GARP Stream Reservation Protocol

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Document Revision History

V0.4	2006/02/28	Changes to Reservation Information Elements (Ch.3.d), Reservation PDU (4.3.1.5.3.d), and Reception of Reservation messages (4.4.1) to solve the false TIMEOUT bug: if the Registration was flooded, then the unintended branch will finally return back a TIMEOUT. This TIMEOUT should not falsely impact the established reservation status by the Talker. *Capitalization changes (To be done).*

1. Introduction

The application of current IEEE 802 technologies for high quality time sensitive streaming allows users to load their networks unknowingly to the extent that the user experience is negatively impacted. To provide the robust guaranteed quality of service (QoS) capability for streaming applications, firstly the availability of network resources along the entire data path should be assured before transmission takes place. This requires the definition of traffic stream descriptors and a protocol to signal the resource reservation along the end-to-end path of streams.

Former Residential Ethernet Study Group has considered several subscription protocol approaches. Common design targets include simplicity and friendliness to existing Bridged LAN. For the sake of the simplicity the subscription protocol is confined to scenarios with homogenous one-to-many Streams. More specifically, each Stream has only one Talker, and every Listeners of the Stream have the same resource requirement on the paths from the Talker to themselves.

This document reflects an initial proposal on the resource reservation work. It is contributed to the meeting as background information for the proposed PAR for the standardization of a Stream Reservation Protocol. It covers the areas that should be addressed by the proposed project: protocols, procedures and management elements to enable the end-to-end management of resource reservation for QoS guaranteed streams. It is based on existing IEEE802.1D specification with following extensions:

a) Stream admission control and resource reservation service that should be provided by a MAC entity to the MAC Relay Entity within a Bridge. It can be provided by the individual MAC for the LAN port by using MAC management service on the MAC layer management entity service access point (MLME-SAP). The service primitives provide an interface to allocate or de-allocate local resources on the MAC for any given stream.

   NOTE—The support of the Stream admission control and resource reservation service will depend on each specific MAC IEEE 802 MAC type. Existing examples for these primitives are MLME_ADDTS/DELTS primitives in IEEE802.11e, MLME_xxx_STREAM primitives in IEEE802.15.3, and MLME_GTS primitives in IEEE802.15.4.

b) A new type of entry in Filtering Database named Stream Registration Entry. It allows control of Forwarding of frames associated with particular Stream. Stream Registration Entries are created, modified and deleted by the operation of GARP Stream Reservation Protocol (GSRP).

c) A new application of GARP named GARP Stream Reservation Protocol (GSRP). It facilitates the registration, de-registration and related maintenance operations of Stream reservation information in relevant bridges to establish end-to-end Stream path.

Figure 1-1 illustrates the components of GSRP Participants in a Bridge.

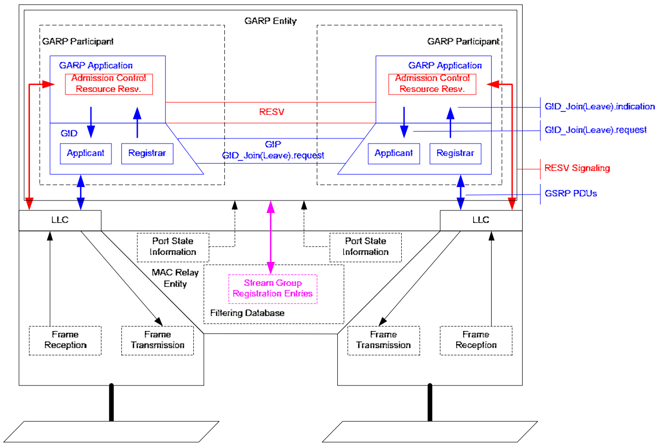

Figure 1-1 GSRP architecture

Compared with other approaches this proposal has the significant advantage of combining simplicity with rich functionality. A large part of the signaling reuses the established GARP specifications and only one new Reservation Message and corresponding processes need to be defined. It can provide explicit acknowledgement using the newly defined Reservation Message. The soft-state characteristic provides graceful and robust support for dynamic membership changes, topology changes and reservation request changes. It is extendable to flexible reservation scenarios and applicable in hybrid networks where Residential Bridges and legacy bridges coexist.

The rest of this document is organized as follows. Section 2 gives the specification for Stream admission control and resource reservation primitives. It could be integrated into 6.4 “Internal Sublayer Service provided with the MAC Bridge” of IEEE Std 802.1D. Section 3 describes the structure of Stream Registration Entries. From the standard documentation point of view, it is intended to be a subclause in 7.9 “The Filtering Database” of IEEE Std 802.1D, parallel to 7.9.1 “Static Filtering Entries”, 7.9.2 “Dynamic Filtering Entries” and 7.9.3 “Group Registration Entries”. In Section 4 we specify the GARP Stream Reservation Protocol, which is a new application of GARP and intended to be a clause parallel to Clause 10 “GARP Multicast Registration Protocol (GMRP)” in IEEE Std 802.1D. A preliminary verification work for GSRP signaling is demonstrated in Section 5.

2 Stream Admission Control and Resource Reservation (ACRR) Service

This section gives the specification for Stream Admission Control and Resource Reservation primitives. It could be integrated into 6.4 “Internal Sublayer Service provided with the MAC Bridge” of IEEE Std 802.1D.

ACRR service is provided by the individual MAC for the LAN port by using MAC management service on the MAC layer management entity service access point (MLME-SAP). The service primitives provide an interface to allocate or de-allocate local resources on the MAC for any given stream. Figure 2-1 depicts the reference model of MLME-SAP.

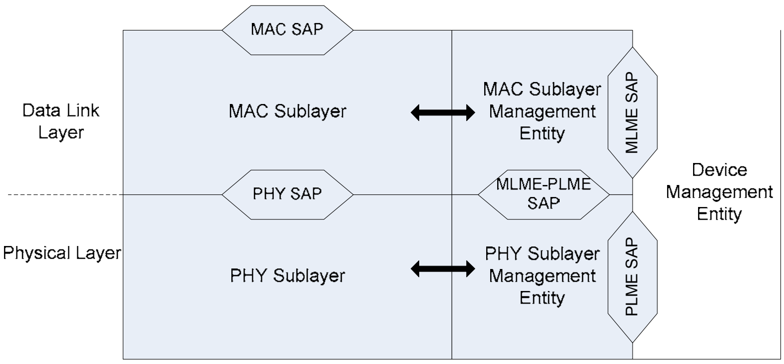

Figure 4-1 GSRP PDU structure

The support of the Stream admission control and resource reservation service will depend on each specific MAC IEEE 802 MAC type. Existing examples for primitives mapping are MLME_ADDTS/DELTS primitives in IEEE802.11e, MLME_xxx_STREAM primitives in IEEE802.15.3, and MLME_GTS primitives in IEEE802.15.4.

The primitives supported by Stream ACRR Services are

```
ACRR_ADD_STREAM.request        {    Stream Identifier,
                                    Resource Requirement
                               }
```

The Stream Identifier parameter is the identifier of a Stream.

The Resource Requirement parameter indicates the resource expected to be reserved by a Stream.
TBD—The detail format of Resource Requirement depends on the specification method of traffic profile.

```
ACRR_ADD_STREAM.response       {    Stream Identifier,
                                    Result Code
                               }
```

The Stream Identifier parameter is the identifier of a Stream.

The Result Code indicates the reservation results for a Stream.

ACRR_TEAR_STREAM.request { Stream Identifier
}

The Stream Identifier parameter is the identifier of a Stream.

ACRR_TEAR_STREAM.confirm { Stream Identifier,
Result Code
}

The Stream Identifier parameter is the identifier of a Stream.

The Result Code indicates the results of teardown operation for a Stream.

3 Stream Registration Entries

This section describes the structure of Stream Registration Entries. From the standard documentation point of view, it is intended to be a subclause in 7.9 “The Filtering Database” of IEEE Std 802.1D, parallel to 7.9.1 “Static Filtering Entries”, 7.9.2 “Dynamic Filtering Entries” and 7.9.3 “Group Registration Entries”.

A Stream Registration Entry specifies

a) The Stream Identifier to which the dynamic filtering information applies;
b) A Reservation Message Port Map consisting of a control element for each outbound Port that specifies forwarding or filtering of Reservation messages signaling frames of the Stream. The initial value shall be filtering.
c) A Stream Data Port Map consisting of a control element for each outbound port that specifies forwarding or filtering of Stream data frames of the Stream. The initial value shall be filtering.
d) A Reservation Information Element consisting of following components:
    1) Resource Requirement.
    2) Inbound Port.
    3) Reservation Status. The permitted values and their meanings for this field are as follows:

        0: INITIAL
        1: TIMEOUT
        2: FAILED
        3: SUCCEEDED

    The default value shall be 0.

Stream Registration Entries are created, modified and deleted by the operation of GSRP. No more than one Stream Registration Entry shall be created in the Filtering Database for a given Stream Identifier specification.

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<#>TIMEOUT¶
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<#>SUCCEEDED¶

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4. GARP Stream Reservation Protocol (GSRP)

This section describes the GARP Stream Reservation Protocol, which is a new application of GARP and intended to be a clause parallel to Clause 10 “GARP Multicast Registration Protocol (GMRP)” in IEEE Std 802.1D.

4.1 Purpose

The GARP (Generic Attribute Registration Protocol) Stream Reservation Protocol (GSRP) provides a mechanism for dynamic maintenance of the contents of Stream Registration Entries, and for propagating the information they contain to other Bridges. This information allows GSRP-aware devices to dynamically establish and update their knowledge of the set of Streams that currently have active Listeners, and through which ports those Listeners can be reached. This information further allows indications to relevant Bridges that corresponding forwarding resources should be reserved or released for specific traffic streams. The operation of GSRP relies upon the services provided by GARP, defined in Clause 12 of IEEE Std 802.1D.

NOTE—The enforcement of the forwarding resources reservation/release is out of the scope of GSRP.

GSRP consists of two parts: a Registration Part and a Reservation Part. These two parts provide mechanisms for dynamic maintenance of the Reservation Message Port Map and Stream Data Port Map of Stream Registration Entries, respectively. The structure of Stream Registration Entries is described in Section 3.

The operation of registration part of GSRP is closely similar to the operation of GMRP (IEEE Std 802.1D, Clause 10).The information registered, de-registered, and disseminated via the registration part of GSRP is in the following forms:

a) *Stream membership information*. This indicates the presence of GSRP participants that are Listeners of a particular Stream, and carries the Identifier(es) associated with the Stream(s). The exchange of specific Stream membership information can result in the creation or updating of Stream Registration Entries (more specifically, the Reservation Message Port Map) in the Filtering Database to indicate the Port(s) on which Listeners of the Stream(s) have been registered.

The operation of the registration part can result in the propagation of Stream membership information, and consequent creation, updating, or deletion of Stream Registration Entries in the Filtering Databases of relevant Bridges in the network.

Registration of Stream membership information makes Bridges aware that Reservation messages destined for the Stream concerned should only be forwarded in the direction of the registered members of the Stream. Therefore, forwarding of Reservation messages destined for that Stream occurs only on Ports on which such membership registration has been received.

The reservation part of GSRP operates on the reception and generation of Reservation messages. The structure of Reservation messages is described in 4.3.1.5. The reception of Reservation messages indicates Bridges that corresponding forwarding resources should be reserved for the Stream concerned. Forwarding of frames destined for the Identifier associated with the Stream concerned occurs only on Ports on which such membership registration has been received and forwarding resources has been successfully reserved.

4.2 Model of operation

GSRP defines a *GARP Application*. It makes use of following services defined in GARP:

a) The declaration and propagation services offered by GARP Information Distribution (GID) and GARP Information Propagation (GIP) to declare and propagate Stream membership information within the Bridged Local Area Network.
b) The registration services offered by GID to allow Stream membership information to control the Reservation frame filtering behavior of participating devices.

GSRP further defines operation rules for Reservation messages which trigger the admission control and reservation operations in participating devices and serves as end-to-end acknowledgement and negative acknowledgement for Listeners.

4.2.1 Source pruning

For each Stream concerned, the operation of GSRP defines two subtrees of the Spanning Tree as a result of the creation of Stream Registration Entries in the Filtering Databases of the Bridges. One is defined by the Reservation Message Port Map and the other is defined by the Stream Data Port Map. End stations shall make use of the Stream Membership information registered via GSRP to allow them to keep track of the set of Streams for which active Listeners currently exist and their resource reservation statuses. End stations that are sources of Streams shall:

a) suppress the transmission of Reservation messages if the Reservation Message Port Map of their registered Stream membership indicates that there are no valid Listeners reachable via the LANs to which they are attached;
b) suppress the transmission of Stream Data frames if the Stream Data Port Map of their registered Stream membership indicates that there are no valid Listeners reachable via the LANs to which they are attached; This end system behavior is known as *source pruning*.

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NOTE—In effect, for the purposes of frame transmission, the end station can be viewed as if it operates as a single Port Bridge, with its own "Filtering Database" entries updated via GSRP. In order to achieve this, it is necessary for the end station to implement both the Registrar and the Applicant functionality of GARP. The Applicant Only and Simple-Applicant Participants do not contain the Registrar functionality that would be required for source pruning.

4.3 Definition of the GSRP Application

4.3.1 Definition of GARP protocol elements

4.3.1.1 Use of GIP Contexts by GSRP

Since the Stream membership information carries the MAC Address of the Talker concerned (4.3.1.4), the GIP Contexts used by GSRP can be refined to be a subset of Base Spanning Tree Context. This refined Context identifies the set of Bridge Ports that are forwarding ports for the Talker MAC Addresses concerned according to the Bridge Filtering Database.

4.3.1.2 GSRP Application address

The group MAC Address used as the destination address for GARP PDUs destined for GSRP Participants shall be the GSRP address identified in Table 4-1. Received PDUs that are constructed in accordance with the PDU format defined in IEEE Std 802.1D, 12.11, and which carry a destination MAC Address equal to the GSRP address are processed as follows:

a) In Bridges and end stations that support the operation of GSRP, all such PDUs shall be submitted to the GSRP participant associated with the receiving Port for further processing.
b) In Bridges that do not support the operation of GSRP, all such PDUs shall be submitted to the Forwarding Process.

Table 4-1 GSRP Application address

Assignment	Value
GSRP address	xx-xx-xx-xx-xx-xx

4.3.1.3 Encoding of GSRP Attribute Types

GSRP defines a single Attribute Types that are carried in GARP protocol exchanges: the Stream Attribute Type. The Stream Attribute Type is used to identify values of Stream Identifiers and values of Talker MAC Addresses. The value of the Stream Attribute Type carried in GARP PDUs shall be 1.

4.3.1.4 Encoding of GSRP Attribute Values

Values of instances of the Stream Attribute Type shall be encoded as Attribute Values in GARP PDUs as XX octets, each taken to represent an unsigned binary number. Each attribute value shall have the following structure and parameters as shown in Figure 4-1.

	Octet
Stream Identifier	x-x
Talker MAC Address	x-x

Figure 4-1 GSRP PDU structure

Although the Talker MAC Address component is included in GSRP PDU, from the point of view of GSRP Registration Part, Talker MAC Address component has no impact on the number of Applicant State Machines and Registrar State Machines. Only one Applicant State Machine and one Registrar State Machine shall be kept in a GID instance for any certain value of Stream Identifier, no matter what Talker MAC Address value the GSRP PDUs carries.

4.3.1.5 Reservation messages

All GSRP applications use a unique group MAC Address as the destination address of Reservation PDUs. Table 4-2 specifies this unique group MAC Address.

Table 4-2 Reservation PDU address

Assignment	Value
Reservation PDU address	xx-xx-xx-xx-xx-xx

The transmission and reception of Reservation PDUs between GSRP Participants shall use LLC Type 1 procedures. The standard Bridge Spanning Tree Protocol LLC Address in Table 7-9 of IEEE Std 802.1D shall be used as the source and destination LLC address.

Reservation PDUs, i.e., frames with the destination MAC and LLC addresses as specified in this subclause that are not well formed (i.e., are not structured and encoded as defined in this subclause) shall be discarded on receipt.

4.3.1.5.1 Transmission and representation of octets

All Reservation PDUs shall contain an integral number of octets. The octets in a Reservation PDUs are numbered starting from 1 and increasing in the order they are put into a Data Link Service Data Unit (DLSDU). The bits in an octet are numbered from 1 to 8, where 1 is the less significant bit.

When consecutive bits within an octet are used to represent a binary number, the higher bit number has the most significant value. When consecutive octets are used to represent a binary number, the lower octet number has the most significant value.

4.3.1.5.2 Structure definition

A Protocol Identifier is encoded in the initial octets of all Reservation PDUs. This standard specifies a single Protocol Identifier value for identify the GSRP Reservation messages. Reservation PDUs operating the Protocol specified in this clause carry this reserved Protocol Identifier value, and shall have the following structure as shown in Figure 4-2.

	Octet
Protocol Identifier	1-2
Stream Identifier	x-x
Resource Requirement	x-x
Reservation Status	x-x
Reserved	x-x

Figure 4-2 Reservation PDU structure

4.3.1.5.3 Reservation PDU parameters

a) The Protocol Identifier is encoded in Octets 1 and 2, taken to represent an unsigned binary number. It takes the value 0x0002.

b) The Stream Identifier is encoded in Octets x-x, taken to represent an unsigned binary number.

c) The Resource Requirement is encoded in Octets x-x.

TBD—The detail format of Resource Requirement depends on the specification method of traffic profile.

d) The Reservation Status is encoded in Octets x-x, taken to represent a binary integer. The permitted values and their meanings of the Reservation Status are as follows:

1: TIMEOUT

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2: FAILED
3: SUCCEEDED

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e) Reserved fields for future extensions

4.3.2 Provision and support of Stream Filtering Services

4.3.2.1 End system registration and de-registration

The GSRP Application element of a GARP Participant provides the dynamic registration and de-registration services as follows:

On receipt of a REGISTRATION_STREAM_MEMBER service primitive, the GSRP Participant issues a GID_Join.request. The attribute_type parameter of the request carries the value of the Stream Attribute Type (4.3.1.3) and the attribute_value parameter carries the value of the TALKER_MAC_ADDRESS and STREAM_IDENTIFIER parameters of the service primitive.

On receipt of a DEREGISTRATION_STREAM_MEMBER service primitive, the GSRP Participant issues a GID_Leave.request. The attribute_type parameter of the request carries the value of the Stream Attribute Type (4.3.1.3) and the attribute_value parameter carries the value of the TALKER_MAC_ADDRESS and STREAM_IDENTIFIER parameters of the service primitive.

4.3.2.2 Registration and de-registration events

The GSRP Application element of a GARP Participant responds to registration and de-registration events signalled by GID as follows:

On receipt of a GID_Join.indication whose attribute_type is equal to the value of the Stream Attribute Type (4.3.1.3),

a) The GSRP Application element specifies the Port associated with the GSRP Participant as Forwarding in the Reservation Message Port Map of the Stream Registration Entry for the Stream Identifier specification carried in the Stream_Identifier component of attribute_value parameter. If such a Stream Registration Entry does not exist in the Filtering Database, a new Stream Registration Entry is created, and a Resvtimer is started for the Stream (4.4.2).
b) If the Talker MAC Address component of the Attribute Value associated with the registration event equals to a local MAC Address, which indicates local node is the Talker of the associated Stream, then the Reservation Information element shall be set as follows when the Stream Registration Entry is created:

    1) The Resource Requirement is provided by the upper layer application of the Stream.
    2) The Reservation Status is set to SUCCEEDED or FAILED according to the result of Talker local initialization procedures.

c) If the Reservation Status field in Reservation Information of the Stream Registration Entry for the associated Stream has a value of TIMEOUT or FAILED, a Reservation Message shall be sent out of the Port associated with the GSRP Participant. The Stream Identifier, Resource Requirement, and Reservation Status parameters of the Reservation Message shall be copied from corresponding fields in the associated Stream Registration Entry;

d) Otherwise, if the Reservation Status field in Reservation Information of the Stream Registration Entry for the associated Stream has a value of SUCCEEDED, the GSRP Application element uses the ACRR_ADD_STREAM.request primitive to make local admission control and resource reservation for the associated Stream on the Port associated with the GSRP Participant. The Stream Identifier and Resource Requirement parameters of the primitive are copied from corresponding fields in the associated Stream Registration Entry. Admission control and resource reservation results are received through the corresponding ACRR_ADD_STREAM.response primitive. Then a Reservation Message shall be sent out of the Port associated with the GSRP Participant. The Stream Identifier and Resource Requirement parameters of the Reservation Message shall be copied from corresponding fields in the associated Stream Registration Entry. The Reservation Status parameter shall be copied from the Result Code of the corresponding ACRR_ADD_STREAM.response primitive. If the Reservation Status is SUCCEEDED, the GSRP Application element specifies the Port associated with the GSRP Participant as Forwarding in the Stream Data Port Map of the associated Stream Registration Entry.

On receipt of a GID_Leave.indication whose attribute_type is equal to the value of the Stream Attribute Type (4.3.1.3),

e) The GSRP Application element specifies the Port associated with the GSRP Participant as Filtering in the Stream Data Port Map of the Stream Registration Entry for the Stream Identifier specification carried in the Stream_Identifier component of attribute_value parameter. If such a Stream Registration entry does not exist in the Filtering Database, then the indication is ignored. The GSRP Application element uses the ACRR_TEAR_STREAM.request primitive to release reserved resources for the associated Stream on the Port associated with the GSRP Participant.

f) The GSRP Application element specifies the Port associated with the GSRP Participant as Filtering in the Reservation Message Port Map of the Stream Registration Entry for the Stream Identifier specification carried in the Stream_Identifier component of attribute_value parameter. If such a Stream Registration entry does not exist in the Filtering Database, then the indication is ignored. If setting that Port to Filtering results in there being no Ports in the Reservation Message Port Map specified as Forwarding (i.e., all Stream members are de-registered), then that Group Registration Entry is removed from the Filtering Database.

4.4 Reservation message operations

4.4.1 Reception of Reservation messages (rResv)

On reception of a Reservation message, the GSRP Application element shall

a) If an associated Stream Registration entry does not exist in the Filtering Database, then the Reservation message shall be discarded and no further operations shall be performed for it.

b) If the inbound port from which the Reservation message arrives is not equal to the Inbound Port field stored in the associated Stream Registration Entry, and the value of Reservation Status parameter that the Reservation message carries is smaller than the value of Reservation Status filed stored in the associated Stream Registration Entry, then the Reservation message shall be discarded and no further operations shall be performed for it.

c) Set the Resource Requirement, Inbound Port and Reservation Status fields in the Reservation Information Element of the associated Stream Registration Entry according to the Reservation message.

d) Restart Resvtimer, if it is running.

e) If in step a) the Reservation Status of the associated Stream Registration Entry is changed from

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INITIAL, TIMEOUT or FAILED to SUCCEEDED, rule 4.3.2.2.d shall be performed by the GSRP Application element for each Port which is Forwarding in the Reservation Message Port Map of the associated Stream Registration Entry; or

f) If in step a) the Reservation Status of the associated Stream Registration Entry is changed from a value other than SUCCEEDED to TIMEOUT or FAILED, rule 4.3.2.2.c shall be performed by the GSRP Application element for each Port which is Forwarding in the Reservation Message Port Map of the associated Stream Registration Entry; or

g) If in step a) the Reservation Status of the associated Stream Registration Entry is changed from SUCCEEDED to TIMEOUT or FAILED, rules 4.3.2.2.e and 4.3.2.2.c shall be performed by the GSRP Application element for each Port which is Forwarding in the Reservation Message Port Map of the associated Stream Registration Entry.

4.4.2 Expiration of Reservation message timer (Resvtimer!)

A GSRP Participant maintains a single instance of Resvtimer for each Stream that is currently registered, or that the Registrar state machine is in the process of de-registering. The Resvtimer controls the period of time that the GSRP Application will wait before it set the Reservation Status to TIMEOUT. The Resvtimer is set to the value ResvTime when it is started or restarted. ResvTime is defined in Table 4-3.

Table 4-3 Reservation timer parameter value

Parameter	Value (milliseconds)
RefreshTime	200
ResvTime	600

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On expiration of Resvtimer, the Reservation Status of the associated Stream Registration Entry shall be set to TIMEOUT. Then rules 4.4.1.d and 4.4.1.e shall be performed if the corresponding conditions are satisfied.

4.4.3 Expiration of Refresh timer (Refreshtimer!)

An instance of Refreshtimer is required on a per-Port, per-GSRP Participant basis. The Refreshtimer controls the interval between refresh events for Reservation messages. The Refreshtimer is set to the value RefreshTime when it is started or restarted. RefreshTime is defined in Table 4-3. Refreshtimer is started upon the initialization of GSRP Participant.

On expiration of Refreshtimer, a Reservation Message shall be sent out of each Port that is Forwarding in the Reservation Message Port Map of the associated Stream Registration Entry. The Stream Identifier, Resource and Requirement parameters of the Reservation Message shall be copied from corresponding fields in the associated Stream Registration Entry. The Reservation Status parameter is decided as follows:

a) If the Reservation Status of the associated Stream Registration Entry is TIMEOUT, then the Reservation Status parameter of the Reservation message shall be TIMEOUT; or
b) If the Reservation Status of the associated Stream Registration Entry is FAILED, then the Reservation Status parameter of the Reservation message shall be FAILED; or
c) If the Reservation Status of the associated Stream Registration Entry is SUCCEEDED, then the Reservation Status parameter of the Reservation message shall be
    1) FAILED, if the Port is Filtering in the Stream Data Port Map of the associated Stream Registration Entry.
    2) SUCCEEDED, if the Port is Forwarding in the Stream Data Port Map of the associated Stream

Registration Entry.

4.5 Conformance to GSRP

This subclause defines the conformance requirements for implementations claiming conformance to GSRP. Three cases are covered: implementation of GSRP in MAC Bridges, implementation of GSRP in Talker stations and implementation of GSRP in Listeners.

4.5.1 Conformance to GSRP in MAC Bridges

A MAC Bridge for which conformance to GSRP is claimed shall

a) Conform to the operation of the GARP Applicant and Registrar state machines, and the LeaveAll generation mechanism, as defined in 12.7.1, 12.7.2, and 12.7.3 of IEEE Std 802.1D.
b) Exchange GARP PDUs as required by those state machines, formatted in accordance with the generic PDU format described in 12.10 of IEEE Std 802.1D, and able to carry application-specific information as defined in 4.3.1, using the GSRP Address as defined in Table 4-1.
c) Propagate registration information in accordance with the operation of GIP for the Refined Spanning Tree Context, as defined in 4.3.1.
d) Implement the GSRP Application component as defined in 4.3.
e) Implement the source pruning operations as defined in 4.2.1.

4.5.2 Conformance to GSRP in Talker stations

A Talker station for which conformance to GSRP is claimed shall

a) Conform to the operation of the GARP Registrar state machines, and the LeaveAll generation mechanism, as defined in 12.7.1, 12.7.2, and 12.7.3 of IEEE Std 802.1D.
b) Exchange GARP PDUs as required by those state machines, formatted in accordance with the generic PDU format described in 12.10 of IEEE Std 802.1D, and able to carry application-specific information as defined in 4.3.1, using the GSRP Address as defined in Table 4-1.
c) Implement the GSRP Application component as defined in 4.3.
d) Implement the source pruning operations as defined in 4.2.1.

4.5.3 Conformance to GSRP in Listener stations

An end station for which conformance to GSRP is claimed shall

a) Conform to the operation of one of the following:
    1) the Applicant state machine, as defined in 12.7.1 of IEEE Std 802.1D; or
    2) the Applicant Only state machine, as defined in 12.7.5 of IEEE Std 802.1D; or
    3) the Simple Applicant state machine, as defined in 12.7.6 of IEEE Std 802.1D.
b) Exchange GARP PDUs as required by the GARP state machine(s) implemented, formatted in accordance with the generic PDU format described in 12.10 of IEEE Std 802.1D, and able to carry application-specific information as defined in 4.3.1, using the GSRP Application address as defined in Table 4-1.
c) Support the provision of end system registration and de-registration as defined in 4.3.2.1.
d) Discard MAC frames carrying any GARP Application address as the destination MAC Address in

accordance with the requirements of 7.12.3 of IEEE Std 802.1D.

A Listener station for which conformance to the operation of the Applicant state machine is claimed shall also

e) Conform to the operation of the GARP Registrar state machine and the LeaveAll generation mechanism, as defined in 12.7.2 and 12.7.3 of IEEE Std 802.1D.

5. Verification of GSRP

Here we use the tool Uppaal developed by Uppsala University and Aalborg University to verify the GSRP specification. Uppaal is based on the theory of timed automata. It is appropriate for systems that can be modeled as a collection of non-deterministic processes with finite control structure and real-valued clocks, communicating through channels (currently Uppaal supports only synchronous (rendezvous) channel) and shared variables. It is designed mainly to check invariant and reachability properties by exploring the state space of a system.

We implemented GSRP model using state machine programming via Uppaal GUI. The model includes four major components: Applicant, Registrar, LeaveAll and Reservation. The state machines of each component are shown from Figure 5-1 to Figure 5-4.

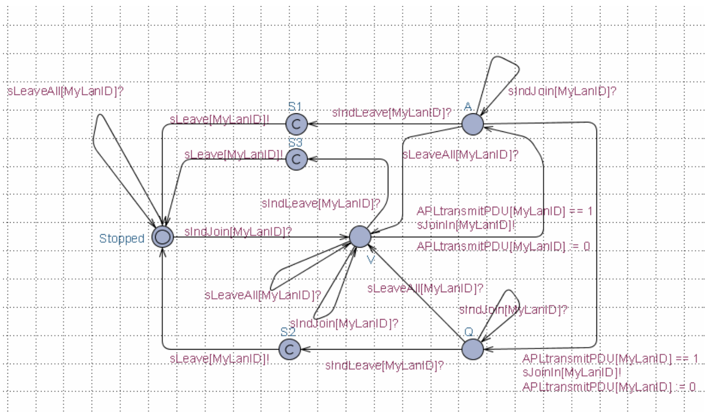

Figure 5-1 Applicant State Machine

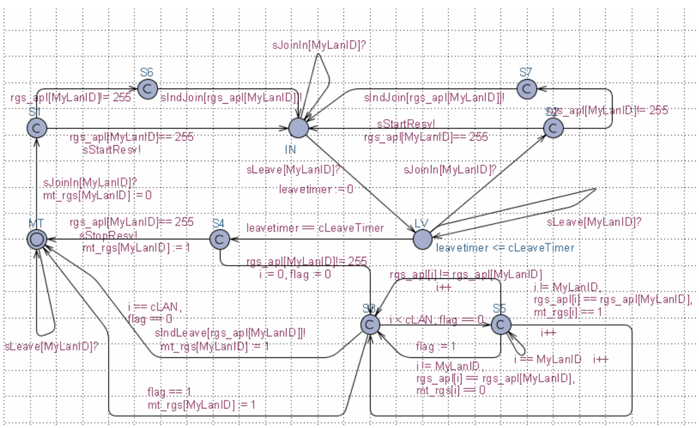

Figure 5-2 Registrar State Machine

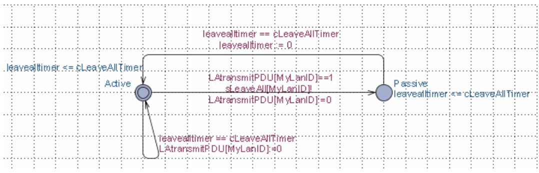

Figure 5-3 LeaveAll State Machine

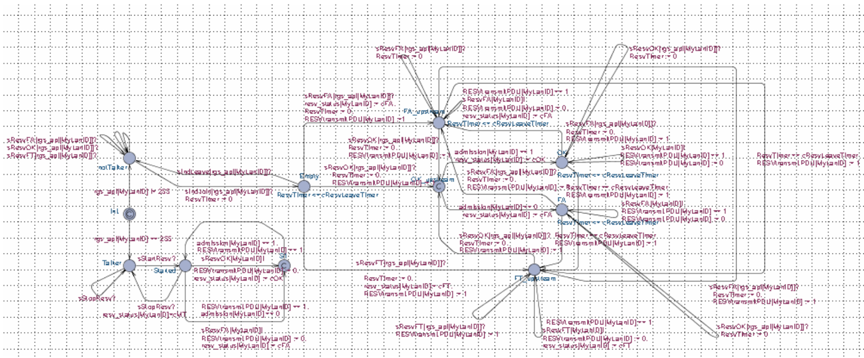

Figure 5-4 Reservation State Machine

With the implemented GSRP model, we conducted protocol verification for GSRP using a very simple network topology, which includes only one Talker, one Listener and one Residential Bridge that connects the Talker and Listener. A screenshot of the results is shown in Figure 5-5.

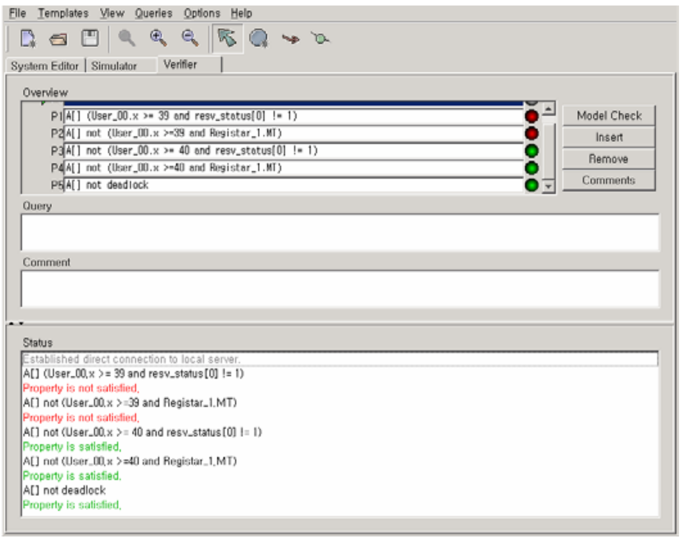

Figure 5-5 Verification Results for the Sample Network

It is shown in Figure 5-5 that

a) This sample system has no deadlock.
b) After a certain time (calculated from corresponding timeout constants), GARP registration will always be finished
c) After a certain time (calculated from corresponding timeout constants), Stream path will always be set up

Uppaal is not suitable to verify complex network topologies. Another limitation of this verification work is that the model did not take various practical network effects into account, such as bounded loss, delay, disordering and duplication of signaling messages, as well as possible misbehaviors of different network components.

Future protocol verification work should include the study of these effects. Random simulation methods using discrete event simulation tools such as OPNET or NS-2 may be applied for this purpose. Random simulation is obviously more scalable but it can not provide strict invariant and reachability analysis.