DetNet

Bounded Packet-Delay-Variation

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

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[1] Ehsan Mohammadpour is supported by Huawei Technologies Co., Ltd. project "Large Scale Deterministic Network."

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 [draft-ietf-detnet-bounded-latency-07]

- 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 premption, 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, ≤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:

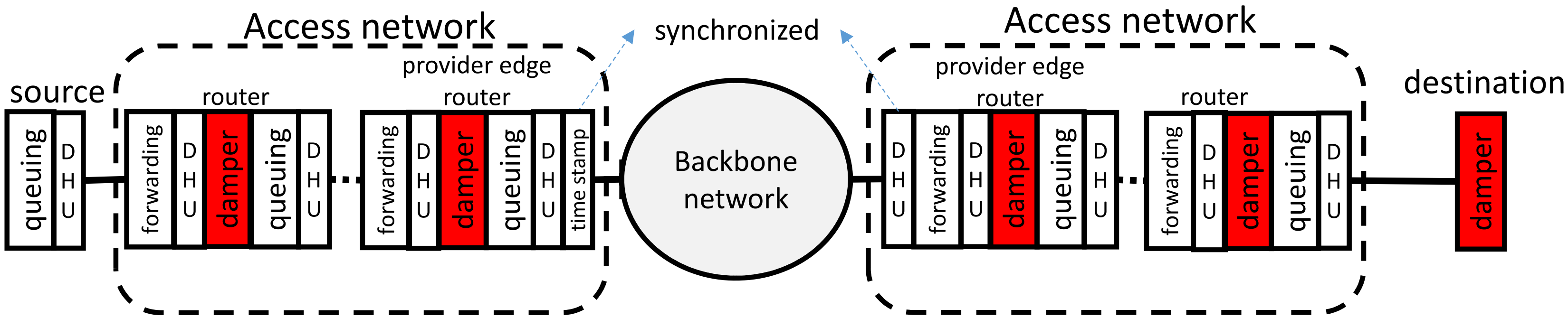
- specify a methodology to compute **guaranteed upper-bound on delay-variation** in a DetNet;
- apply it to existing or proposed mechanisms.

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

[1] ITU-T, "ITU-T.3000-series - representative use cases and key network requirements for network 2030," vol. Y.Sup67, 2020.

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].



[Zhang 93] Zhang, H. and Ferrari, D., 1993, March. Rate-controlled static-priority queueing. In *IEEE INFOCOM'93 The Conference on Computer Communications, Proceedings* (pp. 227-236).

[Shoushou 2020] R. Shoushou, L. Bingyang, M. Rui, W. Chuang, J.-Y. Le Boudec, E. Mohammadpour, and A. El Fawal, “A method for sending data packets and network equipment,” China Patent, Jul., 2020.

[Grigorjew 2020] Grigorjew, A., Metzger, F., Hoßfeld, T., Specht, J., Götz, F.J., Chen, F. and Schmitt, J., 2020. Asynchronous Traffic Shaping with Jitter Control. Preprint Uni Würzburg.

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:

$$-\min\left(\left(1-\frac{1}{\rho}\right)d+\frac{\eta}{\rho},2\omega\right)\le d^{\mathrm{true}}-d\le\min((\rho-1)d+\eta,2\omega)$$

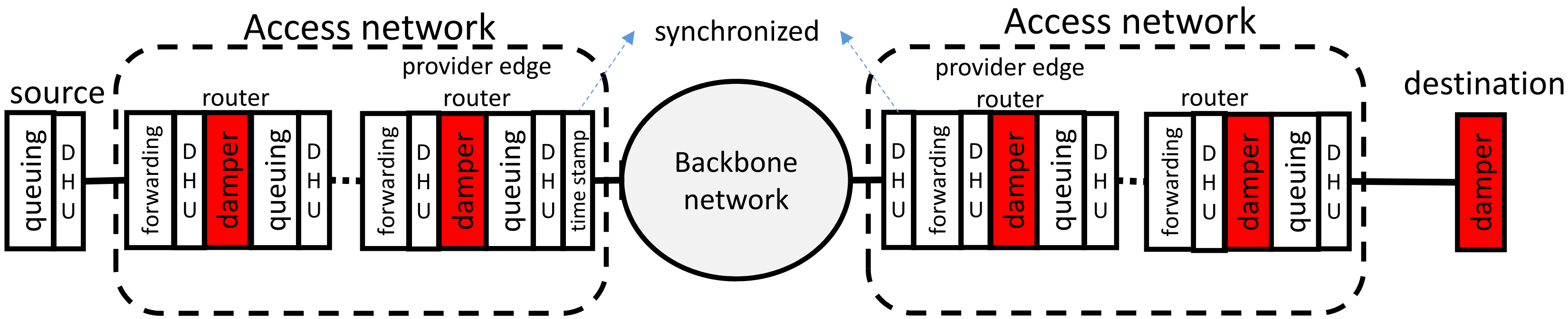
$\omega =$ time error bound = 1μs in TSN with PTP; = $+\infty$ if no synchronization;
$\rho =$ clock-stability bound =1.0001; $\eta =$ timing-jitter bound = 2ns (e.g. in TSN);

$d =$ delay measurement with local clock; $d^{\mathrm{true}} =$ same in true time.

[Thomas 2020] Thomas, L. and Le Boudec, J.Y., 2020. On Time Synchronization Issues in Time-Sensitive Networks with Regulators and Nonideal Clocks. *Proceedings of the ACM on Measurement and Analysis of Computing Systems*, *4*(2), pp.1-41.

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 $1.001\mu s$!



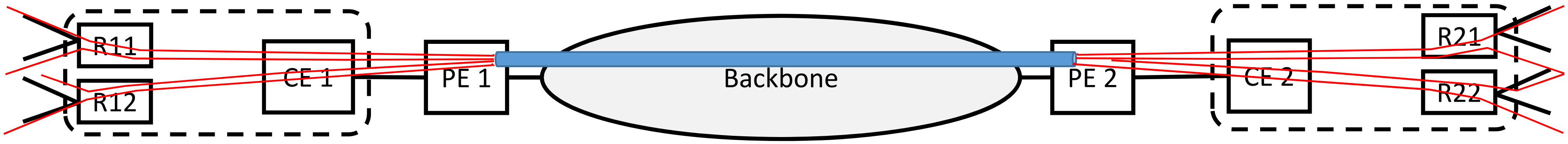
[Mohammadpour 2021] Mohammadpour E, and Le Boudec, J.Y., 2021. Analysis of Dampers in Time-Sensitive Networks with Non-ideal Clocks. *Arxiv pre-print, https://arxiv.org/abs/2109.02757,* 2021

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

Per-flow state, per-flow queue	DRR, Guaranteed Service of IntServ	• Not scalable
Per-flow state, per-class queue	IEEE TSN ATS	• Not scalable
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.