Scheduling of Time-sensitive and Bursty Traffic in Reduced Available Bandwidth (STSBT)

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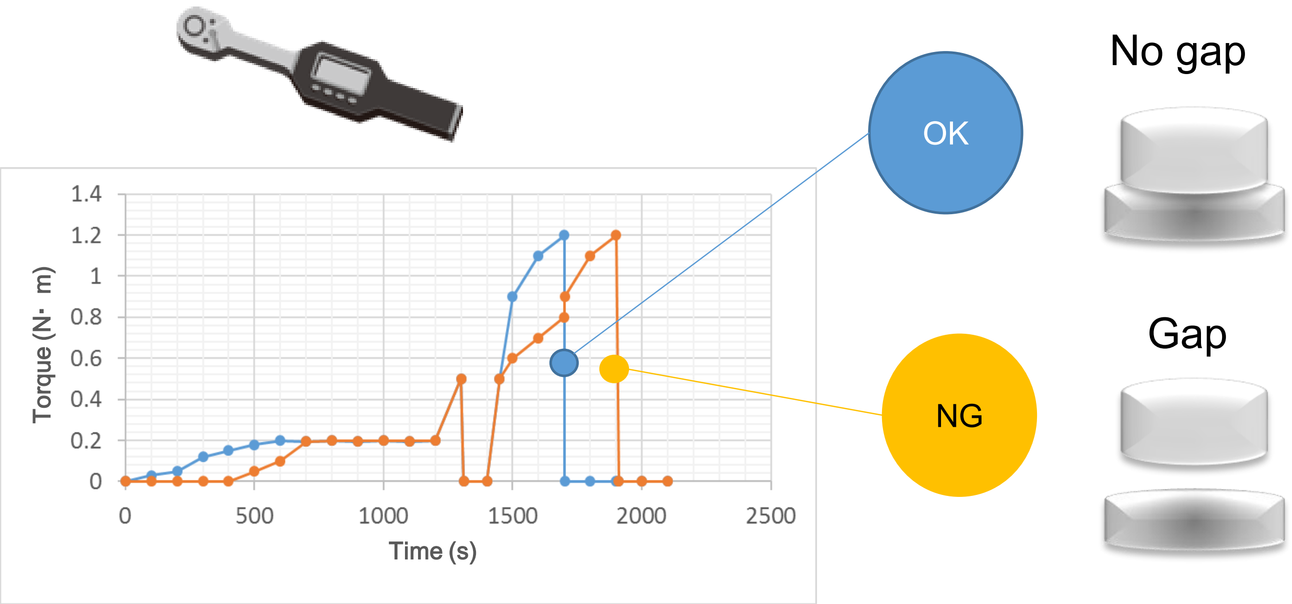
Introduction

- This document addresses the need for the scheduling of time-sensitive and sporadic bursty traffic in reduced available bandwidth (STSBT).
- It shows that appropriate scheduling mitigates against occasionally reduced bandwidth, to maintain QoS for sporadic bursty traffic.
- Across the end-to-end links with varying bandwidth, the required minimum bandwidth for each time-sensitive stream is needed at each bridge node.
- Configuration mechanism for this scheduling method and related information are not considered in current IEEE Std 802.1Q-2018 or its amendments.

Example of IoT Device to Generate Bursty Traffic

- Intelligent Torque Wrench measures tightening force in order to check the quality of manufacturing operation.
- It sends data to the network when it senses something happens.
- The data must reach the administering system in time.



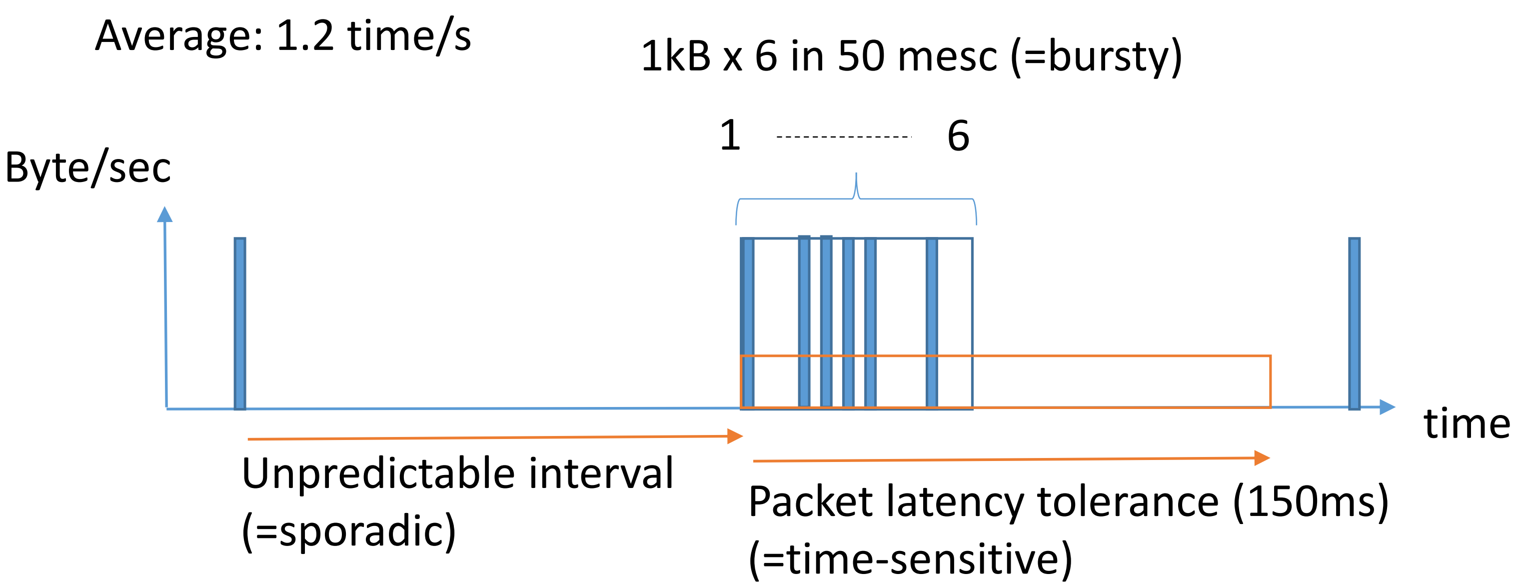
Data Generation Time (s)

…
41.129864
41.130438
41.130773
41.131157
41.133885
41.17374
…

6 packets within 50msec (measurement)

Traffic Generated by Torque Wrench (TW)

- A torque wrench generates 1kB-packets. Mean packet rate was 1.2 times/s but 6 packets were generated in 50msec during concentrated period (measurement).



Bursty Traffic in .1Q

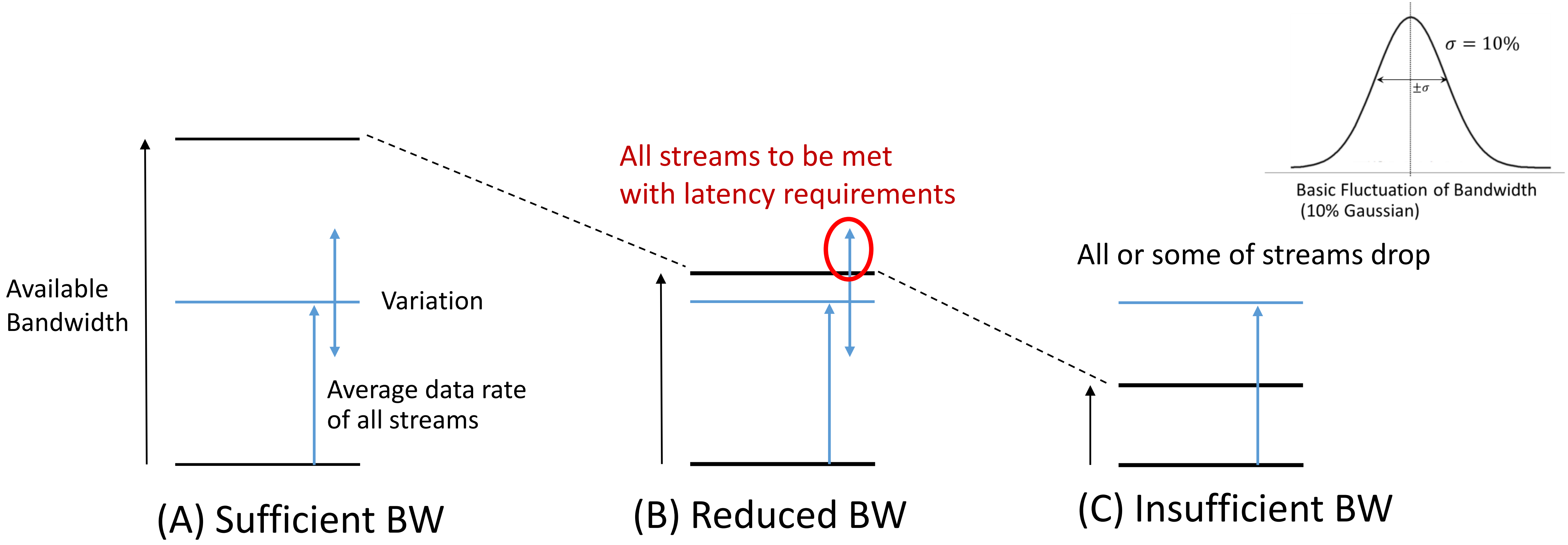
- “Larger bursts of data have a negative impact on the overall performance of the QCN algorithm, and can lead to lower link utilization.“ (31.2.2.4 Rate Limiter)

QCN: Quantized Congestion Notification protocol

- In credit-based shaper, bursty traffic can be treated frame by frame. “For the numerically highest traffic class, maxInterferenceSize is exactly equal to the maximum sized frame that can be transmitted through the Port.” (L.1 Overview of credit-based shaper operation)
- Problem: No way to keep QoS for a bunch of frames of time sensitive and sporadic bursty traffic in reduced available bandwidth for high link utilization.

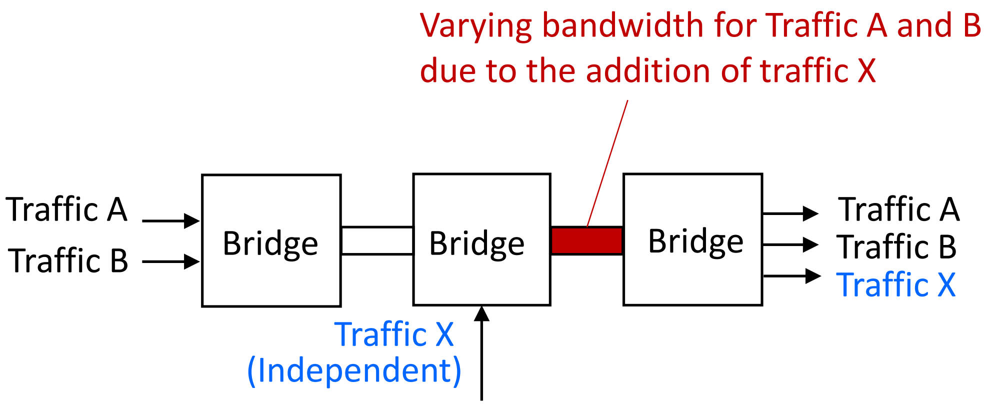
Reduced Available Bandwidth

- For reduced bandwidth (BW), all streams are possible to be met with latency requirements.
- Bursty traffic, which is increasing with M2M communication in IoT network, may be problematic.

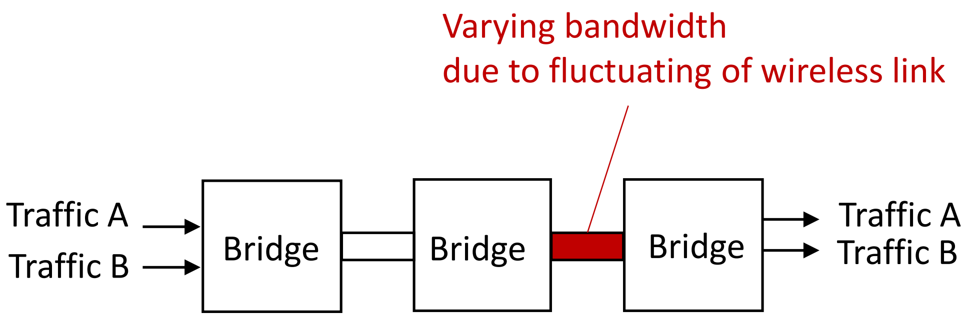


Examples of Reduced Available Bandwidth

- The following situations need to be considered for links occasionally with reduced available bandwidth:
  - ✓ Existing of other independent traffic over shared media (by new additions of traffic)
  - ✓ Fluctuating bandwidth of wireless link



Other independent traffic over shared media



Bandwidth fluctuation of wireless link

Existing Functions in Current 802.1Q

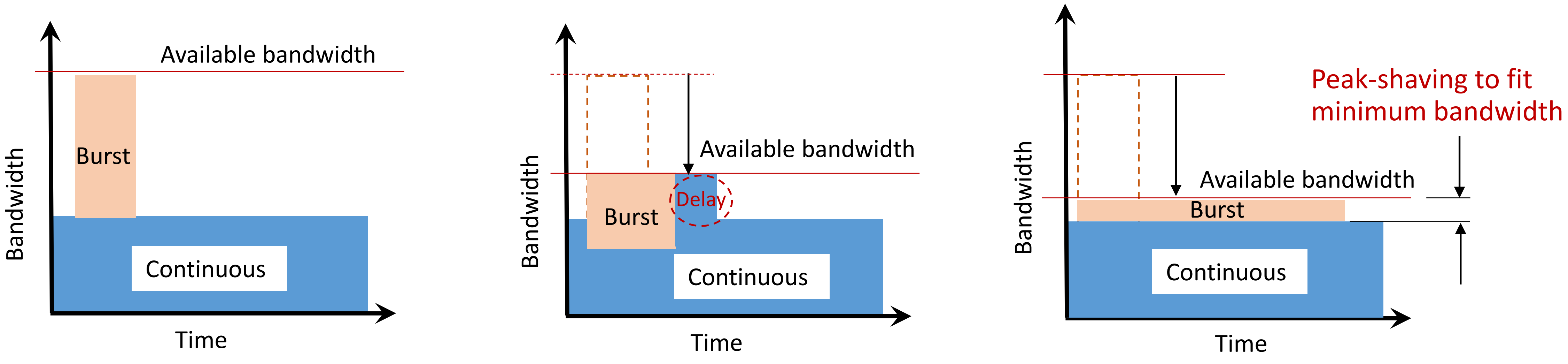
- Strict Priority
  - ✓ Priorities of streams is accomplished by ordering but QoS is still not guaranteed.
  - ✓ Number of priories are limited by traffic classes.
  - ✓ It is difficult to assign priorities to various data by IoT devices.
- Bandwidth Allocation/Stream Reservation
  - ✓ Over-provisioning is required to allocate bandwidth at peak-rate for a stream.
  - ✓ SRP supports only constant traffic.
  - ✓ No information how much bandwidth needs to be allocated for bursty traffic.

Peak-shaving

- The process of peak-shaving is used to define and allocate minimum bandwidth for busrty traffic to minimize available bandwidth as follows.

  Minimum bandwidth = (data size) / (tolerable latency) ;

  The notion of such minimum bandwidth is Not defined in 1Q



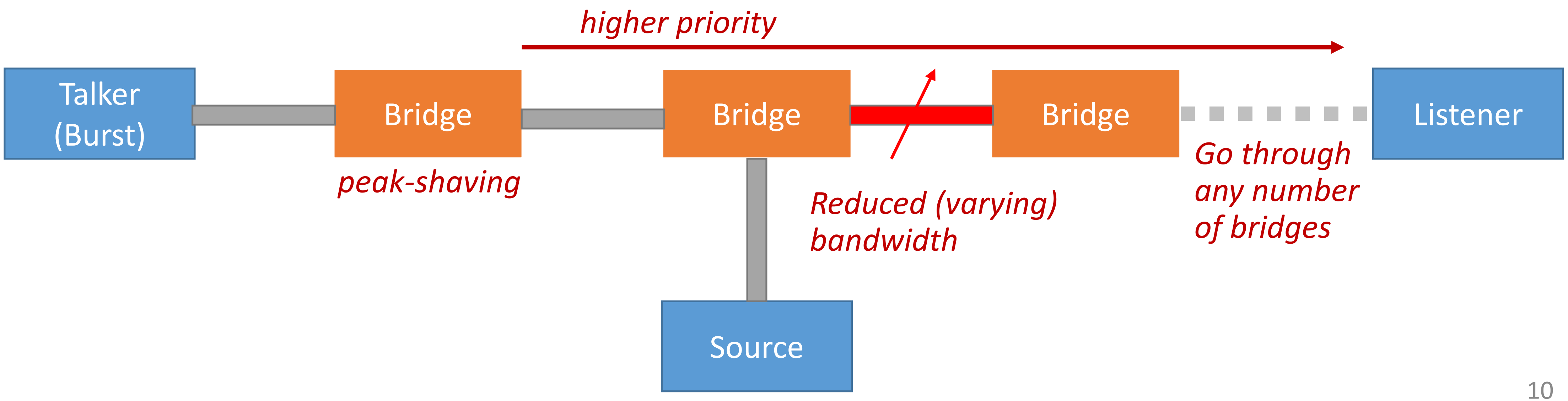
(a) Sufficient bandwidth

(b) Reduced Bandwidth (No priority control)

(c) Peak-shaving for bursty traffic (Priority control)

STSBT Operation

- Shaping for peak shaving.
- Higher priority assignment for the shaped stream to avoid additional delay.



Ideas of Amendments for STSBT

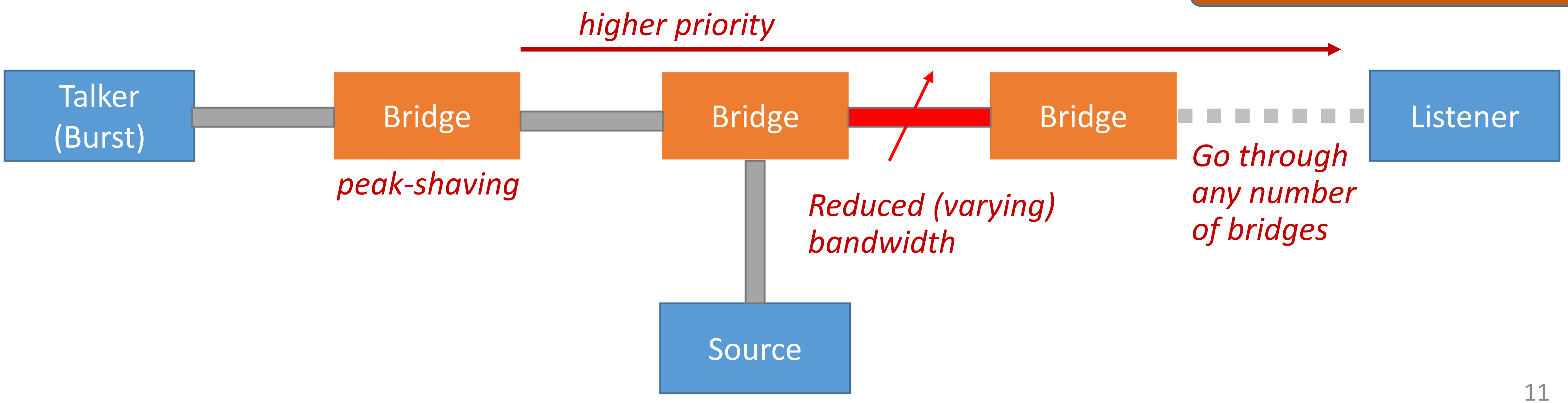
Proposed changes

Control Plane

- Distribute information of targeted bursty traffics with "minimum bandwidth."
  → amend .1Q with new information.

- Configure bridges next to source nodes to peak-shave the traffics.
  → Use CBS, ATS or any other shapers
- Configure bridges across the path towards the listeners to protect the STSBT streams to guarantee E2E bounded latency. → Use a queue with higher priority
- Identify streams to be controlled with this mechanism → Use .1CB/CBdb.

Configuration of Data Plane



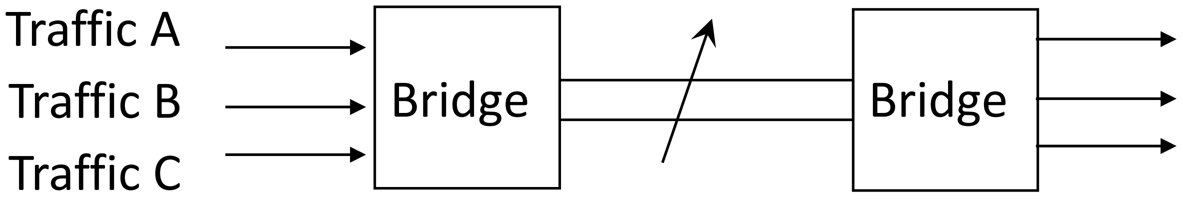
Verification - Simulation for STSBT -

Simplified Model

- Some scheduling is needed in order to mitigate the impact of reduced bandwidth while maintaining QoS for multiple traffic:
  - ✓ Multiple traffic with different requirements, i.e. maximum latency and packet (or frame) size and number.
  - ✓ Uncontrollable and unknown varying bandwidth.

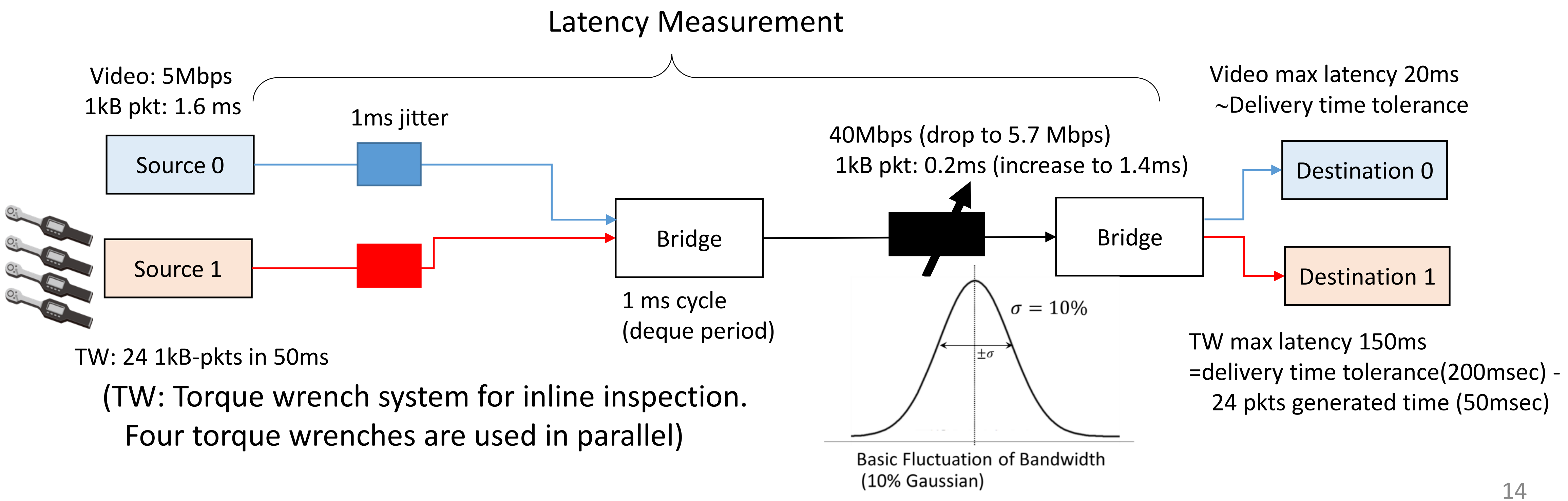
Multiple traffic with different:
1) Latency
2) Packets / Frames size and number

Varying Bandwidth (uncontrollable)



Case Study

- A simulation has been conducted for factory applications based on the Nendica FFIoT report.
- Latency calculations were carried out for average bandwidths dropping from 40Mbps to 5.7 Mbps.
- Both streams have priority- Neither are best effort traffic.



(TW: Torque wrench system for inline inspection.
Four torque wrenches are used in parallel)

Case Study – simulation-base

- For scheduling, Credit-based (CBS) is applied in a simulation for peak-shaving.
- Peak shaving is independent of transmission selection algorithm.

Strict priority (8.6.8.1)
Credit-based shaper (8.6.8.2)
Enhanced Transmission Selection (ETS) (8.6.8.3)

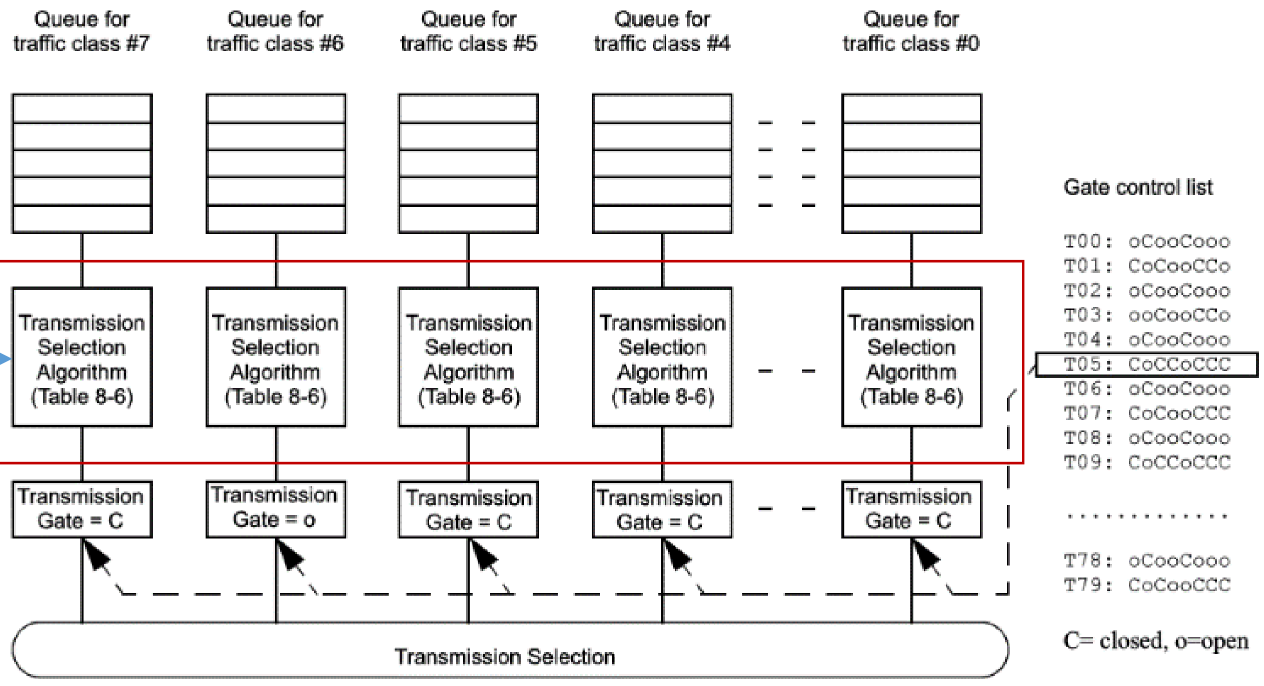
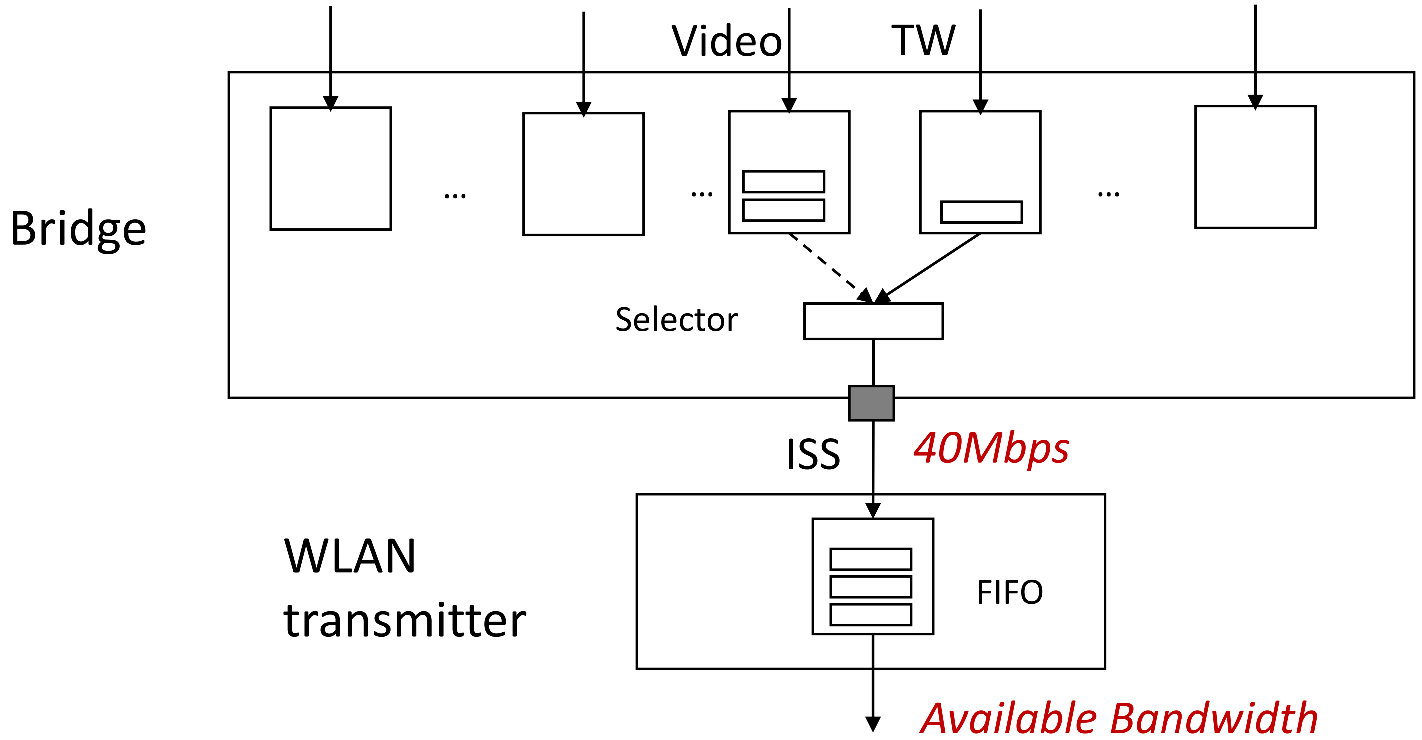


Figure 8-14—Transmission selection with gates

Case Study – scheduling method

- Peak-shaving is achieving by allocating an appropriate bandwidth (in a percentage of 40Mbps) to each flow.
  - Video: 5Mbps (1kB packet every 1.6 ms), Max packet delay tolerance: 20 msec
  - TW (Torque wrench system) : 1kB-packet x 24 in 50 ms, Max packet delay tolerance: 150 msec



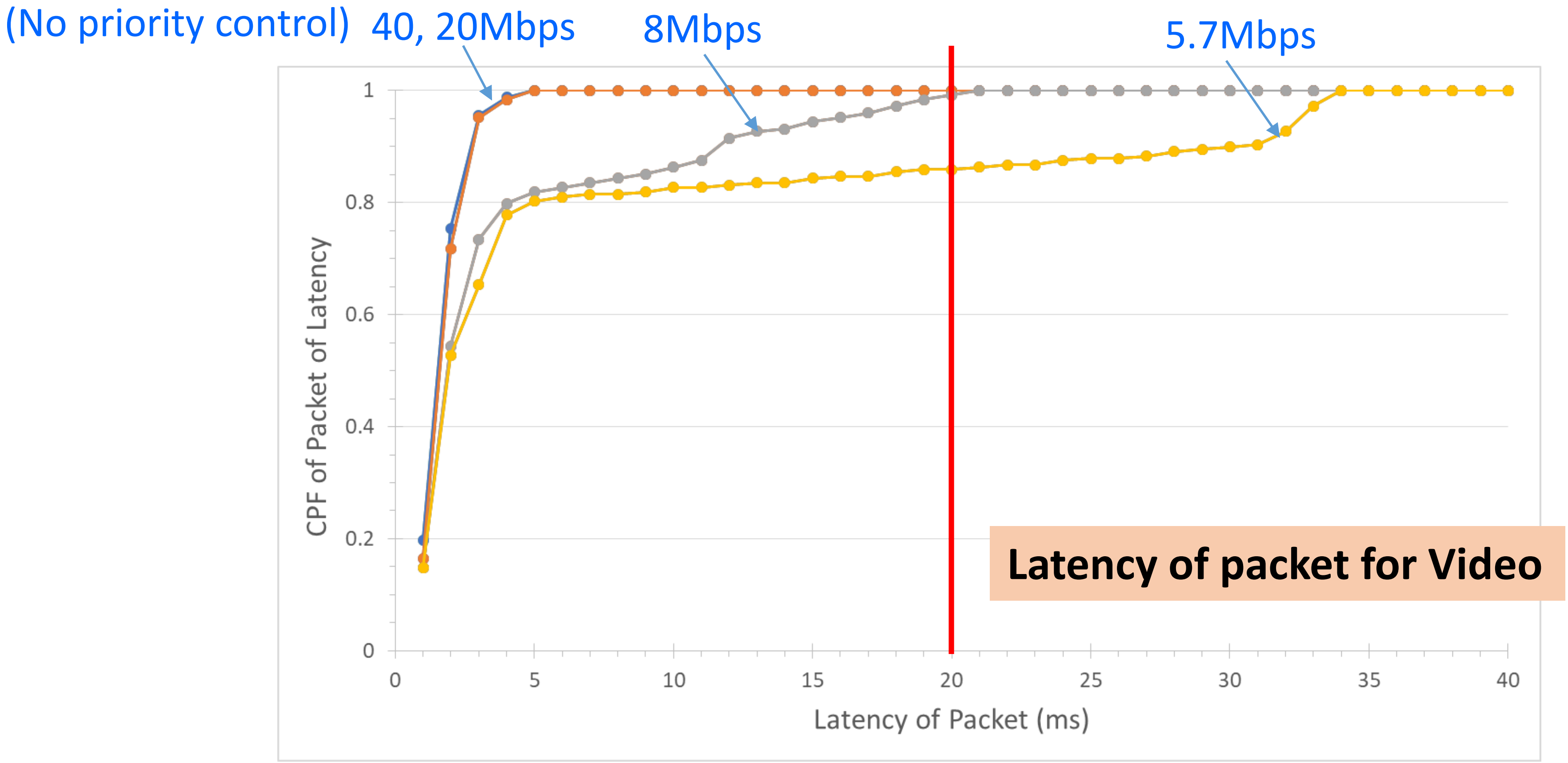
Bandwidth Allocation:

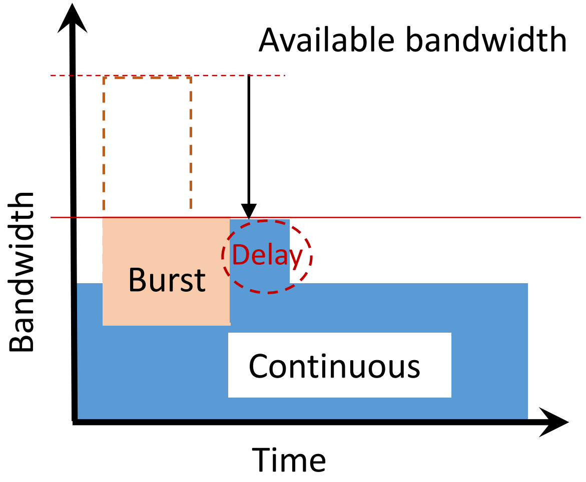
idleSlope= Minimum bandwidth

Minimum bandwidth of TW
= 1KB x 24 / 150 msec =1.28Mbps
(3.2% of 40 Mbps)

Case Study – result (1)

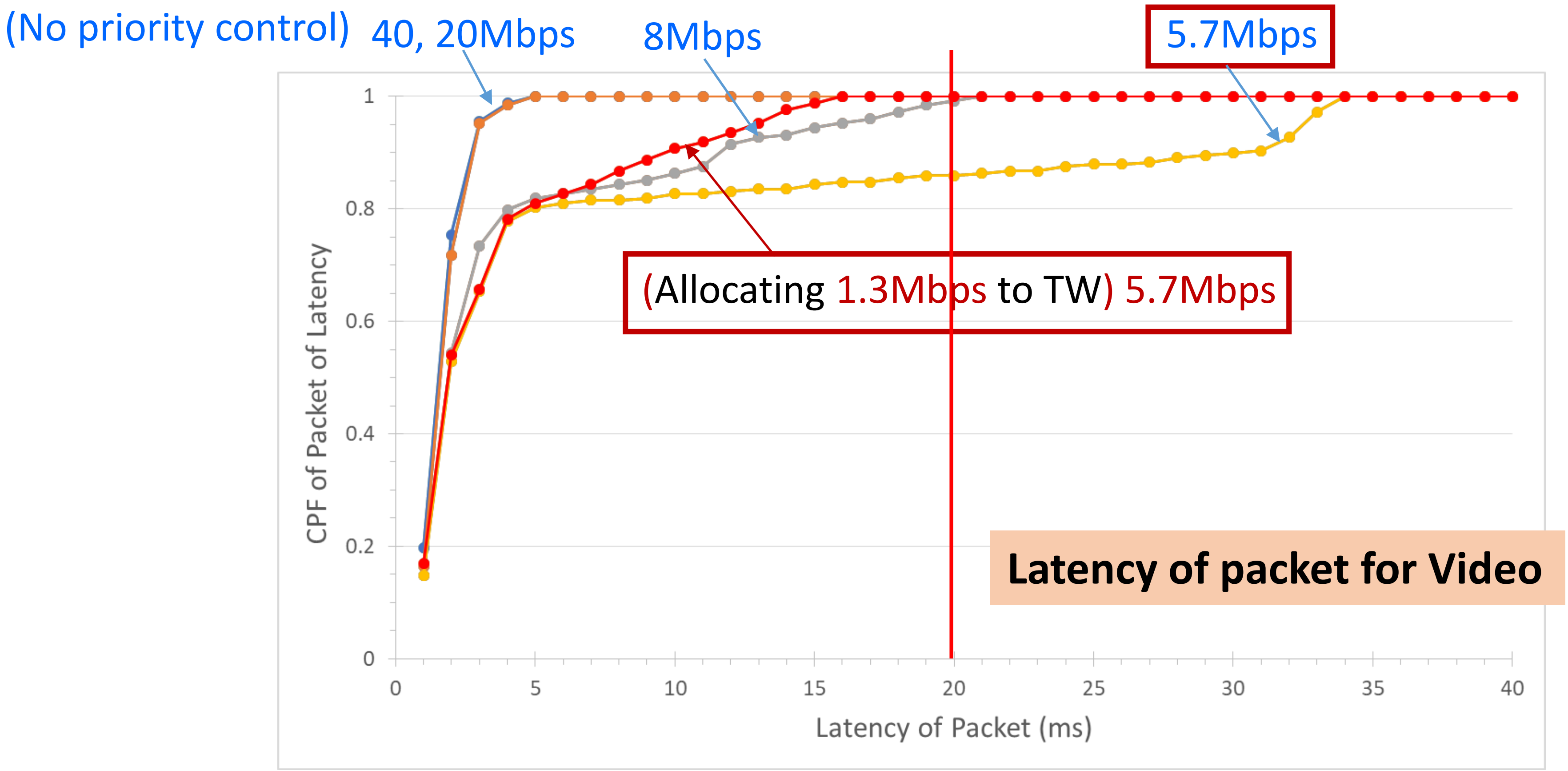
- Virtually "No priority control" results in a latency of less than 20ms for video stream in cases where the average bandwidth drops to 8Mbps.

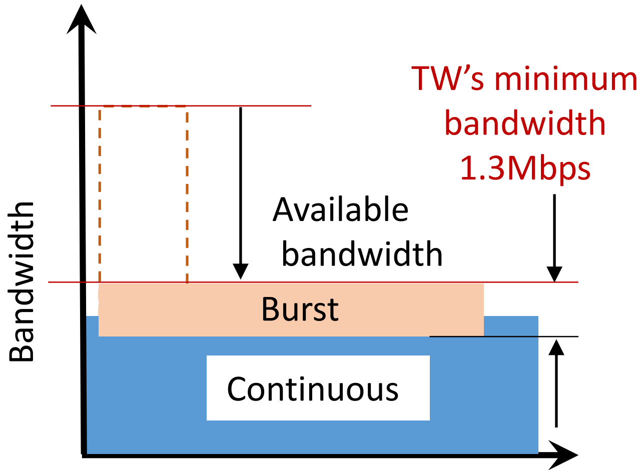




Case Study – result (1) cont'd

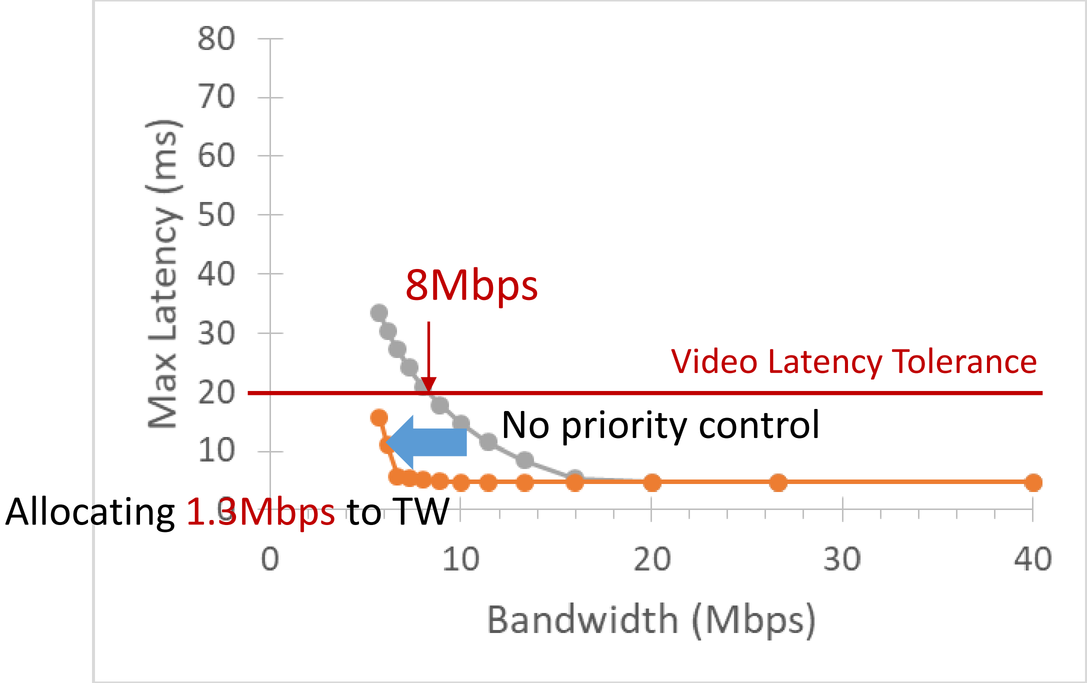
- "Allocating 1.3Mbps to TW" results in a latency of less than 20ms for video stream in cases where the average bandwidth drops to 5.7Mbps.



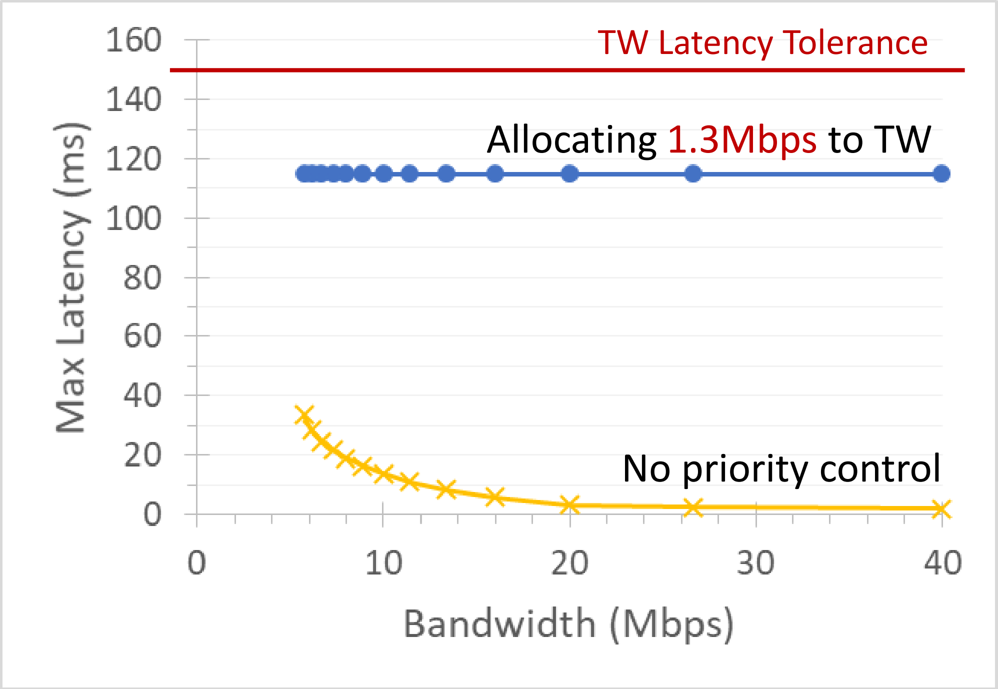


Case Study – result (2)

- “Allocating 1.3Mbps to TW” meets latency requirements for both video and TW but “No priority control” meets neither below 8Mbps.



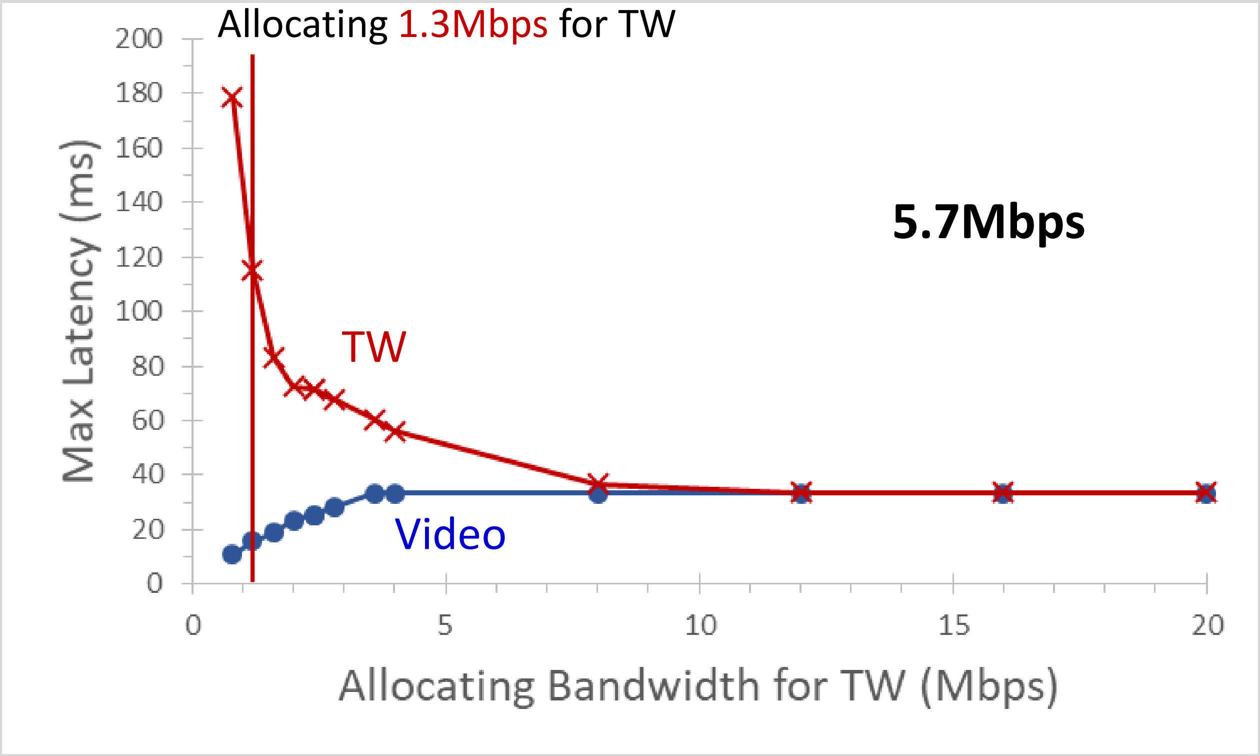
Max latency for video v.s. bandwidth



Max latency for TW v.s. bandwidth

Case Study – result (3)

- Trade-off of Video vs. TW (Available BW:5.7Mbps)



Max Packet Latency for Video and TW

Draft for Main parts of PAR and CSD

Main Part of PAR

- 2.1 – Project Title

Standard for Local and metropolitan area networks--Bridges and Bridged Networks
Amendment: Scheduler for Time-Sensitive and Bursty Traffic

- 4.2 and 4.3 Project dates

4.2 Expected Date of submission of draft to the IEEE-SA for Initial Sponsor Ballot:

03/2021

- 4.3 Projected Completion Date for Submittal to RevCom

01/2022

Main Part of PAR –cont'd

- 5.2A – Standard scope

This standard specifies Bridges that interconnect individual LANs, each supporting the IEEE 802 MAC Service using a different or identical media access control method, to provide Bridged Networks and VLANs.

- 5.2B – Project scope

This project specifies procedures and managed objects for bridges and end stations to configure and perform shapers over reduced available bandwidth links for sporadic bursty traffic type.

Main Part of PAR –cont'd

- 5.3 – Project contingency

5.3 Is the completion of this standard dependent upon the completion of another standard:

No

- 5.4 – Project purpose

Bridges, as specified by this standard, allow the compatible interconnection of information technology equipment attached to separate individual LANs.

Main Part of PAR –cont'd

- 5.5 – Project need

Industrial networks serve a variety of traffic types including irregular bursty traffics which requires to be conveyed across reduced available bandwidth links with deterministic latency. Shaping is needed in order to mitigate the impact of reduced bandwidth while maintaining QoS for multiple traffic. Current bridging standards do not address configuration mechanism for shaper for reduced available bandwidth for variety of traffic types including Sporadic bursty traffic.

- 5.6 Stakeholders for the Standard:

Developers, providers, and users of networking services and equipment for streaming of time-sensitive data. This includes software developers, networking integrated circuit developers, bridge and network interface controller vendors, and users.

Main Part of CSD - 1.1.1 Managed objects

Describe the plan for developing a definition of managed objects. The plan shall specify one of the following:

a) The definitions will be part of this project.

b) The definitions will be part of a different project and provide the plan for that project or anticipated future project.

c) The definitions will not be developed and explain why such definitions are not needed.

This project will use method a). The managed objects definitions will be part of this project.

Main Part of CSD - Coexistence

A WG proposing a wireless project shall demonstrate coexistence through the preparation of a Coexistence Assurance (CA) document unless it is not applicable.

a) Will the WG create a CA document as part of the WG balloting process as described in Clause 13? (yes/no)

b) If not, explain why the CA document is not applicable.

This project will use method b). This project is not a wireless project.

Main Part of CSD - Broad market potential

Each proposed IEEE 802 LMSC standard shall have broad market potential. At a minimum, address the following areas:

a) Broad sets of applicability.

b) Multiple vendors and numerous users.

The proposed amendment enhances bridges functionality allowing systems to further provision for broad variety services, applications and traffic types in reduced available bandwidth networks.

TSN has been applicable for many applications including industrial automation and other applications. This amendment further extends the application of TSN to include IoT devices broadening TSN applications and use.

Furthermore, the proposed amendment enable efficient utilization of legacy network in support of increased traffic in industrial applications.

This proposal supports network with dense IoT devices that are deployed in factories, warehouses, hospitals, market places, stadiums and etc.

Multiple vendors and users of industrial automation, professional audio-video, automotive, and other systems require complete and comprehensive management of TSN features in bridged LAN networks through common interfaces.

Main Part of CSD - Compatibility

Each proposed IEEE 802 LMSC standard should be in conformance with IEEE Std 802, IEEE 802.1AC, and IEEE 802.1Q. If any variances in conformance emerge, they shall be thoroughly disclosed and reviewed with IEEE 802.1 WG prior to submitting a PAR to the Sponsor.

- **a) Will the proposed standard comply with IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q?**
- **b) If the answer to a) is no, supply the response from the IEEE 802.1 WG.**

The review and response is not required if the proposed standard is an amendment or revision to an existing standard for which it has been previously determined that compliance with the above IEEE 802 standards is not possible. In this case, the CSD statement shall state that this is the case.

As an amendment to 802.1Q, the proposed standard shall comply with IEEE Std 802, IEEE Std 802.1AC and IEEE 802.1Q.

Main Part of CSD - Distinct Identity

Each proposed IEEE 802 LMSC standard shall provide evidence of a distinct identity. Identify standards and standards projects with similar scopes and for each one describe why the proposed project is substantially different.

This amendment differs from existing IEEE 802.1 standard in that it address scheduling and shaper for variety of traffic types including bursty data rates traffic over links with varying bandwidth operating at reduced available bandwidth.

Main Part of CSD - Technical Feasibility

Each proposed IEEE 802 LMSC standard shall provide evidence that the project is technically feasible within the time frame of the project. At a minimum, address the following items to demonstrate technical feasibility:

a) Demonstrated system feasibility.

The proposed shaper is similar in principle to the ones introduced in IEEE Std 802.1Q-2018 and will build on them to provide additional capabilities.

b) Proven similar technology via testing, modeling, simulation, etc.

The technical feasibility has been demonstrated by analysis. In particular, feasibility has been shown by modeling and simulation (see http://www.ieee802.org/1/files/public/docs2019/New-NakanoZein-Scheduling_of_Time_sensitive_and_Bursty_Traffic_in_Reduced_Available_Bandwidth-0919.ppx).

This project is based on mature virtual LAN bridging and transmit selection and scheduling

Main Part of CSD - Economic Feasibility

Each proposed IEEE 802 LMSC standard shall provide evidence of economic feasibility. Demonstrate, as far as can reasonably be estimated, the economic feasibility of the proposed project for its intended applications. Among the areas that may be addressed in the cost for performance analysis are the following:

- a) Balanced costs (infrastructure versus attached stations).
- b) Known cost factors.
- c) Consideration of installation costs.
- d) Consideration of operational costs (e.g., energy consumption).
- e) Other areas, as appropriate.

The well-established balance between infrastructure and attached stations will not be changed by this enhancement.

The cost factors, including installation and operational factors, are well known from similar technologies and proportional to the benefits gained.

The proposed amendment does not require additional hardware cost as it proposes STSBT shaper that can be accommodated into the current specifications.