WDM for Future Access Architecture

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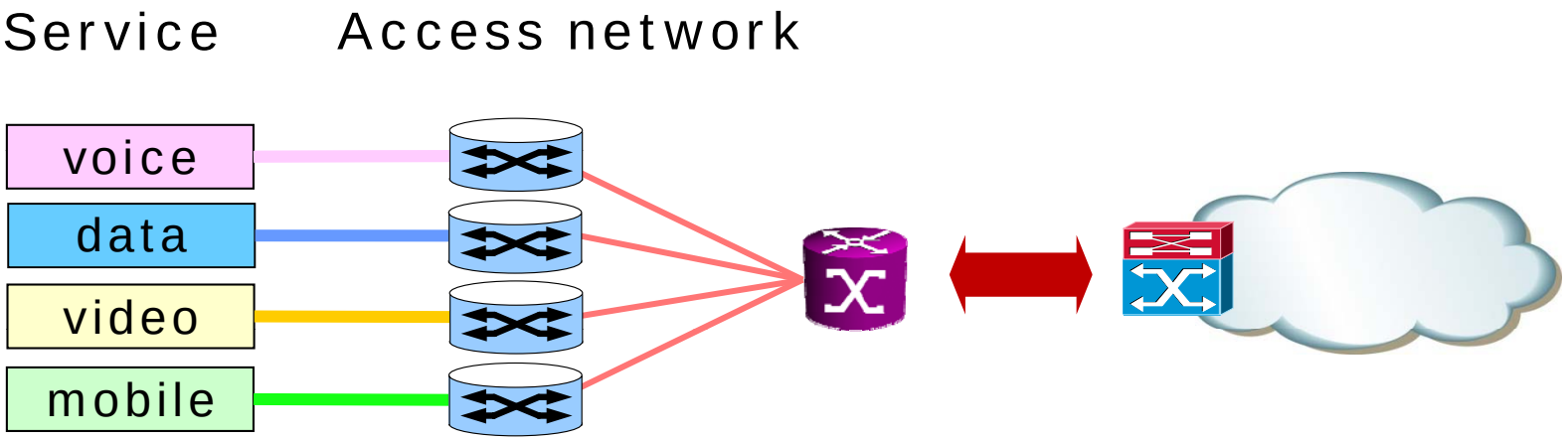
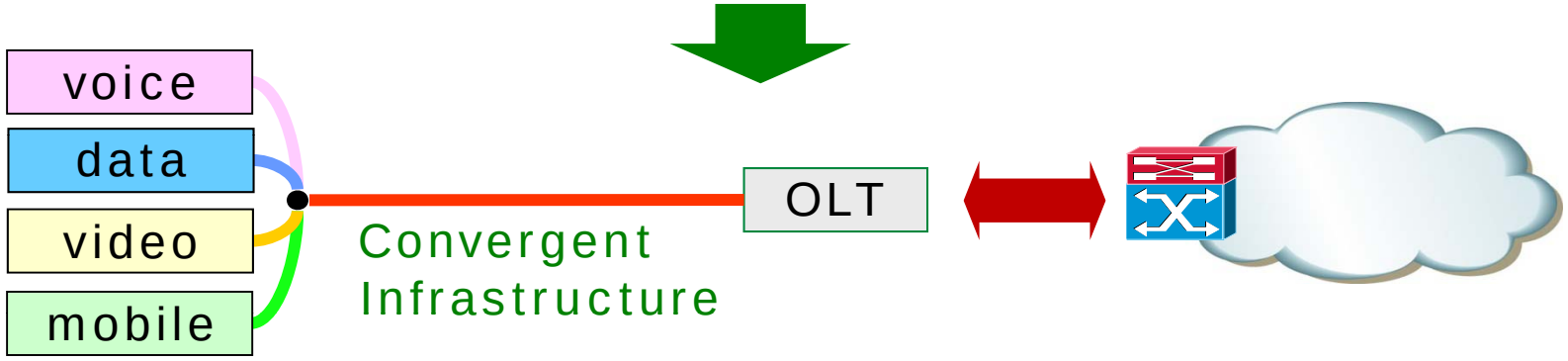
Agenda

1. Issues in Future Access
2. WDM for Future Access
3. WDM-PON Status
4. Other Issues
5. Conclusions

Issues in Future Access: Convergence



Various services converged into a common infrastructure

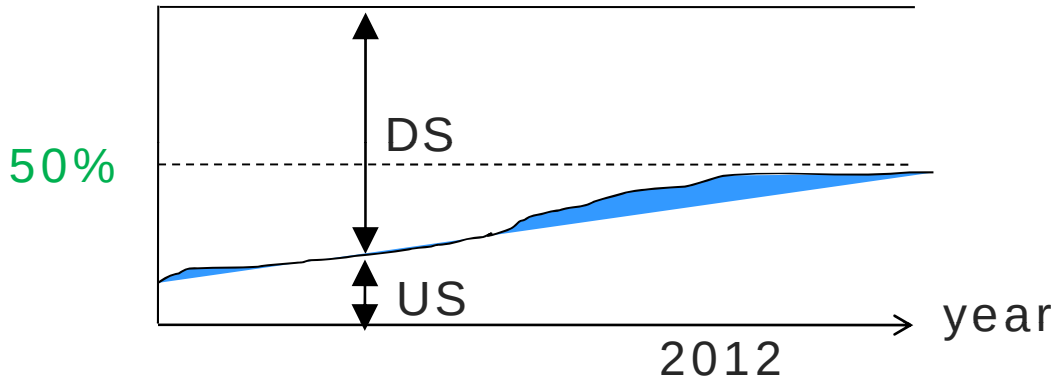


Issues in Future Access: More Symmetrical Traffic

Services	Nature
IP-TV	Multicast
IP-Education	Multicast now, but toward Interactive p2p
IP-Business	Interactive p2p
IP-Culture	Interactive p2p

- Decrease in statistical multiplexing of upstream traffic
- Decrease in downstream broadcasting

Leading to p2p & symmetrical BW

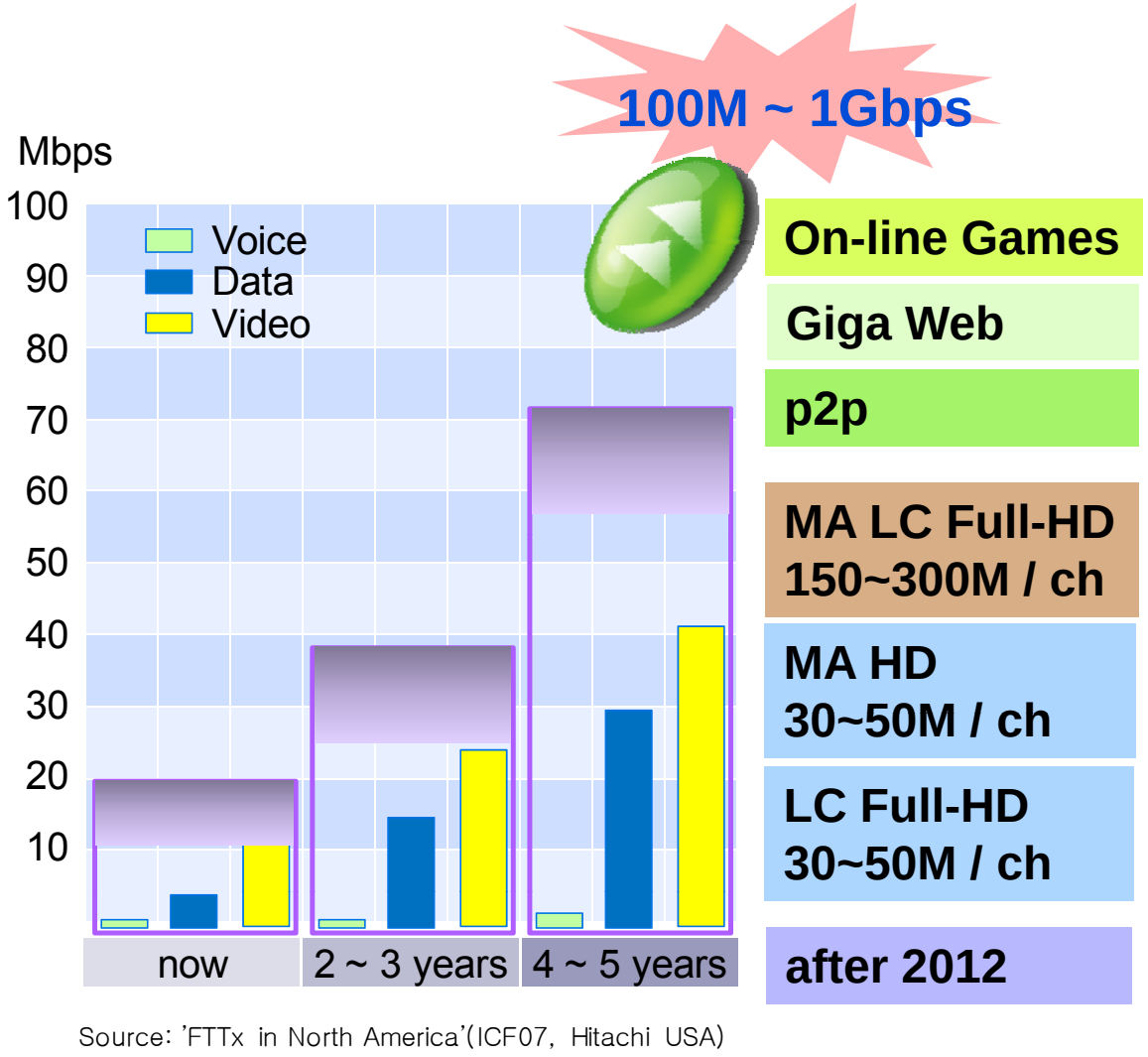


Issues in Future Access: Larger BW

Current Bandwidth Demand	
Voice	64-100Kbps
Data	2 – 5Mbps
Video (2 SDTV)	4 – 6Mbps
HDTV (one 42")	6 – 9Mbps
TOTAL	**12 – 20Mbps**

Bandwidth Demand in 2-3 Years	
Voice/Multimedia	300-600 Kbps
Data	10 – 15 Mbps
Video (2 SDTV)	2 – 4 Mbps
HDTV (27")	3 – 5 Mbps
HDTV (50"+)	10 – 15Mbps
TOTAL	**25 – 39Mbps**

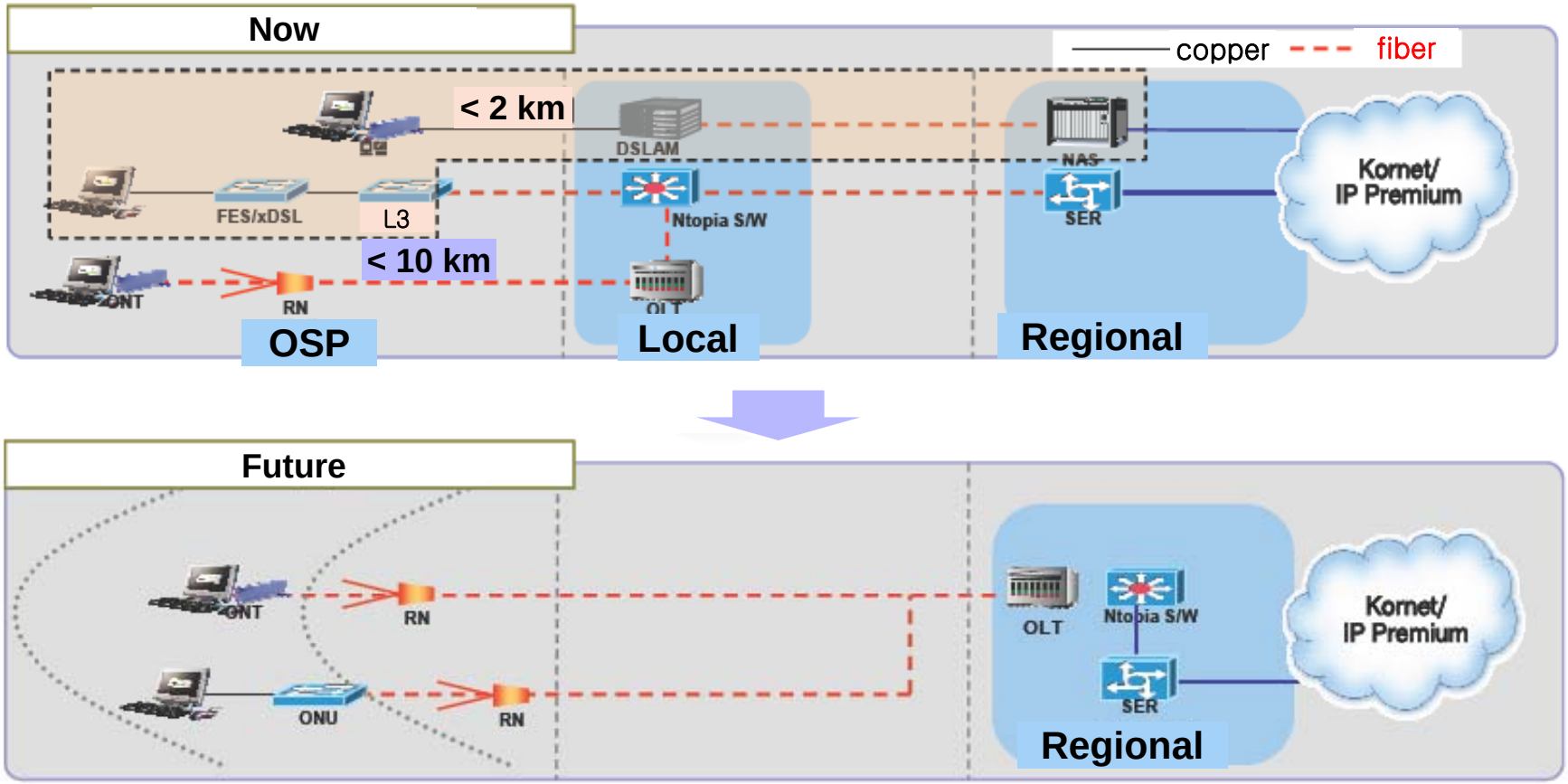
Bandwidth Demand in 4-5 Years	
Voice/Multimedia	0.5 – 1 Mbps
Data	100Mbps best effort (25-30M avg)
HDTV x 2 (35")	6 – 8Mbps
60fps/S-HD (50"+)	20 – 25Mbps
HDTV (PIP)	6 – 8Mbps
TOTAL	**57.5 – 72Mbps**



Source: 'FTTx in North America'(ICF07, Hitachi USA)

MA: Multi Angle LC: Low Compressed

Issues in Future Access: Long-Reach Access

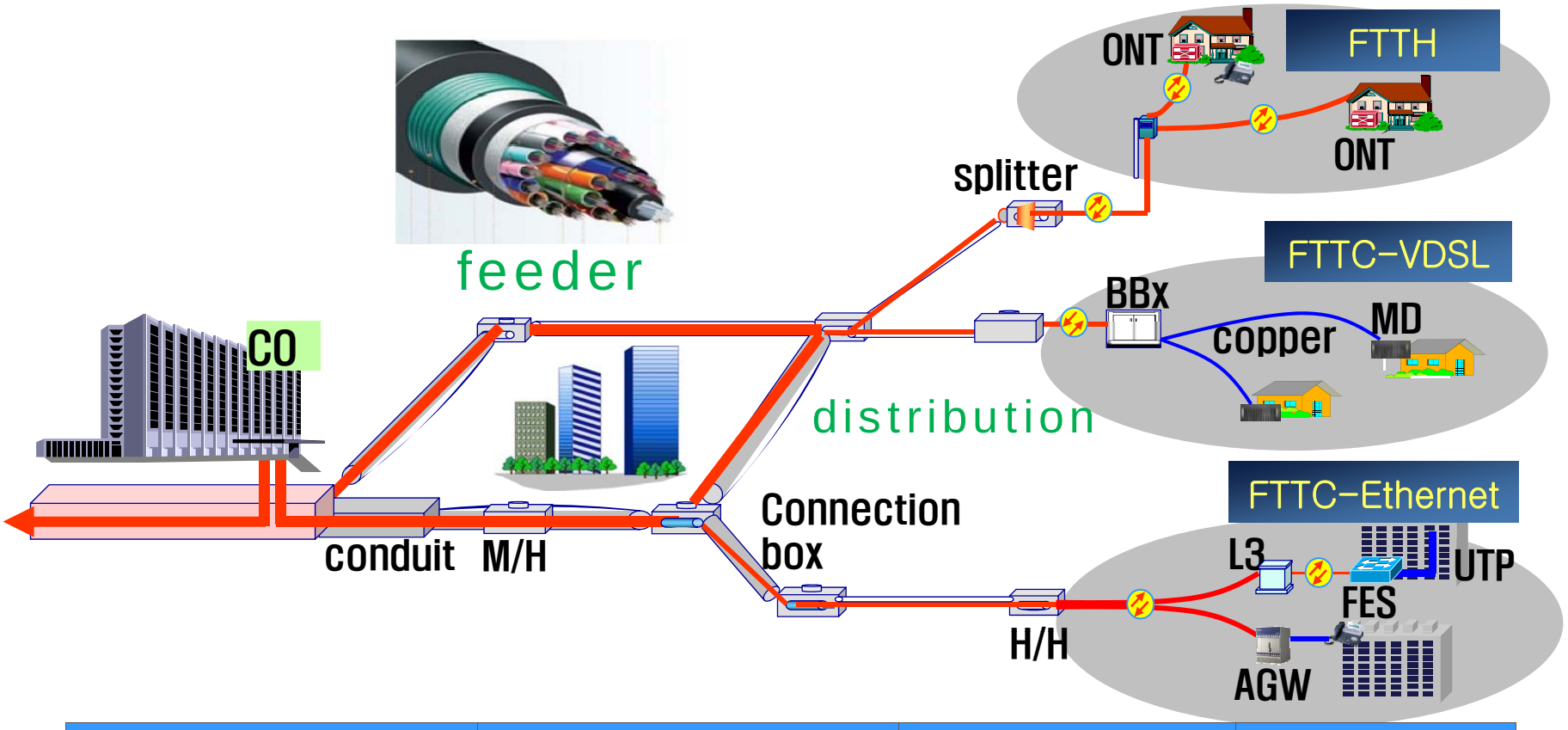


CO's	408	~ 200	~ 100
Coverage	4 km	20 km	50 km

PSTN ↓
Leased Lines ↓
High speed Internet ↓

Source: KT

Issues in Future Access: Open Infrastructure



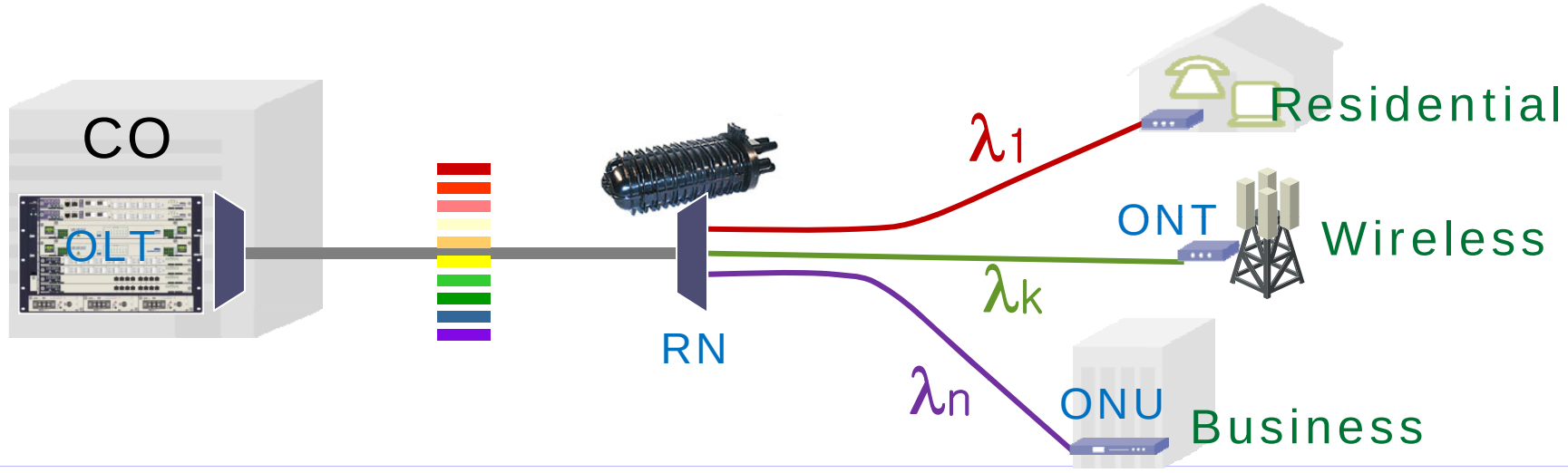
Technology	Feeder	Distribution	In Building
AON	Duct, Cable	Duct	
TDM-PON	Duct, Cable	Duct	
WDM-PON (1 λ)	Duct, Cable, Fiber	Duct, RN	
WDM-PON (2 λ's)	Duct, Cable, Fiber	Duct, RN, fiber	ONT

WDM for Future Access

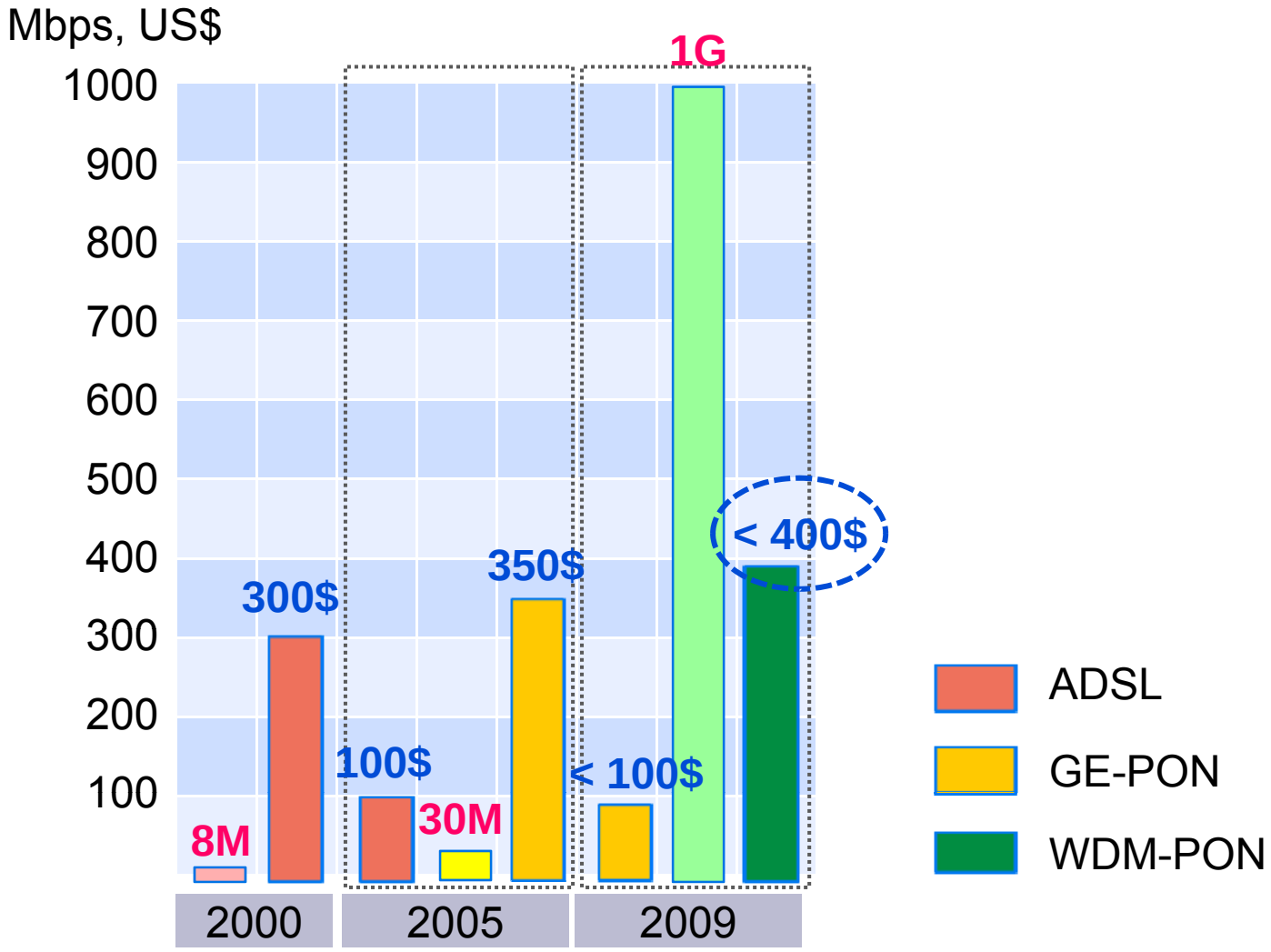
- Service and Network Convergence
- More Symmetric and Larger BW
- Long-Reach Access
- Open Infrastructure

- Logically independent p2p connectivity
- Increased total link speed
- Extended transmission distance

☞ Use of WDM is inevitable..
But we need different one from the legacy WDM in Backbone



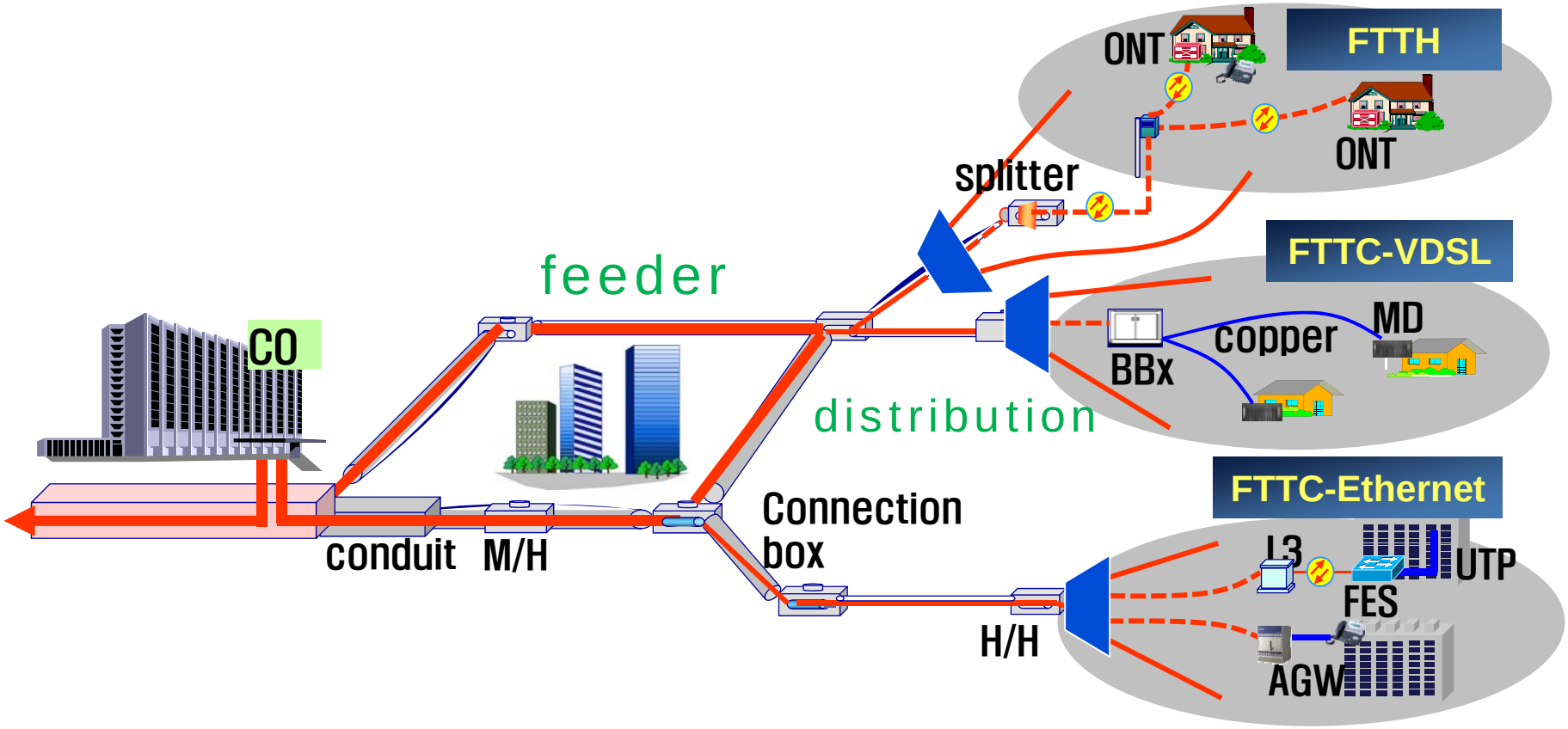
WDM for Future Access: Equipment cost



Source: Private communication

WDM for Future Access: Infrastructure Change

- Maximum compatibility with existing infrastructures
  - Coexistence with legacy PON
  - Minimum change in existing infrastructures



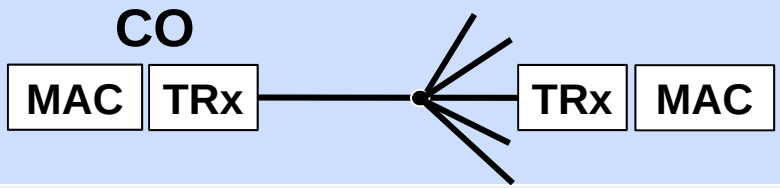
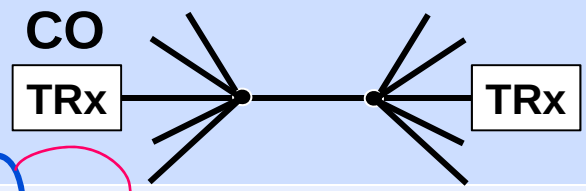
WDM for Future Access: Reduced Opex

Issues	Details	Directions
1. Scalability	● Bandwidth Extension ● Reach Extension ● Service Extension ● User Accommodation	● **Dense WDM** ● Wavelengths in low fiber loss and easy amplification
2. OAM Efficiency	● System Simplicity ● # of OAM points (active points) ● Energy Consumption	● **Colorless** ● Minimum Form Factor ● Protocol Transparent ● Minimum Power Consumption ● Layer-1 Extension
3. Networking Efficiency	● IOP ● Network Openness ● Topological Simplicity ● Service Convergence	

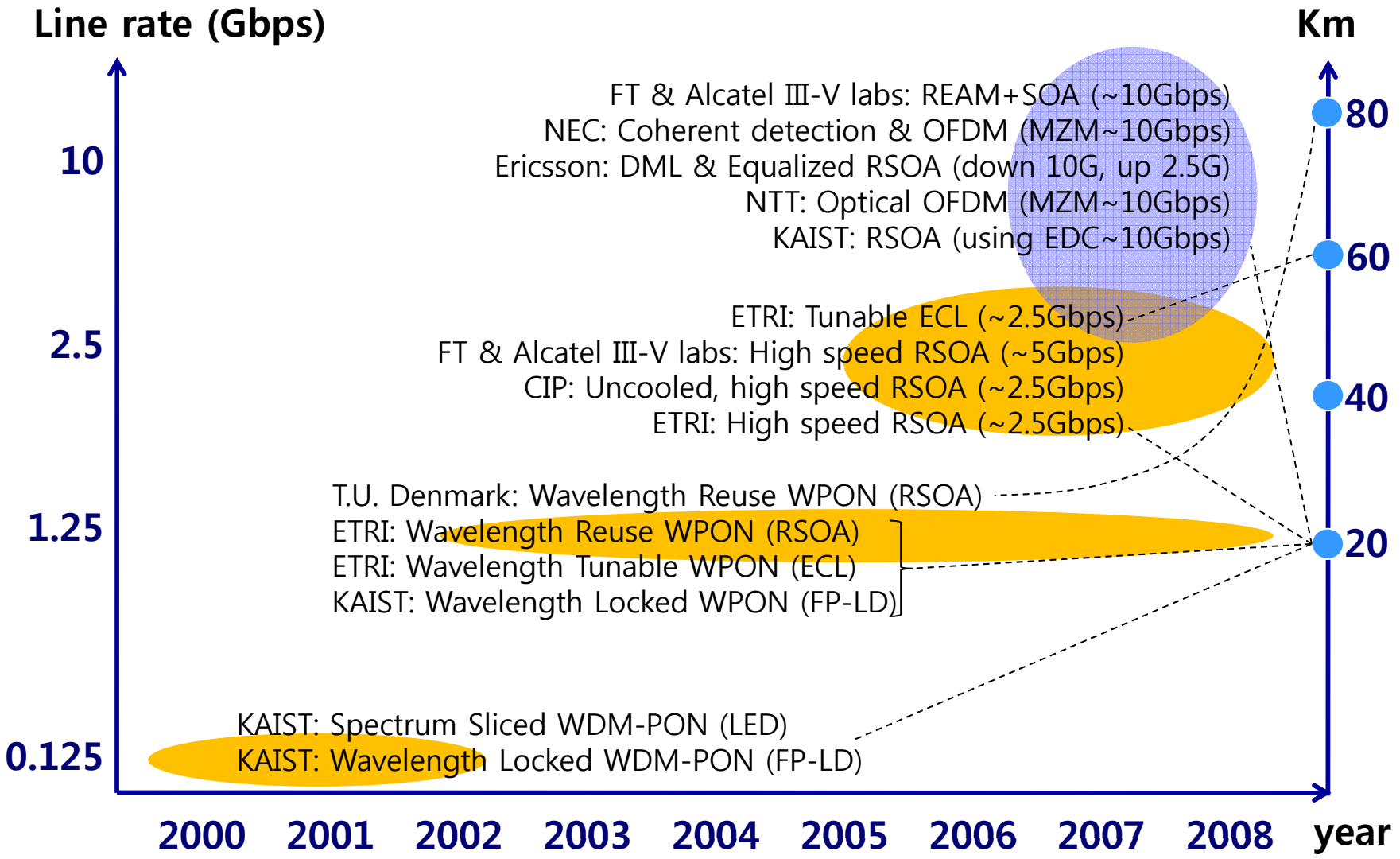
BB Service
CAPEX: $200/line
Rate: $20/month
ROI duration: 24 months

OPEX is bigger than CAPEX

WDM for Future Access: Comparisons

	EPON	WPON
Topology	➢ Fiber is shared by 32 on TDMA 	➢ Fiber is shared by 32 on WDM 
TRx	➢ 1 + N ➢ Cheap ➢ No inventory	➢ N + N ➢ Expensive ➢ No inventory Need larger space
Link	➢ Burst Mode (1~2dB power penalty) ➢ Power splitter (17dB power loss) ➢ 1310nm (0.35dB/km)	➢ Continuous Mode ➢ WDM MUX (4dB power loss) ➢ 1550nm (0.2dB/km)
Protocol	➢ Protocols for TDMA ➢ Decrease effective BW ➢ Cause large latency ➢ Increase complexity in system OAM ➢ inter-ch. traffic dependence (shared BW)	➢ Transparent ➢ No BW loss ➢ Only propagation delay ➢ Simple system operation ➢ Independent p-t-p channels
BW	➢ 1 Gbps per fiber	➢ 32 Gbps per fiber

WDM-PON Status: R&D Perspective

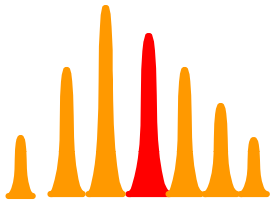


WDM-PON Status: Commercial Products

Wavelength Locking WPON

Fabry-Perot Laser Diode with

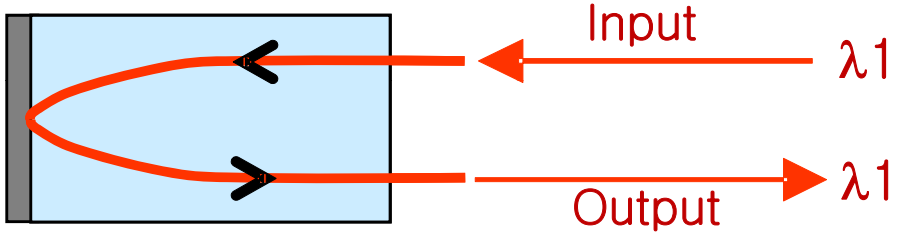
- Wide gain bandwidth
- AR coated front facet



Wavelength Reuse WPON

Reflective Semiconductor Optical Amplifier as

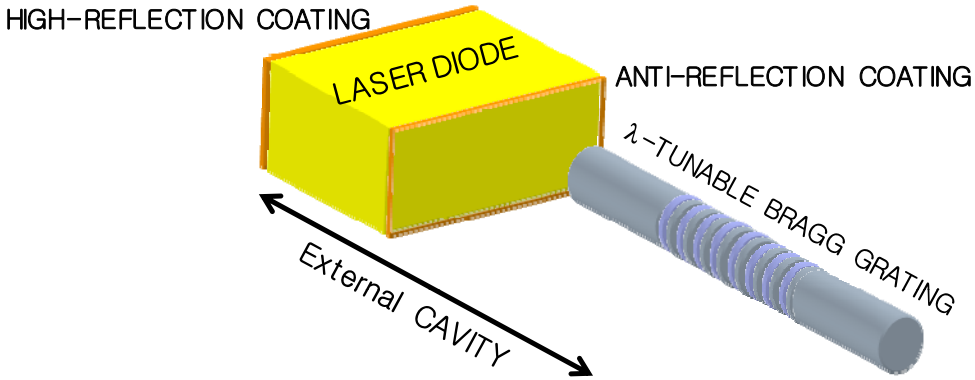
➔ Eraser + Amplifier + Modulator



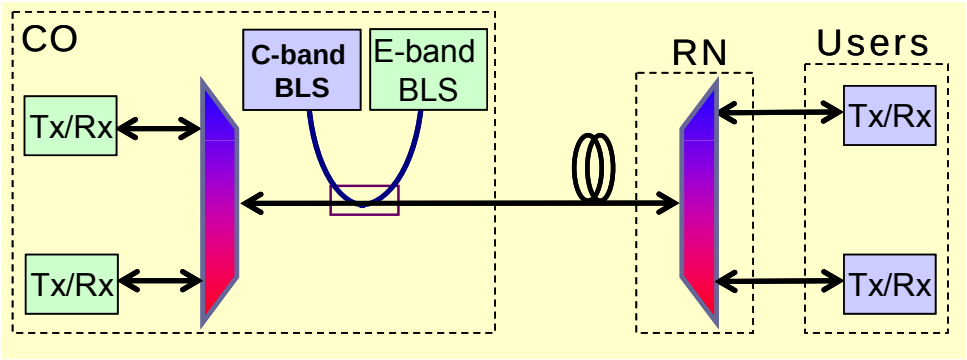
Wavelength Tunable WPON

External Cavity Laser as

➔ Low-cost Tunable Laser

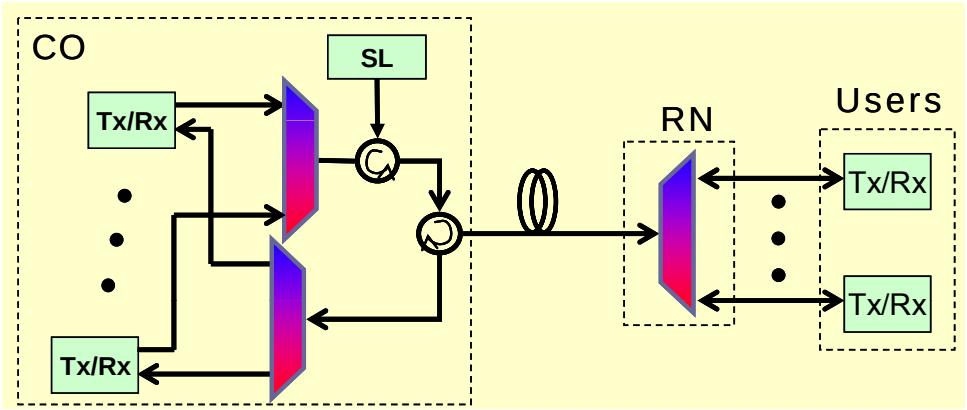


WDM-PON Schemes with commercial products



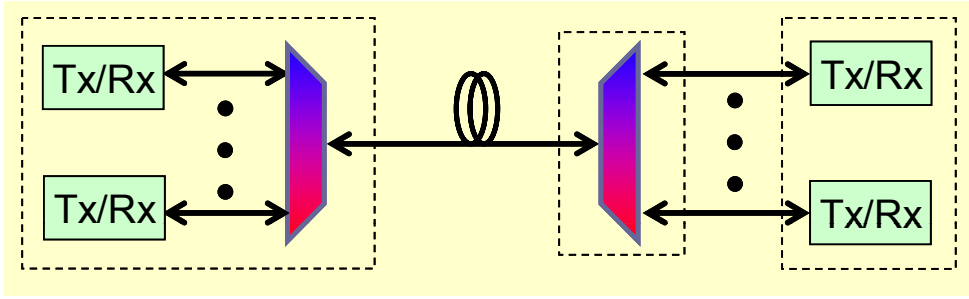
Wavelength Locking (KIAST)

- **Two BLSs for seeding light to OLT and ONU**
- **E-band for DS, C-band for US**
- **Special FP-LD in Transmitters**



Wavelength Re-use (ETRI)

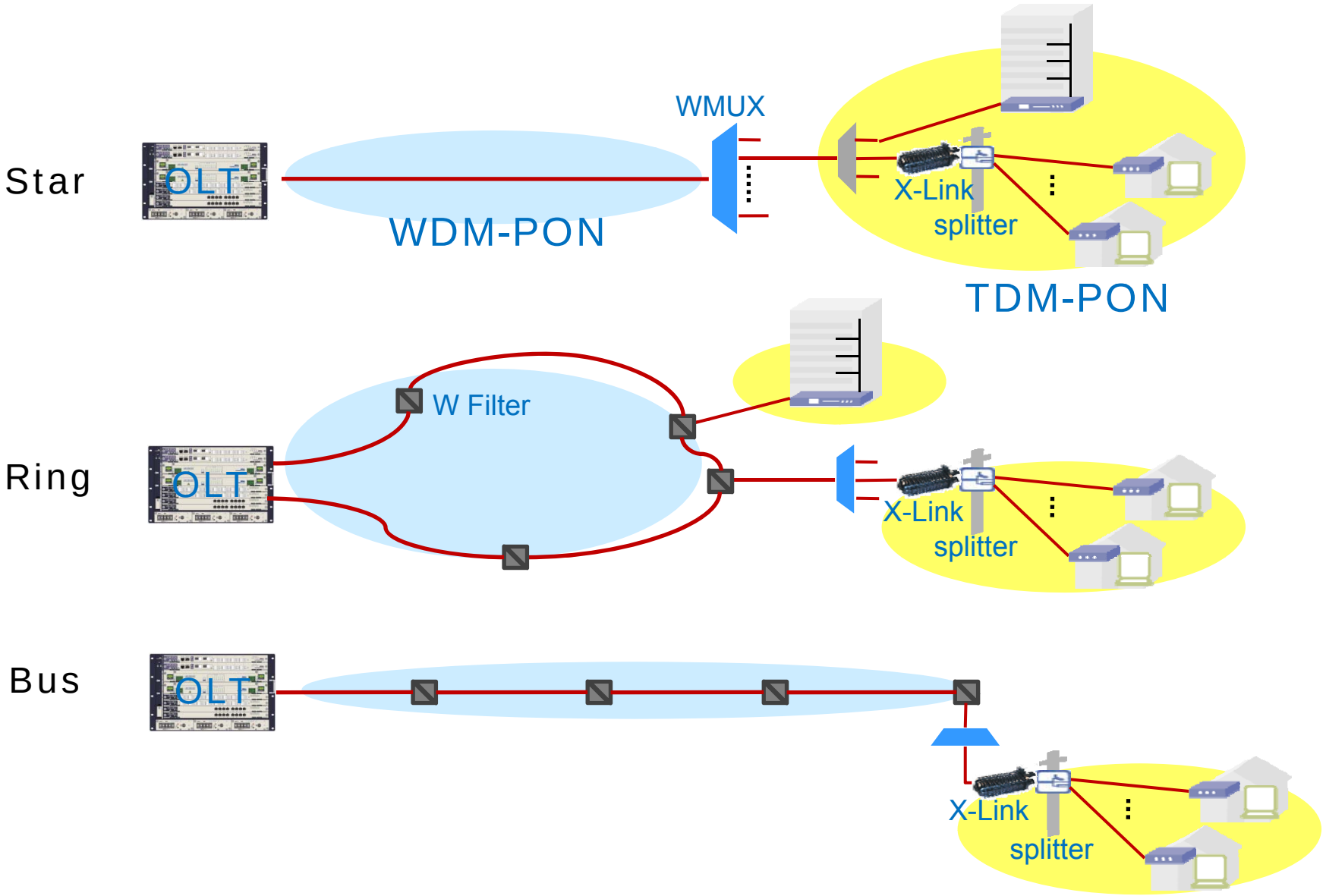
- **One Seed Light for OLT transmitters**
- **Reuse of DS light for US transmission**
- **RSOA in transmitters**



Wavelength Tunable (ETRI)

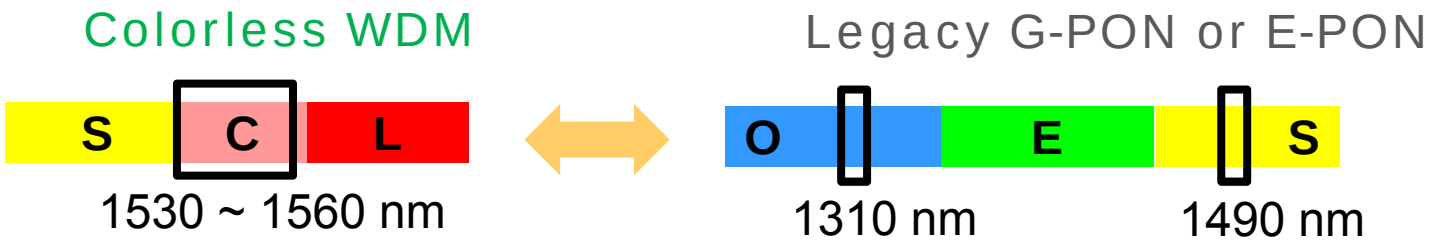
- **No Seed Light needed**
- **Low-cost Tunable ECL in transmitters**

Hybrid PON for Longer reach & Smooth migration

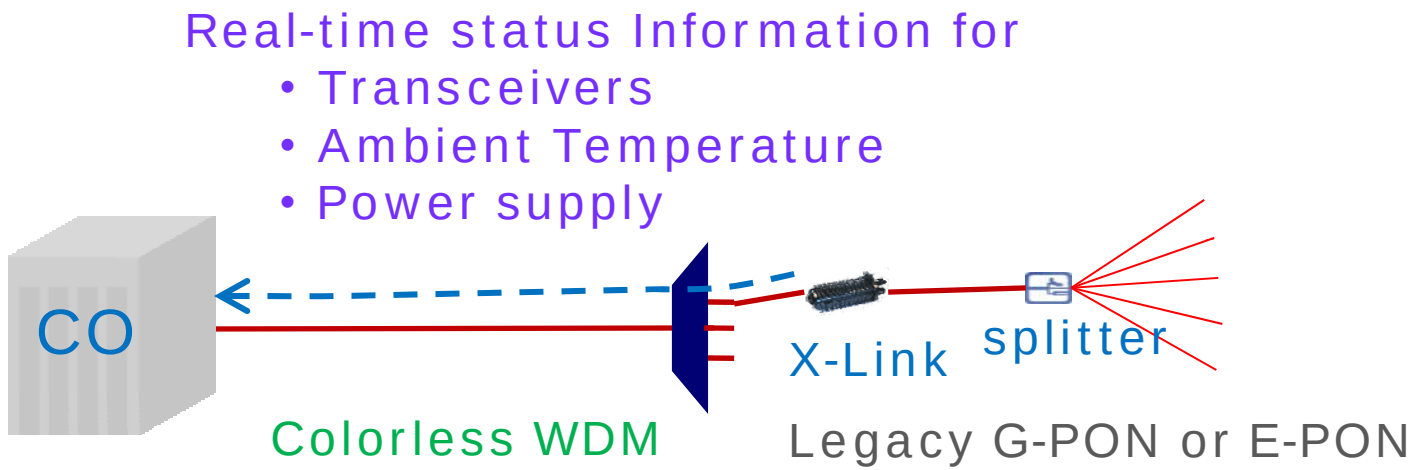


X-Link as a Layer 1 Extender

① Wavelength Conversion



② Remote OAM from CO in Physical Layer

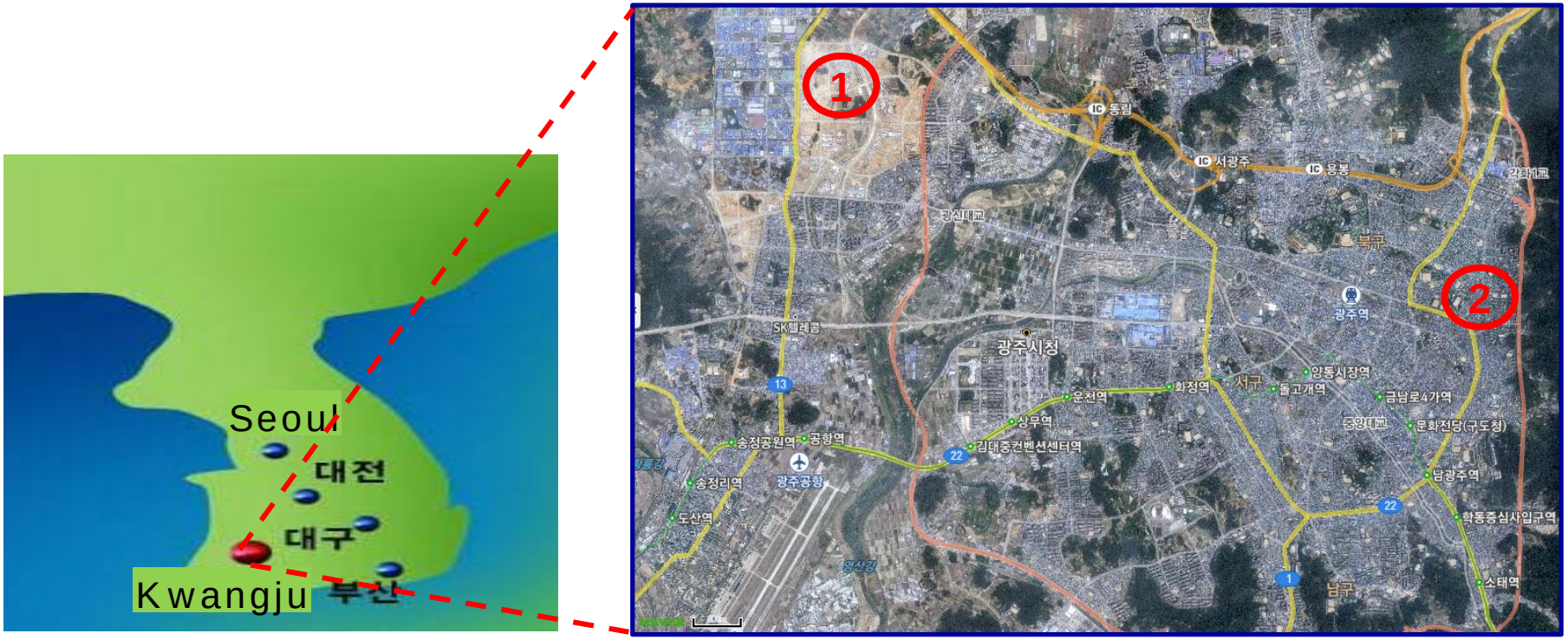


WDM-PON Status: Commercial Service

☐ Reference sites to commercial services

① **Wavelength Reuse WPON** in East Kwangju city by KT since March, 2008

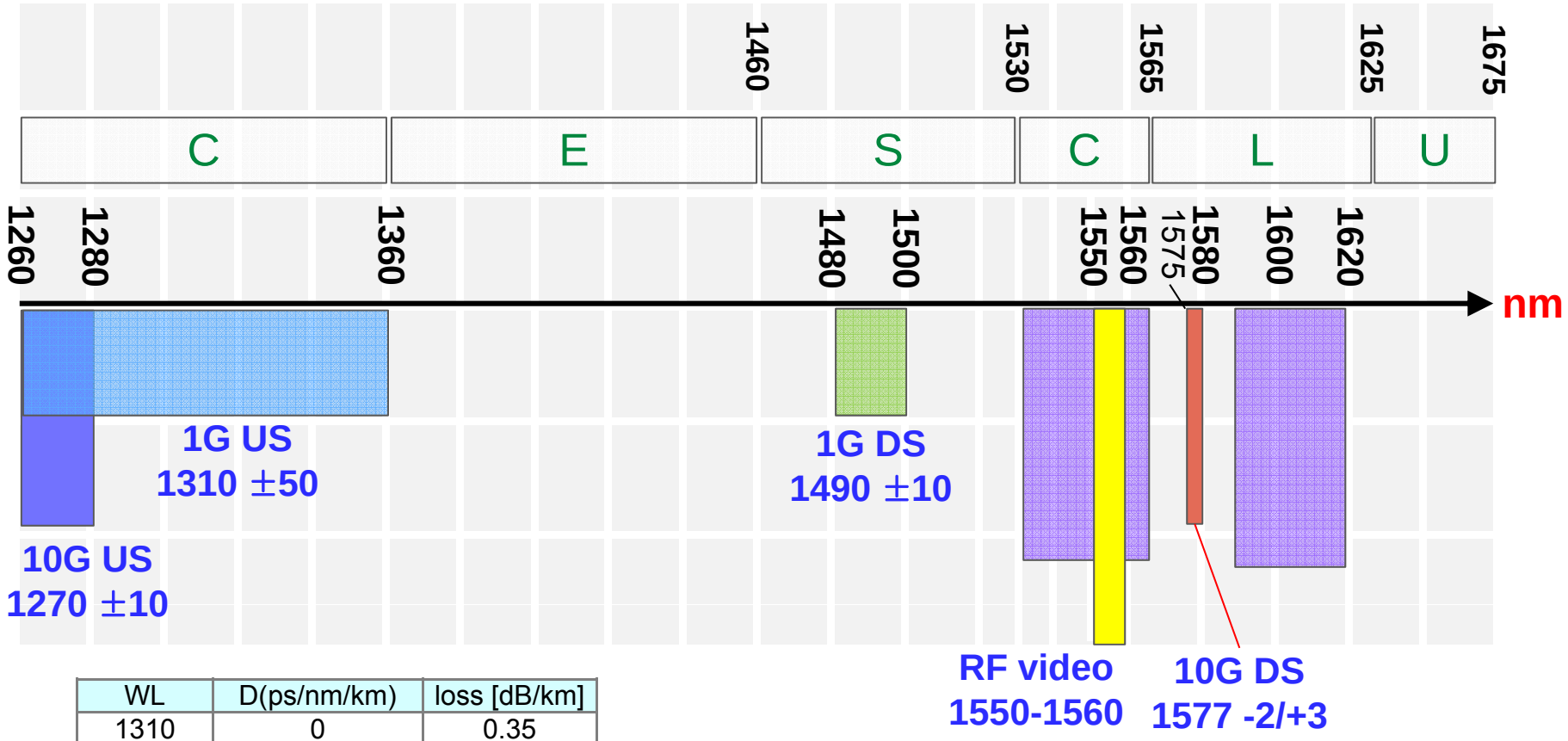
② **WDM-TDM-PON** in North Kwangju city by KT from April, 2009



Other Issues: Standardization

- **Fundamental Differences in**
  - **Wavelength band**
  - **Colorless method**
- **Difficult to achieve complete interoperability**
- **Two-category standardization**
  1. Category for common OSP and Link OAM
     - **Wavelength band**
     - **Wavelength spacing**
     - **Number of channels**
     - **Channel rate**
     - **Filter spec.**
     - **Tx and Rx spec.**
     - **Link OAM**
  2. Category for further details
     - **Differential items from colorless schemes**

Other Issues: Wavelengths for coexistence



WL	D(ps/nm/km)	loss [dB/km]
1310	0	0.35
1425	8	0.35
1450	11	
1490	13	
1530	16	0.22 ~ 0.25
1560	18	
1580	19	
1600	20	

For Long-Reach & Colorless WDM
US: 1525 ~ 1550 ~ 1565 nm
DS: 1590 ~ 1615 nm

Conclusions

Use of WDM is inevitable for future access to implement

- Service and Network Convergence
- More Symmetric and Larger BW
- Long-Reach Access
- Open Infrastructure

WDM for Access Networks needs to be

- Colorless
- Dense WDM
- Wavelengths in low fiber loss and easy amplification
- Smaller Form Factor
- Protocol Transparent
- Lower Power Consumption

Thank you....