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A Simpler Method for Resolving Alert-Info URNs

Abstract

The "alert" namespace of Uniform Resource Names (URNs) can be used in the Alert-Info header field of Session Initiation Protocol (SIP) requests and responses to inform a voice over IP (VoIP) telephone (user agent) of the characteristics of the call that the user agent has originated or terminated. The user agent must resolve the URNs into a signal; that is, it must select the best available signal to present to its user to indicate the characteristics of the call.

RFC 7462 describes a non-normative algorithm for signal selection. This document describes a more efficient alternative algorithm: a user agent's designer can, based on the user agent's signals and their meanings, construct a finite state machine (FSM) to process the URNs to select a signal in a way that obeys the restrictions given in the definition of the "alert" URN namespace.

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Table of Contents

1. Introduction

When a SIP user agent (UA) server receives an incoming INVITE request, it chooses an alerting signal (the ring tone) to present to its user (the called user) by processing the Alert-Info header field(s) in the incoming INVITE request [RFC3261]. Similarly, a SIP UA client determines an alerting signal (the ringback tone) to present to its user (the calling user) by processing the Alert-Info header field(s) in the incoming provisional response(s) to its outgoing INVITE request.

[RFC3261] envisioned that the Alert-Info header field value would be a URL that the UA could use to retrieve the encoded media of the signal. This usage has security problems and is inconvenient to implement in practice.

[RFC7462] introduced an alternative practice: the Alert-Info values can be URNs in the "alert" URN namespace that specify features of the call or of the signal that should be signaled to the user. [RFC7462] defined a large set of "alert" URNs and procedures for extending the set.

A UA is unlikely to provide more than a small set of alerting signals, and there are an infinite number of possible combinations of "alert" URNs. Thus, a UA is often required to select an alerting signal that renders only a subset of the information in the Alert-Info header field(s) -- which is the resolution process for "alert" URNs. The requirements for resolving "alert" URNs are given in Section 11.1 of [RFC7462].

Section 12 of [RFC7462] gives a (non-normative) resolution algorithm for selecting a signal that satisfies the requirements of Section 11.1 of that document. That algorithm can be used regardless of the set of alerting signals that the UA provides and their specified meanings. The existence of the algorithm defined in [RFC7462] demonstrates that the resolution requirements can always be satisfied. However, the algorithm is complex and slow.

The purpose of this document is to describe an improved implementation -- a more efficient resolution algorithm for selecting signals that conforms to the requirements of Section 11.1 of [RFC7462]. (Of course, like any such algorithm, it is non-normative, and the implementation is free to use any algorithm that conforms to the requirements of Section 11.1 of [RFC7462].)

In the algorithm defined in this document, once the UA designer has chosen the set of signals that the UA produces and the "alert" URNs that they express, a finite state machine (FSM) is constructed that

selects alerting signals based on the URNs in the Alert-Info header field(s) in a SIP message. The incoming "alert" URNs are preprocessed in a straightforward manner into a sequence of "symbols" drawn from a fixed finite set; these symbols are then used as input to the FSM. After processing the input, the state of the FSM selects the correct alerting signal to present to the user.

Both the preprocessor and the FSM are determined only by the selected set of signals and the set of "alert" URNs expressed by the signals, so the processing machinery can be fixed at the time of designing the UA.

1.1. Requirements Governing Resolution Algorithms

The requirements for the resolution of "alert" URNs are given in Section 11.1 of [RFC7462] and can be described as follows:

- The "alert" URNs are processed from left to right. Each "alert" URN has precedence over all URNs that follow it, and its interpretation is subordinate to all URNs that precede it.

- As each URN is processed, one of the UA's signals is chosen that expresses that URN as far as can be done without reducing the degree to which any of the preceding URNs were expressed by the signal chosen for the preceding URN. Thus, as processing proceeds, the chosen signals become increasingly specific and contain more information, but all of the information about a particular URN that is expressed by the signal chosen for that URN is also expressed by the signals chosen for all following URNs.

- If the entirety of the current URN cannot be expressed by any allowed signal, then each of the trailing alert-ind-parts (the sections separated by colons) is in turn removed until the reduced URN can be expressed by some signal that also expresses at least the same reduced versions of the preceding URNs that were expressed by the signal chosen for the preceding URN. This can be described as "a signal that expresses as much of the current URN as possible while still expressing as much of the previous URNs as the preceding signal did."

So, for instance, consider processing

```
Alert-Info: urn:alert:category-a:part-a1:part-a2,
            urn:alert:category-b:part-b1:part-b2
```

If the UA has no signal for urn:alert:category-a:part-a1:part-a2, it removes part-a2 from the URN and checks whether it has a signal for the less-specific URN urn:alert:category-a:part-a1. If it has no

signal for that URN, it gives up on the URN entirely (since urn:alert:category-a doesn't exist and can be considered to express nothing about the call), and the chosen signal is the default signal of the UA, i.e., the signal that is used when there is no Alert-Info.

But let us suppose the UA has a signal for urn:alert:category-a:part-a1 and chooses that signal when processing the first URN. All processing after this point will be restricted to signals that express urn:alert:category-a:part-a1 or a more specific URN of the category "category-a".

The UA then goes on to examine the next URN, urn:alert:category-b:part-b1:part-b2. If there is a signal that expresses both urn:alert:category-a:part-a1 and urn:alert:category-b:part-b1:part-b2, then the UA chooses that signal. If there is no such signal, the second URN is reduced to urn:alert:category-b:part-b1, and the UA checks for a signal that expresses that URN along with urn:alert:category-a:part-a1. If there is no such signal that matches that relaxed requirement, the second URN is reduced to urn:alert:category-b, which is discarded, and the chosen signal for the first URN is chosen for the second URN. In any case, all processing after this point will be restricted to signals that express urn:alert:category-a:part-a1 or a more specific URN of the category "category-a" and that also express the chosen part of urn:alert:category-b:part-b1:part-b2.

This process is continued until the last "alert" URN is processed; the signal chosen for the last URN is the signal that the UA uses.

1.2. Summary of the New Resolution Algorithm

The purpose of this document is to describe a resolution algorithm that conforms to Section 11.1 of [RFC7462] but is simpler than the algorithm described in Section 12 of [RFC7462]: once the UA designer has chosen a set of signals and the URNs that they express, an FSM is constructed that selects alerting signals based on the URNs in the Alert-Info header field(s) in a SIP message.

- The designer selects the set of signals that the UA produces, matching each signal to a set of "alert" URNs that together specify the meaning that is carried by the signal. (If the signal is a "default" signal that has no specific meaning, the set is empty. If the signal carries the meaning of one "alert" URN, the set contains that URN. If the signal carries a meaning that is the logical AND of two or more "alert" URNs, the set contains those URNs.)

- Based on the UA's signals and their meanings, the designer constructs an "alphabet" containing a finite number of symbols; each possible "alert" URN is mapped into one particular symbol.

- The designer constructs an FSM whose input is the alphabet of symbols and whose states describe the information extracted from the Alert-Info URNs.

- Each state of the FSM has an associated signal. Processing the Alert-Info URNs will leave the FSM in some particular state; the UA renders the signal that is attached to that final state.

To select a ring tone or ringback tone based on a SIP message, the UA processes the "alert" URNs in the Alert-Info header field from left to right. Initially, the FSM is in a designated initial state. The UA maps each successive URN into the corresponding symbol and then executes the state transition of the FSM specified by the symbol. The state of the FSM after processing the URNs determines which signal the UA will render to the user.

Note that the UA generally has two FSMs, because a UA usually wants to signal different information in ring tones than it signals in ringback tones. One FSM is used to select the ring tone to render for an incoming INVITE request. The other FSM is used to select the ringback tone to render based on an incoming provisional response to an outgoing INVITE request. Both FSMs are constructed in the same way, but the constructions are based on different lists of signals and corresponding URNs.

All of the steps of the method after the designer has selected the signals and their URNs are algorithmic, and the algorithm of those steps ensures that the operation of the FSM will satisfy the constraints of Section 11.1 of [RFC7462]. A Python implementation of the algorithmic steps is provided in [code].

In simple situations, a suitable FSM or equivalent ad hoc code can be constructed by hand using ad hoc analysis. Generally, this is only practical in situations where a small number of alert-categories and alert-indications are signaled and the categories interact in a simple, uniform way. For example, the examples in Sections 5.1 and 5.2 could be constructed by ad hoc analysis. But automatic processing is valuable if the situation is too complicated to construct a correct FSM by ad hoc analysis, or if the set of signals will change too frequently for human production to be economical.

1.3. Conventions Used in This Document

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

2. Selecting the Signals and Their Corresponding "alert" URNs

The designer must select signals that the UA will generate and define the meanings that the signals will have to the user. Based on this, the designer determines for each signal the "alert" URN or combination of "alert" URNs that (1) indicate that signal's meaning in SIP messages and (2) consequently should elicit that signal from the UA.

For example, suppose the UA has a particular ring tone for calls from an external source. A call from an external source is marked with the URN urn:alert:source:external (specified in Section 9 of [RFC7462]). Thus, the table of signals includes:

Signal	URN(s)
external source	urn:alert:source:external

Similarly, if the UA has a particular ring tone for calls from an internal source, the table includes:

Signal	URN(s)
internal source	urn:alert:source:internal

If the UA has ring tones for calls that are marked as having higher or lower priority, then the table includes:

Signal	URN(s)
high priority	urn:alert:priority:high
low priority	urn:alert:priority:low

Note that the UA must be able to signal for a message that has no "alert" URNs in the Alert-Info header field, which means that there must always be a default signal that has zero corresponding URNs:

Signal	URN(s)
default	(none)

A signal can be defined to indicate a combination of conditions. For instance, a signal that is used only for high-priority, internal-source calls expresses two URNs and will only be used when both URNs are present in Alert-Info:

Signal	URN(s)
high priority, internal source	urn:alert:priority:high, urn:alert:source:internal

A signal can be defined to cover a number of related conditions by specifying a URN that is the common prefix of the URNs for the various conditions. For instance, the URNs for "recall due to callback", "recall due to call hold", and "recall due to transfer" all start with urn:alert:service:recall, and so one signal can be provided for all of them by:

Signal	URN(s)
recall	urn:alert:service:recall

But if a specific signal is also provided for "recall due to callback" by this entry:

Signal	URN(s)
recall generally	urn:alert:service:recall
recall due to callback	urn:alert:service:recall:callback

then if the message contains urn:alert:service:recall:callback, the "recall due to callback" signal will be chosen instead of "recall generally" because the UA chooses the signal that most completely expresses the information in the Alert-Info header field.

The designer may wish to define extension URNs that provide more specific information about a call than the standard "alert" URNs do. One method is to add additional components to standard URNs. For instance, an extra-high priority could be indicated by the URN urn:alert:priority:high:extra@example. The final "extra@example" is an "alert-ind-part" that is a private extension. (See Sections 7 and 10.2 of [RFC7462] for a discussion of private extensions.) In any case, adding an alert-ind-part to a URN makes its meaning more specific, in that any call to which the longer URN can be applied can also have the shorter URN applied. In this case, "extra-high-priority calls" are considered a subset of "high-priority calls".

Signal	URN(s)
high priority	urn:alert:priority:high
extra-high priority	urn:alert:priority:high:extra@example.com

Of course, for this extension to be useful, the senders of SIP messages (e.g., other UAs) must generate the extension URN in suitable circumstances.

In some circumstances, the designer may want to create an entirely new category of "alert" URNs to indicate a type of information that is not indicated by any standard category of URNs. In that case, the designer uses a private extension as the alert-category (the third component of the URN), combined with whatever alert-ind-part (fourth component) values are desired. For example, a simplified version of the U.S. military security designations could be:

Signal	URN(s)
unclassified	urn:alert:security@example:unclassified
confidential	urn:alert:security@example:confidential
secret	urn:alert:security@example:secret
top secret	urn:alert:security@example:top-secret

The designer should ensure that the new alert-category is orthogonal to all defined standard alert-categories, in that any combination of one of the new URNs with one of the standard URNs is meaningful in that there could be a message carrying both URNs.

In addition, the set of alert-ind-parts for the new alert-category should be comprehensive and disjoint, in that every message can be described by exactly one of them.

3. General Considerations for Processing Alert-Info

In this section, we will discuss various considerations that arise when processing Alert-Info. These have to be taken care of properly in order to conform to the standards, as well as to ensure a good user experience. But since they are largely independent of the generated FSM and its processing, they are gathered here in a separate section.

The UA may have a number of different FSMs for processing URNs. Generally, there will be different FSMs for processing Alert-Info in incoming INVITE requests and for incoming provisional responses to outgoing INVITE requests. But any situation that changes the set of signals that the UA is willing to generate specifies a different set of signals and corresponding URNs and thus generates a different FSM.

For example, if a call is active on the UA, all audible signals may become unavailable, or audible signals may be available only if urn:alert:priority:high is specified.

Similarly, if the set of signals is customized by user action or local policy, the generated FSM must be updated. This can be done by (1) regenerating it according to the method described here or (2) generating a "generic" FSM and instantiating it based on the available signals. (See Section 7 for a discussion of this.)

Note that the values in an Alert-Info header field are allowed to be URIs of any scheme and, within the "urn" scheme, are allowed to have any namespace [RFC3261]. The processing of URIs that are not "alert" URNs is not considered by this document, nor is that processing specified by [RFC7462]. But the algorithm designer must consider what to do with such URIs if they are encountered. The simplest choice is to ignore them. Alternatively, the algorithm may examine the URI to determine if it names an alerting signal or describes how to retrieve an alerting signal, and, if so, choose to render that signal rather than process the "alert" URNs to select a signal. In any case, the remainder of this document assumes that (1) the signal is to be chosen based on the "alert" URNs in Alert-Info and (2) all Alert-Info URIs that are not "alert" URNs have been removed.

The UA may also receive "alert" URNs that are semantically invalid in various ways. For example, the URN may have only three components, despite the fact that all valid "alert" URNs have at least one alert-ind-part and thus four components. The only useful strategy is to ignore such URNs (and possibly log them for analysis).

The method described here is robust in its handling of categories and alert-ind-parts that are unknown to the UA; as a consequence, it is also robust if they are not valid standardized URNs. Thus, these error conditions need not be handled specially.

4. Constructing the Finite State Machine for a Very Simple Example

Constructing the FSM involves:

1. Listing the URNs that are expressed by the various signals of the UA.

2. From the expressed URNs, constructing the finite alphabet of symbols into which input URNs are mapped and that drive the state transitions of the FSM.

3. Constructing the states of the FSM and the transitions between them.

4. Selecting a signal to be associated with each FSM state.

We will explain the process using a very simple example in which there are two signals -- one expressing "internal source" and one expressing "external source" -- along with a default signal (for when there is no source information to signal). The "internal source" signal expresses urn:alert:source:internal, and the "external source" signal expresses urn:alert:source:external.

4.1. Listing the Expressed URNs

The first step is to establish for each of the UA's signals what call characteristics it represents, which is to say, the set of "alert" URNs that are its information content.

Signal	URN(s)
default	(none)
internal source	urn:alert:source:internal
external source	urn:alert:source:external

From the totality of these expressed URNs, the designer can then determine which sets of URNs must be distinguished from each other. In our simple example, the expressed URNs are:

urn:alert:source:external
urn:alert:source:internal

4.2. Constructing the Alphabet of Symbols

In order to reduce the infinite set of possible "alert" URNs to a finite alphabet of input symbols that cause the FSM's transitions, the designer must partition the "alert" URNs into a finite set of categories.

Once we've listed all the expressed URNs, we can list all of the alert-categories that are relevant to the UA's signaling; "alert" URNs in any other alert-category cannot affect the signaling and can be ignored. (The easiest way to ignore the non-relevant URNs is to skip over them during Alert-Info processing. A more formal method is to map all of them into one "Other" symbol and then, for each state of the FSM, have the "Other" symbol transition to that same state.)

Within each relevant alert-category, we now define a distinct symbol for every expressed URN and for all of their "ancestor" URNs (those that can be created by removing one or more trailing alert-ind-parts). In order to name the symbols in a way that distinguishes them from the corresponding URNs, we remove the initial "urn:alert:" and capitalize each alert-ind-part. Thus, in our example, we get these symbols:

```
Source
Source:External
Source:Internal
```

Note that there is a "Source" symbol even though there is no corresponding URN. (urn:alert:source is not a valid URN -- see Section 7 of [RFC7462] -- although the processing algorithm must be prepared to screen out such a purported URN if it appears in the Alert-Info header field.) However, its existence as a symbol will be useful later when we construct the FSM.

For each of these symbols, we add a symbol that classifies URNs that extend the symbol's corresponding URN with alert-ind-parts that cannot be expressed by signals:

```
Source:Other
Source:External:Other
Source:Internal:Other
```

The latter two classify URNs, such as urn:alert:source:external:foo@example, that extend URNs that we already have symbols for. The first is for classifying URNs, such as urn:alert:source:bar@example, that have first alert-ind-parts that contradict all the "source" URNs that the UA can signal.

These steps give us this set of symbols:

```
Source
Source:External
Source:External:Other
Source:Internal
Source:Internal:Other
Source:Other
```

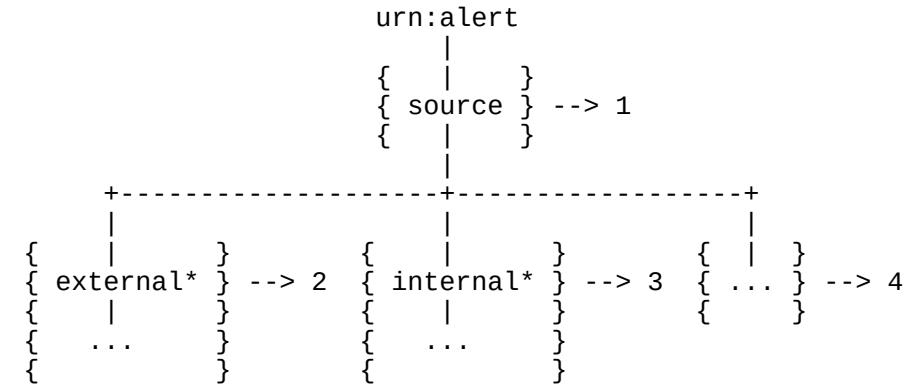
We can then simplify the set of symbols by removing the ones like Source:External:Other and Source:Internal:Other that consist of adding "Other" to a symbol that corresponds to an expressed URN that is not ancestral to any other expressed URNs. This works because adding further alert-ind-parts to a URN that is a leaf in regard to

the set of signals has no additional effect. In this example, urn:alert:source:external:foo@example has the same effect as urn:alert:source:external for both (1) causing a signal to be chosen and (2) suppressing the effect of later URNs.

This leaves the following symbols for the "source" category:

Source
Source:External
Source:Internal
Source:Other

These can be visually summarized by showing the infinite tree of possible source "alert" URNs and how it is partitioned into subtrees that map to each of these symbols. We also mark with "*" the expressed URNs.



1 = Source
2 = Source:External
3 = Source:Internal
4 = Source:Other

4.3. Constructing the States and Transitions

The UA processes the Alert-Info URNs from left to right using an FSM, with each successive URN causing the FSM to transition to a new state. Each state of the FSM records the information that has so far been extracted from the URNs. The state of the FSM after processing all the URNs determines which signal the UA will render to the user.

We label each state with a set of symbols, one from each relevant category, that describe the information that’s been extracted from all of the URNs that have so far been processed. The initial state is labeled with the "null" symbols that are just the category names,

because no information has yet been recorded. In our simple example, the initial state is labeled "Source", since that's the only relevant category.

State: Source (initial state)

Each state has a corresponding alerting signal, which is the signal that the UA will produce when URN processing leaves the FSM in that state. The signal is the one that best expresses the information that has been extracted from the URNs. Usually, the choice of signal is obvious to the designer, but there are certain constraints that the choice must satisfy. The main constraint is that the signal's expressed URNs must be semantic supersets of (i.e., identical to or a prefix of) the URNs corresponding to the symbols in the state's label. In particular, if the expressed URN of the signal in a certain category is shorter than the state's label, we show that in the state's name by putting parentheses around the trailing part of the symbol that is not expressed by the signal. For instance, if the symbol in the label is "Source:External" but the signal only expresses "Source" (i.e., no "source" URN at all), then the symbol in the label is modified to be "Source:(External)".

The reason for this nonintuitive construction is that in some states, the FSM has recorded information that the chosen signal cannot express.

Note that the parentheses are part of the state name, so in some circumstances there may be two or more distinct states labeled with the same symbols but with different placement of parentheses within the symbols. These similar state names are relevant when the FSM can record information from multiple "alert" URNs but cannot express all of them -- depending on the order in which the URNs appear, the UA may have to render different signals, so it needs states that record the same information but render different subsets of that information.

The initial state's label is the string of null symbols for the relevant categories, so the only allowed signal is the default signal, which expresses no URNs:

State: Source (initial state)
Signal: default

From each state, we must construct the transition for each possible input symbol. For a particular current state and symbol, we construct the label of the next state by combining the input symbol with the symbol in the current state's label for the same category. If one of the symbols is a prefix of the other, we select the longer one; if not, we select the symbol in the current state's label.

Thus, in our simple example, the initial state has the following transitions:

```
State: Source (initial state)
Signal: default
Transitions:
    Source:External -> Source:External
    Source:Internal -> Source:Internal
    Source:Other -> Source:Other
```

In all of these transitions, the input symbol is compatible with the matching label of the current state, "Source", so the next state's label is the full input symbol.

However, there is a further constraint on the next state: its signal must express URNs that at least contain the expressed URNs of the signal of the current state. Within that constraint, and being compatible with the next state's label, for the category of the input URN, the next state's signal must express the longest URN that can be expressed by any signal.

In our example, this means that the next Source:External state has the "external source" signal, which expresses urn:alert:source:external. Since that signal expresses all of the state's label, it is the chosen state. Similarly, the next Source:Internal state has the "internal source" signal. But for the transition on input Source:Other, the "Source:Other" state must have the default signal, as there is no signal that expresses urn:alert:source:[some-unknown-alert-ind-part]. So the next state is "Source:(Other)", where the parentheses record that the "Other" part of the label is not expressed by the state's signal.

Thus, the current state and the next states that it can transition to are:

```
    State: Source (initial state)
    Signal: default
    Transitions:
        Source:External -> Source:External
        Source:Internal -> Source:Internal
        Source:Other -> Source:(Other)

    State: Source:External
    Signal: external source (urn:alert:source:external)

    State: Source:Internal
    Signal: internal source (urn:alert:source:internal)

    State: Source:(Other)
    Signal: default
```

Looking at the state Source:External, we see that it is incompatible with all input symbols other than Source:External, and thus all of its transitions are to itself:

```
    State: Source:External
    Signal: external source (urn:alert:source:external)
    Transitions:
        Source:External -> Source:External
        Source:Internal -> Source:External
        Source:Other -> Source:External
```

and similarly:

```
    State: Source:Internal
    Signal: internal source (urn:alert:source:internal)
    Transitions:
        Source:External -> Source:Internal
        Source:Internal -> Source:Internal
        Source:Other -> Source:Internal

    State: Source:(Other)
    Signal: default
    Transitions:
        Source:External -> Source:(Other)
        Source:Internal -> Source:(Other)
        Source:Other -> Source:(Other)
```

4.4. Summary

The FSM can be constructed by processing the file "very-simple.txt" with the program "alert-info-fsm.py" in [code]. The program's output shows the stages of the construction, which are as follows:

1. The signals have the meanings:

Signal	URN(s)
default	(none)
internal source	urn:alert:source:internal
external source	urn:alert:source:external

2. The expressed URNs are:

```
urn:alert:source:external
urn:alert:source:internal
```

3. The relevant categories of "alert" URNs are only:

```
source
```

4. Thus, the infinite universe of possible "alert" URNs can be reduced to these symbols, which are the categories of URNs that are different in ways that are significant to the resolution process:

```
Source
Source:External
Source:Internal
Source:Other
```

5. The FSM is:

```
State: Source (initial state)
Signal: default
Transitions:
    Source:External -> Source:External
    Source:Internal -> Source:Internal
    Source:Other -> Source:(Other)

State: Source:External
Signal: external source (urn:alert:source:external)
Transitions:
    Source:External -> Source:External
    Source:Internal -> Source:External
    Source:Other -> Source:External
```

```
State: Source:Internal
Signal: internal source (urn:alert:source:internal)
Transitions:
    Source:External -> Source:Internal
    Source:Internal -> Source:Internal
    Source:Other -> Source:Internal

State: Source:(Other)
Signal: default
Transitions:
    Source:External -> Source:(Other)
    Source:Internal -> Source:(Other)
    Source:Other -> Source:(Other)
```

* Each state is labeled by a set of symbols that describe the information that has been extracted from the URNs so far.

* Each state has a signal that is a semantic superset of the state's label, i.e., the signal's expressed URNs match the initial portion of the label symbols. If Alert-Info processing finishes with the FSM in a state, the UA will render the state's signal to the user.

* The state's label is marked to show what subset of the symbols are expressed by the state's signal. Two states can have the same label but different signals.

* If a transition's input symbol is compatible with (is a semantic subset of) the current state's label for that category, the next state's label is updated with the input symbol. If not, the next state is the current state. This is how the state's label records what information has been accumulated while processing the Alert-Info URNs.

* A transition's next state has a signal that semantically subsets the current state's signal as much as possible in the category of the input symbol. (In most cases, the choice of signal is unique. In rare cases, there may be more than one signal that meets this criterion, so the designer may have some flexibility.)

4.5. Examples of Processing Alert-Info URNs

In the trivial case where the UA receives no Alert-Info URNs, processing begins and ends with the FSM in the initial state, and the default signal is selected.

If the UA receives

```
Alert-Info: <urn:alert:source:internal>
```

then processing progresses:

```
State: Source
    Process: Source:Internal (urn:alert:source:internal)
State: Source:Internal
Signal: internal source
```

If the UA receives

```
Alert-Info: <urn:alert:source:external>,
    <urn:alert:source:internal>
```

then processing progresses:

```
State: Source
    Process: Source:External (urn:alert:source:external)
State: Source:External
    Process: Source:Internal (urn:alert:source:internal)
State: Source:External
Signal: external source
```

If the UA receives

```
Alert-Info: <urn:alert:source:unclassified>,
    <urn:alert:source:internal>
```

then processing progresses:

```
State: Source
    Process: Source:Other (urn:alert:source:unclassified)
State: Source:(Other)
    Process: Source:Internal (urn:alert:source:internal)
State: Source:(Other)
Signal: default
```

If the UA receives

```
Alert-Info: <urn:alert:priority:high>,
    <urn:alert:source:internal>
```

then processing progresses:

```
State: Source
    Ignore: urn:alert:priority:high
State: Source
    Process: Source:Internal (urn:alert:source:internal)
State: Source:Internal
Signal: internal source
```

5. Further Examples

5.1. Example with "source" and "priority" URNs

Now consider an example where the UA can signal "external source", "internal source", "low priority", and "high priority" individually or in any combination of source and priority, along with a default signal. This example is essentially the Cartesian product of two copies of the example in Section 4: one dealing with the call's source and one dealing with the call's priority. So there are a total of 9 signals:

Signal	URN(s)
default	(none)
external source	urn:alert:source:external
internal source	urn:alert:source:internal
low priority	urn:alert:priority:low
low priority/external source	urn:alert:priority:low, urn:alert:source:external
low priority/internal source	urn:alert:priority:low, urn:alert:source:internal
high priority	urn:alert:priority:high
high priority/external source	urn:alert:priority:high, urn:alert:source:external
high priority/internal source	urn:alert:priority:high, urn:alert:source:internal

The expressed URNs are:

```
urn:alert:source:external
urn:alert:source:internal
urn:alert:priority:low
urn:alert:priority:high
```

The relevant categories of "alert" URNs are only:

```
source
priority
```

The alphabet of symbols is:

```
Source
Source:External
Source:Internal
Source:Other
Priority
Priority:Low
Priority:High
Priority:Other
```

The 16 states are as follows, where 9 states are "sink" states from which no further information can be recorded, as all transitions from the state lead to itself.

```
State: Priority/Source
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source
    Priority:High -> Priority:High/Source
    Priority:Low -> Priority:Low/Source
    Source:Other -> Priority/Source:(Other)
    Source:External -> Priority/Source:External
    Source:Internal -> Priority/Source:Internal

State: Priority:(Other)/Source
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source
    Priority:High -> Priority:(Other)/Source
    Priority:Low -> Priority:(Other)/Source
    Source:Other -> Priority:(Other)/Source:(Other)
    Source:External -> Priority:(Other)/Source:External
    Source:Internal -> Priority:(Other)/Source:Internal

State: Priority:(Other)/Source:(Other)
Signal: default
Transitions:
    any -> Priority:(Other)/Source:(Other)
```

```
State: Priority:(Other)/Source:External
Signal: external source
Transitions:
    any -> Priority:(Other)/Source:External

State: Priority:(Other)/Source:Internal
Signal: internal source
Transitions:
    any -> Priority:(Other)/Source:Internal

State: Priority:High/Source
Signal: high priority
Transitions:
    Priority:Other -> Priority:High/Source
    Priority:High -> Priority:High/Source
    Priority:Low -> Priority:High/Source
    Source:Other -> Priority:High/Source:(Other)
    Source:External -> Priority:High/Source:External
    Source:Internal -> Priority:High/Source:Internal

State: Priority:High/Source:(Other)
Signal: high priority
Transitions:
    any -> Priority:High/Source:(Other)

State: Priority:High/Source:External
Signal: high priority/external source
Transitions:
    any -> Priority:High/Source:External

State: Priority:High/Source:Internal
Signal: high priority/internal source
Transitions:
    any -> Priority:High/Source:Internal

State: Priority:Low/Source
Signal: low priority
Transitions:
    Priority:Other -> Priority:Low/Source
    Priority:High -> Priority:Low/Source
    Priority:Low -> Priority:Low/Source
    Source:Other -> Priority:Low/Source:(Other)
    Source:External -> Priority:Low/Source:External
    Source:Internal -> Priority:Low/Source:Internal
```

```
State: Priority:Low/Source:(Other)
Signal: low priority
Transitions:
    any -> Priority:Low/Source:(Other)

State: Priority:Low/Source:External
Signal: low priority/external source
Transitions:
    any -> Priority:Low/Source:External

State: Priority:Low/Source:Internal
Signal: low priority/internal source
Transitions:
    any -> Priority:Low/Source:Internal

State: Priority/Source:(Other)
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source:(Other)
    Priority:High -> Priority:High/Source:(Other)
    Priority:Low -> Priority:Low/Source:(Other)
    Source:Other -> Priority/Source:(Other)
    Source:External -> Priority/Source:(Other)
    Source:Internal -> Priority/Source:(Other)

State: Priority/Source:External
Signal: external source
Transitions:
    Priority:Other -> Priority:(Other)/Source:External
    Priority:High -> Priority:High/Source:External
    Priority:Low -> Priority:Low/Source:External
    Source:Other -> Priority/Source:External
    Source:External -> Priority/Source:External
    Source:Internal -> Priority/Source:External

State: Priority/Source:Internal
Signal: internal source
Transitions:
    Priority:Other -> Priority:(Other)/Source:Internal
    Priority:High -> Priority:High/Source:Internal
    Priority:Low -> Priority:Low/Source:Internal
    Source:Other -> Priority/Source:Internal
    Source:External -> Priority/Source:Internal
    Source:Internal -> Priority/Source:Internal
```

An example of processing that involves multiple "source" URNs and one "priority" URN:

```
Alert-Info: <urn:alert:source:internal>,
    <urn:alert:source:unclassified>,
    <urn:alert:priority:high>
```

in which case processing progresses:

```
State: Source/Priority
    Process: Source:Internal (urn:alert:source:internal)
State: Source:Internal/Priority
    Process: Source:(Other) (urn:alert:source:unclassified)
State: Source:Internal/Priority
    Process: Priority:High (urn:alert:priority:high)
State: Source:Internal/Priority:High
Signal: internal source/high priority
```

5.2. Example 1 of RFC 7462

A more complicated example is provided in Section 12.2.1 of [RFC7462]. It is like the example in Section 5.1 of this document, except that the UA can only signal "external source", "internal source", "low priority", and "high priority" individually but not in combination, as well as a default signal:

Signal	URN(s)
default	(none)
internal source	urn:alert:source:external
external source	urn:alert:source:internal
low priority	urn:alert:priority:low
high priority	urn:alert:priority:high

The signals can express the following URNs:

```
urn:alert:source:external
urn:alert:source:internal
urn:alert:priority:low
urn:alert:priority:high
```

The relevant categories of "alert" URNs are:

```
source
priority
```

The alphabet of symbols is:

```
Source
Source:External
Source:Internal
Source:Other
Priority
Priority:Low
Priority:High
Priority:Other
```

In this example, the FSM has 20 states because both "source" and "priority" URNs are recorded, but the order in which the two appear affects the signal:

```
State: Priority/Source
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source
    Priority:High -> Priority:High/Source
    Priority:Low -> Priority:Low/Source
    Source:Other -> Priority/Source:(Other)
    Source:External -> Priority/Source:External
    Source:Internal -> Priority/Source:Internal
```

State Priority:(Other)/Source can transition to states that can signal the source, because the recorded priority can’t be signaled and thus does not block the signaling of the source:

```
State: Priority:(Other)/Source
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source
    Priority:High -> Priority:(Other)/Source
    Priority:Low -> Priority:(Other)/Source
    Source:Other -> Priority:(Other)/Source:(Other)
    Source:External -> Priority:(Other)/Source:External
    Source:Internal -> Priority:(Other)/Source:Internal

State: Priority:(Other)/Source:(Other)
Signal: default
Transitions:
    any -> Priority:(Other)/Source:(Other)

State: Priority:(Other)/Source:External
Signal: external source
Transitions:
    any -> Priority:(Other)/Source:External
```

```
    State: Priority:(Other)/Source:Internal
    Signal: internal source
    Transitions:
        any -> Priority:(Other)/Source:Internal
```

Because there are no signals for combinations of "source" and "priority" URNs, processing a "source" URN from the state Priority:High/Source leads to a state that records the priority information but does not signal it:

```
    State: Priority:High/Source
    Signal: high priority
    Transitions:
        Priority:Other -> Priority:High/Source
        Priority:High -> Priority:High/Source
        Priority:Low -> Priority:High/Source
        Source:Other -> Priority:High/Source:(Other)
        Source:External -> Priority:High/Source:(External)
        Source:Internal -> Priority:High/Source:(Internal)

    State: Priority:High/Source:(Other)
    Signal: high priority
    Transitions:
        any -> Priority:High/Source:(Other)
```

From the state Priority:High/Source, "source" URNs transition to states that record both source and priority but signal only priority, one of which is Priority:High/Source:(External). But from Priority/Source:External, the symbol Priority:High transitions to the state Priority:(High)/Source:External, which records the same information but signals the source, not the priority. One state is reached by processing a "priority" URN and then a "source" URN, whereas the other is reached by processing a "source" URN and then a "priority" URN.

```
    State: Priority:High/Source:(External)
    Signal: high priority
    Transitions:
        any -> Priority:High/Source:(External)

    State: Priority:High/Source:(Internal)
    Signal: high priority
    Transitions:
        any -> Priority:High/Source:(Internal)
```

and similarly for Priority:Low/Source:

```
State: Priority:Low/Source
Signal: low priority
Transitions:
    Priority:Other -> Priority:Low/Source
    Priority:High -> Priority:Low/Source
    Priority:Low -> Priority:Low/Source
    Source:Other -> Priority:Low/Source:(Other)
    Source:External -> Priority:Low/Source:(External)
    Source:Internal -> Priority:Low/Source:(Internal)

State: Priority:Low/Source:(Other)
Signal: low priority
Transitions:
    any -> Priority:Low/Source:(Other)

State: Priority:Low/Source:(External)
Signal: low priority
Transitions:
    any -> Priority:Low/Source:(External)

State: Priority:Low/Source:(Internal)
Signal: low priority
Transitions:
    any -> Priority:Low/Source:(Internal)

State: Priority/Source:(Other)
Signal: default
Transitions:
    Priority:Other -> Priority:(Other)/Source:(Other)
    Priority:High -> Priority:High/Source:(Other)
    Priority:Low -> Priority:Low/Source:(Other)
    Source:Other -> Priority/Source:(Other)
    Source:External -> Priority/Source:(Other)
    Source:Internal -> Priority/Source:(Other)

State: Priority/Source:External
Signal: external source
Transitions:
    Priority:Other -> Priority:(Other)/Source:External
    Priority:High -> Priority:(High)/Source:External
    Priority:Low -> Priority:(Low)/Source:External
    Source:Other -> Priority/Source:External
    Source:External -> Priority/Source:External
    Source:Internal -> Priority/Source:External
```

```
State: Priority:(High)/Source:External
Signal: external source
Transitions:
    any -> Priority:(High)/Source:External

State: Priority:(Low)/Source:External
Signal: external source
Transitions:
    any -> Priority:(Low)/Source:External

State: Priority/Source:Internal
Signal: internal source
Transitions:
    Priority:Other -> Priority:(Other)/Source:Internal
    Priority:High -> Priority:(High)/Source:Internal
    Priority:Low -> Priority:(Low)/Source:Internal
    Source:Other -> Priority/Source:Internal
    Source:External -> Priority/Source:Internal
    Source:Internal -> Priority/Source:Internal

State: Priority:(High)/Source:Internal
Signal: internal source
Transitions:
    any -> Priority:(High)/Source:Internal

State: Priority:(Low)/Source:Internal
Signal: internal source
Transitions:
    any -> Priority:(Low)/Source:Internal
```

As an example of processing, if the UA receives

```
Alert-Info: <urn:alert:source:internal>
```

then processing progresses:

```
State: Priority/Source
    Process: Source:Internal (urn:alert:source:internal)
State: Priority/Source:Internal
Signal: internal source
```

A more complicated example involves multiple "source" URNs that do not select a non-default signal and one "priority" URN that can be signaled:

```
Alert-Info: <urn:alert:source:unclassified>,
    <urn:alert:source:internal>,
    <urn:alert:priority:high>
```

in which case processing progresses:

```
State: Priority/Source
    Process: Source:Other (urn:alert:source:unclassified)
State: Priority/Source:(Other)
    Process: Source:Internal (urn:alert:source:internal)
State: Priority/Source:(Other)
    Process: Priority:High (urn:alert:priority:high)
State: Priority:High/Source:(Other)
Signal: high priority
```

The only output of the FSM is the state’s signal. Based on this, several groups of states in this FSM can be merged using standard FSM optimization algorithms:

```
states with signal "high priority":
    Priority:High/Source
    Priority:High/Source:(Other)
    Priority:High/Source:(External)
    Priority:High/Source:(Internal)

states with signal "low priority":
    Priority:Low/Source
    Priority:Low/Source:(Other)
    Priority:Low/Source:(External)
    Priority:Low/Source:(Internal)

states with signal "external source":
    Priority/Source:External
    Priority:(High)/Source:External
    Priority:(Low)/Source:External
    Priority:(Other)/Source:External

states with signal "internal source":
    Priority/Source:Internal
    Priority:(High)/Source:Internal
    Priority:(Low)/Source:Internal
    Priority:(Other)/Source:Internal
```

This reduces the FSM to eight states:

```
Priority/Source
Priority:(Other)/Source
Priority:(Other)/Source:(Other)
Priority:High/Source  [aggregated]
Priority:Low/Source  [aggregated]
Priority/Source:(Other)
Priority/Source:External  [aggregated]
Priority/Source:Internal  [aggregated]
```

5.3. Examples 2, 3, and 4 of RFC 7462

Examples 2, 3, and 4 of [RFC7462] are similar to the example in Section 5.1 of this document, but they do not include a signal for the combination "internal source, low priority" to make resolution examples work asymmetrically.

The FSM for this example has the same alphabet as the FSM of Section 5.1. Most of the states of this FSM are the same as the states of the FSM of Section 5.1, but the state Source:Internal/Priority:Low is missing because there is no signal for that combination. It is replaced by two states:

1. One state is Source:Internal/Priority:(Low); it records that Source:Internal was specified first (and is to be signaled) and that Priority:Low was specified later (and cannot be signaled -- but it still prevents any further "priority" URNs from having an effect).

2. The other state is Source:(Internal)/Priority:Low; it records the reverse sequence of events.

The changes in the FSM are:

```
State: Priority:Low/Source
Signal: low priority
Transitions:
    Source:Internal -> Priority:Low/Source:(Internal)
    (other transitions unchanged)

State: Priority:Low/Source:(Internal)
Signal: low priority
Transitions:
    any -> Priority:Low/Source:(Internal)
```

```
    State: Priority/Source:Internal
    Signal: internal source
    Transitions:
        Priority:Low -> Priority:(Low)/Source:Internal
        (other transitions unchanged)

    State: Priority:(Low)/Source:Internal
    Signal: internal source
    Transitions:
        any -> Priority:(Low)/Source:Internal
```

An example of processing that involves multiple "source" URNs and one "priority" URN:

```
    Alert-Info: <urn:alert:source:internal>,
        <urn:alert:source:unclassified>,
        <urn:alert:priority:high>
```

then processing progresses:

```
    State: Priority/Source
        Process: Source:Internal (urn:alert:source:internal)
    State: Priority/Source:Internal
        Process: Source:Other (urn:alert:source:unclassified)
    State: Priority/Source:Internal
        Process: Priority:High (urn:alert:priority:high)
    State: Priority:High/Source:Internal
    Signal: internal source/high priority
```

If the UA receives

```
    Alert-Info: <urn:alert:source:internal>
```

then processing progresses:

```
    State: Priority/Source
        Process: Source:Internal (urn:alert:source:internal)
    State: Priority/Source:Internal
    Signal: internal source
```

If the UA receives

```
Alert-Info: <urn:alert:source:external>,
    <urn:alert:priority:low>
```

then processing progresses:

```
Alert-Info: <urn:alert:source:external>,
    <urn:alert:priority:low>
State: Priority/Source
    Process: Source:External (urn:alert:source:external)
State: Priority/Source:External
    Process: Priority:Low (urn:alert:priority:low)
State: Priority:Low/Source:External
Signal: external source/low priority
```

Suppose the same UA receives

```
Alert-Info: <urn:alert:source:internal>,
    <urn:alert:priority:low>
```

Note that there is no signal that corresponds to this combination. In that case, the processing is:

```
Alert-Info: <urn:alert:source:internal>,
    <urn:alert:priority:low>
State: Priority/Source
    Process: Source:Internal (urn:alert:source:internal)
State: Priority/Source:Internal
    Process: Priority:Low (urn:alert:priority:low)
State: Priority:(Low)/Source:Internal
Signal: internal source
```

If the order of the URNs is reversed, what is signaled is the meaning of the now-different first URN:

```
Alert-Info: <urn:alert:priority:low>,
    <urn:alert:source:internal>

State: Priority/Source
    Process: Priority:Low (urn:alert:priority:low)
State: Priority:Low/Source
    Process: Source:Internal (urn:alert:source:internal)
State: Priority:Low/Source:(Internal)
Signal: low priority
```

Notice that the existence of the new states prevents later URNs of a category from overriding earlier URNs of that category, even if the earlier one was not itself signalable and the later one would be signalable in the absence of the earlier one:

```
Alert-Info: <urn:alert:priority:low>,
    <urn:alert:source:internal>,
    <urn:alert:source:external>

State: Priority/Source
    Process: Priority:Low (urn:alert:priority:low)
State: Priority:Low/Source
    Process: Source:Internal (urn:alert:source:internal)
State: Priority:Low/Source:(Internal)
    Process: Source:External (urn:alert:source:external)
State: Priority:Low/Source:(Internal)
Signal: low priority
```

This situation shows the necessity of states whose labels contain parentheses. If the second transition had been to the state Priority:Low/Source (on the basis that there is no proper state Priority:Low/Source:Internal), then the third transition would have been to the state Priority:Low/Source:External, and the signal would have been "external source/low priority".

5.4. An Example That Subsets Internal Sources

In the example of Section 4, there are signals for "external source" and "internal source". Let us add to that example a signal for "source internal from a VIP (Very Important Person)". That last signal expresses the private extension URN urn:alert:source:internal:vip@example, which is a subset of urn:alert:source:internal, which is expressed by the "source internal" signal. There are a total of three expressed URNs, one of which is a subset of another:

```
urn:alert:source:internal
urn:alert:source:internal:vip@example
urn:alert:source:external
```

This generates the following alphabet of symbols, which includes two "Other" symbols for the "source" category:

```
Source
Source:Internal
Source:Internal:Vip@example
Source:Internal:Other
Source:Other
```

5.5. An Example of "alert:service" URNs

In this example, there are signals for "service forward" (the call has been forwarded) and "source recall callback" (a recall due to a callback). This gives two expressed URNs:

```
urn:alert:service:forward
urn:alert:service:recall:callback
```

This generates the following alphabet of symbols. Note that there are two "Other" symbols, because the "alert:service" URNs have an additional level of qualification.

```
Service
Service:Forward
Service:Recall
Service:Recall:Callback
Service:Recall:Other
Service:Other
```

5.6. An Example Using Country Codes

In this example, we consider how a UA generates ringback signals when the UA wishes to reproduce the traditional behavior where the caller hears the ringback signals defined by the telephone service in the callee’s country rather than the ringback signals defined by the service in the caller’s country. In the Alert-Info header field of the 180 (Ringing) provisional response, we assume that the called UA provides an "alert:country" URN [RFC7462] containing the ISO 3166-1 [ISO-3166-1] alpha-2 country code of the callee’s country.

The UA has a default signal and a "non-country" signal for urn:alert:service:call-waiting. For the example country with code "XA", the UA has a default signal and signals for urn:alert:service:call-waiting and urn:alert:service:forward. For the example country with code "XB", the UA has a default signal and a signal for urn:alert:service:forward. These inconsistencies between the non-country signals and the country signals are chosen to demonstrate the flexibility of the construction method, showing that three systems of signals can be combined correctly even when the systems were established without coordination between them.

The signals are:

Signal	URN(s)
default	(none)
call-waiting	urn:alert:service:call-waiting
XA default	urn:alert:country:xa
XA call-waiting	urn:alert:country:xa, urn:alert:service:call-waiting
XA forward	urn:alert:country:xa, urn:alert:service:forward
XB default	urn:alert:country:xb
XB forward	urn:alert:country:xb, urn:alert:service:forward

The expressed URNs are:

```
urn:alert:country:xa
urn:alert:country:xb
urn:alert:service:call-waiting
urn:alert:service:forward
```

The relevant categories of "alert" URNs are only:

```
country
service
```

The alphabet of symbols is:

```
Country
Country:[other]
Country:Xa
Country:Xb
Service
Service:[other]
Service:Call-waiting
Service:Forward
```

The 17 states are as follows:

```
    State: 0 Country/Service
    Signal: default
    Transitions:
        Country:[other] -> 1 Country:([other])/Service
        Country:Xa -> 5 Country:Xa/Service
        Country:Xb -> 9 Country:Xb/Service
        Service:[other] -> 13 Country/Service:([other])
        Service:Call-waiting -> 14 Country/Service:Call-waiting
        Service:Forward -> 16 Country/Service:(Forward)

 State: 1 Country:([other])/Service
 Signal: default
 Transitions:
     Country:[other] -> 1 Country:([other])/Service
     Country:Xa -> 1 Country:([other])/Service
     Country:Xb -> 1 Country:([other])/Service
     Service:[other] -> 2 Country:([other])/Service:([other])
     Service:Call-waiting -> 3 Country:([other])/Service:Call-waiting
     Service:Forward -> 4 Country:([other])/Service:(Forward)

    State: 2 Country:([other])/Service:([other])
    Signal: default
    Transitions:
        any -> 2 Country:([other])/Service:([other])

    State: 3 Country:([other])/Service:Call-waiting
    Signal: call-waiting
    Transitions:
        any -> 3 Country:([other])/Service:Call-waiting

    State: 4 Country:([other])/Service:(Forward)
    Signal: default
    Transitions:
        any -> 4 Country:([other])/Service:(Forward)

    State: 5 Country:Xa/Service
    Signal: XA default
    Transitions:
        Country:[other] -> 5 Country:Xa/Service
        Country:Xa -> 5 Country:Xa/Service
        Country:Xb -> 5 Country:Xa/Service
        Service:[other] -> 6 Country:Xa/Service:([other])
        Service:Call-waiting -> 7 Country:Xa/Service:Call-waiting
        Service:Forward -> 8 Country:Xa/Service:Forward
```

```
State: 6 Country:Xa/Service:([other])
Signal: XA default
Transitions:
    any -> 6 Country:Xa/Service:([other])

State: 7 Country:Xa/Service:Call-waiting
Signal: XA call-waiting
Transitions:
    any -> 7 Country:Xa/Service:Call-waiting

State: 8 Country:Xa/Service:Forward
Signal: XA forward
Transitions:
    any -> 8 Country:Xa/Service:Forward

State: 9 Country:Xb/Service
Signal: XB default
Transitions:
    Country:[other] -> 9 Country:Xb/Service
    Country:Xa -> 9 Country:Xb/Service
    Country:Xb -> 9 Country:Xb/Service
    Service:[other] -> 10 Country:Xb/Service:([other])
    Service:Call-waiting -> 11 Country:Xb/Service:(Call-waiting)
    Service:Forward -> 12 Country:Xb/Service:Forward

State: 10 Country:Xb/Service:([other])
Signal: XB default
Transitions:
    any -> 10 Country:Xb/Service:([other])

State: 11 Country:Xb/Service:(Call-waiting)
Signal: XB default
Transitions:
    any -> 11 Country:Xb/Service:(Call-waiting)

State: 12 Country:Xb/Service:Forward
Signal: XB forward
Transitions:
    any -> 12 Country:Xb/Service:Forward
```

```
      State: 13 Country/Service:([other])
      Signal: default
      Transitions:
          Country:[other] -> 2 Country:([other])/Service:([other])
          Country:Xa -> 6 Country:Xa/Service:([other])
          Country:Xb -> 10 Country:Xb/Service:([other])
          Service:[other] -> 13 Country/Service:([other])
          Service:Call-waiting -> 13 Country/Service:([other])
          Service:Forward -> 13 Country/Service:([other])

      State: 14 Country/Service:Call-waiting
      Signal: call-waiting
      Transitions:
          Country:[other] -> 3 Country:([other])/Service:Call-waiting
          Country:Xa -> 7 Country:Xa/Service:Call-waiting
          Country:Xb -> 15 Country:(Xb)/Service:Call-waiting
          Service:[other] -> 14 Country/Service:Call-waiting
          Service:Call-waiting -> 14 Country/Service:Call-waiting
          Service:Forward -> 14 Country/Service:Call-waiting

      State: 15 Country:(Xb)/Service:Call-waiting
      Signal: call-waiting
      Transitions:
          any -> 15 Country:(Xb)/Service:Call-waiting

      State: 16 Country/Service:(Forward)
      Signal: default
      Transitions:
          Country:[other] -> 4 Country:([other])/Service:(Forward)
          Country:Xa -> 8 Country:Xa/Service:Forward
          Country:Xb -> 12 Country:Xb/Service:Forward
          Service:[other] -> 16 Country/Service:(Forward)
          Service:Call-waiting -> 16 Country/Service:(Forward)
          Service:Forward -> 16 Country/Service:(Forward)
```

Call-waiting can be signaled in conjunction with country XA but not in conjunction with country XB, as the UA does not have a signal to present call-waiting alerts for country XB. Thus, the ordering of urn:alert:service:call-waiting with urn:alert:country:xa does not matter, but if urn:alert:country:xb appears before urn:alert:service:call-waiting, call-waiting cannot be signaled.

On the other hand, if urn:alert:service:call-waiting appears before urn:alert:country:xb, then call-waiting is signaled, but using the non-country signal.

```
Alert-Info: urn:alert:country:xa,
        urn:alert:service:call-waiting

State: 0 Country/Service
    Process: Country:Xa (urn:alert:country:xa)
State: 5 Country:Xa/Service
    Process: Service:Call-waiting (urn:alert:service:call-waiting)
State: 7 Country:Xa/Service:Call-waiting
Signal: XA call-waiting

Alert-Info: urn:alert:service:call-waiting,
        urn:alert:country:xa

State: 0 Country/Service
    Process: Service:Call-waiting (urn:alert:service:call-waiting)
State: 14 Country/Service:Call-waiting
    Process: Country:Xa (urn:alert:country:xa)
State: 7 Country:Xa/Service:Call-waiting
Signal: XA call-waiting

Alert-Info: urn:alert:country:xb,
        urn:alert:service:call-waiting

State: 0 Country/Service
    Process: Country:Xb (urn:alert:country:xb)
State: 9 Country:Xb/Service
    Process: Service:Call-waiting (urn:alert:service:call-waiting)
State: 11 Country:Xb/Service:(Call-waiting)
Signal: XB default

Alert-Info: urn:alert:service:call-waiting,
        urn:alert:country:xb

State: 0 Country/Service
    Process: Service:Call-waiting (urn:alert:service:call-waiting)
State: 14 Country/Service:Call-waiting
    Process: Country:Xb (urn:alert:country:xb)
State: 15 Country:(Xb)/Service:Call-waiting
Signal: call-waiting
```

6. Prioritizing Signals

The specifications provided in [RFC7462] are oriented toward giving the sender of Alert-Info control over which of the "alert" URNs are most important. But in some situations, the UA may prefer to prioritize expressing one URN category over another regardless of the order in which their URNs appear in Alert-Info. This section describes how that can be accommodated within the framework of [RFC7462] and presents an example FSM resulting from that approach.

This example uses the signals of Section 5.2, viz., "external source", "internal source", "low priority", and "high priority", but this time, we want to signal "high priority" in preference to any other signal that might be applicable.

We accommodate this within the framework of [RFC7462] by assigning the signal "high priority" for each of these combinations of URNs:

```
urn:alert:priority:high
urn:alert:priority:high, urn:alert:source:internal
urn:alert:priority:high, urn:alert:source:external
```

The result is that the signal "high priority" is the "best" signal for any combination of urn:alert:priority:high with "source" URNs.

Constructing the symbols produces the same results as before. The signals can express the following URNs:

```
urn:alert:source:external
urn:alert:source:internal
urn:alert:priority:low
urn:alert:priority:high
```

The relevant categories of "alert" URNs are:

```
source
priority
```

The alphabet of symbols is:

```
Source
Source:External
Source:Internal
Source:Other
Priority
Priority:Low
Priority:High
Priority:Other
```

When the FSM is constructed, it is the same as the FSM of Section 5.2, except that certain states are effectively renamed and merged, because any "source" is defined to be expressed if high priority is expressed:

```
Priority:(High)/Source:External and
Priority:High/Source:(External) become:

    State: Priority:High/Source:External
    Signal: high priority

Priority:(High)/Source:Internal and
Priority:High/Source:(Internal) become:

    State: Priority:High/Source:Internal
    Signal: high priority
```

This reduces the FSM to 18 states. In addition, these two new states, along with a number of other states, can be merged by FSM optimization, since all of them have the signal "high priority" and from them, there are no transitions to states outside this set. The optimized FSM has 10 states.

7. Dynamic Sets of Signals

This section discusses how to construct FSMs for a UA that allows variable sets of signals -- for example, if the user can configure the use of ring tones. Several approaches can be used:

- Whenever the set of ring tones is changed, re-execute the processes of Section 4.
- Whenever the set of ring tones is changed, rebuild the list of expressed URNs (Section 4.1) and reconstruct the alphabet of symbols (Section 4.2). Then, use an algorithm for dynamically constructing the states of the FSM as needed during Alert-Info processing.
- If the sets of possible URNs expressed by the ring tones are sufficiently limited, the steps of Section 4 can be carried out "generically", and the generic FSM can be specialized for the current ring tone configuration.

The remainder of this section gives an example of the third approach.

For the example, we will use a set of ring tones that express the identity of the caller. To signal this information, a private extension "alert" URN category, "caller@example", is used:

```
urn:alert:caller@example:alice@example.com
urn:alert:caller@example:bob@example.com
etc.
```

which we can express by the generic pattern

```
urn:alert:caller@example:IDENTITY
```

where "IDENTITY" is replaced in succession by the set of caller identities that have their own ring tones to generate the set of expressed URNs.

The alphabet is then:

```
Caller@example
Caller@example:IDENTITY
Caller@example:Other
```

where "IDENTITY" is replaced in succession by the set of caller identities. The "Caller@example:Other" symbol includes all URNs of the category "caller@example" that are not included in any of the "Caller@example:IDENTITY" symbols, i.e, where the second alert-ind-part is not one of the known caller identities.

The states and transitions of the FSM are:

```
State: Caller@example (initial state)
Signal: default
Transitions:
    Caller@example:IDENTITY -> Caller@example:IDENTITY
    Caller@example:Other -> Caller@example:(Other)

State: Caller@example:IDENTITY
Signal: signal for caller IDENTITY
Transitions:
    any -> Caller@example:IDENTITY

State: Caller@example:(Other)
Signal: default
Transitions:
    any -> Caller@example:(Other)
```

where again, the second state is replicated once for each caller identity that has a ring tone, with "IDENTITY" replaced with the caller identity.

8. Security Considerations

The security considerations discussed in Section 16 of [RFC7462] regarding the use and processing of "alert" URNs MUST be followed when the algorithm described in this document is used.

Like any implementation of [RFC7462], implementations of the algorithm defined in this document MUST take into account that the value of a received Alert-Info header field may contain URIs of any scheme, may contain syntactically invalid values, and may be syntactically invalid overall. The handling of syntactically invalid values is specified by [RFC3261]. The handling of URIs other than "alert" URIs is outside the scope of this document (and outside the scope of [RFC7462]) and MAY be subject to local policy.

Like the algorithm described in Section 12 of [RFC7462], the output of the algorithm defined in this document is limited to a choice among the signals that it has been configured for, limiting the security issues regarding the processing of its output. This algorithm will use at most linear time and constant space to process a sequence of "alert" URNs. This is significantly more efficient than the algorithm of [RFC7462] and minimizes the security vulnerabilities of this processing step that are due to resource consumption.

However, the process defined in this document for constructing an FSM can use more than linear time and constant space -- probably exponential time and space in the worst case. This SHOULD be taken into consideration whenever an FSM is constructed using this algorithm and MUST be taken into consideration when it is done dynamically by a UA. Whenever an FSM is constructed by a process that is not under the direct supervision of a human user, procedures MUST be used to ensure that (1) the processing and memory consumption are limited to acceptable amounts and (2) if the FSM construction is aborted due to excessive consumption, the designated consumers of the FSM MUST have appropriate fallback procedures.

9. IANA Considerations

This document has no IANA actions.

10. References

10.1. Normative References

[ISO-3166-1] International Organization for Standardization, "Codes for the representation of names of countries and their subdivisions -- Part 1: Country codes", ISO Standard 3166-1:2013, November 2013, <https://www.iso.org/iso-3166-country-codes.html>.

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10.2. Informative References

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