archive. That information usually changes, per-archive run, as e.g. the current datetime is included, which obviously progresses.

When sharing and publishing a WAMP Interface Catalog, it is crucial that the archive only depends on the actual contents of the compressed files.

Removing all unwanted ZIP archive metadata can be achieved using [stripzip](#):

```
stripzip example.zip
```

The user build scripts for compiling and bundling an Interface Catalog ZIP file **MUST** be repeatable, and only depend on the input source files. A build process that fulfills this requirement is called [Reproducible build](#).

The easiest way to check if your build scripts producing `example.zip` is reproducible is repeat the build and check that the file fingerprint of the resulting archive stays the same:

```
openssl sha256 example.zip
```

Catalog Publication on Ethereum and IPFS

Write me.

7.3. Interface Reflection

Feature status: **sketch**

Reflection denotes the ability of WAMP peers to examine the procedures, topics and errors provided or used by other peers.

I.e. a WAMP *Caller*, *Callee*, *Subscriber* or *Publisher* may be interested in retrieving a machine readable list and description of WAMP procedures and topics it is authorized to access or provide in the context of a WAMP session with a *Dealer* or *Broker*.

Reflection may be useful in the following cases:

- documentation
- discoverability
- generating stubs and proxies

WAMP predefines the following procedures for performing run-time reflection on WAMP peers which act as *Brokers* and/or *Dealers*.

Predefined WAMP reflection procedures to *list* resources by type:

```
wamp.reflection.topic.list  
wamp.reflection.procedure.list  
wamp.reflection.error.list
```

Predefined WAMP reflection procedures to *describe* resources by type:

```
wamp.reflection.topic.describe  
wamp.reflection.procedure.describe  
wamp.reflection.error.describe
```

A peer that acts as a *Broker* SHOULD announce support for the reflection API by sending

```
HELLO.Details.roles.broker.reflection|bool := true
```

A peer that acts as a *Dealer* SHOULD announce support for the reflection API by sending

```
HELLO.Details.roles.dealer.reflection|bool := true
```

Since *Brokers* might provide (broker) procedures and *Dealers* might provide (dealer) topics, both SHOULD implement the complete API above (even if the peer only implements one of *Broker* or *Dealer* roles).

Reflection Events and Procedures

A topic or procedure is defined for reflection:

```
wamp.reflect.define
```

A topic or procedure is asked to be described (reflected upon):

```
wamp.reflect.describe
```

A topic or procedure has been defined for reflection:

```
wamp.reflect.on_define
```

A topic or procedure has been undefined from reflection:

```
wamp.reflect.on_undefine
```

8. Router-to-Router Links

Write me.

1. Resolve global realm name `R_name` via ENS to the on-chain address `R_adr` of the realm.
2. Retrieve list of Domains `R_DR` routing realm `R_adr`.
3. Retrieve the node's `N1` own domain `D_N1` given the node's address `N1_adr`.
4. Check `D_N1` is in `R_DR`.
5. Select a domain `D` from `R_DR` and get endpoint `E` for `D`.
6. Connect to `D` and authenticate via WAMP-Cryptosign.
7. Verify connected node `N2` by checking against `D`
8. Subscribe to `wamp.r2r.traffic_payable`
9. When receiving a traffic payable event, buy the respective key by calling `xbr.pool.buy_key`, and calling `wamp.r2r.submit_traffic_payment`, which returns a traffic usage report.

Data Spaces are end-to-end encrypted routing realms connecting data driven microservices.

The message routing between the microservice endpoints in

9. Advanced Profile URIs

WAMP pre-defines the following error URIs for the **Advanced Profile**. WAMP peers SHOULD only use the defined error messages.

A *Dealer* or (U+00A0)*Callee* canceled a call previously issued

```
wamp.error.canceled
```

A *Peer* requested an interaction with an option that was disallowed by the *Router*

```
wamp.error.option_not_allowed
```

A *Router* rejected client request to disclose its identity

```
wamp.error.option_disallowed.disclose_me
```

A *Router* encountered a network failure

```
wamp.error.network_failure
```

A *Callee* is not able to handle an invocation for a *call* and intends for the *Router* to re-route the *call* to another fitting *Callee*. For details, refer to [RPC Call Rerouting](#)

```
wamp.error.unavailable
```

A *Dealer* could not perform a call, since a procedure with the given URI is registered, but all available registrations have responded with `wamp.error.unavailable`

```
wamp.error.no_available_callee
```

10. IANA Considerations

WAMP uses the Subprotocol Identifier `wamp` registered with the [WebSocket Subprotocol Name Registry](#), operated by the Internet Assigned Numbers Authority (IANA).

11. Conformance Requirements

All diagrams, examples, and notes in this specification are non-normative, as are all sections explicitly marked non-normative. Everything else in this specification is normative.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [[RFC2119](#)].

Requirements phrased in the imperative as part of algorithms (such as "strip any leading space characters" or "return false and abort these steps") are to be interpreted with the meaning of the key word ("MUST", "SHOULD", "MAY", etc.) used in introducing the algorithm.

Conformance requirements phrased as algorithms or specific steps MAY be implemented in any manner, so long as the end result is equivalent.

11.1. Terminology and Other Conventions

Key terms such as named algorithms or definitions are indicated like *this* when they first occur, and are capitalized throughout the text.

12. Normative References

- [RFC4122] Leach, P., Mealling, M., and R. Salz, "A Universally Unique Identifier (UUID) URN Namespace", RFC 4122, DOI 10.17487/RFC4122, July 2005, <<https://www.rfc-editor.org/info/rfc4122>>.

13. Informative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

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=D_N1 [Section 8, Paragraph 2, Item 5](#)

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