P802.1Qdq
(assuming the approval of the PAR)

Text Contribution

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Annex Y

(Informative)

Shaper Parameter Settings for Bursty Traffic Requiring Bounded Latency

Y.1 Introduction

This annex clarifies a type of traffic requiring bounded latency that occurs sporadically and that consists of multiple frames an occurrence. This type of traffic is widely observed in actual cases and profiles discussed as IEEE 802.1 standards and reports published by IEEE 802 NENDICA point it out.

<< Contributor's Note: should we mention examples?>>

<<Contributor's Note: Add the following reference?
[Z1] IEEE 802 Nendica Report: Flexible Factory IoT: Use Cases and Communication Requirements for Wired and Wireless Bridged Networks, April, 2020>>

IEEE Std 802.1Q time-sensitive bridged network equipped with shapers is capable of handling this type of traffic and guaranteeing the bounded latency. Figure Y-1 shows an example of the network configuration under consideration. This network comprises Talkers, Listeners, and bridges, which connect directly or indirectly to each other. Each stream of traffic generated by an application is sent from the Talker to the Listener via bridges across its route.

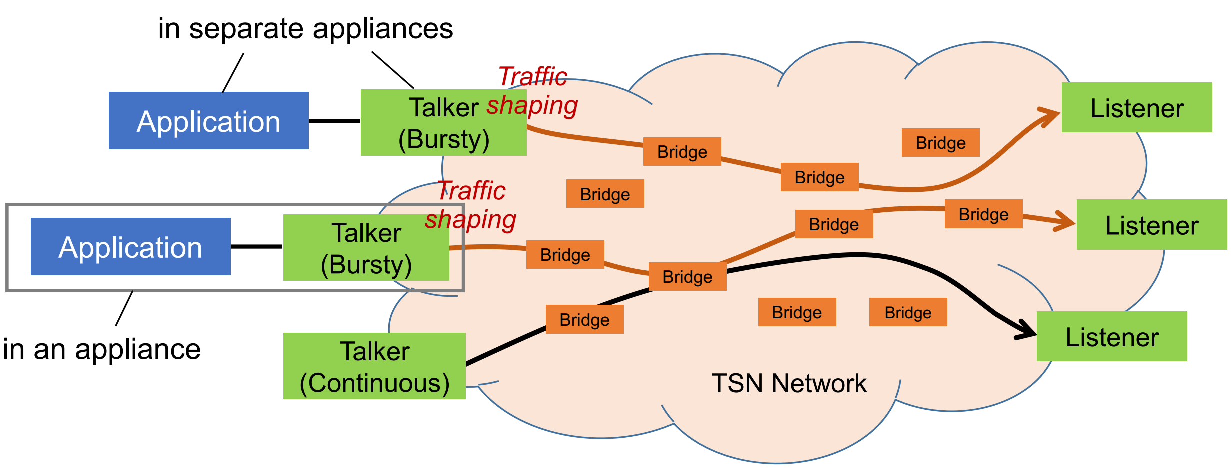

Figure Y-1 — An example of network structure under consideration

There are multiple streams flowing through this network, and they may flow into a common bridge. Traffic shaping is performed in the Talker and resource reservation is performed in bridges based on TSpec provided by the Talker. The specific traffic shaping method is based either on the credit-based shaper transmission selection algorithm (8.6.8.2) or on the ATS transmission selection algorithm (8.6.8.5).

<< Contributor's Note: referring the ATS transmission selection algorithm (8.6.8.5) in the P802.1Qcr/D2.3 >>

However, the shaper parameter settings are not obvious because the discussion of shapers tends to be for continuous streams with fixed bandwidth. More importantly, this type of traffic requires to be defined properly enough to discuss. This enables the shaper parameter settings to be logically defined and efficient, that is, not over-provisioned.

In this annex, Y.2 defines the type of traffic and then Y.3 discusses worst-case latency imposed by a bridged network. Finally, Y.4 illustrates shaper parameter settings according to shapers and configuration frameworks.

Y.2 Bursty Traffic Requiring Bounded Latency

This clause defines the traffic type handled a bridged network and its parameters that describe this type of traffic.

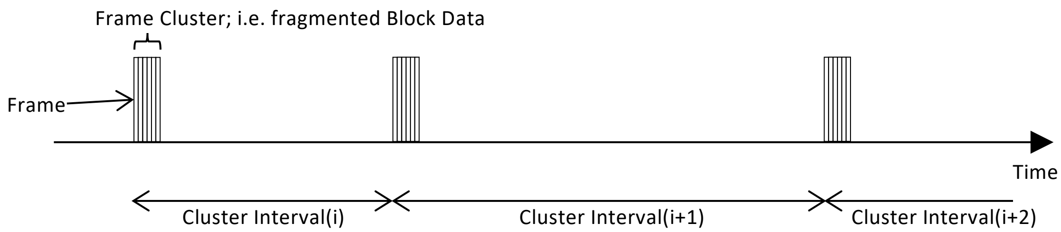

Figure Y-2— Burst traffic of fragmented block data

Figure Y-2 illustrates the bursty traffic pattern. Each data block has a bounded latency. The bounded latency is assumed to be pre-determined by an application or set manually by an operator of an application. It defines the maximum time from the reference point at the application in the Talker to the reference point at the Listener. In view of the characteristics of some data transmission with a large interval between clusters that can exceed several tens of milliseconds or event-driven data generation by IoT devices [Z1], the traffic treated here is sporadic, with condition that the next frame cluster never arrives until the entire corresponding queue in a bridge becomes empty.

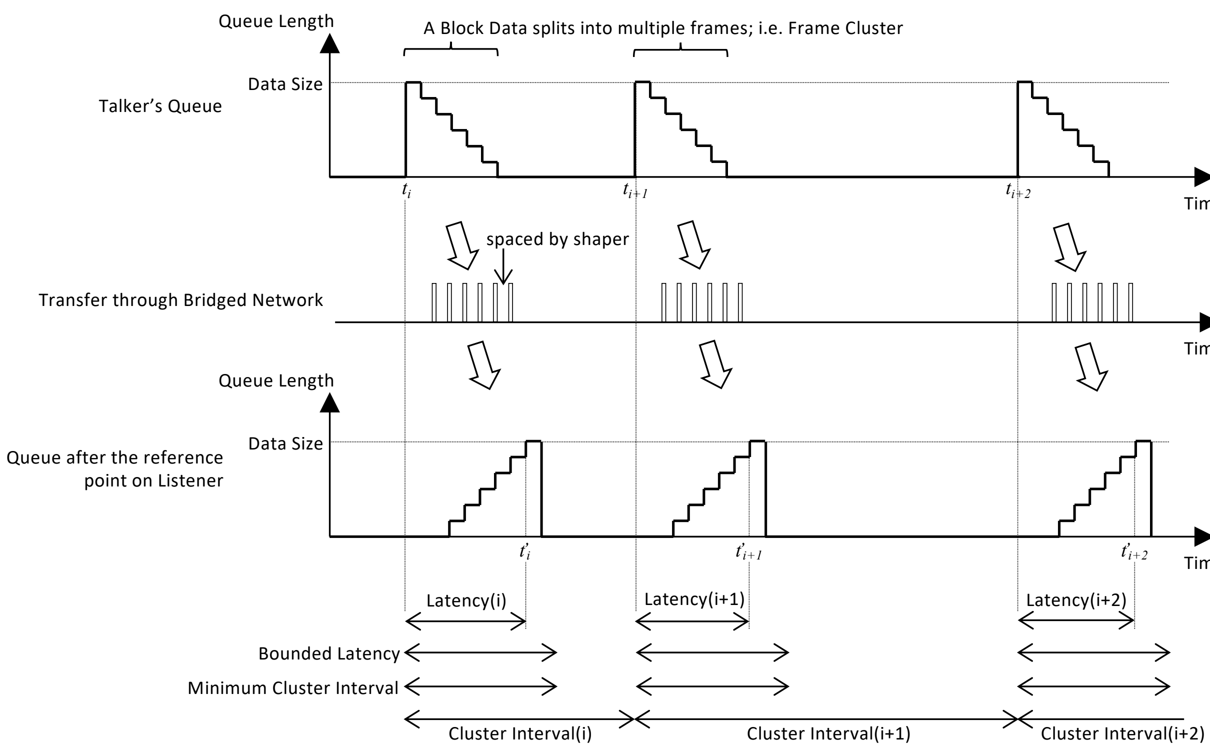

Figure Y-3— Traffic pattern in an application's point of view

Figure Y-3 illustrates the detailed traffic pattern and queues of the traffic type to be defined here in the application's point of view. The traffic is described by the three given parameters: Data Size, Bounded Latency and Minimum Cluster Interval. At the time t_i, a transmitting application sends a block data Data(i) whose size is equal to or less than "Data Size" and may be greater than frames the bridged network can handle. The whole block data requires to reach the corresponding receiving application through the bridged network by the time t'_i that is equal to or less than t_i plus "Bounded Latency." In addition, the transmitting application puts the subsequent block data at time t_{i+1}, which should be equal to or greater than t_i plus "Minimum Cluster Interval."

Latency(i) represents t'_i - t_i, which is the time it takes the whole block data to be transferred from the queue of Talker to the input queue of Listener. Cluster Interval(i) represents t_{i+1} - t_i, which is the interval time between a block data and the subsequent block data. Both Latency(i) and Cluster Interval(i) often vary according to i, thus it is described as "sporadic," however for any i Latency(i) requires to be equal to or less than Bounded Latency and Cluster Interval(i) requires to be equal to or greater than Minimum Cluster Interval.

In the bridged network's point of view, a block data is transferred with multiple frames through the bridged network since Data Size is larger than a frame the bridged network can handle. Bursty transmission of these frames often results in disruption of other communication in the bridged network, hence as opposed to a single frame it is required to discuss the shaper parameter settings that enable the requirement to be satisfied.

The flow of frames from the Talker to the Listener in the bridged network is shown in Figure Y-4.

The data size of each cluster comprising n-frames is equivalent to the sum of frame lengths.

$$dataSize(i) = \sum_{k=1}^{n(i)} frameLength(i,k) \qquad (Y-1)$$

Bursty traffic is shaped by the Talker. As a result of traffic shaping, the interval in which the Talker sends each frame becomes equal to the frame length divided by the shaping rate. Then, at the input of a Listener, the delivery time of this frame cluster (as shown in Figure Y-4) becomes as follows:

$$deliveryTime(i) = \frac{\sum_{k=1}^{n-1} frameLength(n)}{shapingRate} + accumulatedLatency \qquad (Y-2)$$

The shaping rate, within the traffic shaper, is set so that the delivery time is within the bounded latency required by the application. The accumulatedLatency is the sum of delays of a stream in all the bridges across the route from the Talker to the Listener as given in Equation (V-6) in Annex V (IEEE Std 802.1Qcr-2020). The accumulatedLatency is regarded as the propagation delay from the Talker to the Listener.

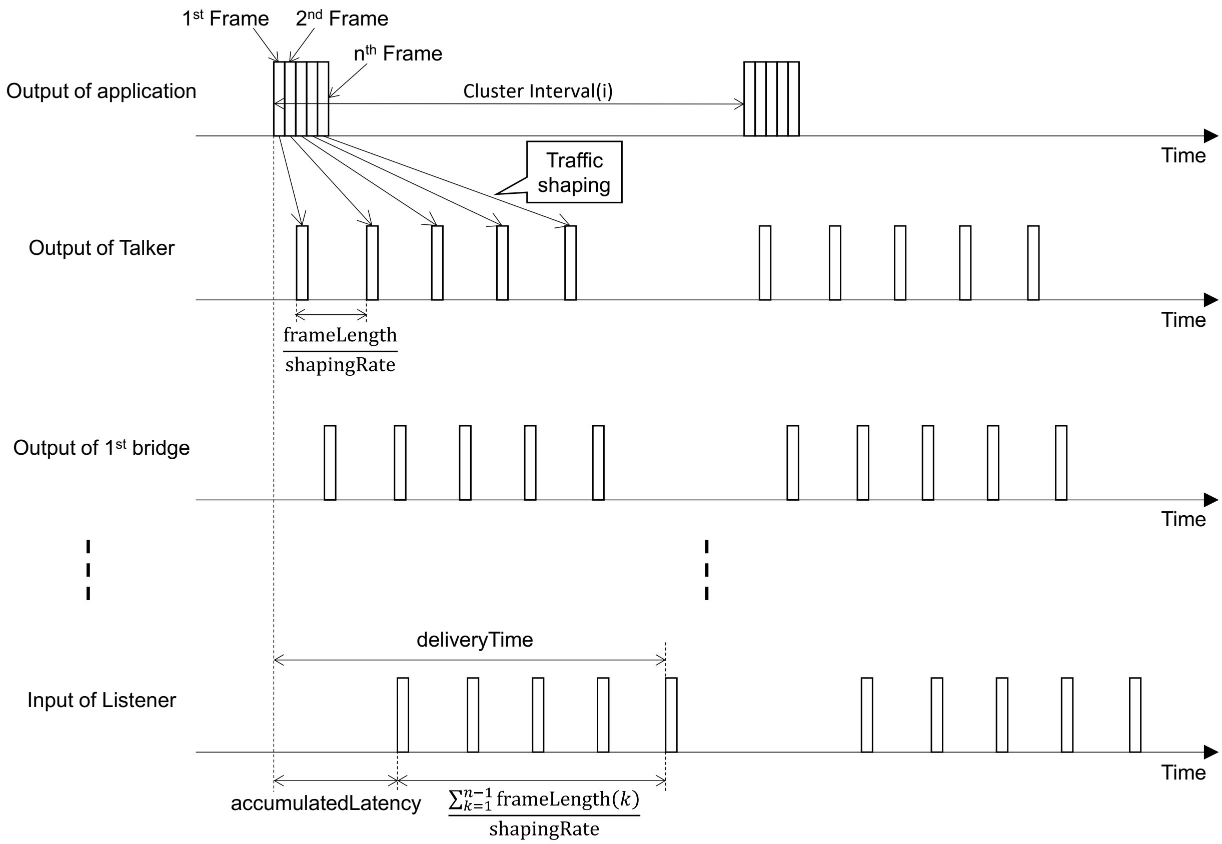

Figure Y-4— Frame propagation from Talker to Listener

Y.3 Accumulated Latency and Bridged Network

Y.3.1 Accumulated Latency

Per-hop latency imposed by a bridged network against a single frame is discussed in Clause 35 and Annex L. Latency between Talker and Listener (hereinafter referred to as Network Latency) is derived from the sum of per-hop latency along the path between them. In bridged networks controlled by SRP, the value portTcMaxLatency and AccumulatedLatency can be obtained from the system, while it can be manually evaluated by the same way in networks without SRP.

<< Contributor's Note: should we mention the problem of MaxLatency and preemption discussed in Qdj?>>

The value AccumulatedLatency is used as one of inputs of the calculating procedure for shaper parameter settings defined in Y.4.

Y.3.2 Dynamic Reservation with SRP

When the fully distributed model (IEEE Std 802.1Qcc-2018, Clause 46.1.3.1) without a CNC (Centralized Network Configuration) is applied to the TSN network, no complete information is available in advance for computing the accumulated latency at all nodes along possible paths between the Talker and Listener. Therefore, an iterative method, which may result in local/approximate solution, is used to address this problem.

In the fully distributed model, the UNI (User Network Interface) is used to exchange information related to propagation delay between bridges. The Talker may use the MaxLatency element of the

UserToNetworkRequirements group (IEEE Std 802.1Qcc-2018, Clause 46.2.3.6.2) and the AccumulatedLatency group (IEEE Std 802.1Qcc-2018, Clause 46.2.5.2) in order to obtain accumulatedLatency. The UNI specification requires the Talker to request joining a target stream. That is, the Talker cannot obtain the information before requesting to join a stream. Therefore, the Talker has to request to join a stream first with a tentative TSpec. The tentative TSpec is derived assuming the accumulatedLatency which can be set by implementer's choice, such as determining by the network administrator, and adopting a value of zero as simple recommendation. Then the Talker requests to join again with the amount obtained by the first request. The first calculated reservation and the second one are not guaranteed to return the same values of the accumulatedLatency and the Talker will try to join with different TSpec and MaxLatency based on the previously obtained accumulatedLatency repeatedly until successful joining the target stream. This method can be applied to the Stream Reservation Protocol. (IEEE Std 802.1Qcc-2018, Clause 35).

Y.3.3 Dynamic Reservation with CNC

A CNC does not have the same problem as the fully distributed network described in clause Y.3.2. This is because when a CNC in the centralized network/distributed user model (IEEE Std 802.1Qcc-2018, Clause 46.1.3.2) or the fully centralized model (IEEE Std 802.1Qcc-2018, Clause 46.1.3.3) is used to configure the TSN network, the CNC obtains all information from the network directly. For example, the CNC reads the bridge delay (12.32.1) and propagation delay (12.32.2) from each bridge in order to compute accumulatedLatency (-see Annex U, Clause U2, step 5, IEEE Std 802.1Qcc-2018).

Y.4 Shaper Parameter Settings

Y.4.1 General Discussion of Shaping Rate

This standard defines several types of shapers. Any of those shapers makes intervals between frames, however its parameters vary according to the type of the shaper. Each shaper is discussed in the following subclauses.

In order to minimize over-provisioning of bandwidth reservation while ensuring the requirement for the delivery time is met, the bursty traffic should be shaped with the minimum shaping rate within the required bounded latency (required minimum shaping rate). Frame propagation within bounded latency while minimizing over-provision of bandwidth reservation is illustrated in Figure Y-5 and referred to as the target latency. From Figure Y-5, the target latency can be derived from bounded latency and accumulatedLatency. The required minimum shaping rate for traffic shaping is equal to:

$$requiredMinimumShapingRate = \frac{\sum_{k=1}^{n-1} frameLength(k)}{targetLatency}$$

$$= \frac{dataSize - frameLength(n)}{targetLatency} \qquad (Y-3)$$

In practice, the required minimum shaping rate can be approximated to (dataSize/targetLatency), which is slightly larger than the exact value if the frame length is smaller than data size. Actually, regardless small or large value of *n*-th frame length compared with data size, it gives an additional delivery time margin to the bounded latency.

If the Talker does not have enough memory buffer compared with the data size, it does not function any more.

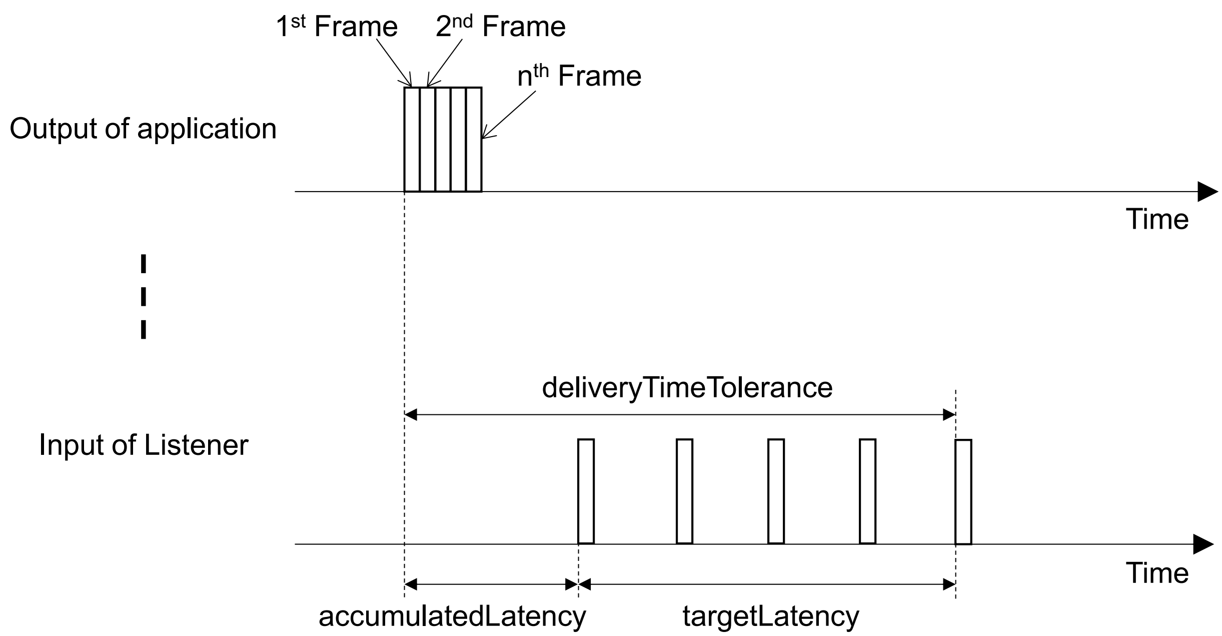

Figure Y-5— Frame propagation within bounded latency while minimizing over-provision of bandwidth reservation

Y.4.2 Credit-Based Shaper

idleSlope is the only parameter describing a credit-based shaper. The following equation follows from the equation L-1.

$$idleSlop = requiredMinimumShapingRate \qquad (Y-4)$$

Y.4.3 Asynchronous Traffic Shaping

According to the definition of the ATS scheduler state machine in Clause 8.6.11 (IEEE Std 802.1Qcr-2020), CommittedBurstSize should be equal to or greater than frames sent by the Talker. In this case, it is recommended to be equal to the Maximum SDU Size. CommittedInformationRate is the data rate reserved for the stream and is recommended to be equal to the requiredMinimumShapingRate shown in Equation (Y-3). The approximation discussed in Clause Z.3 can also be applied. These lead to the following settings values:

$$CommittedBurstSize = Maximum\ SDU\ Size \qquad (Y-5)$$

$$CommittedInformationRate = \frac{dataSize}{targetLatency} \qquad (Y-6)$$

Since the ATS scheduler state machine operation (8.6.11) assumes that the frame sizes that are processed are less than or equal to the associated CommittedBurstSize parameter (8.6.11.3.5), the CommittedBurstSize is set to be the maximum size of frame. That is equal to the Maximum SDU Size as shown in Equation (Y-5).

<< Contributor's Note: The ATS scheduler should also works for the case in which the CommittedBurstSize is greater than Maximum SDU Size. It does not affect other traffic for which the long-term averaged shaping rate.

However, a small value of the CommittedBurstSize is desirable because the transient data rate, which is higher than the required minimum shaping rate, may be suppressed. This transient manner can be caused by the arrival of a new frame cluster at the shaper that has already accumulated large number of tokens causing some frames to be forwarded instantly. Such token-bucket state can occur when no frames arrive at the shaper for a period of time between clusters. >>

Y.4.4 Traffic Specification in SRP

The MSRP TSpec is used in the credit-based shaper transmission selection algorithm. This type of TSpec is intended for use by reservations that compatibly supports AVB SR class A or SR class B. Unlike audio/video streaming, TSpec for bursty traffic, which characterizes the bandwidth that a stream can consume, needs to consider dataSize and targetLatency.

The TSpec parameters for MSRP are recommended to be set as follows:

$$MaxFrameSize = \min\left(\text{floor}\left(\frac{dataSize}{targetLatency} \times classMeasurementInterval\right), Maximum\ SDU\ Size\right) \quad (Y-7)$$

$$MaxIntervalFrames = \text{ceil}\left(\frac{1}{MaxFrameSize} \times \frac{dataSize}{targetLatency} \times classMeasurementInterval\right) \quad (Y-8)$$

The Maximum SDU (Service Data Unit) size is defined in (6.5.8). The MaxFrameSize is recommended to set the Maximum SDU Size. However, the MaxFrameSize should be smaller than the Maximum SDU size in case that classMeasurementInterval in (34.3) is shorter, i.e. the number of bytes within the classMeasurementInterval is smaller than the Maximum SDU size. The MaxIntrvalFrame needs to be guaranteed so as to become a positive integer (1 or lager value).

When considering the definition of the FirstValue for the UNI TLVs as in (35.2.2.10.6), and the values of TrafficSpecification TLV as specified in (46.2.3.5) in IEEE Std 802.1Qcc™-2018, then equation Y-7 and Y-8 can be presented as follows:

$$MaxFrameSize = \min\left(\text{floor}\left(\frac{dataSize}{targetLatency} \times Interval\right), Maximum\ SDU\ Size\right) \quad (Y-9)$$

$$MaxFramesPerInterval = \text{ceil}\left(\frac{1}{MaxFrameSize} \times \frac{dataSize}{targetLatency} \times Interval\right) \quad (Y-10)$$

The parameter “Interval” is referred in (46.2.3.5.1), which replaced classMeasurementInterval in Equations (Y-7) and (Y-8). The Interval is recommended to be set less than the bounded latency for controlling the shaping rate during the shaping duration.

Y.99 Further Considerations (not intended to be incorporated into the standard)

<< Contributor’s Note: This section is a memorandum during the development process of this standard and not intended to be incorporated into the standard. >>