OECC 2009 Workshop: Next-generation Broadband Optical Access – Future Challenges
Session 1: Broadband Network Architectures, WDM PON Evolution Strategies and Future Ultra-high- bandwidth Services

WDM Passive Optical Networks: Protection and Restoration

Calvin C K CHAN

Lightwave Communications Laboratory
Department of Information Engineering
The Chinese University of Hong Kong
HONG KONG

Network Survivability in PONs

- Conventional PONs have limited protection features to keep the cost low.

- The traffic on PONs is getting more data-centric. Subscribers are requesting high-availability services and connections.

➔ need to provide resilience against failures due to catastrophic events like fires, flooding, earthquakes, etc.

Network Survivability in PONs

Fault Management in optical networks

Conventional approach: diagnosis on high layers

→ based on status reports collected from various checkpoints on the managed optical network

→ incurred overhead in network signaling and network management system

→ no guarantee that higher layers could provide recovery from faults in the physical layer.

➔ Network protection in optical layer

→ simple fiber link or equipment duplication with protection switching or some other intelligent schemes with minimal resource duplication

→ faster response

Network Survivability in PONs

For PONs

- Equipment failures at either OLT or ONU
  - → having a backup unit in a controlled environment.
- Fiber cut
  - → takes a relatively long time to perform the repair

➔ **Survivable network architectures for PONs** with protection switching is highly desirable to bypass the failed fiber links and re-route the affected traffic.

Survivable WDM-PONs

Design Consideration: Protection / Restoration

Protection	Restoration
Protection lightpaths are *pre-planned* at the network design stage.	*Dynamically search* for spare lightpaths to restore the disrupted traffic after network failure.
Low traffic restoration time → only protection switching is needed to enable the protection lightpath.	Maybe long traffic restoration time → depending on the dynamic re-routing of the disrupted traffic, and the routing decision computation.

For **WDM-PONs**, topology is regular (tree / ring)

- Preplanned protection
- Protection on optical layer → further reduce the traffic restoration time
- Minimize the disturbance to the higher layers

Survivable WDM-PONs

Design Consideration: Wavelength Routing

In addition to lightpath diversity with fiber link duplication and switching,

WDM-PONs offer one more dimension (Wavelength)

→ wavelength routing

→ may reduce the amount of resource duplication

Design Consideration: Network Topology

Network topology determines the paths or connections between the OLT and the ONUs

→ influences how the protection lightpaths or fibers be duplicated or incorporated

Tree topology: feeder fibers, distribution fibers

Ring topology: dual fiber ring, or single fiber ring with uni-/bi-directional OADM in each network node

Survivable WDM-PONs

Design Consideration: Single / Multiple Failures

Mostly consider single failure at a time

→ the occurrence of a fiber or equipment failure is statistically independent in a network.

→ mean time between failures is generally much longer than the mean time to repair a failure

Protection against multiple failure scenarios has also been investigated recently.

Design Consideration: Automatic Protection Switching (APS)

Centralized control → all APS at OLT

→ better APS management

→ requires monitoring and collection of fault alarms throughout the network

Distributed control → APS at individual ONUs,

→ requires protection switches at the ONUs, transparent to OLT

→ ONU only monitors the status of its attached fibers

→ increases the complexity and cost of ONUs

Survivable WDM-PONs

Design Consideration: Fault Monitoring

Fault monitoring units have to be installed at strategic checkpoints to gather the network status information

→ Can be as simple as mere optical power level monitoring (loss of signal) or presence of a particular wavelength, etc.

Collected monitoring information has to be delivered to APS units for appropriate remedies, a signaling channel may be needed in some cases.

Design Consideration: Traffic Restoration Time

Time period between when the failure is detected and when the affected traffic is restored.

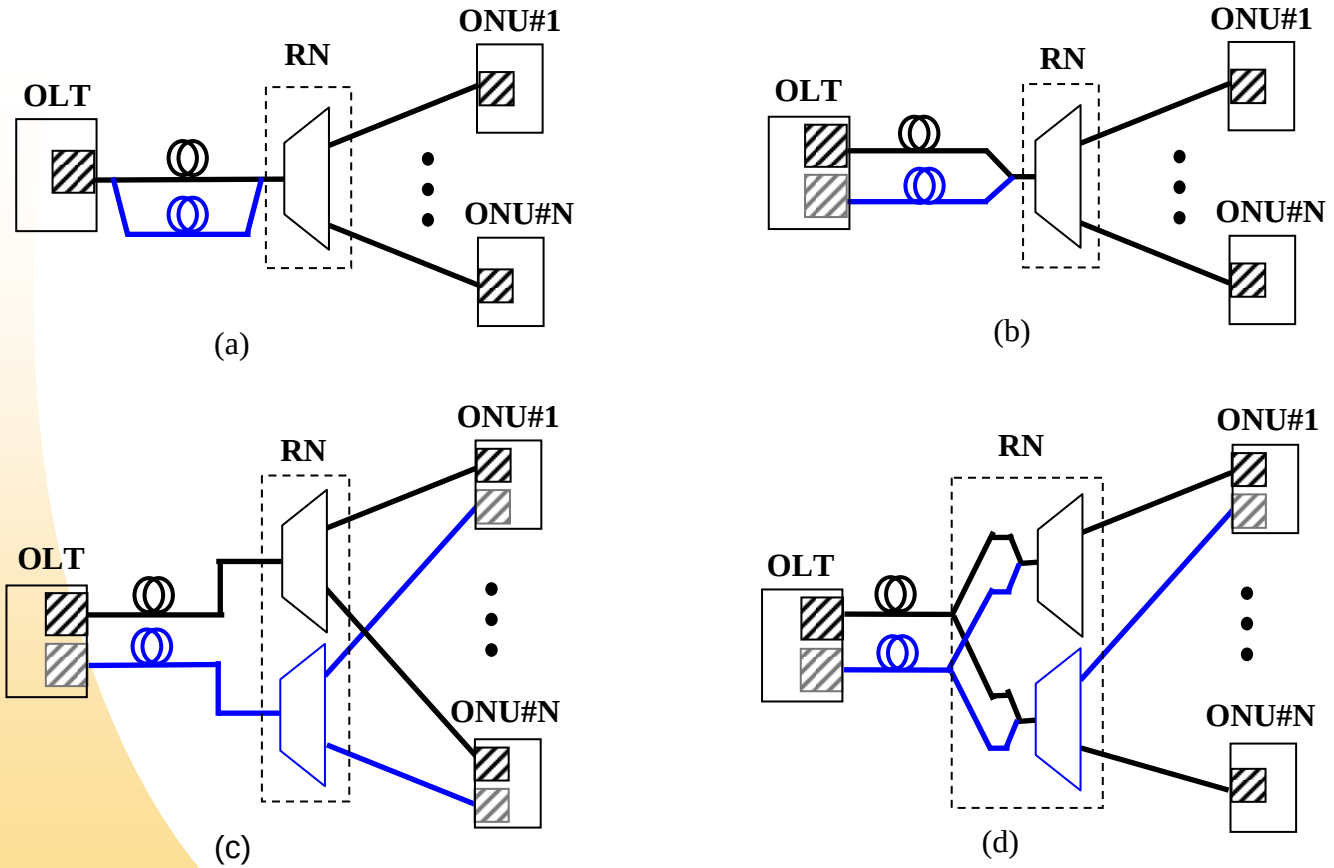
→ should be kept small, say a few tens of milliseconds

→ depends on:

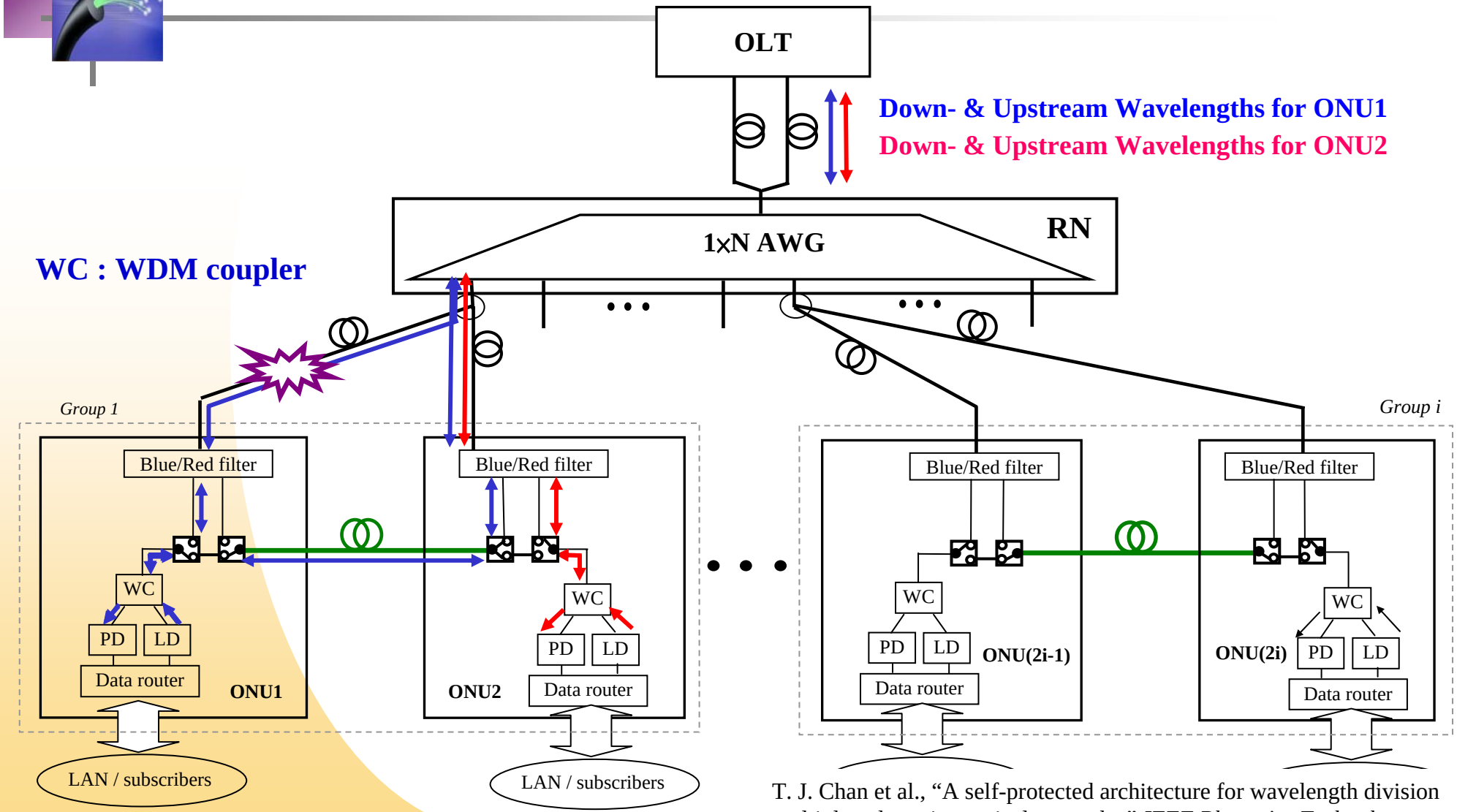
- → the intrinsic response of the optoelectronic detection and the optical switching devices used in APS,
- → possible induced additional latency of the protection lightpath

Protection Architectures for PONs

ITU-T G.983.1



Group Protection Architecture



T. J. Chan et al., "A self-protected architecture for wavelength division multiplexed passive optical networks," *IEEE Photonics Technology Letters*, vol. 15, no. 11, pp. 1660-1662, Nov. 2003.

Remote Node Duplication

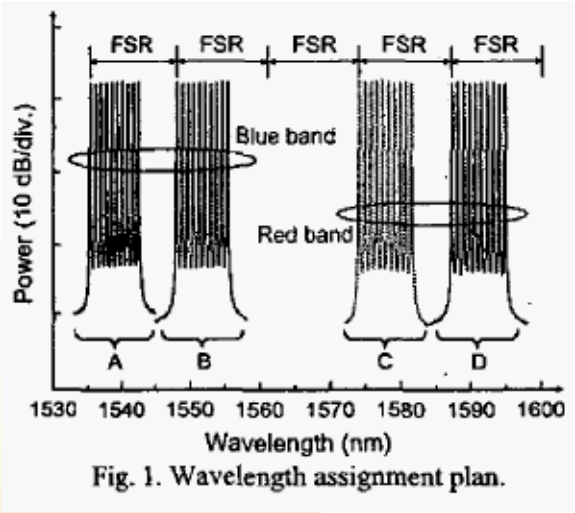


Fig. 1. Wavelength assignment plan.

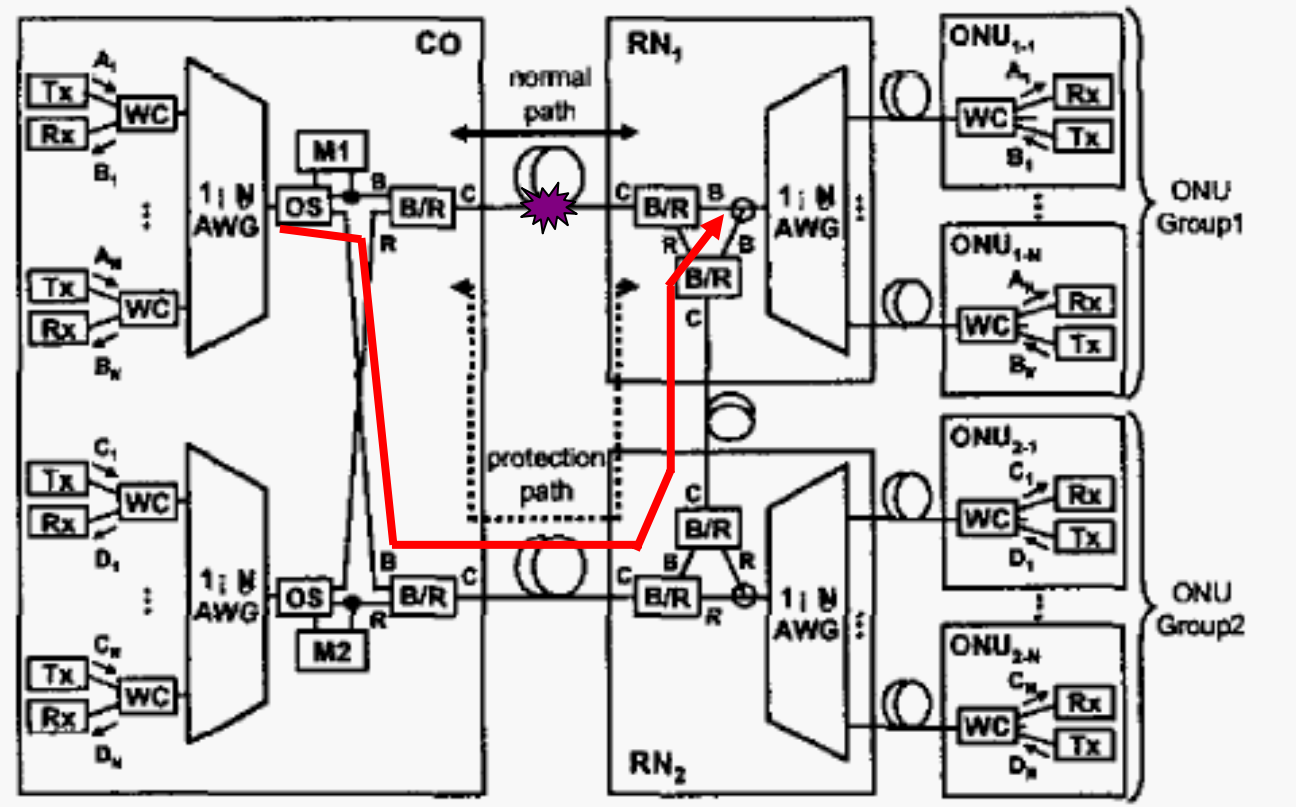


Fig. 2. Self-protecting architecture against feeder fiber failure.

E. S. Son et al, "Survivable network architectures for WDM PON", *OFC/NFOEC'05*, Paper OFI4, Anaheim, California, USA, 2005.

RN Duplication

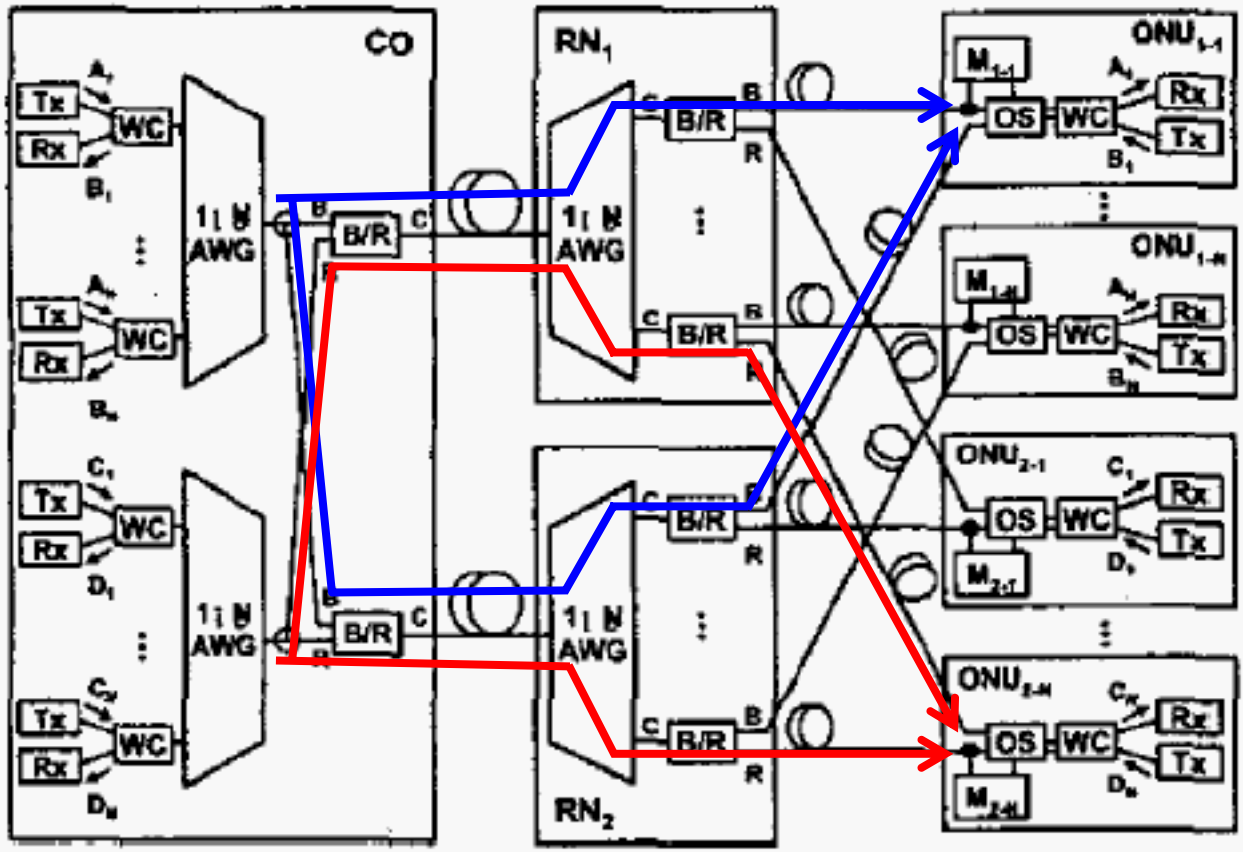
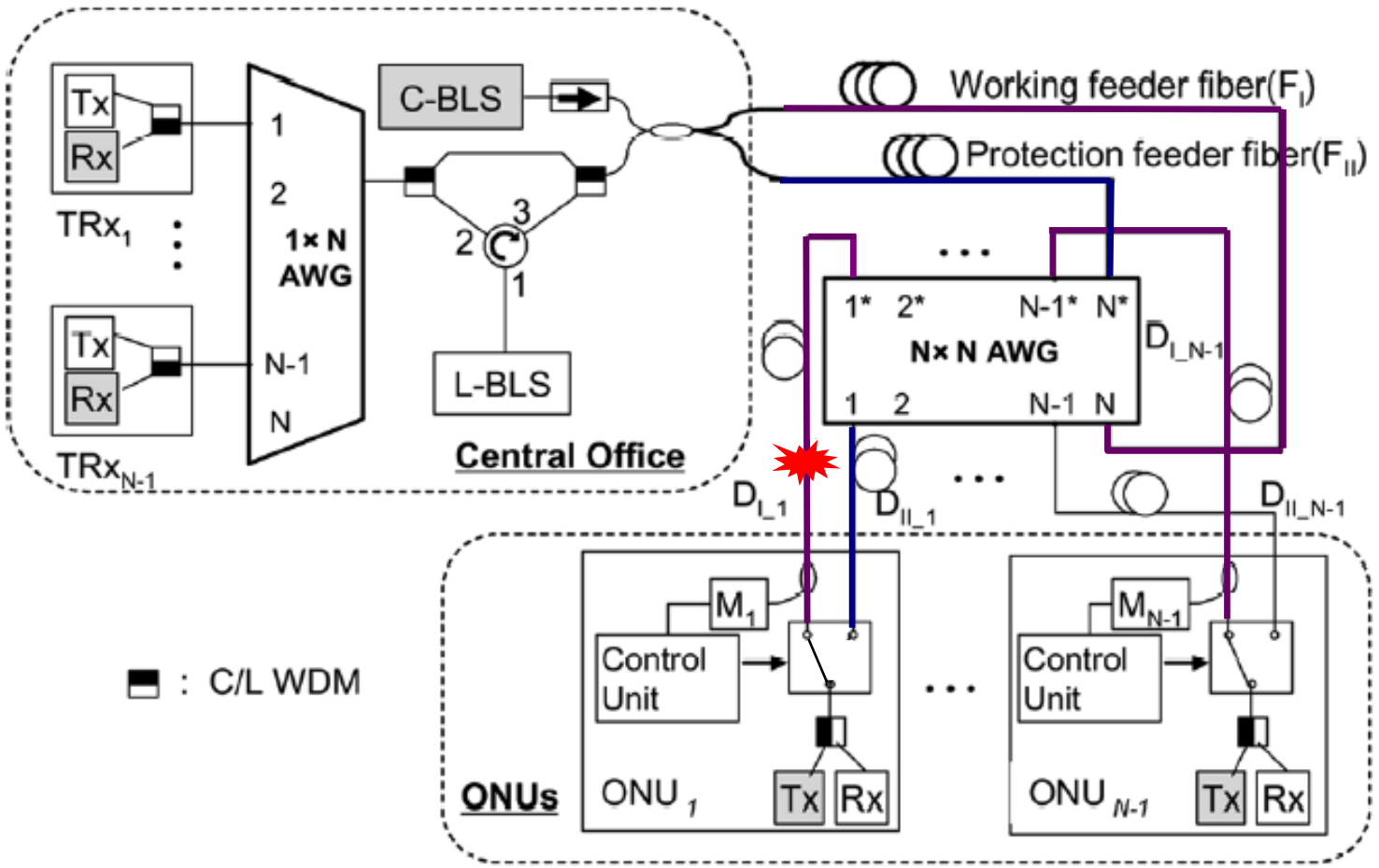


Fig. 3. Self-protecting architecture against both feeder and distribution fiber failures.

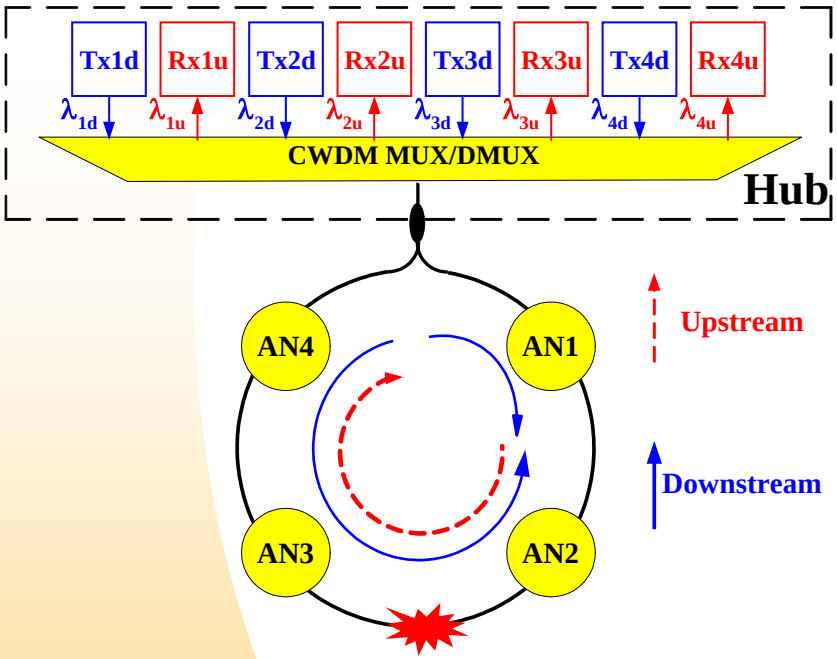
E. S. Son et al, "Survivable network architectures for WDM PON", *OFC/NFOEC'05*, Paper OFI4, Anaheim, California, USA, 2005.

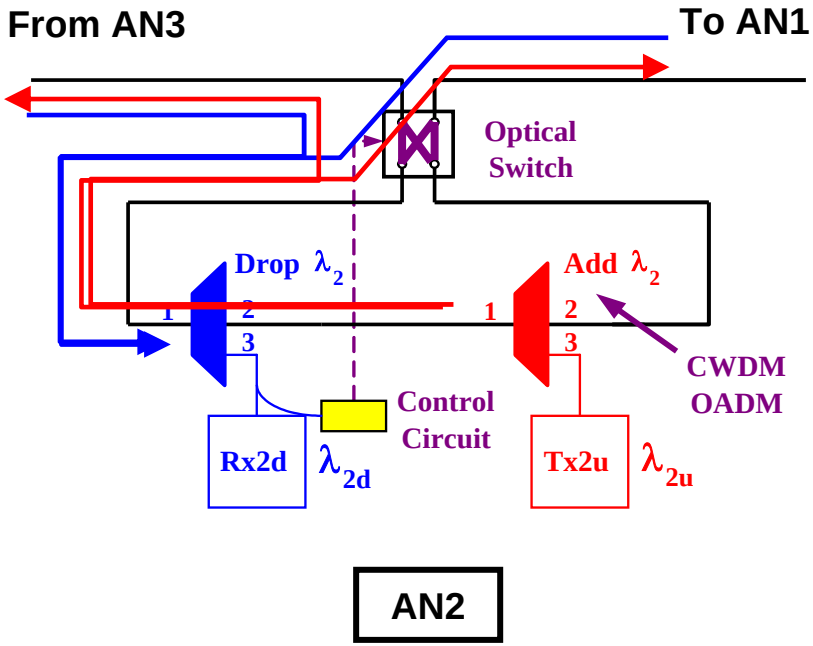
Using *N*×*N* AWG at RN



K. Lee, S. G. Mun, C. H. Lee, and S. B. Lee, "Reliable wavelength-division-multiplexed passive optical network using novel protection scheme," *IEEE Photon. Technol. Lett., vol.* 20, No. 9, pp. 679-701, 2008.

Survivable Single-Fiber Access Ring





Z. X. Wang et al., "Demonstration of a single-fiber self-healing CWDM metro access ring network with uni-directional OADM," *IEEE Photonics Technology Letters*, vol. 18, no. 1, Jan. 2006.

Issues

- For evaluation of various feasible survivable network architectures, here are some issues to consider / compare
  - Degree of Protection: feeder fiber, and/or distribution fibers, and/or WDM router at remote node, and/or ONUs, and/or transceivers at OLT, etc.
  - Network Availability
  - Ease of management and control (at OLT or ONU)
  - Amount of duplicated and additional fibers/components → cost / complexity
  - Intrusiveness to the other in-service traffic
  - Traffic restoration time
  - Practical issues, such as availability of laid fiber, power consumption, etc.