GE Aerospace

Filtering Enhancements For Scheduled Traffic

July 13th, 2026

Abdul Jabbar
GE Aerospace

Purpose/Agenda

1. Discuss scheduling (feasibility, efficiency) given current per-stream filtering and policing features
2. Identify scheduling limitations due to lack of minimum SDU filtering
3. Proposal to add MinSDU Size filtering to PSFP

References:

- IEEE Std. 802.1Q-2022
- Minimum Frame Size Filter for PSFP – presented at IEEE 2026 March Plenary
  https://www.ieee802.org/1/files/public/docs2026/new-jabbar-psfp-MinSDUsize-0326-v02.pdf
- Filtering Enhancements for Dependable 802.1 Networks – presented at TSN TG Meeting on Mar 23, 2026
  https://www.ieee802.org/1/files/public/docs2026/new-jabbar-filtering-enhancements-0326-v02.pdf
- Filtering Enhancements for Scheduled Networks – contribution at TSN TG Meeting on July 6th 2026
  https://www.ieee802.org/1/files/public/docs2026/new-jabbar-filtering-enhancements-0726-v01.pdf

Purpose/Agenda

1. Discuss scheduling (feasibility, efficiency) given current per-stream filtering and policing features
2. Identify scheduling limitations due to lack of minimum SDU filtering
3. Proposal to add MinSDU Size filtering to PSFP

References:

- IEEE Std. 802.1Q-2022
- Minimum Frame Size Filter for PSFP – presented at IEEE 2026 March Plenary https://www.ieee802.org/1/files/public/docs2026/new-jabbar-psfp-MinSDUsize-0326-v02.pdf

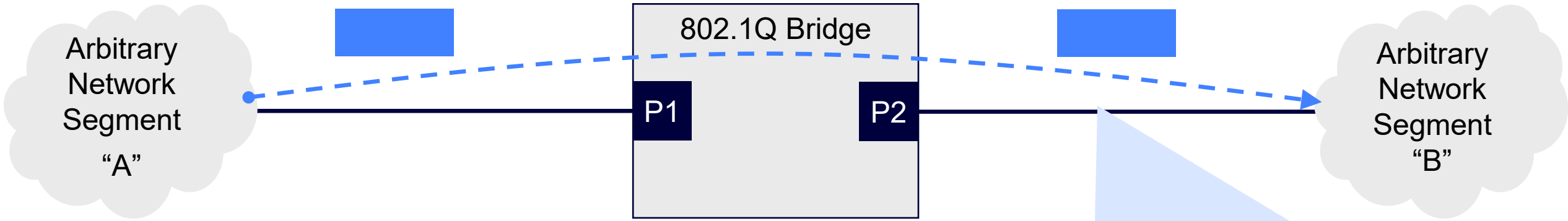
- **This contribution takes a first principles approach without dependencies on any specific use case.**
- **The material presented here is widely applicable to 802.1 Scheduled Traffic.**
- **The contribution strictly relies on the existing scope of 802.1Q Bridges.**

Basic Scheduling Scenario

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



1. Calculate transmission window duration on egress port P2
2. Assign a transmission slot (schedule) on the egress port P2
3. Assign a transmission slot (schedule) on the previous hop

Requirement: Zero queueing/congestion delay as the frame traverses the Bridge.

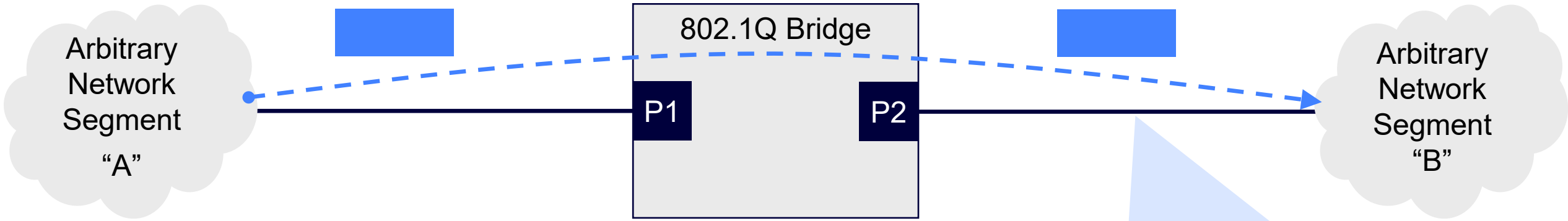
Primary Question: What is the required transmission window duration on egress port P2?

Basic Scheduling Scenario

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Simplifying Assumptions:

1. Negligible time synchronization error
2. Negligible propagation delay
3. Fixed port-to-port bridge delay
4. Links Speed of 1 Gbps
5. Ignore frame overhead

1. What is the duration of the transmission window on egress port P2?
2. Assign a transmission slot (schedule) on the egress port P2
3. Assign a transmission slot (schedule) on the previous hop

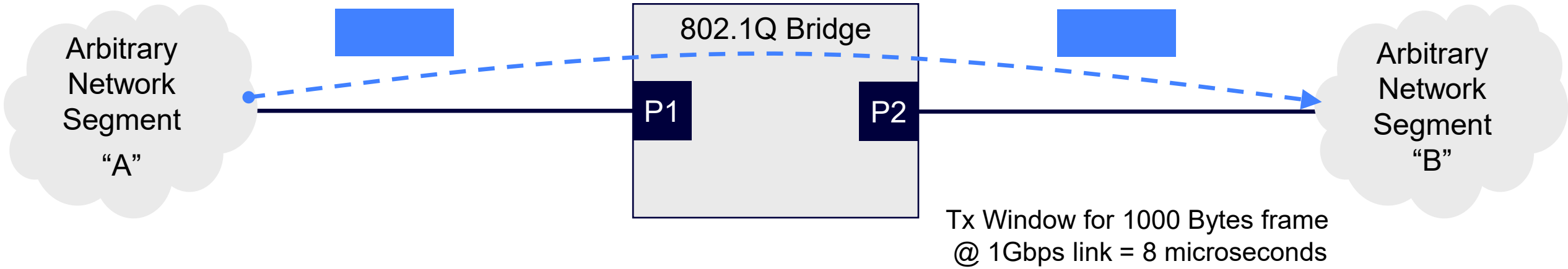
Requirement: Zero queueing/congestion delay as the frame traverses the Bridge.

Basic Scheduling Scenario: Calculate Transmission Window Duration

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Simplifying Assumptions:

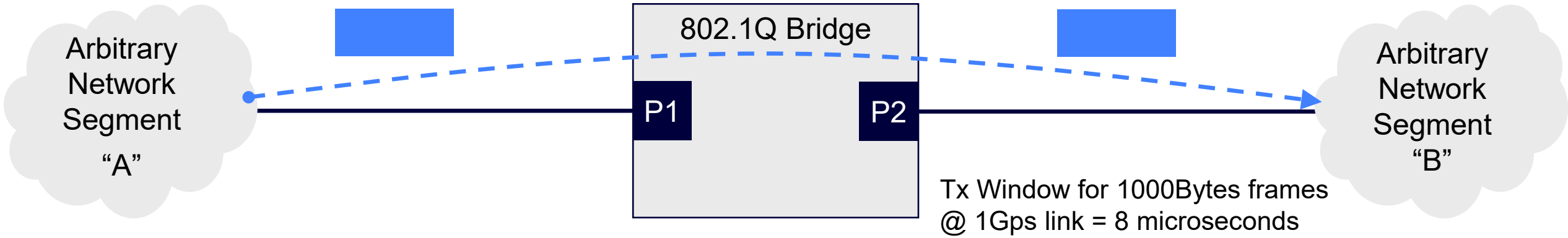
1. Negligible time synchronization error
2. Negligible propagation delay
3. Fixed port-to-port bridge delay
4. Links Speed of 1 Gbps
5. Ignore frame overhead

Basic Scheduling Scenario: Assign Transmission Window

Stream Definition:

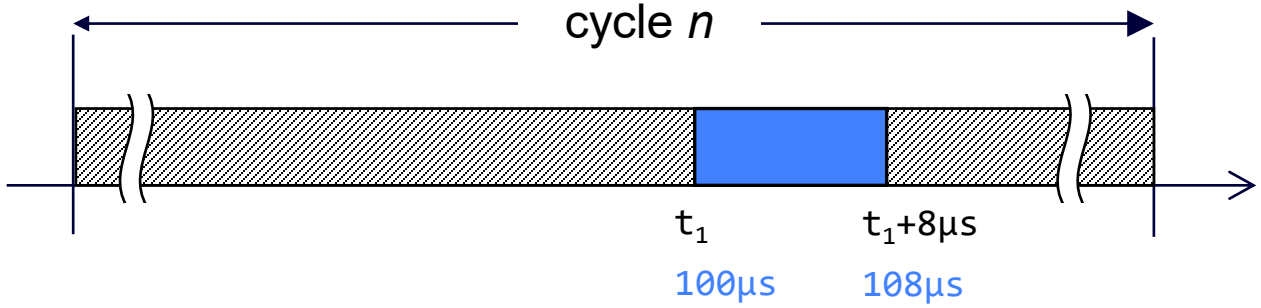
Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Simplifying Assumptions:

1. Negligible time synchronization error
2. Negligible propagation delay
3. Fixed port-to-port bridge delay
4. Links Speed of 1 Gbps
5. Ignore frame overhead

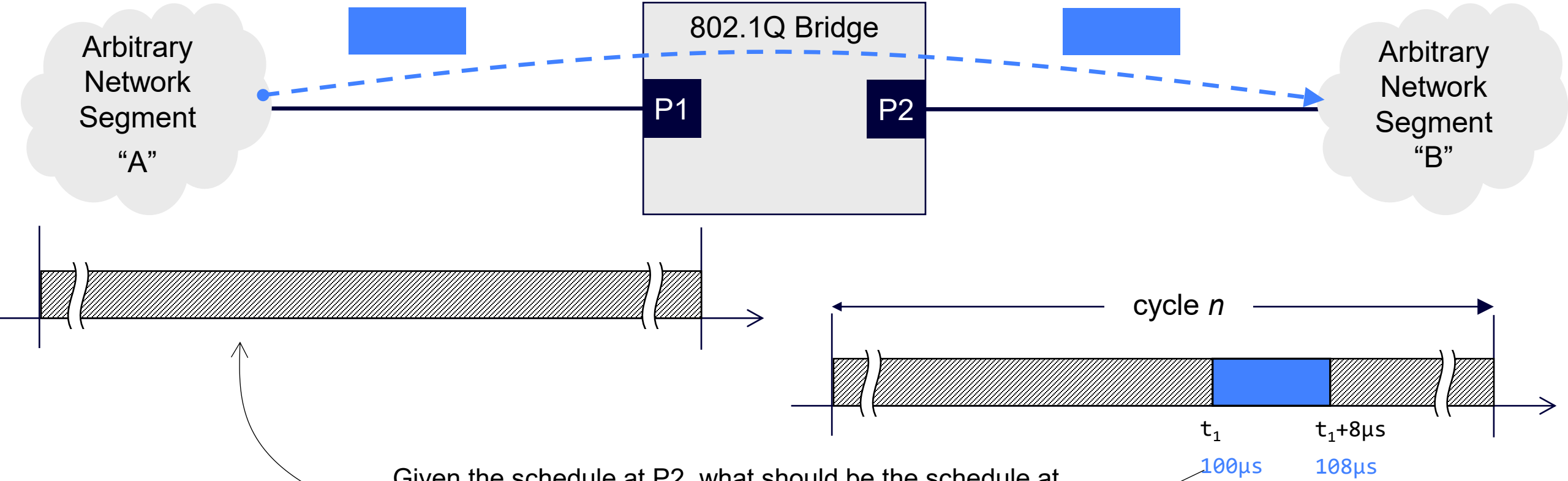


Basic Scheduling Scenario: Assing Transmission Schedule at Prior Hop

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



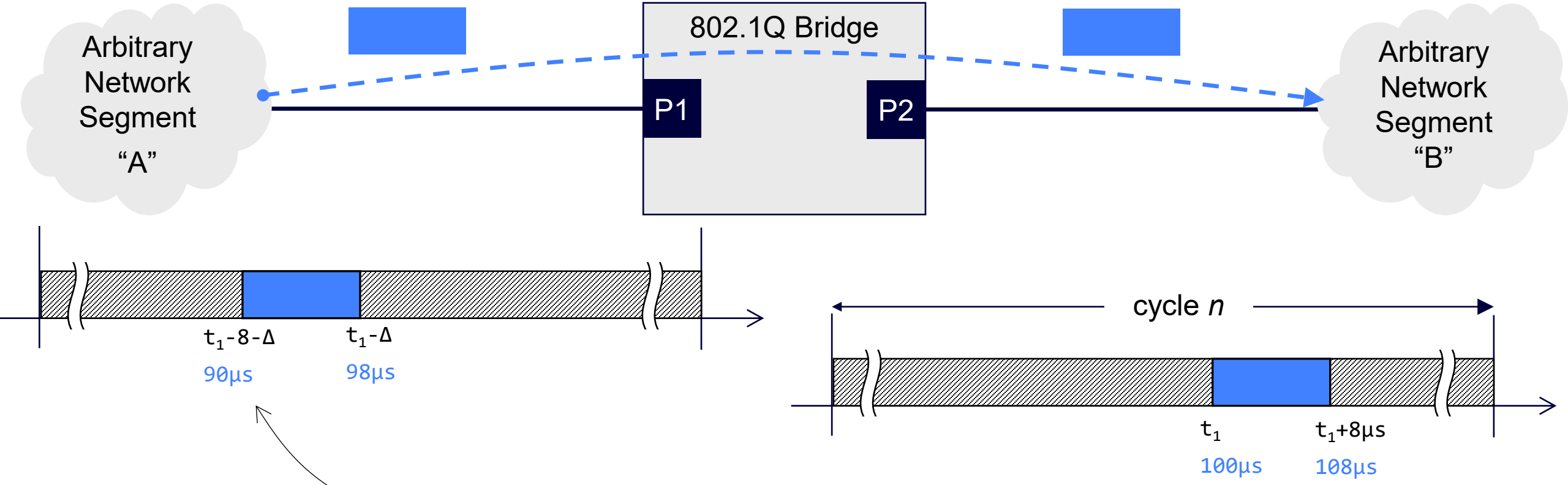
Given the schedule at P2, what should be the schedule at prior hop for zero queueing/congestion delay at the Bridge?

Basic Scheduling Scenario: Assing Transmission Schedule at Prior Hop

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



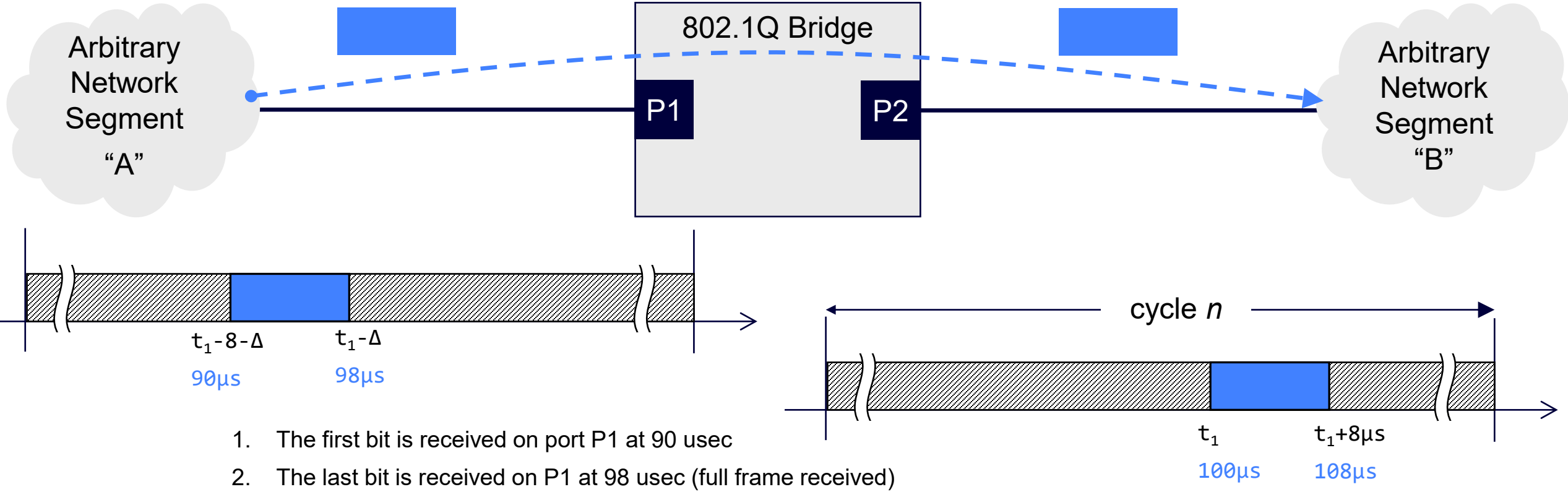
Δ = Bridge port-to-port delay (2 usec)

Basic Scheduling Scenario: The Solution

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



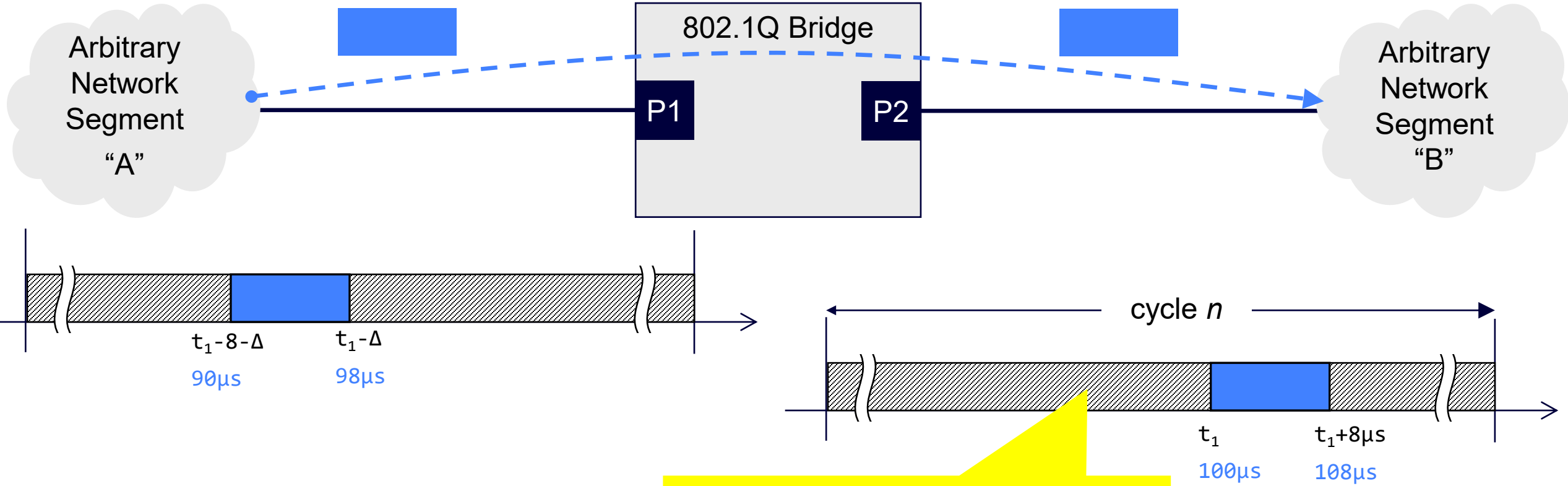
1. The first bit is received on port P1 at 90 usec
2. The last bit is received on P1 at 98 usec (full frame received)
3. The frame is moved to egress port and ready for transmission at 100 usec
4. The first bit is transmitted on P2 at 100 usec
5. The last bit is transmitted on P2 at 108 usec (full frame transmitted)

Basic Scheduling Scenario: The Solution

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Note: This is not free time! It would be allocated to other streams. This time is not available/allocated for blue stream

802.1Q Network Robustness

Per Stream Filtering and Policing (PSFP)

"…Policing and filtering functions include the **detection and mitigation of disruptive transmissions** by other systems in a network, improving the robustness of that network."

Because,

"… devices that exceed the allocated bandwidth for one stream can prevent the network from achieving the benefits of TSN for any or all streams, not just the misbehaving stream"

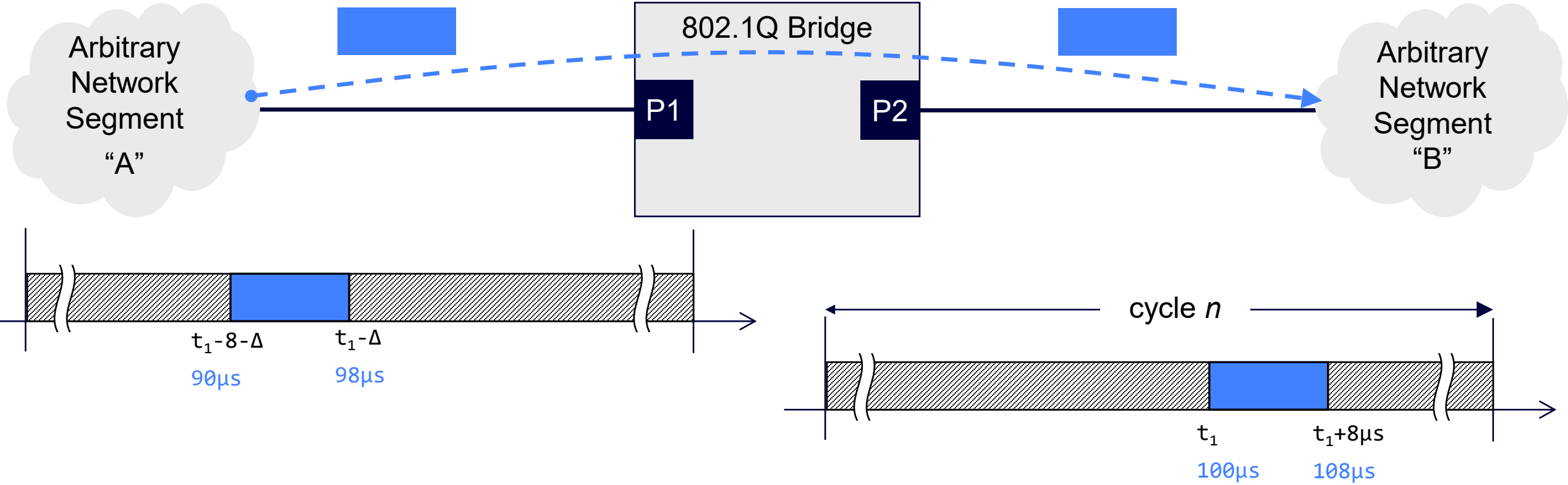
[Source: 802.1Qci PAR]

Normal Behavior

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes

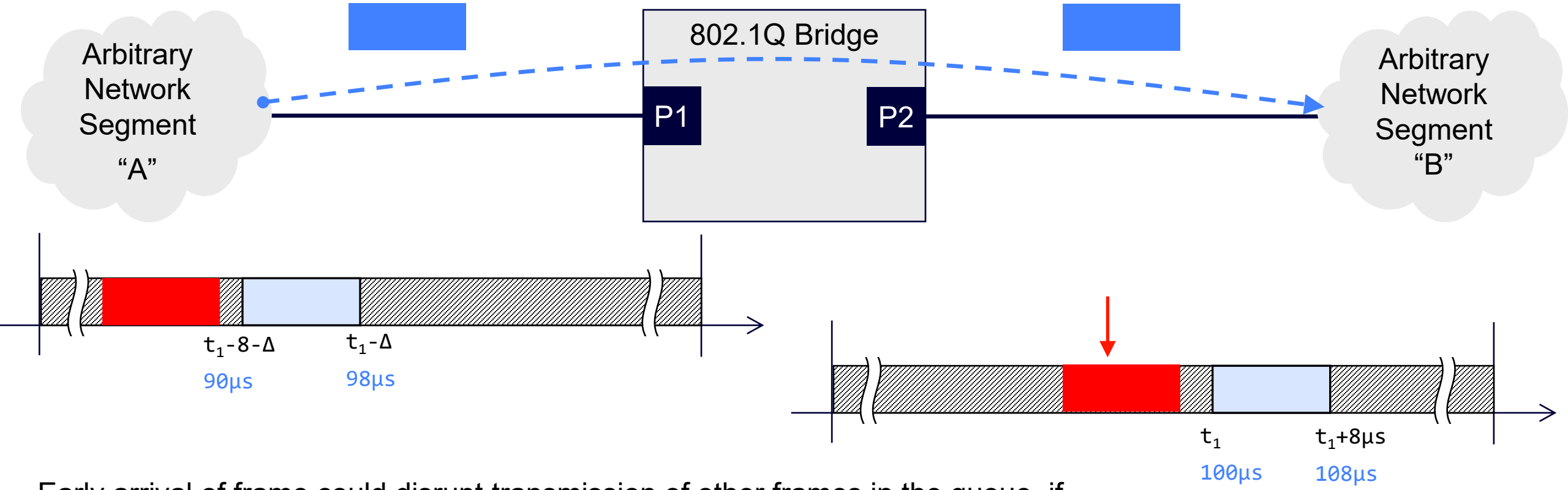


Robustness to disruptive transmission: Incorrect arrival time

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



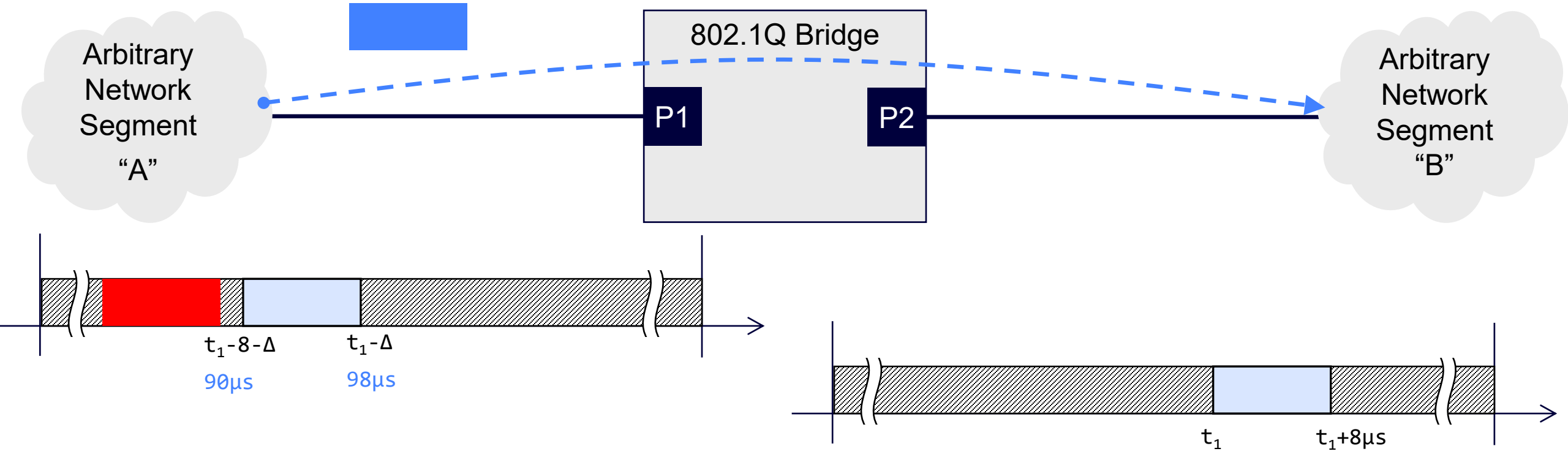
Early arrival of frame could disrupt transmission of other frames in the queue, if the queue is open during that window

Robustness to disruptive transmission: Incorrect arrival time

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Early arrival of frame could disrupt transmission of other frames in the queue

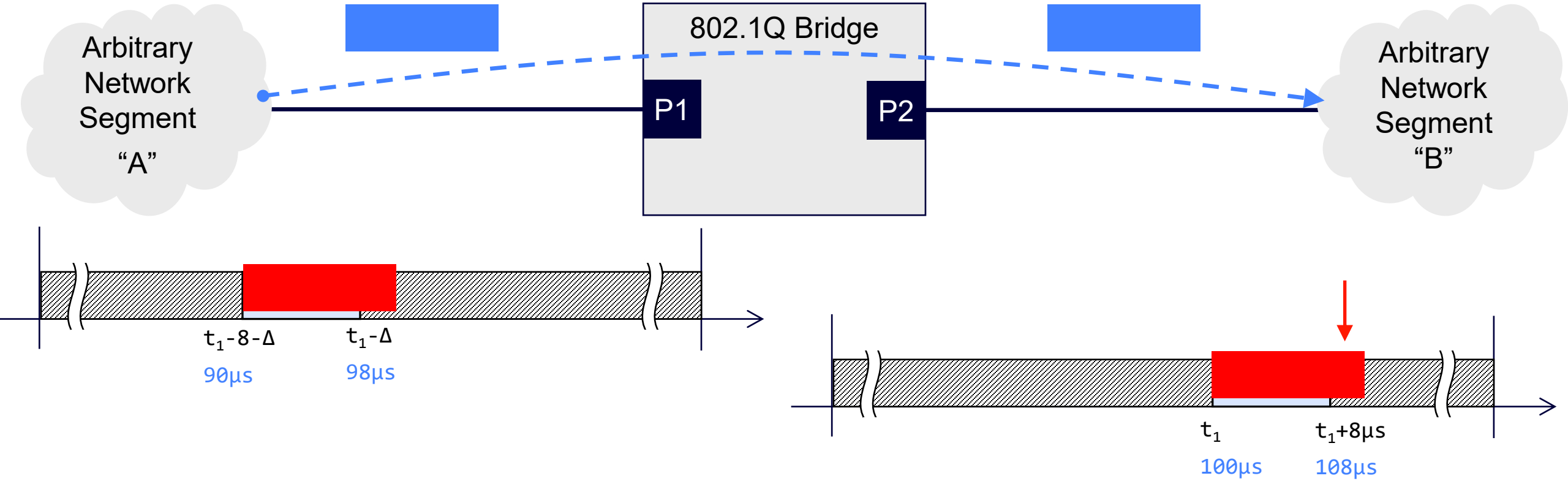
PSFP Solution: Stream Gating detects and discards errant frame. Transmit widow goes unused on P2

Robustness to disruptive transmission: Larger than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



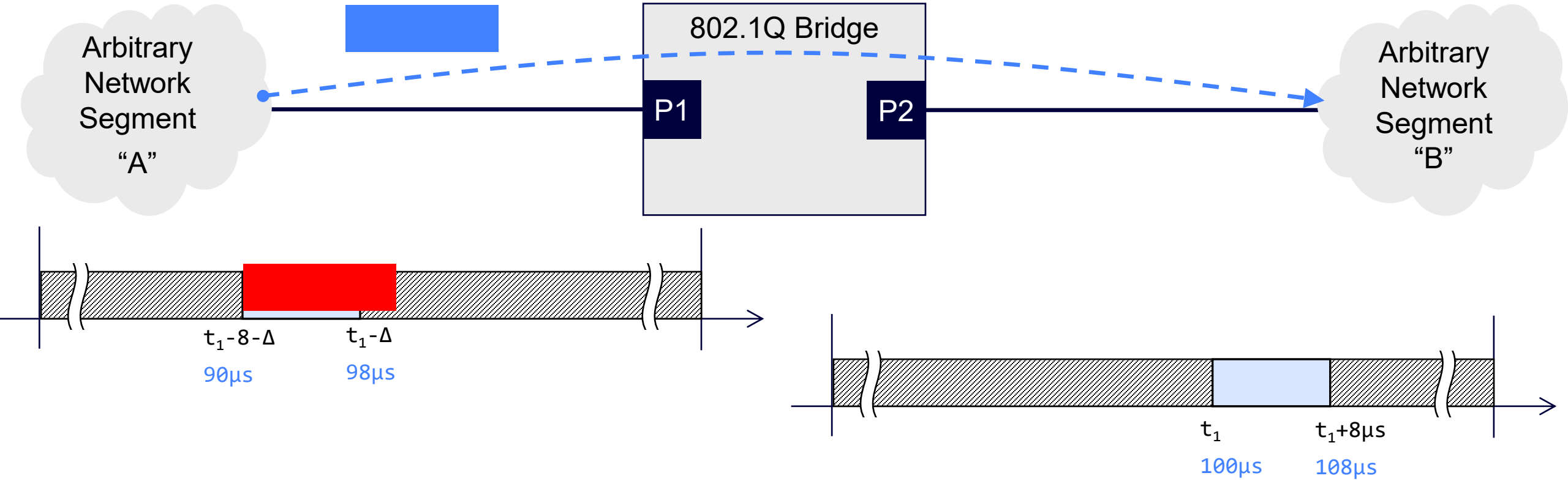
A larger than expected frame would over run the allocated transmit window and/or cause head of the line blocking

Robustness to disruptive transmission: Larger than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



A larger than expected frame would over run the allocated transmit window and/or cause head of the line blocking

PSFP Solution: MaxSDU Filtering detects and discards the errant frame. Transmit widow goes unused on P2

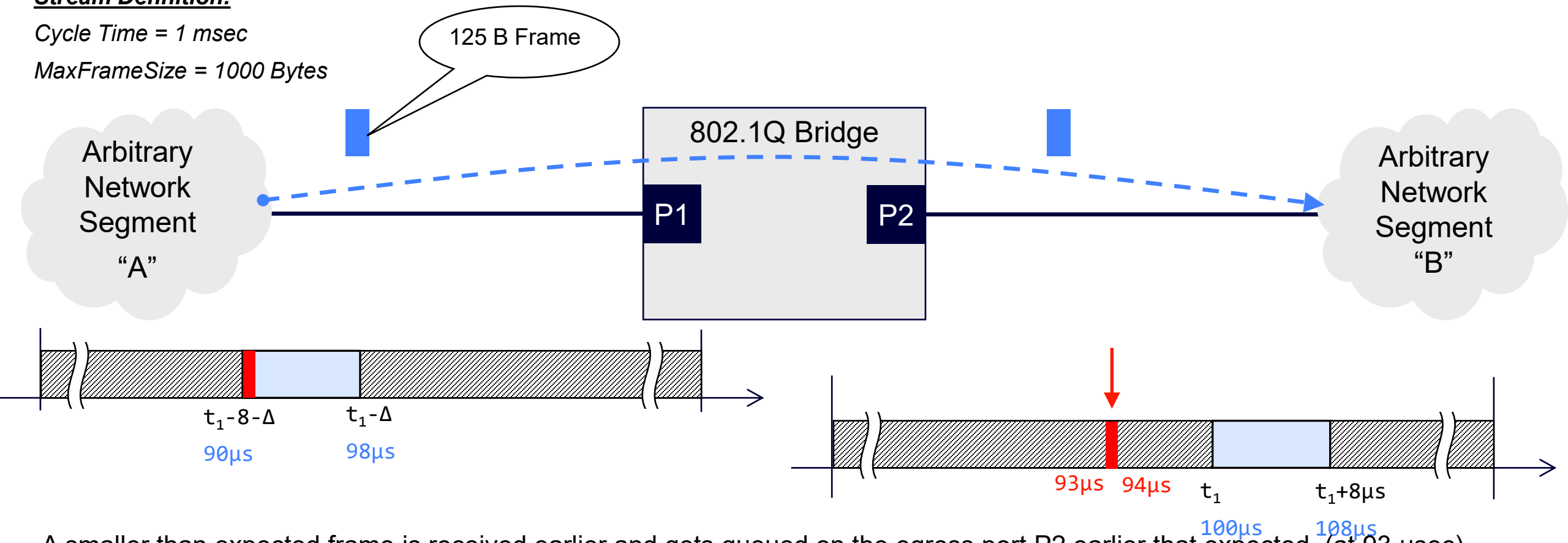
- What about smaller than expected frames?

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



A smaller than expected frame is received earlier and gets queued on the egress port P2 earlier that expected (at 93 usec)

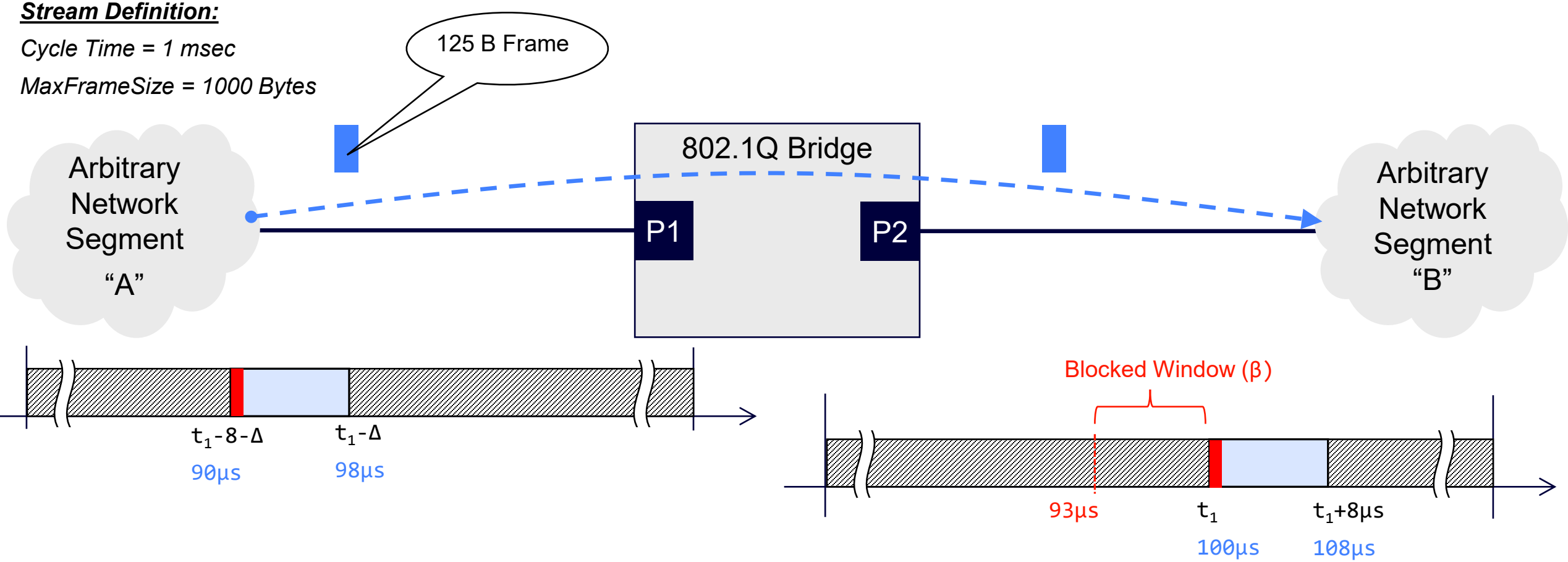
- If the queue gate is open (for a different stream), the errant frame will take that transmission slot
- May disrupt other streams scheduled in that window
- Stream Gating does not block this frame. MaxSDU Filter does not block this frame

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes

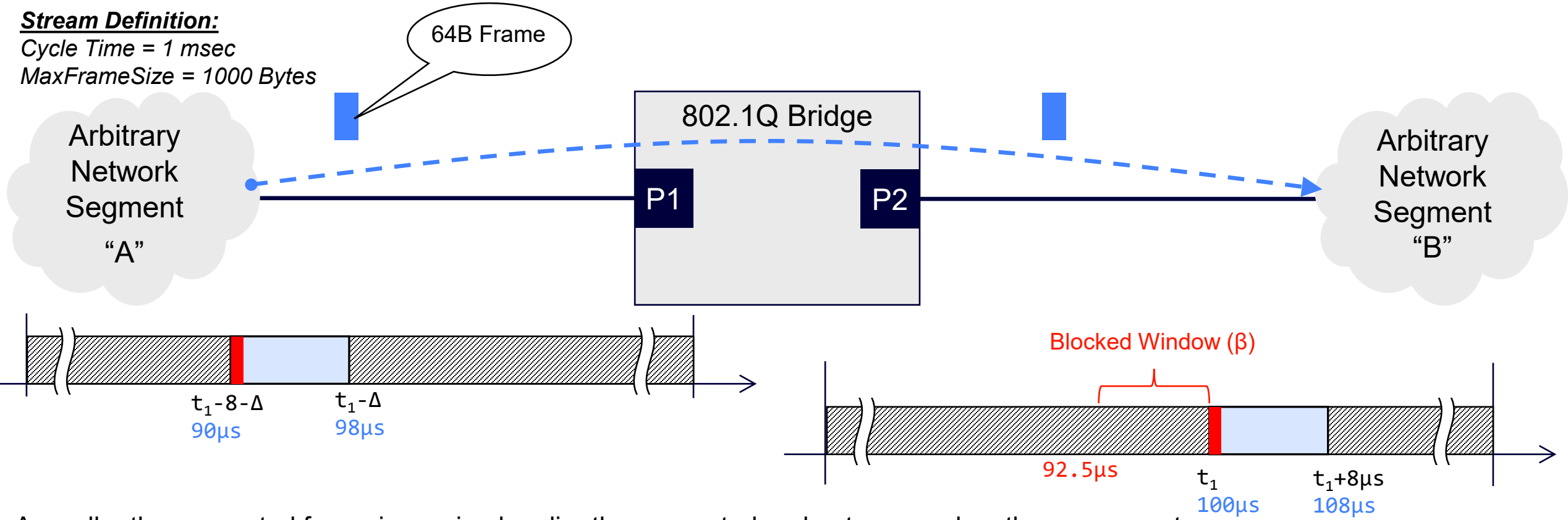


A smaller than expected frame is received earlier and gets queued on the egress port earlier than expected (e.g., at 93 usec)

- If the queue gate is closed till time t_1, the errant frame remains queued at the front of the queue → effectively blocking transmissions from the queue during that window
- No other streams can be scheduled during the blocked window

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:
Cycle Time = 1 msec
MaxFrameSize = 1000 Bytes

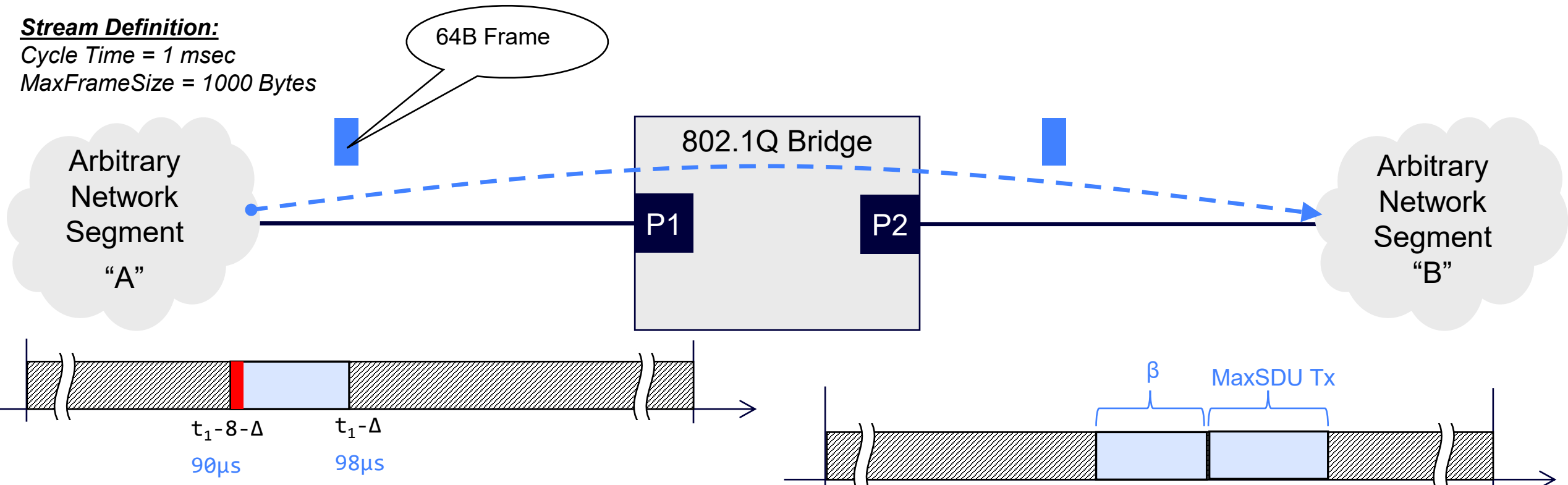


A smaller than expected frame is received earlier than expected and gets queued on the egress port

- If the queue gate is closed, the errant frame is still at the front of the queue → effectively blocking the queue for that window
- Blocked Window duration β = (MaxSDU Tx) – (64Byte Tx)
- The bigger the MaxFrameSize, the bigger is the blocked window (β).

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:
Cycle Time = 1 msec
MaxFrameSize = 1000 Bytes



Potential Workaround:

Assign the blocked window to the stream with gate closed (similar to a guard band)

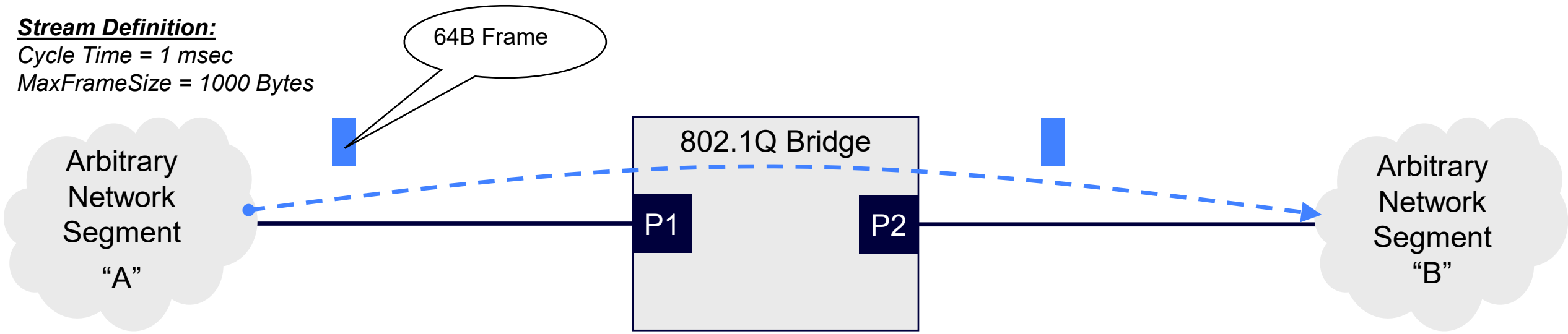
Allocated Window Duration = MaxSDU Tx Time + β

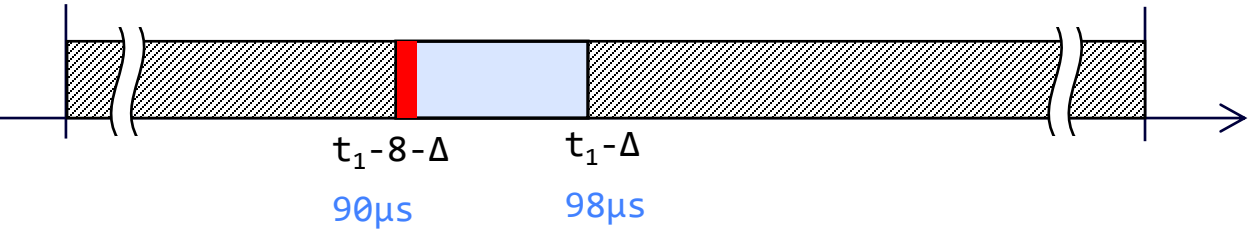
wherein βrepresents the early arrival duration of smaller frames

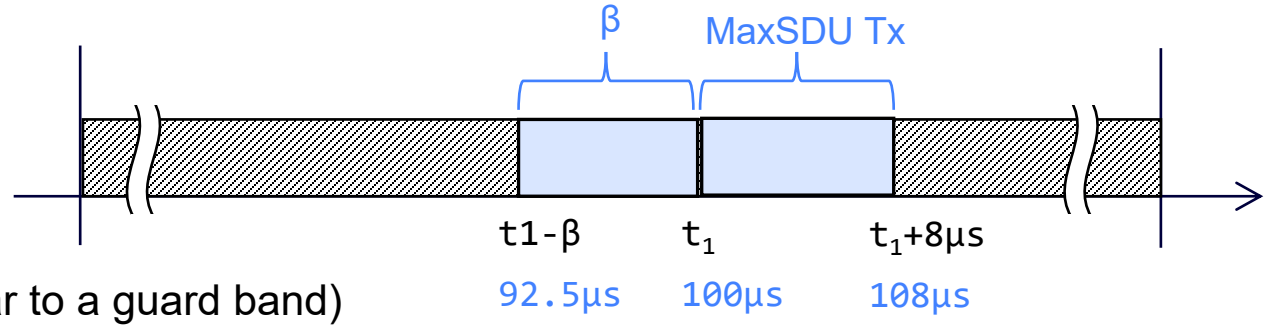
β = (MaxSDU Tx) – (64Byte Tx) ≈ MaxSDU Tx (for large SDUs)

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:
Cycle Time = 1 msec
MaxFrameSize = 1000 Bytes







Potential Workaround:

Assign the blocked window to the stream with gate closed (similar to a guard band)

Allocated Window Duration = MaxSDU Tx Time + β

wherein βrepresents the early arrival duration of smaller frames

β = (MaxSDU Tx) – (64Byte Tx) ≈ MaxSDU Tx (for large SDUs)

- Total allocated window ≈ 2 *(MaxSDU Tx)
- 100% "Overhead"
- Reduces effective link utilization to ~ 50%

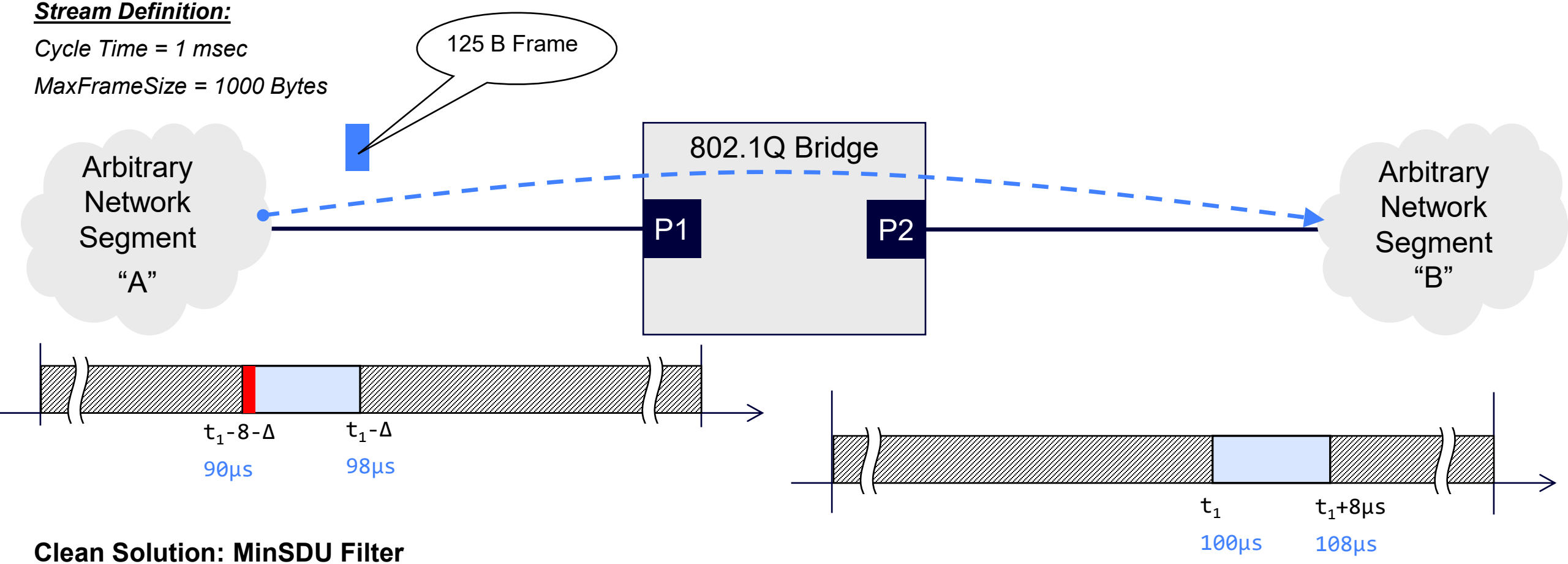
– Proposal: MinSDU Filtering

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Clean Solution: MinSDU Filter

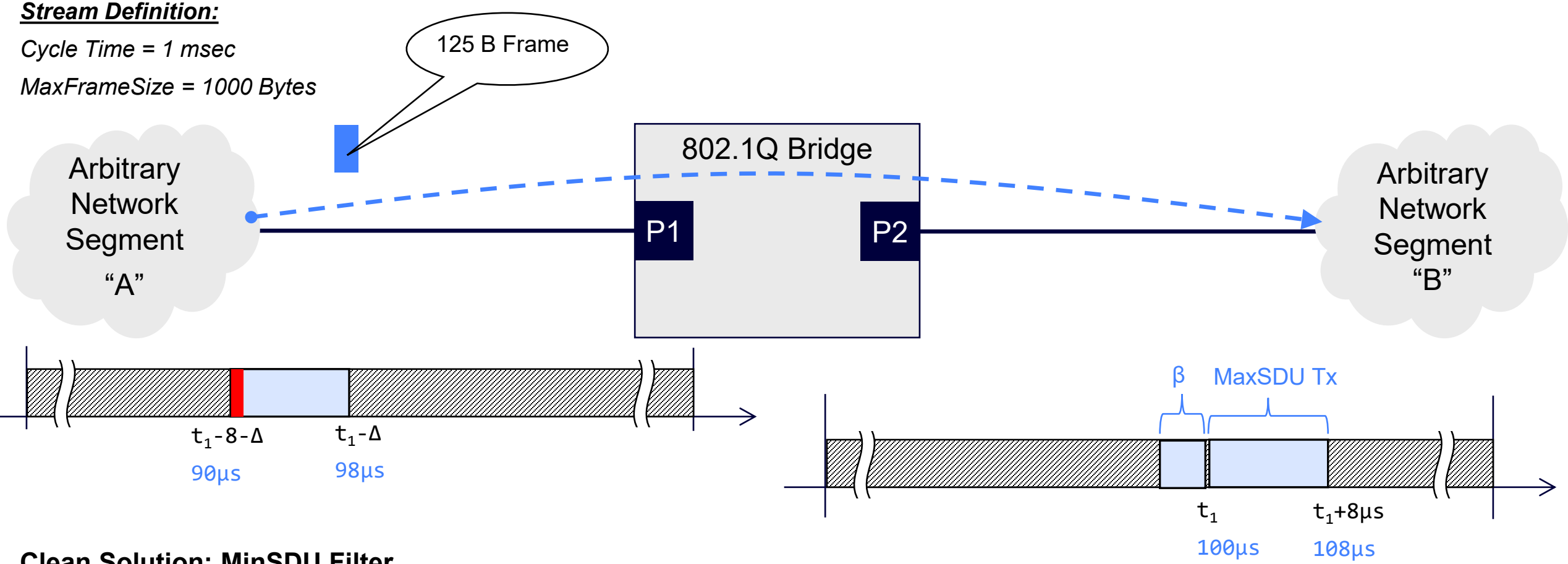
- MinSDU size filter detects smaller than expected frames and discards the frame. Transmit widow goes unused on P2
- The above assumes that MinSDU is set to be greater than 125 Bytes

Robustness to disruptive transmission: Smaller than expected frame size

Stream Definition:

Cycle Time = 1 msec

MaxFrameSize = 1000 Bytes



Clean Solution: MinSDU Filter

- If MinSDU = MaxSDU, the filters only allow fixed sized frames; β = 0
- If MinSDU < MaxSDU, system designers still need to allocate a transmission window larger than the MaxSDU Tx, but the MinSDU sets a smaller bound on the extra window allocation (β)

Summary

1. Enhancement for scheduled traffic requires assignment of transmission windows
2. Transmission windows must be coordinated between hops to eliminate congestion/queueing delays
3. Per Stream Filtering and Policing is within the scope of 802.1Q to “detect and mitigate disruptive transmissions”
4. PSFP is required to realize the benefits of TSN and scheduled networks
5. PSFP detects and mitigate “larger than expected/configured frame size” and “unexpected arrival times” for TSN streams
6. PSFP does not have any mechanism to detect and mitigate “smaller than expected/configured frame size”. This leads to one of two issues:
    a. Smaller than expected frames disrupt other streams
    b. An overhead of ~100% to prevent smaller frames from disruption other streams
7. MinSDUSize filtering addresses the problem directly – frames violating the configured minimum size are discarded without impacting any other traffic
8. **Proposal:** Add MinSDUSize filtering option for Stream Filters in 802.1Q 8.6.5.3


GE Aerospace