Next Generation Passive Optical Networks

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Agenda

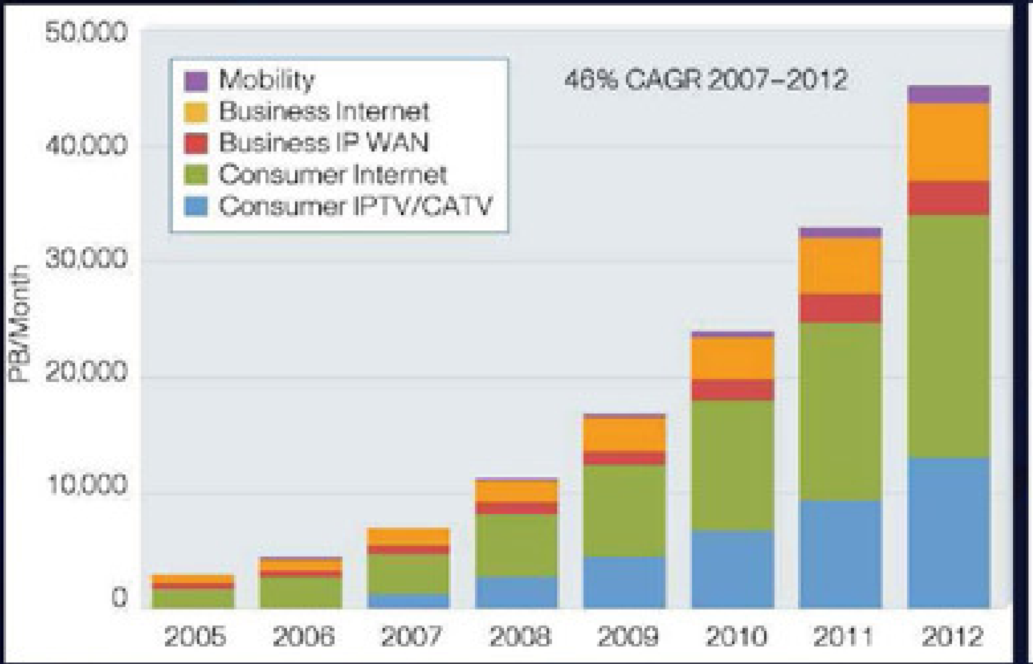
1 Industry and technology trends

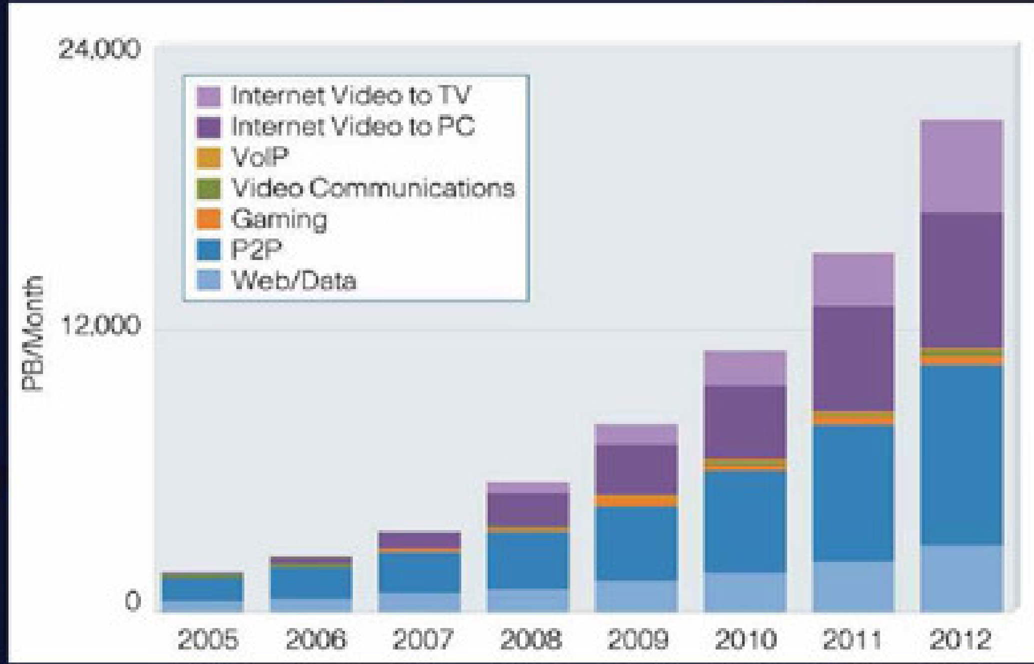
2 Next-generation PON chipset

3 10G EPON design consideration

4 Concluding remarks

Internet: Era of Zettabyte





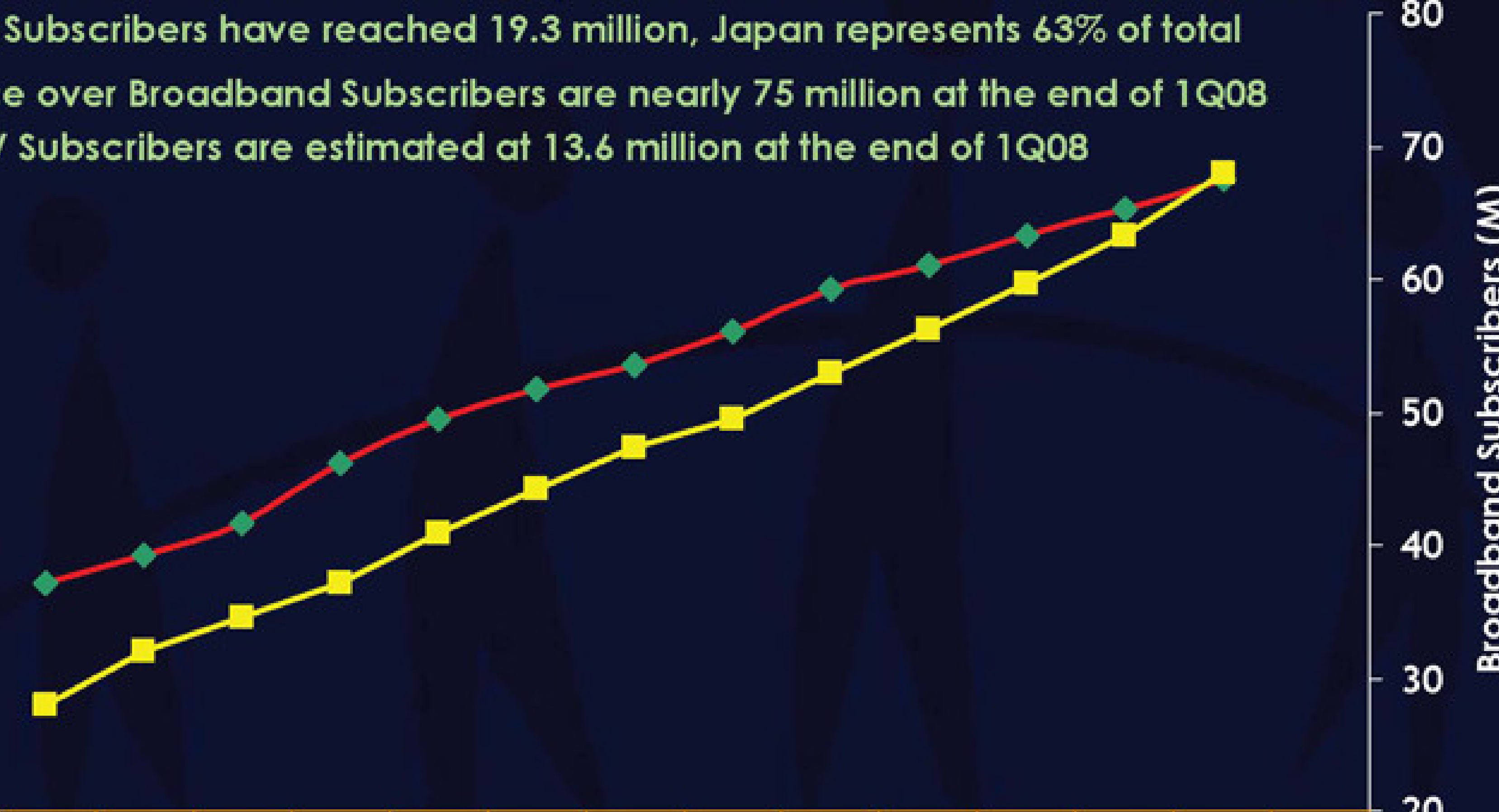
- Annual global IP Traffic will exceed half a zettabyte in four years.
- Global IP traffic will nearly double every two years through 2012
- Internet video is now approximately one-quarter of all consumer Internet traffic
- The sum of all forms of video (TV, VoD, Internet, and P2P) will account for close to 90 percent of consumer traffic by 2012
- In 2010 Internet video will surpass P2P in volume
- In 2012, Internet video will be nearly 400 times the U.S. Internet backbone in 2000
- Mobile data traffic will double each year from now through 2012

Prefixes
Kilo - 10^3
Mega - 10^6
Giga - 10^9
Tera - 10^{12}
Peta - 10^{15}
Exa - 10^{18}
Zetta - 10^{21}

Source: Cisco

Broadband Race (1Q05 – 1Q08)

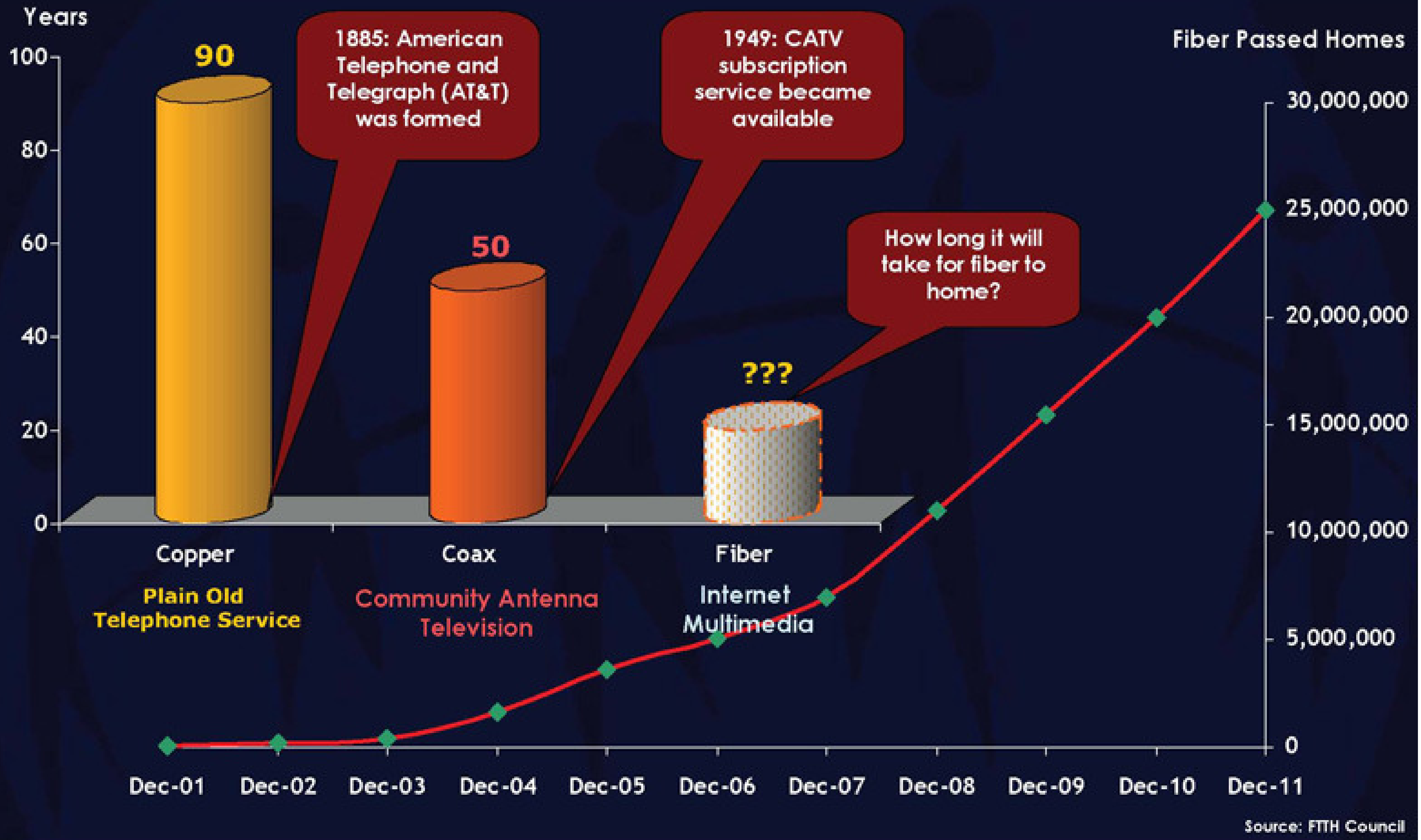
- China surpassed the US in 1Q'08 to be the global leader in # of broadband subscribers
- Global FTTH Subscribers have reached 19.3 million, Japan represents 63% of total
- Global Voice over Broadband Subscribers are nearly 75 million at the end of 1Q08
- Global IP-TV Subscribers are estimated at 13.6 million at the end of 1Q08



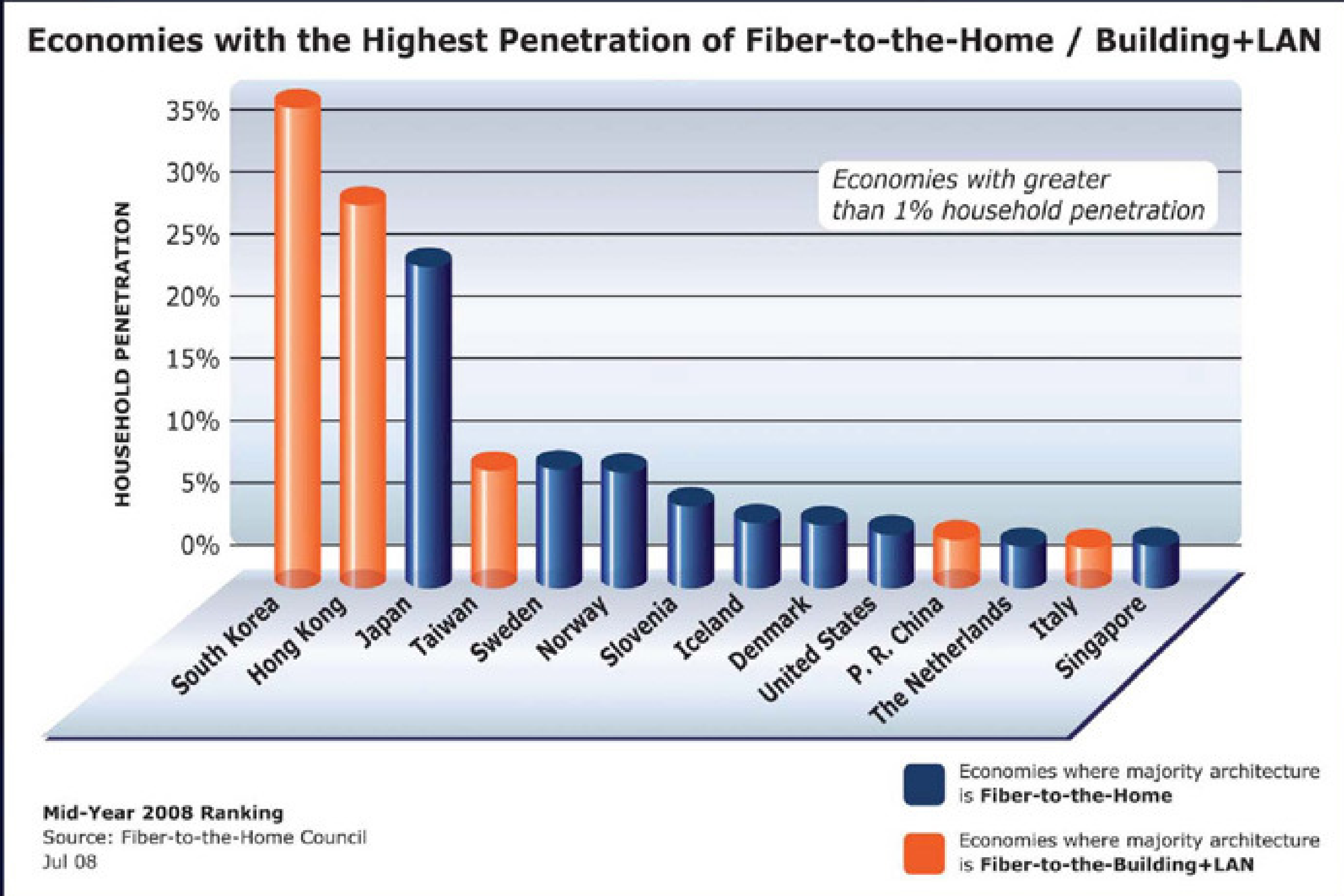
	1Q05	2Q05	3Q05	4Q05	1Q06	2Q06	3Q06	4Q06	1Q07	2Q07	3Q07	4Q07	1Q08	2Q08
North America	37.2	39.2	41.7	46.1	49.4	51.7	53.5	56.1	59.2	61.1	63.3	65.2	67.5	
China	27.9	32.1	34.6	37.2	40.9	44.2	47.4	49.4	52.9	56.3	59.7	63.3	67.9	

Source: broadbandtrends.com

Access Technology Evolution (NA)



Worldwide FTTH Penetration Ranking



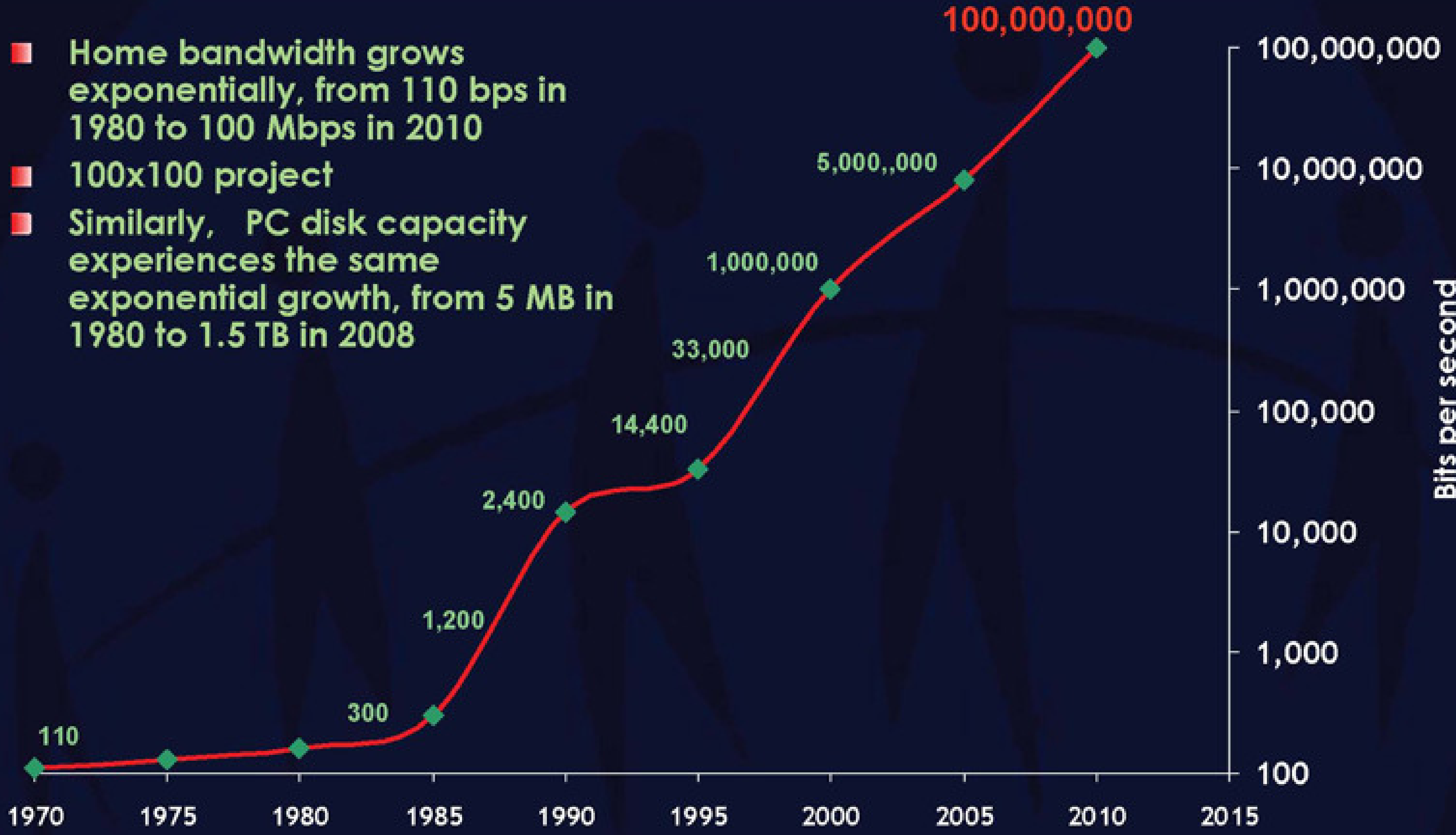
FTTH Households Growth (NA)

- FTTH households in North America reached 3.3 million in August 2008, with 2.9% market penetration
- The U.S. continues to experience the highest rate of growth of any economy in terms of FTTH subscribers - doubling the number of connections year over year.

Source: FTTH Council

Home Bandwidth Growth

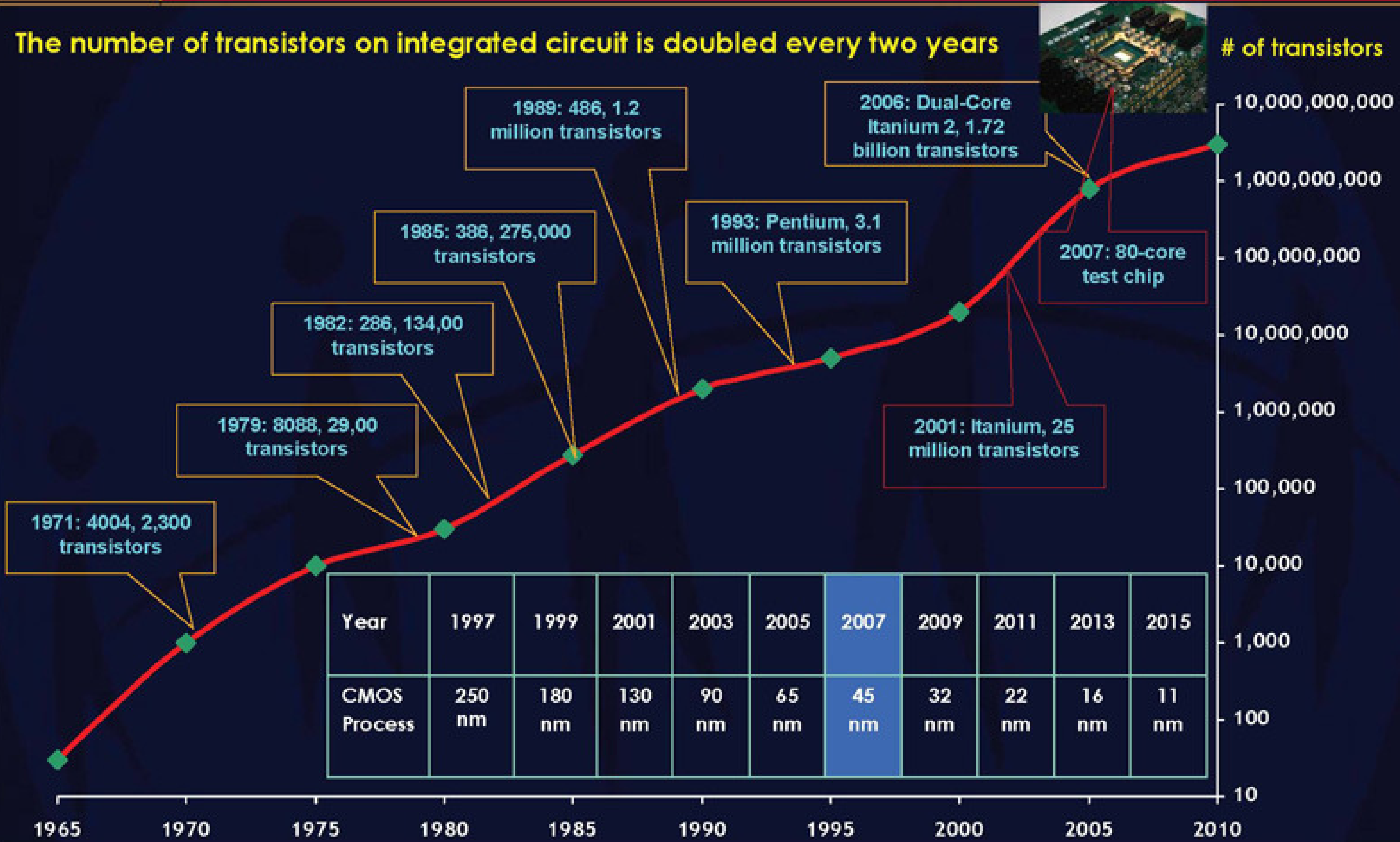
- Home bandwidth grows exponentially, from 110 bps in 1980 to 100 Mbps in 2010
- 100x100 project
- Similarly, PC disk capacity experiences the same exponential growth, from 5 MB in 1980 to 1.5 TB in 2008



Source: FTTH Council

Moore's Law: Era of Tera

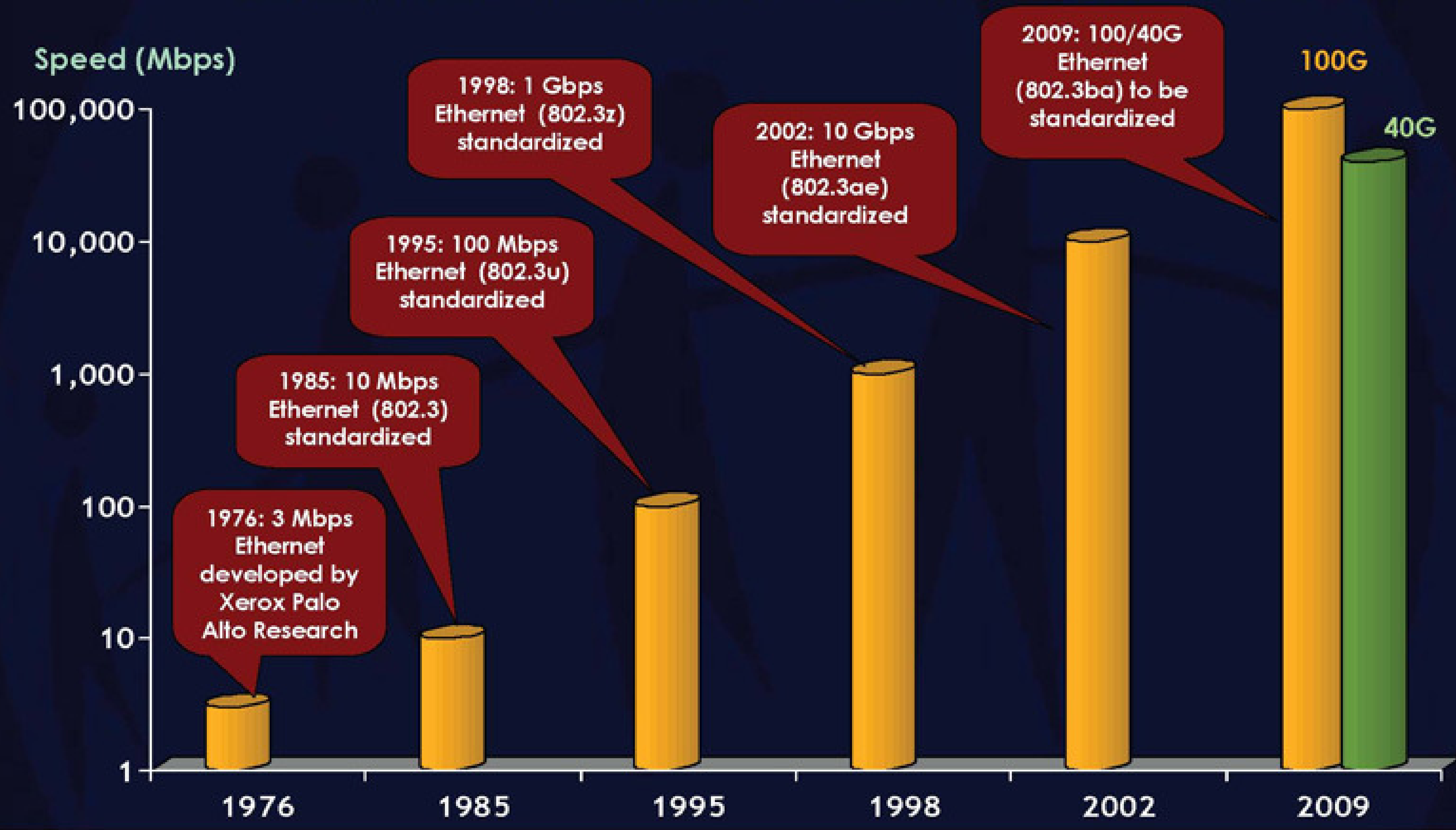
The number of transistors on integrated circuit is doubled every two years



Year	1997	1999	2001	2003	2005	2007	2009	2011	2013	2015
CMOS Process	250 nm	180 nm	130 nm	90 nm	65 nm	45 nm	32 nm	22 nm	16 nm	11 nm

Ethernet Timeline

Ethernet speed has been 10 x increased about every five years at a reduced cost



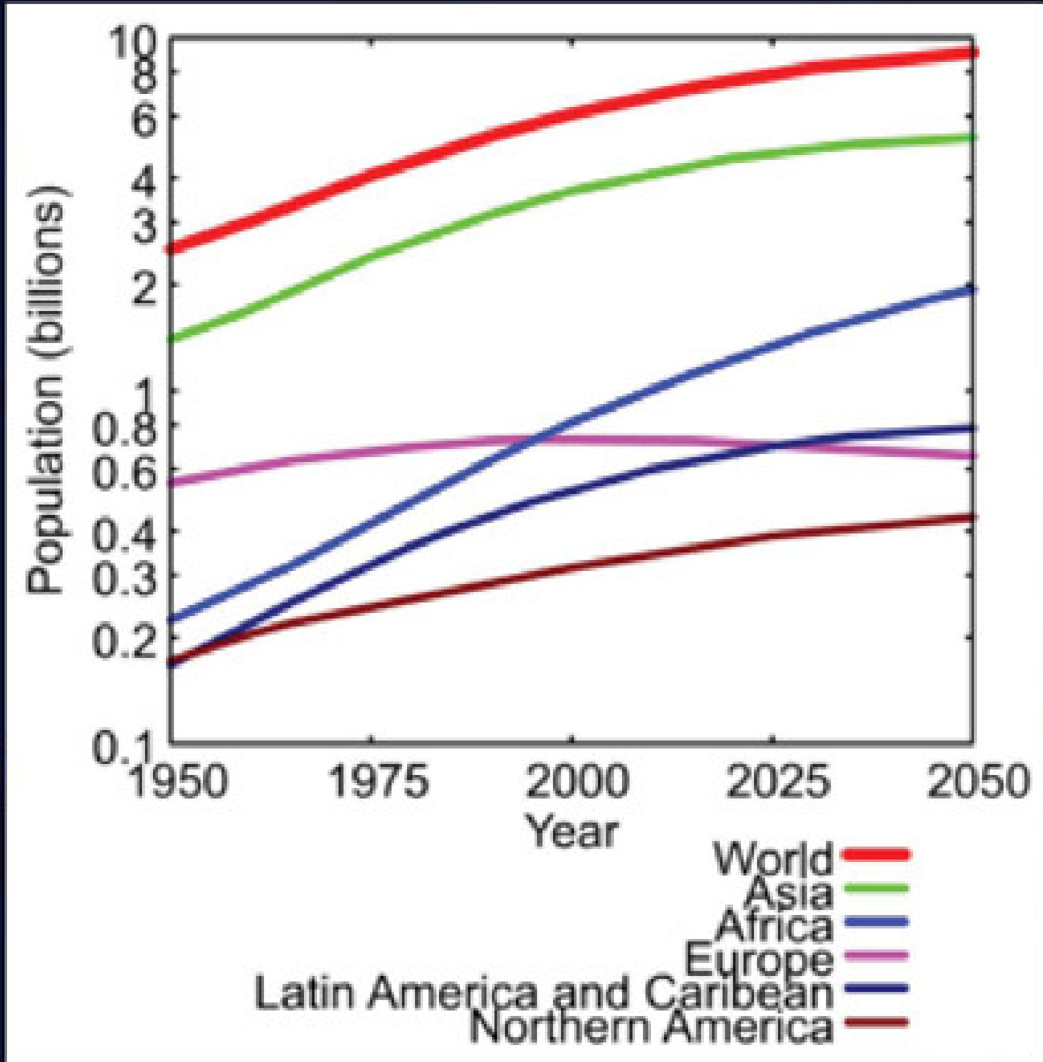
Metcalfe's Law and Network Evolution Theory

Metcalfe's Law

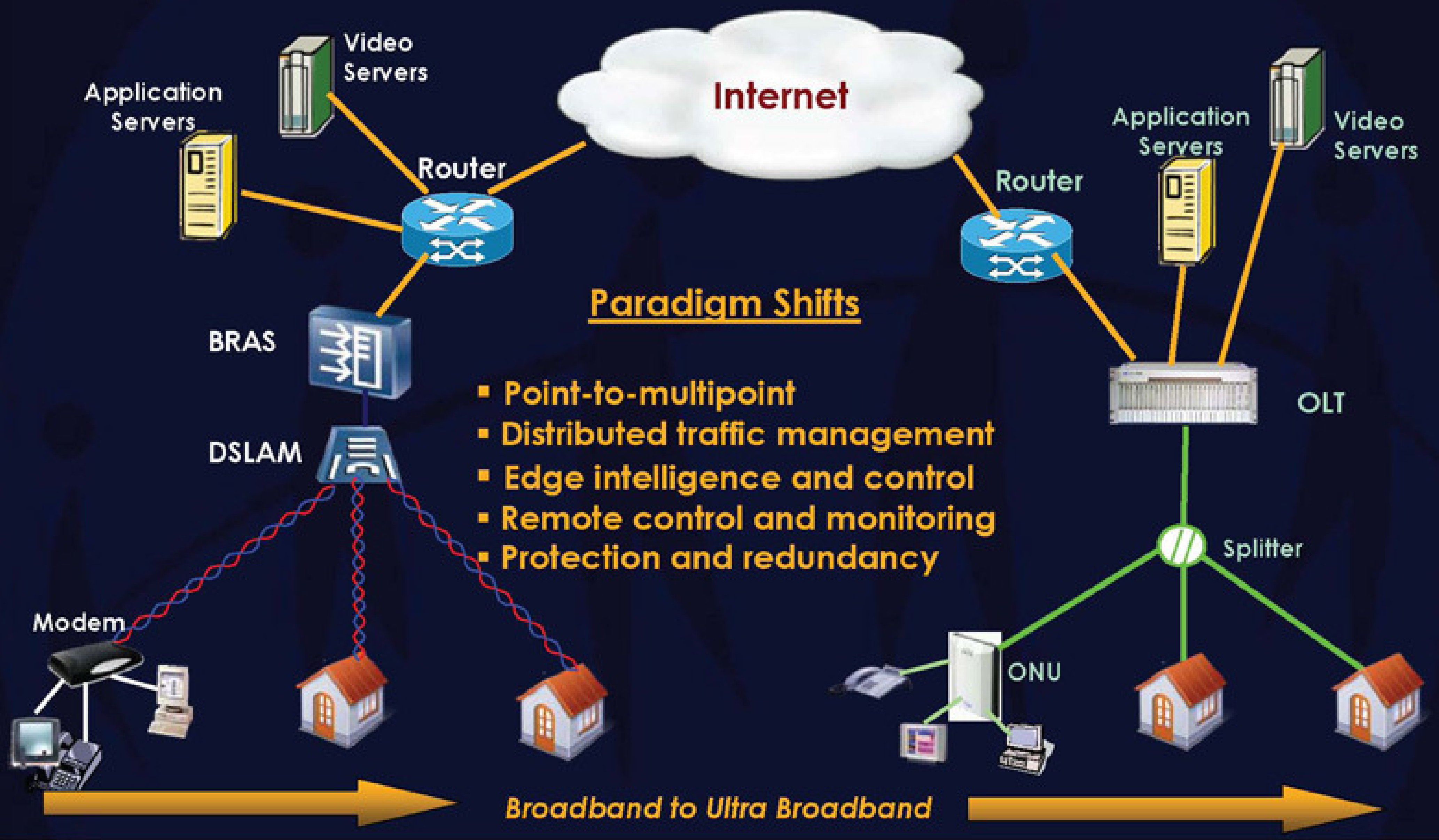
The value of
a telecommunication network
is proportional to
the square of the number of users of
the system (n^2).

Networks Theory of Evolution

One and only one competing
technology evolves to dominate a
market via *market selection.*



Evolution of Access Networks



Paradigm Shifts

- Point-to-multipoint
- Distributed traffic management
- Edge intelligence and control
- Remote control and monitoring
- Protection and redundancy

Broadband to Ultra Broadband

Evolution of EPON Chipset

1996

1st Generation Chipset

- Single Family ONU (SFU)
- Single PON port OLT
- Targeted at Japan and Korea markets
- Lack of key feature support
- Based on vendor-specific OAM
- High cost per subscriber

2nd Generation Chipset

- 4 PON port OLT
- SFU with extended feature set
- Based on carrier-or country defined OAM extension
- Enhanced performance
- Reduced cost per subscriber

Today

3rd Generation Chipset

- MDU with integrated LAN and DSL support
- SFU with integrated residential gateway
- SFU with integrated VoIP
- SFU with small footprint
- Significantly cost reduction for volume deployment

4th Generation Chipset

- 10G EPON
- Dual-rate and dual mode OLT
- Asymmetric or symmetric ONU chip
- International agreement for multi-vendor interoperability (encryption and management)

ONU Chip Types and Design Objectives

Low Cost

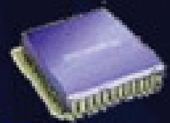
- Small footprint
- Fit into a SFP module
- Fit into other devices
- Reduced cost

SFU-Connector Chip

High Integration

- Integrated with residential gateway
- VoIP and security support
- Value added service
- Reduced total system cost

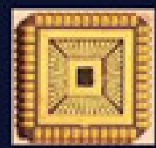
SFU-Residential Gateway Chip



MDU

- Multi-subscriber support
- Integrated with DSL or LAN
- Enhanced system performance

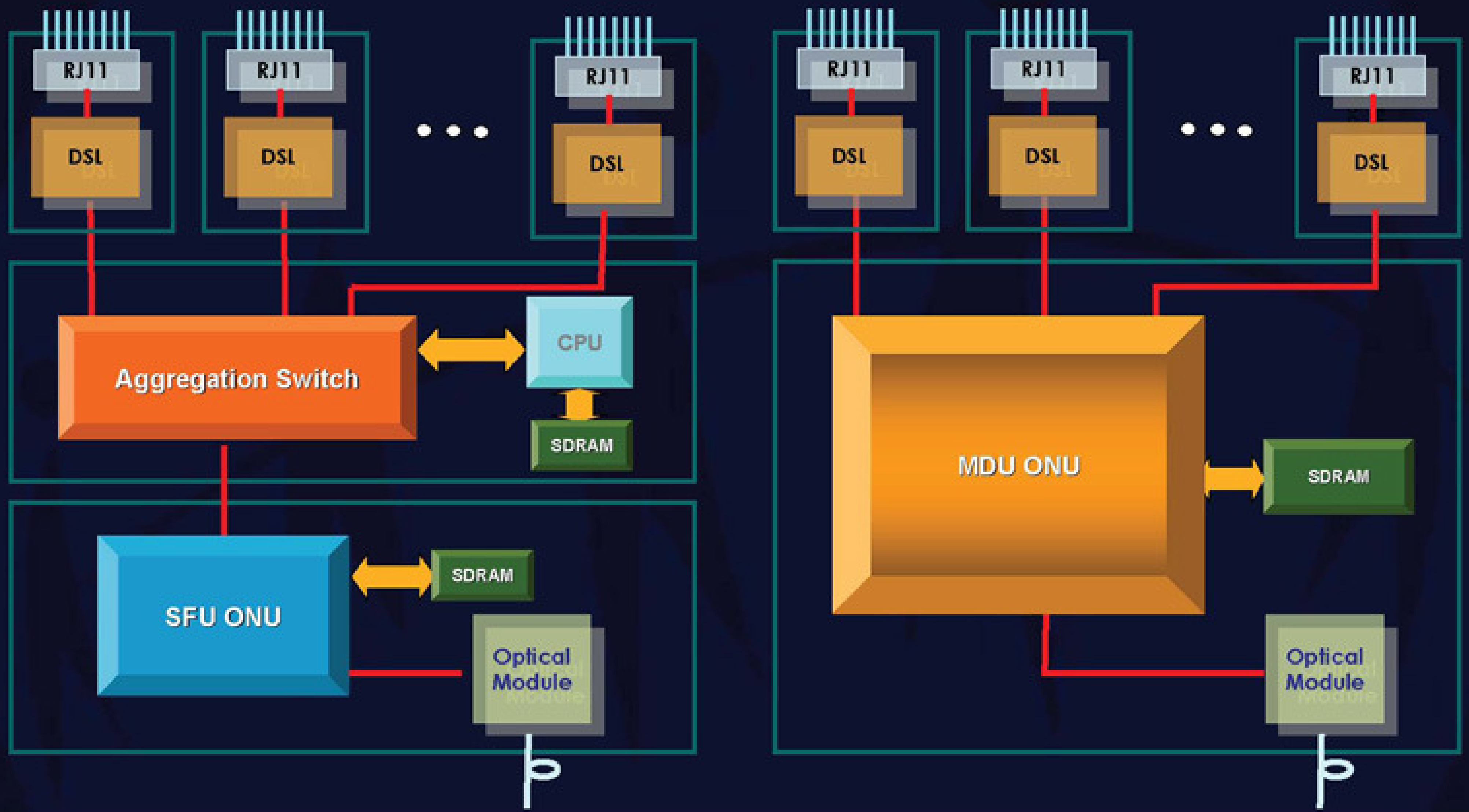
MDU Chip



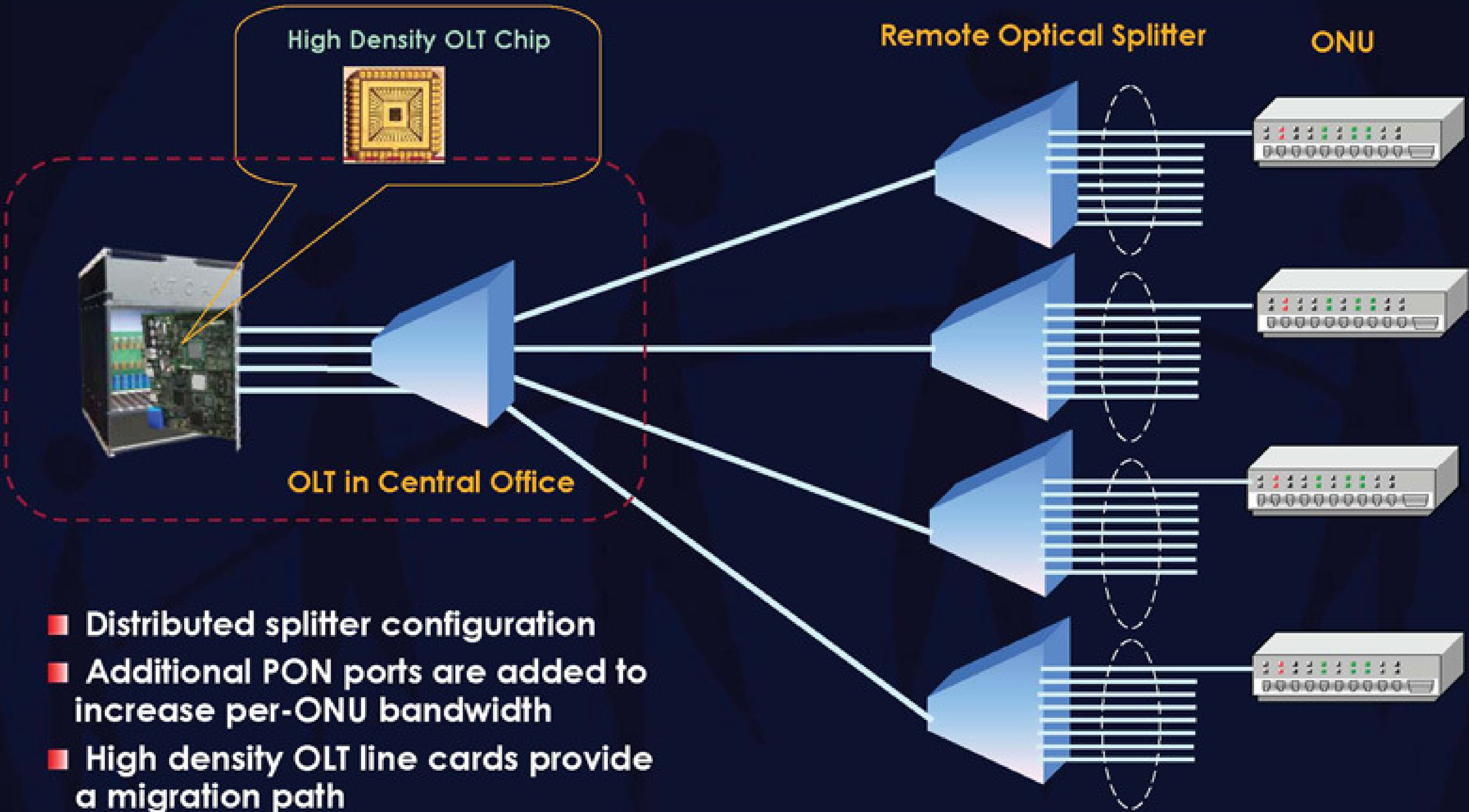
MDU Solution Comparison

Multiple-Chip Solution

Single-Chip Solution



High Density OLT for Migration



- Distributed splitter configuration
- Additional PON ports are added to increase per-ONU bandwidth
- High density OLT line cards provide a migration path

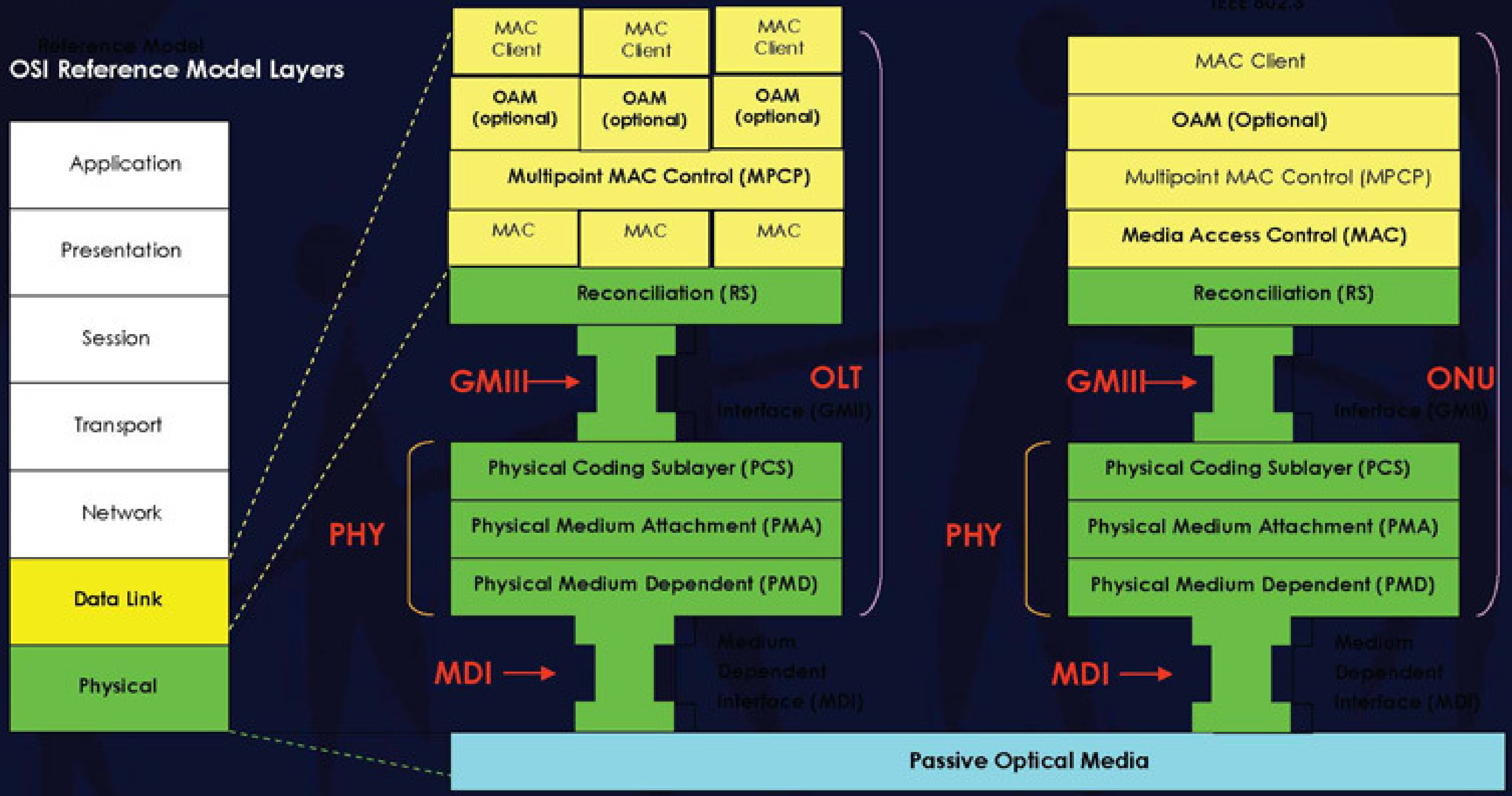
10G EPON Standard Development

- **March 2006**
  - CFI for 10G EPON
- **Sept 2006**
  - The first official task force meeting
  - 802.3av: PHY for 10G EPON
- **Nov 2007**
  - Draft 1.0 published
- **July 2008**
  - Draft 2.0 published
- **Mar 2009**
  - Draft 3.0 to be published
- **Sept 2009**
  - Final standard to be published

Baseline Proposal

- Serial 10.3125 Gb/s transmission
  - Existing "10GBase-R" PHY is the starting point
  - 64b/66b line code is used as basic protocol
- FEC code built-in from the start
  - Inclination is to use a strong "E-FEC", with more gain than RS(255,239)
  - Rate adaptation method is sub-rating (payload less than 10G)
- Two "nominal" PHYs: 10/1 and 10/10
  - Asymmetric rate: 10G downstream and 1G upstream
  - Symmetric rate: 10G downstream and 10G upstream
- Coexistence with 1G EPON on the same plant
  - Downstream: wavelength multiplexing (1490nm and 1590 nm)
  - Upstream: TDMA sharing (wavelength overlapping)
- Three power budgets
  - PR10 = 20dB, PR20 = 24dB, PR30 = 29dB

10G EPON Protocol Stack

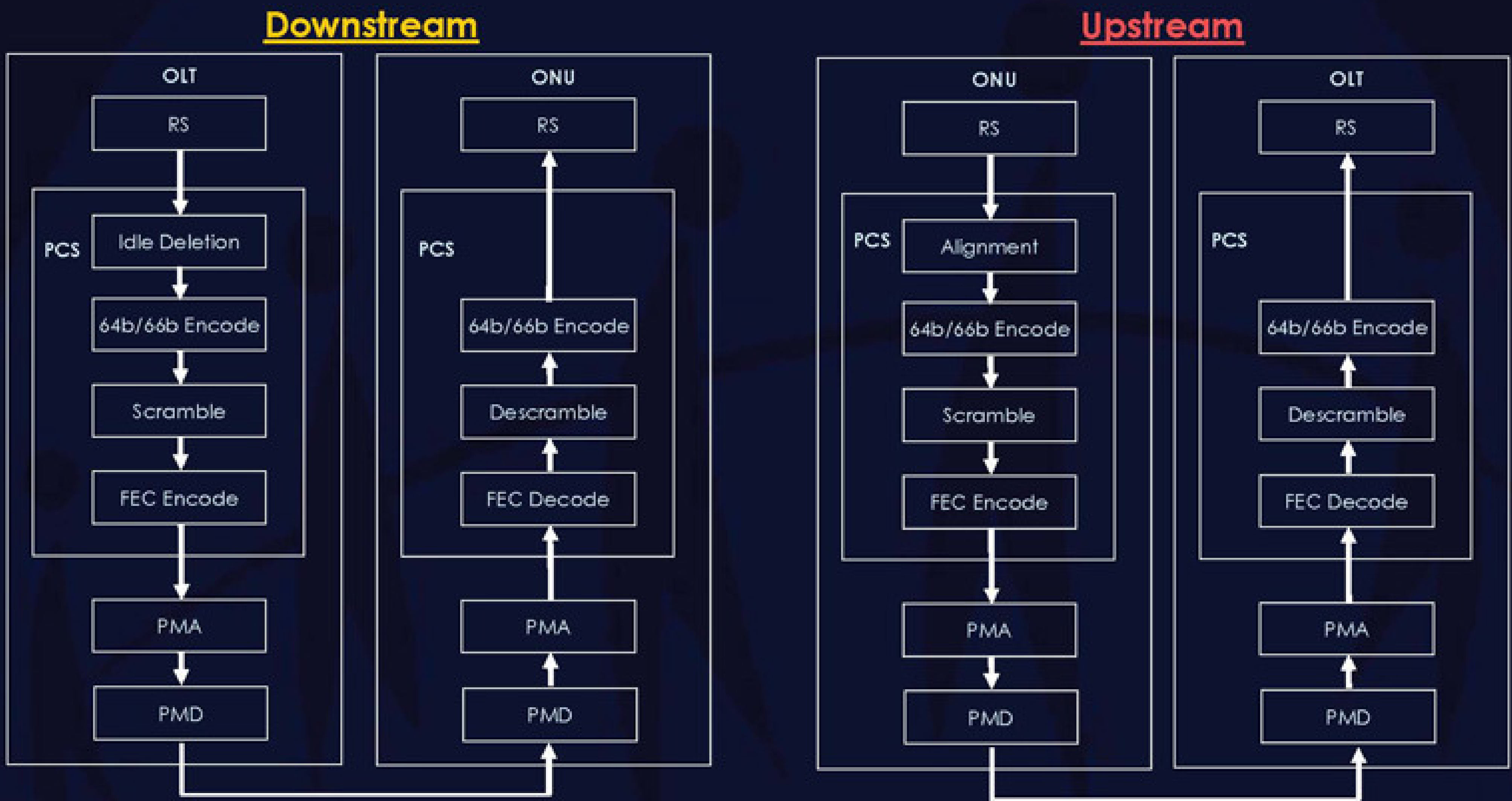


- Physical layer specification including RS, PCS, and PMD
- Minimum change at the MPCP and MAC layer to address co-existence

PMD Types and Power Budgets

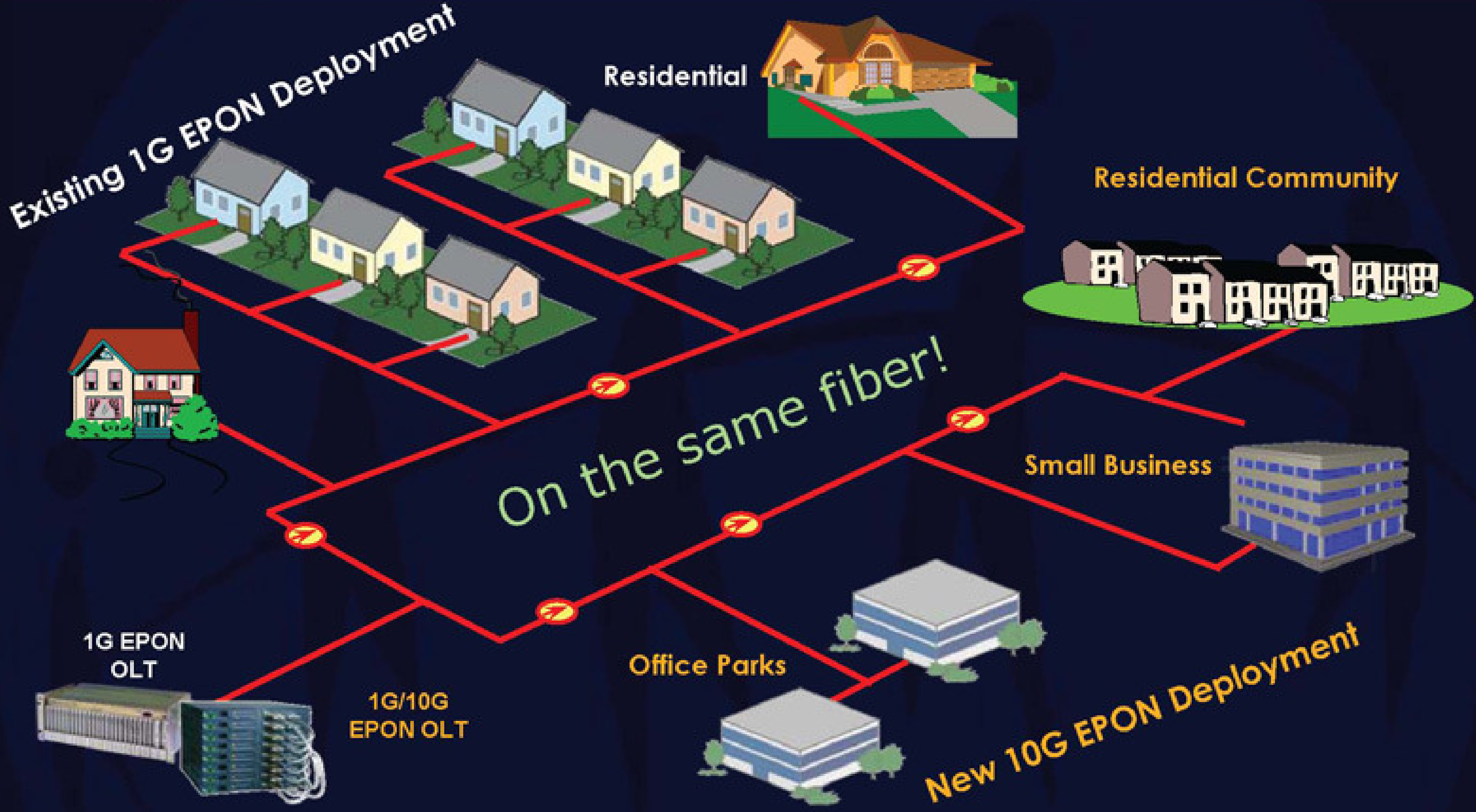
Description	Low Power Budget		Medium Power Budget		PRX20 PR20		Unit
	PRX10	PR10	PRX20	PR20	PRX20	PR20	
Maximum Channel Insertion Loss	20		24		29		dB
Maximum Reach	≥10		≥20				km
Downstream Data Rate	10						Gbps
Upstream Data Rate	1	10	1	10	1	10	Gbps
Nominal Downstream Wavelength	1590				1577		nm
Downstream Wavelength Bandwidth	20				6		nm
Nominal Upstream Wavelength	1310	1270	1310	1270	1310	1270	nm
Upstream Wavelength Bandwidth	100	20	100	20	100	20	nm

10G EPON Data Path Flows

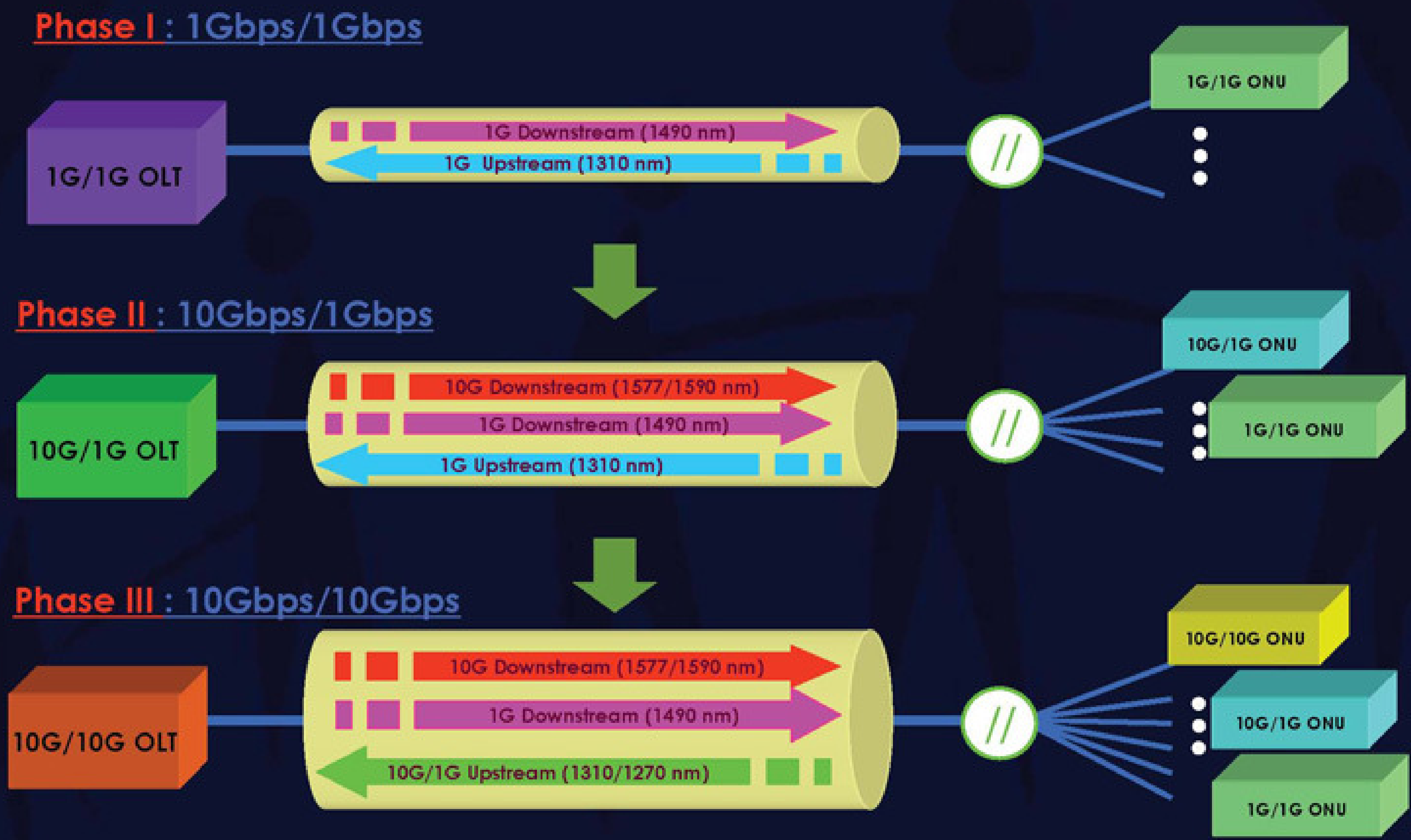


- Based on 10GBASE-R with major modifications in PCS and RS sublayers
- 64b/66b line coding and scramblers, and Forward Error Correction = RS(255, 223)

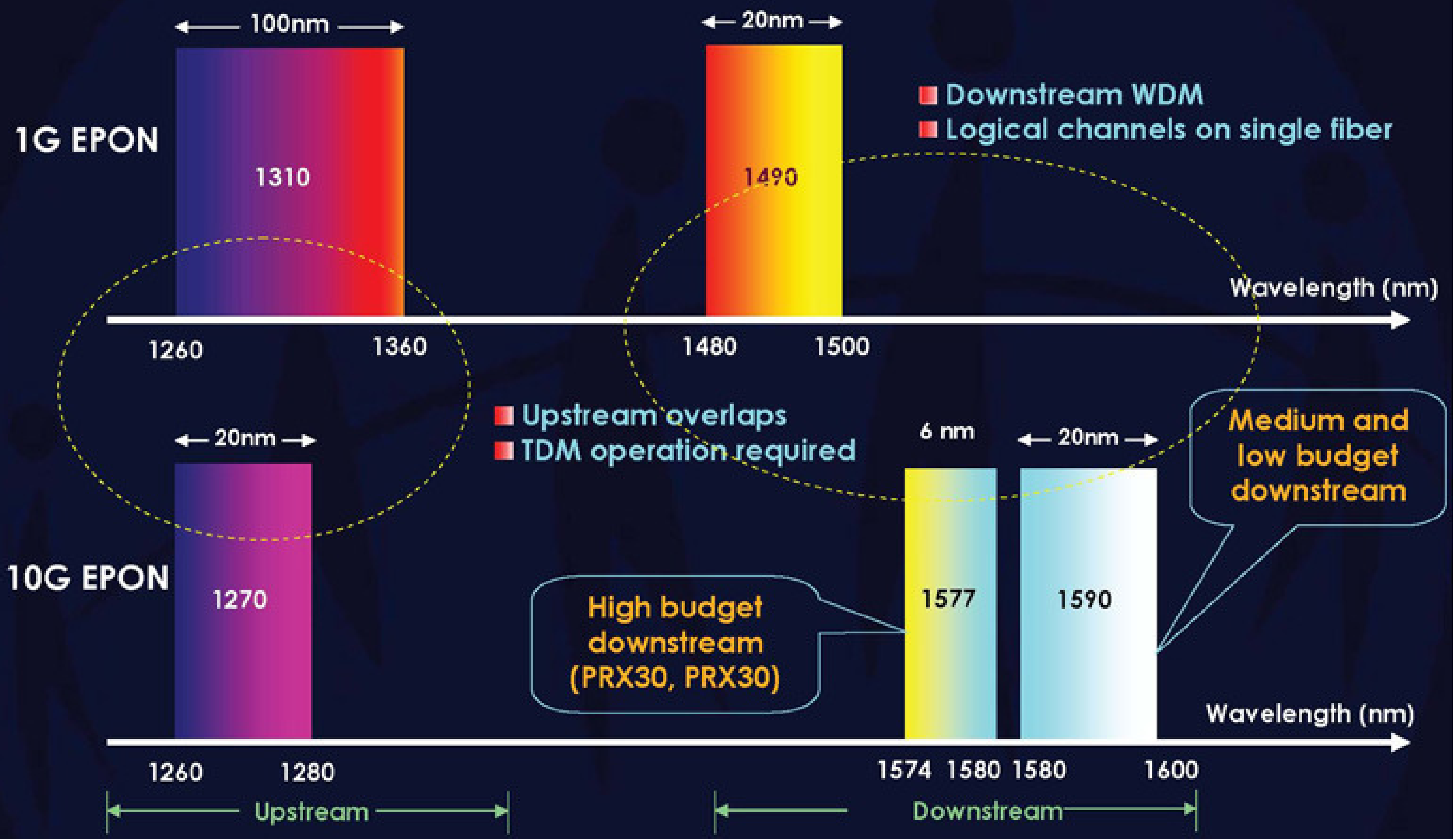
1G EPON and 10G EPON Co-existence



EPON Migration Path



Wavelength Allocation



Discovery Gate MPCP Message

CORTINA

Existing Discovery Gate

Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0002
Timestamp
Number of Grants/Flags
Grant #1 Start Time
Grant # 1 Length
Sync Time
Pad/Reserved
FCS

New Discovery Gate

Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0002
Timestamp
Number of Grants/Flags
Grant #1 Start Time
Grant # 1 Length
Sync Time
Discovery Information (2Bytes)
Pad/Reserved
FCS

Bit	Flag Field	Values
0	OLT I is 1G US capable	0 – OLT supports 1G US 1 – OLT doesn't support 1G US
1	OLT is 10 G US capable	0 – OLT doesn't 10G US 1 – OLT supports 10G US
2 -3	Reserved	Ignored upon reception
4	OLT is opening 1G discovery window	0 – OLT can receive 1G in this window 1 – OLT cannot receive 1G in this window
5	OLT is opening 10G discovery window	0 – OLT cannot receive 10G in this window 1 – OLT can receive 10G in this window
6 - 15	Reserved	Ignored upon reception

Register Request MPCP Message

Existing Register Request

Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0004
Timestamp
Flags
Pending Grants
Pad/Reserved
FCS

New Register Request

Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0004
Timestamp
Flags
Pending Grants
Discovery Information (2Bytes)
Laser On Time (1 Byte)
Laser Off Time (1 Byte)
Pad/Reserved
FCS

Bit	Flag Field	Values
0	ONU I is 1G US capable	0 – ONU supports 1G US 1 – ONU doesn't support 1G US
1	ONU is 10 G US capable	0 – ONU doesn't 10G US 1 – ONU supports 10G US
2 -3	Reserved	Ignored upon reception
4	1G registration attempt	0 – 1G registration is attempted 1 – 1G registration is not attempted
5	10G registration attempt	0 – 10G registration is not attempted 1 – 10G registration is attempted
6 - 15	Reserved	Ignored upon reception

- ONU laser on and off times information to DBA at the OLT can improve the upstream throughput
- Register message echo those values

Register MPCP Message

Existing Register

Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0005
Timestamp
Assigned Port
Flags
Sync Time
Echoed Pending Grants
Pad/Reserved
FCS

New Register

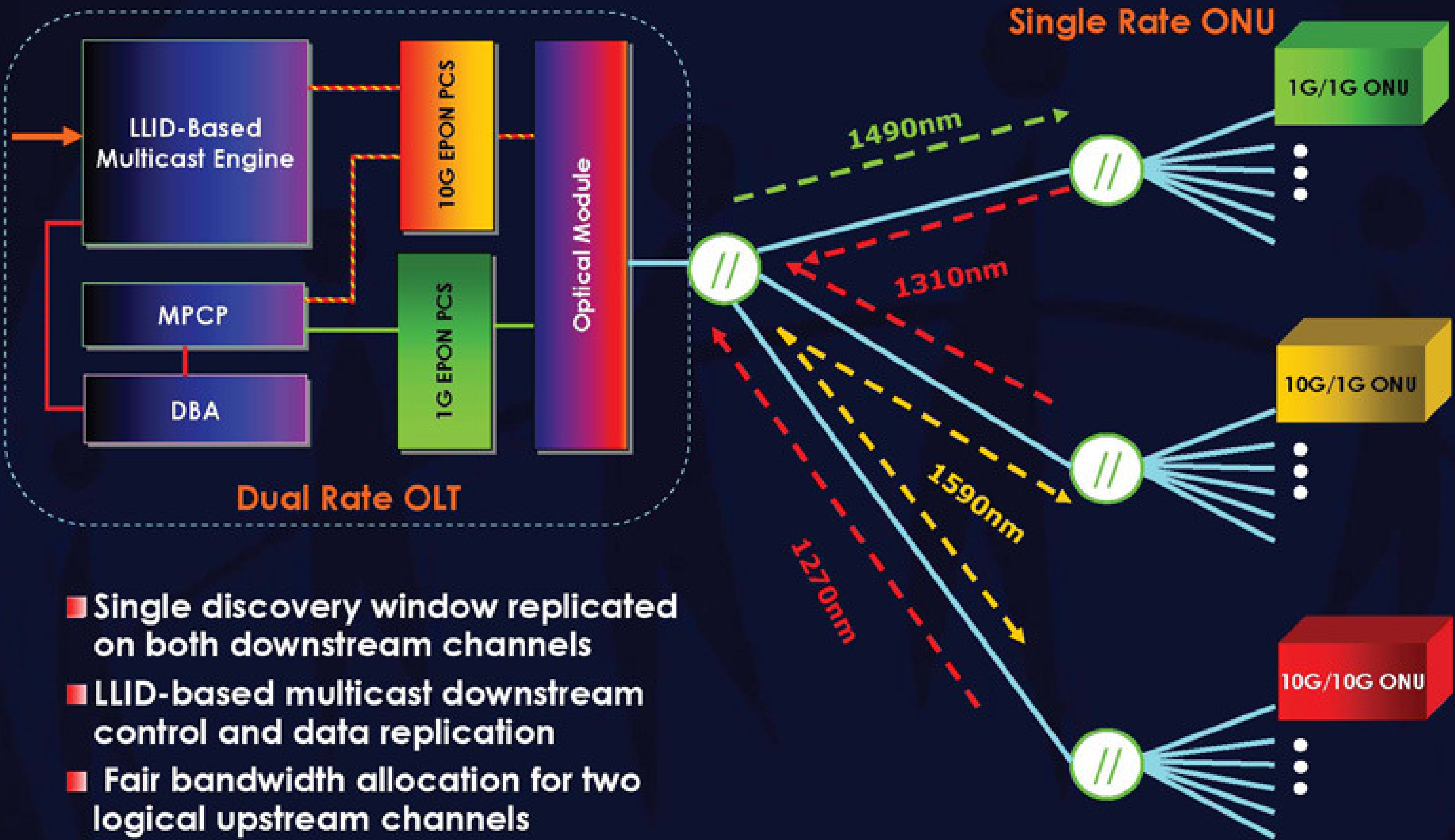
Destination Address
Source Address
Length/Type = 0x8808
Opcode = 0x0004
Timestamp
Assigned Port
Flags
Sync Time
Echoed Pending Grants
Echoed Laser On Time (1 Byte)
Echoed Laser Off Time (1 Byte)
Pad/Reserved
FCS

- **Register acknowledges the values of laser on and laser off from the ONU**
- **OLT DBA uses those values to calculate the grant window**
- **This dynamic information is designed to improve the upstream utilization**
- **Standard-defined default value for laser on or laser off is 512 ns, but today's optical transceivers can achieve 64ns**

10G EPON Design Considerations

- Many possible choices for OLT and ONU design
  - Single rate or dual rate support in each direction
  - Major impact on the network upgrade, component cost, and system performance
- Highly recommended
  - Dual rate OLT (two types of OLT)
  - Single rate ONU (three types of ONU)
- Single DBA engine due to upstream wavelength overlap
  - Single logical upstream channel (aggregated rate: 1G <-> 10G)
  - Two logical downstream channels
  - Fair bandwidth allocation among 1G ONUs and 10G ONUs
- Downstream multicast
  - Two logical multicast channels (LLID= 0x7FFF for 1G EPON, LLID=0x7FFE for 10G EPON)

10G EPON Operation Example



- Single discovery window replicated on both downstream channels
- LLID-based multicast downstream control and data replication
- Fair bandwidth allocation for two logical upstream channels

10G and 1G EPON Summary

Item \ Speed	1G EPON	10G EPON
Downstream wavelength	1490nm	1590nm or 1577nm
Upstream wavelength	1310nm	1270nm
PMD Type	PX10, and PX20	PRX10, PRX20, PRX30 PR10, PR20, PR30
PCS line coding	10b/8b	64b/66b
Single broadcast channel (SCB)	0x7FFF	0x7FFE
Mode of operation	Symmetric operation	Asymmetric or symmetric operation
Forward error correction	Optional (Frame based)	Mandatory, RS(255,223)

Concluding Remarks

- **Industry and technology trends**
  - Internet is approaching Zettabyte era
  - Moore's law continues for a foreseeable future: Era of Tera
  - PON chip cost and performance can surpass any past technology, thanks to the advancement in silicon technology
- **PON chips continue to evolve**
  - Driven by Internet growth and market demand
  - Low cost, high integration, and enhanced performance
  - Application specific ONUs
  - High density OLT
- **10G EPON is the next generation solution**
  - MDU applications and 100Mbps to homes
  - Fiber exhaustion
  - Key design considerations

Thank You

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