
NETWORKING BENEFIT OF MULTI-SUBCARRIER TRANSCEIVERS

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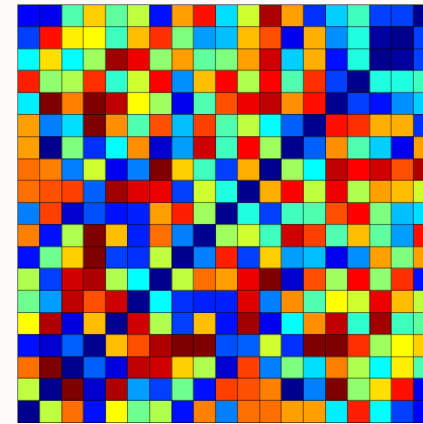
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STATE-OF-THE-ART

- Transponders operating **polarization-division-multiplexed** multilevel modulation formats
- **DSP-based coherent Rx** including equalization
- **No** in-line dispersion compensation
- Any-to-any optical transmission enabled by **transparent wavelength routing**
- LP transmission is limited by **ASE noise and NLI**
- **Generalized SNR** is the LP performance meter

- The transparent connectivity matrix is **full and elastic**, and each LP SNR depends on network use

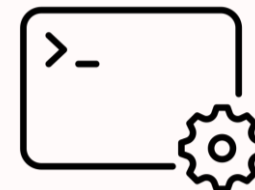


- **Physical-layer-aware networking is mandatory to optimize performances**



Vendor-agnostic Networking

- **Selecting** network **elements** from vendors' portfolios to **optimize optical performance**
- Multi-vendor and open-line systems

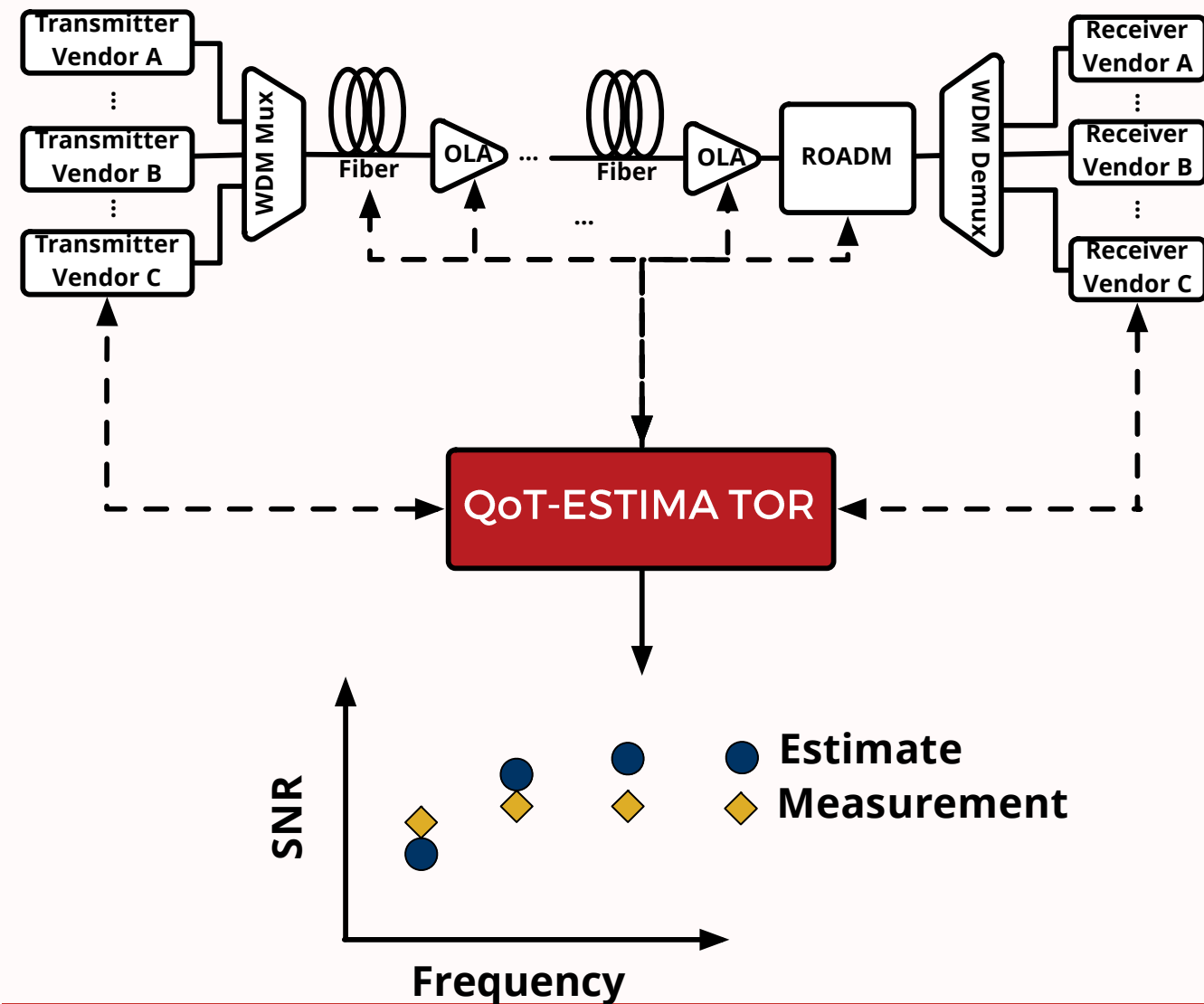


Network Management & Orchestration

- Get **optical feasibility evaluation right**
- **Select** hardware **working points to optimize capacity, flexibility and resiliency** of the network infrastructure

VENDOR&TRAFFIC AGNOSTIC QOT ESTIMATOR NEEDED!

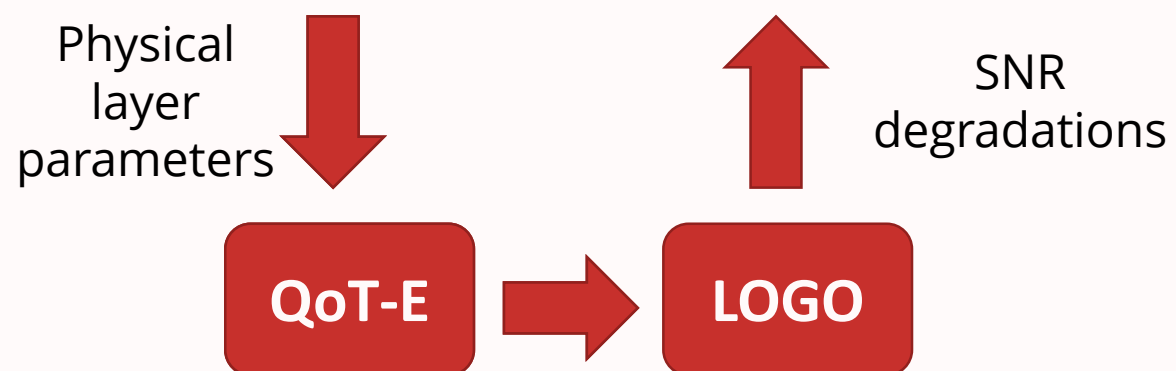
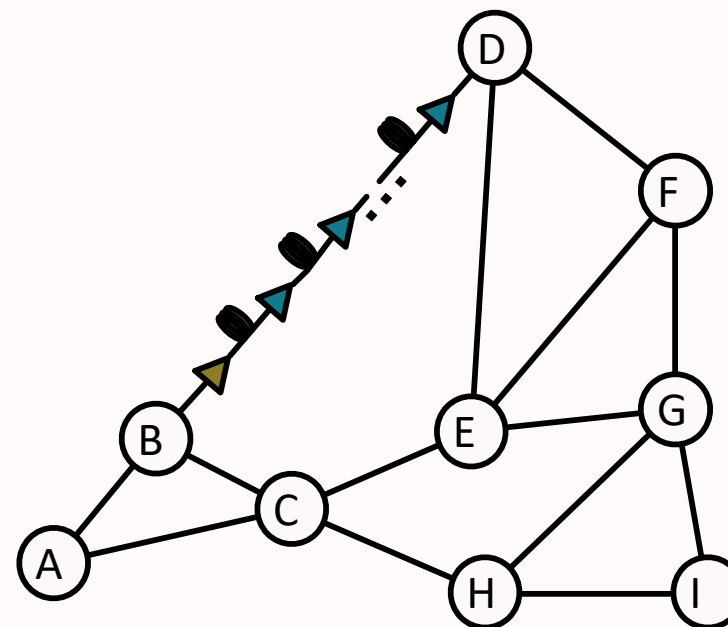
QOT-E: REQUIREMENTS



- **QoT-E: quick estimation of SNR degradation** for each network element
- For designing and planning, **SNR degradation** must be
 - **Local:** independent for each element
 - **Vendor&Traffic-agnostic**
- **Losses, gains and ASE noise:** challenge is getting the exact working-point of equipment
- **NLI generated by fibers:** approximated by **GN-model** delivering accurate yet **conservative QoT-E**
- Within TIP, a GN-model based **QoT-E** has been tested on commercial equipment^{1,2,3}

PHYSICAL LAYER CONTROLLER: LOGO

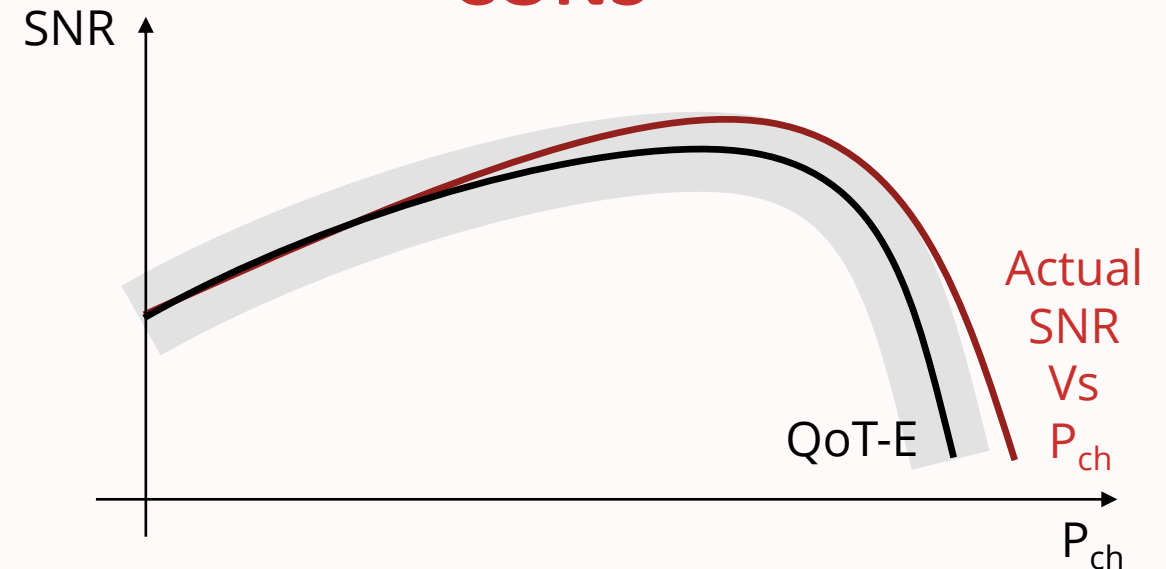
- The GN-model based **QoT-E enables** to evaluating the **optimal power** at every span supposing full channel load (worst-case)
- **LOGO¹**: locally-optimized globally-optimized
- Assuming LOGO, a network topology becomes a **graph weighted by SNR degradation** over arcs



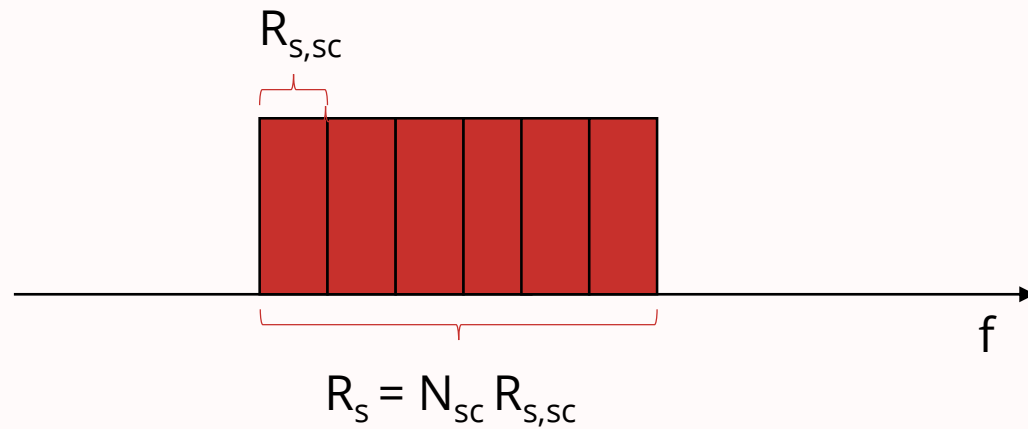
PROS

- It relies on a QoT-E that is **local** and **traffic&vendor agnostic**
- It is **adequate for physical-layer controlling** that cannot vary with traffic load
- Enables **off-line** network assessments
- Enables on-line **software-defined network** management
 - LP deployment
 - LP restoration

CONS



- In case **working point of amplifiers** is not completely under control, the induced **inaccuracy is dominant**¹
- In case all network elements defining ASE noise are under control the GN-model-based QoT-E is **conservative**
 - Full spectral load is not inducing large underestimation²
 - In general standard multilevel modulation formats underestimation is limited³



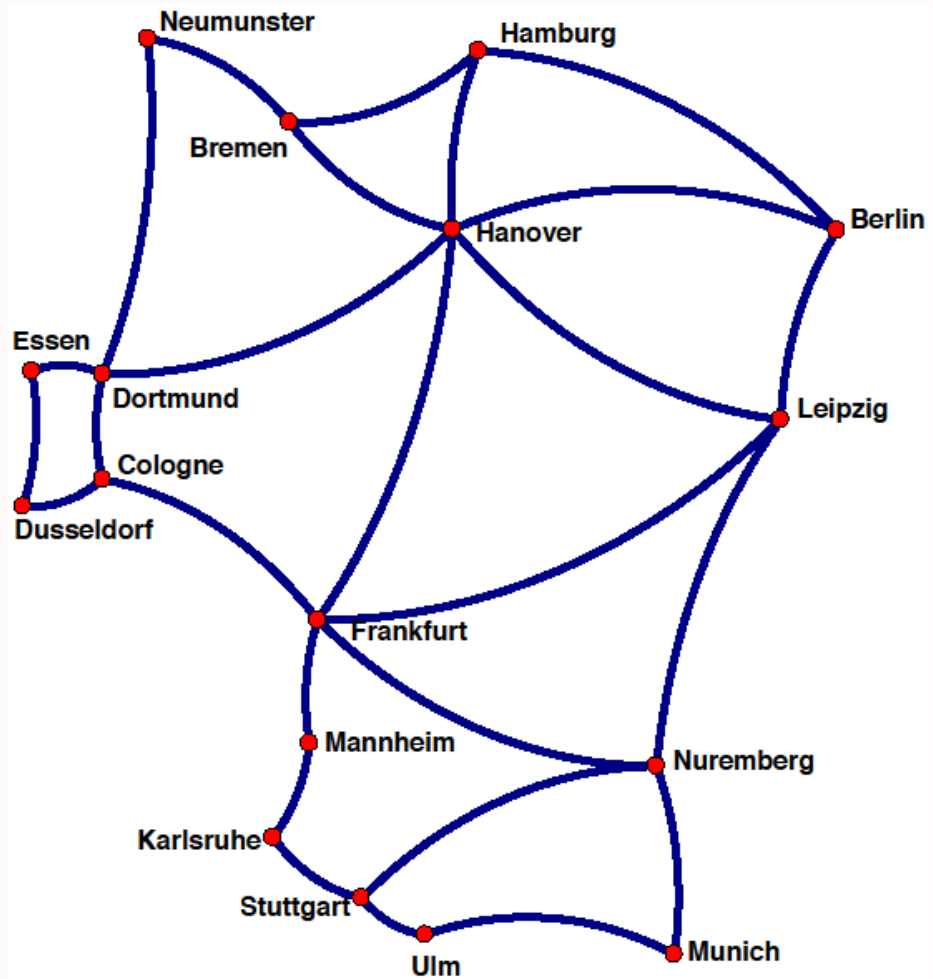
- Delivering the **overall rate** as the sum of many subcarriers
- Assuming several SCs, a **fine tuning** adapted to the available QoT can be done deploying different constellations on different SC: **FDHMF**

- **Optimal $R_{s,sc}$** depending on the route over network and on traffic
- Supposing **absence of uncertainty** on OAs, the **advantage** with respect to the GN-model-based QoT-E prediction can be of **up to 1.5 dB**
- **Line system:** We have to keep LOGO, because it is non feasible to adapting the controller to traffic
- So, what is the **network advantage** of SC transceivers?

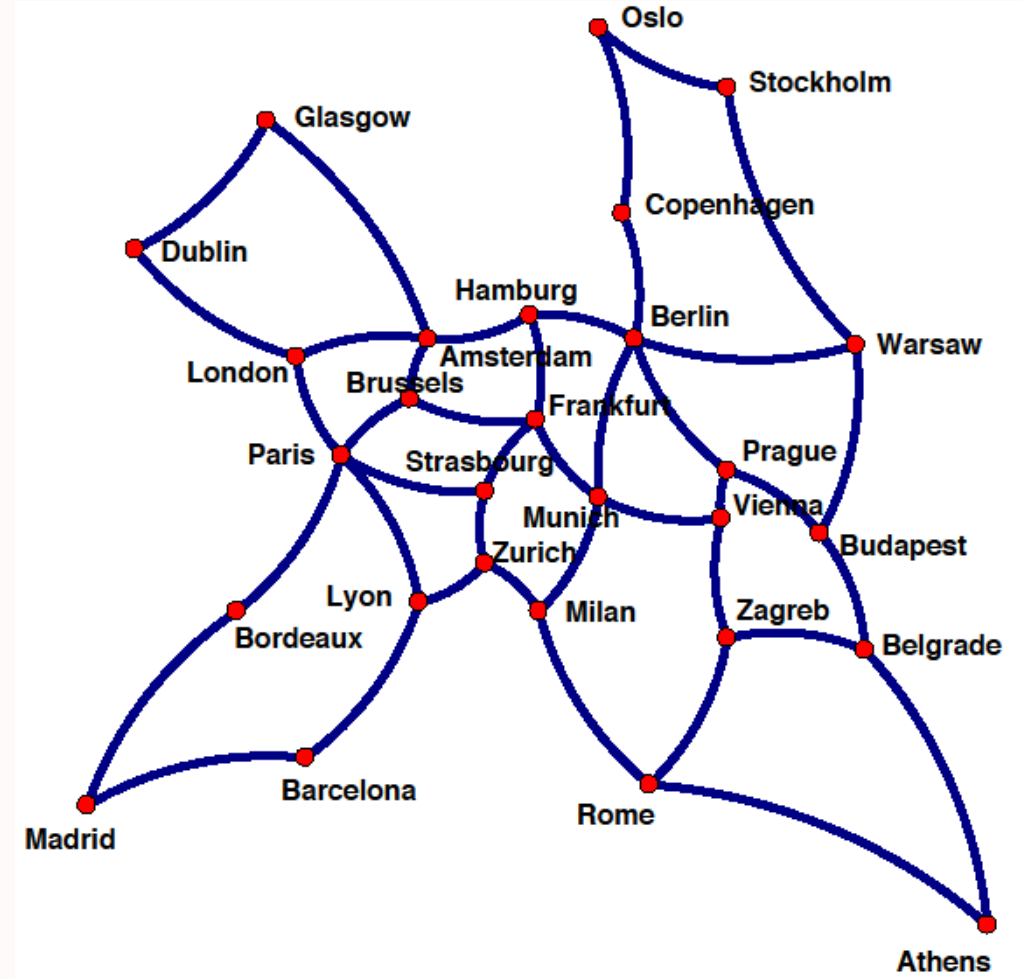
- Two **back-bone** network topologies
- Suppose **SSMF and 100 km** of fiber spans
- **LOGO** to define power levels
- **OAs with NF of 5 dB** and gain exactly recovering spans' losses: no uncertainties
- **Routing space** set by the shortest-path up to **kmax = 10**
- Off-line assessments of **SNR statistics of routes** supposing uniform full spectral load
 - Estimated using the **GN-model**
 - Calculated using the **EGN-model** that is able to evaluate the SRO

- WDM fixed-grid of **50 GHz**
- $R_s = 32$ **Gbaud**
- $N_{sc} = 1$ to **16**
- **SRO** on the two topologies on the **average SNR** of the **routing space**
- Quantitative evaluation of **advantages of SC** transceivers in terms of **average SNR on LP**

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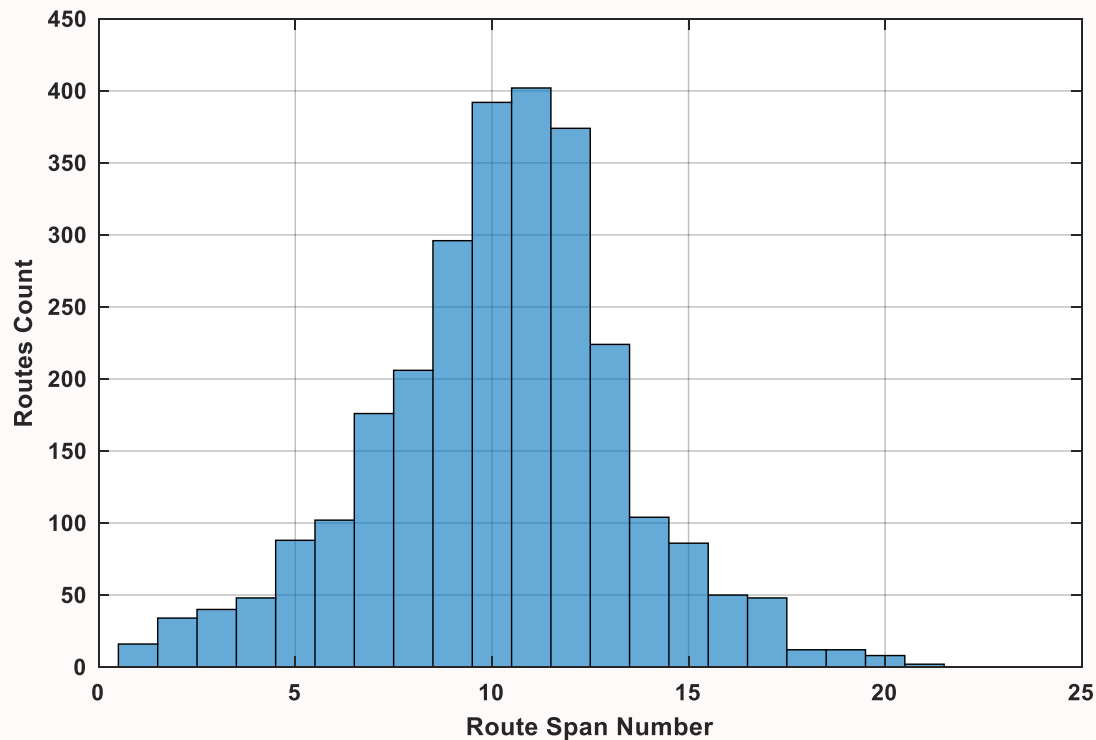


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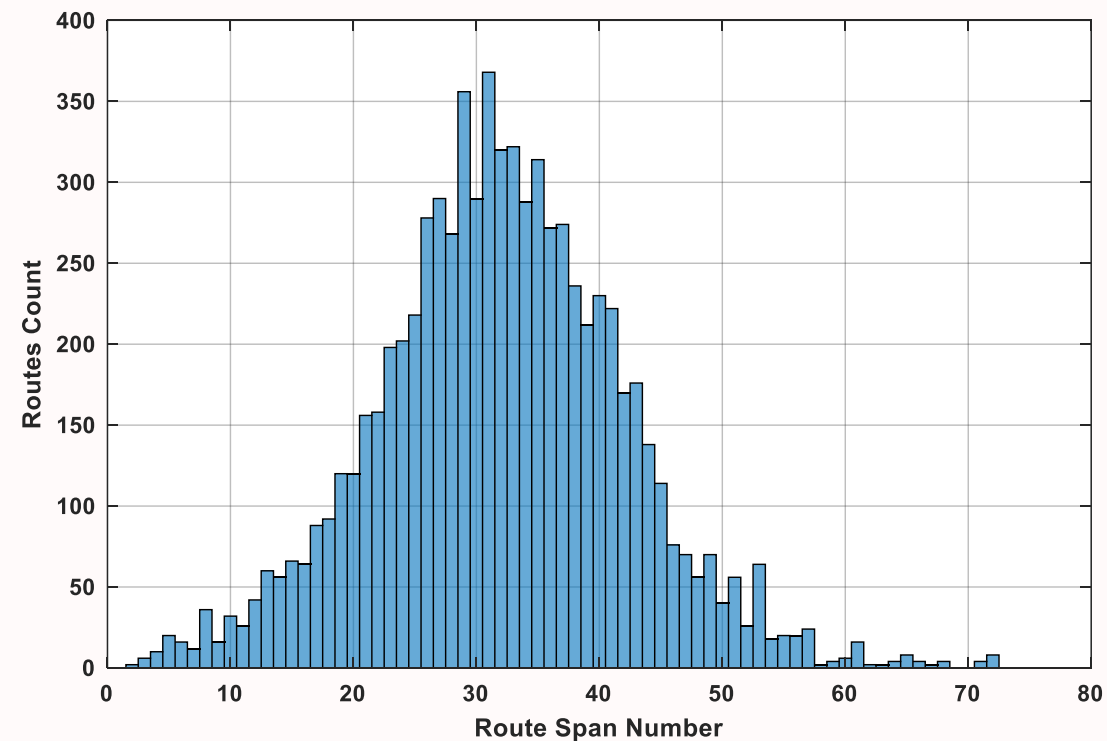


ROUTING SPACE: LP LENGTHS AS NUMBER OF OAs

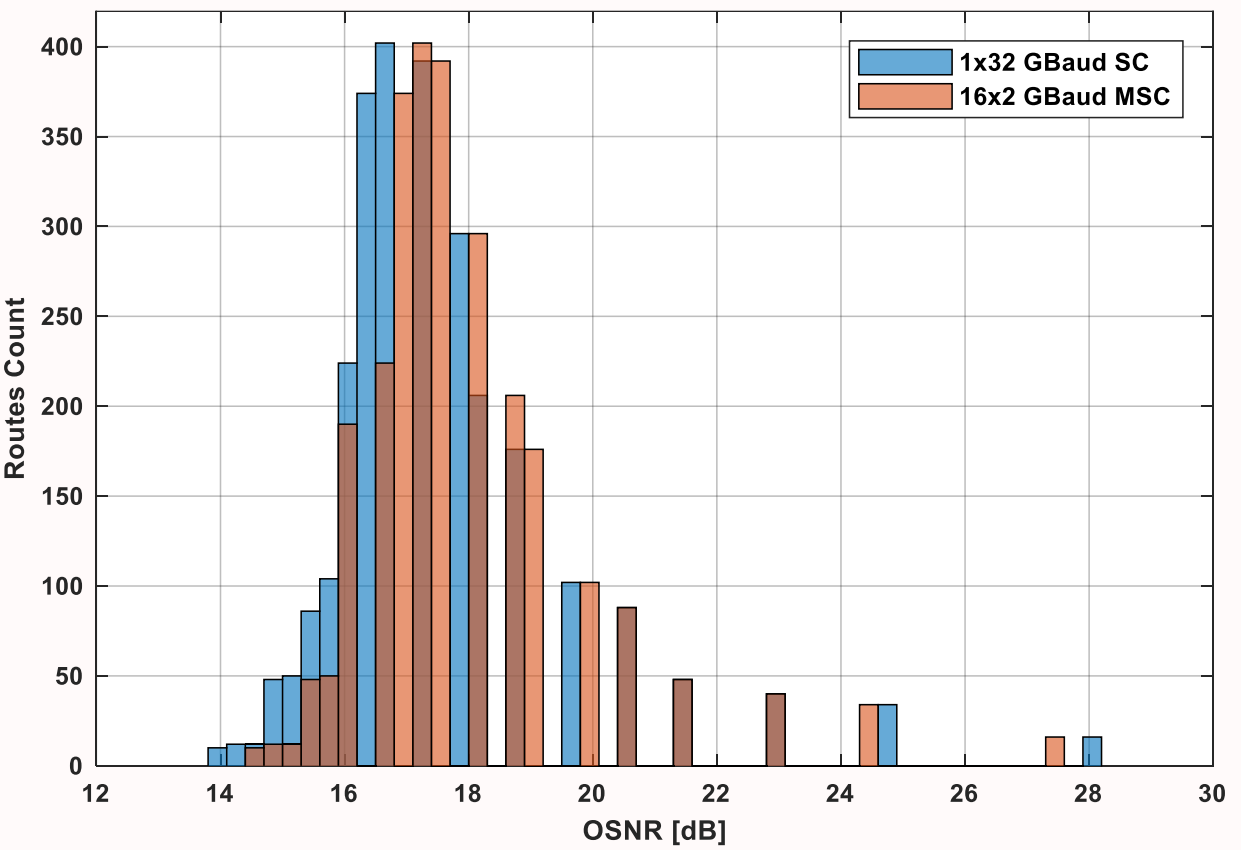
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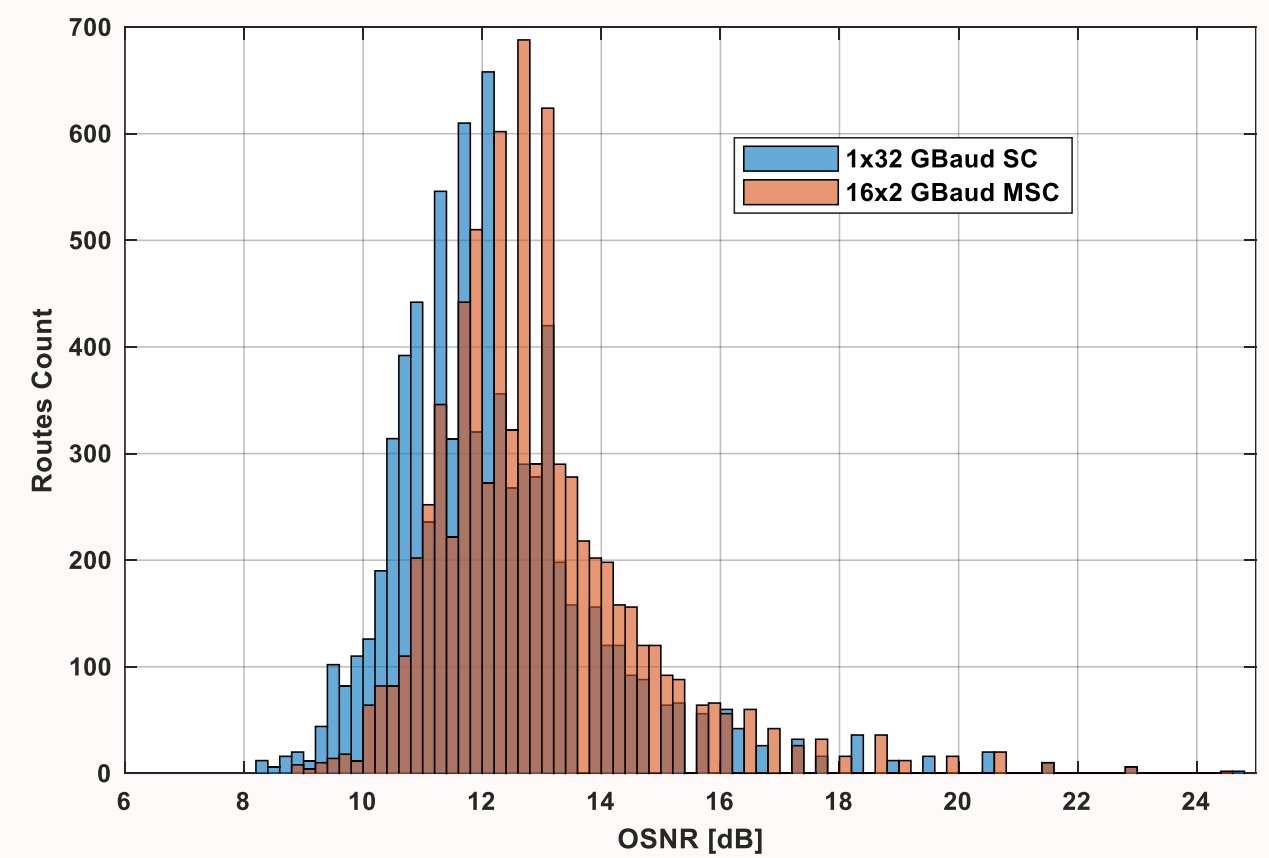
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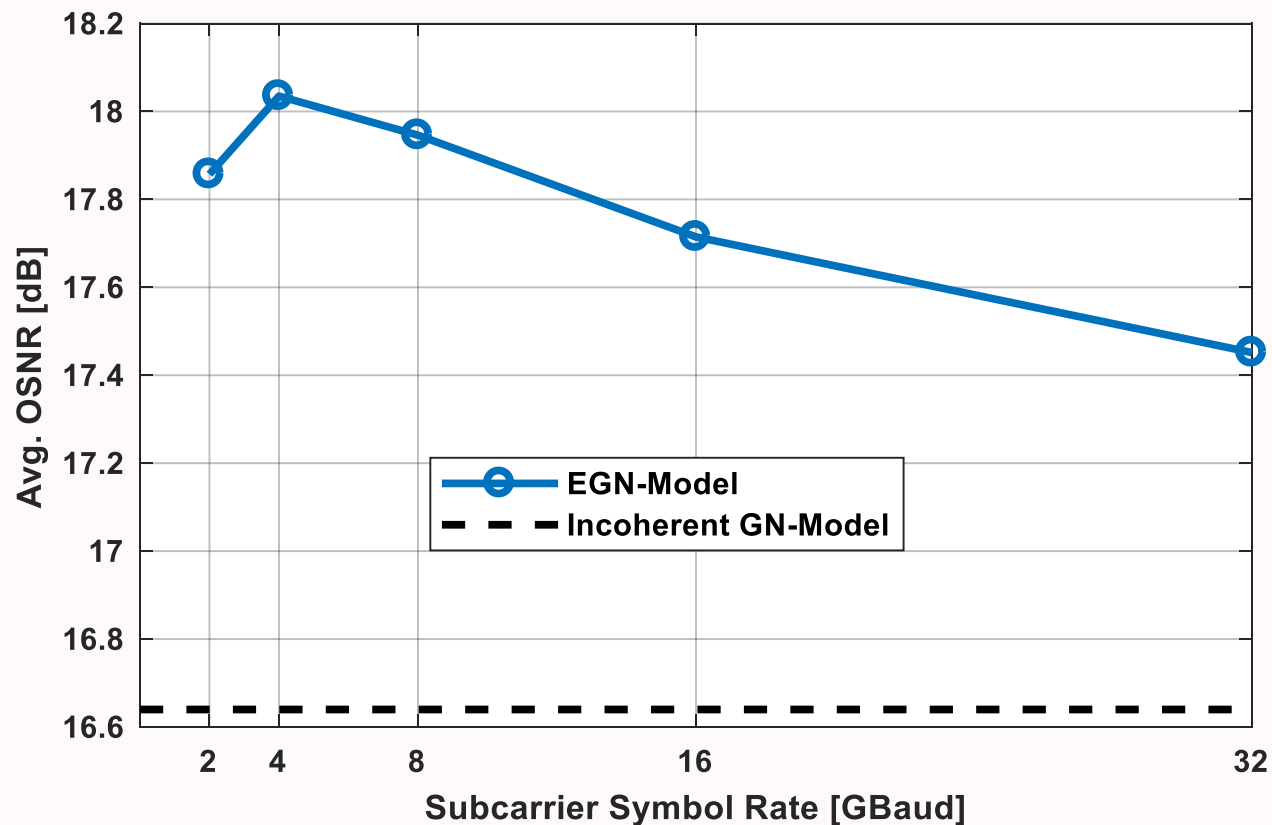
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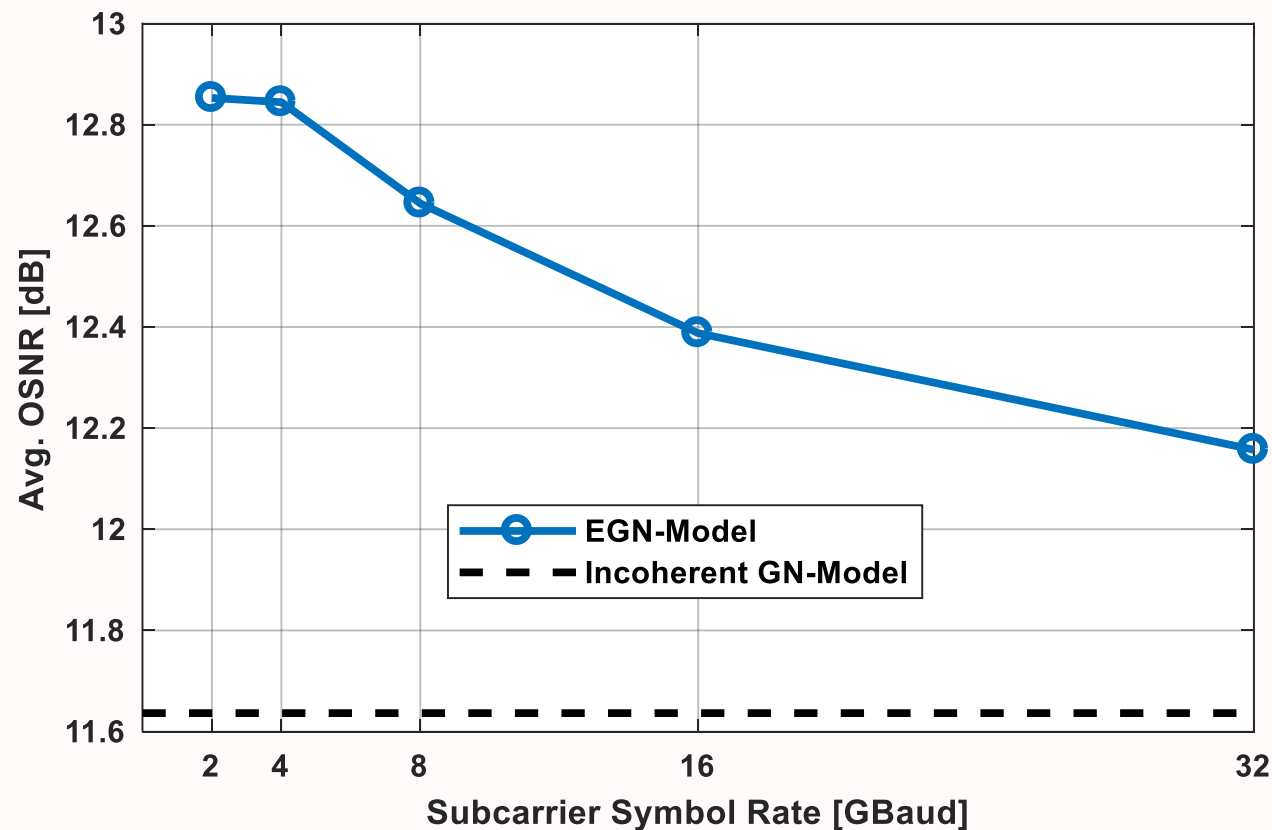
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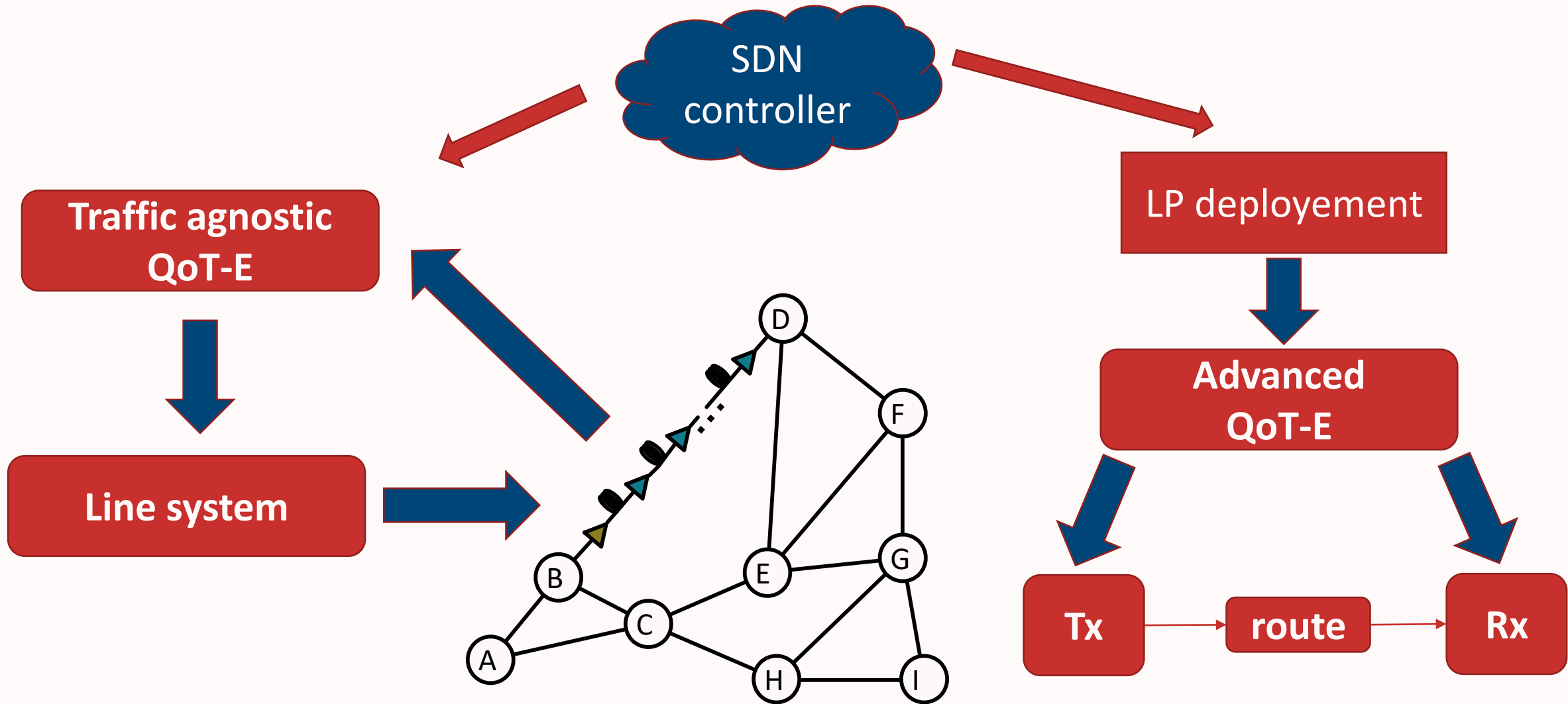
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HOW TO EXPLOIT THIS EXTRA MARGIN?



- For **planning and designing: vendor&traffic agnostic QoT-E** based on local modeling of network elements: for NLI evaluation GN-model or GGN-model for wideband
- Need for **accurate knowledge of linear propagation**, otherwise large reliability range on SNR predictions
- For LP deployment some extra **margin can be available**, depending on route, traffic and transmission technique
- How to use the **extra margin?**
 - A **longer route** can be exploited, if available
 - A **larger bit rate** can be deployed in case **the transponder is indeed flexible**¹
 - For SC transponder, flexibility could be available on each SC
- In general, **flexible-rate transponders are needed** take all the advantages of the physical layer
- Presentation will be available at **www.optcom.polito.it/talks**