NEGONET

Advances in Fiber Access Networks Development: Efficient Resource Allocation and Cost-effective Protection

Jiajia Chen and Lena Wosinska
Email: jiajiac@kth.se

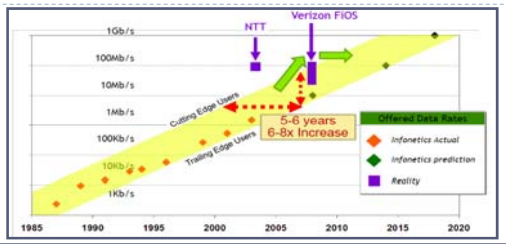
Next Generation Optical NETworks ***NEGONET***
http://www.ict.kth.se/MAP/FMI/Negonet/

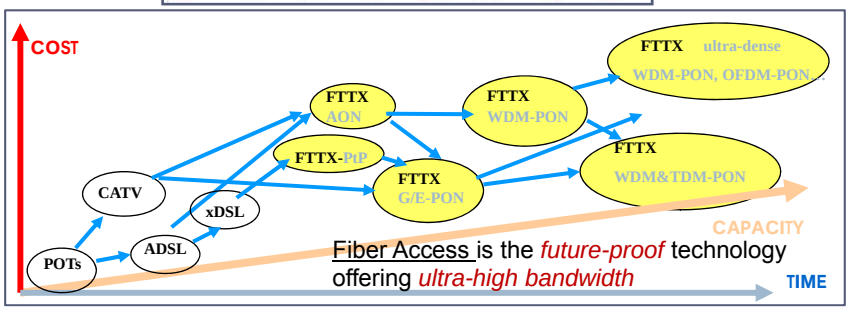
Outline

NEGONET

- Overview of fiber access technologies
- Passive optical network (PON)
- Efficient resource allocation
- Cost-effective protection
- Conclusions

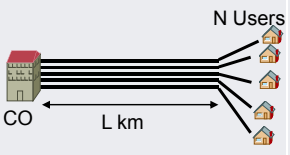
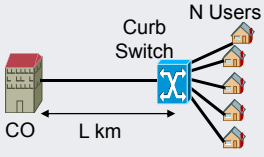
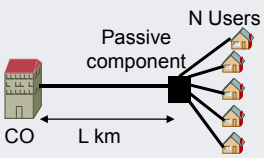
Access Network Evolution





3 2/1/2011

Fiber access solutions

Point-to-point P2P (Home-run)	Active optical network AON	Passive optical network PON
N fiber lines	1 fiber line	1 fiber line
2*N* transceivers	2*N*+2 transceivers	N+1 transceivers *
Significant outside fiber plant deployment	Curb Switch → power in the field	Passive devices → No active elements in the outside plant
		

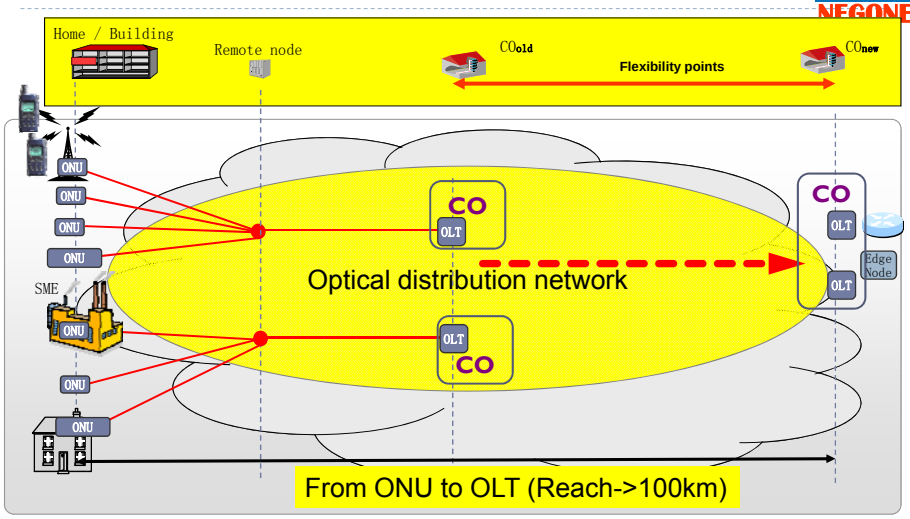
* for TDM PON

4 2/1/2011

Passive optical network

- Downstream → *point-to-multipoint* network
  - The Optical Line Terminal (OLT) manages the bandwidth
- Upstream → *multipoint-to-point* network
  - Optical Network Units (ONUs) transmit only towards the OLT
  - ONUs cannot detect other ONUs transmissions
  - Collisions may occur ➔ Need of a channel separation mechanism for resource sharing
- Different techniques for Multiple access
  - Time division multiplexing -> TDM PON (e.g. GPON, EPON)
  - Wavelength division multiplexing -> WDM PON
  - Hybrid WDM/TDM PON
  - Code division multiplexing -> CDM PON
  - Orthogonal frequency-division multiplexing -> OFDM PON

Reach Extension

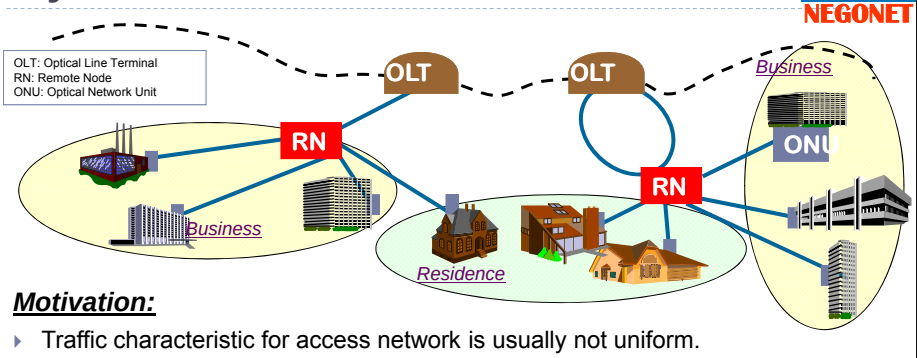


NEGONET

Efficient Resource Allocation

NEGONET

Dynamic Bandwidth Allocation DBA

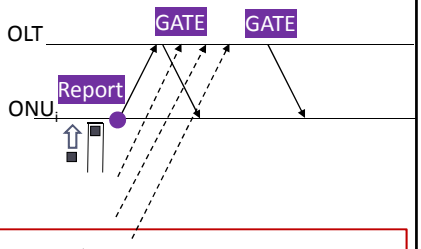


Motivation:

- Traffic characteristic for access network is usually not uniform.
  - The load of diverse channels is varied not only in distinct time periods but also at different locations.
- Multiple quality of service (QoS) provisioning is required.
  - *Priority* for different types of traffic classes
  - *Fairness* between different end users and/or service providers

DBA Algorithms

1) **On-line scheme**: the DBA is executed per ONU upon reception of one report message at the OLT
   - *E.g.* *Interleaved polling with adaptive cycle time (IPACT) with limited service*



2) **Off-line scheme**: the DBA is executed after reception of all required report messages
   - *E.g.* *Weight-based algorithm for fairness in [1]*

[1] C. Assi et al., Dynamic bandwidth allocation for quality of service over Ethernet PON," IEEE J. Select. Areas Commun. Vol. 21, pp.1467-1477, Nov. 2003.

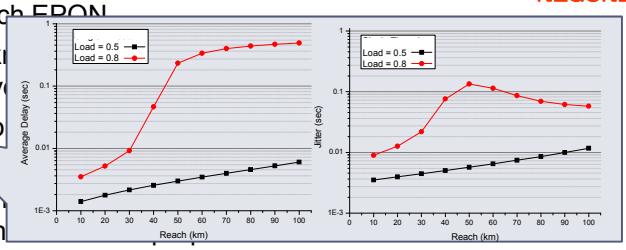
$$B_i^{\text{assigned}} = \begin{cases} B_i^{\text{request}}, ONU_i \in \textbf{underload} \\ B_i^{\min} + \omega_i \cdot B^{remain}, ONU_i \in \textbf{overload} \end{cases}$$

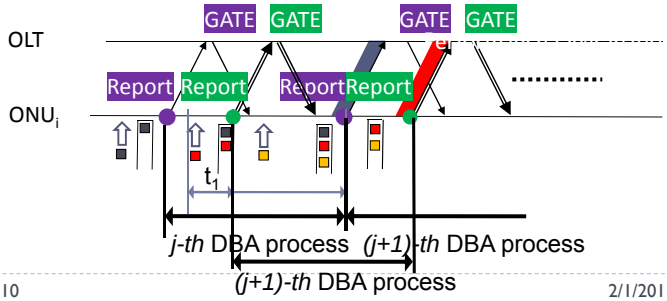
$$\omega_i = B_i^{\min} \Big/ \sum_{ONU_k \in \textbf{overload}} B_k^{\min}$$

$$B^{remain} = \sum_{ONU_k \in \textbf{underload}} (B_k^{\min} - B_k^{\text{request}})$$

Multi-thread DBA

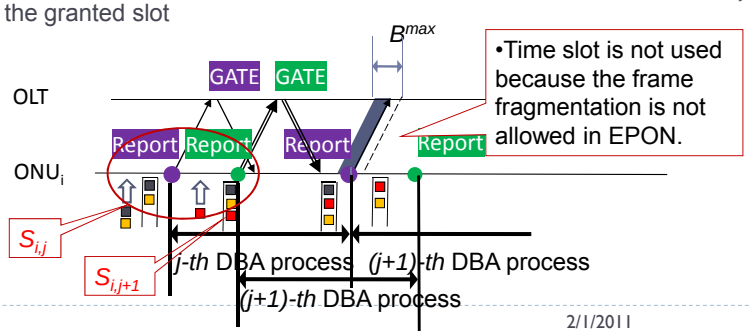
EPON vs. Long-reach EPON
- 20km to 100k
  1ms (and bey
- Increased pro
  performan
- To address th
  for long-reach





IPACT with limited service

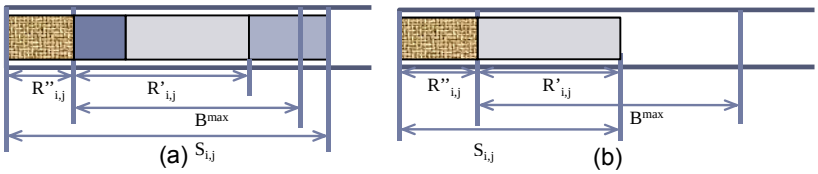
- Steps of one DBA process
  1. ONU_i Sending a REPORT with information regarding the amount of required bandwidth $R_{i,j}$, which is typically set as *the buffer occupancy* $S_{i,j}$
  2. OLT calculating bandwidth grant $B_{i,j} = min(B^{max}, S_{i,j})$
     - B^{max}: predefined maximum limit, which is imposed in order to avoid bandwidth hogging by greedy ONUs.
  3. OLT sending a GATE with information on the *start time* and *length* ($B_{i,j}$) of the granted slot



Enhanced IPACT with limited service

- Steps of one DBA process
  1. ONU_i Sending a REPORT with information regarding the amount of required bandwidth $R_{i,j}$, which is set as $R'_{i,j}$
     - the *adjusted bandwidth demand reported* by ONU_i in the $(j-1)$-th DBA process

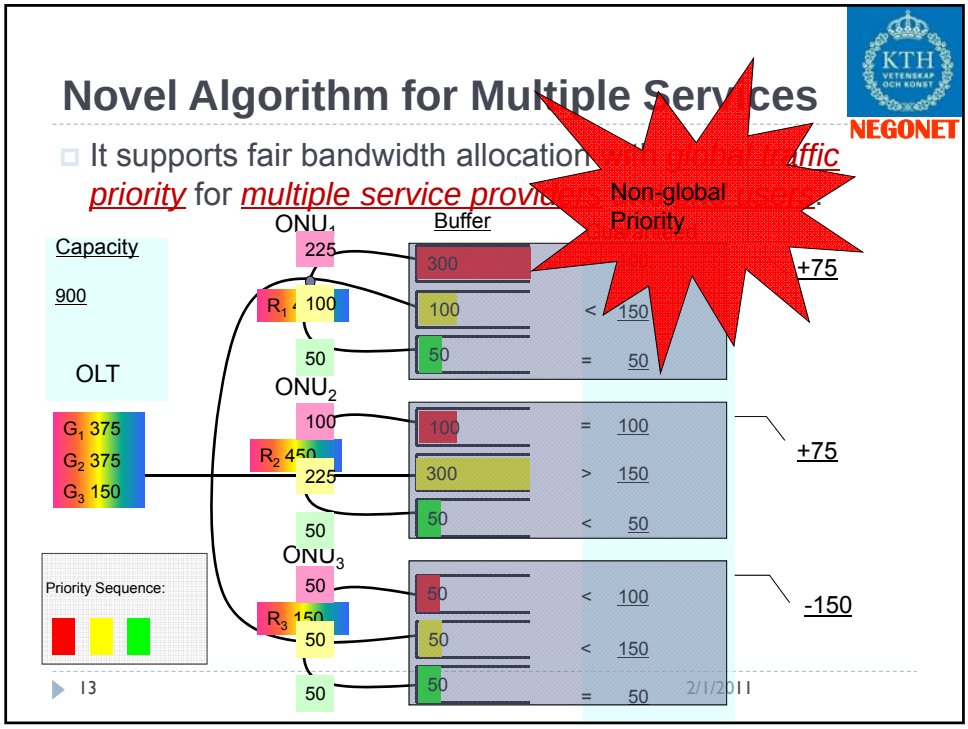
Buffer at ONU_i at the time of reporting for the j-th DBA process

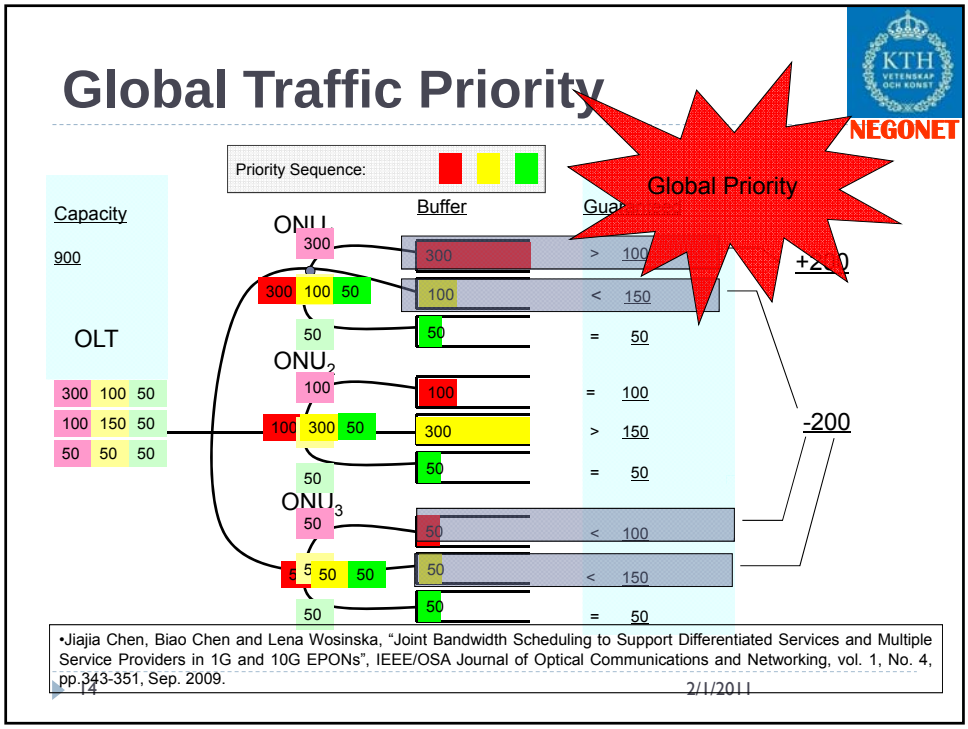


$R''_{i,j}$: the bandwidth required by the traffic that has previously been reported to the OLT but not yet left the ONU_i queue

$R'_{i,j}$ $R'_{i,j+1}$ *j-th* DBA process *(j+1)-th* DBA process

J. Chen, et al., Enhancing IPACT with Limited Service for Multi-thread DBA in Long-reach EPON, IEEE/OSA/SPIE ACP2010


Novel Algorithm for Multiple Services
NEGONET
Non-global Priority
Capacity
900
OLT
G1 375
G2 375
G3 150
Priority Sequence:
ONU1
ONU2
ONU3
Buffer
225
100
50
300
100
50
< 150
= 50
= 100
> 150
< 50
< 100
< 150
= 50
+75
+75
-150
13
2/1/2011


Global Traffic Priority
NEGONET
Global Priority
Priority Sequence:
Capacity
900
OLT
300 100 50
100 150 50
50 50 50
Buffer
ONU1
ONU2
ONU3
> 100
< 150
= 50
= 100
> 150
= 50
< 100
< 150
= 50
-200
•Jiajia Chen, Biao Chen and Lena Wosinska, "Joint Bandwidth Scheduling to Support Differentiated Services and Multiple Service Providers in 1G and 10G EPONs", IEEE/OSA Journal of Optical Communications and Networking, vol. 1, No. 4, pp.343-351, Sep. 2009.
14
2/1/2011

NEGONET

Cost-effective Protection

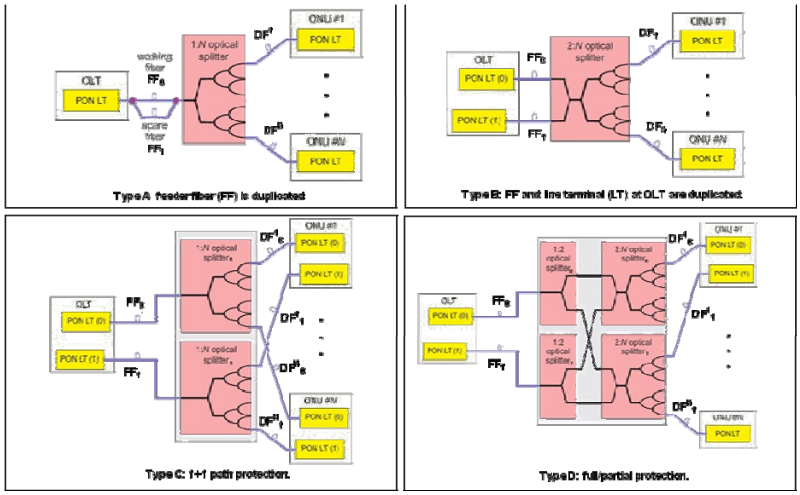
Motivation

NEGONET

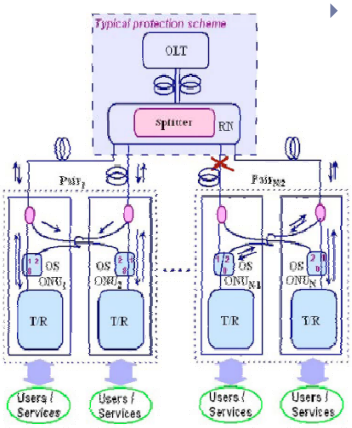
- Importance of reliable access to broadband network services is growing.
- PON without any protection has poor reliability performance.
- Network providers need to keep capital and operational expenditures (CAPEX & OPEX) low to offer economical solutions for the customs.

Thus, minimizing the cost of network protection while maintaining an acceptable level of connection availability is an important challenge.

Standard schemes (ITU-T G.983.5)



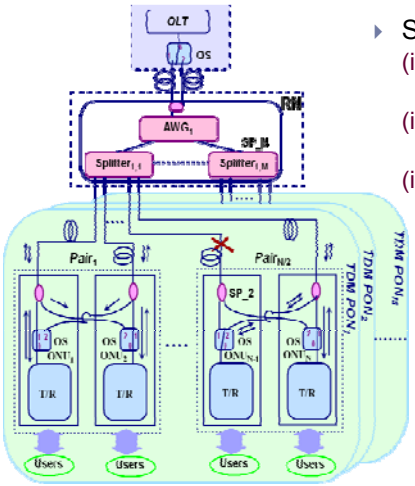
Neighboring Protection (NP) for TDM PON



- Scheme for TDM PON
  - (i) *no extra DFs are needed for protection → CAPEX saving*
  - (ii) *proposed scheme is for both physical and media access control layers*
  - (iii) *restoration time depends mainly on the switch time of the physical layer*

• Jiajia Chen, Biao Chen, and Sailing He, "Self-protection Scheme against Failures of Distributed Fiber Links in An Ethernet Passive Optical Network", OSA Journal of Optical Networking, vol. 5, pp. 662-666, Sep. 2006.

NP for hybrid PON



- Scheme for Hybrid WDM/TDM PON
  (i) *no extra DFs are needed for protection → CAPEX saving*
  (ii) *protection for both FF and DF failures is provided.*
  (iii) *compatible with smooth migration from a TDM PON to a hybrid PON*

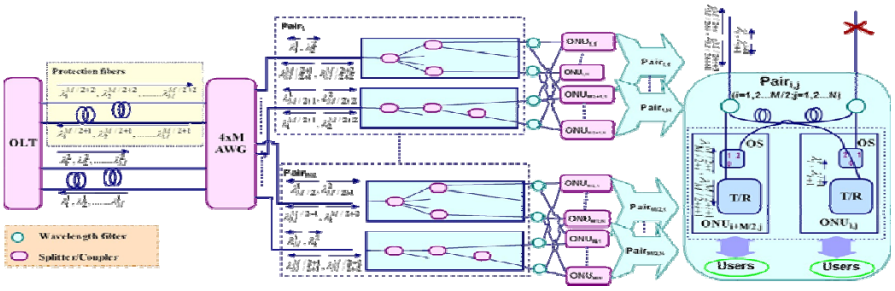
• Jiajia Chen, and Lena Wosinska, "Protection Schemes in PON Compatible with Smooth Migration from TDM-PON to Hybrid WDM/TDM PON", OSA Journal of Optical Networking, vol. 6, pp. 514-526, May 2007.

NP for WDM and hybrid PON

- Utilizing the cyclic property of the AWG our protection scheme has two main advantages (compared to the existing schemes):

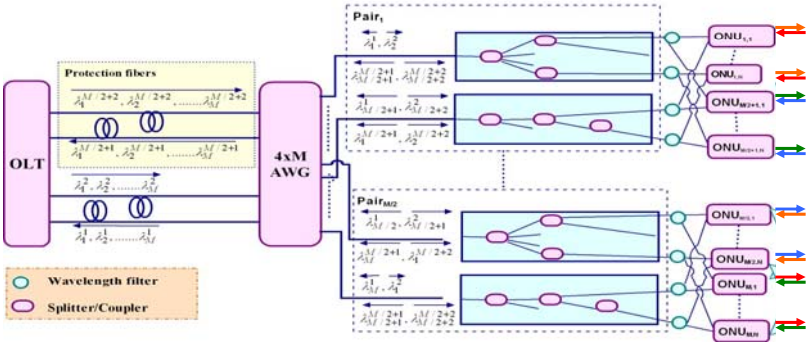
  (i) *50% fewer wavelengths are needed;*

  (ii) *in the case of DF break there is no influence on the remaining ONUs;*



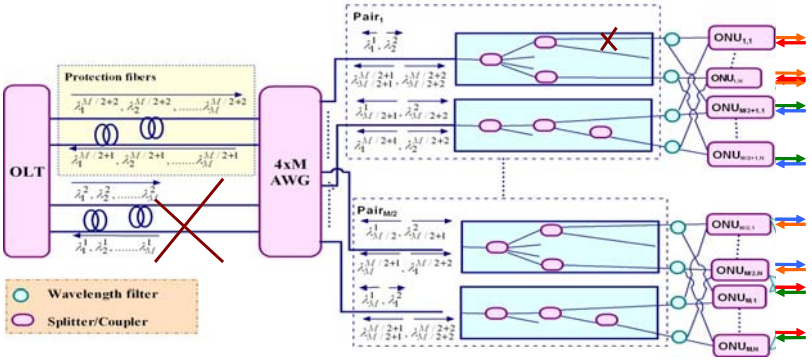
• Jiajia Chen, Lena Wosinska, and Sailing He, "High Utilization of Wavelengths and Simple Interconnection between Users in A Protection Scheme for Passive Optical Networks", IEEE Photonics Technology Letters, vol. 20, pp. 389-391, Mar. 2008.

Normal Operation

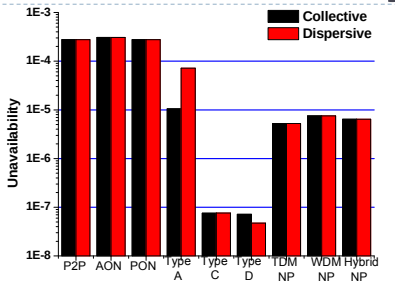


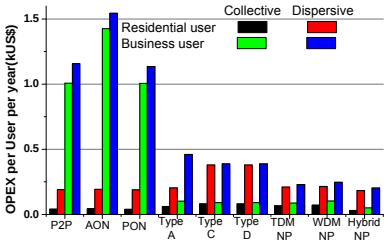
Protection

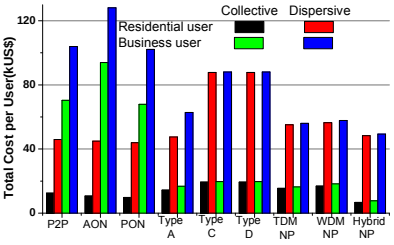
- In the case of distributed fiber-cut between AWG and $ONU_{1,1}$
- In the case of feeder fiber-cut between OLT and AWG



Cost vs. Reliability







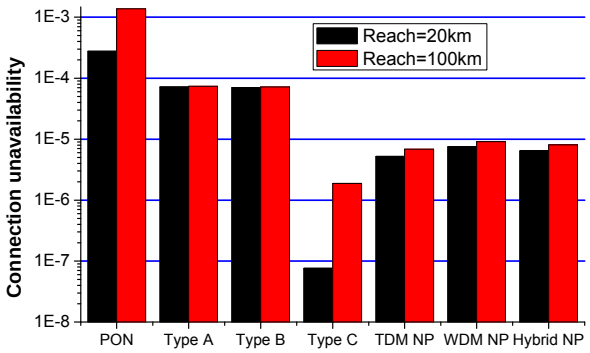
Residential User: Unprotected PON have lowest OPEX and total cost.

Business User:

- *Protected architectures have lower OPEX* due to larger connection availability and consequently lower penalty.
- *Neighboring protected (NP) architecture also have lower total cost* due to relatively low CAPEX and OPEX.

J. Chen, C. Mas, L. Wosinska and M. Jaeger, "Cost vs. Reliability Performance Study of Fiber Access Network Architectures", IEEE Communications Magazine, February 2010

Reach vs. Reliability



- Reliability performance of the PON with neighboring protection is *not notably degraded* by reach extension while connection unavailability for basic PON and Type C *increases significantly.*

Conclusions

- The advances in two important research aspects related to PONs have been reviewed.
- Challenges:
  - *Efficient resource allocation*
    - Increased dimensions for resource allocation
      - Time slot and wavelength
    - Reach extension
    - Energy efficiency
  - *Cost-effective protection*.
    - Total cost minimization include capital and operational cost
    - Smooth migration

Thank you!!

Email: jiajiac@kth.se
http://www.ict.kth.se/MAP/FMI/Negonet/