DetNet

Bounded Packet-Delay-Variation

draft-mohammadpour-detnet-bounded-delay-variation-00

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Latency = end-to-end delay

- “L is an upper bound on latency” means: $D_n \leq L$ where $D_n$ is end-to-end delay of packet $n$ of the flow of interest.
- Of interest in DetNet is a **guaranteed upper-bound on latency**

Packet delay variation = (worst-case delay) – (best case delay)

- “$V$ is an upper bound on packet delay variation” means: $|D_n - D_m| \leq V$ for any two packets $n, m$ of the flow of interest.
- Terminology comes from RFC 3393; also called “latency variation” or “jitter” in RFC 8655.
- DetNet may also be interested in a **guaranteed upper-bound on packet delay variation**
Bounded Latency  

- How to compute **guaranteed upper-bound on latency** in a DetNet.
- Gives a methodology, including a timing model and relationship with control plane (static versus dynamic reservation of resources).
- Applies the methodology to various queuing/scheduling/regulator mechanisms presented in RFC 8655 (Deterministic Networking Architecture): frame preemption, TAS, CBS, ATS, IntServ, CQF.
- Packet delay variation is out of scope.
Bounded Packet Delay Variation

• An upper bound $L$ on latency is also an upper bound on delay variation.
• This is sufficient for many applications (e.g. 50ms in AVB, $\leq 1$ ms Tactile Internet\(^1\))
  • but not always e.g. remote process control requires latency bound 1ms, delay variation bound $1\mu s$\(^1\); latency bound alone is not sufficient for some machine control applications.

⇒ There is a need to:
• specify a methodology to compute guaranteed upper-bound on delay-variation in a DetNet;
• apply it to existing or proposed mechanisms.

\[\text{[draft-mohammadpour-detnet-bounded-delay-variation-00]}\]

Mechanisms for Low Jitter

• Cyclic Queuing and Forwarding with small cycle time

• Damper [Cruz 98]
  • Delays a packet by “earliness”, read from packet header
  • Removes most of jitter

• Stateless: RCSP [Zhang 1993], RGCQ [Shoushou 2020], ATS with Jitter Control [Grigorjew 2020].


Clock Accuracy Matters for Very Low Jitter

- Clocks are not perfect, even in synchronized networks.
- This affects regulators such as ATS [Thomas 2020].
- In general, does not seriously affect latency bounds. May affect jitter bounds when they are very small
- Clock model:
  \[-\min \left( \left( 1 - \frac{1}{\rho} \right) d + \frac{\eta}{\rho}, 2\omega \right) \leq d^{\text{true}} - d \leq \min((\rho - 1)d + \eta, 2\omega)\]

  \(\omega = \) time error bound = 1\(\mu\)s in TSN with PTP; = \(+\infty\) if no synchronization;
  \(\rho = \) clock-stability bound = 1.0001; \(\eta = \) timing-jitter bound = 2ns (e.g. in TSN);
  \(d = \) delay measurement with local clock; \(d^{\text{true}} = \) same in true time.

Example [Mohammadpour 2021]

- Wide area network, PE routers synchronized, RCSP dampers
- Latency upper bound $L = 34.2$ ms
- Jitter bound $V = 13.7\mu s$
- Jitter bound when ignoring clock accuracy is $1.001\mu s$
## Scalability

[draft-eckert-detnet-bounded-latency-problems-00]

<table>
<thead>
<tr>
<th>Per-flow state, per-flow queue</th>
<th>DRR, Guaranteed Service of IntServ</th>
<th>• Not scalable</th>
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<tbody>
<tr>
<td>Per-flow state, per-class queue</td>
<td>IEEE TSN ATS</td>
<td>• Not scalable</td>
</tr>
</tbody>
</table>
| Per-class | Static Class Priority, Per-class DRR, IEEE TSN CBS, Pulsed Queues, DiffServ, CQF, Packet tagging based CQF, Packet tagging based CQF with SR, Per-hop latency indications for SR, Latency Based Forwarding, Dampers | • Scalable  
• Latency and jitter bounds differ widely |
Mechanisms are compounded

• Example: MPLS tunnels between Provider-Edge nodes

MPLS Label stacks
One single MPLS tunnel between PE1 and PE2 for all detnet flows from customer 1 to customer 2
Re-shaping (ATS) at PE1
Backbone and customer networks use different DetNet mechanisms
Backbone sees only PE to PE tunnels
Backbone Delays

• Backbone delays decrease with technology
  • Access network: buffer drain time \( \sim \) seconds
    \( \Rightarrow \) here detnet requires queuing mechanisms
  • High speed nodes: buffer drain time \( \sim \) 0.2 ms\(^1\)
    \( \Rightarrow \) here diffserv / static priority may suffice in the core
    complemented with e.g. dampers at edge

\(^1\) https://www.nextplatform.com/2016/10/31/broadcom-strikes-100g-ethernet-harder-tomahawk-ii/ sampled on 2021/09/07
Conclusion

Separate the issues of

1. Bounded delay variation (define a methodology to compute guaranteed bounds on delay variation, apply it to proposed mechanisms)

2. Scalability

3. Specification of mechanisms

True behaviour of clocks should be considered when computing very low jitter bounds.