



PON Protection Architectures Achieving Total Cost Reduction

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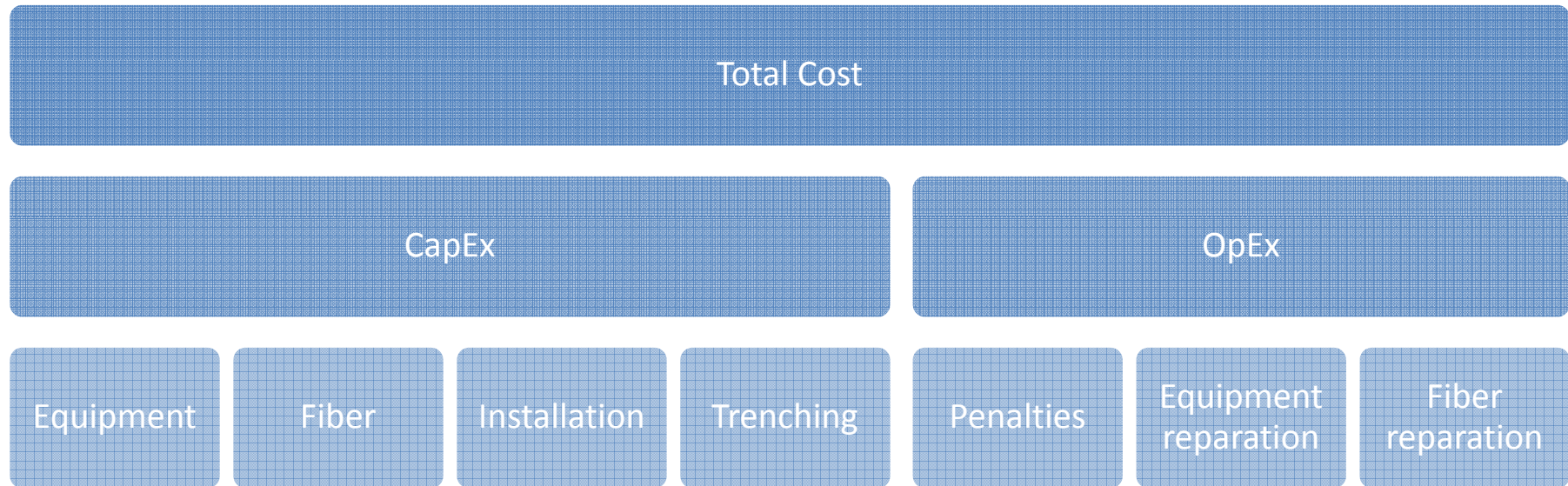
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- Introduction
- Evaluated costs
- Protection schemes and comparative study
- Conclusions

- Fiber to the home (FTTH) is the future-proof technology for broadband access networks.
 - Currently double digit growth in USA, Europe and some Asian countries
- PON is considered as the most promising solution due to the relatively low deployment cost and high resource efficiency.
- The growing demand for reliable service delivery, force operators to offer high connection availability
- However, protection of access networks is known to be very costly

This work aims at evaluating the cost of protecting access networks in terms of equipment, infrastructure, failure reparation and penalties to be paid for connection interruption.

- Comparison of different protection schemes
- Comparison of different protection reach



- Capital Expenditures:

- Component cost $\sum_i c_i \cdot n_i$

- Infrastructure cost $c_{fiber} \cdot l_{fiber} + c_d \cdot l_d + c_b \cdot l_b$

- Installation cost $\sum_i \left(IT_i + 2 \frac{d_i}{v} \right) \cdot TS \cdot NTI_i$

c_i : cost of component i

n_i : No. of components of type i

c_{fiber} : cost of 1 km of fiber

c_d : cost of 1km of duct

c_b : cost of 1km of blowing fiber

$l_{fiber,d}$: length of fiber/duct

l_b : length of blowing fiber

IT_i : installation time of component i

d_i : distance from CO to component i

v : travelling speed

TS : technician salary

NTI_i : Number of required technicians to install component i

- Operational expenditures: Given a network operational time T , and the failure rate of components and infrastructure, the expected failures f are calculated. Based on these failures, two costs can be computed:

- Failure reparation cost $TS \sum \left(MTTR_f + 2 \frac{d_f}{v} \right) NTR_f$
- Penalty cost $P \cdot \sum_f \left(MTTR_f + \frac{d_f}{v} \right) \cdot IC_f \cdot BUP$

TS : technician salary

$MTTR_f$: mean time to repair failure f

d_f : distance from CO to failure f

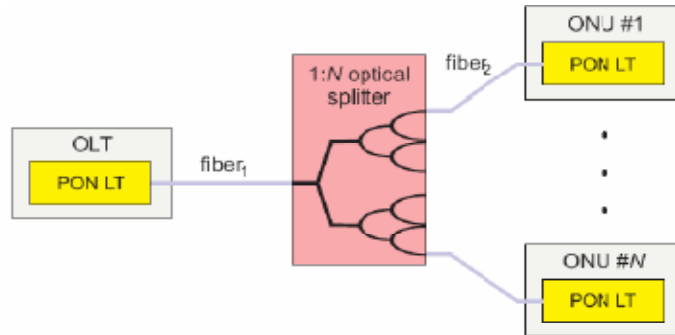
NTR_f : Number of required technicians to repair failure f

v : travelling speed

P : penalty for an hour of interrupted connection

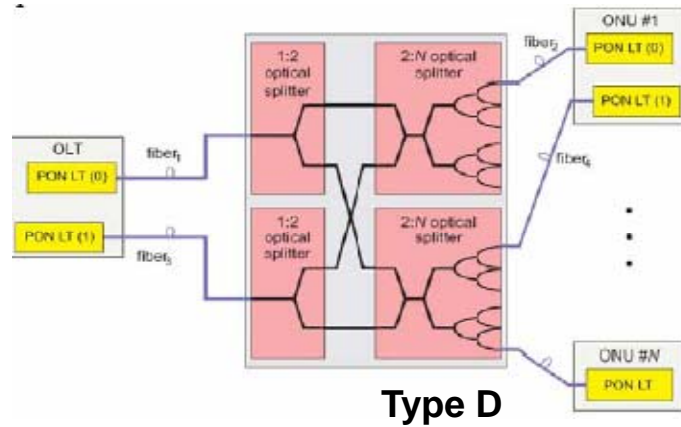
IC_f : interrupted connections associated to failure f

BUP : Business Users Percentage



Basic architecture

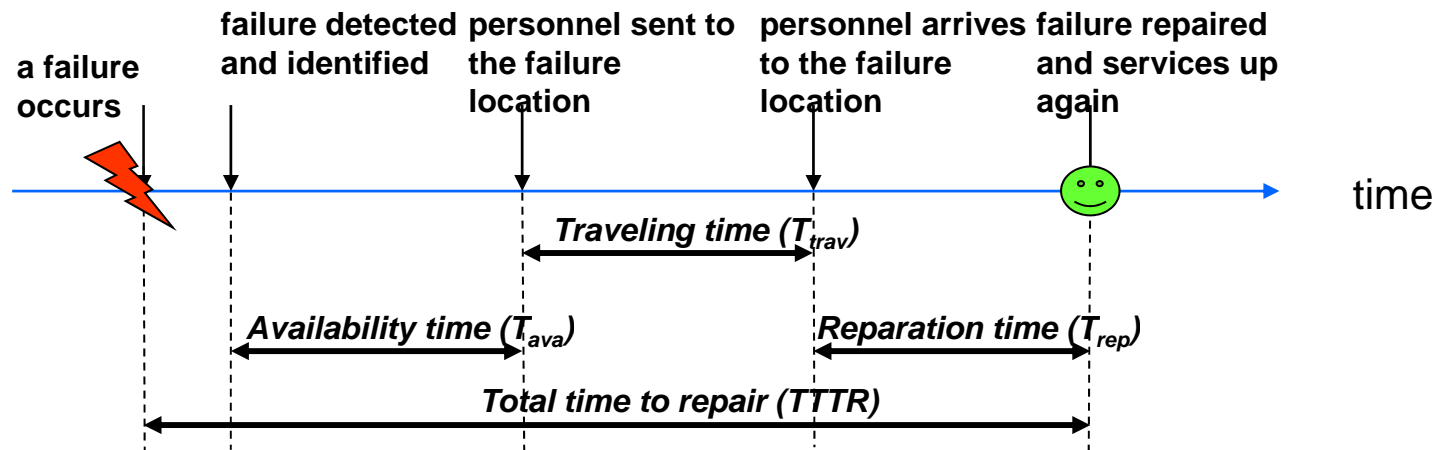
Broadband optical access systems based on passive optical network (PON), ITU-T recommendation G983.1, 1998.



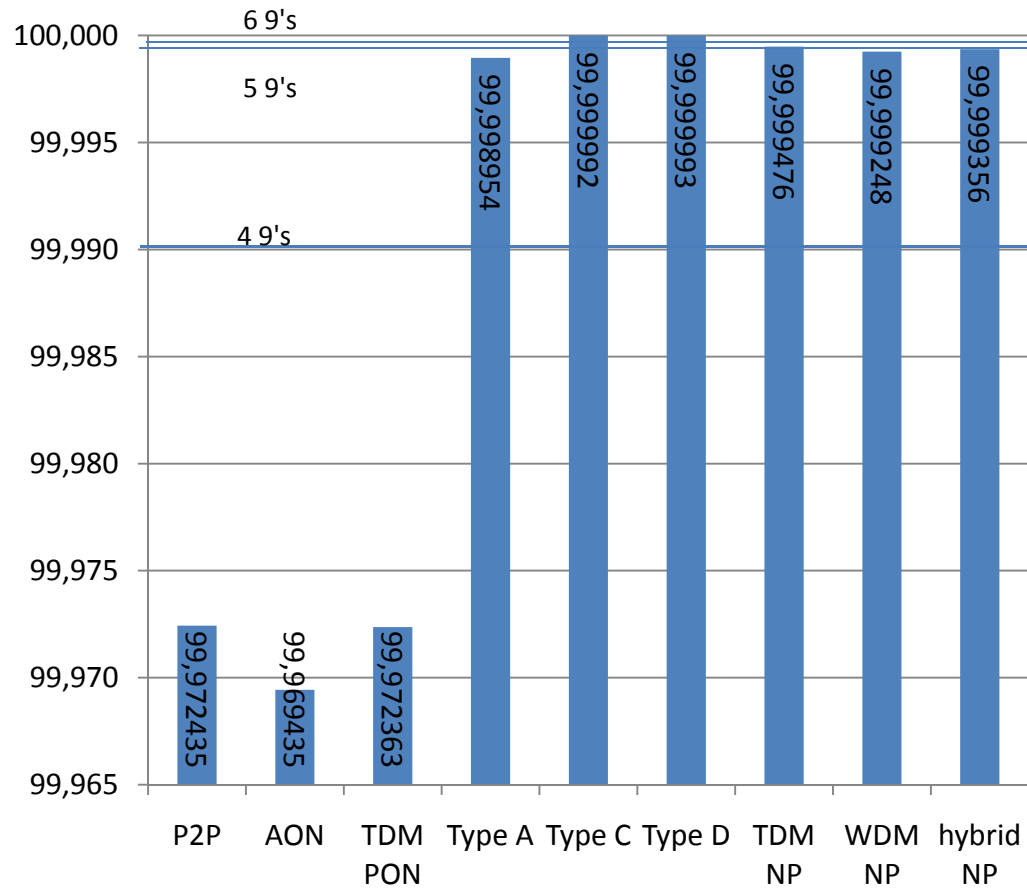
OSA JON 2006
 IEEE PTL 2003.
 .. *Wosinska OS*

- Compare the different protection schemes
 - Connection availability
 - CapEx
 - OpEx
- Network operational time: 20 years
- Access networks host 32 ONUs, except Hybrid that hosts 16 PONs of 16 ONUs.

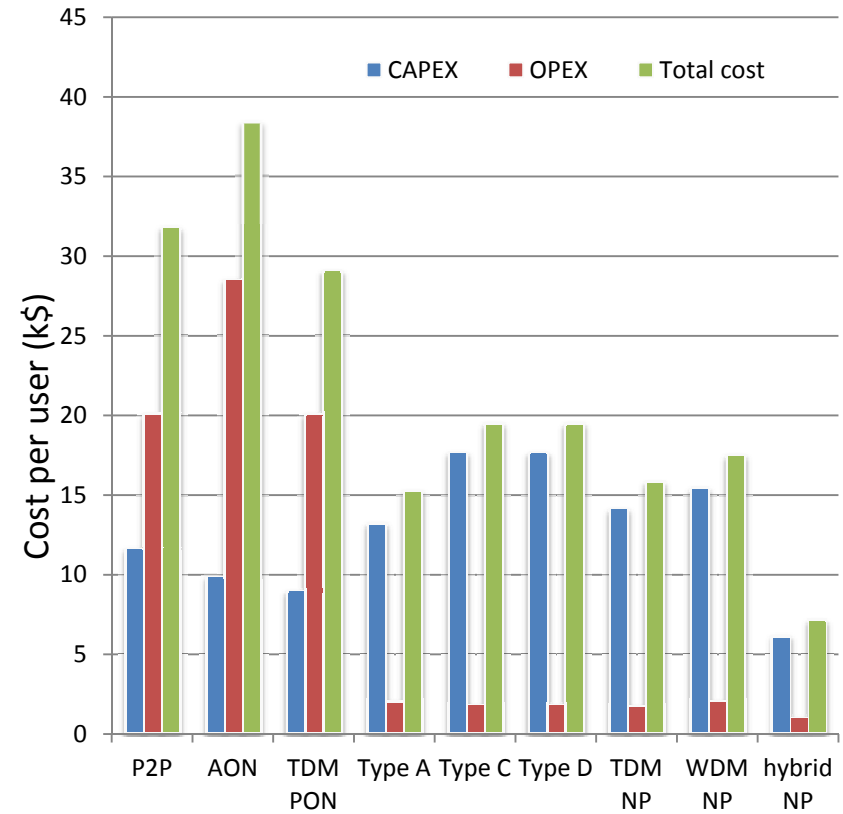
- Any component can fail and causes the interruption of all the traffic using the failed component.
- Traffic may be restored through protection path when available
- Operator personnel can be located at the OLT
- Failure diagnosis and availability times are assumed to be negligible compared with travelling and reparation times. Spare component cost is considered.



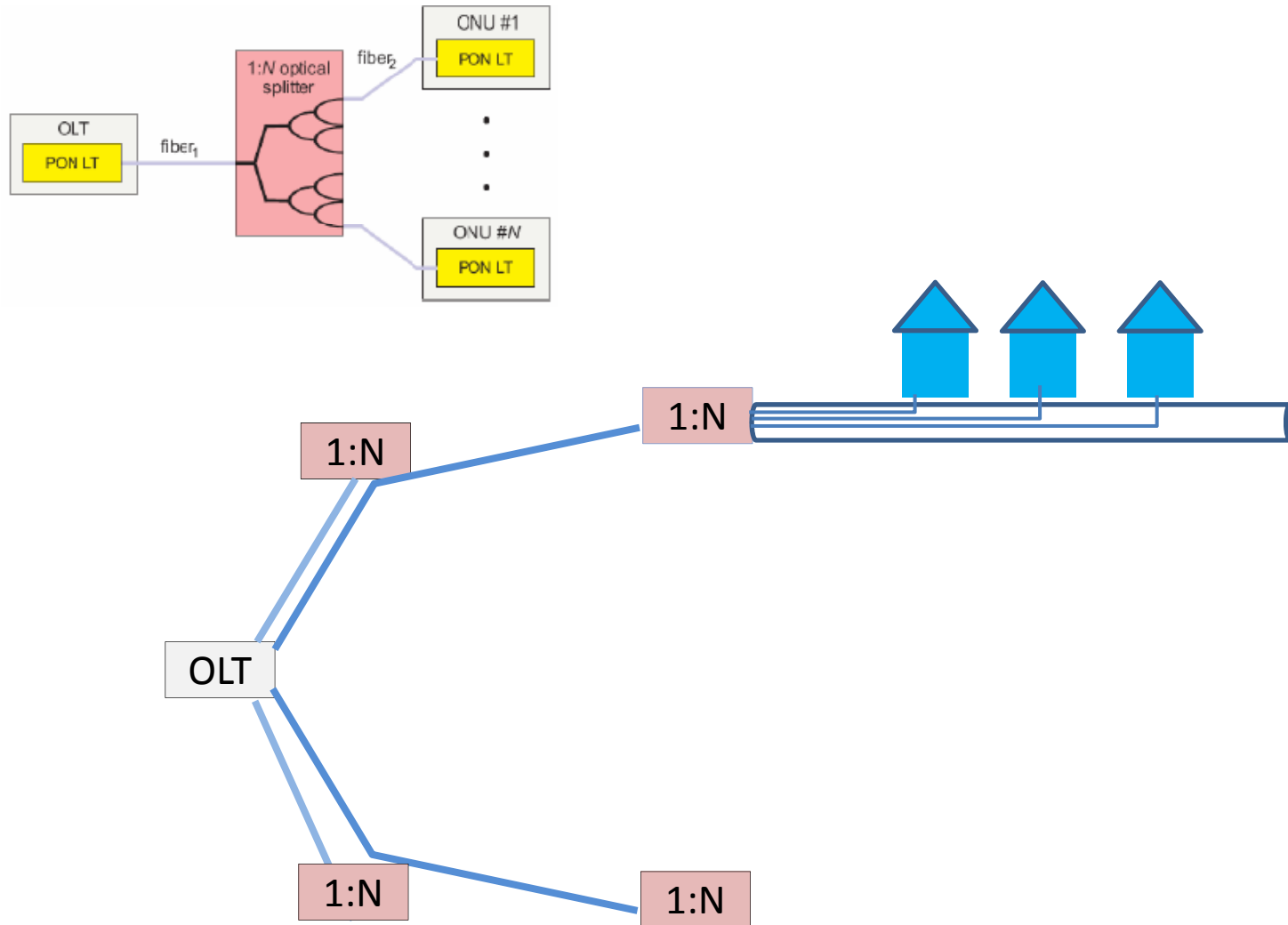
availability

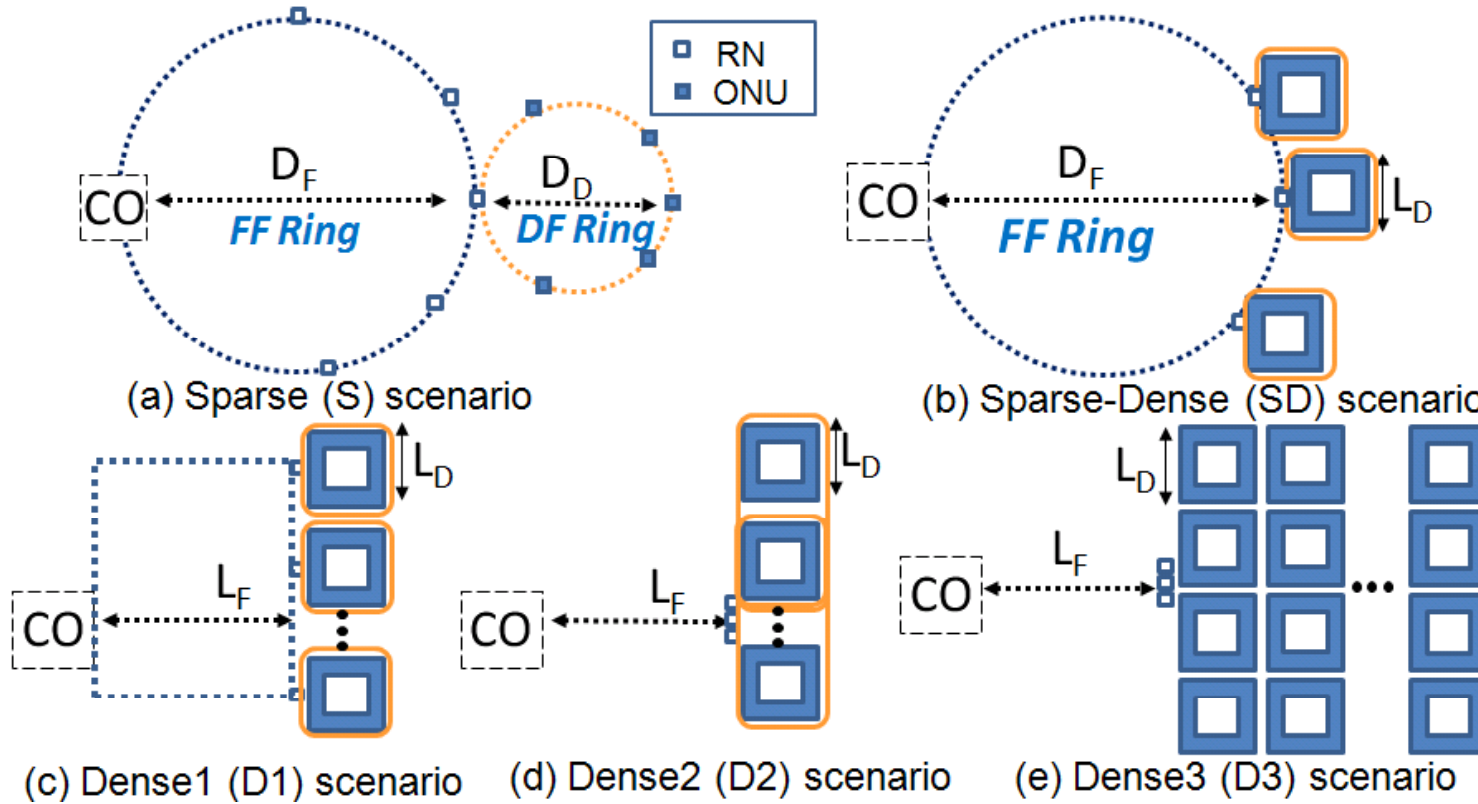


J. Chen et al, IEEE Communications Magazine, 2000



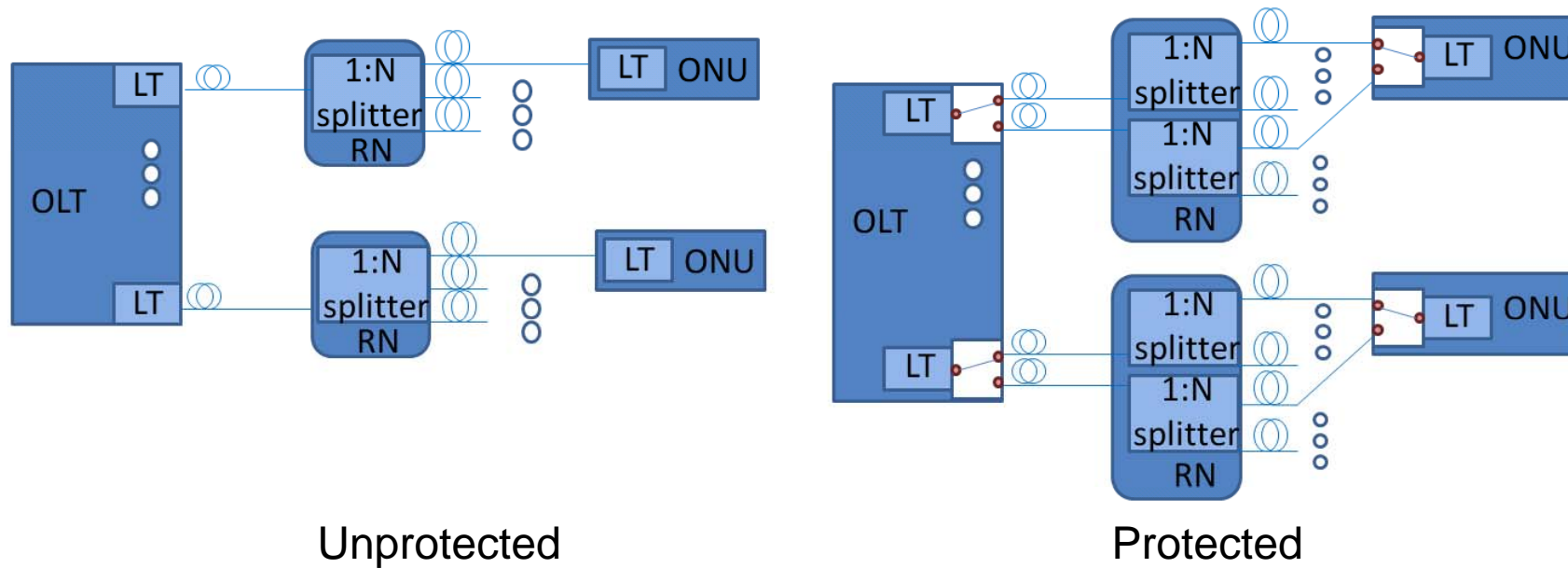
- Network operational time: 20 years
- Focus on TDM PON
- Access networks host 1024 ONUs (32 PONs with 32 users)
- Traffic may be restored through protection path when available
- Operator personnel can be located at the OLT
- Failure diagnosis and availability times are assumed to be negligible compared with travelling and reparation times. Spare component cost is considered.
- Evaluate cost and availability of different fiber layout scenarios.



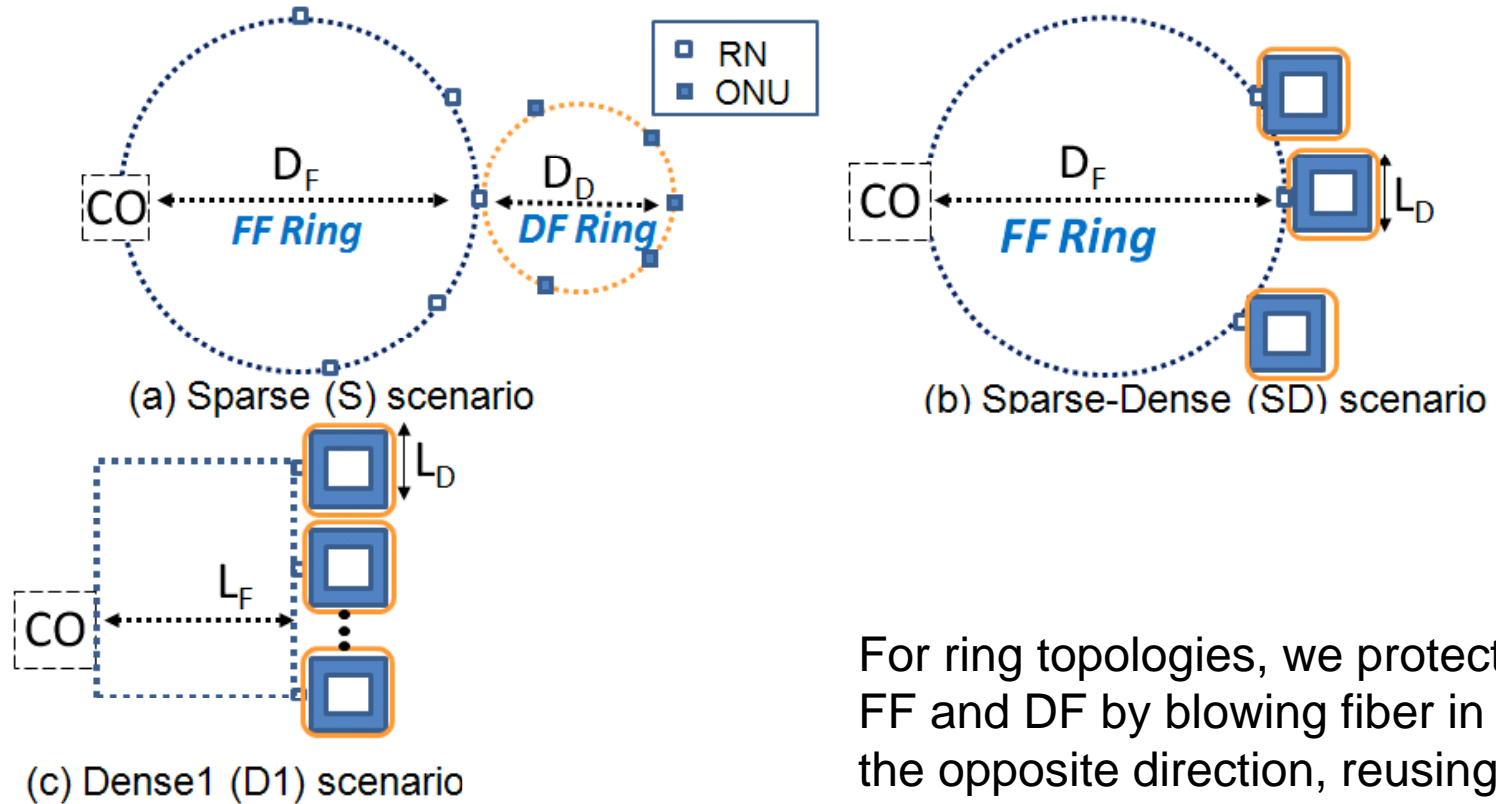


| | Travel speed[km/h] | D_F or L_F [km] | D_D or L_D [km] |
|----|--------------------|---------------------|---------------------|
| S | 50 | 4,8 | 0,4 |
| SD | 50/20 | 5,11 | 0,133 |
| D1 | 20 | 13,37 | 0,133 |
| D2 | 20 | 11,54 | 0,133 |
| D3 | 20 | 18,67 | 0,133 |

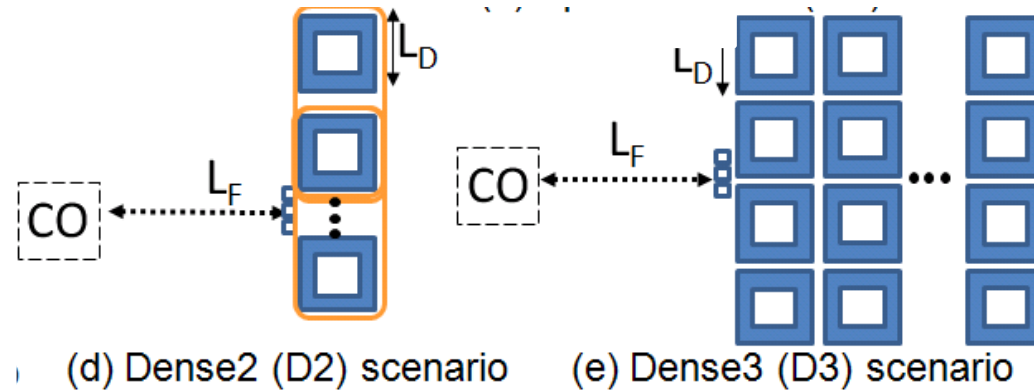
- Two scenarios are considered:



 1x2 optical switch

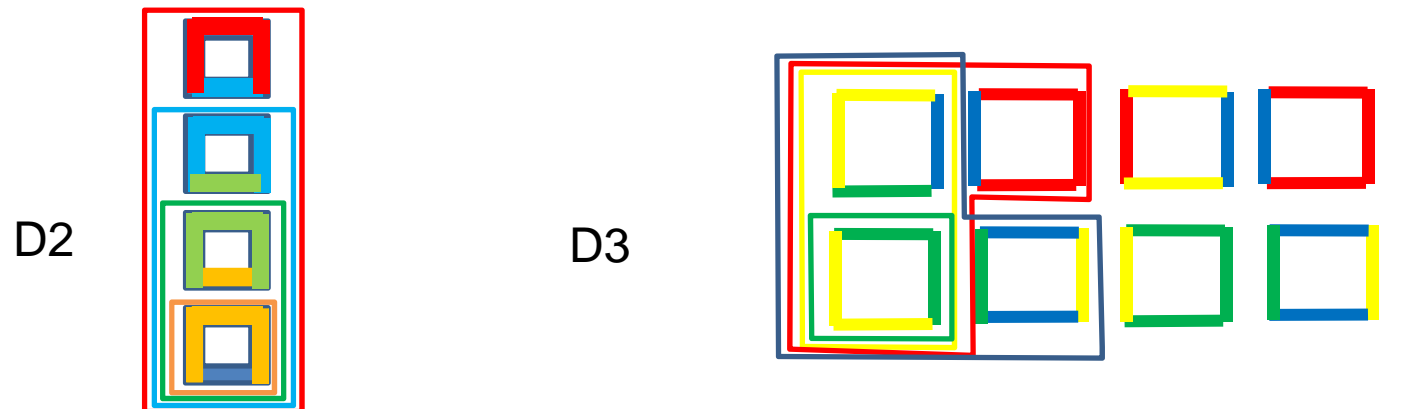


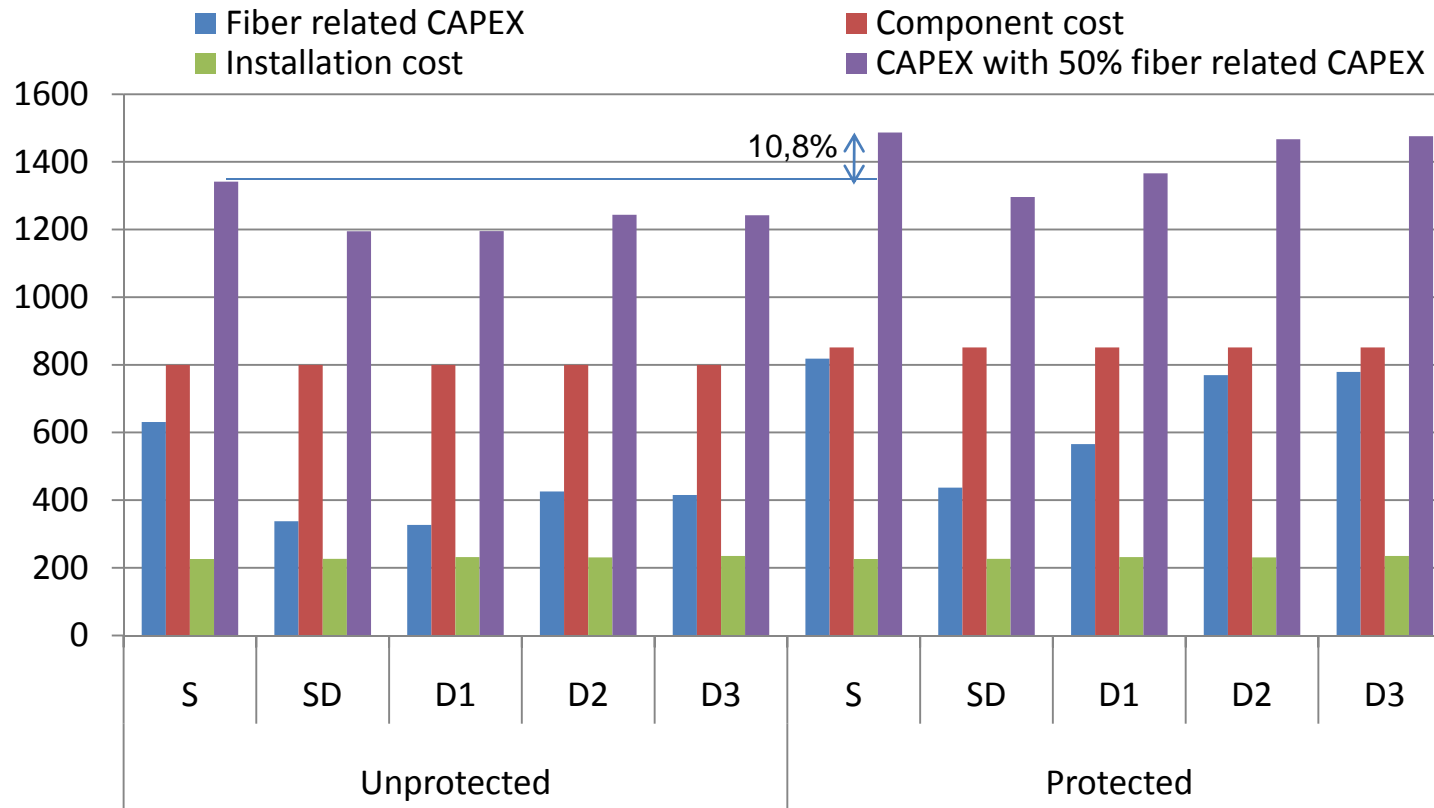
For ring topologies, we protect FF and DF by blowing fiber in the opposite direction, reusing the existing duct.



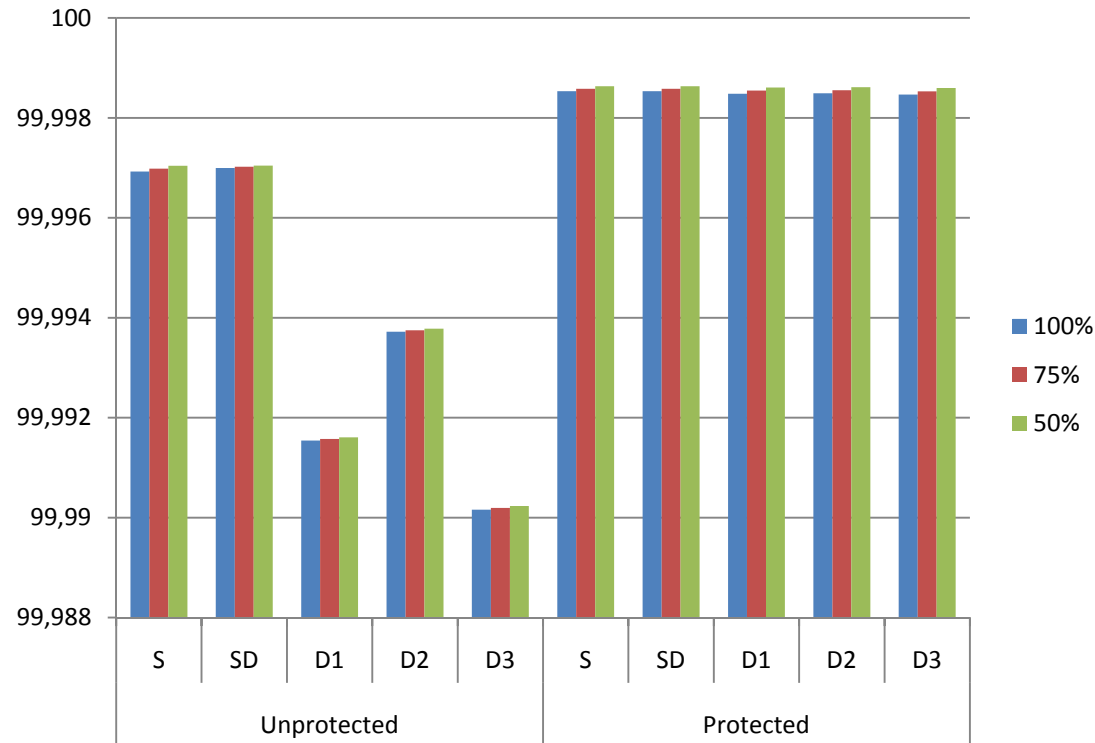
For D2 and D3 scenarios, we protect FF by installing duct and fiber in parallel street.

The DF fiber has the following layout



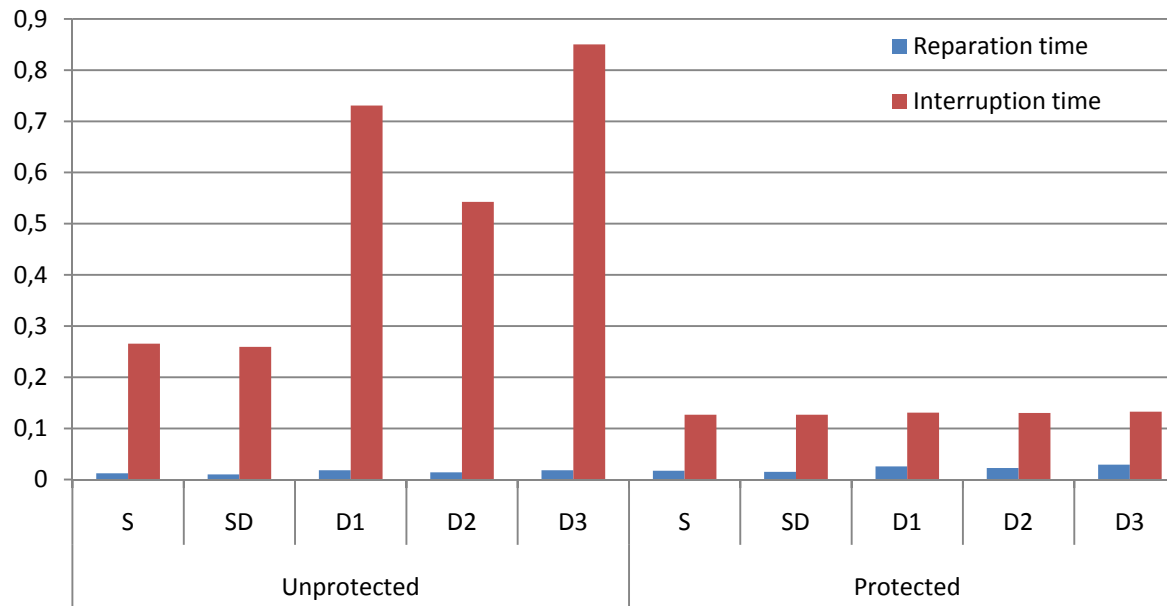


- Component and installation cost is almost the same for all the scenarios with and without protection, since few extra components are required to protect the network.
- Infrastructure cost in protected networks is much less than the double in unprotected networks.



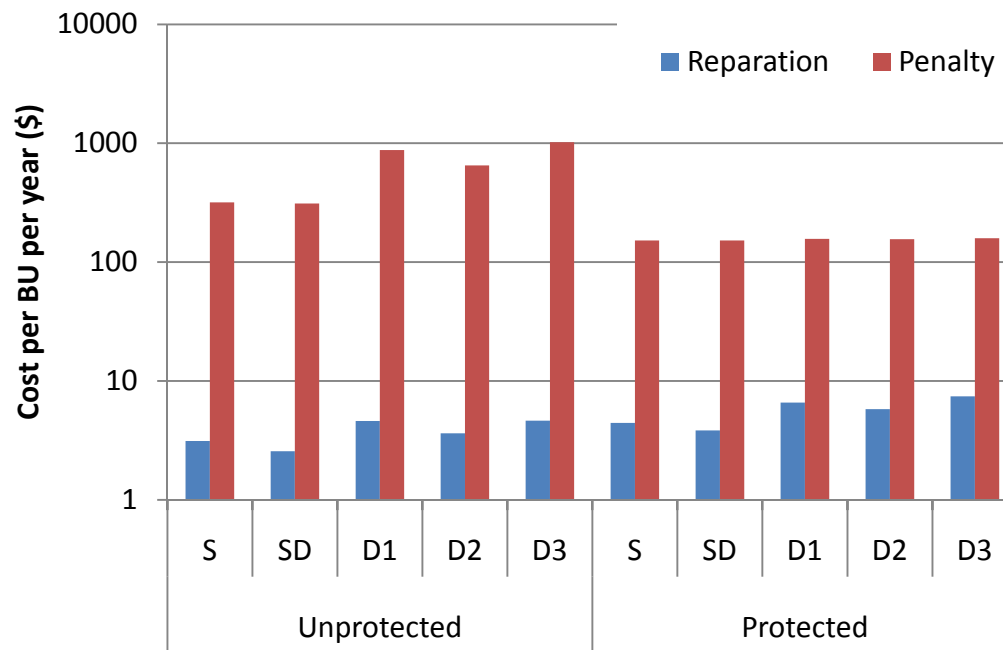
- The connection availability is comparable for all the protected scenarios, which corresponds to almost 5 9's availability.
- For unprotected scenarios, the availability for dense scenarios drops to 4 9's due to the longer FF whose failure affects all connections and implies lower reparation times.
- Low impact of the take rate

Reparation and connection interruption times [hours] per user per year



It can be observed that reparation time increases slightly for protected schemes, since more equipment implies more failures, but the time is shared among users. Interruption time is longer than reparation since one failure may affect several (and even all) users, hence, the interruption time is not *shared* as the reparation time. Interruption time is significantly lower for protected scheme since link failures do not cause connection interruption

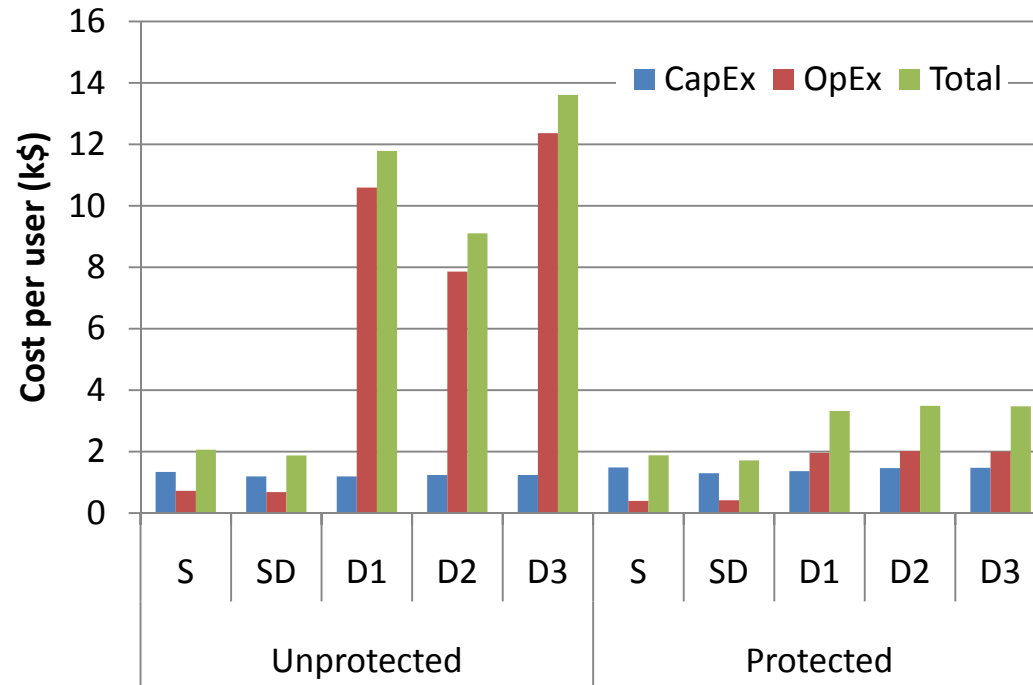
- Impact of failures to operational costs



Penalty costs are significantly higher than reparation costs.

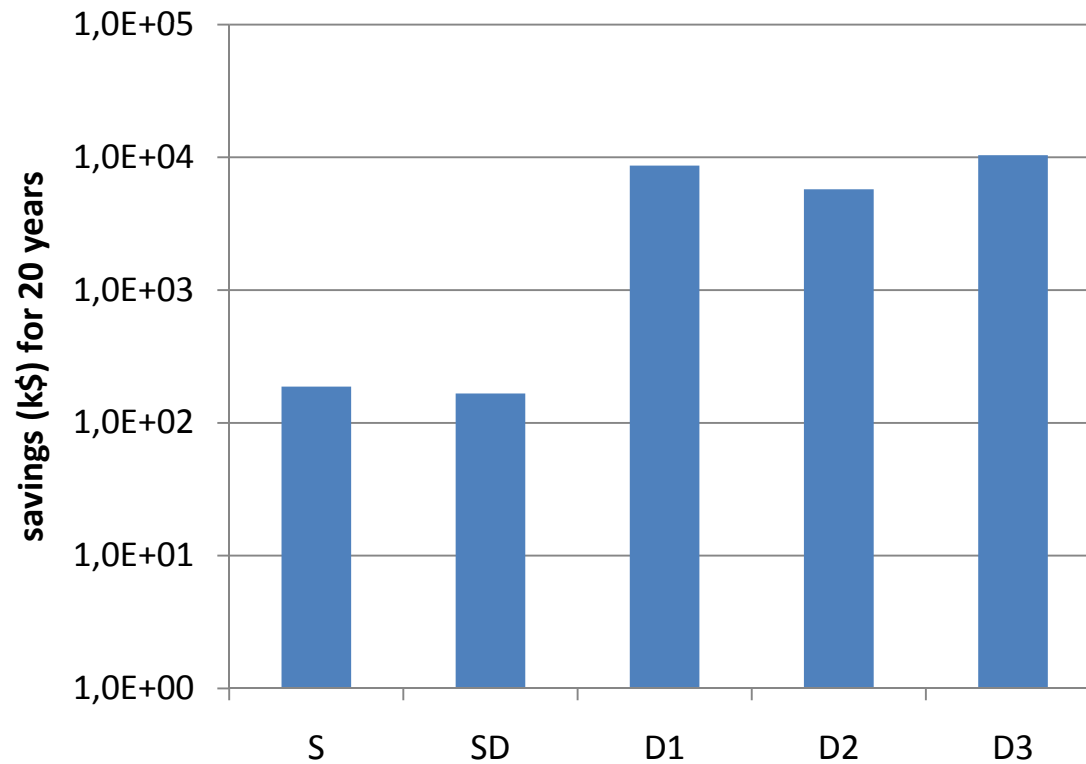
When offering protection, penalty costs decrease more than 50% for S and SD areas, and more than 75% for D areas. These savings are much important than the increase of reparation cost.

- Network operational time: 20 years



Penalty costs consider different percentage of business users depending on the area (20% for S and SD; 80% for D areas). Savings are significant in dense areas (10.000\$/users, more than 10 million\$ for 1024 users)

- Savings in 20 years



- Impact of protection on cost and availability has been provided for different protection schemes.
- Cost-efficient fiber layout to provide protection for PONs is proposed and evaluated.
 - a significant increase of connection availability can be achieved at very low increase of infrastructure expenses
 - the total cost can be reduced due to the diminution of the OPEX related to the failure management.

Thank you!

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