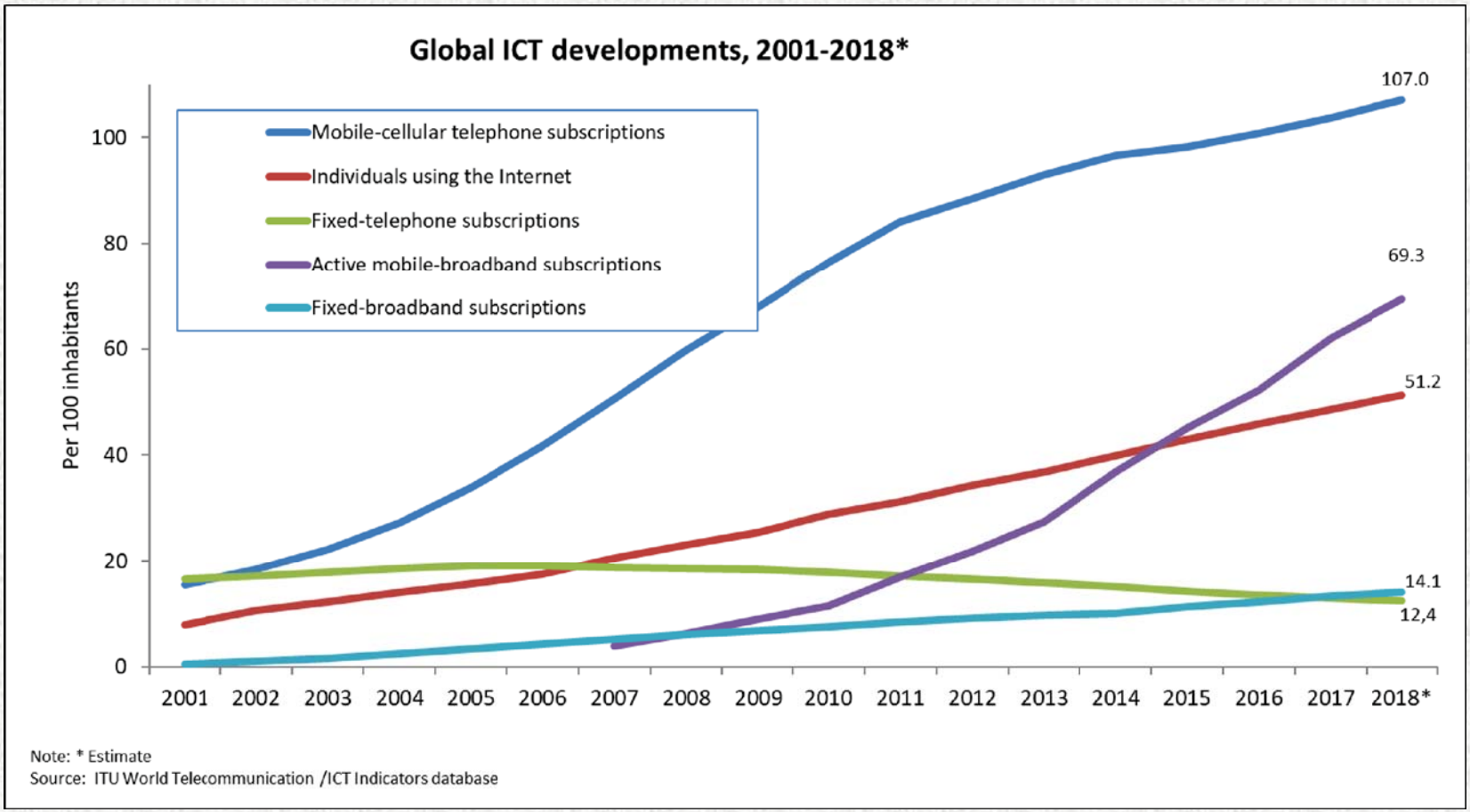
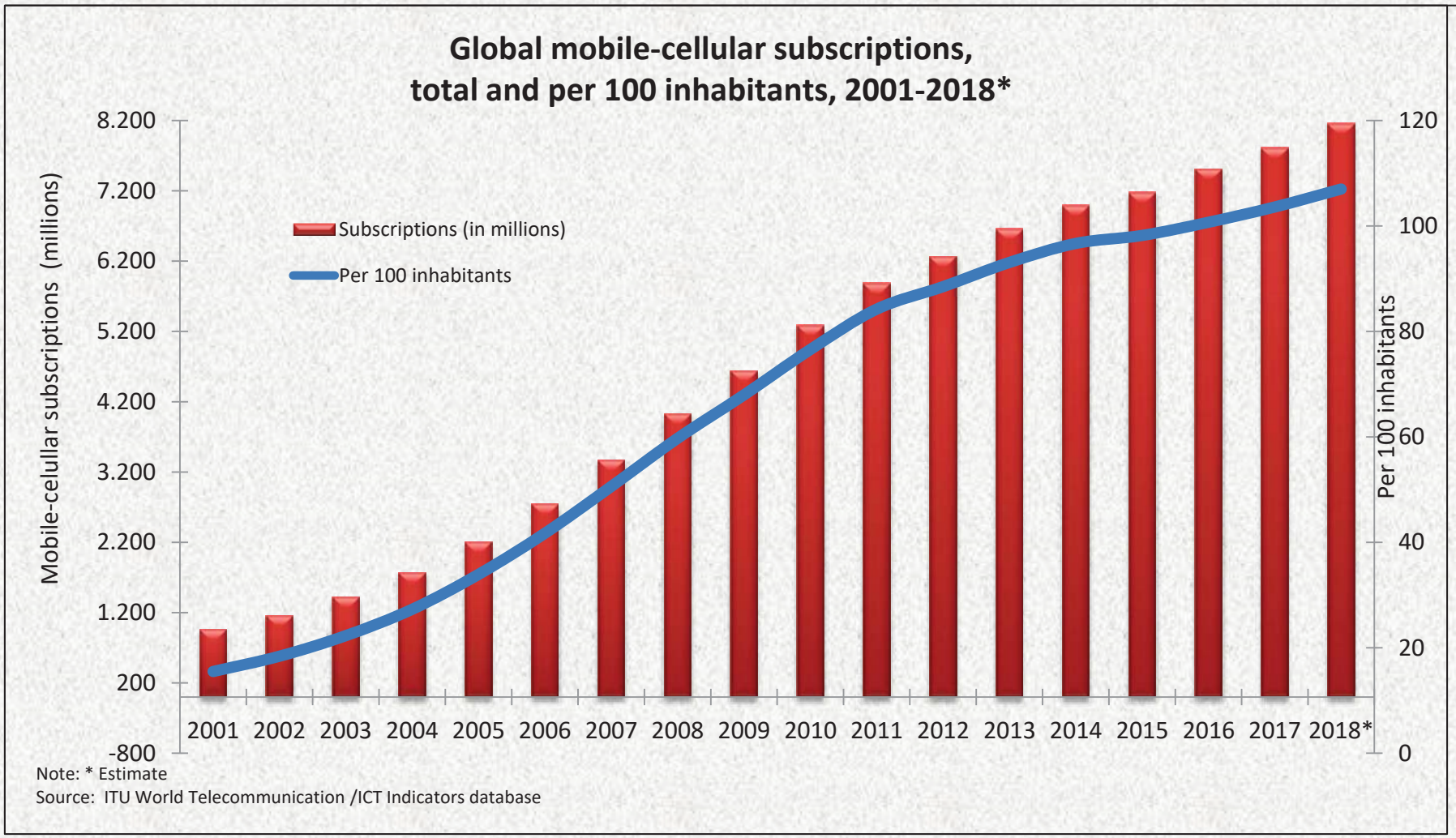
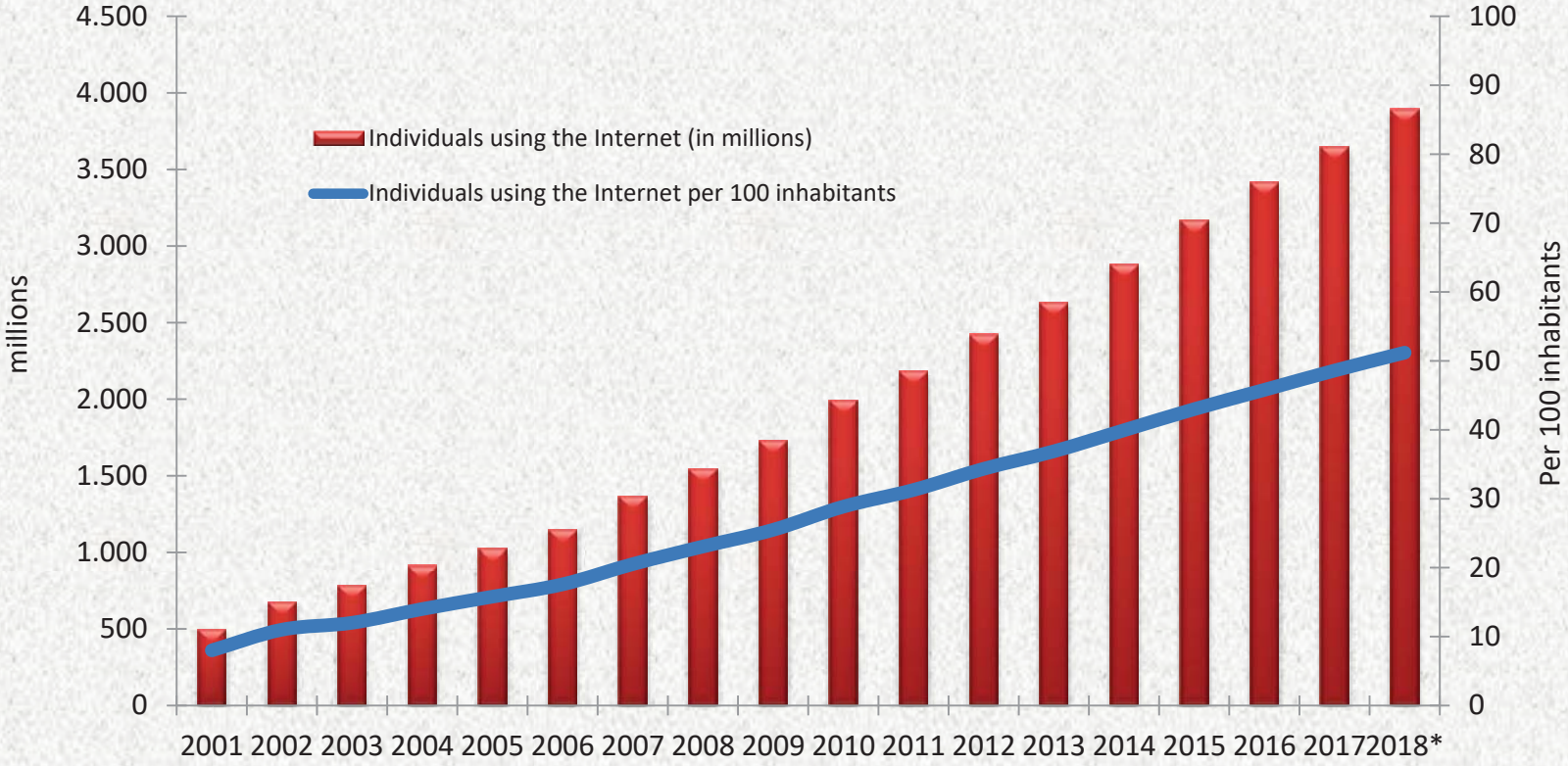

Global ICT developments, 2001-2018*
Mobile-cellular telephone subscriptions
Individuals using the Internet
Fixed-telephone subscriptions
Active mobile-broadband subscriptions
Fixed-broadband subscriptions
Per 100 inhabitants
0
20
40
60
80
100
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018*
107.0
69.3
51.2
14.1
12,4
Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database

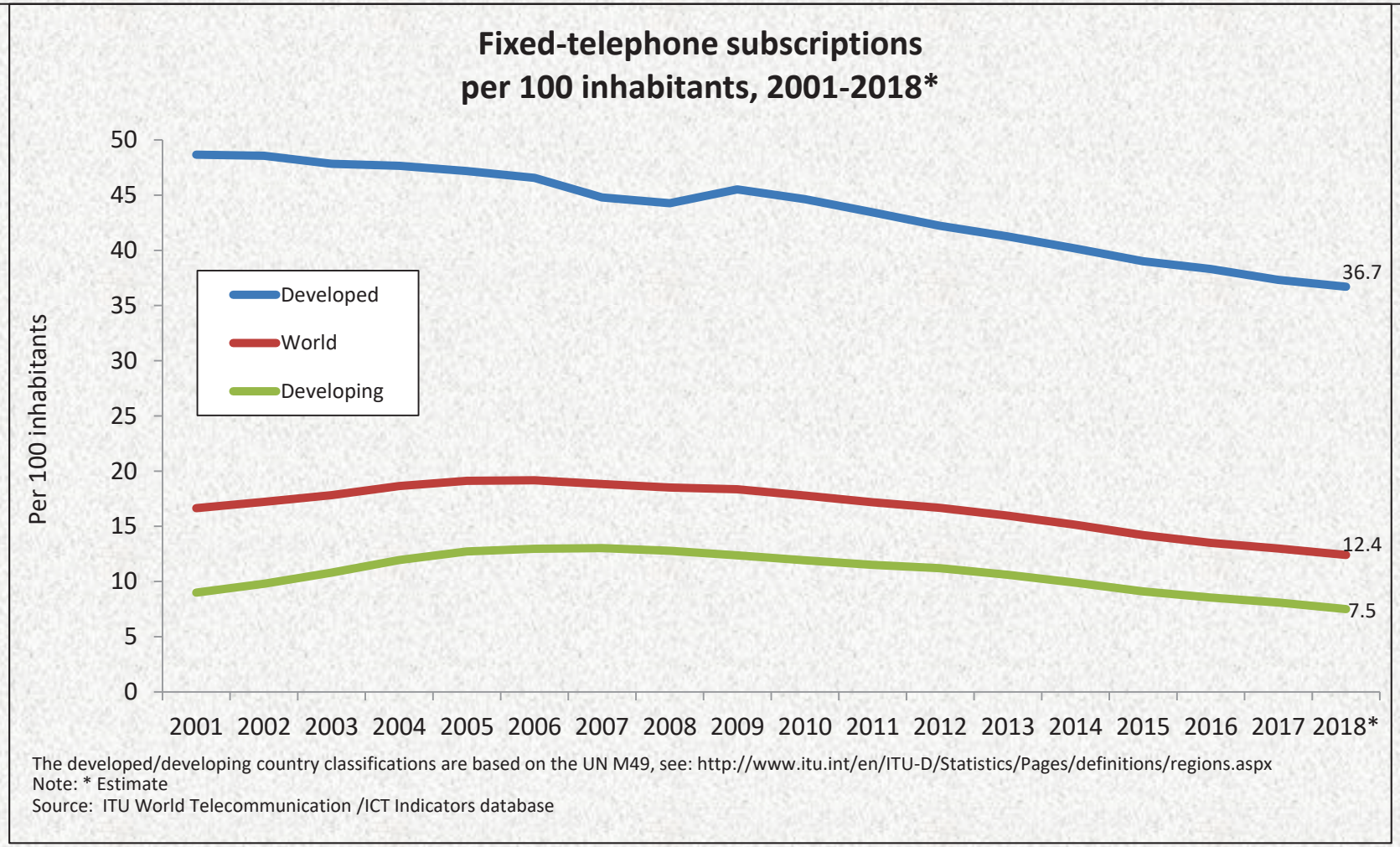
S2-TE


Global mobile-cellular subscriptions,
total and per 100 inhabitants, 2001-2018*
Mobile-celullar subscriptions (millions)
Per 100 inhabitants
Subscriptions (in millions)
Per 100 inhabitants
8.200
7.200
6.200
5.200
4.200
3.200
2.200
1.200
200
-800
120
100
80
60
40
20
0
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018*
Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database

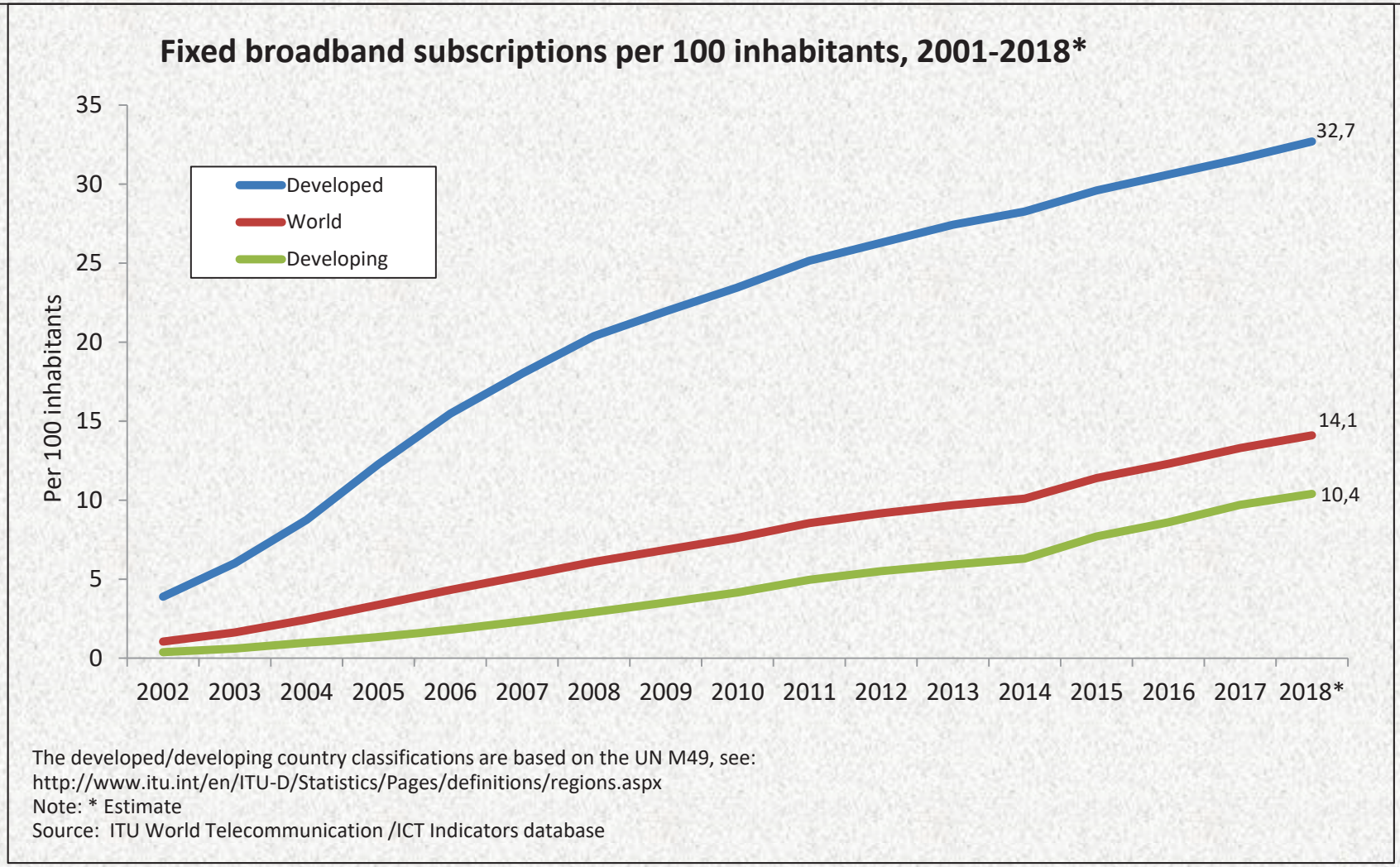
Global numbers of individuals using the Internet, total and per 100 inhabitants, 2001-2018*



Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database



The developed/developing country classifications are based on the UN M49, see: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx
Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database



The developed/developing country classifications are based on the UN M49, see:
http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx
Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database

New communication architectures

- Challenge: offer QoS in the Internet network
- Multipmedia applications, VoD, IPTV for Internet will be developed and used when QoS mechanismes will exist
- New functions must be developed to guarantee performance, offer security, avoid jitter, allow the respect of time-constraints,...

Next Generation Internet

- MPLS, Native IP, Carrier Grade Ethernet
- Unique network: wired and wireless, data, voice
- Problem of TCP/IP: electrical consumption, complexity
- Intelligence in the network: smart, active autonomic networks => autoconfiguration
- Vitual Internet: Cloud and Data Center

Evolution IP-oriented Network

Evolution of IP-oriented Network Technologies

	IP	MPLS	MPLS-TE	GMPLS
Connection	Connection-less	Connection Oriented LSP (LSP, VP/VC, DLCI)	MPLS+TE Extensions	Multi-Layer LSPs + TE Extensions
Routing/ Forwarding	Hop-by-Hop Packet Routing	Label Switching with Label Swapping	MPLS+Explicitly Routed TE-Tunneling	Explicitly Routed TE-Tunneling with Multi-layer LSPs
Control and Data Plane	Coupled	Logically Separated	Logically/ Physically Separated	Logically/ Physically Separated
Routing	Distributed IGP Protocol for Routing and Path Calculation (Distribute Topology Information Only)	Hop-by-Hop Routed Path: OSPF, ISIS, BGP-4	Constrained-based Routing: OSPF-TE, ISIS-TE, BGP-TE	Extensions to Handle Multi-Layer TE and Each Layer Path Peculiarities Link management protocol (LMP)
Signaling	IGP, RSVP	LDP RSVP-TE	CR-LDP, RSVP-TE	CR-LDP-EXT, RSVP-TE-EXT

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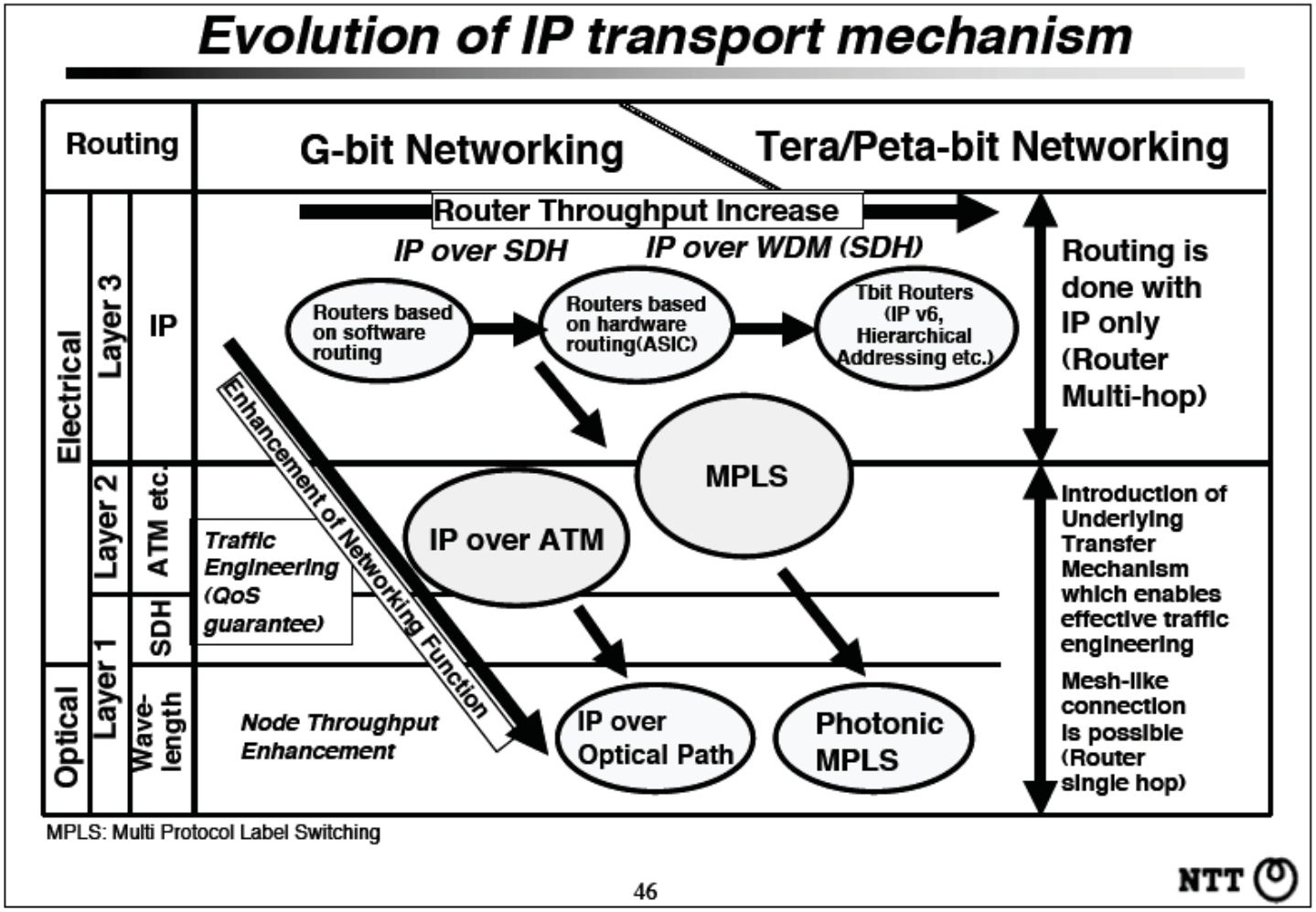
Evolution of IP transport



IP Traffic Characteristics

Characteristics of IP Traffic

IP Traffic	*Voice Traffic*
Rapid and Unpredictable Traffic Growth - Data traffic grows very rapid - Data traffic demands are unpredictable in terms of capacity and location. - Traditional capacity planning methods for voice traffic are rendered obsolete.	Slow/Steady and Predictable Traffic Growth
Unpredictable Traffic Pattern Change	Predictable Traffic Pattern Change
Distance Insensitive	Most calls Terminate within Local Area
Minimum Intervals in Service Provisioning - Need to be attained in response to the unpredictable traffic demand.	Service Provisioning can be based on Planning

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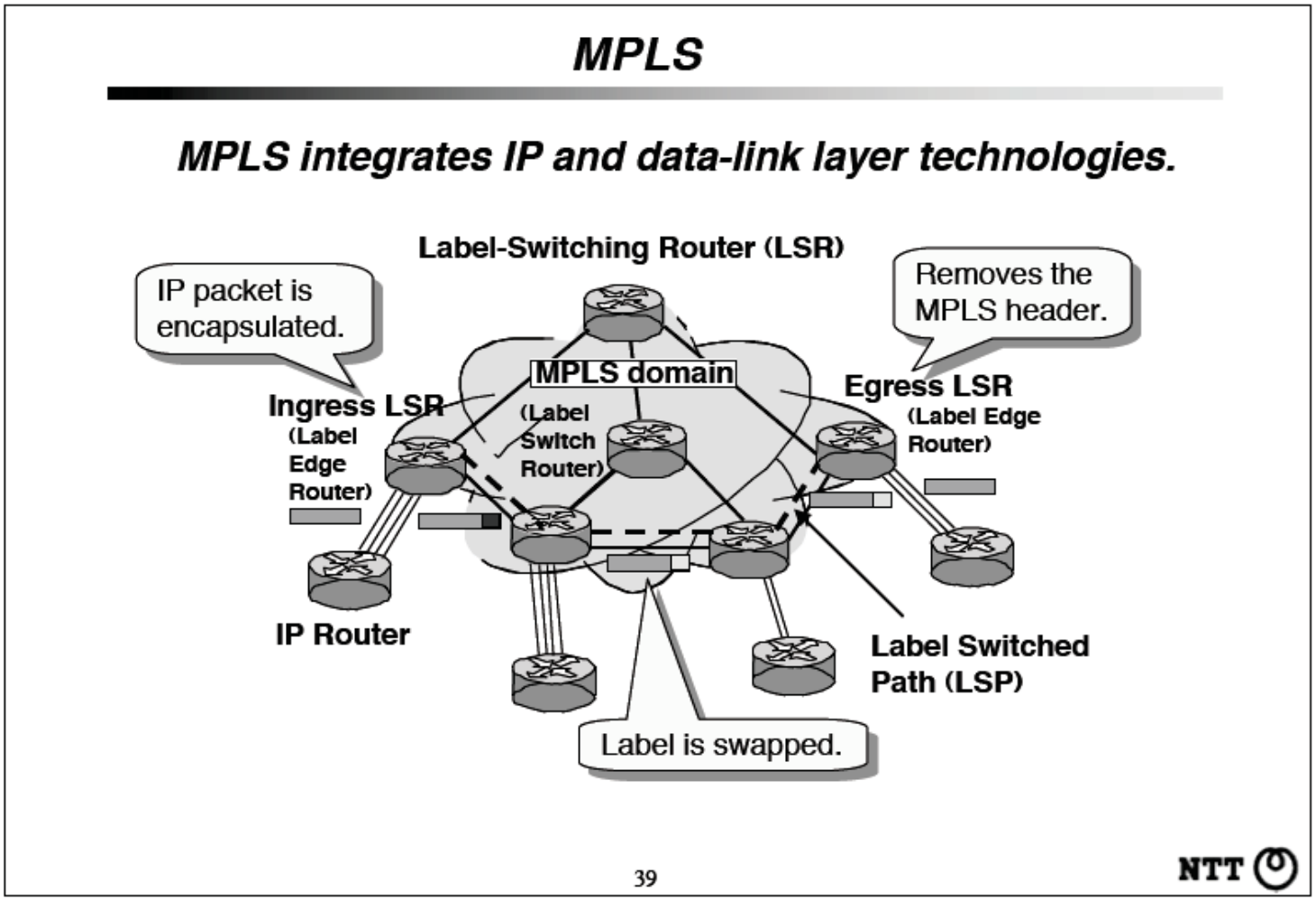
MPLS


MPLS
MPLS integrates IP and data-link layer technologies.
Label-Switching Router (LSR)
IP packet is encapsulated.
Removes the MPLS header.
MPLS domain
Ingress LSR
(Label Edge Router)
(Label Switch Router)
Egress LSR
(Label Edge Router)
IP Router
Label Switched Path (LSP)
Label is swapped.
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MPLS (Cont.)

Why MPLS?

- MPLS helps scaling pubic IP networks and enhance network performances
- MPLS provides network providers with means that can differentiate their services from others.

☆Traffic Engineering (Path oriented)
- Possibility to set-up other paths than "shortest paths"
- Multiple paths between two points: Load sharing, 1 + 1, 1 : N, M : N Protection

☆Very flexible because of de-coupling of forwarding and routing (forwarding decision is separated from routing process)

☆Support capabilities of VPNs and new service provisioning
- by allowing the forwarding infrastructure to remain the same while new services are built through the assignment of packets to an LSP

☆Enahanced QoS

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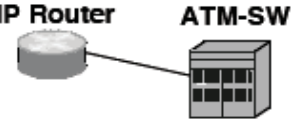
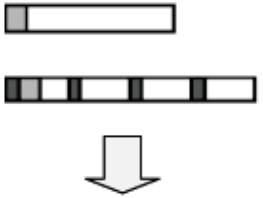
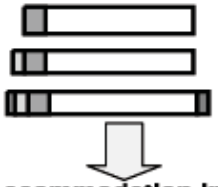
Comparison IP over ATM and MPLS

Comparison of IP over ATM and MPLS (IP+ATM)

	IP over ATM	MPLS
Structure		
Mapping of IP Packet into Layer 1		
Characteristics	- VPI(/VCI) is swapped link by link - SAR Burden - Meshed VP connection between routers (Limited network expandability)	- Label swapping (link by link) - Variable length packet processing at MPLS-SW - Hierarchical LSPs with label stacking
Network Operation	- Separate (Independent) IP and ATM layer operation (ATM will be common transport platform to other services than IP)	- Integrated IP and MPLS layer operation - Operation on different label switched path realization techniques - Standardized MPLS signaling protocols

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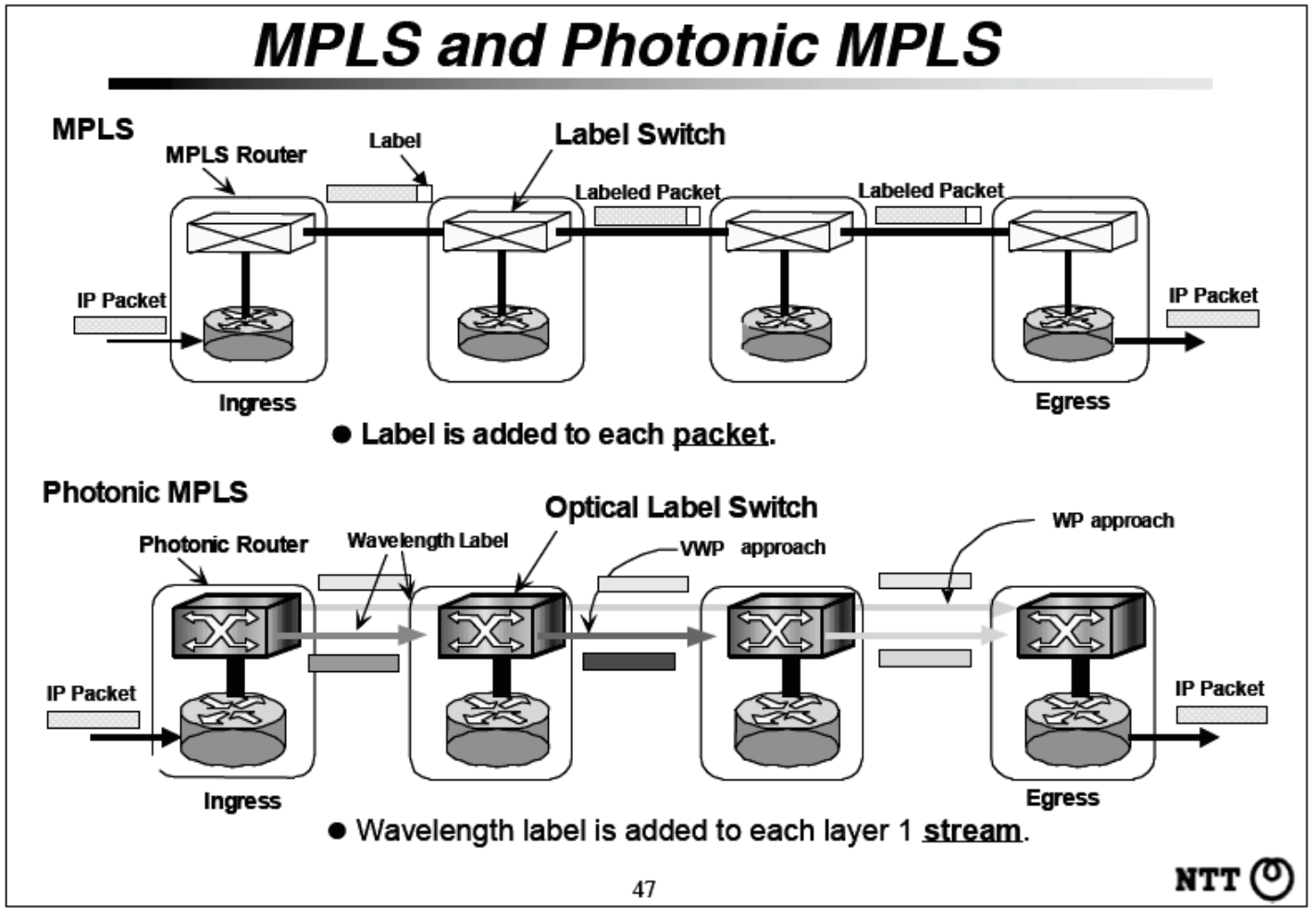
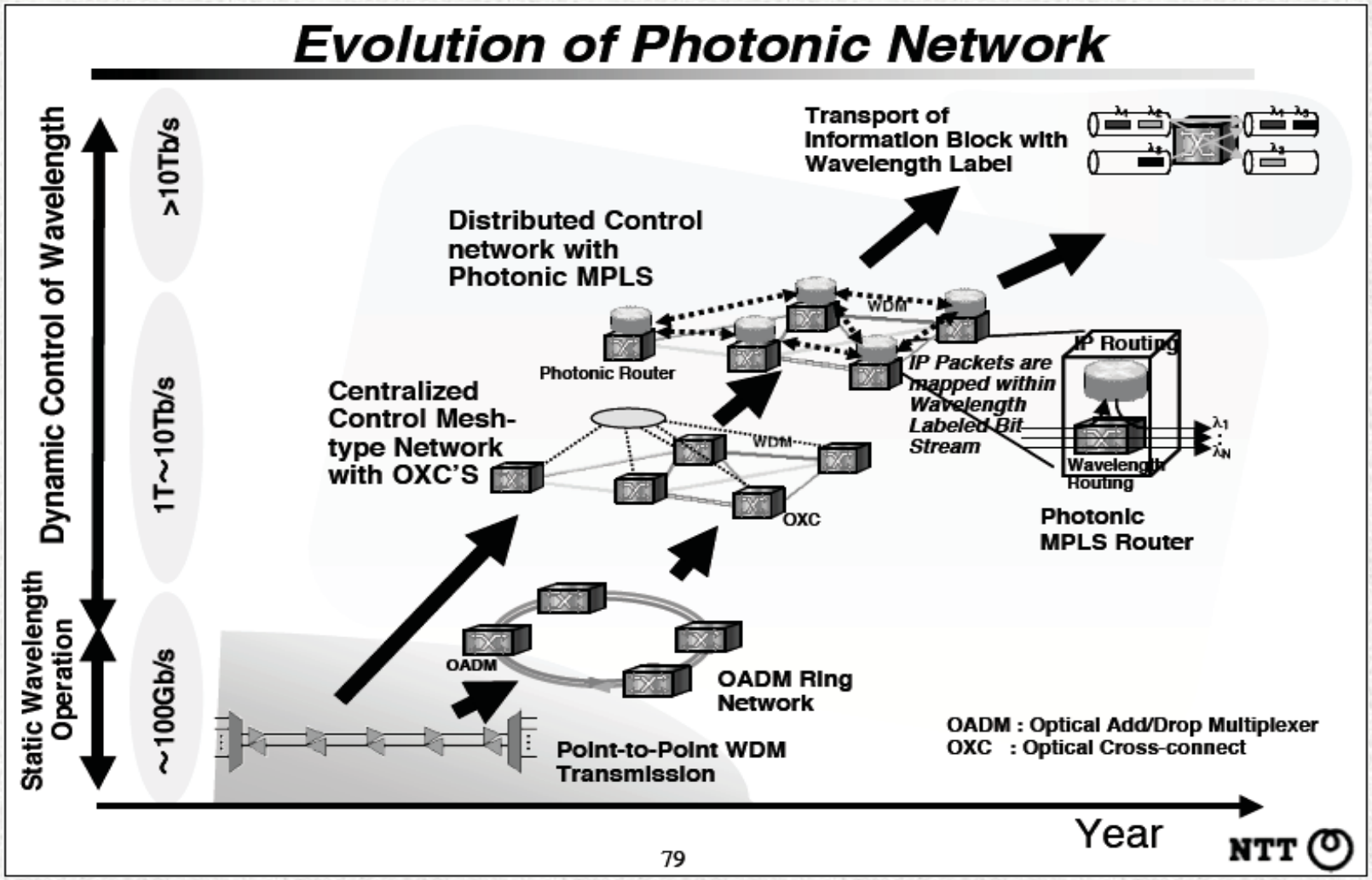
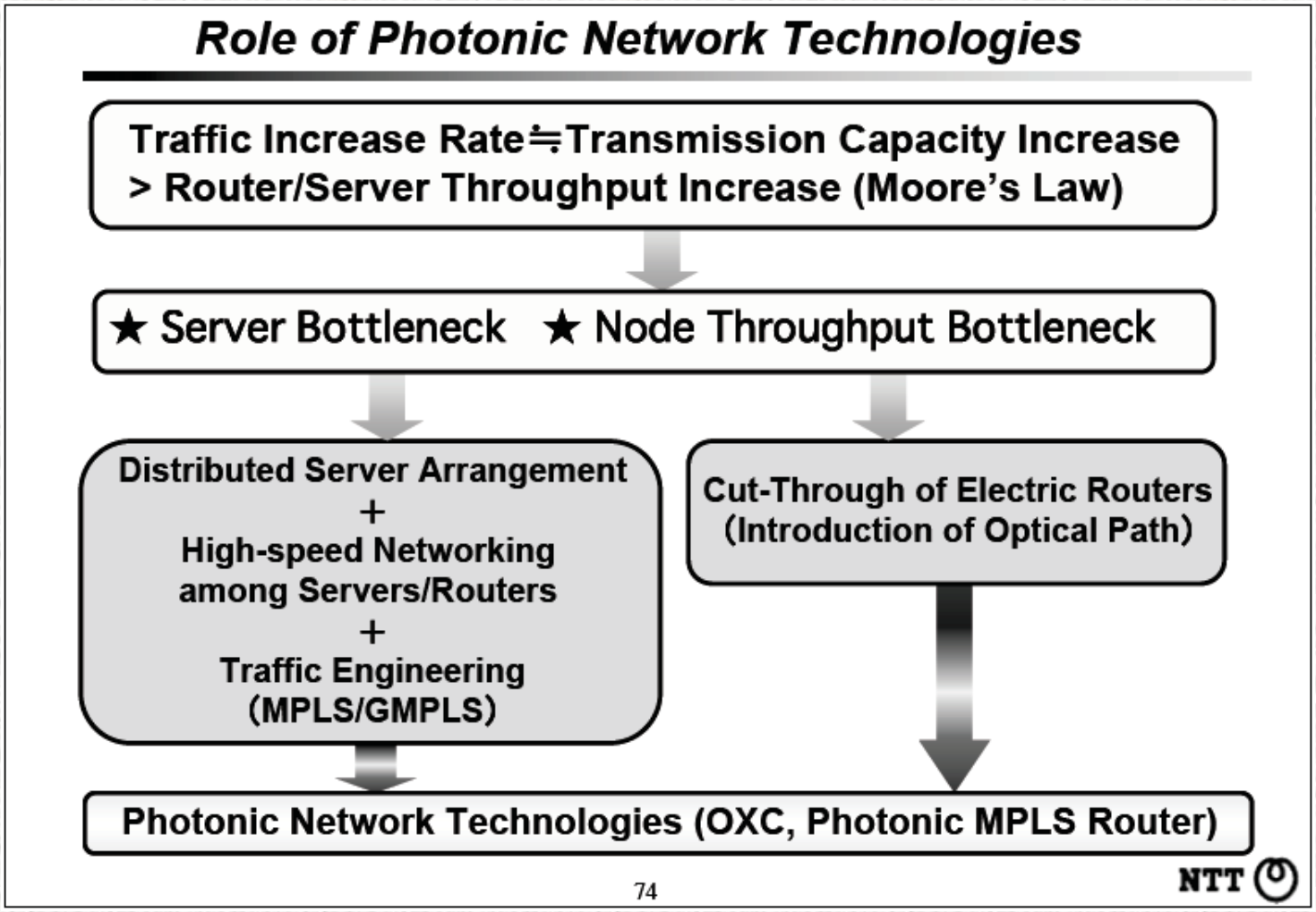
Photonic MPLS



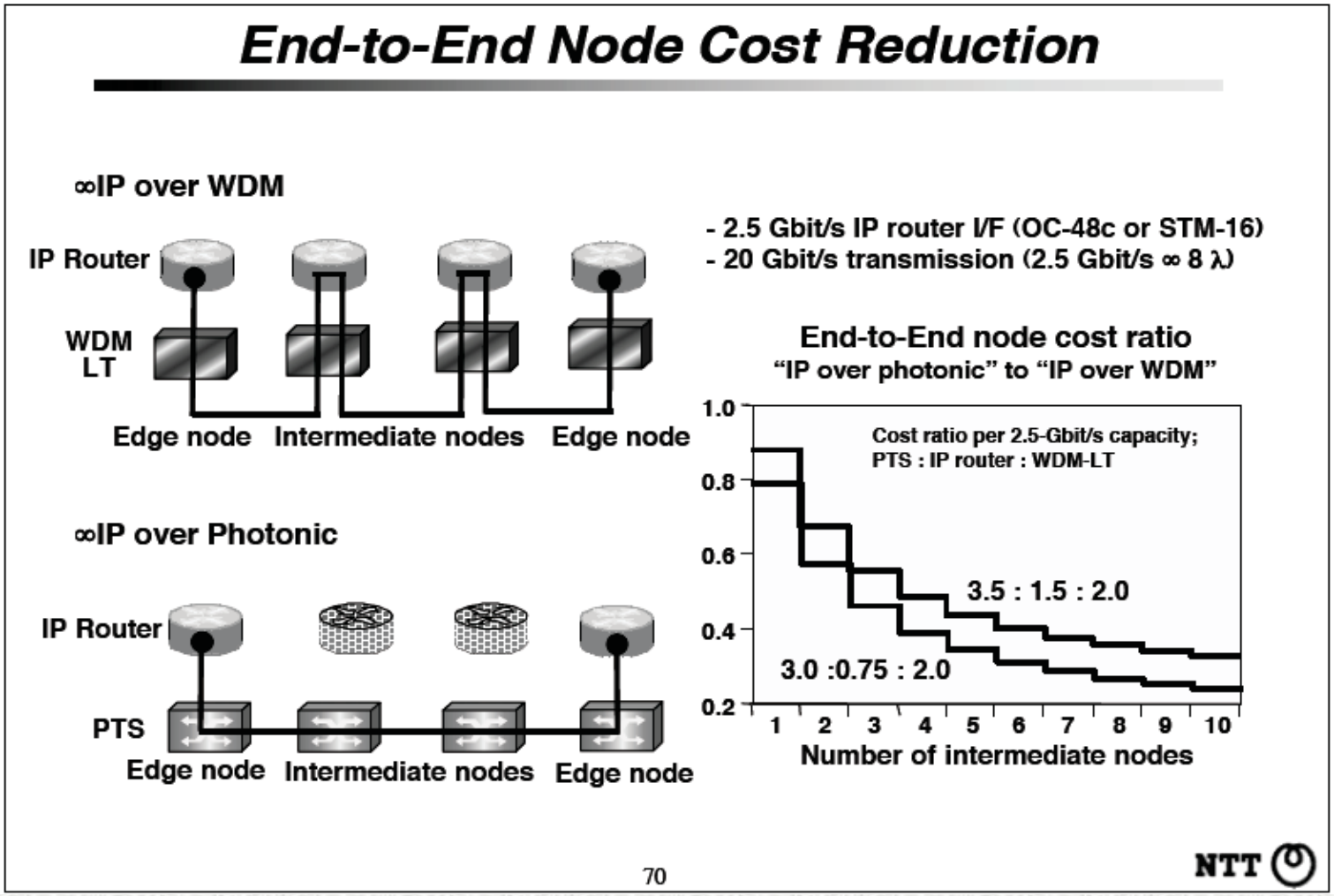
Photonic Network Architecture



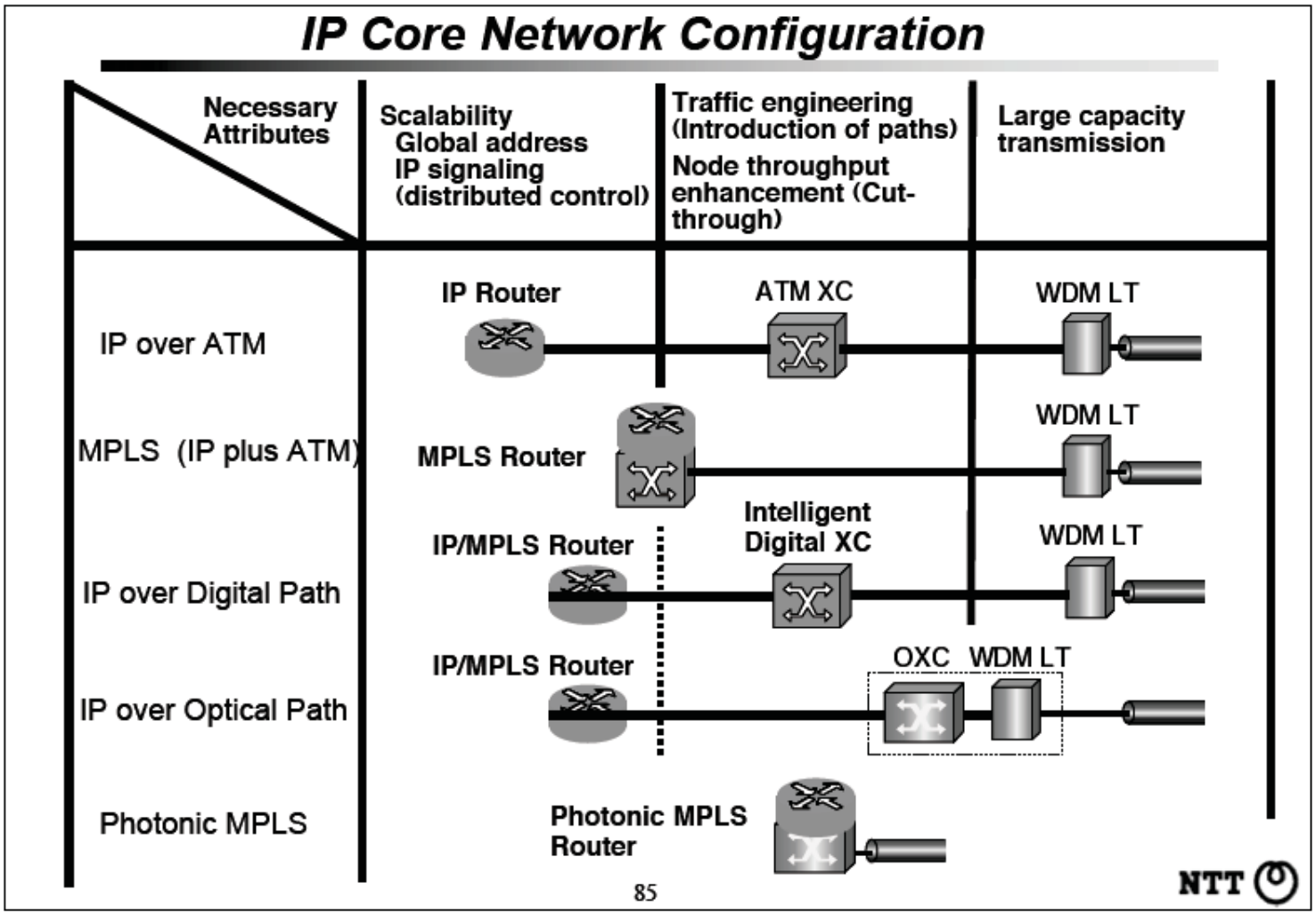
Fundamental Photonic Network



Fundamental Photonic Network (Cont.)

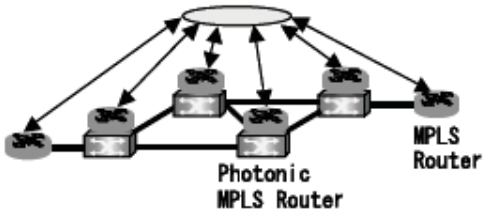
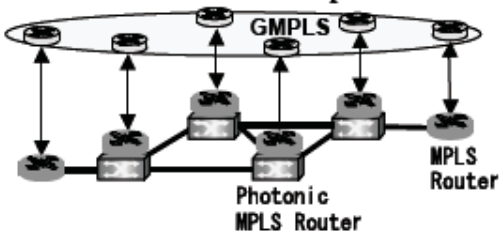
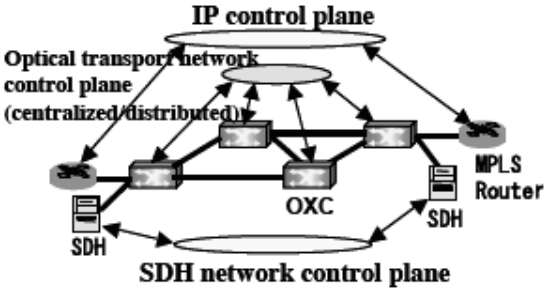
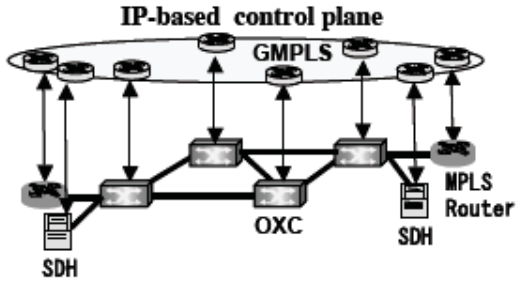


Fundamental Photonic Network (Cont.)



Fundamental Photonic Network (Cont.)

Different Service Network Architecture

Control / System	Centralized Control (carrier oriented approach)	Distributed Control (router-based approach)
Photonic MPLS Router (Integration of IP router and OXC function)	IP and photonic layer control 	IP router control plane 
Optical Path Platform (OXC/OADM: different transfer mode services are supported)	Overlay model (in case of centralized control; distributed control is also possible.) 	Peer model 

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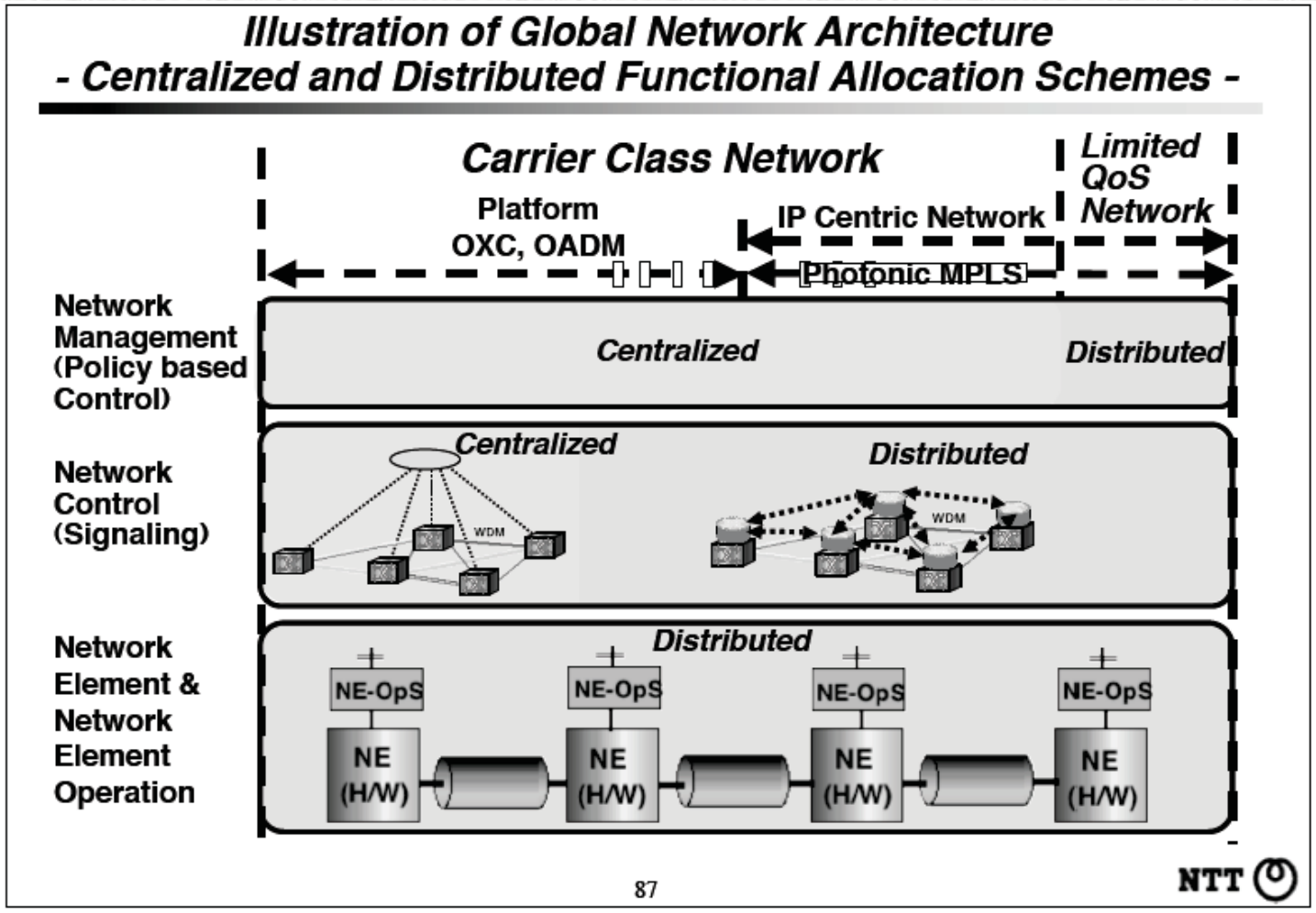
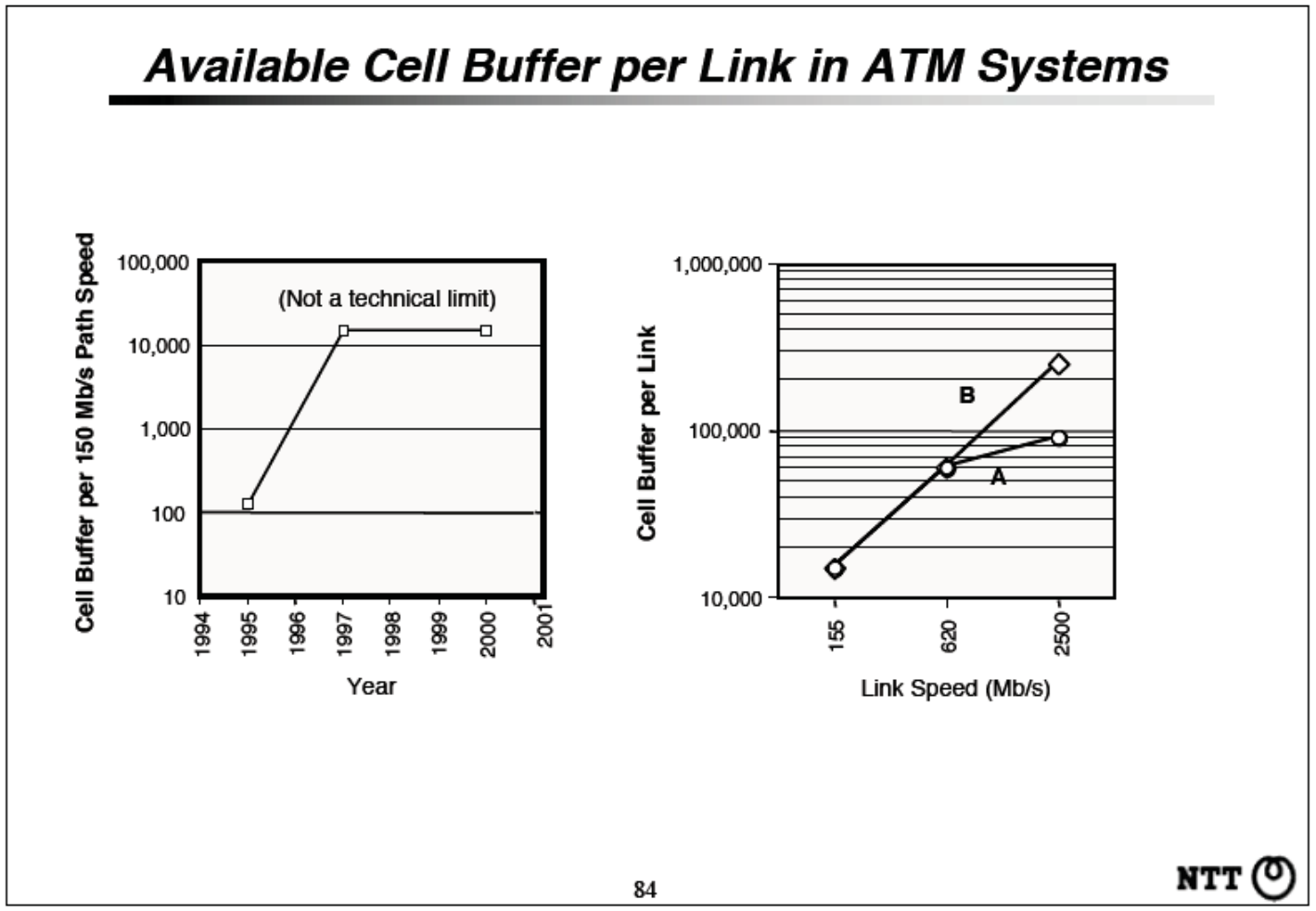
Fundamental Photonic Network (Cont.)



Availability cell in ATM Systems



THANK YOU