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**Telecommunications and exchange
between information technology
systems — Requirements for local
and metropolitan area networks —**

**Part 1Q:
Bridges and bridged networks**

**AMENDMENT 38: Configuration
enhancements for time-sensitive
networking**

*Télécommunications et échange entre systèmes informatiques —
Exigences pour les réseaux locaux et métropolitains —*

Partie 1Q: Ponts et réseaux pontés

*AMENDEMENT 38: Améliorations de la configuration pour les
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IEEE Standard for
Local and Metropolitan Area Networks—

Bridges and Bridged Networks

Amendment 38: Configuration Enhancements for Time-Sensitive Networking

(This amendment is based on IEEE Std 802.1Q™-2022 as amended by IEEE Std 802.1Qcz™-2023, IEEE Std 802.1Qcw™-2023, and IEEE Std 802.1Qcj™-2023.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italics***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~striketrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this note will not be carried over into future editions because the changes will be incorporated into the base standard.⁶

⁶ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

1. Overview

1.3 Introduction

Change the paragraph beginning “This standard specifies enhancements to protocols, procedures, and managed objects for the configuration of network resources” (as amended by IEEE Std 802.1Qcw-2023) as follows, and renumber the subsequent list items accordingly:

This standard specifies enhancements to protocols, procedures, and managed objects for the configuration of network resources for time-sensitive ~~(i.e., bounded-latency)~~ applications that require timely, high probability, delivery of frames without end station retransmission. ~~The enhancements address Time-Sensitive Networking (TSN) application requirements beyond audio/video (AV) traffic.~~ To this end, it:

- ~~em) Specifies a software interface between the user (i.e., time-sensitive application) and network components, such that the user provides Stream requirements (e.g., for bounded latency), and the network configures resources from Talker to Listeners to meet those requirements. This user/network interface (UNI) is specified as an information model that can be applied to any protocol.~~
- cm) Describes three approaches to network configuration: ~~Specifies three models for the UNI:~~ fully distributed, centralized network/distributed user, and fully centralized.
- ~~eo) Specifies enhancements to the Stream Reservation Protocol (SRP), using a new application version, MSRPv1. MSRPv1 integrates the UNI TLVs for the benefits of enhanced configuration. For compatibility, MSRPv1 translates to the previous version (MSRPv0).~~
- cn) Specifies ~~enhancements to the~~ managed objects for forwarding and queuing enhancements for time-sensitive streams (FQTSS).
- ~~eq) Specifies enhancements to the managed objects for SRP.~~
- co) Describes Centralized User Configuration (CUC) and Centralized Network Configuration (CNC) entities.
- cp) Specifies managed objects for configuration of Bridges by a ~~Centralized Network Configuration (CNC) component.~~
- cq) ~~Define~~ Specifies YANG configuration and operational state models (Clause 48) in support of Scheduled Traffic, frame preemption, ~~and~~ Per-Stream Filtering and Policing, and CUC configuration.

3. Definitions

Insert the following definitions in the appropriate collating sequence, renumbering accordingly:

3.1 Configuration Domain: A set of stations that are under a common configuration and management scheme, and a single administration.

3.2 TSN features: The protocols and mechanisms that constitute the set of tools available for building a time-sensitive network.

5. Conformance

5.29 TSN CNC station requirements

Change 5.29, as follows:

This subclause (5.29) defines the conformance requirements for a station that supports the Time-Sensitive Networking (TSN) Centralized Network Configuration (CNC) requirements (46.1.3). The TSN CNC station component is implemented within an end station or Bridge.

A TSN CNC station implementation that conforms to the provisions of this standard shall:

- a) Support the use of a remote management protocol. The TSN CNC claiming to support remote management shall state the following:
 - 1) Which remote management protocol standard(s) or specification(s) are supported for the client implementation.
 - 2) Which standard(s) or specification(s) for managed object definitions and encodings are supported for use by the remote management protocol.
- b) Support the managed object definitions and encodings for Stream reservation remote management (12.32).
- c) Support the use of at least one protocol for User/network configuration information that complies with the requirements for protocol integration defined in 46.2. The TSN CNC shall state which User/network configuration information protocol standard(s) or specification(s) are supported.
- ~~d) If a YANG-based protocol is supported by the TSN CNC for the User/network configuration information, that protocol shall use the YANG module specified in 46.3.~~
- d) If SRP (Clause 35) is supported by the TSN CNC for the User/network configuration information, the TSN CNC shall support MRP External Control (12.32.4).

A TSN CNC station implementation that conforms to the provisions of this standard may:

- e) Use the YANG modules identified in 46.3.

46. Time-Sensitive Networking (TSN) configuration

46.1 Overview of TSN configuration

Change the title and text of 46.1.1 as follows:

46.1.1 ~~User/Network Interface (UNI)~~ Streams, Talkers, and Listeners

TSN configuration uses the concept of a Stream that is transmitted by a Talker to one or more Listeners. The Talkers and Listeners are located within end stations.

This clause specifies configuration information ~~that is exchanged over a User/Network Interface (UNI). The user side of the interface represents for Streams requested by~~ Talkers and Listeners, ~~or by network management entities acting on their behalf. The network side of the interface represents the Bridges that transfer frames of the Stream from each Talker to its Listeners. Each user specifies Stream requirements for its data, but are initially specified by, or for, Talker and Listener~~ without detailed knowledge of the network. ~~The network Network entities or administrators obtains these requirements from users, analyzes the topology and TSN capabilities of the Bridges, and configures the Bridges to meet user the requirements. The network returns the success or failure of each Stream's configuration to the user its Talker(s) and Listener(s).~~

Change the title and text of 46.1.2 as follows:

46.1.2 ~~Modeling of user/network~~ TSN configuration information protocols

A variety of protocols can be used for the exchange of configuration information ~~over the TSN UNI~~ (e.g., signaling protocols, remote network management protocols). ~~These protocols can exchange the configuration information as text or as binary fields. To enable flexible integration of TSN configuration into a variety of protocols, 46.2 specifies the TSN user/network configuration information in a manner that is independent of schema, encoding, or protocol.~~

Specific TSN-capable products list the ~~user/network~~ protocol that is supported as part of their conformance [e.g., 5.18.3, item c) in 5.29]. Each user/network protocol will specify a specific schema and/or encoding for the configuration information in 46.2. Examples of these protocols are described for each of the TSN configuration models in 46.1.3.

46.1.3 TSN configuration models

Change the introductory text of 46.1.3 as follows:

~~This subclause describes three~~ Three models for TSN user/network configuration ~~are described~~. These models provide an architectural context for subsequent specifications. Each model specification shows the logical flow of ~~user/network~~ configuration information between various entities in the network.

46.1.3.1 Fully distributed model

Change 46.1.3.1 as follows:

In the fully distributed model, the end stations that contain ~~users of Streams (i.e., Talkers and Listeners)~~ communicate the user requirements directly ~~over the TSN user/network protocol to the neighboring Bridge~~. The network is configured in a fully distributed manner, without a centralized network configuration entity. The distributed network configuration is performed using a protocol that propagates ~~TSN user/network~~ configuration information along the active topology for the Stream (i.e., Bridges in the tree from Talker to Listeners).

As ~~user~~ Stream requirements propagate through each Bridge, management of the Bridge's resources is effectively performed locally. This local management is limited to the information that the Bridge has knowledge of and does not necessarily include knowledge of the entire network.

Figure 46-1 provides a graphical representation of the fully distributed model.

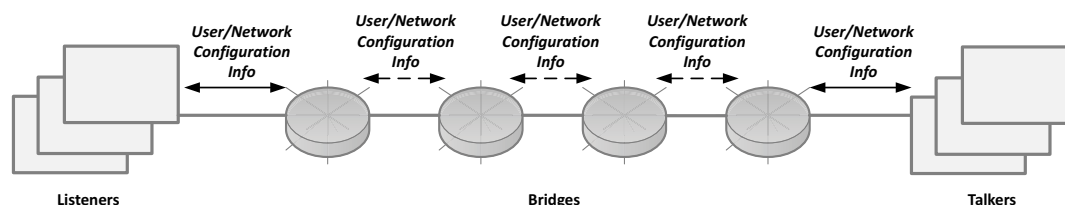


Figure 46-1—Fully distributed model

In the figure, the solid arrows represent the protocol that is used ~~as the UNI for to~~ exchange of configuration information between Talkers/Listeners (users) and Bridges (network). This ~~configuration~~ information is specified in 46.2.

In the figure, the dashed arrows represent the protocol that propagates ~~configuration~~ information within the network. This protocol carries ~~the TSN user/network~~ Stream configuration information (46.2) as well as additional information ~~that is~~ specific to network configuration.

The following TSN features can be configured by Bridges using this model:

- a) Credit-based shaper algorithm (8.6.8.2) and its configuration (Clause 34)

The Stream Reservation Protocol (SRP) of Clause 35 can be used ~~as the UNI by Talkers and Listeners~~, and to propagate configuration information throughout the network of Bridges. ~~SRP exchanges configuration information as binary fields using the Type Length Value (TLV) technique. Using this technique, the protocol's top-level message contains a list of one or more TLVs. Each TLV consists of a Type field that specifies what the Value field contains, a Length field that specifies the number of octets in the Value field, and the Value field. In SRP specifications, each TLV Type identifies one of the groups specified in 46.2, and the TLV Value contains a binary representation of the elements in that group.~~

46.1.3.2 Centralized network/distributed user model

Change 46.1.3.2 as follows:

Some TSN use cases are computationally complex. For example, for scheduled traffic (8.6.8.4), computation of the gate control list of each Port can take significant time. For such use cases, it is helpful to centralize the computation in a single entity (Bridge or end station), rather than perform the computation in all Bridges.

Some TSN use cases can benefit from a complete knowledge of all Streams in the network. For example, if the bandwidth for multiple Streams is greater than the available bandwidth along the shortest path between Talkers and Listeners, it is helpful to forward a subset of those Streams along a path other than the shortest. For these use cases, a centralized entity can gather information for the entire network in order to find the best configuration.

~~The In the~~ centralized network/distributed user model, ~~is similar to the fully distributed model in that~~ end stations communicate their Talker/Listener requirements directly ~~over the TSN UNI to the neighboring Bridge, just as in the fully distributed model. However, in the centralized network/distributed user model, a~~

Centralized Network Configuration (CNC, 46.1.6) entity configures Bridges to pass Talker/ Listener Stream requirements directly to the CNC, rather than propagating that information along the path to be taken by Stream data. ~~In contrast, in the centralized network/distributed user model, the configuration information is directed to/from a Centralized Network Configuration (CNC) entity.~~ All configuration of Bridges for TSN Streams is performed by this CNC using a remote network management protocol.

The CNC has a complete view of the physical topology of the network as well as the capabilities of each Bridge. This enables the CNC to centralize complex computations. The CNC can exist in either an end station or a Bridge.

~~The CNC knows the address of all Bridges at the edge of the network (those with an end station connected). The CNC configures those edge Bridges to act as a proxy, transferring Talker/Listener information directly between the edge Bridge and the CNC, rather than propagate the information to the interior of the network.~~

Figure 46-2 provides a graphical representation of the centralized network/distributed user model.

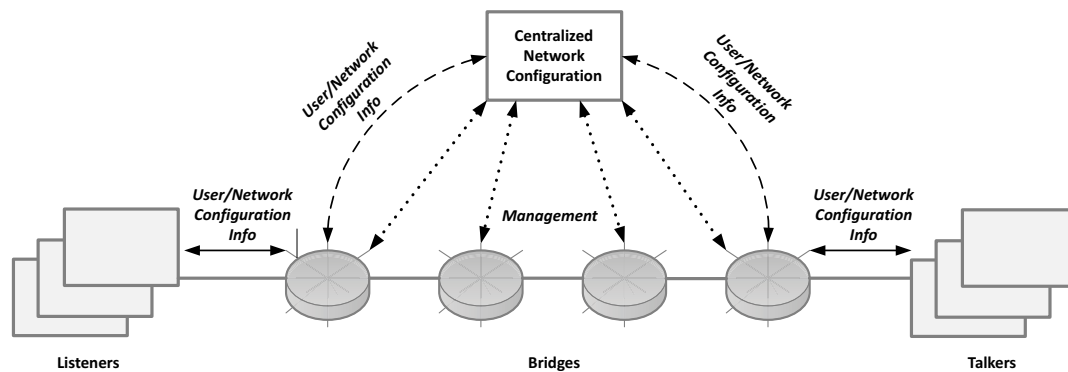


Figure 46-2—Centralized network/distributed user model

In the figure, the solid arrows represent the protocol that is used ~~as the UNI for to~~ exchange ~~of configuration~~ Stream information between Talkers/Listeners (users) and Bridges (network). This ~~configuration~~ information is specified in 46.2.

In the figure, the dashed arrows represent the protocol that transfers Stream configuration information between ~~edge~~ Bridges and the CNC. This ~~configuration~~ information is specified in 46.2.

In the figure, dotted arrows represent the remote network management protocol. The CNC acts as the management client, and each Bridge acts as the management server. The CNC uses remote management to discover physical topology, retrieve Bridge capabilities, and configure TSN features in each Bridge. Talkers and Listeners are not required to participate in this remote network management protocol. The information carried by the remote network management protocol is specified in Clause 12.

NOTE 1—If the Talker/Listener protocol of the fully distributed model is selected to be the same as the Talker/Listener protocol of the centralized network/distributed user model, end stations can support both models without explicit knowledge of how the network is configured.

The following TSN features can be configured by the CNC using this model:

- a) Credit-based shaper algorithm (8.6.8.2) and its configuration (Clause 34)
- b) Frame preemption (6.7.2)
- c) Scheduled traffic (8.6.8.4, 8.6.9)

- d) Frame Replication and Elimination for Reliability (IEEE Std 802.1CB)
- e) Per-Stream Filtering and Policing (8.6.5.1)
- f) Cyclic queuing and forwarding (Annex T)

SRP (Clause 35) can be used as the ~~UNI~~ [Talker/Listener protocol](#) (solid arrows of Figure 46-2). SRP's MRP External Control (12.32.4) feature can be used to exchange configuration information with the CNC component (dashed arrows of Figure 46-2). SRP exchanges configuration information using the TLV technique to reference elements in 46.2 (see 46.1.3.1). Examples of a remote network management protocol (dotted arrows of Figure 46-2) include Simple Network Management Protocol (SNMP), NETCONF (IETF RFC 6241 [B39]), and RESTCONF (IETF RFC 8040 [B47]).

NOTE 2—NETCONF and RESTCONF specify a startup datastore: nonvolatile configuration that is applied when the Bridge powers on. The startup datastore feature enables a ~~TSN~~ CNC to configure Bridges and then remove itself from the network. SNMP does not specify a startup datastore feature. If SNMP is used by a ~~TSN~~ CNC, this can be mitigated by a) using a proprietary (Bridge-specific) startup datastore feature or b) ensuring that the ~~TSN~~ CNC is always active in the network in order to reconfigure Bridges that cycle power.

46.1.3.3 Fully centralized model

Change the first four paragraphs of 46.1.3.3 as follows:

Many TSN use cases require significant user configuration in the end stations that act as Talkers and Listeners. For example, in many automotive and industrial control applications, the timing of physical inputs and outputs (I/Os) is determined by the physical environment under control, and the timing requirements for ~~TSN~~ Streams are derived from that I/O timing. In some use cases, these I/O timing requirements can be computationally complex and involve detailed knowledge of the application software/hardware within each end station.

In order to accommodate this sort of TSN use case, the fully centralized model enables a Centralized User Configuration (CUC, [46.1.5](#)) entity to discover end stations, retrieve end station capabilities and user requirements, and configure TSN features in end stations. The protocols that the CUC uses for this purpose are ~~specific to the user application and outside the scope of~~ [not specified in](#) this standard.

From a network perspective, the primary difference between the fully centralized model and the centralized network/distributed user model is that all user requirements are exchanged between the CNC and CUC. ~~Therefore, the TSN UNI exists between the CNC and CUC.~~

Figure 46-3 provides a graphical representation of the fully centralized model [with multiple CUCs](#).

Replace Figure 46-3 with the following figure:

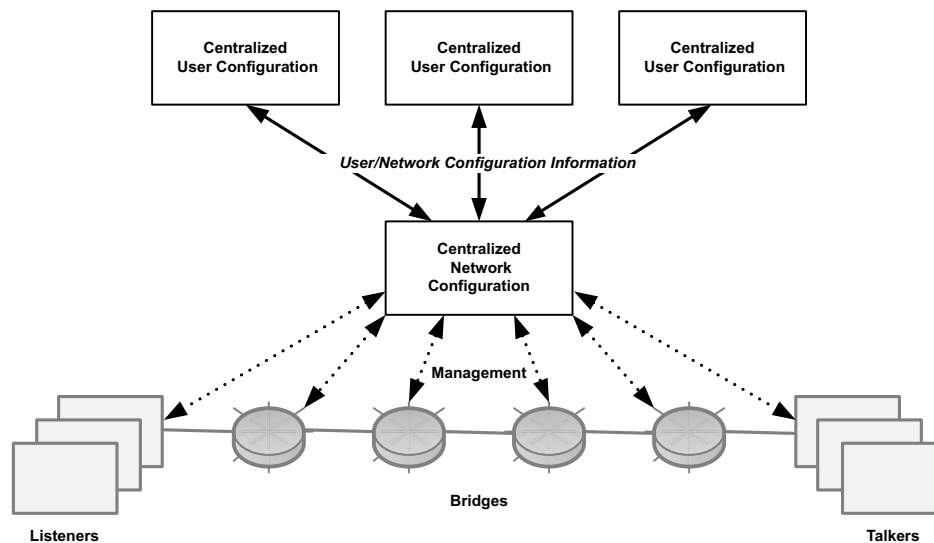


Figure 46-3—Fully centralized model

Change 46.1.3.3 from paragraph five onwards, as follows:

In the figure, the solid arrows represent the protocol that is used ~~as the UNI for to~~ exchange ~~of configuration~~ Stream information between the CUC and the CNC. This ~~configuration~~ information is specified in 46.2.

In the figure, the dotted arrows represent the remote network management protocol. The CNC acts as the management client, and each Bridge acts as the management server. The CNC uses remote management to discover physical topology, retrieve Bridge capabilities, and configure TSN features in each Bridge. Talkers and Listeners are not required to participate in this remote network management protocol. The information carried by the remote network management protocol is specified in Clause 12.

In this fully centralized model, a protocol is used between the CUC and end stations (Talkers and Listeners) to retrieve end station capabilities and requirements and to configure the end stations. ~~Since that protocol is user-to-user, its configuration information is considered to be outside the scope of this standard, and it is not shown in Figure 46-3.~~

The following TSN features can be configured by the CNC using this model:

- Credit-based shaper algorithm (8.6.8.2) and its configuration (Clause 34)
- Frame preemption (6.7.2)
- Scheduled traffic (8.6.8.4, 8.6.9)
- Frame Replication and Elimination for Reliability (IEEE Std 802.1CB)
- Per-Stream Filtering and Policing (8.6.5.1)
- Cyclic queuing and forwarding (Annex T)

YANG (IETF RFC 7950) is a data modeling language used to model configuration data and state data for remote network management protocols. The remote network management protocol uses a specific encoding such as XML or JSON. For a particular feature, a YANG module specifies the organization and rules for the feature's management data, and a mapping from YANG to the specific encoding enables the data to be understood correctly by both client (e.g., network manager) and server (e.g., Bridge). ~~Technically speaking,~~

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~~the TSN user/network configuration is not network management, in that information is exchanged between user and network, and not between a network manager and the network's Bridges (Clause 12). Nevertheless, the concepts are sufficiently similar that YANG is useful for modeling the configuration and state data for the TSN user/network configuration information.~~

In order to support the use of YANG-based protocols for the fully centralized model, 46.3 specifies a YANG module. The YANG module specifies a YANG typedef/grouping for each group of information in 46.2.

~~NOTE—At the time that this clause was developed, specific protocol implementations for the fully centralized model were a work in progress. One protocol explored for the UNI between CUC and CNC is RESTCONF (IETF RFC 8040 [B47]). A complete YANG module for the TSN UNI can be specified in a document other than IEEE Std 802.1Q. In order to conform with this clause, the complete TSN UNI YANG module imports the YANG module of 46.3 for use within its containers and lists. The complete TSN UNI YANG module will presumably specify features outside the scope of this clause, such as operations to control the deployment of Stream configuration to the network. The JSON encoding can be used with RESTCONF. Although the TSN UNI is technically not network management, use of RESTCONF provides a simple and effective application programming interface (API) for TSN configuration.~~

For an informative example workflow using the fully centralized model, refer to U.2.

Change the title and text of 46.1.4 as follows:

46.1.4 Stream identification and transformation

TSN configuration uses the concept of a Stream of data that is transmitted by a Talker to one or more Listeners. ~~The Talkers and Listeners are end stations.~~

In order to apply TSN behavior to a Streams (e.g., to reserved bandwidth ~~guarantees~~), the network ~~must be able to~~ distinguish one Streams from ~~another Stream and distinguish Streams~~ each other and from non-TSN traffic (e.g., best-effort). ~~Therefore, each~~ Each frame of ~~the a Stream~~ must contains fields in its header that uniquely identify the Stream.

The goal of TSN configuration is to allow Talkers and Listeners to use their existing transport layer and application layer protocols for data, rather than requiring a TSN-specific frame format. TSN achieves this goal by identifying each Stream using fields from well-established frame formats such as Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and IEEE 802.1 (i.e., MAC addresses and VLAN identifier).

As the frames of each Stream cross the user/network boundary, the identification of the Stream in its frames can be different between the network and the user. For example, the user can use UDP without an awareness of VLAN IDs, but the network can require a specific VLAN ID in order to apply TSN features. In order to support this sort of difference in frame format, the TSN user/network configuration information (46.2) provides features to enable transformation of the Stream's identification at the user/network boundary. The user identification translates to/from the network identification at the boundary, either within the end station or a nearest Bridge. This transformation has the benefit of allowing the user's identification to match its higher layer application protocol and the network's identification to match the bridging technology.

Stream transformation can be accomplished using the functions specified in IEEE Std 802.1CB. The functions of IEEE Std 802.1CB can be implemented in the end station (Talker/Listener) or within the nearest Bridge. The descriptions in this clause focus on Stream transformation in the end station and use features of the TSN user/network configuration information (46.2).

NOTE 1—In this clause, Stream transformation refers to changes to the fields of a frame that identify the Stream. IEEE Std 802.1CB specifies Stream transformation for identification as well as for frame replication and elimination (redundancy).

NOTE 2—Stream transformation is an optional capability of end stations and Bridges. If stream transformation is not supported, the user's identification of the Stream must be the same as the network's identification, and the user must use an identification that is consistent with bridging as specified for TSN features in this standard (e.g., VLAN tag and group destination MAC address).

Figure 46-4 provides an example of Stream transformation in the Talker end station. Stream transformation in the Listener end station is similar. The example of Figure 46-4 assumes use of the centralized network/distributed user model (46.1.3.2). Use of the fully centralized model (46.1.3.3) is similar.

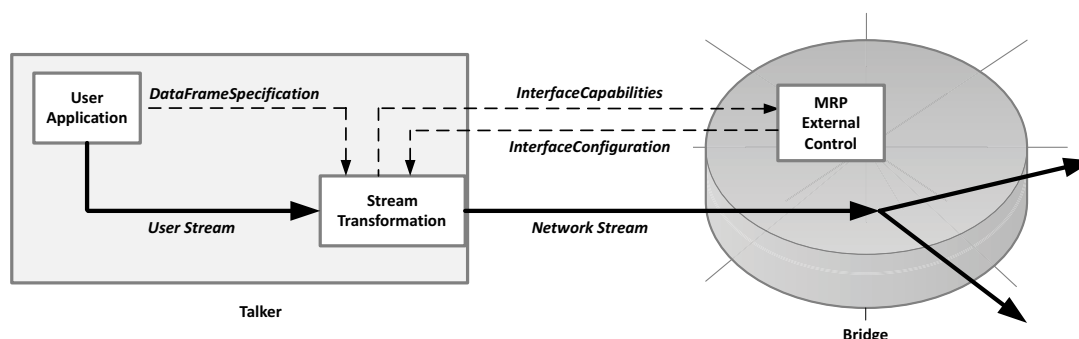


Figure 46-4—Example of Stream transformation in Talker end station

For Stream transformation in the end station, the end station's interface to the network can provide the transformation capability, acting as a network entity within the user's end station.

The identification of the Stream in the user originates from the User Application block, specified by the Talker as the DataFrameSpecification (46.2.3.4). The end station knows this user identification, but not the identification that the network requires. To negotiate the network identification, the Talker uses SRP to transmit InterfaceCapabilities (46.2.3.7) that describe its Stream transformation capabilities to the nearest Bridge. The Bridge uses MRP External Control (12.32.4) to send the InterfaceCapabilities to a CNC. The CNC consults its configuration of network identification and uses MRP External Control to send InterfaceConfiguration (46.2.5.3) along with successful Status (46.2.5) back to the Bridge. When the Bridge receives this information, it propagates back to the Talker using SRP. The InterfaceConfiguration provides the network identification, which the end station uses to perform Stream transformation for data frames.

NOTE 3—The network identification typically entails allocation of a group MAC address for the Stream. If a CNC is used, the CNC can allocate a group MAC address from a pool that it maintains.

Figure 46-5 provides an example of IEEE 802.1CB functions within the Stream Transformation block in the Talker end station. The example assumes that the user identification uses an Internet Protocol (IP) packet for identification and that the frame conveying the IP packet does not use the appropriate MAC address and VLAN tag for TSN features in Bridges (e.g., IP packet unicast destination MAC address, untagged). The IEEE 802.1CB function for IP Stream identification uses fields of the IP packet to identify the packet as a specific TSN-Stream. That TSN-Stream identification is then applied to the IEEE 802.1CB function for Active Destination MAC and VLAN Stream identification to replace the destination MAC address and add a