PRE-DRAFT IEEE 802 Nendica Report: Network Stream and Flow Interworking

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Table of Contents

Scope

The scope of this report is the characterization, from a unified perspective, of network streams and flows in IEEE 802 networks, and in some networks that are typically connected to IEEE 802 networks, including an assessment of the process of interworking flows and streams across network boundaries and the feasibility and value of such interworking in achieving end-to-end flow management and QoS. Standardization implications are identified.

Purpose

By taking a unified perspective toward the assessment of network streams and flows, this document is intended to encourage a common understanding of concepts that are largely considered from a unique perspective in each network technology. That unified perspective is intended to motivate efforts to consider procedures to interwork streams and flows across network boundaries, so that QoS characteristics that are managed within a single network by stream and flow control can be joined across network boundaries, allowing a level of end-to-end QoS control. The intention is not to specify interworking protocols but ideally to identify particular network pairs that can benefit from stream and flow interworking, assess the feasibility of such interworking in those cases, identify gaps preventing interworking, and identify standardization activities that would promote successful interworking.

Introduction

This document has been developed within the IEEE 802 IEEE 802 “Network Enhancements for the Next Decade” Industry Connections Activity (Nendica) in accordance with the Nendica Work Item on “Network Stream and Flow Interworking” **Error! Reference source not found.**[1]).

Network Streams and Flows

Network traffic is increasingly managed as a set of streams or flows rather than series of frames or packets. IEEE 802 networks have developed and utilized flow concepts; e.g.:

- IEEE 802.11 Parameterized Traffic Streams (TSs)
- IEEE 802.1 TSN Streams for time-sensitive networking (various standards)
- IEEE Std 1722 Audio/Video Transport Protocol (AVTP) streams
- IEEE 802.1Qcz Congestion isolation
- IEEE 802.16 Service Flows for all traffic
- IEEE 802.15.4 use of Guaranteed Time Slots

Non-802 networks have developed and utilized flow concepts:

- MEF Carrier Ethernet Virtual Connections
- IETF DetNet
- IETF RAW
- Software-Defined Networking, including OpenFlow
- DOCSIS Service Flows
- 3GPP Bearers
- IP flows (DSCP; IPV6 flow identifier)
- other

While these network streams and flows can be characterized by various parameters and are qualitatively different concepts in different networks, some characteristics are common. Here we attempt to generalize the concept of a stream or flow into a definition suitable for use in this report…

[1]Information on references can be found at the end of the document in the Citations section.

Uses for Streams and Flows

Stream and flows can be used for:

Stream and Flow Concepts in Standards

IEEE 802.1 Standards

The words “flow” and “stream” are used in IEEE Std 802.1 standards in several contexts, some of which are only loosely related to others.

IEEE Std 802.1Q Flow Identifier for Congestion Notification

IEEE Std 802.1Q discusses flows in the context of a “Flow Identifier” used in Congestion Notification (CN). A congestion-aware end station labels frames of the flow with a Flow Identifier (Flow ID) within a CN-TAG attached to the frame. When a Congestion Point identifies congestion due to a particular flow, based on the Flow ID, it may notify a Reaction Point of congestion due to the particular flow, with reference to the congesting Flow ID. This mechanism reduces the need for frames to be repeatedly classified.

The Flow ID is two bytes in length. Its meaning and encoding are not specified in IEEE Std 802.1Q.

IEEE Std 802.1Q Flow Hash for Equal Cost Multipath

IEEE Std 802.1Q also discusses flows in the context of “flow filtering.” Per subclause 44.2, flow filtering “enables Bridges to distinguish frames belonging to different client flows and to use this information in the forwarding process.” Such flows are used when Shortest Path Bridging operates in conjunction with Equal Cost Multiple Path (ECMP), which spreads traffic across multiple paths. In order to prevent problematic frame reordering, frames within an identified flow are constrained to a single such path. During operation, frames are classified into a flow and identified with a flow filtering tag (F-TAG) containing a flow hash value. Transmission order is maintained for all frames from a source to a destination with the same flow hash value. The “flow_hash” parameter is passed among the Enhanced Internal Sublayer Service (EISS) service primitives along with the frame. It appears that the flow hash is not used for other purposes in IEEE Std 802.1Q.

IEEE Std 802.1Q stream_handle for Flow Classification and Metering

IEEE Std 802.1Q also discusses flows in the context of “flow classification and metering.” Per subclause 8.6.5, flow classification “identifies a subset of traffic (frames) that may be subject to the same treatment in terms of metering and forwarding.” Frames classified to a flow are subject to a flow meter specified for that flow. Classification rules may be based on destination MAC address, source MAC address, VID, priority, and connection_identifier (the last one only for bridges that support Per-Stream Filtering and Policing (PSFP)). It appears that the flow_hash is not considered in classification.

PSFP uses the term “stream” rather than flow. IEEE Std 802.1Q does not define “flow” and defines a stream as “a unidirectional flow of data (e.g., audio and/or video) from a Talker to one or more Listeners.” Support of PSFP requires use of the stream_handle provided by the stream identification function of IEEE Std 802.1CB. PSFP supports differentiated queuing, as well as filtering and policing, based on the stream_handle and priority parameters of the frame. The stream_handle is considered a sub-parameter of the connection_identifier parameter and thereby passes as an EISS service primitive.

IEEE Std 802.1Q in some cases refer to Stream ID and “stream identifier” but appears to include no formal or informal definition of either. IEEE Std 802.1CB (in subclause 7.2, “Use of the term *Stream*”) says that “IEEE Std 802.1Q defines a StreamID that is used to identify a stream between a Talker and one or more Listener(s). In contrast, the present standard defines a stream_handle subparameter that is used internally to identify a Stream.”

IEEE Std 802.1Q defines StreamID as “a 64-bit field that uniquely identifies a stream” (comprising an EUI-48 MAC Address associated with the stream source [which “can, but does not necessarily, have the same value as the source_address parameter of any frame in the actual data stream”] and a 16-bit Unique ID used to distinguish among multiple streams from source).” StreamID is used in the Stream Reservation Protocol (SRP).

IEEE Std 802.1Q Multiple Stream Registration Protocol (MSRP)

IEEE Std 802.1Q discusses streams and StreamID in the context of “Multiple Stream Registration Protocol (MSRP),” which is used by Stream Reservation Protocol (SRP). MSRP “provides end stations with the ability to reserve network resources that will guarantee the transmission and reception of data streams across a network with the requested QoS. These end stations are referred to as Talkers (devices that produce data streams) and Listeners (devices that consume data streams).” Bridges “associate Talker and Listener attributes via the StreamID present in each of those attributes.”

IEEE Std 1722 StreamID and Multicast Destination Address

IEEE Std 1722 (“IEEE Standard for a Transport Protocol for Time-Sensitive Applications in Bridged Local Area Networks”) uses “Stream ID” and “StreamID” as the 64-bit StreamID parameter of subclause 35.2.2.8.2 of IEEE Std 802.1Q, comprising an EUI-48 followed by a Unique ID. The content of the EUI-48 appears not to be specified beyond the requirement of IEEE Std 802.1Q that it be associated with the source. The StreamID used for stream identification, is said to uniquely identify a stream, and is carried in the Audio/Video Transport Protocol (AVTP) header of every AVTP frame carrying stream data.

IEEE Std 1722 includes an informative (non-normative) Annex C on “IEEE 802.3 Media-specific encapsulation” which is provided “to aid in the understanding of the relationship of Audio/Video Transport Protocol (AVTP) to the overall Ethernet protocol stack.” Annex C indicates that, in the case of SRP reserved frames, the VLAN identifier “is not to be used as a stream identifier in any way.” Annex C also indicates that the Ethernet source address is the sender’s unicast MAC address and that, in the case of SRP reserved frames, the Ethernet destination address “of each stream will be unique for the layer 2 network and may either be a locally administered unicast address or a multicast address (as defined in SRP).” Furthermore, “Multicast addresses may be assigned by use of MAAP defined in Annex B. The use of MAAP allows for multicast addresses to be unique per AVTP stream.”

A block of multicast addresses is reserved for use; these are distributed using the MAC Address Acquisition Protocol (MAAP), as specified in (normative) Annex B of IEEE Std 1722.

Annex C, though non-normative, indicates that an assigned multicast address is used as IEEE 802 Destination Address and that “use of MAAP allows for multicast addresses to be unique per AVTP stream.” On the other hand, the 64-bit StreamID, which is carried in the ATVP protocol header of stream data and uniquely identifies the stream, is built from an EUI-48 that is associated with the source and may be a multicast address. Therefore, it appears permissible, though not mandatory, to assign the multicast address, which seems to be unique per AVTP stream, as the base of the 64-bit StreamID. However, in that case, it appears that only one 64-bit StreamID may be constructed from such an EUI-48; otherwise, multiple StreamIDs would identify multiple streams all associated with the same Destination Address, leading to an apparent contradiction, depending perhaps on the interpretation of “MAAP allows for multicast addresses to be unique per AVTP stream.”

Based on this review, it appears that the intention of IEEE Std 1722 is:

- the SRP StreamID is built from the Talker’s EUI-48 along with a Unique ID and uniquely specifies the stream,
- the MAAP-assigned multicast address is linked to a Talker and a set of Listeners,
- while a single multicast address could in principle support multiple streams, all of which are linked to the same Talker and the same set of Listeners, it is possible for each such stream to be assigned to a different multicast address, and it appears that the intention is for them to be assigned unique multicast addresses

It therefore appears that the MAAP-assigned multicast address functions, or at least can function, as a stream identifier exposed to Layer 2.

IEEE Std 802.11 Streams

IEEE Std 802.11 (“IEEE Standard for Information Technology—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN MAC and PHY Specifications”) supports several stream concepts.

The Traffic Stream (TS) concept was introduced along with HCCA (hybrid coordination function controlled channel access) in IEEE 802.11e-2005. HCCA, while little used historically, is a centralized, polling-based scheme specified to provide transmission scheduling authority to the access point (AP), offering controlled QoS. The TS is a preconfigured parameterized QoS flow, characterized by a traffic specification (TSPEC) that specifies the QoS requirements of the flow. The standard provides for eight traffic streams per link, per direction, identified by one of eight traffic stream identifier (TSID) values. Flexible traffic classification (TCLAS) is used to classify frames to a TSID.

Stations may be specified to support the “stream classification service” (SCS). Using SCS, an AP classifies incoming unicast frames based upon Layer 2 and/or Layer 3 parameters, as specified by the terminal. The SCS allows the priority, drop eligibility, and transmit queue to be selected for all frames matching the classification.

Interworking with the IEEE 802.1Q Stream Reservation Protocol (SRP) may be supported, enabling end-to-end SRP reservations when a IEEE 802.11 link forms part of a path from Talker to Listener. In this case, SRP is integrated with the 802.11 functionality for adding a TS. When a station supports “Robust AV Streaming,” it can make a Higher Layer QoS Reservation Request to the AP, including a Higher Layer Stream ID that identifies the stream, as specified by SRP.

Manufactured IEEE 802.16 devices do not support HCCA but instead use enhanced distributed channel access (EDCA) for distributed probabilistic QoS management. EDCA manages not frame flows in Traffic Streams but instead single frames assigned to an Access Category reflecting a User Priority.

Stream and Flow identification

Stream and flows can be identified by:

IEEE 802.1Q VLANs

IEEE Std 802.1Q VLANs and VIDs.

Stream and Flow Characterization

Stream and flows can be characterized by parameters including:

- Specification document
- Network architecture
- Conditions
- Addressing
- End station
- Control
- Flow-sensitive elements
- Flow name
- Flow identification
- Flow quantity
- Flow descriptor
- Flow addition process
- Flow deletion process
- Flow change process
- Flow QoS properties
- Frame classification
- Request/grant system and polling services
- Admission control
- Interworking

Characteristics of Stream and Flow Concepts in Specific Networks

IEEE 802.11 Traffic Streams

Characteristic	IEEE 802.11 Traffic Streams	notes
Specification document	IEEE Std 802.11	
Sub-specification	HCCA	
Network architecture	Shared medium Point-to-Multipoint	HCCA is centralized
Conditions	Operates under CSMA/CA	Scheduling is by an AP within its BSS; not guaranteed in the presence of non-HCCA devices, or another HCCA BSS
Addressing	802 unicast	
End station	Non-AP STA	
Control	Access point (AP) scheduler	
Flow-sensitive elements	AP	
Flow name	parameterized traffic stream (TS)	
Flow identification	traffic stream identifier (TSID)	
Flow quantity	8 (3 bits)	per connection (AP+STA), per direction
Flow descriptor	traffic specification (TSPEC)	
Flow addition process	add traffic stream (ADDTS)	
Flow deletion process	delete traffic stream (DELTS)	
Flow change process	[none]	
Flow QoS properties	Nominal MSDU Size, Maximum MSDU Size, Minimum Service Interval, Maximum Service Interval, Inactivity Interval, Suspension Interval, Service Start Time, Minimum Data Rate, Mean Data Rate, Peak Data Rate, Burst Size, Delay Bound, Minimum PHY Rate, Surplus Bandwidth Allowance, Medium Time	9.4.2.29
Frame classification	stream classification service (SCS)?	11.26
Request/grant system and polling services	Polled TXOP Buffer status report (BSR) [P802.11ax]	10.23.3.3
Admission control	yes	
Interworking	R.3 QoS mapping guidelines for interworking with external networks	

MEF Carrier Ethernet – Ethernet Virtual Connections

Characteristic	MEF Carrier Ethernet	notes
Specification document	MEF 6.3	and other MEF specs
Sub-specification	EVC: Ethernet Virtual Private Line (EVPL) Ethernet Virtual Private LAN (EVP-LAN) Ethernet Virtual Private Tree (EVP-Tree)	port-based services are not included here
Network architecture	Shared medium EVC Type: Point-to-Point, Multipoint-to-Multipoint, or Rooted-Multipoint	
Conditions		
Addressing	IEEE 802 48-bit address	
End station	Ethernet connected at port (UNI)	
Control		
Flow-sensitive elements	bridges or other operator elements	
Flow name	service	
Flow identification	Customer-Edge VLAN ID	
Flow quantity	4094 (12 bits)	
Flow descriptor	Service attributes	
Flow addition process	manual (historically)	may be automated per MEF Lifecycle Service Orchestration (LSO)
Flow deletion process	manual (historically)	may be automated per MEF Lifecycle Service Orchestration (LSO)
Flow change process	manual (historically)	may be automated per MEF Lifecycle Service Orchestration (LSO)
Flow QoS properties	many	
Frame classification	unspecified	
Request/grant system and polling services	None; full-duplex system, reservation-based	
Admission control	Yes	
Interworking	unspecified	

DOCSIS Service Flows

Characteristic	DOCSIS	notes
Specification document	DOCSIS 4.0 MAC and Upper Layer Protocols Interface Specification	key features date to DOCSIS 1.1
Sub-specification		
Network architecture	point-to-multipoint	
Conditions		
Addressing	IEEE 802 48-bit address	
End station	cable modem (CM)	
Control	cable modem termination system (CMTS)	
Flow-sensitive elements	CMTS and CM	
Flow name	service flow	unidirectional
Flow identification	service identifier (SID)	Service flows are identified by SFID and described by QoS parameters. Active service flows are assigned an SID.
Flow quantity	SID 14 bits	SFID is 32 bits
Flow descriptor	QoS Parameter Set	
Flow addition process	Dynamic Service Addition	
Flow deletion process	Dynamic Service Deletion	
Flow change process	Dynamic Service Change	
Flow QoS properties	Traffic Priority, Maximum Sustained Traffic Rate, Maximum Traffic Burst, Minimum Reserved Traffic Rate, etc.	
Frame classification	Upstream and Downstream Classifiers; Payload Header Suppression Rules;	
Request/grant system and polling services	Upstream Service Flow Scheduling Services, including Unsolicited Grant Service (UGS), Real-Time Polling Service (rtPS), Unsolicited Grant Service with Activity Detection (UGS-AD), Non-Real-Time Polling Service (nrtPS) and Best Effort (BE) service	
Admission control	yes	
Interworking		

Interworking of Streams and Flows

1. Value of interworking
2. Feasibility of interworking
3. Network combinations of practical interest

Standardization Implications

Suggestions for standardization

Conclusion

Conclusions regarding network stream and flow interworking

Citations

[1] "IEEE 802 Nendica Work Item Proposal: Network Stream and Flow Interworking," 2020-02-20 https://mentor.ieee.org/802.1/dcn/1-20-0004-04-ICne.pdf

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