Telemetry Methodologies for Analog Measurement Instrumentation

draft-janzking-nmrg-telemetry-instrumentation

Christopher Janz (Huawei - presenter); Daniel King (Lancaster University)

IETF 119 Brisbane, March 2024

- Existing studies for network telemetry typically deal with packet-oriented measurements, generating packet traffic, path, discard, latency and other data
    - E.g. IETF RFC 7799, Morton, A., "Active and Passive Metrics and Methods (with Hybrid Types In-Between)”May 2016, https://www.rfc-editor.org/info/rfc7799
- However, some networking equipment and network operations scenarios feature or use more physically-oriented measurement instrumentation that generates data of a different character
- Here, focus is - by way of example - on optical network instrumentation, and use cases related to optical network digital twin (NDT) and optical network fault management

- Measurement instruments used for conditioning, commissioning, testing and troubleshooting of optical fiber facilities and networks include, e.g.:
  - Optical Time-Domain Reflectometers (OTDRs)
  - Optical Spectrum Analyzers (OSAs)
  - Network Analyzers and BER Testers
  - Etc.
- In recent years, research has generated new technologies for embedded, continuous measurement of optical transmission performance-relevant parameters, (mostly) at coherent receivers, suitable for telemetry, e.g.*:
  - Optical spectra (narrow-band-filtered power measured at a series of center wavelengths)
  - Differential group delay (DGD), polarization mode dispersion (PMD) & polarization dependent loss (PDL)
  - Stokes vector components reflecting state of polarization (SOP)
  - Linear optical signal-to-noise ratio (OSNR) and generalized optical signal-to-noise ratio (GSNR)
  - Etc.

  (* Journal of Lightwave Technology, vol. 40, No. 10, pp. 3128-3136, "Progresses of Pilot Tone Based Optical Performance Monitoring in Coherent Systems", 1 October 2023, https://opg.optica.org/jlt/abstract.cfm?uri=jlt-40-10-3128)
- Data generated is analog: continuous-time real-number (scalars or vectors)

Use Cases (1):

- **Optical NDT:**
  - Predicts optical transmission performance on the current network, or targeted variations of it
  - Requires knowledge and modeling of fiber and service characteristics, transmission impairments and (where available) performance
  - The NDT state should be continuously updated to reflect the real network condition and state
  - However, large volumes of continuous-time, real-number (“analog”) data pose a volumetric challenge to telemetry

  E.g.:

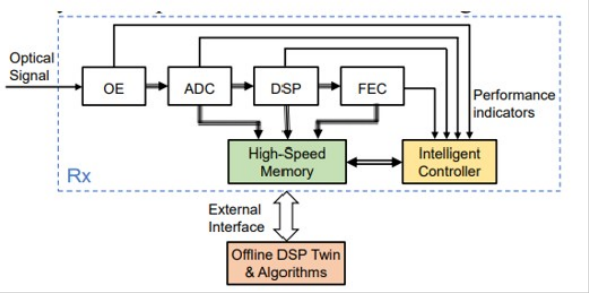
  IEEE/IFP Network Operations and Management Symposium, Workshop on Technologies for Network Twins, "Digital Twin for the Optical Network: Key Technologies and Enabled Automation Applications", April 2022 https://ieeexplore.ieee.org/document/9789844

  IRTF “Performance-Oriented Digital Twins for Packet and Optical Networks,” Work in Progress, October 2023, https://datatracker.ietf.org/doc/draft-paillisse-nmrg-performance-digital-twin/02

Use Cases (2):

- **Deep Analysis of Rich Data (e.g. for Fault Management):**
  - E.g. reconstruction of detailed longitudinal optical loss profiles at a point in time, based on post-analysis of received I-Q time-based waveforms

(E.g. Jiang et al, Optical Fiber Communications, "On the Spatial Resolution of Location-Resolved Performance Monitoring by Correlation Method", 1 March 2023, https://doi.org/10.1364/OFC.2023.W1H.2)



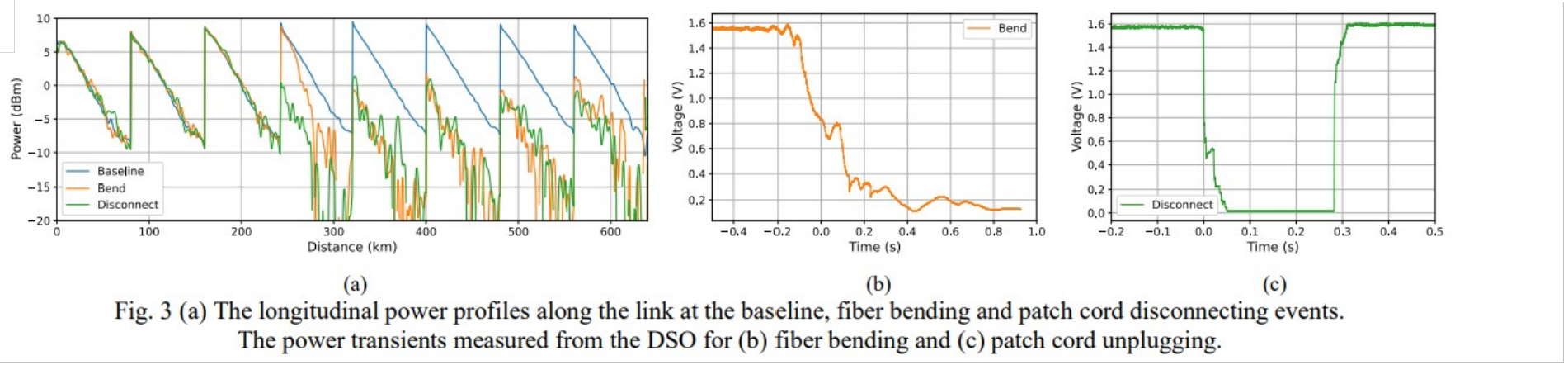


Fig. 3 (a) The longitudinal power profiles along the link at the baseline, fiber bending and patch cord disconnecting events. The power transients measured from the DSO for (b) fiber bending and (c) patch cord unplugging.

  - Frequency-domain views of polarization rotation dynamics may also provide useful information about disturbances to fiber transmission plant

- Resonance/alignment with many aspects of IETF **RFC 9232**:
  Song, H., Qin, F., Martinez-Julia, P., Ciavaglia, L., and A. Wang,
  "**Network Telemetry Framework**", May 2022, https://www.rfc-editor.org/info/rfc9232

- **Sampling:**
  - The "mirroring" (i.e. transmission for replication at a different place) of continuous-time real number data, generated by in-network instrumentation, begins with sampling and representing measured values by a scalar or vector of finite-decimal-place numbers
  - As neither sampling at fixed intervals, nor fixed time alignment or offset among measurement points in the network or between such points and the off-network realm, can generally be assumed; it is useful that **instrumentation should generate, as primary data, a series of couplets or vectors consisting of sample time stamps and corresponding measured data values**

- **Time Precision:**
  - Requirements on the precision of reconstructed data, its time basis, and the alignment in time of different reconstructed measurements; are determined by the operational role played by the analytical functions that consume the data
    - Some operations – e.g. network and service planning - may impose only relatively relaxed requirements on time synchronization among measurement instruments, and between those instruments and the software domain
    - Other applications - e.g., those concerning operations tending toward closed loop control - may impose tighter temporal alignment requirements
  - In general, requirements are generally more like "network time" than "digital time“

- **Pre-Processing and Post-Processing for Data Reduction:**
  - **Lossless Compression:** Generates (uncontrollably) variable data reduction; time stamps critical; post-processing (decompression) unavoidable

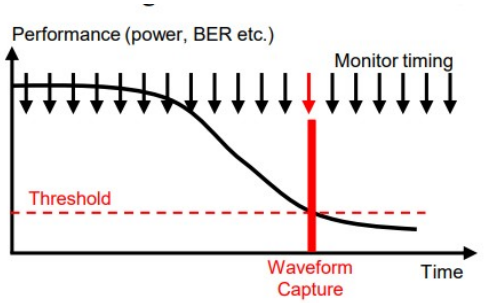
  - **Thresholding:** Data samples are transmitted only if and when a measured value, or a derivative of the measured value, crosses a threshold. Possible examples include:
    - Exceeding some absolute or proportional variation from the last transmitted sample value
    - Exceeding a previously observed and transmitted maximum or minimum value
    - Exceeding some time rate-of-change of the measured value

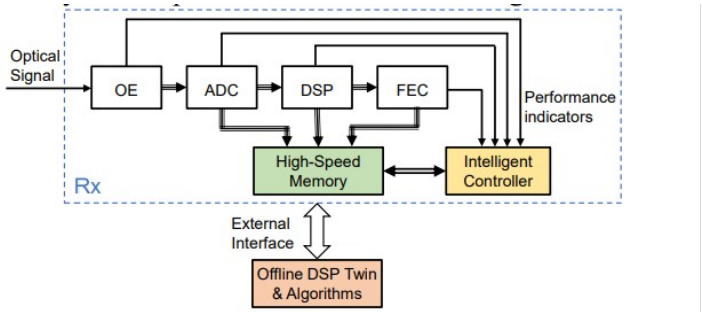
    Post-processing of thresholding-based may or may not be required:

    - E.g. an NDT requires all "current" data from network instrumentation; to whatever precision is effectively reflected in the details of the operating thresholding mechanisms, that data is simply *the most recently transmitted sample* from network measurement instruments.

- **Pre-Processing and Post-Processing for Data Reduction:**
  - **Normalization, Frequency Domain Conversion, Generation of Statistics**

- **Pre-Processing and Post-Processing for Data Reduction:**
  - **Triggering:** An extension or variation of thresholding, triggering may refer to, e.g. the transmission of a series of samples - from a defined set of measurement instruments, over a defined period of time and at defined time intervals - on crossing of a particular threshold (i.e., that threshold crossing "triggers" the transmission of the defined data series). Triggering of this kind may be useful in e.g. fault and impairment management.





Required pre-processing includes processing of triggers, and the sliding storage of instrumentation data sample values sufficient to cover the targeted data capture time "window" as well as trigger processing and transmission intervals

- **Programmable Streaming**
  - In-network pre-processing of telemetry data may usefully be programmed by telemetry clients (i.e., software applications that are consumers of instrumentation data), including dynamically or variably
  - The range and nature of software applications and their data requirements may vary among systems, may evolve with time within any given system, based on experience and learning (automated or not) or with the deployment of new capabilities, including instrumentation
- **Streaming vs. Polling**
  - It is worth considering whether polling can or should be completely dispensed with, or whether it might retain some utility in some cases or circumstances
  - Polling could be used if e.g. NDT-based analyses are required relatively infrequently, do not require very rapid execution, and do not draw arbitrarily on historical data
  - Polling might also be useful as a complementary mechanism to streaming, especially if unreliable channels are used

- **A complete framework** for analog instrumentation telemetry might require data models supporting:

  - Identification of instrumentation-equipped and telemetry-capable network equipment, the latter's available instrumentation, its available pre-processing, and what aspects of available pre-processing are programmable;

  - Subscription to streaming from specific instrumentation;

  - Programming (or re-programming) of pre-processing on specific subscriptions and instrumentation, including type of pre-processing, applicable thresholds or triggers, and definition of trigger-associated data sets (included data and start/stop interval limits vs. triggering events);

  - Transmission of applicable time stamp-data value couplets, vectors or batches.

- **Next Steps:**
  - Possible optical network PoC implementation supporting analog instrumentation telemetry operational framework and demonstrating major use cases, using example YANG models;
  - Provide inputs to IETF efforts developing related operational framework aspects