Workshop: Technology Trends for Optical Networks Towards 2020 and Beyond

Emerging Research Directions for Machine Learning in Optical Networks

Speaker: Massimo Tornatore

Associate Professor, Politecnico di Milano, Italy

European Conference on Optical Communication

Sept 23rd, 2018, Rome, Italy

What is Machine Learning?

- *"Field of study that gives computers the ability to learn without being explicitly programmed" (A. Samuel, 1959)*
- *"… through data observation"*

- For our purposes: An set of math/statistical tools to make predictions/decisions based on monitored data

  …in the context of optical networks

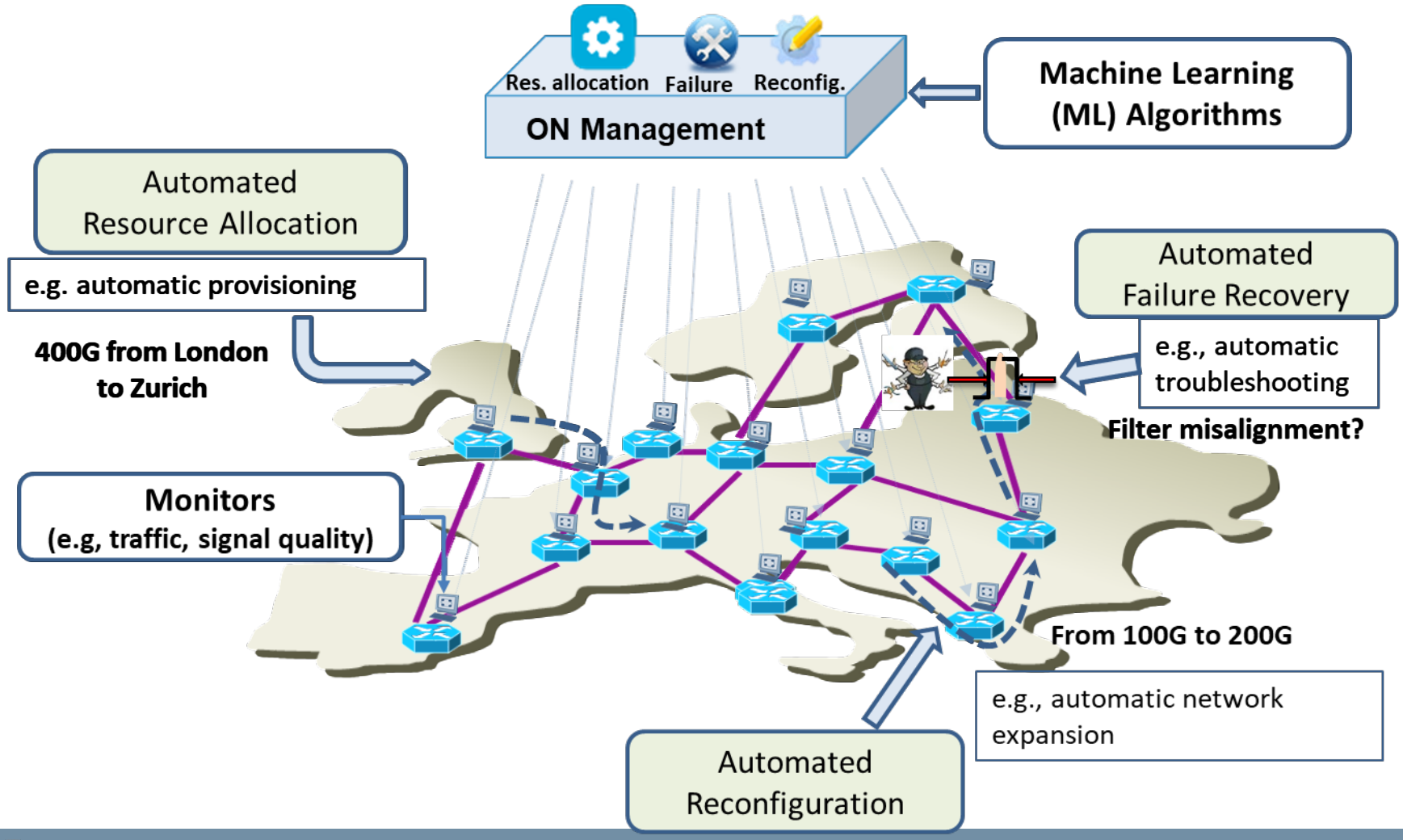
- Confusing overlap with other terms: Artificial Intelligence, Deep Learning, Data Analytics, Data Mining, etc.

Why only now in optical networks?

- Dominating complexity
  - Coherent Trasmission /Elastic Networks
    - Several system parameters: channel bandwidth, modulation formats, coding rates, symbol rates..
- Lack of skilled workforce
  - NTT warning *(OFC 2017)*: aging population, increasing competition for young STEM workforce
- 5G Transport
- New enablers @ *Mngt&Cntr* plane
  - Software Defined Networking
  - Edge computing
  - OPM's (some are for free.. as in coherent receivers..)

Automation of Optical Network Management

- Management is still largely manual/human-based!

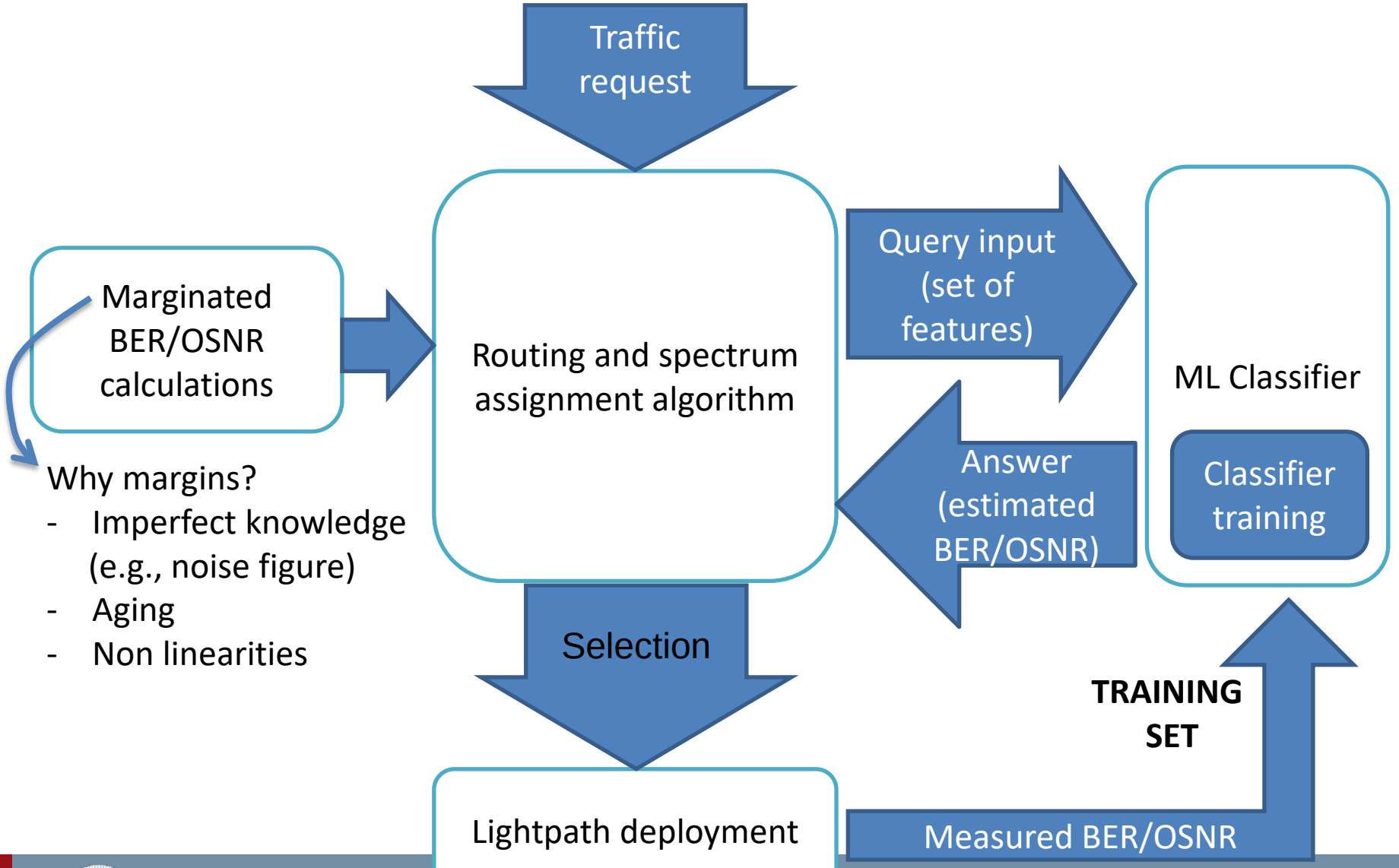


Covered topics

- QoT estimation and Routing and Spectrum Assignment
- Soft-Failure Mode Identification
- Quickly, some other applications…

I'll share my experience in developing ML-based solutions in Optical Networks

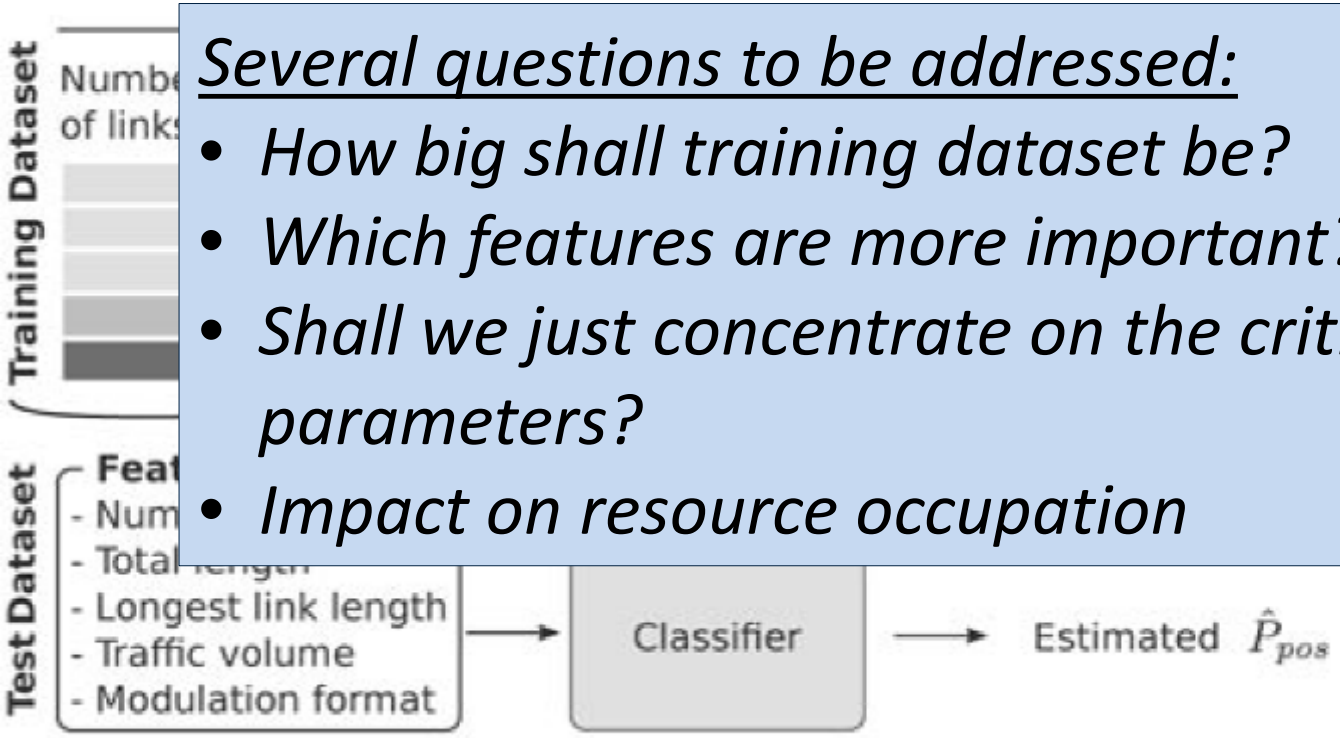
RSA interplays with QoT estimation



How does it work?

A possible implementation of ML-based QoT estimation

- Input: set of lightpath features
- Output: probabilty that BER ≤ T*



Several questions to be addressed:

- *How big shall training dataset be?*
- *Which features are more important?*
- *Shall we just concentrate on the critical parameters?*
- *Impact on resource occupation*

(Case of **local knowledge**, but we can add more features for **network knowledge**)

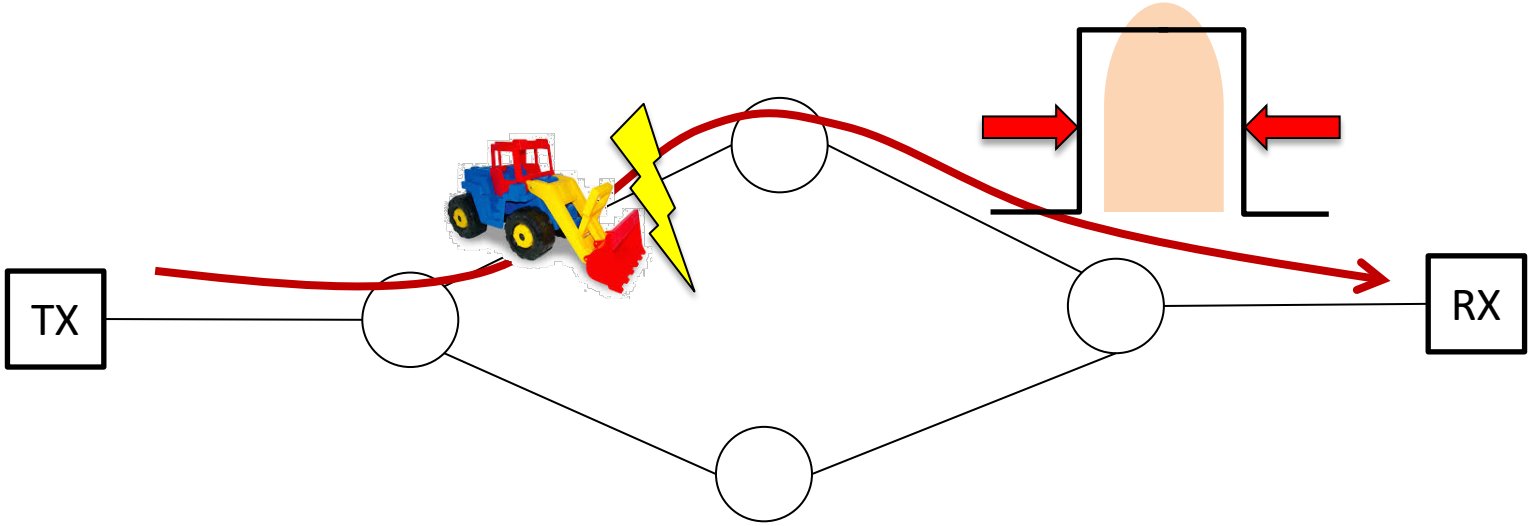
C. Rottondi, L. Barletta, A. Giusti and M. Tornatore, *A Machine Learning Method for Quality of Transmission Estimation of Unestablished Lightpaths*, JOCN2018

Covered topics

- QoT estimation and Routing and Spectrum Assignment
- Soft-Failure Mode Identification
- Quickly, some other applications…

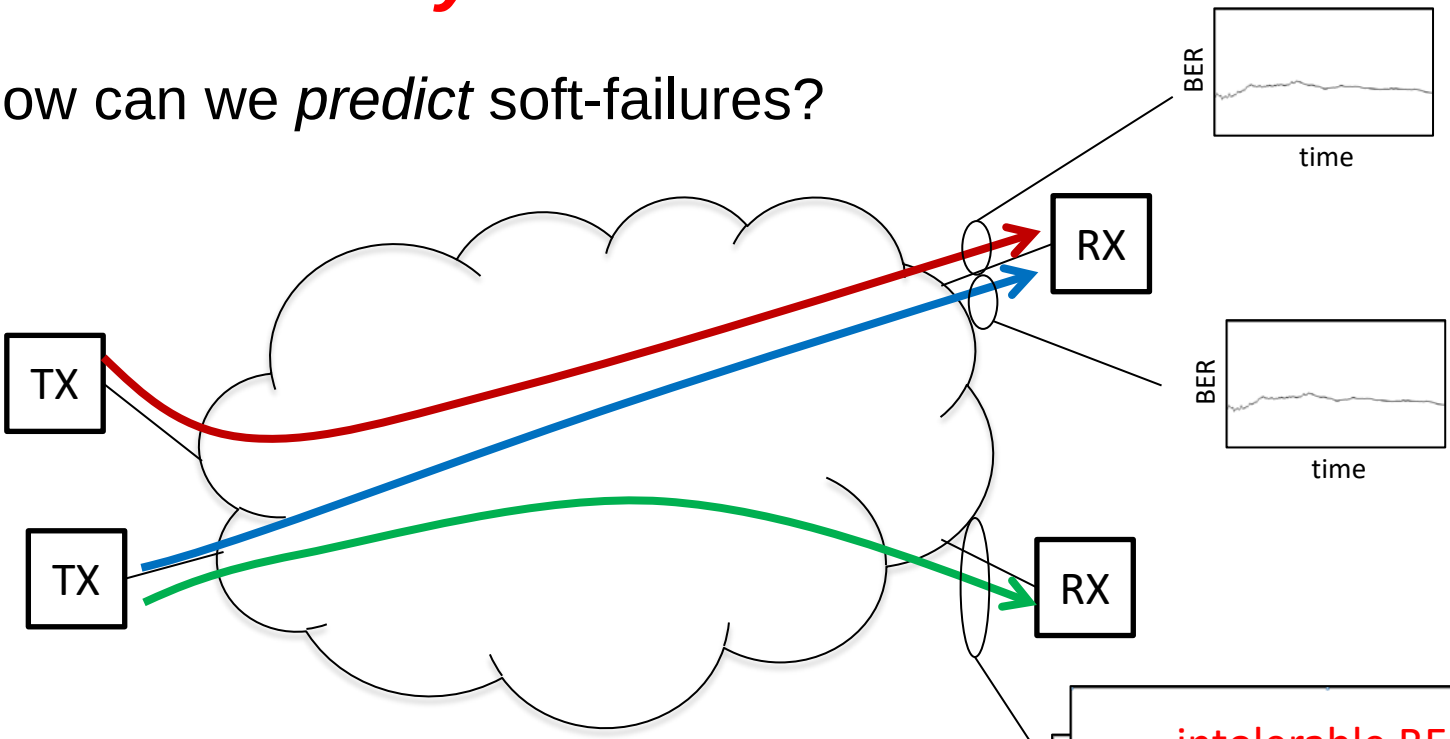
Two main failure types in optical networks

- Hard-failures
  - Sudden events, e.g., fiber cuts, power outages, etc.
  - Unpredictable, require «protection» (*reactive procedures*)
- Soft-failures:
  - Gradual transmission degradation due to equipment malfunctioning, filter shrinking/misalignment…
  - Trigger early network reconfiguration (*proactive* procedures)

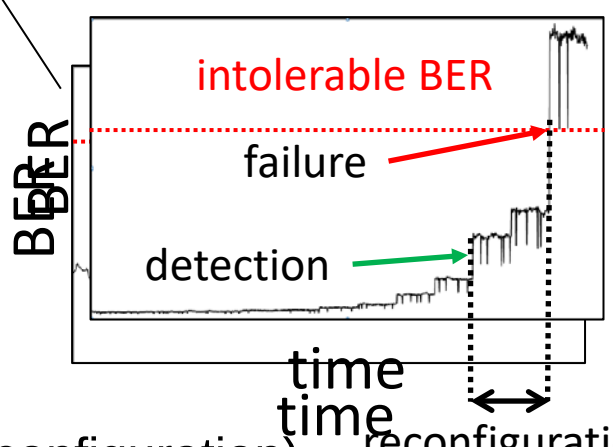


Soft-failure *early detection*

- How can we *predict* soft-failures?



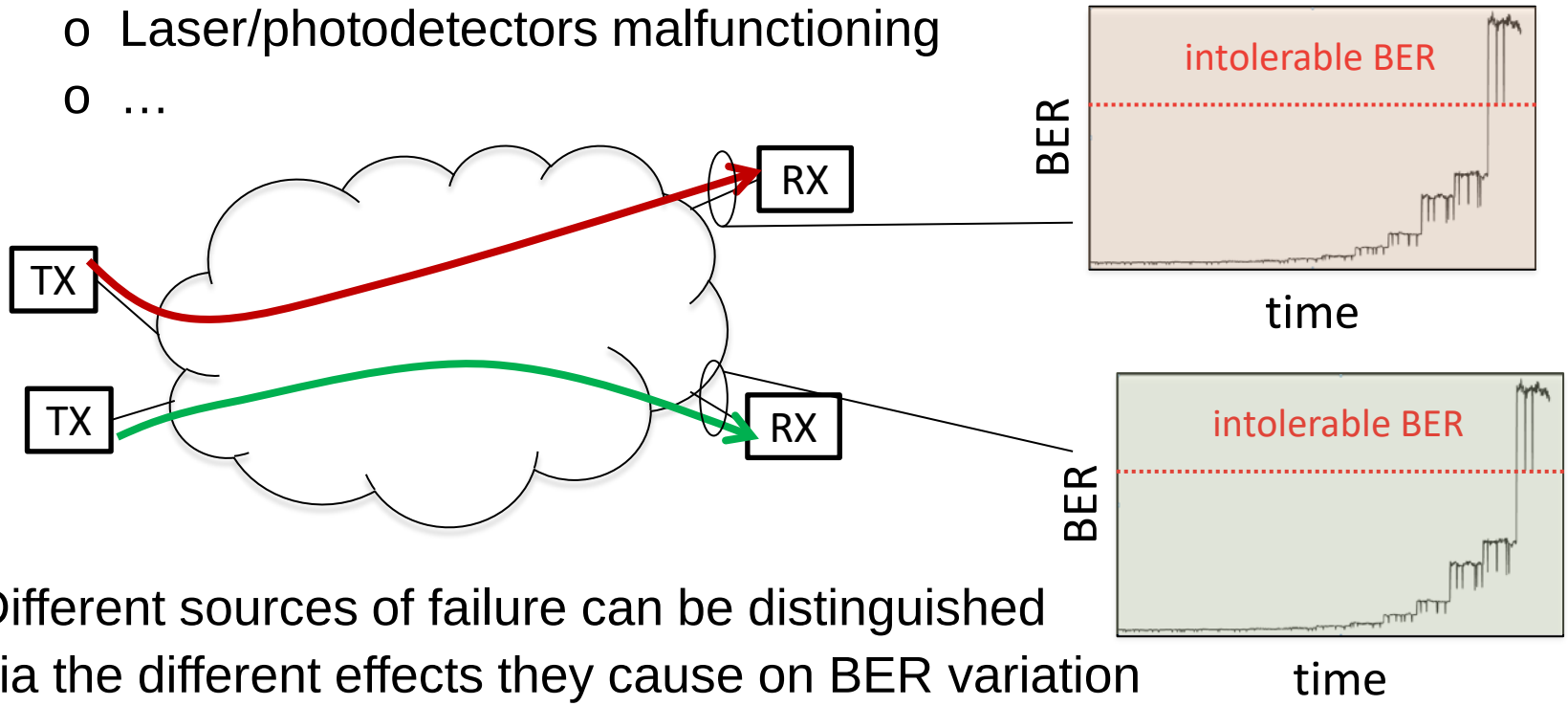
Perform continuous monitoring of
Bit Error Rate (BER) at the receiver…
… until some "anomalies" are detected



Early-detection helps **preventing** service disruption (e.g., through proactive network reconfiguration)

Soft-failure *mode identification*

- How can we identify the *mode* of the failure?
  - Failures can be caused by different sources
    - Filters shrinking/misalignment
    - Excessive attenuation (e.g., due to amplifier malfunctioning)
    - Laser/photodetectors malfunctioning
    - …



Different sources of failure can be distinguished via the different effects they cause on BER variation (i.e., via different BER “features”)

Benefits for operators

- Reduced Time To Repair (TTR)
  - Almost instantaneous troubleshooting
  - TTR from hours/days to minutes/hours?
- Reduced Service Downtime
  - Early detection eliminates a class of failure

- First demonstrations

Vela et al., “BER degradation Detection and Failure Identification in Elastic Optical Networks”, in Journal of Lightwave Technology, vol. 35, no. 21, pp. 4595-4604, Nov. 2017

S. Shahkarami, F. Musumeci, F. Cugini, M. Tornatore, “Machine-Learning-Based Soft-Failure Detection and Identification in Optical Networks,“ in Proceedings, OFC 2018, San Diego (CA), Usa, Mar. 11-15, 2018

Many open questions/challenges!

- **[QoT]** Optical network is a living network
  - Continuos training.. How?

- **[QoT]** How to build the right training set?
  - Rare occurences of false positives -> Low accuracy…
  - Selective probes?

- **[Failure]** What if completely new/unclassified failure arise?
  - «Novelty detection» ?

Overview of other applications

- Physical layer
  1. Optical amplifier control
  2. Modulation format recognition
  3. Nonlinearities mitigation

- Network layer
  1. Traffic prediction and virtual topology design
  2. Flow classification

Classification taken from: F. Musumeci et al., "A Survey on Application of Machine Learning Techniques in Optical Networks", Submitted to IEEE Communication Surveys and Tutorial, available online (Arxiv)

Thanks for your attention!

massimo.tornatore@polimi.it

H2020 Metro Haul

European Commission | Horizon 2020 European Union funding for Research & Innovation