Demo title: Low latency Low-Jitter Bandwidth-Efficient PON for Industry applications.

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Abstract (45 words):

We demonstrate a TDM-PON based end-to-end system that achieves ultra-low latency and jitter with high throughput efficiency for time-sensitive applications. This is achieved using co-scheduling of TDM-PON with Ethernet Time Sensitive Network (TSN) elements to serve industrial applications requiring such end-to-end network performance.

Time Division Multiplexed-Passive Optical Networks (TDM-PON) that had originally been developed for the now widely deployed mass market FTTH/FTTB networks, is currently being explored for diverse applications for e.g., mobile fronthaul and Industrial applications. Unlike traditional FTTH use cases, these applications often require low latency and minimal jitter, particularly in industrial settings where jitter requirements can be very stringent (<1 µs). To support both time-critical and best-effort applications on the same network, the Ethernet IEEE 802.1 standard was extended with time-sensitive networking (TSN) features (e.g., IEEE 802.1Qbv, 802.11Qci etc.) for temporal control of traffic flows. Typically, industrial applications usually have predictable traffic patterns, and TSN 802.1Qbv manages these by scheduling periodic Tx/Rx reservations to control latency. In TDM-PON on the other hand, traffic containers (TCONT) can be provisioned with committed information rates and delay tolerances to meet some application requirements. However, latency and jitter can still occur due to burst placement/alignment w.r.t the application traffic arrival. This can be mitigated by configuring shorter and more frequent burst allocation in the PON frame, but this comes at a cost of sacrificing bandwidth efficiency. An alternative approach that we proposed in [1] is to exploit the knowledge of the application traffic characteristics (phase and periodicity/frequency) to deterministically co-schedule the uplink PON burst allocation to align with the application traffic. This enables the feasibility to achieve ultra-low latency (<100us) and jitter (<1us) end-to-end while achieving the best possible bandwidth efficiency (Fig. 1). Moreover, this scheme can function along with the regular PON-DBA allowing co-existence of time critical best effort traffic over the same PON.

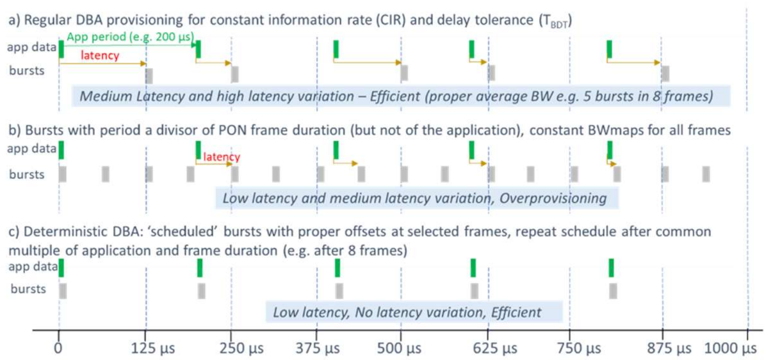

Fig. 1: Concept of deterministic scheduling in TDM-PON for ultra-low latency and jitter with high BW efficiency

Fig. 3: Demonstrator setup (Physical setup)

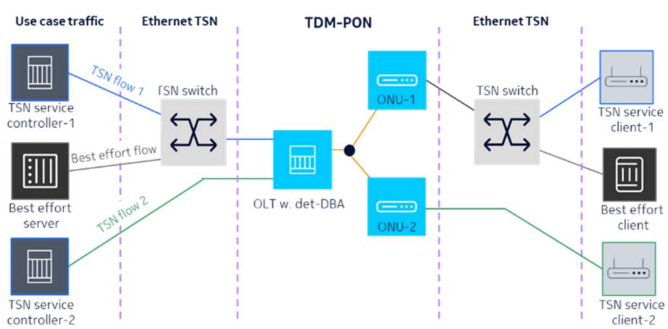

Fig. 2: Demonstrator setup (architectural level)

Fig. 4: Sample result showing the performance of TSN and Best-effort traffic coexisting on same PON.

This demonstrator (Fig. 3) shows the above capability in real-time Ethernet TSN & TDM-PON based converged network setting implemented using NOKIA TDM-PON and commodity TSN switches (Fig.2). Network elements are time synchronized with IEEE 1558 Precision Time Protocol (PTP) and application traffic characteristics are shared with PON and TSN to facilitate deterministic co-scheduling in PON. Traffic generator and analyzer is used for generating both best-effort and time-sensitive application traffic. Result (Fig. 3) shows that <100us of latency and <1us is possible to achieve using this deterministic scheduling.

The demonstrator shown in Fig. 3 will physically be present at the venue and a live demonstration of latency and jitter parameters via the speedometer tools as shown in Fig. 4 is targeted.

[1] K. Christodoulopoulos, S. Bidkar, T. Pfeiffer and R. Bonk, "Deterministically Scheduled PON for Industrial Applications," 2023 Optical Fiber Communications Conference and Exhibition (OFC), San Diego, CA, USA, 2023, pp. 1-3, doi: 10.1364/OFC.2023.Tu3F.5