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Machine Learning Methods for Communication Networks and Systems – 051911

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Part II – 1: Use cases

Overview of use cases*

- Physical layer domain
  1. Quality of Transmission (QoT) estimation
  2. Optical performance monitoring (OPM)
  3. Optical power control
  4. Modulation format recognition
  5. Nonlinearities mitigation
- Network layer domain
  1. Traffic prediction
  2. Failure management
  3. Flow classification

*F. Musumeci, C. Rottondi, A. Nag, I. Macaluso, D. Zibar, M. Ruffini, M. Tornatore, “An Overview on Application of Machine Learning Techniques in Optical Networks”, in *IEEE Communications Surveys & Tutorials (COMST)*, vol. 21, n. 2, pp. 1383-1408, Secondquarter 2019

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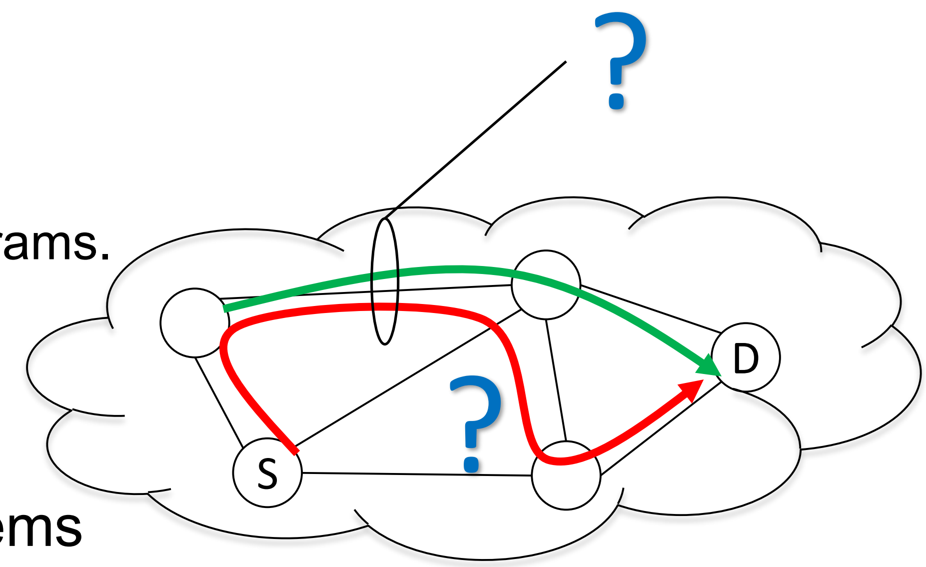
Physical layer domain
QoT estimation

- **Before** a new lightpath (S→D) is established we should check:
  - if it will meet the desired QoT
    - Low-enough BER? High-enough OSNR?
  - if it will affect the living lightpaths (ongoing traffic requests)
    - Will these connections still meet **their** QoT?

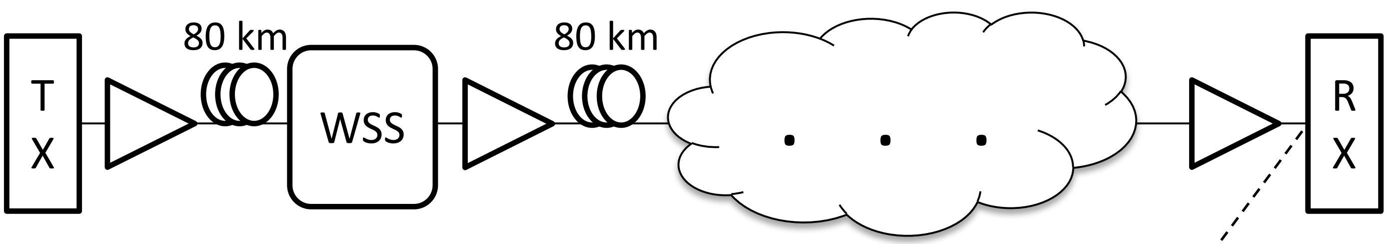
- To answer these questions:
  - Estimate analytically
    - Typically time consuming
    - Involves huge amount of params.
  - Design with margin
    - Approximate models
    - Resources underutilization
  - ML overcomes these problems



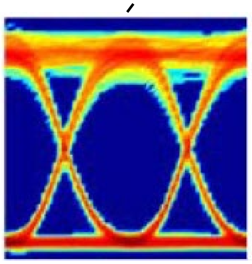
Physical layer domain

Optical performance monitoring

- **During** signal transmission, quality at the receiver (or even in intermediate spans) is constantly monitored to assess transmission performance
- The behaviour of several parameters is evaluated
  - OSNR, Polarization Mode Dispersion (PMD), Cromatic Dispersion (CD)
  - After a degradation in any of them, different actions can be triggered

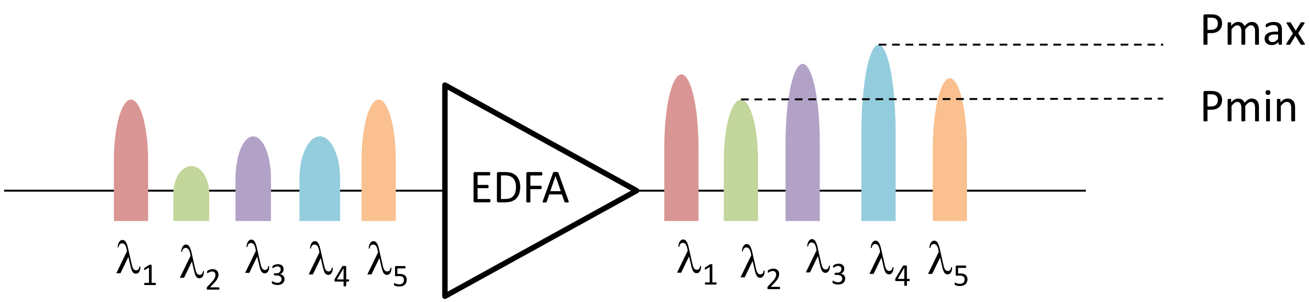


- Traditional approaches:
  - involve several monitoring equipment
  - electrical post-processing is often needed
- ML:
  - enables real-time processing of monitored data
  - creates direct relationship between parameters and monitored data (e.g., eye diagram)



Physical layer domain
Optical power control

- When adding/dropping channels into/from a WDM system, EDFA (Erbium Doped Fiber Amplifiers) gain should be adjusted to have a good balance between channels output power
- This effect is more critical in multiple-span systems

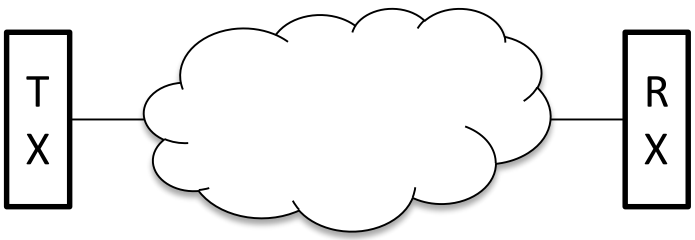


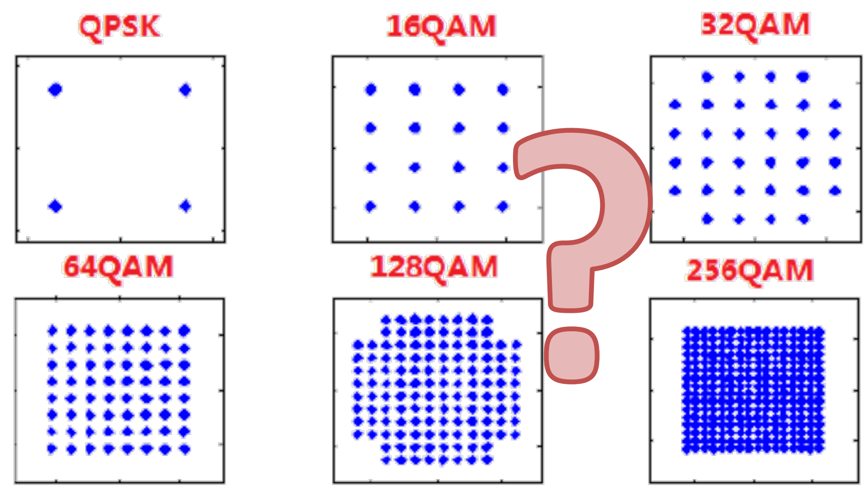
- Analytical models:
  - depend on the specific system (gain-control mechanism, EDFA gain tilt, nr of EDFAs…) and to its variations during lifetime
- ML allows to self-learn together all the parameters of any given system and adapt EDFA's features accordingly

Physical layer domain

Modulation format recognition

- Current optical transmitters/receivers are able to operate at different MFs simultaneously
- Automatic MFR
  - Allows MF-dependent digital signal processing and OPM
  - Enables adaptive and dynamically changing MF Tx/Rx

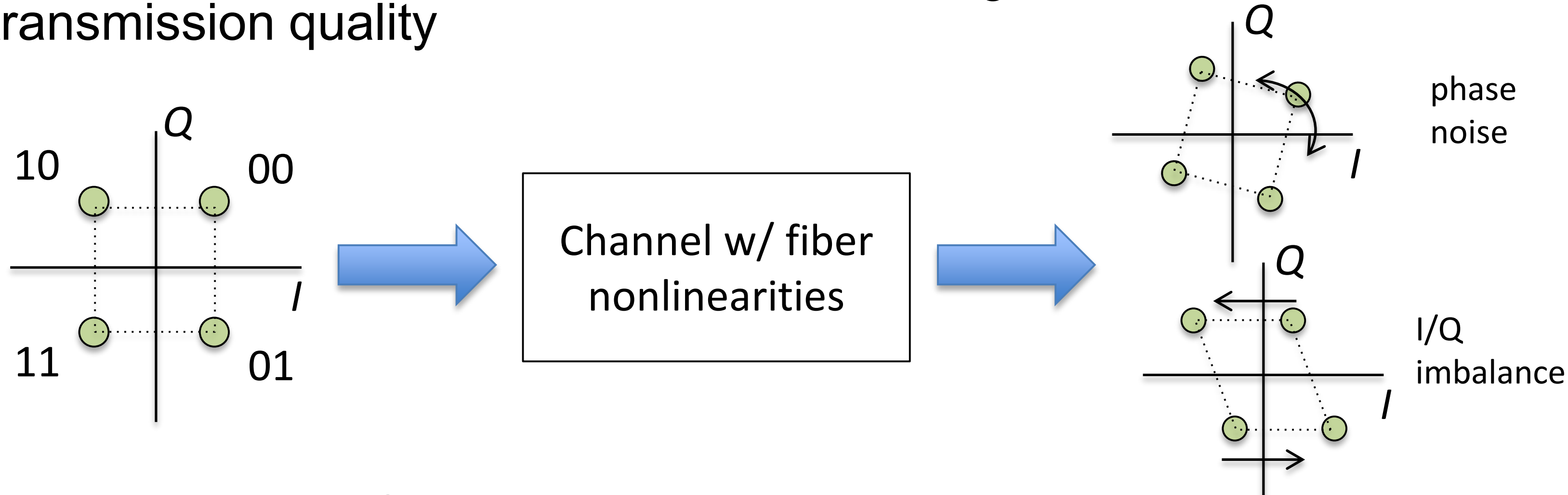




- Traditional MFR requires prior information exchange between end points
  - additional delay for signal detection
- ML enables recognizing MF directly from features of the received signal

Physical layer domain
Nonlinearities mitigation

- Traversing an optical fiber system, optical signal detection can be affected by fiber nonlinearities
  - Kerr effect, self-phase modulation (SPM), cross-phase modulation (XPM)…
  - This limits the transmission distance and degrades BER and transmission quality



- Traditional methods for nonlinearities mitigation require complex mathematical models and prior information on the traversed channel
- ML enables “safer” decision by learning from actual channel properties and allows increased transmission distance

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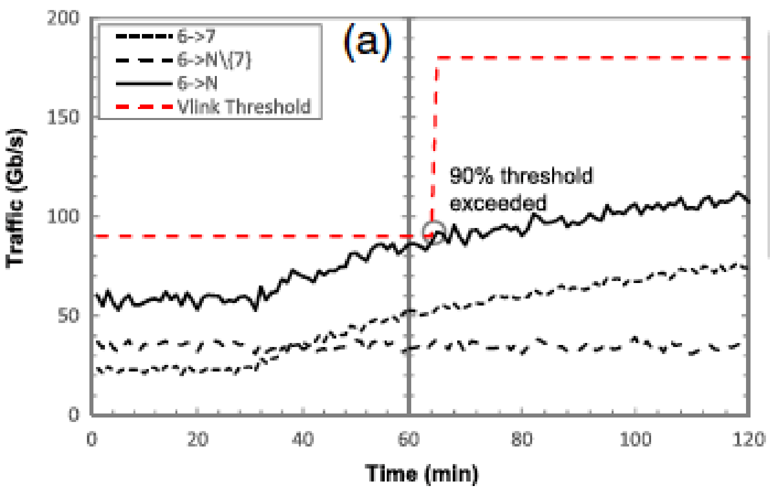
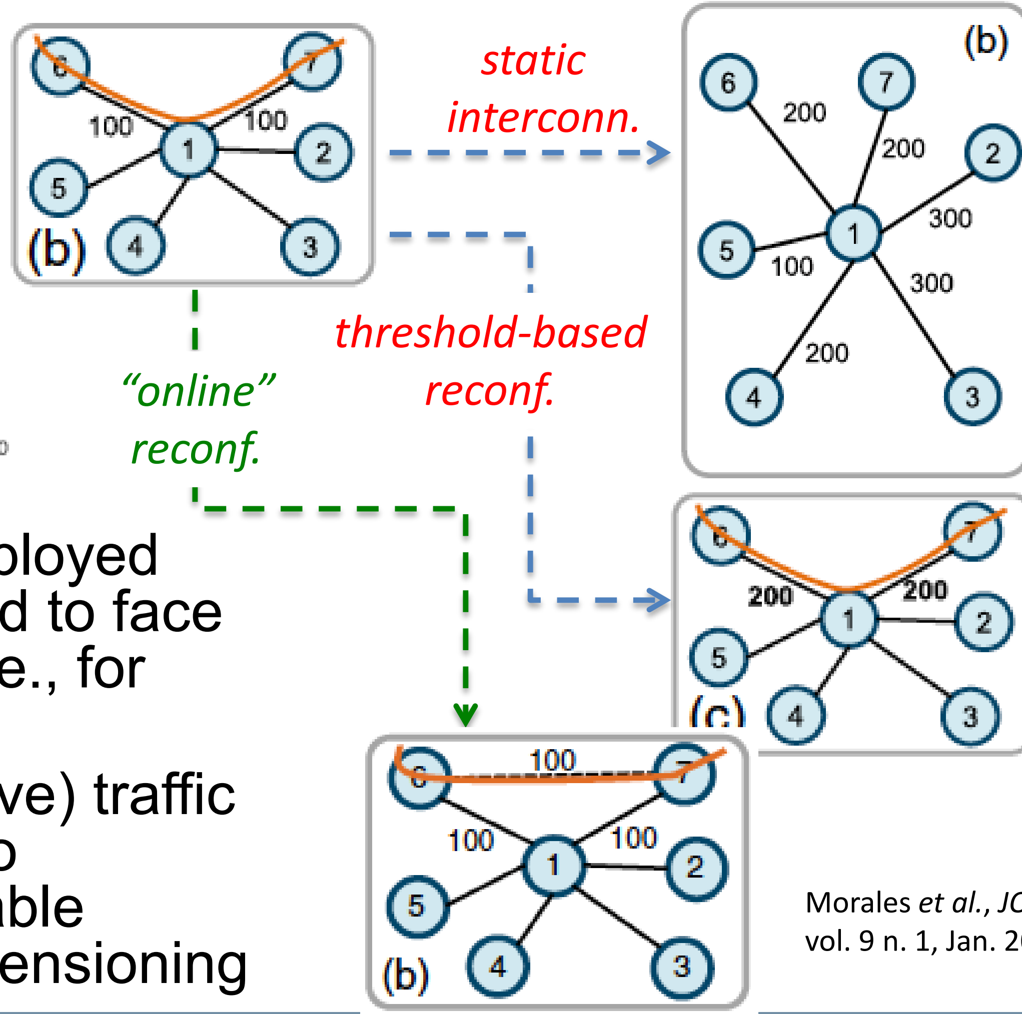
Network layer domain

Traffic prediction

- New network services are featured by high traffic dynamics (variability)



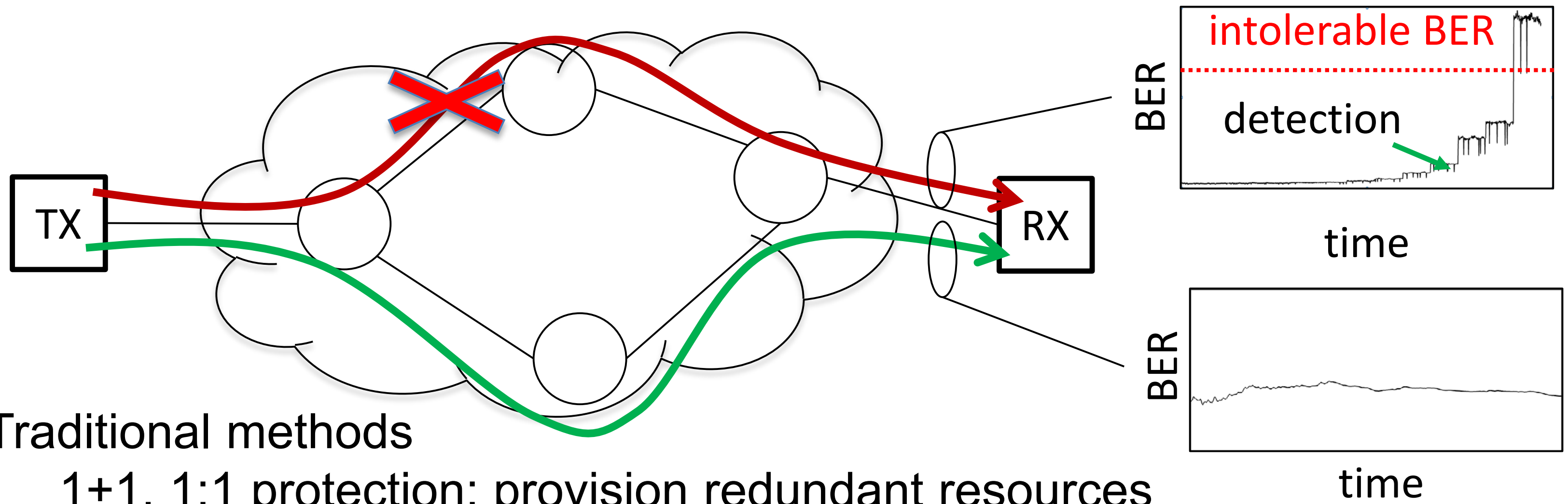


- No reconfiguration: deployed capacity is dimensioned to face worst-case scenario (i.e., for peak-traffic)
- ML leverages *online* (live) traffic monitoring/prediction to efficiently exploit available resources w/o overdimensioning

Morales *et al.*, *JOCN*, vol. 9 n. 1, Jan. 2017

Network layer domain
Failure management

- Early-detection of soft-failures (*gradual* degradation of received signal quality) prevents service disruption
- Quick fault localization is needed for fast equipment repair



- Traditional methods
  - 1+1, 1:1 protection: provision redundant resources
  - Alarm-based recovery: failure is repaired *after* occurrence
- ML
  - creates *direct* relations between observed data and failure occurrence
  - helps reducing overprovisioning
  - enables fast decision-making and fault localization to prevent service disruption and quick fault recovery

Network layer domain

Traffic classification

- Communication networks usually serve heterogeneous traffic flows in terms of:
  - protocols (http, ftp, smtp…)
  - services (fixed vs mobile, VoD, data transfer, text messages…)
  - requirements (latency, bandwidth, jitter…)
  - network “customers” (human end-users, companies, sensors, machines, servers…)
    - E.g., “mice” vs “elephant” flows in Data Centers
- Distinguish between different flows is crucial for resources (i.e., capacity) allocation, scheduling, security/privacy, QoS…
- Traditional classification uses partial information (source/dest IP address, protocol, port number etc.)
  - often unavailable (e.g., due to tunneling or cryptography)
  - sometimes insufficient (e.g., same protocols can carry flows with highly different characteristics)
  - maybe misleading: different protocols can carry flows with similar characteristics
- ML
  - enables traffic features extraction from direct observation of traffic flows
  - allows simultaneous use of heterogeneous features