# Requirements for

# Scaling Deterministic Networks

draft-ietf-detnet-scaling-requirements-08

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# Motivation and Status

- Motivations
  - **In IEEE802.1 TSN TG**, multiple queuing mechanisms have been proposed such as TAS [IEEE802.1Qbv], CBS[IEEE802.1Q-2014], ATS [IEEE802.1Qcr], CQF [IEEE802.1Qch] and so on. But they are not applicable for scaling networks.
  - **In IETF DetNet WG**, technical requirements including the data plane enhancement requirements should be proposed aiming at scaling deterministic network with large variation in latency among hops, great number of flows and/or multiple domains.
  - The enhanced DetNet data plane solutions can be evaluated regarding these requirements.
- Status
  - This document was updated to v-08 and approaches the stable version.
  - It's stable and close to the Last Call according to the milestone.

# Main Updates from -00 to -08

- Version 00:Dec-2022, adopted as WG I-D
- Version 01:Mar-2023, changes of technical requirements(Section 3) based on the comments and closely aligned with each key attributes
- Version 02:May-2023, add some new requirements and  change of the structure according to the discussion in the bi-weekly interim
- Version 03:July-2023, add some analysis of TSN method in the text and some of the solution drafts has evaluated themselves regarding the requirements according to the discussion in the bi-weekly interim
- Version 04:Oct-2023, Add some text to enhance the explanation of requirements and rename some sections according to the discussion in the bi-weekly interim
- Version 05:Nov-2023, add some text to enhance the explanation of requirements and change to informative reference
- Version 06:May-2024, editorial revision
- Version 07:Nov-2024, editorial revision
- Version 08:Jun-2025, no change, being active

# Characteristics in Scaling Networks

- In scaling network with large variation in latency among hops, large number of flows and/or multiple domains, the characteristics should be considered as below:
  - there is relaxed clock synchronization or no clock synchronization in different domains.
  - the end-to-end path is a combination of low and high latency hops.
  - there are various transmission rates supported at different ports and on different network nodes.
  - there are a large number of flows which may be difficult to identify per-flow state and cause the high utilization of bandwidth.
  - the topology changes and failures of links or nodes might be more common.
  - the flow fluctuation caused by a large number of flows may happen frequently.
  - the number of hops might be large with complex topology.
  - the mechanisms used to ensure bounded latency may be multiple or have different configuration parameters in multi-domains.

# Overview of Technical Requirements

- Req 1. Tolerate Time Asynchrony
  - Support Asynchronous Clocks Across Domains
  - Tolerate Clock Jitter & Wander within a Clock Synchronous Domain
  - Provide Mechanisms not Requiring Strict Time Synchronization
  - Provide Mechanisms not Requiring Synchronization
- Req 2. Support Large Single-hop Propagation Latency
- Req 3. Accommodate the Higher Link Speed
- Req 4. Be Scalable to The Large Number of Flows and Tolerate High Utilization of Bandwidth
- Req 5. Tolerate Failures of Links or Nodes and TopologyChanges
- Req 6. Prevent Flow Fluctuation
- Req 7. Be Scalable to a Large Number of Hops with Complex Topology
- Req 8. Support Multi-Mechanisms in Single Domain and Multi-Domains
  - Support Provisioning of Multiple Mechanisms
  - Support Mechanisms Switchover Crossing Multi-domains

# Req1-Tolerate Time Asynchrony

- Support Asynchronous Clocks Across Domains
  - DetNet needs to connect these two TSN domains together and provide end-to-end deterministic latency service. The mechanism adopted by a deterministic network MUST be prepared to cross multiple non-synced TSN domains
- Tolerate Clock Jitter & Wander within a Clock Synchronous Domain
  - The deterministic networks SHOULD be able to recover or absorb such time variance within a domain.
- Provide Mechanisms not Requiring Strict Time Synchronization
  - It is desired that the same deterministic performance in term of the bounded latency and jitter SHOULD be achieved when full time synchronization is not available, that is to say, when only partial synchronization
- Provide Mechanisms not Requiring Synchronization
  - The mechanisms not requiring the time and/or frequency synchronization can eliminate the hardware cost and difficulty at the network nodes.
  - It can naturally tolerate the time variance, but it exhibits the concerns of per-flow state buffer management.

# Req2-Support Large Single-hop Propagation Latency

- Support Large Single-hop Propagation Latency
  - The propagation delay of a single hop can be in the order of a few milliseconds. It is much greater than that of a Local Area Network (LAN), and introduces impacts on queuing mechanisms, such as cyclic or time aware scheduling method.
  - The requirement for propagation delays in end-to-end computations should be considered when setting the period in both time synchronization or frequency synchronization based methods, or setting the extra buffer in the asynchronization based methods, to meet the requirements of deterministic forwarding between the network nodes.

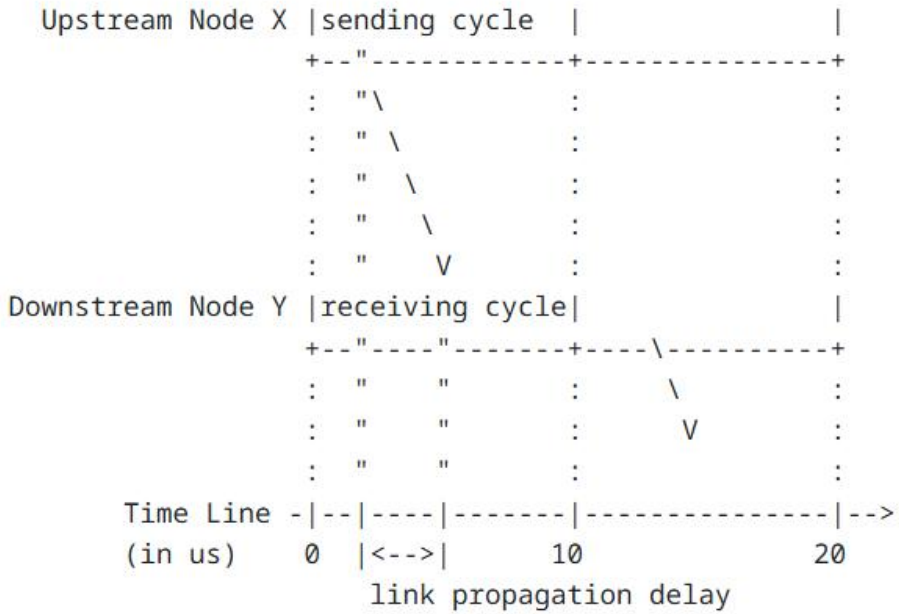


Figure 2: The influence of link propagation delay on a cyclic method

# Req3/Req4

- Req3-Accommodate the Higher Link Speed
  - A deterministic network can use higher speed links  such as data rates of 10G, 100G, 400G in wide area networks.
  - It requires the more precise time control  for the input stream gate and the timed output buffer or more buffer space, which imposes more complex buffer or queue management and larger memory consumption.
  - It requires optimizations to support higher link speeds.

- Req4-Be Scalable to A Large Number of Flows and Tolerate High Utilization of Bandwidth
  - DetNet allows the leverage of the flow aggregation, while individual flows may join and exit the aggregated flow rapidly in the scaling network with a large number of flows, which causes the dynamic in identification of the aggregated DetNet flow.
  - Provisioning on the aggregated flows normally improve the scalability at the cost of coarse granularity of the incoming traffic filtering and protection.
  - The traffic that requires deterministic networking can significantly fill up the capacity of a link or the portion of the link which is dedicated to such traffic, for example, more than 75% and/or up to near 100% utilization.

# Req5/Req6

- Req5-Tolerate Failures of Links or Nodes and Topology Changes
  - Deterministic networks may involve more network devices in scaling networks.
  - The numerous devices may lead to more network link failures. Path switching or re-convergence of routing will cause high latency of packet loss and retransmission. It is necessary to support certain mechanisms to adapt to failures of links or nodes and topology changes.
  - The change of the number of devices may affect the implementation and adjustment of deterministic network mechanism, such as the topology discovery, queuing mechanism and packet replication and elimination. A method is expected to support flexible planning of multiple paths and provide a solid foundation for the implementation of PREOF.
- Req6-Prevent Flow Fluctuation
  - More kinds of DetNet traffic flows will cause more dynamic joining or leaving of the flows, which will further cause more flow fluctuation as well as more unpredictability of the DetNet flows.
  - Non-DetNet flows are also massive and may have potential impact on the scalability of the DetNet flows.
  - It is required to support bursty traffic and some methods to decrease the micro-burst.

# Req7-Be Scalable to a Large Number of Hops with Complex Topology

- Be Scalable to a Large Number of Hops with Complex Topology
  - The network topology can also be complex, including star, ring, mesh, and their combinations, and can possibly be hierarchical. It is required to support networks with such various types of topologies and large hop counts.
  - The queuing mechanism latency for DetNet QoS should be bounded by a fixed constant per hop maximum value so that the resulting end-to-end latency bounds are a linear function of the number of hops in addition to the inherent forwarding latency of the nodes involved.
  - The complexity of resource allocation processing may range from linear to potentially exponential. This resource allocation complexity does not directly affect achievable end-to-end latency and jitter bounds, but it does surface in other areas such as the amount of computation and elapsed time required to admit a new flow to a DetNet network without disrupting the DetNet QoS provided to already admitted flows.
  - Different queuing mechanisms exhibit different properties across achievable end-to-end jitter bounds, achievable end-to-end latency bounds and complexity. All three of these areas are considerations in evaluation and selection of scalable DetNet queuing mechanisms.

# Req8-Support Multi-Mechanisms in Single Domain and Multi-Domains

- Support Provisioning of Multiple Mechanisms
  - The flows may have different levels of demand for DetNet service and the different SLA demands need different DetNet technologies as well as the multi-domain demand in scaling networks.
  - It is required to provide diversified deterministic service for various applications in a deterministic network and to support the corresponding diversified mechanisms (possibly at multiple DetNet QoS levels)
- Support Mechanisms Switchover Crossing Multi-domains
  - In deterministic networks, end-to-end service may across multiple network domains, which may adopt a variety of different queuing mechanisms within each domain, or may have different link speeds for the same queuing mechanism.
  - For the different queuing mechanisms switchover, such as from time synchronous mechanism [IEEE802.1Qbv] to asynchronous mechanism [IEEE802.1Qcr], a collaboration mechanism crossing multi-domains MUST be considered.

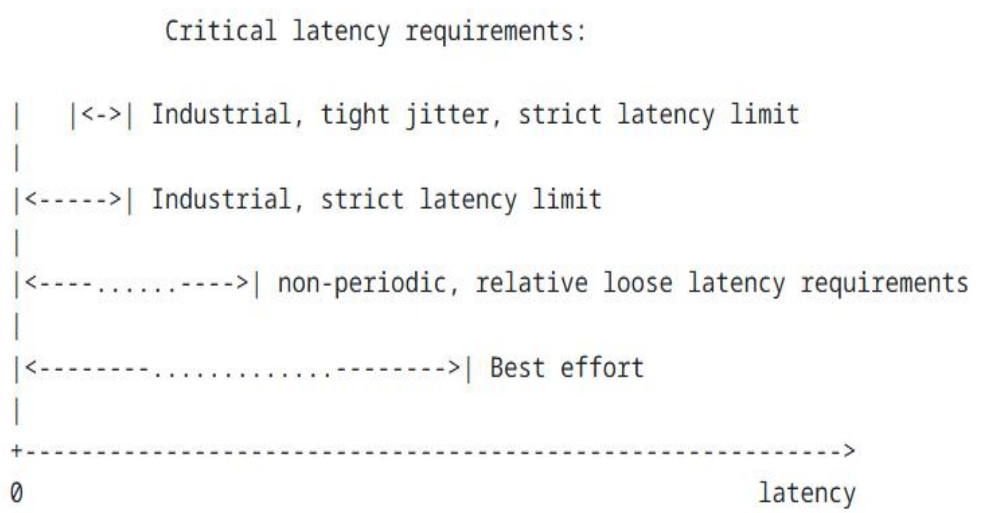


Figure 3: Different levels of application requirements

# Data Plane Enhancement Requirements

- Support Aggregated Flow Identification
  - in deterministic networks the number of individual flows can be huge, and they may randomly join and leave the aggregated flow at each hop, leading to the difficulty in identifying aggregated flows by relying on the prefixes or wildcards. The explicit aggregated flow identification SHOULD be supported.
  - the deterministic services may demand different deterministic QoS requirements according to different levels of application requirements. The flow identification with service-level aggregation should be supported.

- Support Information used by Functions Ensuring Deterministic Latency
  - different queuing mechanisms require different information to be defined as the DetNet-specific metadata to help the functions of ensuring deterministic latency, including regulation, queue management, etc.

# TSN Queuing Mechanisms Evaluation Summary

(David Black from DT)

- TAS / CBS / ATS / CQF / ECQF

| section | Requirements | Evaluation | Notes |
|---|---|---|---|
| 3.1 | Tolerate Time Asynchrony | Yes – 3, No – 2 | No: TAS, CQF |
| 3.2 | Support Large Single-hop Propagation Latency | Yes – 4, No – 1 | No: CQF |
| 3.3 | Accommodate the Higher Link Speed | Yes – 2,<br>Partial – 3 | Partial: TAS, CQF, ECQF |
| 3.4(1) | Be Scalable to the Large Number of Flows | Partial – 5 | |
| 3.4(2) | Tolerate High Utilization | Yes – 2, Partial – 1,<br>No – 2 | Partial: TAS<br>No: CQF, ECQF |
| 3.5 | Prevent Flow Fluctuation from Disrupting Service | Yes – 1, Partial – 3,<br>No – 1 | Partial: ATS, CQF, ECQF<br>No: TAS |
| 3.6 | Tolerate Failures of Links or Nodes and Topology Changes | | Not related to queuing mechanisms directly. |
| 3.7 | Be Scalable to a Large Number of Hops with Complex Topology | Partial – 3,<br>Partial/No - 2 | Partial: TAS, CBS, ATS<br>Partial/No: CQF, ECQF |
| 3.8 | Support Multi-Mechanisms in Single Domain and Multi-Domains | | Not related to a single queuing mechanism directly. |

# New Queuing Mechanisms Evaluation Summary

(David Black from DT)

- C-SCORE/Deadline/TCQF/CSQF/gLBF/TQF

| section | Requirements | Evaluation | Notes |
|---|---|---|---|
| 3.1 | Tolerate Time Asynchrony | Yes – 4, Partial – 2 | Partial: TCQF, CSQF (Partial - within domain. Yes - async across domains & tolerates jitter) |
| 3.2 | Support Large Single-hop Propagation Latency | Yes – 6 | No: CQF |
| 3.3 | Accommodate the Higher Link Speed | Yes – 2,<br>Partial – 3,<br>TBD – 1 | Yes: TCQF, CSQF<br>Partial: C-SCORE, Deadline, TQF<br>TBD: gLBF |
| 3.4(1) | Be Scalable to the Large Number of Flows | Yes – 4, Partial – 2 | Partial: Deadline, TQF |
| 3.4(2) | Tolerate High Utilization | Yes – 4, Partial – 2 | Partial: Deadline, TQF |
| 3.5 (now 3.6) | Prevent Flow Fluctuation from Disrupting Service | Yes – 6 | |
| 3.6 (now 3.5) | Tolerate Failures of Links or Nodes and Topology Changes | | Not related to queuing mechanisms directly. |
| 3.7 | Be Scalable to a Large Number of Hops with Complex Topology | Yes – 3, Partial – 3, | Yes: C-SCORE, CSQF, gLBF (flow interleaving TBD)<br>Partial: Deadline, TCQF, TQF |
| 3.8 | Support Multi-Mechanisms in Single Domain and Multi-Domains | | Not related to a single queuing mechanism directly. |

# Next Steps

- Coordinate and align with the dataplane enhancement taxonomy.
- Welcome more review before the LC.