Self-Calibrating Transponder using Intelligent DSP Metrics for Efficient Optical Networks

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Abstract: We demonstrate a self-aware automated transponder system for disaggregated open ROADM-based networks with automation using real-time inputs from a PS-capable 800Gb/s DSP that facilitates in situ measurement of signal performance, for optimal line-rate selection. © The Authors 2022.

1. Introduction

Network automation has the potential to impact disaggregated ROADM-based networks from the perspective of adding new features and exploiting all the benefits of the optical layer. With increase in line-rates, and network planning tools that are built for a one-size-fits all approach, it is now desired by operators that next generation transponders be able to compute optimal line-rate in real-time, especially when the set up constitutes disaggregate ROADMs line-systems. Today, transponders are assumed to be plugged into a network by provisioning them through a management system that includes keeping margins for end-of-life performance. Once provisioned, transponders are thereafter not re-provisioned in real-time. Measurements beyond basic network telemetry or analysis of traffic restoration post failures are the only real-time considerations on transponders. In a disaggregated environment there is an extra layer of effort to indulge even in network telemetry, and monitoring due to the presence of multiple different vendors' transponders, implying that acting upon associated triggers in real-time is harder. Consider a scenario in which transponders from 2-3 vendors are plugged into a line-system. Even with the open-source oriented advances in network control, provisioning these transponders, implies making consensus-based decisions, many a times not optimal. For example, if there are transponders from vendors A, B and C connected using the ROADM line system of vendor D, then optimally provisioning transponders from A, B, C across the multiple transponders considering their collective performance and impact on each other is a task. What is even harder is to self-provision transponders from A, B and C, by considering the impact of other transponders' performance on the transponder that is being calibrated (and vice versa). What would be desired is if the transponders can manifest themselves, become self-aware of their environment/channel/spectrum, communicate to its counterpart on the other side of the line and compute if the setting juxtaposed on it through the management system can be improved further. Two engineering innovations can facilitate the development of such self-aware transponders: (a) the ability of transponders to generate enough real-time performance metrics (PMs) that can aide in real-time computation of optimal performance, and (b) an automation framework that facilitates conversion of PMs into actionable information in a computationally tractable manner. To this end, we propose, an automation framework built around a 800Gb/s DSP-based transponder [1], which when put into a network and configured for known end-of-life margins, computes the best present mode of operation, and makes this data available for distributed processing and provisioning. Such an automated transponder system thus becomes a responsible, independent and smart element in a disaggregated scenario. Specifically, our system uses PM data from transponder DSPs in conjunction with prediction of required margins kept for expected performance degradation during operation to automatically recalibrate for end-of-life degradation to automatically recalibrate the system for better performance (line-rate). In Section 2, we describe the architecture and the specific use case of transponder automation and engineering innovations.

2. Innovation

Fig. 1 shows the principle of the proposed transponder automation scheme. Quality of transmission (QoT) metrics is streamed from one or several transponders via standard protocols to the automation software layer. An example of the streaming mechanism is through a gNMI or gRPC interface. Telemetry metrics are aggregated and further processed by the QoT engine. Raw data as well as postprocessed data is fed into a time-series database. QoT data and recommendations can be retrieved at any time from the time-series database again and visualized on a dashboard. Alternatively, the data may be taken to drive autonomous decisions. The proposed system relies on continuous evaluation of transmission quality metrics extracted from PM data measured by the transponder combined with known transponder characteristics and parametrized optical performance models. There is no need for information about the line system, fiber type, amplifier characteristics and so on. This makes the proposed approach ideal for systems where only limited information is available or information is not reliable enough to be considered, i.e., disaggregated open line systems. In such situations QoT metrics can be used to verify and improve planning data and line-system parameters or get those parameters in the first place. Since transponders estimate various QoT metrics continually during normal operation, the process takes place without any service interruption. Additionally, other parts of the wavelength spectrum can be gauged during maintenance windows by moving the transponder frequency across the targeted free spectral range for further verification and adjustments. This way a complete picture of an in the beginning unknown line system can be assembled during normal operation. Apart from collecting line system information, various transponder metrics are processed by our QoT engine to estimate the margin which is currently left for safe operation. This may or may not take into account additional safety margins for ageing and repair. Ideally, only a minimal margin is kept, ensuring safe operation under current working conditions. Since margins are monitored constantly, any decreasing margin is detected immediately and will result in a warning or new recommendation for the optimum mode of operation. The system presents recommendations that include which modes and data-rates are suitable in the current working conditions satisfying the operator´s minimum margin requirements fitting the risk profile associated with margins. This leads to all transponders achieving maximum data rate at any given point in time with an exactly defined and maintained minimum margin. At a later stage, recommendations can be turned into immediate actions in order to let transponders maximize the system´s data rate autonomously.

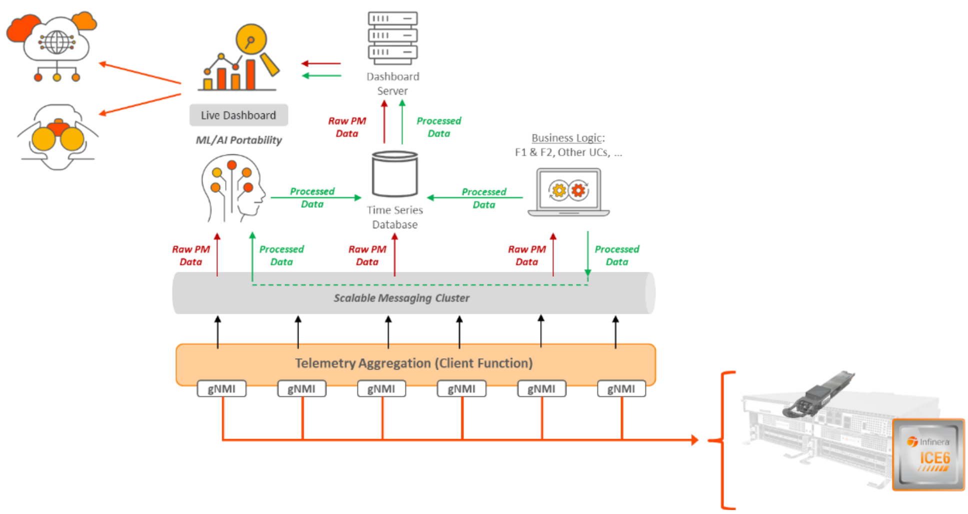

Fig. 1. Self-calibrating transponder architecture.

3. Relevance to OFC

The industry is moving towards disaggregated ROADMs and intelligent systems/sub-systems. The intelligent transponder is a subsystem that automatically detects if sufficient margin is available that can be used to ramp up (or down) the line-rate. The act of using excess margin for line-rate optimization cannot be done with a tool in a disaggregated set up. The innovation is not just to read and process DSP PM data but a combination of PM data together with optical performance models allowing accurate assessment of the transmission quality of the optical channel at current conditions as well as prediction of expected performance variations in the future. The PM data from the DSP indicate as to how much margin can be exploited and the impact of adjacent channels (from other transponders), on to the channel under consideration.

This demo hence facilitates how the industry can take steps towards next generation disaggregation making it feasible as well as inducing automation. In fact, this demo is quintessential towards realizing the disaggregated open ROADM initiatives with transponders from multiple vendors.

4. Demonstration logistics

The demonstration shall include a live demonstration, beamed through an Internet link, with the following set up:

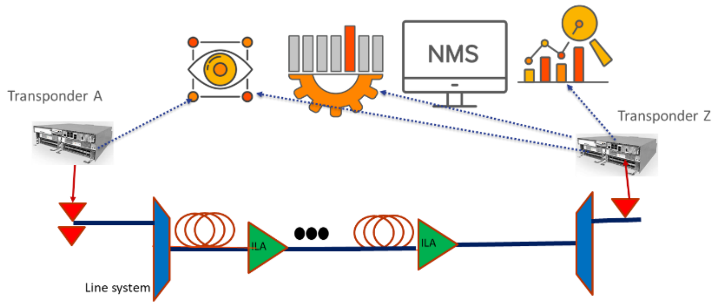

Fig. 2. Demonstration set up.

Objectives: Showcase the DSP PM data, the features, the correlation to line-rates and the GUI. Also showcase the ability to dynamically access and process data.

Set up: The demo will physically be at our office, with live access within the demo zone area. Participants can tweak margin and check for performance changes. The demo shall consist of 2 line-systems, 2 transponders, management system and recommendation system on hand-held devices. The transponders used support a large number of transmission modes with corresponding line-rates from 250Gb/s to 800Gb/s.

Presentation: The demo shall be presented in 3 ways: as posters at the demo zone; through interactive discussions via us at the demo zone area and through touch screen-based interfaces that facilitate participants to change settings and check how a real-disaggregated system can work. We would create 8-12 min modules that would be repeated to cover participants as they visit the demo zone.

5. Scalable Architecture for Future Use Cases

Although this demo essentially uses margins as the QoT metric, other futuristic QoT metrics can be incorporated into this architecture. As the DSP technology evolves for the next generation transponders, this framework will provide an effective method for truly introducing the automation with zero touch, plug-n-play user experience. Further, a policy-based automation framework may be deployed, that will allow operators to control the actions (either manual or automated) based on the recommended inference.

References

[1] H. Sun *et al*., "800G DSP ASIC Design Using Probabilistic Shaping and Digital Sub-Carrier Multiplexing," in *Journal of Lightwave Technology*, vol. 38, no. 17, pp. 4744-4756, 1 Sept.1, 2020, doi: 10.1109/JLT.2020.2996188.