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Auto-attach using LLDP with IEEE 802.1aq SPBM networks
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Abstract

Automatic attachment or auto-attach is a procedure that allows for the automatic connection of network objects (e.g. end stations, network devices, sensors, automation elements) to a core network based on the individual services that are run or configured on the objects, and the mapping of the services to the managed paths in the network.

This document describes an implementation of the auto-attach concept based on the IEEE802.1AB Link Layer Discovery Protocol (LLDP) which is used to automatically attach network devices not supporting the IEEE 802.1ah Provider Backbone Bridges (PBB) to individual services in an IEEE 802.1aq Shortest Path Bridging (SPB) network.

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1. Introduction

The Auto-Attachment Framework described in [AA-FRWK] describes a method that allows for the automatic attachment of network objects (e.g. end stations, network devices, sensors, automation elements) to a core network based on the individual services that are run or configured on the objects, and the mapping of the services to the managed paths in the network. The framework proposed by that document describes the operations that need to happen in order to have the network objects connected to the network ('attached') in an automatic manner and start providing their functionality and services without any requirement or dependency between the protocol stack on the network objects and the method used to build the bridging or routing paths in the network core.

This informational document describes a compact method of implementing the Auto-Attachment Framework by using standards IEEE 802.1 protocols. Specifically this implementation uses IEEE802.1AB Link Layer Discovery Protocol (LLDP)[LLDP] to automatically attach network devices not supporting IEEE 802.1ah [PBB] to individual services in a with IEEE 802.1aq Shortest Path Bridging (SPB) [SPB] network. These network devices typically do not support SPBM, MAC-in-MAC (802.1ah), nor I-SID usage and therefore cannot easily take advantage of the SPB infrastructure without manual configuration of attachment of VLANs to I-SIDs in multiple locations. A motivation for this draft is to suggest a useful means to simplify and automate connections to PBB L2VPN based service networks such as those defined in SPBM-EVPN.

2. Terminology

802.1aq - defines a technology for providing a link state protocol for the control of a common Ethernet switching layer.

802.1ah - Provider Backbone Bridges (PBBs), MAC-IN-MAC encapsulation

AAC - Auto Attach Client agent that resides on a non-SPB/PBB capable element that uses LLDPDUs to request I-SID assignment for the VLANs which have been configured on its network port.

AAS - Auto Attach Server agent that processes VLAN to I-SID requests from AAC elements that are connected to a SPB BEB

BCB - Backbone Core Bridge

BEB - Backbone Edge Bridge

B-TAG - Backbone VLAN Tag

C-TAG - Customer VLAN Tag

Element - Any end device or network node that may implement the auto attach functionality

I-SID - Backbone Service Instance Identifier

IS-IS - Intermediate System to Intermediate System Protocol

L2VPN - - Layer 2 Virtual Private Networks

LAN - Local Area Network

LLDP - IEEE 802.1AB Link Layer Discovery Protocol

SPB - IEEE 802.1aq Shortest Path Bridging

SPBM - Shortest Path Bridging, MAC mode

VLAN - Virtual Local Area Network

3. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

4. Relation to the Auto Attachment Framework

Section 4 in [AA-FRWK] defines the framework, model and components of the auto-attachment functionality. Figure 1 in that document depicts the conceptual Auto Attach Model.

In the implementation described by this document, the role of the discovery protocol is played by IEEE 802.1AB (LLDP). The LLDP exchanges trigger the IS-IS SPBM announcements.

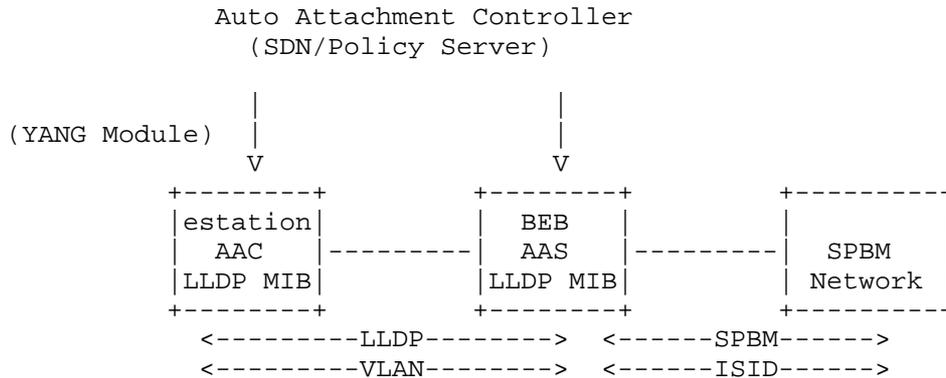


Figure 1: Conceptual LLDP-SPB Auto Attach model

Figure 1 depicts a conceptual example of the process where an AAC can use LLDP to communicate the need to connect a VLAN to the appropriate I-SID on the SPB BEB it is attached to on its network uplink port. The IEEE 802.1AB Link Layer Discovery Protocol (LLDP) and the LLDP MIB are part of the Auto Attachment Framework and will be implemented in the Backbone Edge Bridges (BEB) and the Backbone Core Bridges (BCB).

The mapping to the framework architecture is as follows:

- | | | |
|--|------------|------------------|
| (1) Auto-Attachment Primitives - announcements | | - LLDP |
| (2) Routing Control Plane - announcements | | - IS-IS SPBM ann |
| (3) 'horizontal' data model - | | - LLDP MIB |
| (4) Service Tag - | - VLAN tag | |
| (5) Service Route/Tunnel ID - | | - IS-ID |
| (6) 'vertical' data model - NG Model | | - Auto Attach YA |

The purpose of Auto Attach is to allow a non-SPB device to connect to an SPB capable networking device. The non-SPB device is called an AA client (AAC) and the SPB capable networking device is called the AA server (AAS). An AA Client is a non-SPBM device that supports some form of I-SID/VLAN binding definition and, if connectivity permits, has the ability to advertise this data to a directly connected AA Server. An AA Server is a SPBM device that potentially accepts externally generated I-SID/VLAN assignments that can be used for automated configuration purposes. The client identifies itself to the server and then requests VLAN ID to SPB ISID binding(s). The server will either accept or reject each binding request. If

accepted, any traffic on the (locally significant) VLAN is forwarded through the SPB cloud on the specified ISID.

A prototype of the extension proposed in the memo was successfully implemented and tested with Open vSwitch. IEEE 802.1aq SPB software is available from multiple vendors of Ethernet switches to connect end devices and non-SPB compliant switches to the SPB enabled backbone network. Edge switches in SPBM that utilize the 802.1ah PBB encapsulation are referred to as Backbone Edge Bridges (BEB). In support of SPBM, these bridges map a VLAN ID on the UNI to an I-SID (Individual Service ID), as defined in IEEE 802.1ah. In order to facilitate an automatic way in which a AAC can request individual service connectivity from an SPBM Backbone Edge Bridge BEB acting as a AAS, this method of using IEEE 802.1AB Link Layer Discovery Protocol (LLDP) with IEEE 802.1aq Shortest Path Bridging network can be used. These widely deployed client devices typically do not support SPBM, IEEE 802.1ah and therefore cannot easily take advantage of the SPB infrastructure without manual configuration of attachment of VLANs to I-SIDs in multiple locations.

Elements that utilize this automated method for service assignment pass this data to attached SPBM capable BEB nodes where the mappings are processed and approved or rejected. Specific actions are taken on the non-SPBM devices, referred to as Auto Attach Clients (AAC), as well as the SPBM device, referred to as Auto-Attach Server (AAS), based on the outcome of the mapping request.

5. Auto Attachment Layer 2 Functionality

5.1. Element Discovery

The first stage of establishing AA connectivity involves element discovery. An Auto Attach agent resides on all capable elements. Server agents control the Auto Attach (AA) of VLANs to I-SIDs on themselves when enabled to accept and process such requests from AAC elements. Typically this is done through a global service setting and through per-port settings that control the transmission of information in LLDPDUs on the appropriate links that interface AAC's and AAS's.

Once the required AA settings are enabled on the elements (e.g., the AA service and the per-port AA settings) the AA agent on each element type, both AAC and AAS, advertises its capabilities (i.e., server/client) through LLDPDU packets to each other.

Following discovery of AA capabilities by both the AAC and the AAS, the AA agent on each element is aware of all AA services currently

provided by the network elements to which it is directly connected. Based on this information, an AAC agent can determine whether Auto Attach data, namely locally administered I-SID/VLAN assignments, should be exported to the AAS that is associated with an SPBM BEB to which it is attached to on its network uplink ports.

Initial Auto Attach functionality, when enabled, can be used to extract management VLAN data from the primary AA server advertisements and can use this data to update the in-band management VLAN and initiate IP address acquisition using techniques such as DHCP.

5.2. Service Requests

Service mappings can be established when these two criteria are met:

1. AA Server found during discovery

Assuming that an administrator has defined one or more ports for auto attach mode a discovery message is sent out each port defined using LLDP. Element information is forwarded using LLDP TLV extensions defined in section 6.1.

2. I-SID/VLAN bindings are defined locally

Assuming that an administrator has defined one or more I-SID/VLAN assignments (or AAC bindings have been received for processing), an AAC sends the I-SID/VLAN assignment list to the discovered AAS. I-SID/VLAN data is exported using LLDP TLV extensions defined in section 6.2.

5.2.1. Element Inactivity Timeout

An AAC must handle primary AAS loss and this requires maintenance of a server's inactivity timer. If primary AAS advertisements are not received for a pre-determined amount of time, the I-SID/VLAN assignments accepted by the server are considered rejected. I-SID/VLAN assignment data is then defaulted (reverts to the 'pending' state) and the AA agent, which resides on the AAC, removes related settings.

5.3. Server Mapping Request Processing

Each I-SID/VLAN assignment in an AA request received by the AAS is processed individually and can be accepted or rejected. An assignment may be rejected for a number of reasons, such as server resource limitations or, for example, restrictions related only to

the source AAC. Rejected assignments are passed back to the originating AAC with a rejected state and, if appropriate, an indication as to why the rejection occurred. Limited state information may be maintained on the server related to rejected I-SID/VLAN assignments.

Each VLAN that is associated with an accepted I-SID/VLAN assignment is instantiated on the AAS bridge if it does not already exist. These VLANs are designated SPBM UNI VLANs on a BEB. The port through which the AA I-SID/VLAN assignment list was received (i.e., the AAS downlink) must be a member of the VLAN(s) in the I-SID/VLAN assignment list that are accepted by the AAS. Port membership is automatically updated when the UNI service (I-SID/VLAN/port) is created. To ensure that VLAN markings are maintained between switches, traffic on the downlink port MUST be tagged. The AA agent on the serving BEB handles all of these tasks automatically. No administrator intervention is required.

The AAS agent is responsible for tracking which, if any, of these actions are performed so that settings can be cleared when they are no longer needed. This can occur, for example, when configuration changes on an AAC updates the received I-SID/VLAN assignment list when an AAC associated with a downlink port changes or an AAC connection disappears entirely. Specifically, when an SPBM switched UNI-based VLAN and a switched UNI have been created on a downlink port because of an accepted AA I-SID/VLAN assignment (and not because of an explicit administrator port action), then the UNI and associated VLAN SHOULD be deleted when the related I-SID/VLAN assignment is cleared by the AAS.

5.4. Server Mapping Response Processing

Each VLAN that is associated with an AAC I-SID/VLAN assignment must be defined on the client's device. The port associated with the uplink connecting the AAC to the AAS must be a member of the VLAN(s) in the I-SID/VLAN assignment list that are sent to and accepted by the AAS. This allows traffic on these VLANs to pass through the switch into the SPB fabric when required. To ensure that VLAN markings are maintained between devices, traffic on the uplink port MUST be tagged. If a VLAN has not been created before the I-SID/VLAN assignment itself, it is automatically created by the AAC agent when a proposed assignment is accepted. Port tagging and the port VLAN membership update are also performed by the AAC automatically based on assignment acceptance. To ensure consistency, VLANs SHOULD NOT be deleted while they are referenced in any I-SID/VLAN assignments on the device.

5.5. Service Mapping Timeout

A "last updated" timestamp is associated with all active assignments on the AAS. When this value is not updated for a pre-determined amount of time, the I-SID/VLAN assignment is considered obsolete. Obsolete assignment data and related settings are removed by the AAS, subject to the constraints imposed by section 4.3.

The current I-SID/VLAN assignment list is advertised by an AAC at regular intervals (dictated by LLDP operation). During processing of this data, an AAS must handle list updates and delete assignments from previous advertisements that are no longer present. Though these entries would be processed appropriately when they timeout, the AAS attempts to update the data in real-time and SHOULD initiate deletion immediately upon detection of this condition.

6. Auto Attach LLDP Extensions

The text in this section is not normative. The complete definition of the Auto Attach TLVs is provided in the IEEE 802.1Qcj [AA] Amendment of the IEEE 802.1Q standard.

The Auto Attach TLVs are implemented as extensions to the LLDP standard, using its flexible extension mechanism. They SHOULD be implemented as vendor-specific TLVs using TLV type 127 as described in the 802.1AB (LLDP) standard. TLVs supporting the exchange of AA element data and I-SID/VLAN assignment data have been defined below.

6.1. AA Element TLV

The Element TLV is used by an AA device to announce its capabilities to its LLDP peer on a given interface. Use of the Auto Attach functionality is encoded in to the 802.1AB LLDP Custom Element TLV as follows:

AA Element TLV

```

+-----+
| Type: 127 (7 bits)          |
+-----+
| Length: 49 octets (9 bits)|
+-----+
| OUI:           3 octets    |
+-----+
| Subtype:       11 (1 octet)|
+-----+

```

HMAC-SHA256 Digest:32 oct
Element Type: 6 bits
State: 6 bits
Mgmt VLAN: 12 bits
System ID: 10 octets

Subtype = 11 for AA Element TLV

HMAC-256 Digest:

The Element TLV data integrity and source validation is supported through the use of the HMAC-SHA256 message authentication algorithm. The HMAC-SHA256 generated digest size is 32 octets and the Element TLV includes a field to support the digest exchange between source and destination parties. Symmetric private keys are used for digest generation.

The HMAC-SHA256 data digest computation starts at [0-based] byte 38 of the TLV. The digest is then placed in the HMAC-SHA256 Digest field in the TLV prior to transmission. Upon receipt, the digest is again computed and the resulting digest is compared against the received digest. If the received digest is the same as the newly computed digest, the TLV is considered valid and processing can commence. If the comparison fails, the TLV is discarded and processing is terminated.

Element Type:

The element type identifies the capability of the advertising AA node. The AA Server describes an AAS capable device that can map incoming VLAN to I-SID and announce I-SID connectivity to the SPB network. AA Clients may operate in either tagged or untagged modes. If an AA client announces untagged, then the entire port MUST be mapped to the I-SID on the BEB.

The AA Element TLV can only exist once in a LLDPDU. It is included in all LLDPDUs when the Auto Attach service is enabled and when the

per-port transmission flags associated with this TLV, as required by the 802.1AB standard, are enabled.

A number of AA Element Type values, including the AA Server and several AA Client element types, are currently defined. The list of supported element types will expand as additional devices incorporate AA signaling.

Currently supported Auto Attach Element Type values:

AA Element Type - Other (1)

AA Server (2)

AA Server No Authentication (3)

AA Client - Wireless Access Point Type 1 (4) [wireless clients get direct network attachment]

AA Client - Wireless Access Point Type 2 (5) [wireless clients get tunneled to a controller]

AA Client - Switch (6)

AA Client - Router (7)

AA Client - IP Phone (8)

AA Client - IP Camera (9)

AA Client - IP Video (10)

AA Client - Security Device (11) [FW, IPS/IDS, etc.]

AA Client - Virtual Switch (12)

AA Client - Server/Endpoint (13)

AA Client - SDN Controller (14)

AA Client - SPB-over-IP Network Device (15)

State:

The AA Element TLV State field settings indicate AA Client link tagging requirements in AA Client-sourced frames and current provisioning mode information (bits are numbered left to right):

Link VLAN Tagging Requirements (bit 1)

- 0 - All traffic tagged on link
- 1 - Tagged and untagged traffic on link

Automatic Provisioning Mode (bits 2/3)

- 0 - Automatic provisioning disabled
- 1 - SPB provisioning
- 2 - VLAN provisioning

System ID: conveys information that the TLV recipient can use to enforce connectivity restrictions. It includes System MAC Address, connection type and identifiers. Detailed specification of the System ID sub-fields is TBD.

6.2. I-SID/VLAN Assignment TLV

The AA I-SID/VLAN Assignment TLV is used by the AAC to announce I-SID/VLAN assignments that it would like supported by a directly connected AAS. It is also used by the AAS to announce that that I-SID/VLAN bindings processed by the AAS are active or rejected.

The AA I-SID/VLAN Assignment TLV can only exist once in a LLDPDU. It is only included in a LLDPDU when complementary AA element (i.e., AA server/ client) devices are directly connected. Data integrity and source validation is supported through the use of the HMAC-SHA256 message authentication algorithm. The HMAC-SHA256 generated digest size is 32 octets and the AA I-SID/VLAN Assignment TLV includes a field to support the digest exchange between source and destination parties.

Per-port TLV transmission flags must be enabled on the communicating devices as well. The AA Element TLV must also be present in the LLDPDU for the AA I-SID/VLAN Assignment TLV to be processed. The TLV cannot exceed the LLDP 512 byte TLV size limit, which implies a maximum of 94 I-SID/VLAN assignments in a LLDPDU

The format of the TLV is as follows:

Service Assignment TLV

```

+-----+
| Type:   127 (7 bits)   |
+-----+
| Length: 41-506 octets (9 bits) |
+-----+
| OUI:                3 octets   |
+-----+
| Subtype:             12 (1 octet) |
+-----+
| HMAC-SHA256 Digest: 32 octets |
+-----+
| Assignment Status:  4 bits   |
+-----+
| VLAN:               12 bits   |
+-----+
| I-SID:              3 octets   |
+-----+

```

The HMAC-SHA256 digest is computed for the series (1-94) of I-SID/VLAN assignments (i.e. data for the digest computation starts at [0-based] byte 38 of the TLV). The digest is then placed in the HMAC-SHA256 Digest field in the TLV prior to transmission. Upon receipt, the digest is again computed for the series (1-94) of I-SID/VLAN assignments in the received TLV and the resulting digest is compared against the received digest. If the received digest is the same as the newly computed digest, the TLV is considered valid and processing can commence. If the comparison fails, the TLV is discarded and processing is terminated. Additionally the value for the I-SID in the incoming LLDP exchanges SHOULD trigger an IS-IS SPBM announcement using normal IEEE 802.1aq mechanisms if not already being announced by the BEB.

The assignment status data is returned by the AA Server for each pending I-SID/VLAN assignment request. Assignment rejections may include information to indicate the reason for the rejection. A limited number of detailed rejection error codes will initially be supported.

Assignment Pending(1)

Assignment Accepted(2)

Rejection: Generic(3)

Rejection: AA resources unavailable(4) -the resources that are required for the Auto Attach agent to support additional I-SID/VLAN assignments are currently exhausted. The maximum number of assignments that can be supported has been reached.

Rejection: Duplicate(5)

Rejection: VLAN invalid(6) - the specified VLAN can't be used to create a switched UNI at this time. The VLAN already exists and is either inactive or has an incorrect type for this application.

Rejection: VLAN unknown(7)

Rejection: VLAN resources unavailable(8) - the maximum number of VLANs that can be supported by the device has been reached.

Rejection: Application interaction issue(9) - a failure has been detected during AA interactions with the VLAN and/or the SPBM applications. The VLAN operations to create the required SPBM switched UNI VLAN or enable port tagging may have failed or the SPBM operation to create the switched UNI may have failed

Please note that the status field is only valid when generated by an AA Server. Any Assignment TLVs which are received by an AA server are assumed to be requests. It is recommended that the status field of assignments generated by AA clients be set to 0 or 1.

VLAN: A VLAN value of 0 may indicate that the AAC traffic is untagged.

7. Security Considerations

It is important to provide an option to ensure that the aforementioned Auto Attach communication is secure in terms of data integrity (i.e., the data has not been altered in transit) and authenticity (i.e., the data source is valid).

If communication is occurring between non-secure systems, the HMAC-SHA256 Digest data should always be zero and the digest data, regardless of the value, is ignored. A misconfiguration can occur with one system operating in secure mode and the other operating in

non-secure mode. In this scenario, the Element TLV or the I-SID/VLAN Assignment TLV will always be discarded prior to processing by the system operating in secure mode.

These security requirements are satisfied by using an optional keyed-hash message authentication code (HMAC) to protect the AAC/AAS Element Discovery and I-SID/VLAN assignment exchanges. This type of message authentication allows communicating parties to verify that the contents of the message have not been altered and that the source is authentic. Use of this mechanism is optional and is controlled through a user-configurable attribute.

7.1. TLV Security Considerations

A HMAC-SHA256 digest is computed for Element TLV or for the series of I-SID/VLAN assignments, where the digest computation starts [0 based] at byte 38 of the TLV. The resulting digest is then placed in the TLV prior to sending. Where upon receipt of the digest, the contents are again computed in the same manner and the digests are compared, if the comparison fails then the TLV is discarded, otherwise if both digests are the same the TLV is considered valid and processed appropriately.

8. IANA Considerations

This memo includes no request to IANA.

Note: the section will be removed during conversion into an RFC by the RFC Editor.

9. Further and Related Work

The standard extensions to the IEEE 802.1AB (LLDP) [LLDP] protocol are developed by the IEEE 802.1 Working Group. The relevant project is IEEE 802.1Qcj [AA] for 'Automatic Attachment to Provider Backbone Bridges (PBB) services'.

Current open issues:

- Define whether an AA Proxy needs to be made part of the architecture and if yes, define its role
- Further details on the two AA TLVs fields
- Define semantics of I-SID value of 0
- Alignment with the (normative) definitions in IEEE 802.1Qcj (as they progress)

The Auto Attachment YANG data model is developed as [TBA1].

10. Acknowledgments

The first version of this document that introduced the auto attach concept was co-authored by Nigel Bragg and Ludovic Beliveau.

We would like to thank the following people (in no particular order) for their contributions:

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11.2. Informative References

[AA] IEEE 802.1Qcj, "Standard for Local and Metropolitan Area Networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks Amendment: Automatic Attachment to Provider Backbone Bridging (PBB) services"

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