TELECOMMUNICATIONS AND NETWORKING

Some Issues, Trends and Future Directions

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01.07.09

DAIICT, 24 July 2009

Outline of the Talk

- Communication through a Poem
- Next Generation Networking
- Ubiquitous Networking
- Future Vision and Directions
- Convergence
- Wireless Technology Trends
- Key Technologies
- Long Term Evolution (LTE) – Path to 4G
- Optical Network Research Issues

“UP IN THE AIR”
BOB

Up in the Air

(Bob Aron…….Comm. Mag. 1207.12)

Fiber to the mile's post
Gives to us a speedy host
Copper is still at the end
So, no digging now my friend.

Not by wires do we slave
When we send by microwave.
Even in the media wrath
MIMO tames the signal path.

Up in the Air (Bob)……..Contd.

Thus expect for years to come
We will use more than just one,
Fiber, coax, copper pairs
Signals going through the airs.

It is in the latter case
Where we match the mobile race,
Every one is on the go
Latest info they must know.

Up in the Air (Bob)……..Contd.

It’s WiMAX and Wi-Fi too
(Where the teeth are colored blue)
Not just for our business needs
But finding kids lost in weeds
Further on, by shafts of light
Broadband signals, line of sight
Depending on budget tight
Sending out a terabyte!!
Who will need this wide bit stream?
Why is this a wild dream?
When will we expand our sight?
How to ‘’use up’’ beams of light?

Summary definition of NGN from ITU

ITU

- A Next Generation Network is a
  - packet-based network able to provide telecommunication services
  - able to make use of multiple broadband access technologies
  - QoS-enabled transport technologies, and
  - in which service-related functions are independent from underlying transport-related technologies
- It offers unrestricted access by users to different service providers
- It supports generalised mobility which will allow consistent and ubiquitous provision of services to users

Telecoms operators are moving to NGNs for a number of reasons, including:

- Existing PSTN equipment may be reaching the end of its economical life, e.g. with ongoing maintenance support being harder and more costly to obtain.
- Operational costs can be reduced by running a single converged network rather than multiple legacy networks.
- Innovative services can be developed to improve customer experience.
- New services can be brought to market faster and at lower cost than is possible using traditional technologies.

NGNs also have important service characteristics, as seen from the perspective of a consumer:

- Continuity – Consumers will be able to continue to use those PSTN services they are used to, with essentially no change.
- Ease of migration – Consumers will be able to migrate seamlessly to new services offered by the same operator.
- Single access to multiple services – Driven by the separation of the service layer from the network layer.
- Innovative new services – New services will have richer functionality (e.g. personalised, location-aware), and reduced time-to-market, since they exploit the distributed intelligence inherent in an NGN.
- Empowerment – Consumers will have an increased capability to configure and manage services to meet their personal requirements.

Some of the NGN Industry standards forum

1. ITU – ITU-T and NGN GSI (Global Standards Initiative), Focus group on NGN
2. IETF
3. 3GPP
4. 3GPP – 2
5. TISPAN
6. DSL Forum
7. WiMax Forum
8. IPv6 Forum

Fig 14: NGN is about simplifying networks

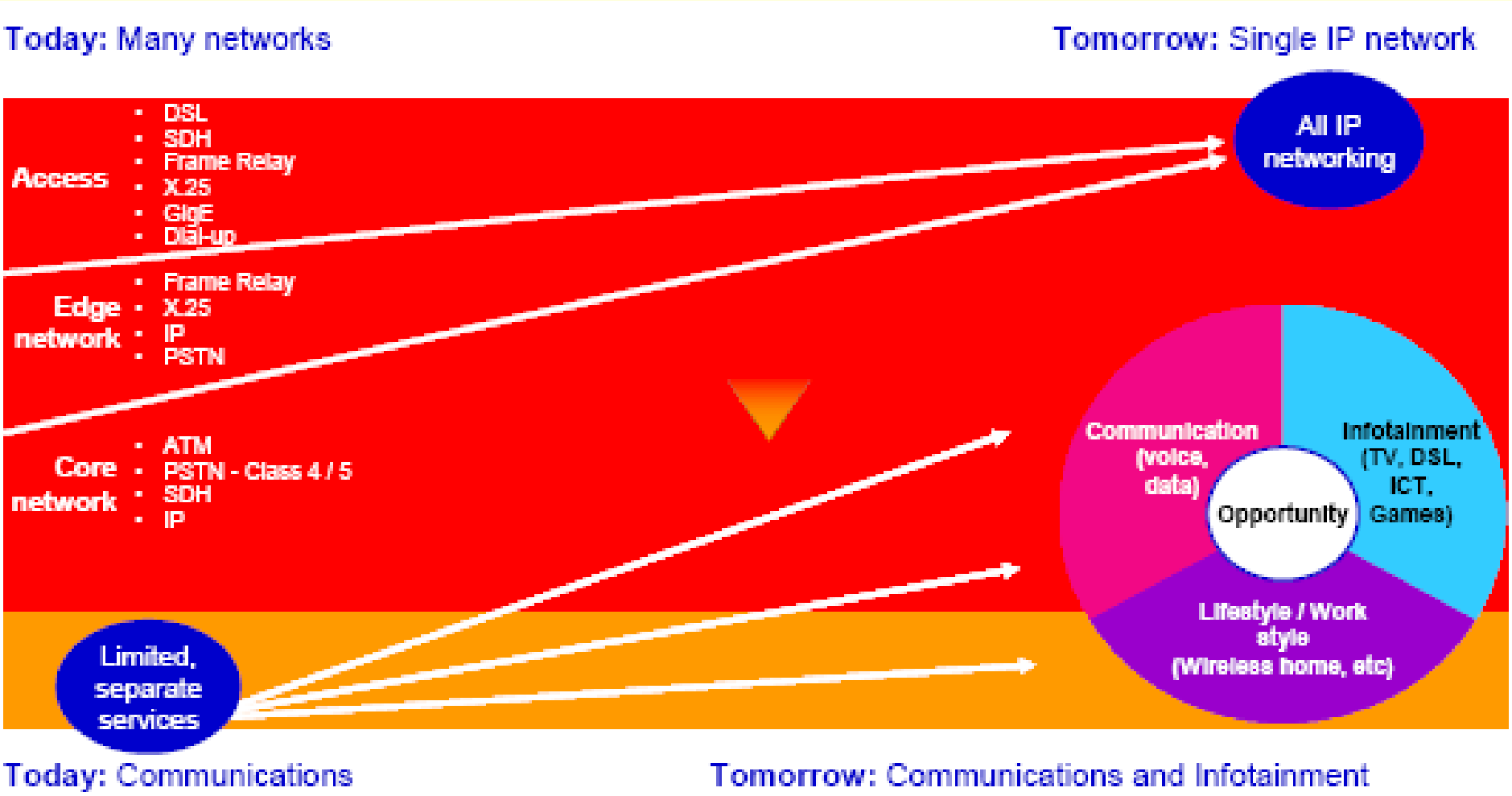
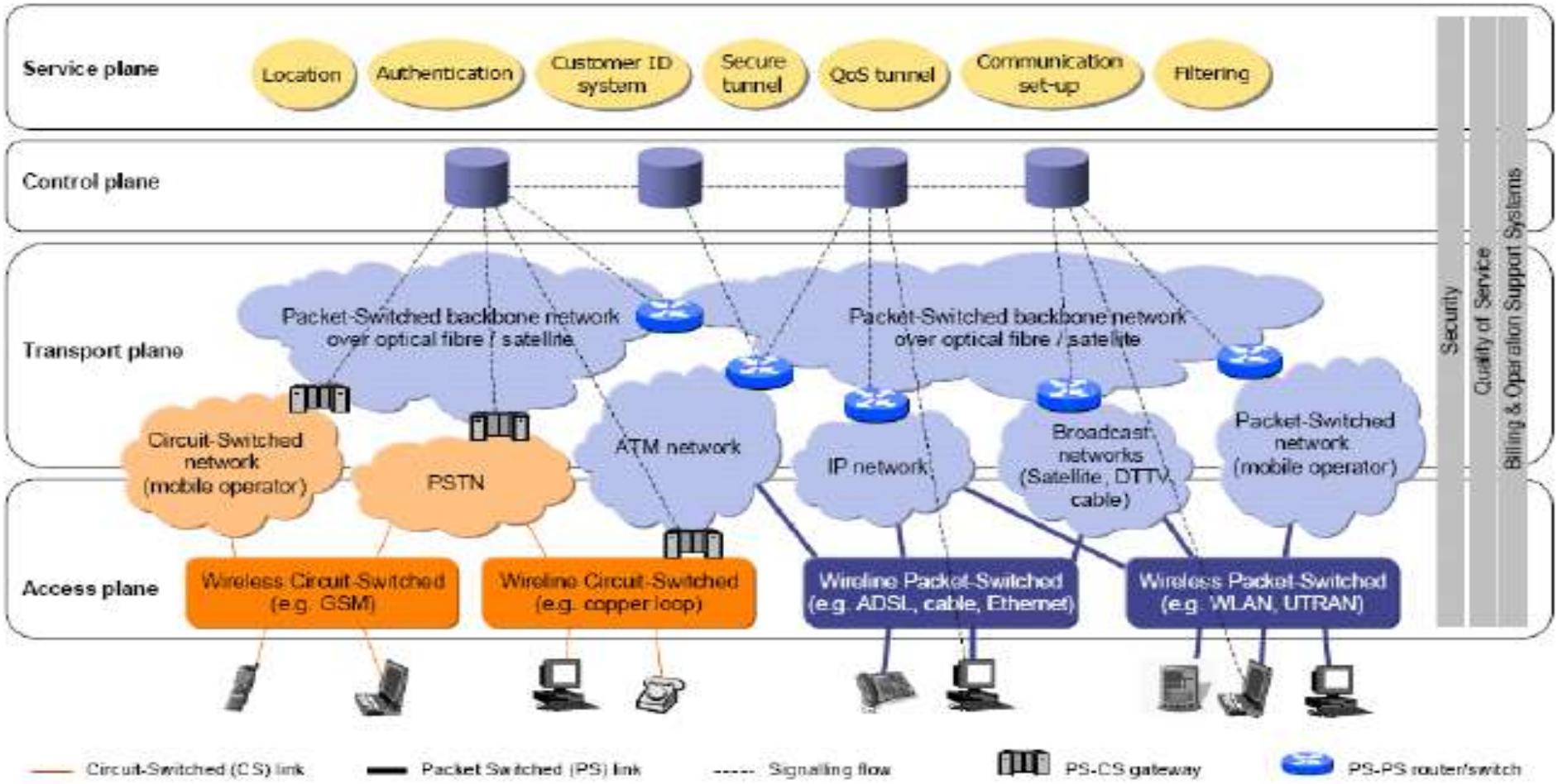


Fig 15: Typical representation of NGN architecture



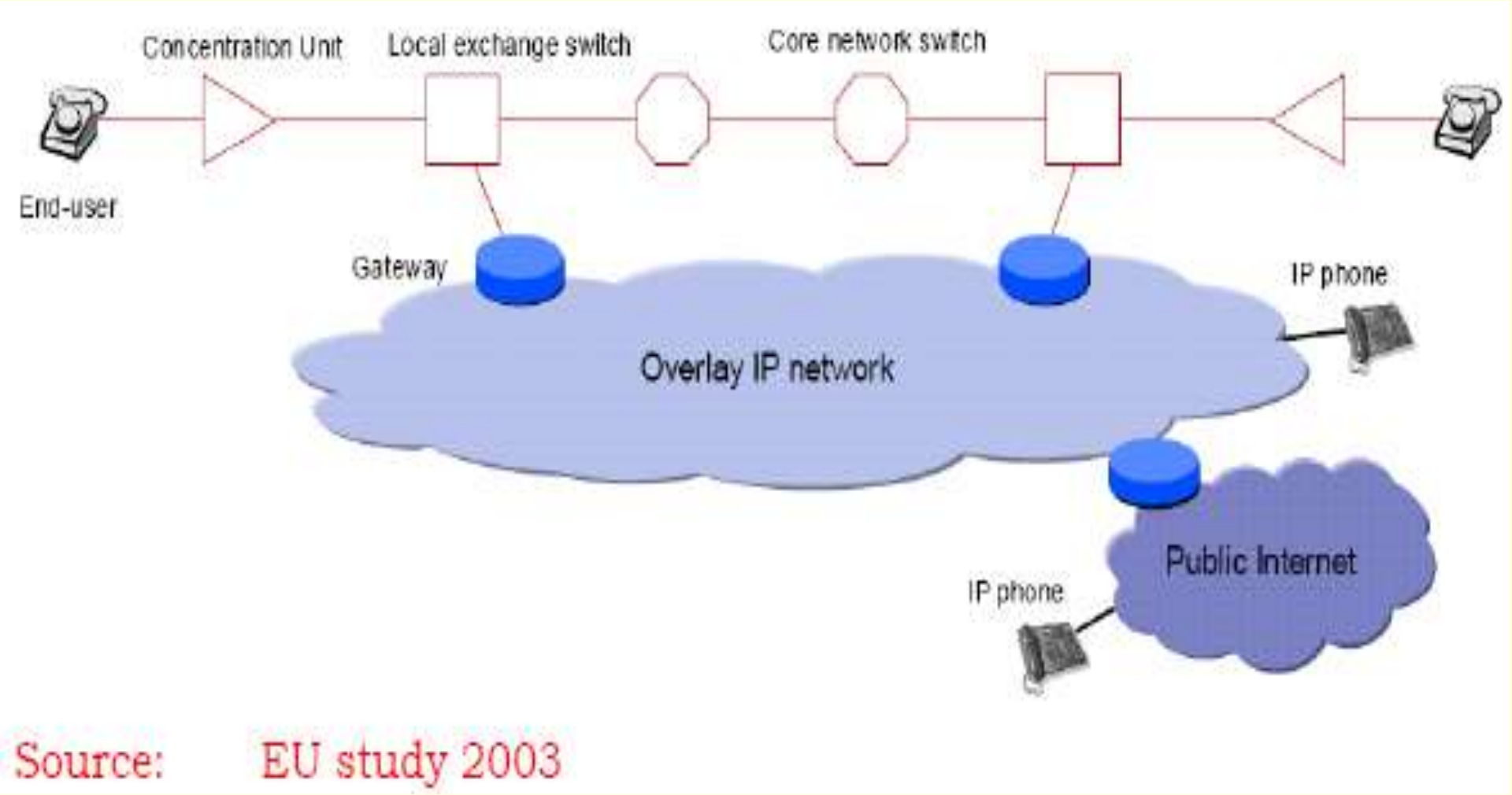
Source: EU study, 2003

Fig 16: Generic benefits, costs and risks for incumbents considering NGN investments

	Access NGN Investment	Core NGN Investment
Benefits	• Improved competitiveness against triple-play cable TV operators (although an incremental ADSL2+ based approach can bring many of the benefits of more capital intensive access NGN moves) • Opportunity to disrupt the business models of DSL resellers and unbundlers (if the regulator doesn't act to prevent this disruption)	• Opportunity for very significant cost reductions, through the rationalisation of legacy products, networks and back-office activities • Opportunity to disrupt the business models of competitors (CPS players, altnets, ISPs etc. (if the regulator doesn't act to prevent this disruption) • Anticipation of the technical obsolescence of the PSTN (as switches and concentrators reach the end of their engineering lifetime).
Costs	• Significant capital investments ahead of any benefits to revenue and profit • Triple play may increase costs without leading to intended ARPU rises. • Regulator may insist on wholesaling • Potential cannibalisation of legacy access svcs (private ccts, FR, ATM etc.)	• Project risk due to huge scope and complexity • Cannibalisation of higher margin legacy services • Risk of failure to realise identified cost savings • Project reveals reality of costs to the regulator, leading to cuts in interconnect and other prices • Regulator forces reselling of core NGN services in forms that are highly beneficial to competitors.

Source: Spectrum, New Street

Fig 17: Overlay scenario



Source: EU study 2003

Fig 18: Expected performance of various access technologies

Technology	ADSL1	ADSL2+	VDSL1	FTTP
Headline Speed	8Mbps	26Mbps	52Mbps	Multi-Gbps
Expected performance in real networks within 1.5Km of exchange	6Mbps	12Mbps	20Mbps	Multi-Gbps
Internet and one TV	✓	✓	✓	✓
Internet and two TVs	X	✓	✓	✓
Internet and one HD TV	XX	✓	✓	✓
Internet and two HD TVs	XX	XX	✓	✓
Internet and more than two HD TVs	XX	XX	X	✓

Note: X = probably inadequate. XX = inadequate
Source: New Street Research

Fig 19: Current BT network

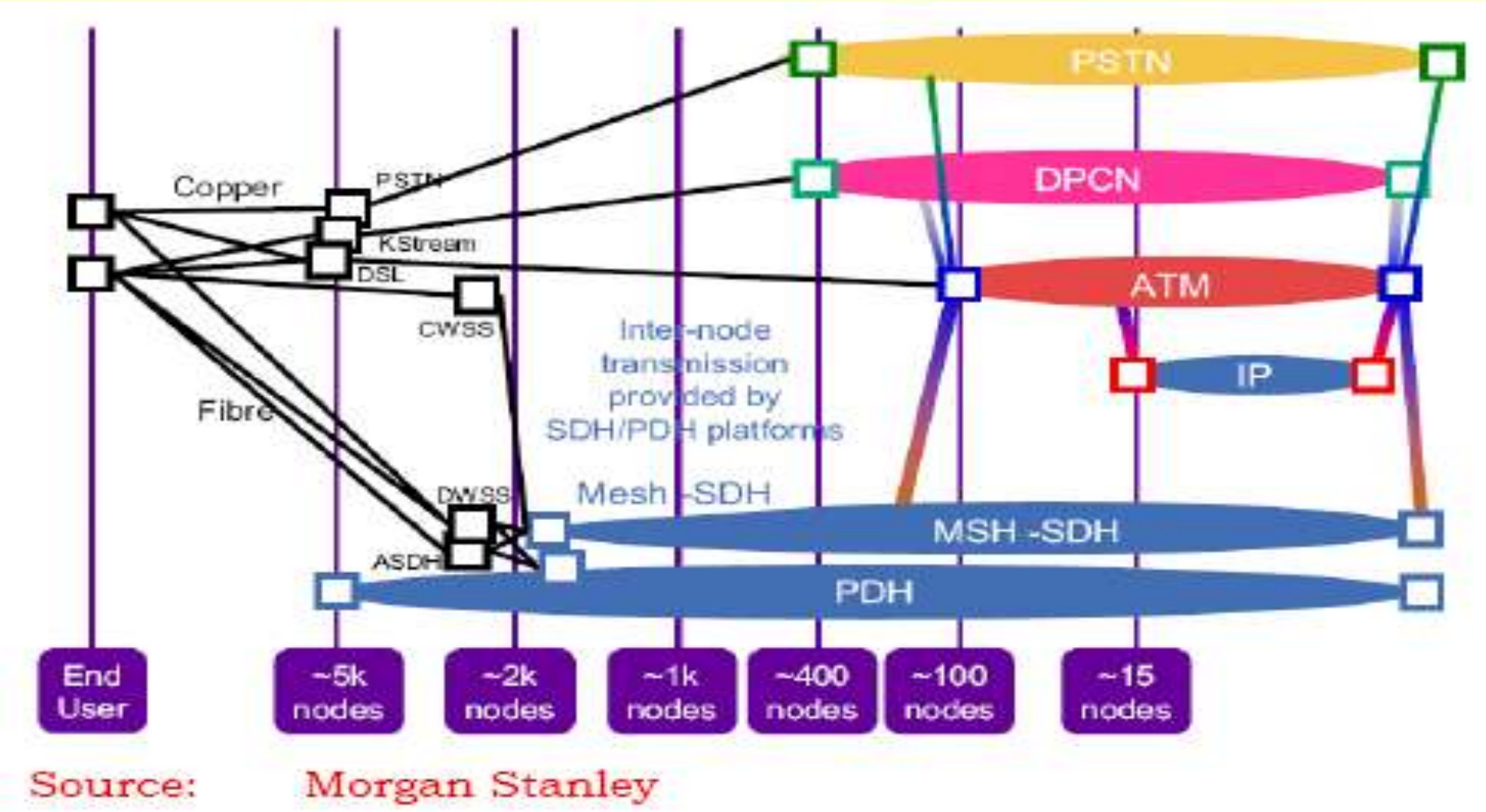
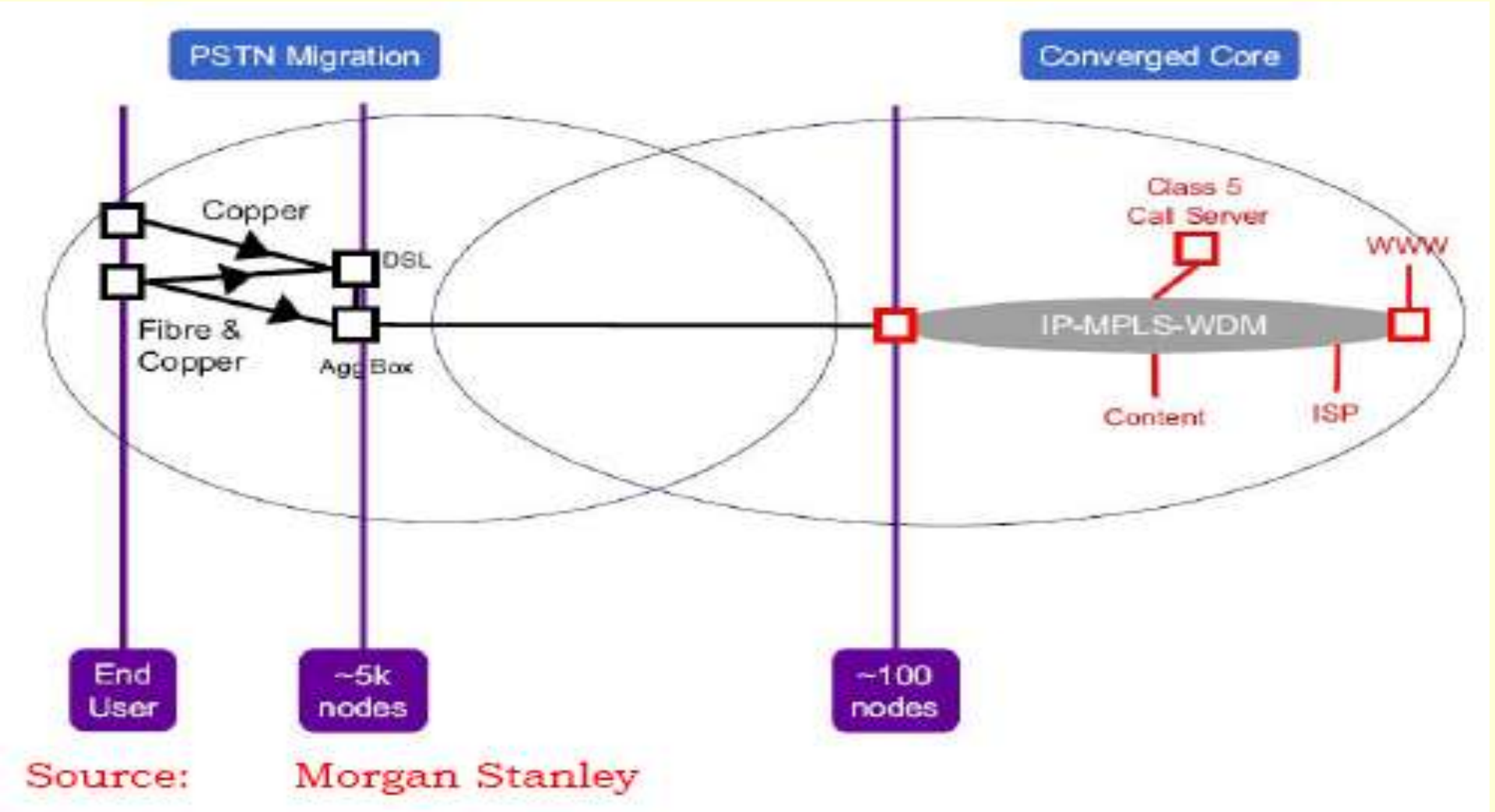
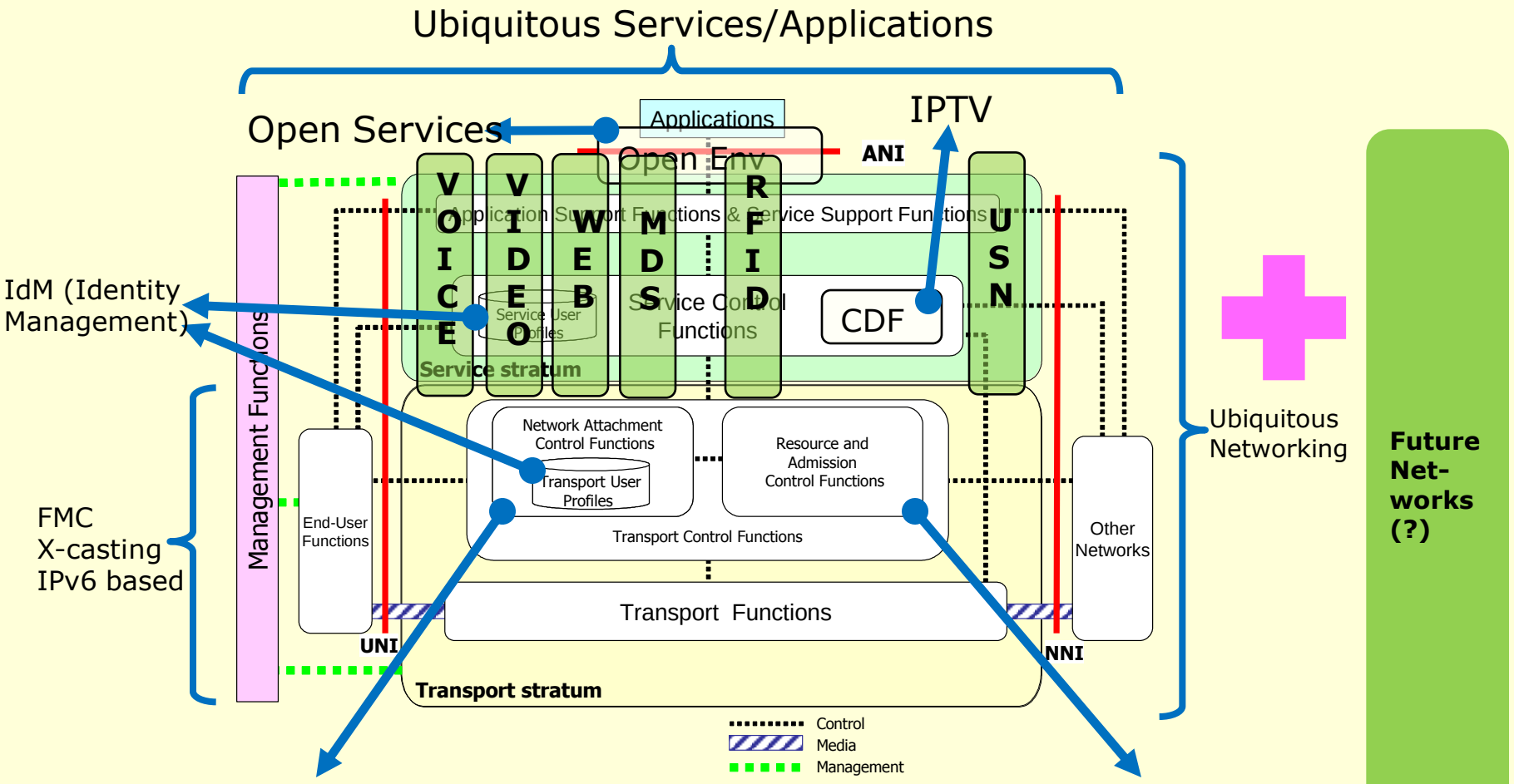


Fig 20: Single IP Architecture



5. Conclusion

Future Direction of ITU-T SG13



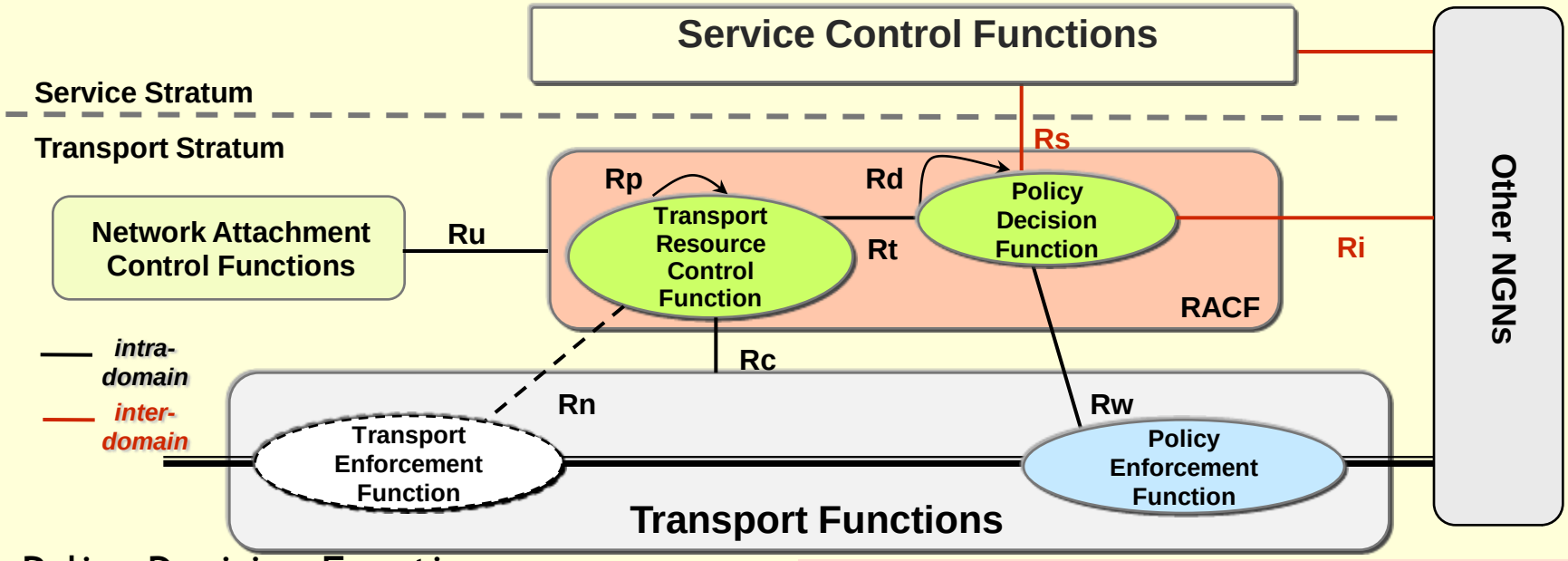
NGN in 4 words…

- by Fixed
- by Mobile
- by Wireless

NGN = Broadband Managed IP Network

- for Services
- for Businesses
- for Players
- for Users

Resource and Admission Control Functions

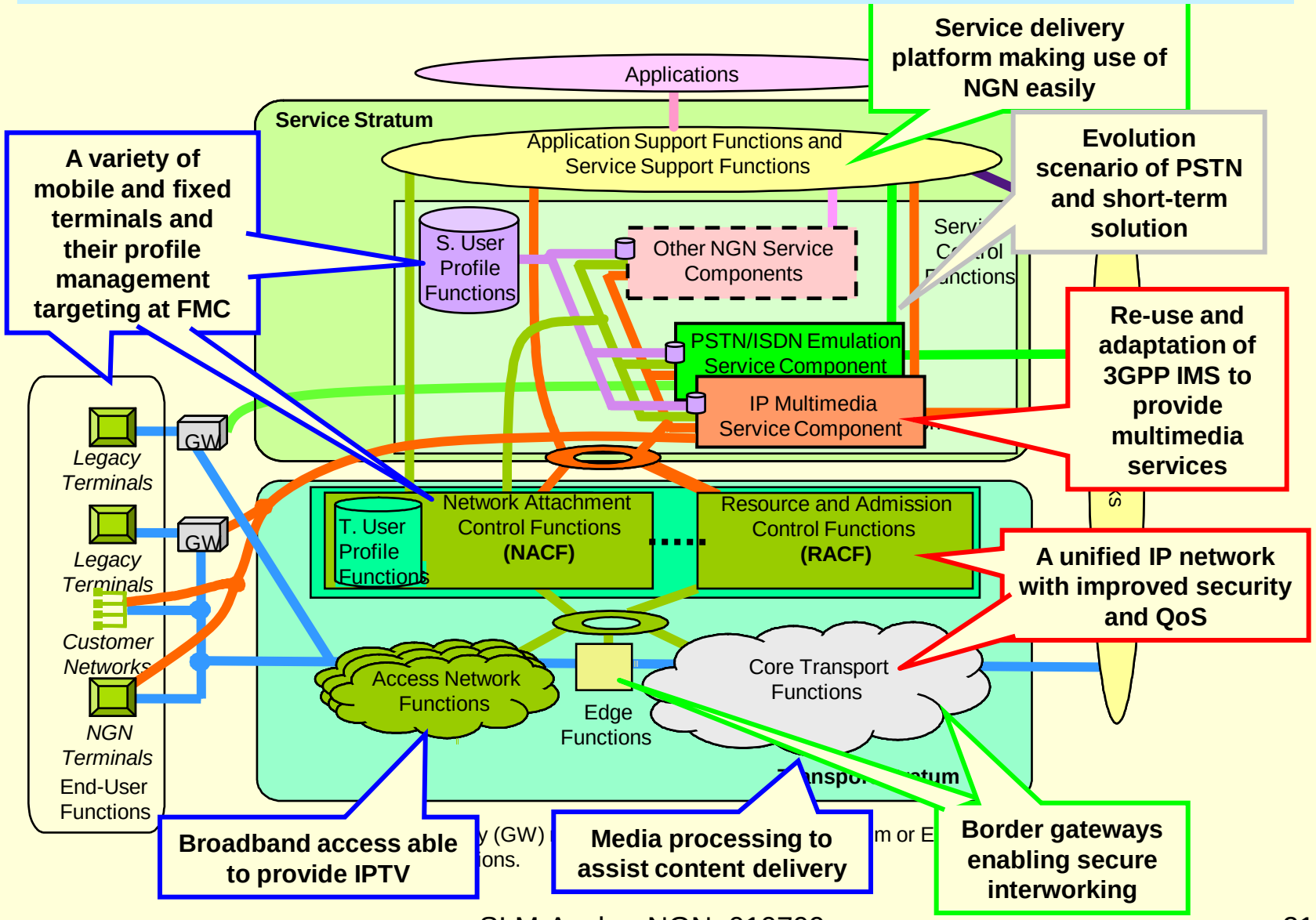


- Policy Decision Function
  service facing, transport independent
- Transport Resource Control Function
  service independent, transport dependent, network-segment specific
- Policy Enforcement Function
  typically part of border transport elements

RACF

- Augments native transport QoS support
  - ✓ Preempting transport congestion at the *service control layer*
  - ✓ Protecting ongoing premium traffic

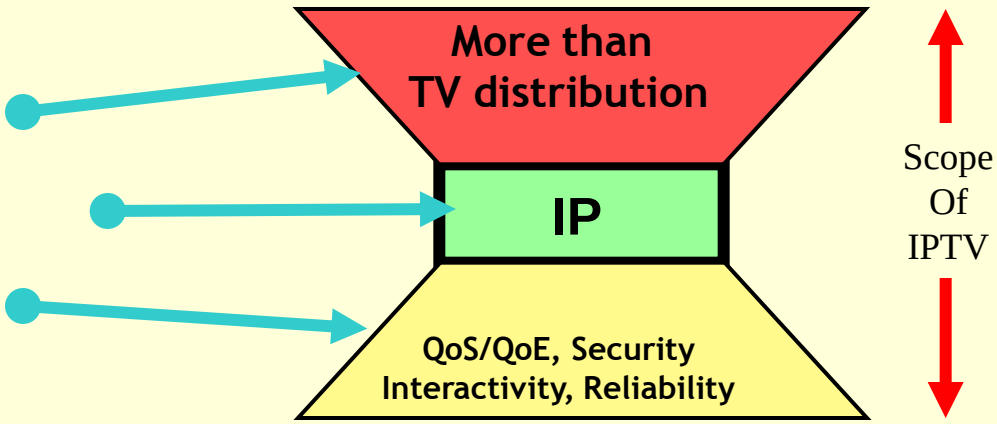
Key Features of NGN Functions



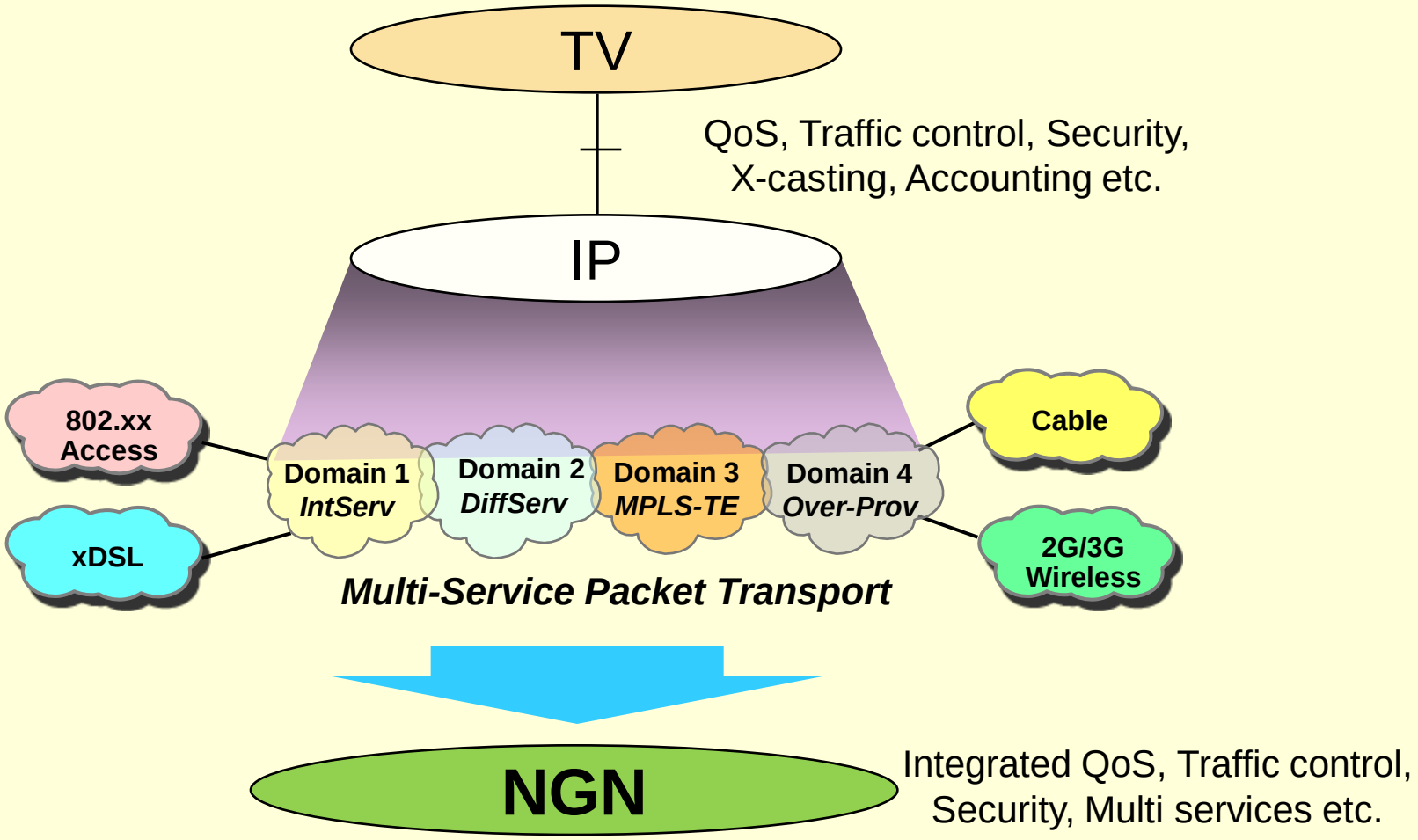
Definition of IPTV

IPTV is defined as multimedia services such as television/video/ audio/text/graphics/data delivered over IP based networks managed to provide the required level of QoS/QoE, security, interactivity and reliability

- **Multimedia Services**
- **Over IP based networks**
- **Managed capabilities**



NGN as an Infrastructure for IPTV



Relationship between NGN and IP

- NGN, by definition, is identified an infrastructure using packet technologies.
  - There is no specific mention which packet technology NGN should use, but generally assuming IP as a dominant packet technology today.
  - There are also no specific statement to specify the version of IP such as ‘version 4’, ‘version 6’ or ‘version 9,’ but most parts of NGN related ITU-T RECs are mainly assumed ‘version 4’

- ITU-T has been initiated the study on ‘Impacts of IPv6 into the NGN’ which looks for the usage of IPv6 features into the NGN.
  - ITU-T SG 13 Q.7 has been developed 4 draft RECs on IPv6 based NGN.

IPv6 Drive

- Ubiquitous network
- Grid networking
- Mobile computing
- Integration of Wireless and Wireline
- Home Appliances
- Peer-2-Peer applications
- Virtual Private Networks
- Multi-user gaming
- Internet-enable new devices
- Military applications

Possible solutions

- Lack of IP addresses: efficient use of v4 but move to v6
- Reliability
  - Improve bandwidth: xDSL, Optics etc.
  - Managed Routing: MPLS etc.
- Quality of Service: Managed by SLA, Session based
- Security: being developed now but intrinsic difficulties
- Mobility: Mobile/Wireless accesses, Mobile IP
- Configurability: Auto-configuration functions

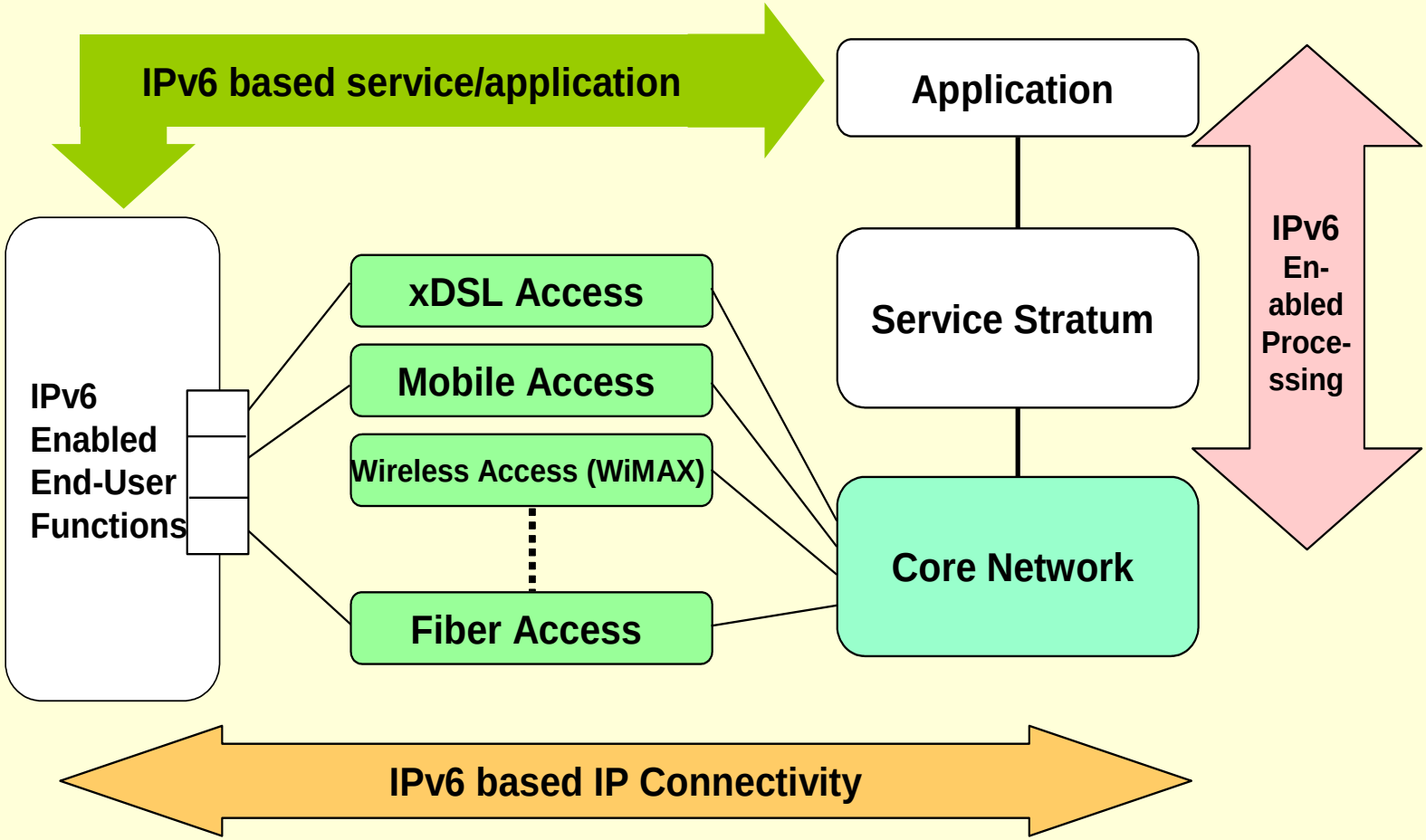
Requirements of IPv6 based NGN

- **General requirements of IPv6-based NGN are identified requirements which influenced by IPv6 features**
- **IPv6 based NGN shall share NGN R1 requirements generally**
- **Further requirements according to IPv6 features identified as IPv6 requirements**
- **IPv6 related requirements would be incorporated into NGN R2 requirements**

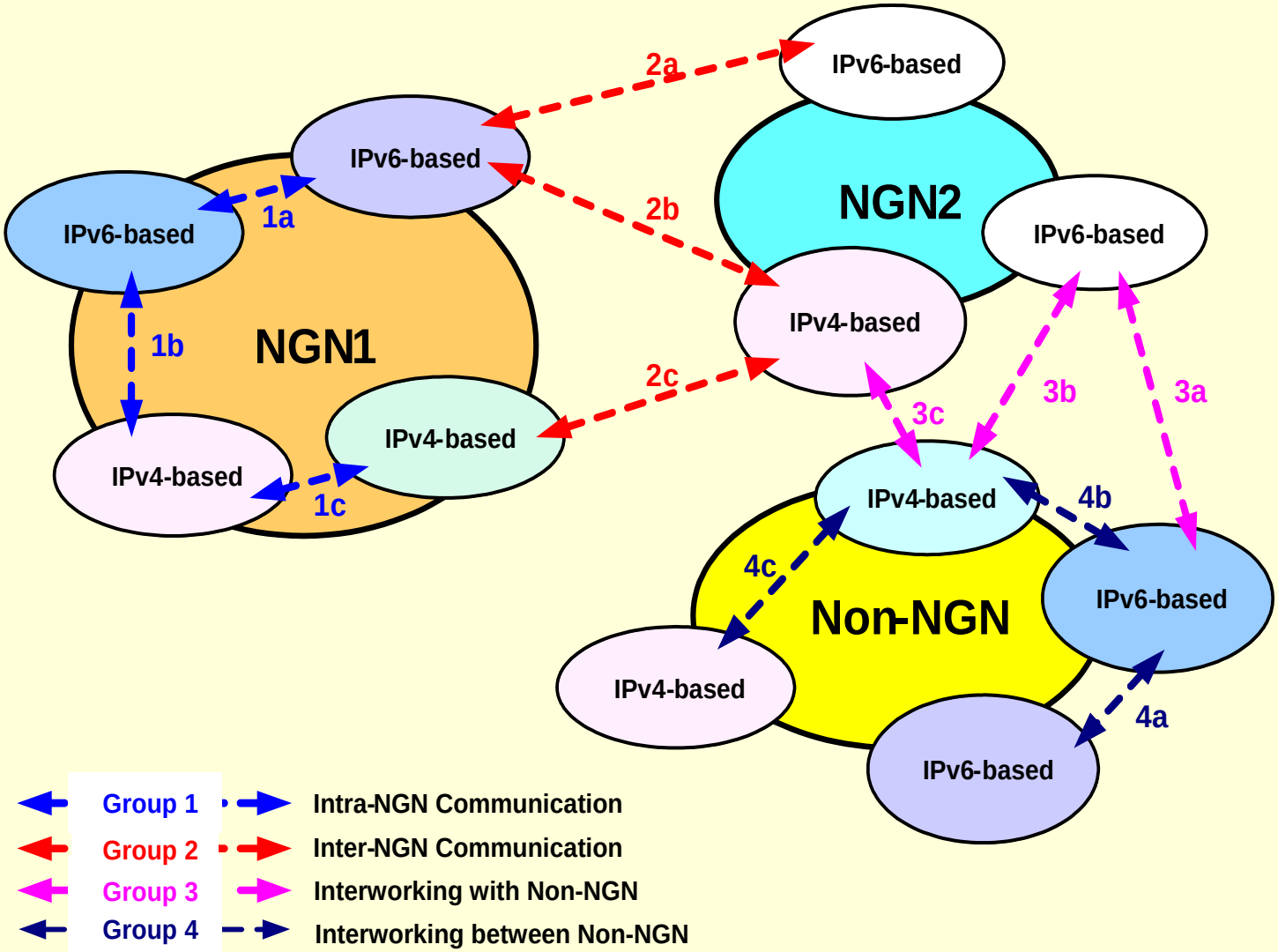
General Requirements of IPv6 based NGN

- IPv6 based NGN shall accommodate the IPv6 addressing schemes.
- IPv6-enabled FEs should differentiate the control information from the IPv6 packets.
- IPv6-based NGN shall support the address transition and interworking without affecting the service provided to users.
- IPv6-based NGN shall support the IPv6 extension headers and options.

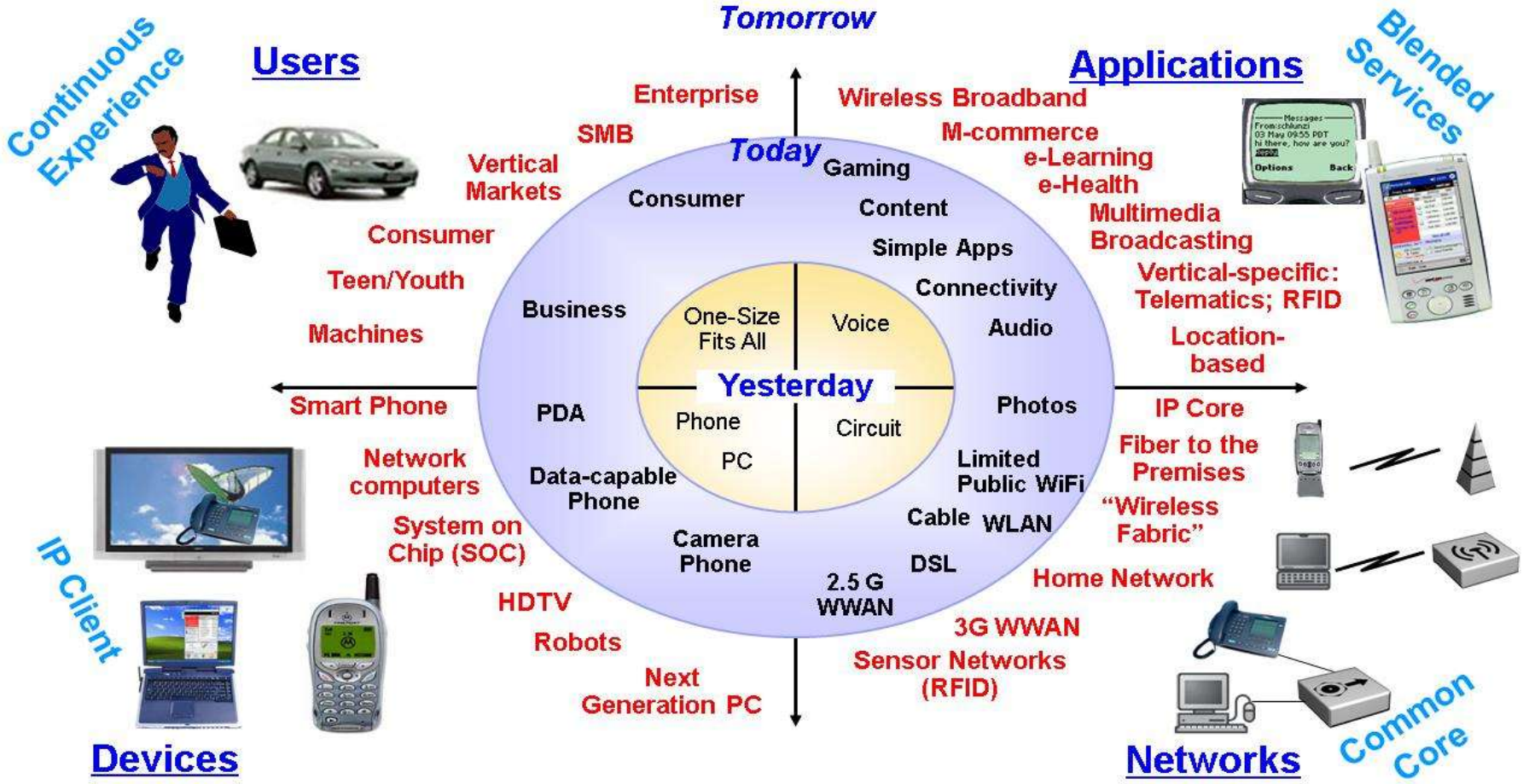
Scope of IPv6 based NGN



Relationship with other networks



Overall Future Directions



Clue for the Future Preparation

Future should direct to the Convergence

- Vision: Any Time, Any Where, Any Services and Any Devices
- FMC should be the 1st instantiation
- 2nd should be the IPTV
- Any information/services over any transport infrastructures: VoDSL, TVoMobile, etc.

Convergence classifies into following:

- **Internal Convergences** (within a industry): FMC, IPTV and others
- **External Convergences**: between/among different industries, e.g., Telematics/ITS, USN, e-Health, Networked Robotics and others

Services on the Convergences









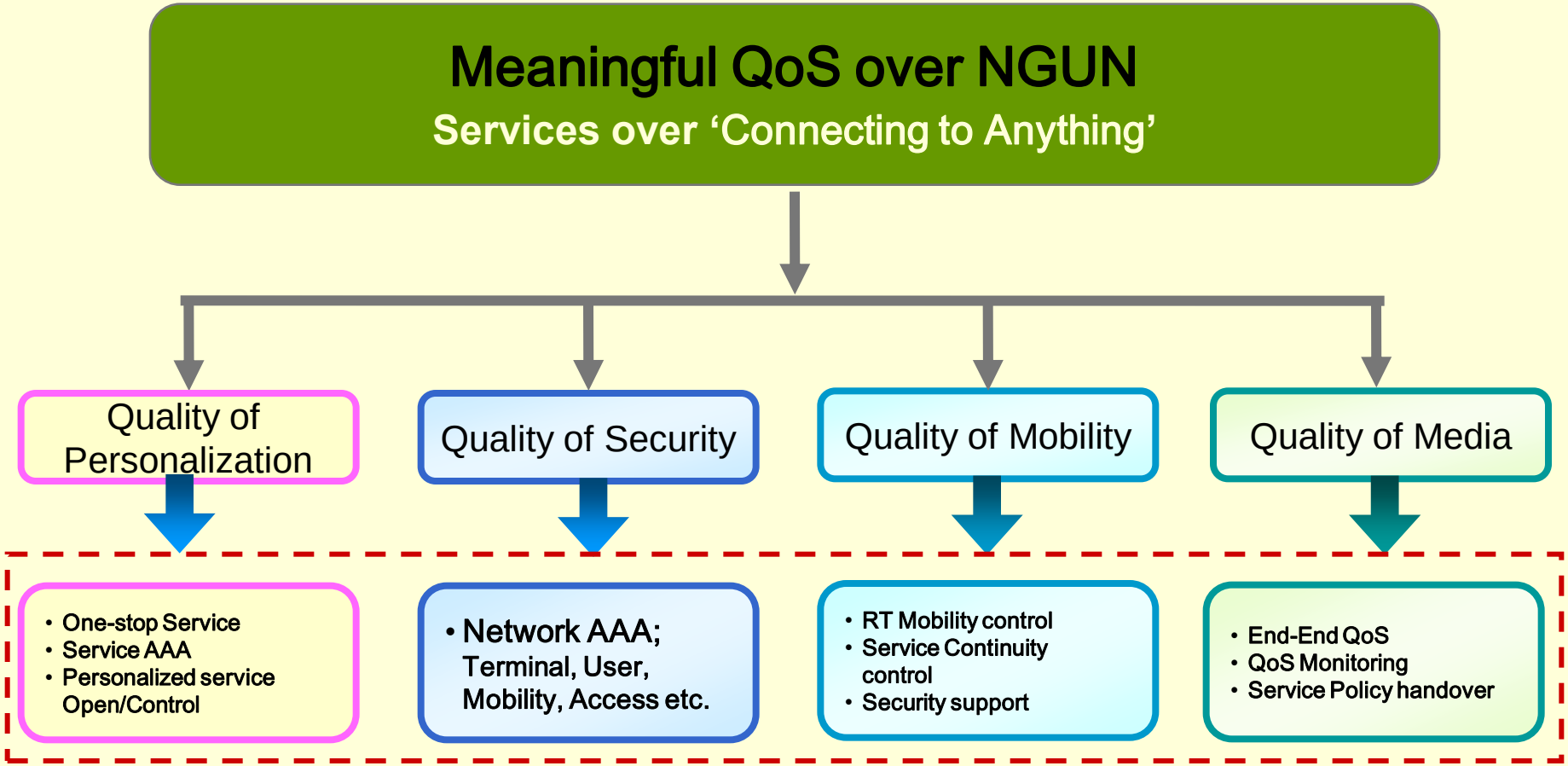






- Always on with Any devices
- Anytime, anywhere and in any form
- Voice and multimedia
- Self service, intuitive
- Simple for the end user
- Secure, trusted and reliable

Extension of “Quality of Service”



Need further study in more details

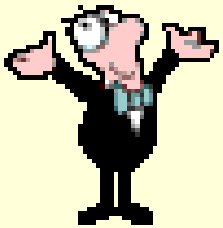
Physical Communication Infrastructure

Full Converged
MM Terminal

Radio/Wireless
Spectrum:
fi

Wave Length:
λi

Logical Communication Infrastructure



User Id:
Earth-Korea-Man:LeeChaesub-19yy-mm-dd

- Certified by UN -

Mobile Phone Nr

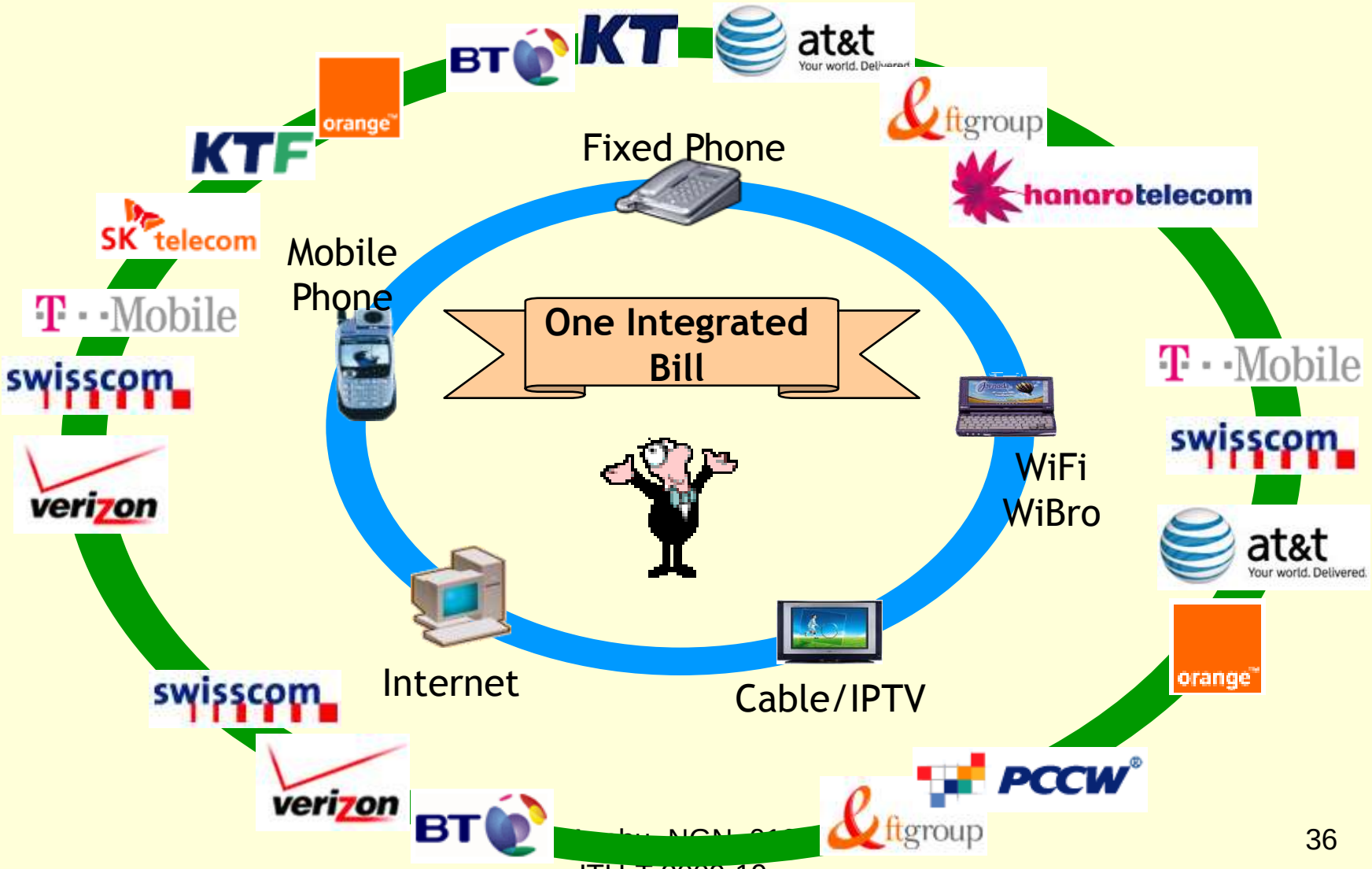
Fixed Phone Nr

WiFi/WiBro Id

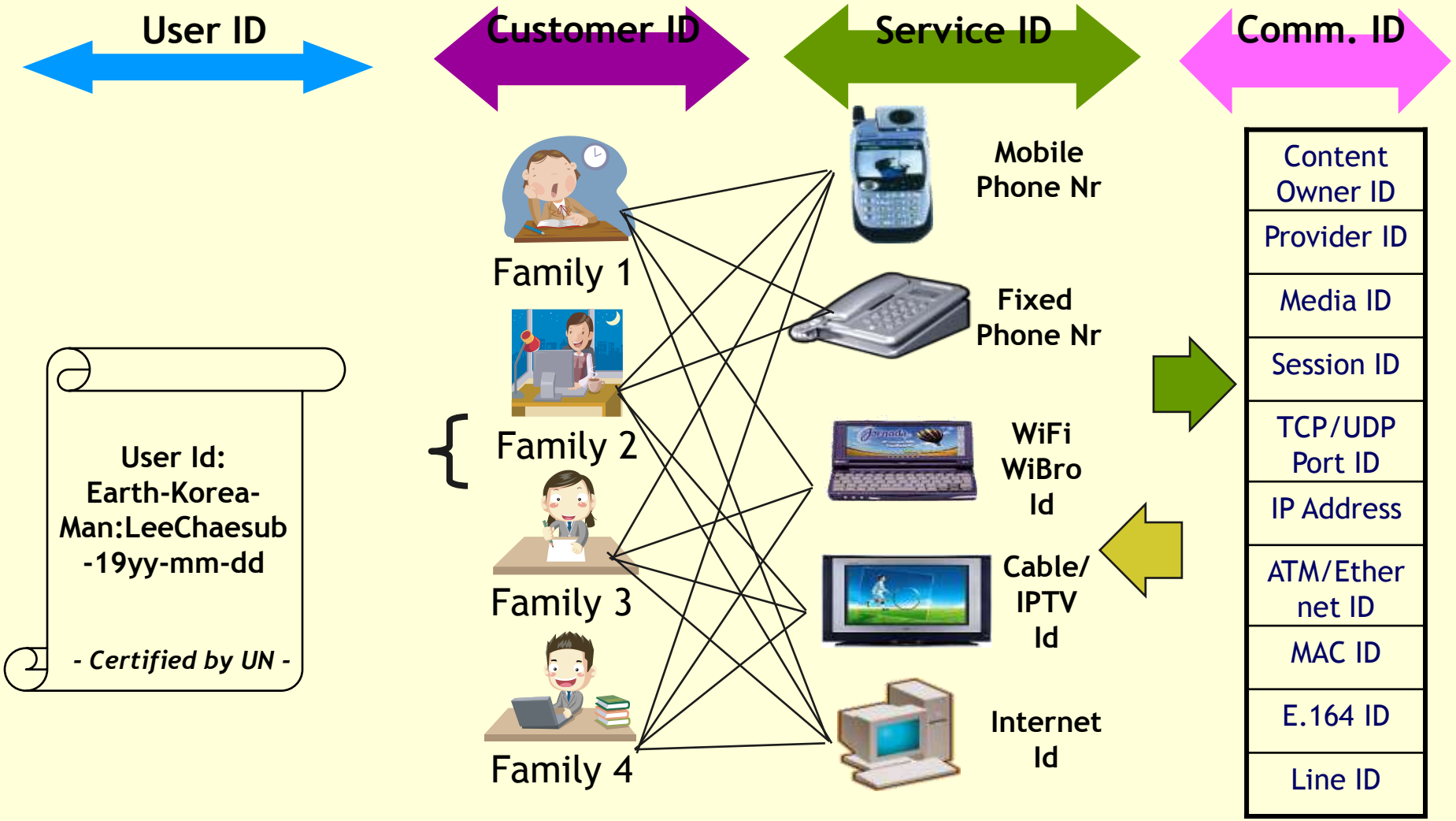
Cable/IPTV Id

Internet Id

Business Communication Infrastructure



Key theme of Future Control Plane: Identity Processing

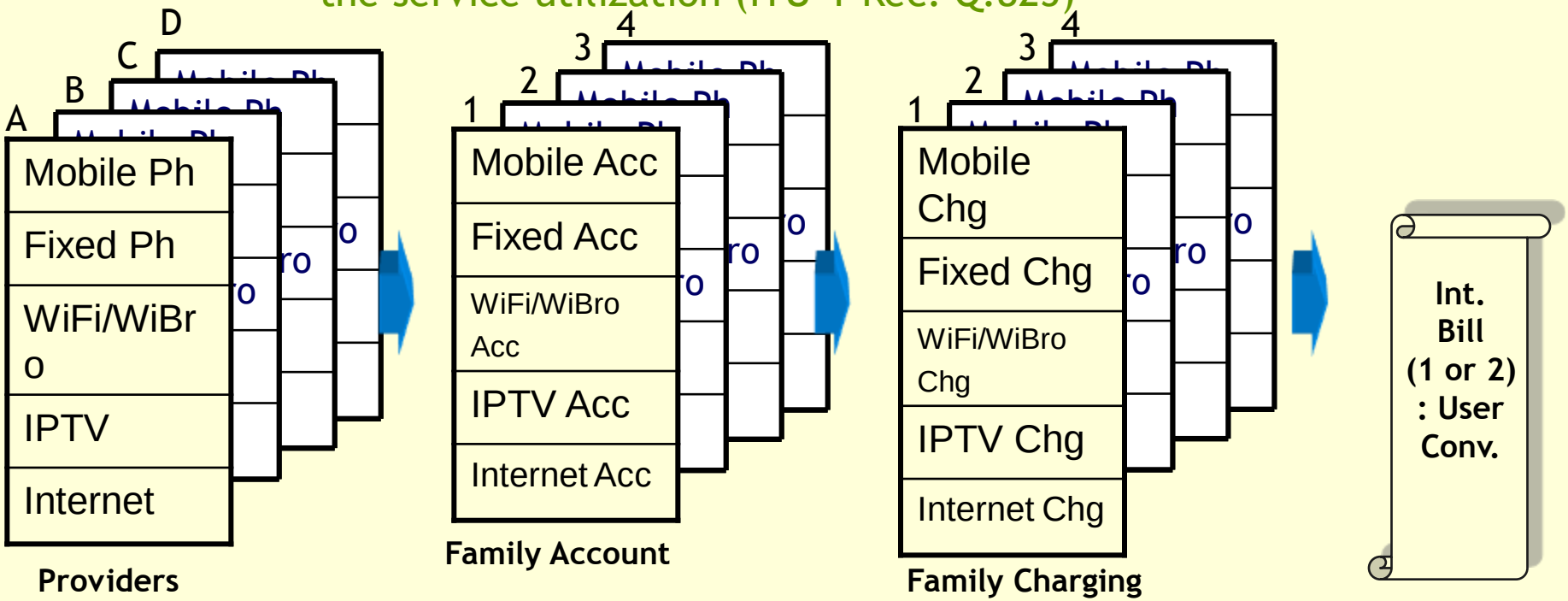


Key theme of Future Management Plane: ABC Processing

Accounting: Set of functions required for Usage Metering, Charging and Billing (ITU-T Rec. Q.825)

Billing: Administrative function to prepare bills to service customers, to prompt payments, to obtain revenues and to take care of customer reclaims (ITU-T Rec. Q.825)

Charging: The set of functions needed to determine the price assigned to the service utilization (ITU-T Rec. Q.825)



Definition of Ubiquitous in ITU-T

"The term used for networking capabilities to support various classes of applications/services which require "Any Services, Any Time, Any Where and Any Devices" operation using NGN enabled capabilities. This networking capability should support human-to-human, human-to-object (e.g., device and/or machine) and object-to-object communications."

Temporary definition in ITU-T Draft Rec. Y.NGN-UbiNet:
'Overview and Principles for Ubiquitous Networking in NGN'

Vision and Goals of NGUN

Vision

- Everything of value is connected to the network
  - Physical mobility & Service mobility

Goals

- Widespread interconnection of computing and communication devices
- Pervasive networks that include both wireline and wireless segments
- Mobile-to-fixed; mobile-to-mobile architectures
- Includes public and private information spaces
- Embedded intelligence, anywhere and anytime

Key Requirements for NGUN

- **More connectivity** for whenever, whoever, wherever, whatever, etc;
- **More reality** for subconscious connectivity to provide connectable real world environments;
- **More intelligence** for innovative communication to accelerate value creation.

Four Key Technology Enablers

Tagging Things: RFID

- enabling real-time identification and tracking

Sensing Things: Sensor technologies

- enabling detection of environmental status and sensory information

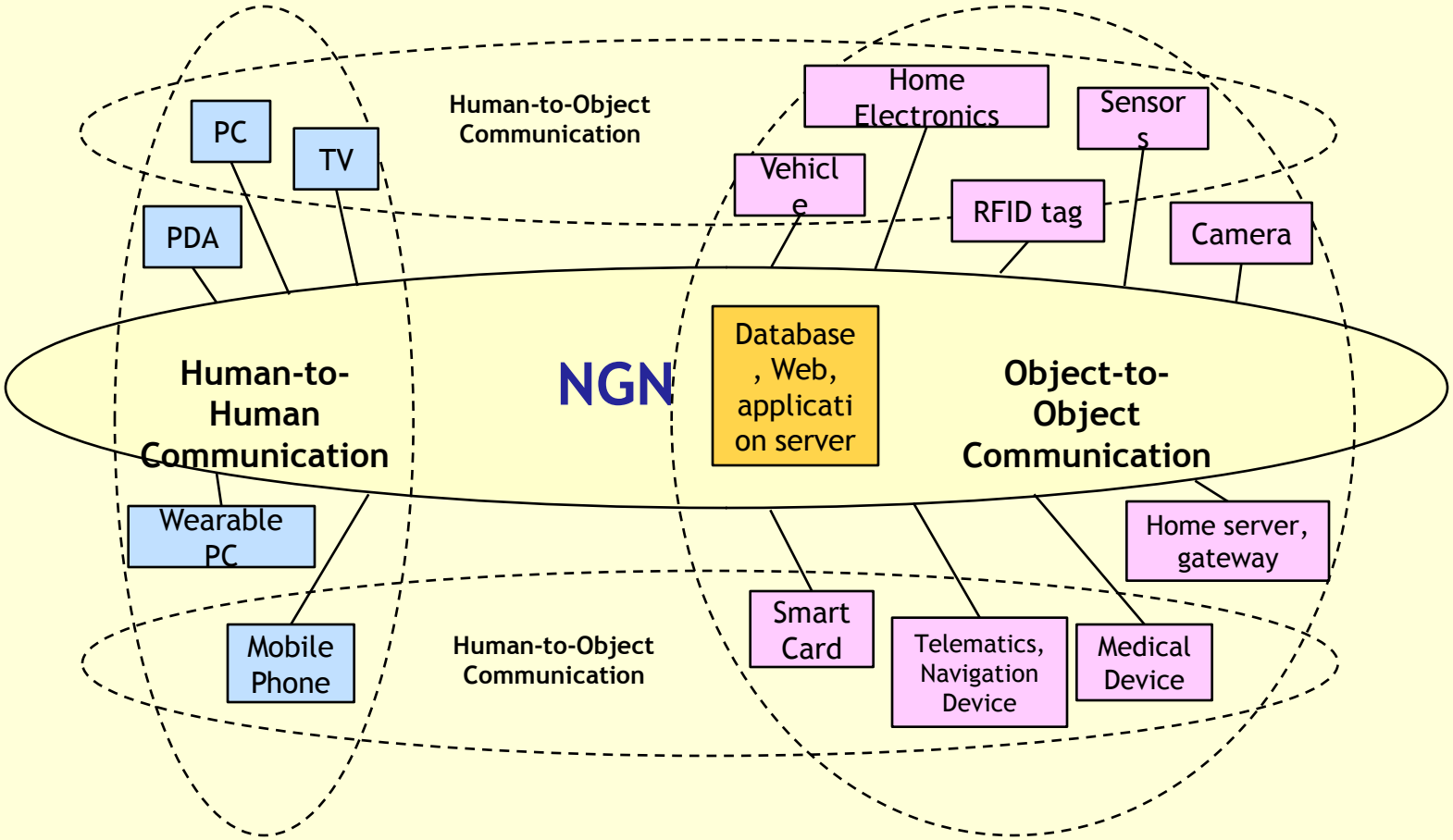
Thinking Things: Smart technologies

- building intelligence into the edges of the network
- enabling smart homes, smart vehicles etc

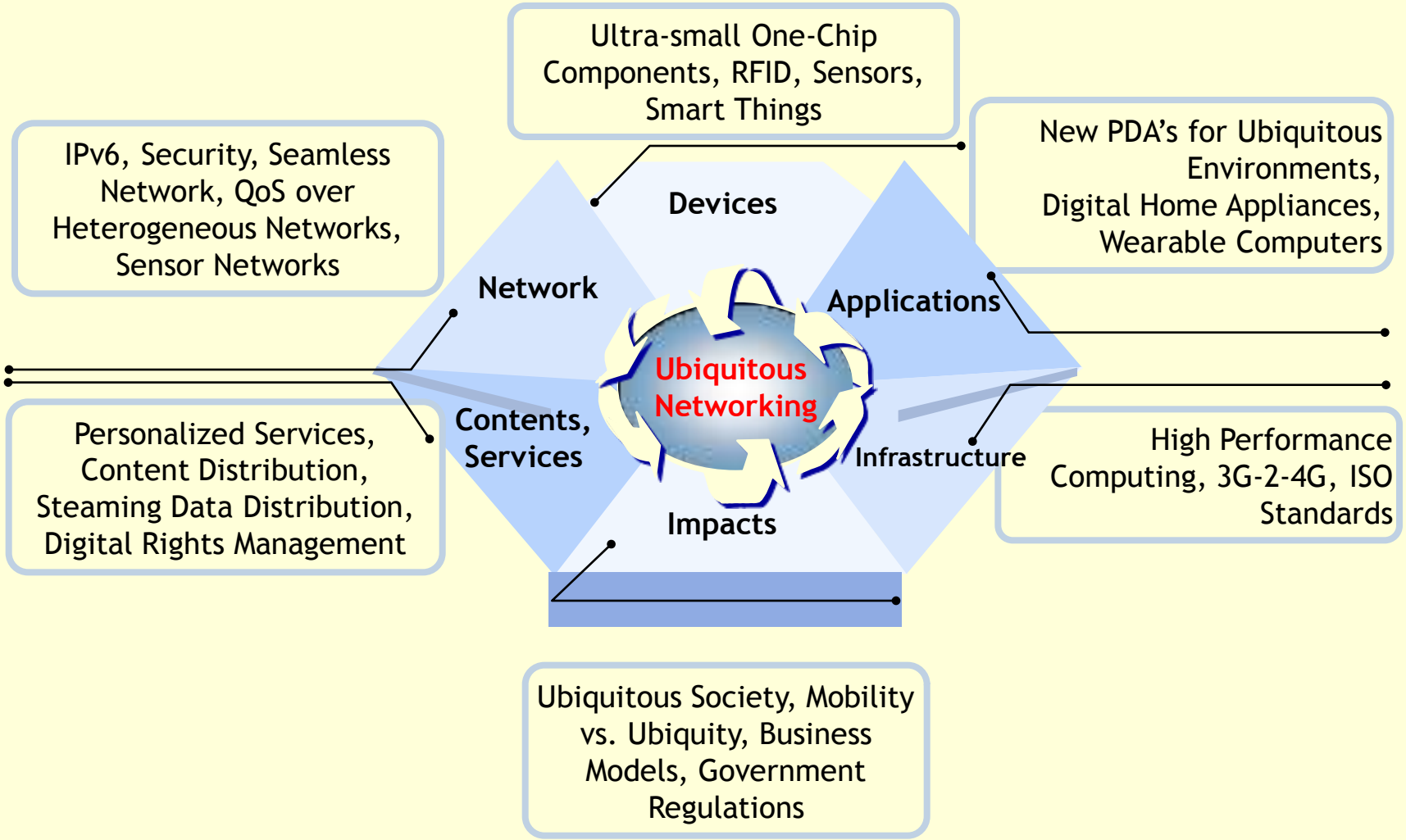
Shrinking Things: Nanotechnology

- making possible the “networking” of smaller and smaller objects (more powerful?!)

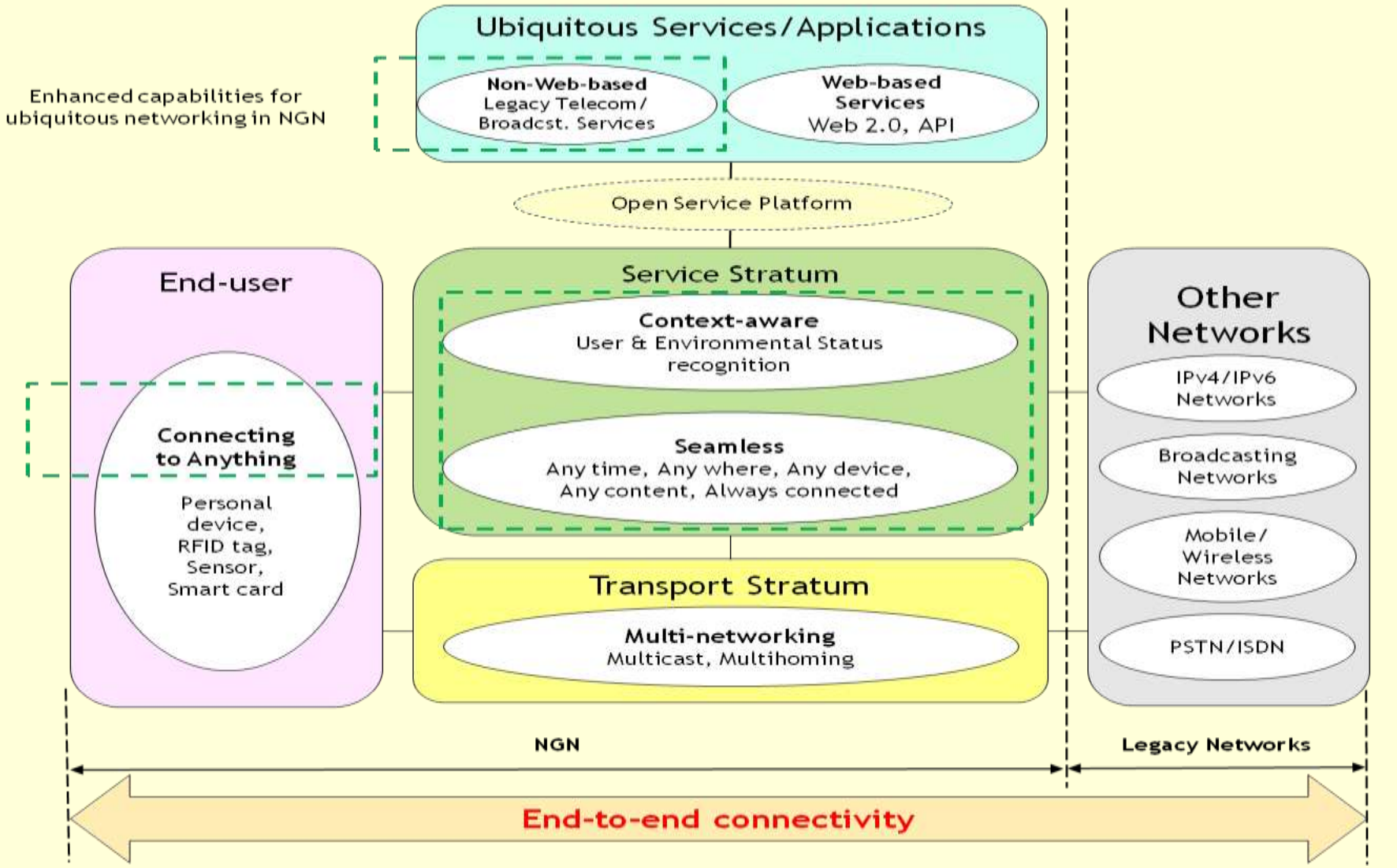
Basic conceptual Model of NGUN



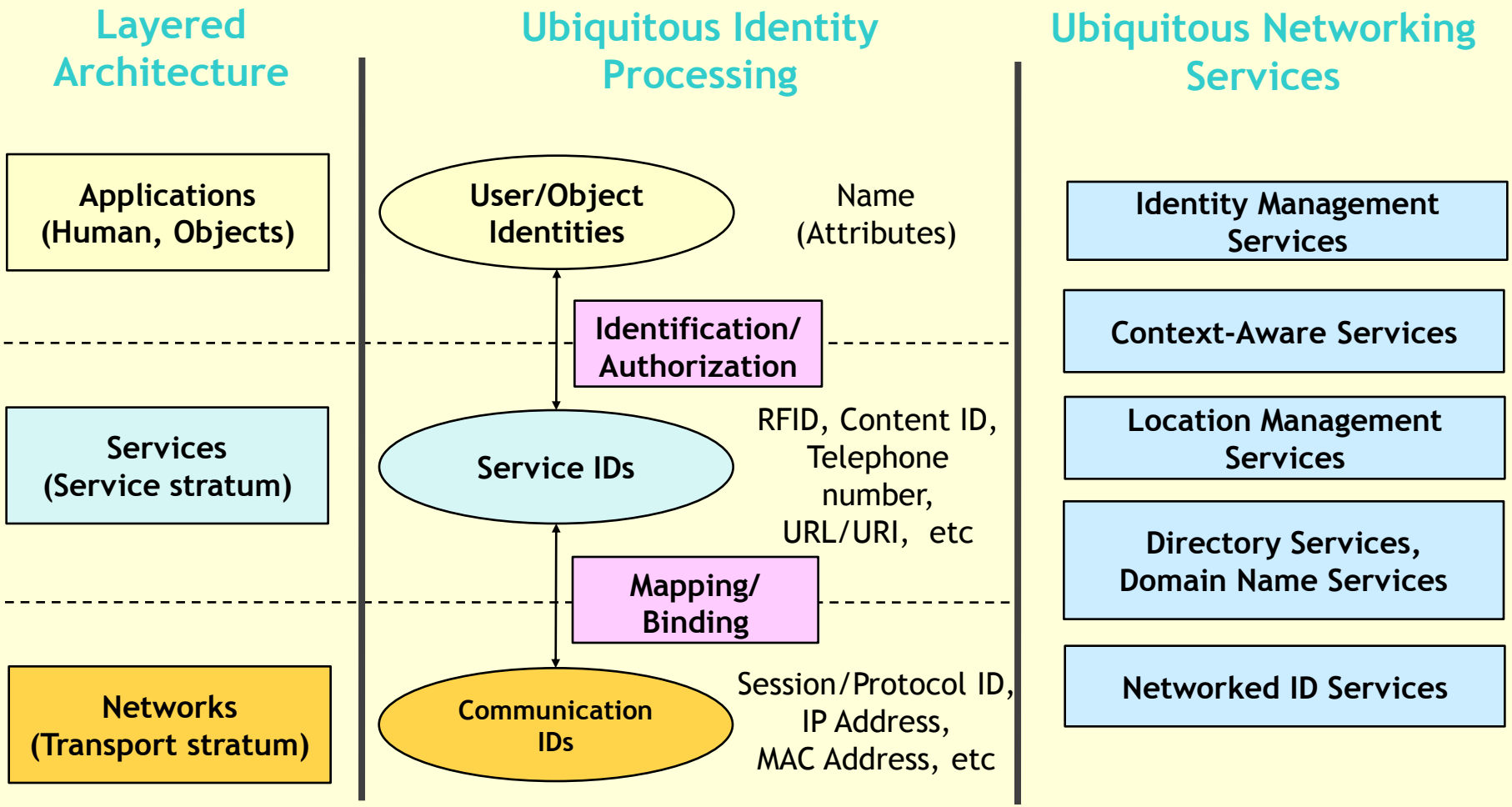
Technologies for NGUN



Functional Architecture of NGUN based on NGN

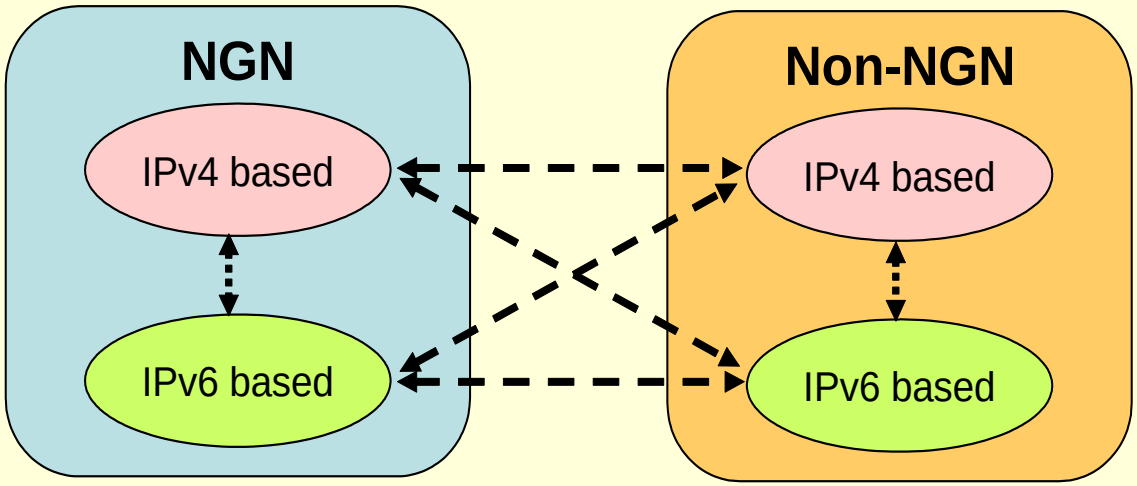


Identity Processing for NGUN

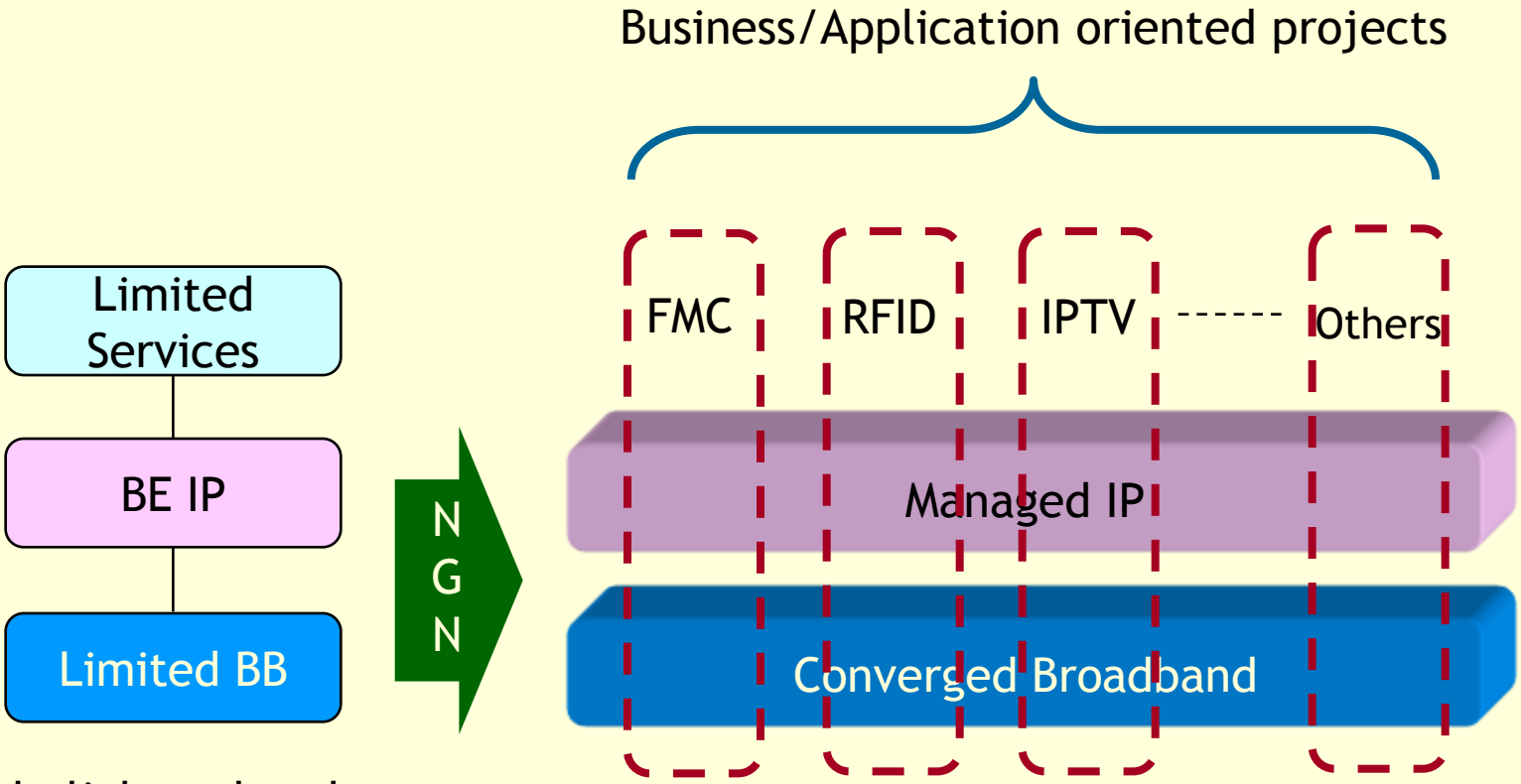


NGN: Currently IP based …

- IPv6-based NGN: This is a NGN which support addressing, routing protocol and mechanisms of IPv6
- IPv4-based NGN: This is a NGN which support addressing, routing protocol and mechanisms of IPv4
- IPv6-based Non-NGN: This is an IPv6 based packet network which is not comply with NGN
- IPv4-based Non-NGN: This is an IPv4 based packet network which is not comply with NGN



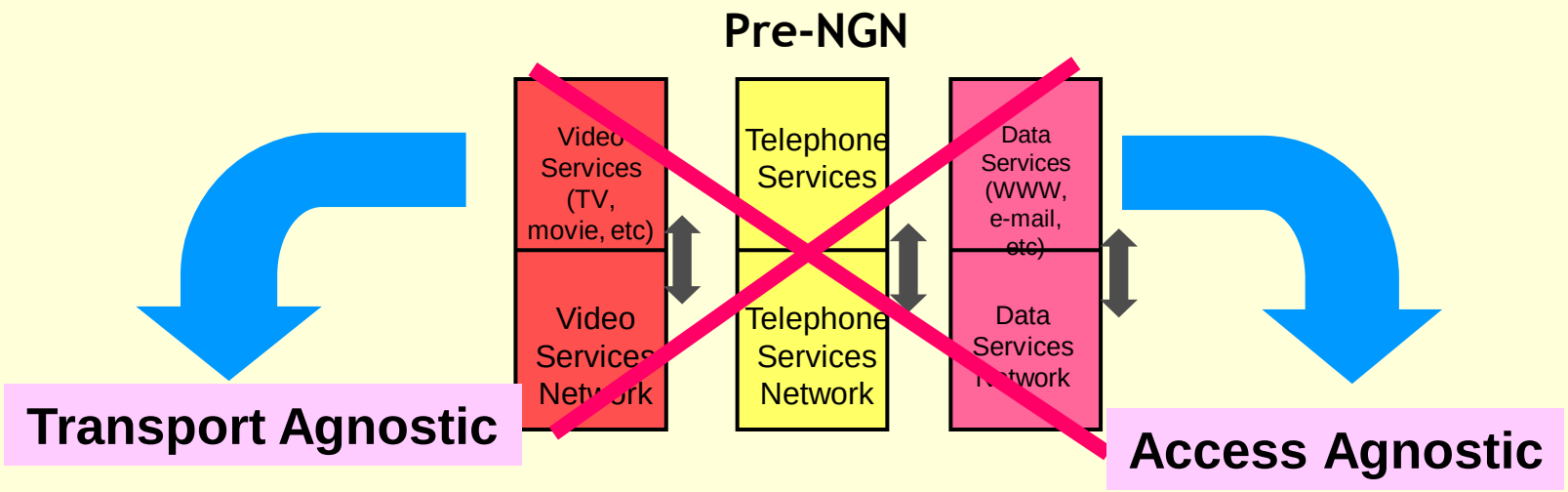
NGN: Enabler for Convergence

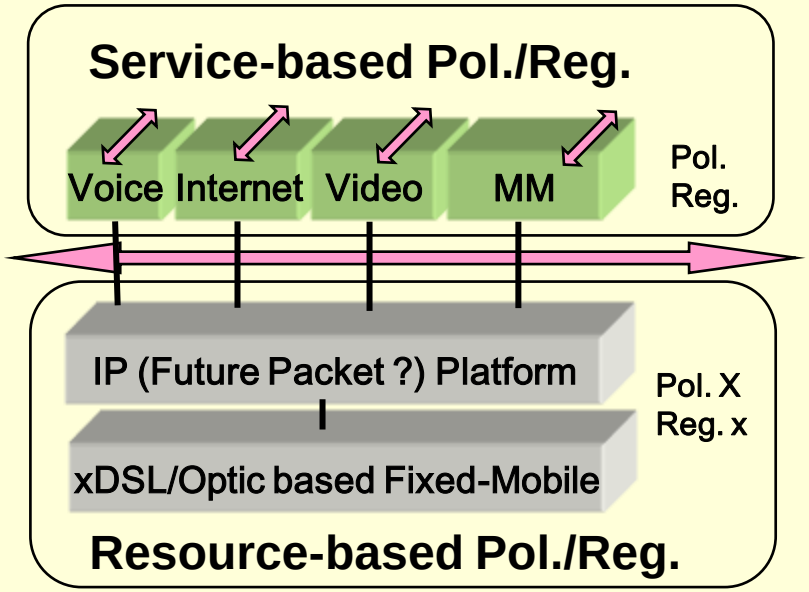


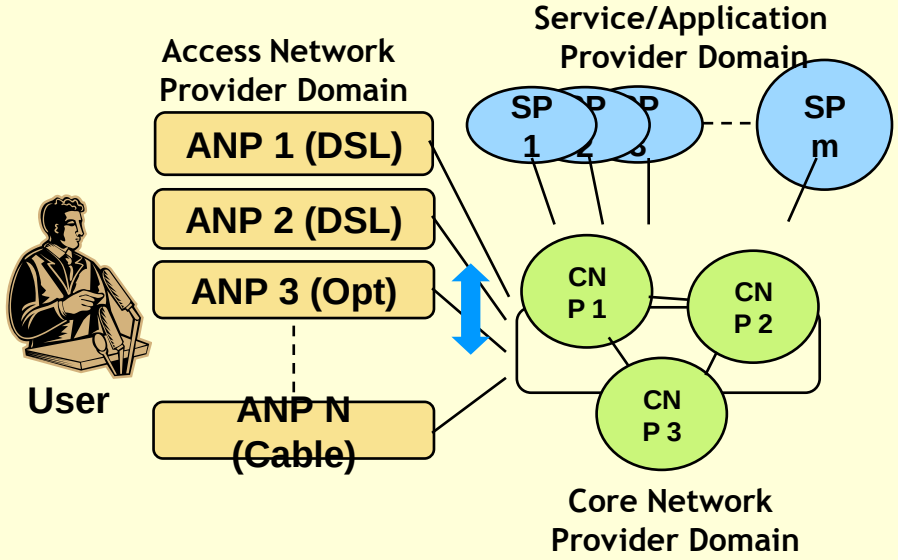
- Simple linkage btw layers
- Simple business relationships
- Simple players

- Simple linkage btw layers with dynamics
- Diverse and Flexible business relationships
- Diverse business models and players

NGN: Changing Regulation Frameworks

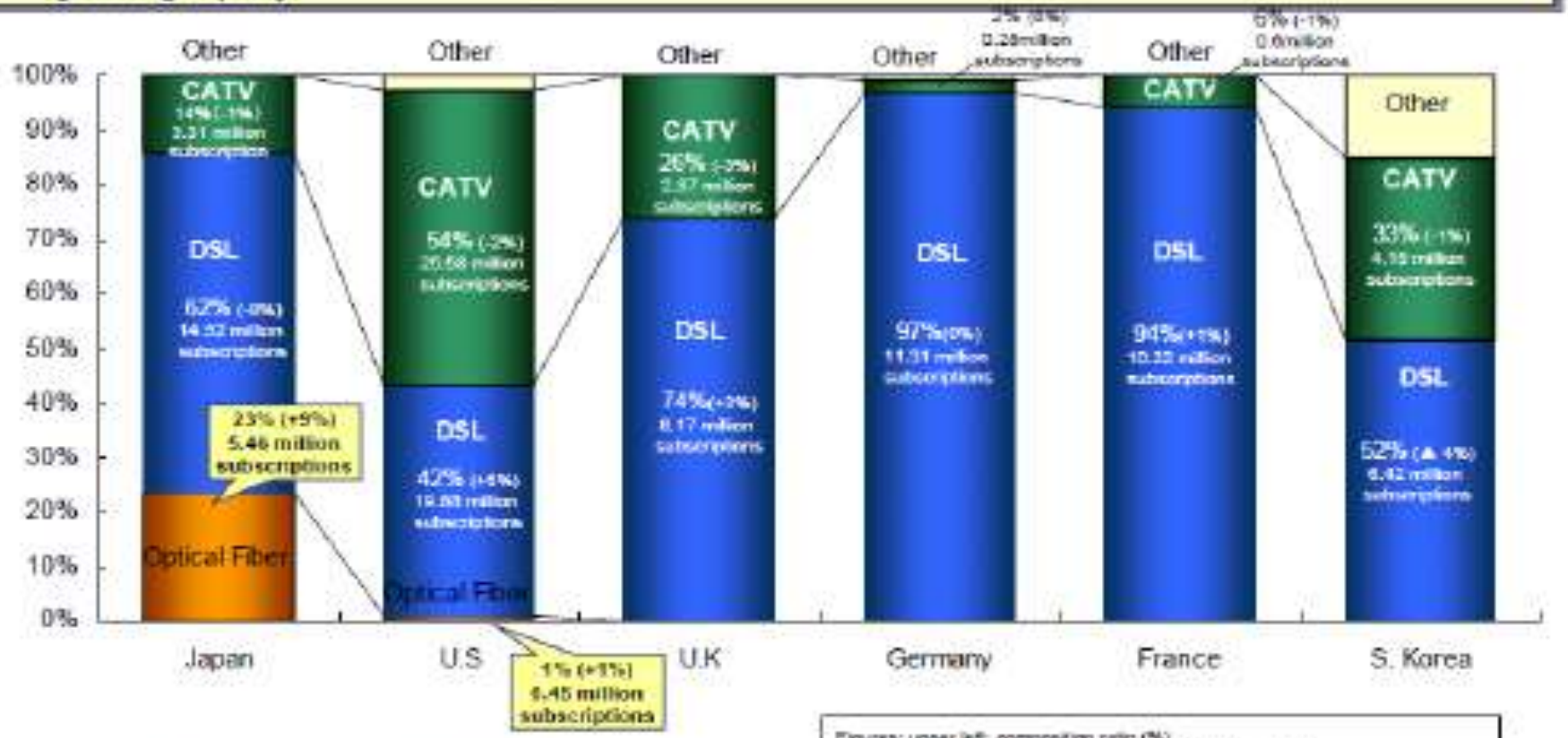






Broadband Share by Service Type, by Country

- In the US, Verizon and AT&T have just launched fiber-optic broadband services, and in Europe, service providers are still at the planning stage. In Japan, however, fiber-optic services are growing rapidly



Sources: Regulatory agencies in countries

Figures: upper left: composition ratio (%);
Upper right: Composition ratio year-on-year changes (%));
Bottom line: number of subscriptions (as of end of 2005 for U.S., and as of end of March 2006 for other countries)

5

Specific Initiatives for Promoting NTT Group's Medium-Term Management Strategy [Released on Nov. 9, 2005]

Building Next-Generation Network

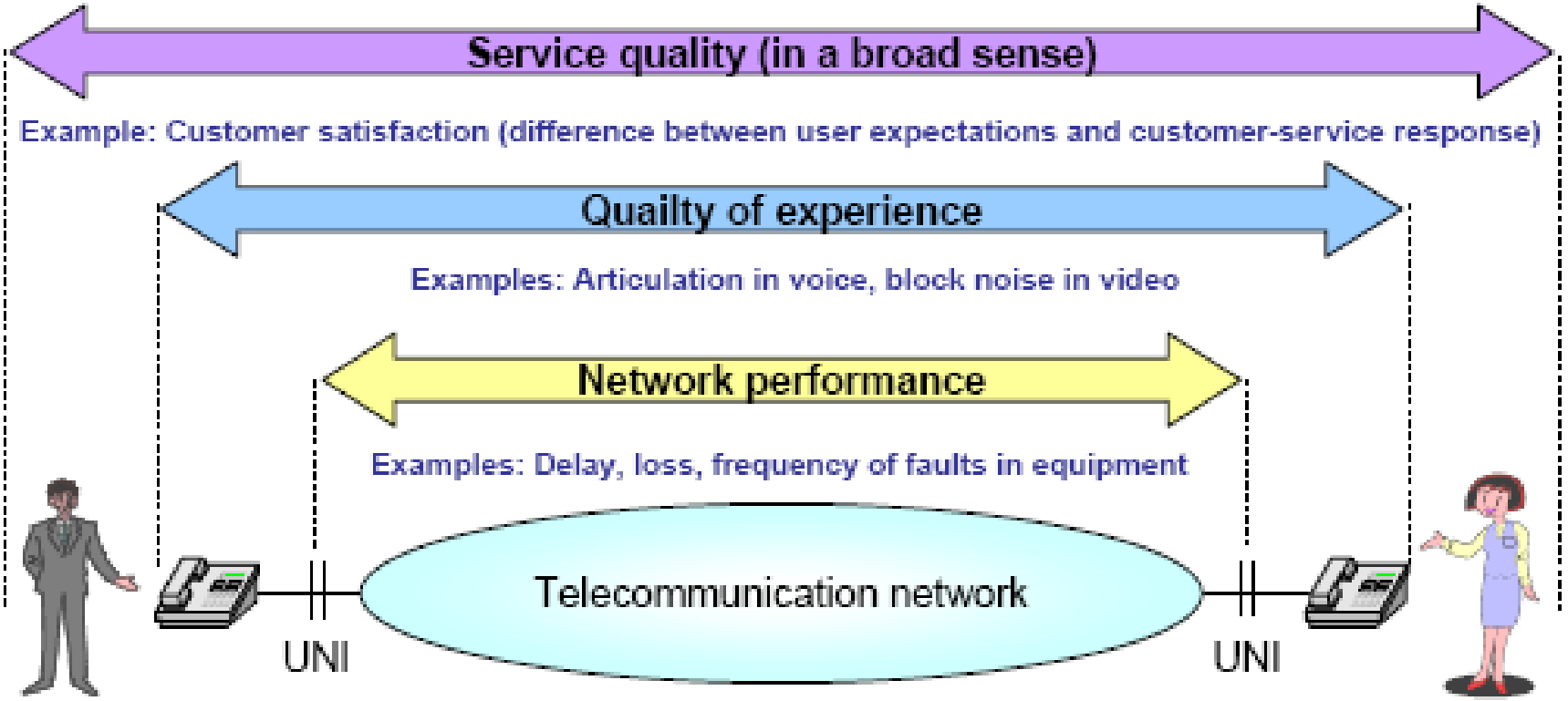
- Basic concepts
  - A safe, secure, and convenient network which can handle rapid increase of IP traffic
  - providing services that ensures Quality of Services ("QoS")
  - IP-based network enabling the provision of seamless fixed communications (intra-and inter-prefectural) and mobile communications
  - Adoption of a layered structure model to conform to international standards
  - Disclosure of interface between application layers enabling (service providers) to provide a wide array of application services
  - An open network ensuring security and connectivity (interconnectivity) with other carriers and ISPs
- Designing of roadmap and implementation of field trials (commencing in the 2nd half of FY2006)

Developing Ubiquitous Broadband Services

- Network services
  - Highly-functional, highly-reliable optical fiber services
  - High-speed and advanced functions of mobile services, and multi-functions of wireless handsets
  - Promotion of FMC
- Upper-layer services enhancement such as Internet connection and portal
- Enhancement of corporate customer service
- Promotion of convergence of telecommunications and broadcasting
- Provision of one-stop services
- Expansion of International business and standardization activities
- Efforts directed to realize a "safe and secure" society as envisioned by new innovative IT strategy and u-Japan Policy

7

Quality in telecommunication services



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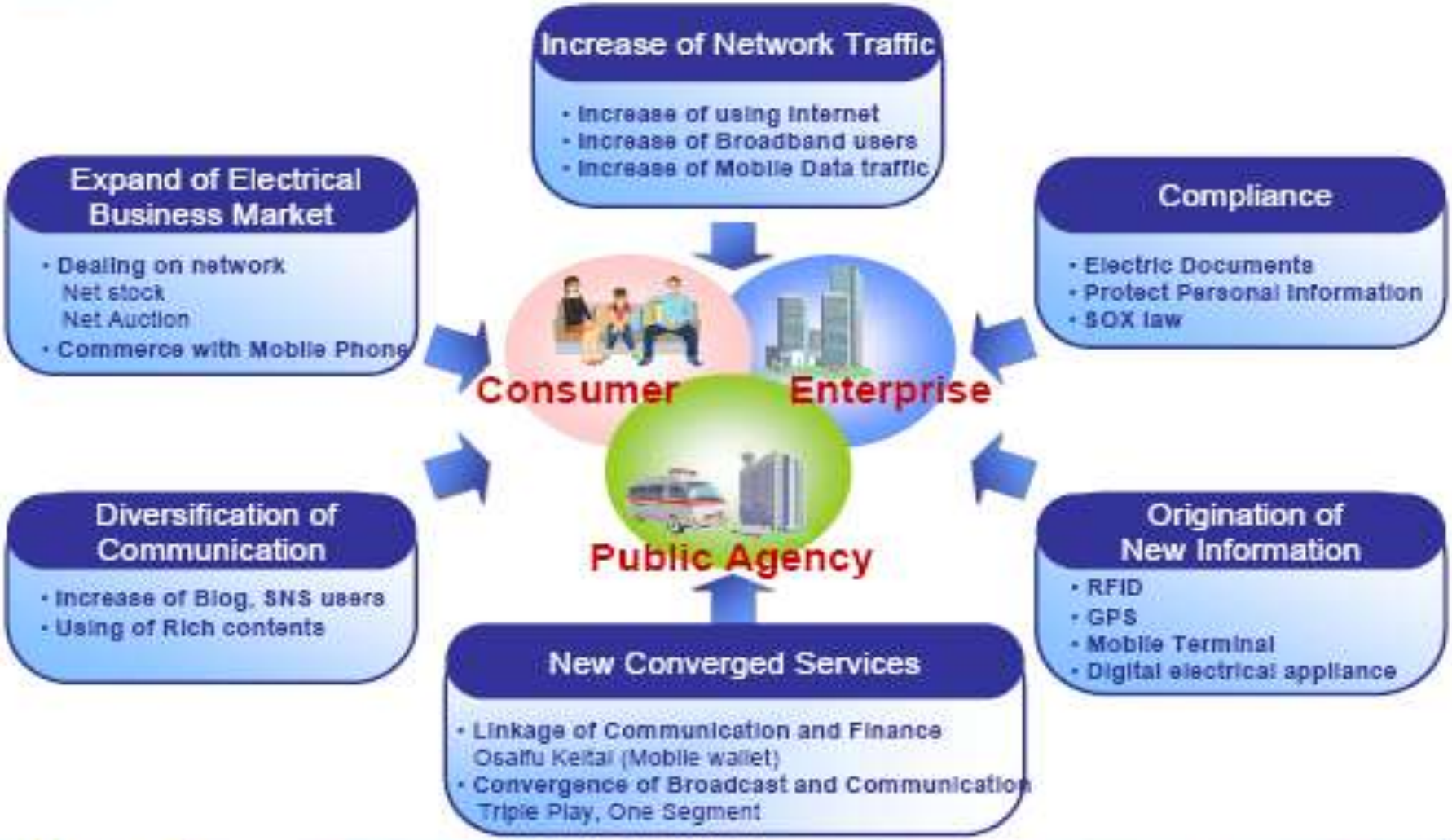
Background for NGN



U can change.

Expectation for NGN

IP based multi-service platform capable of any traffic type and services over a single fabric

U can change.

Characteristic of NGN

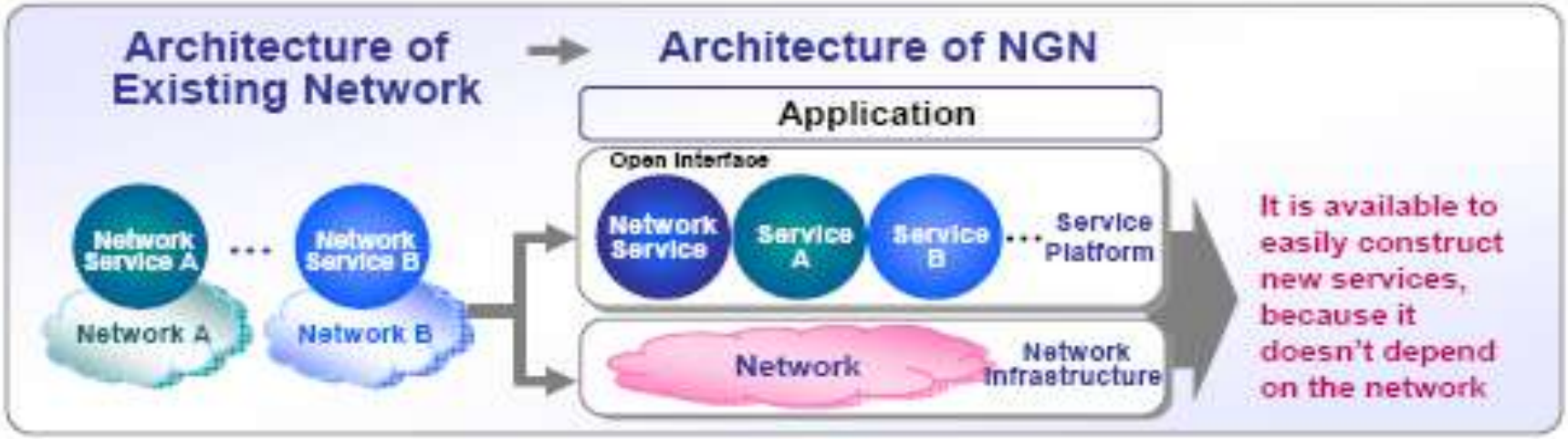
Characteristic of NGN

1. Broadband
2. Control for QoS
3. Packet based network
4. Providing services with separating Service and Transport
5. Without limitation of Access Network
6. Providing general Mobility services

Providing "Network Infrastructure" With High Speed and High Capacity

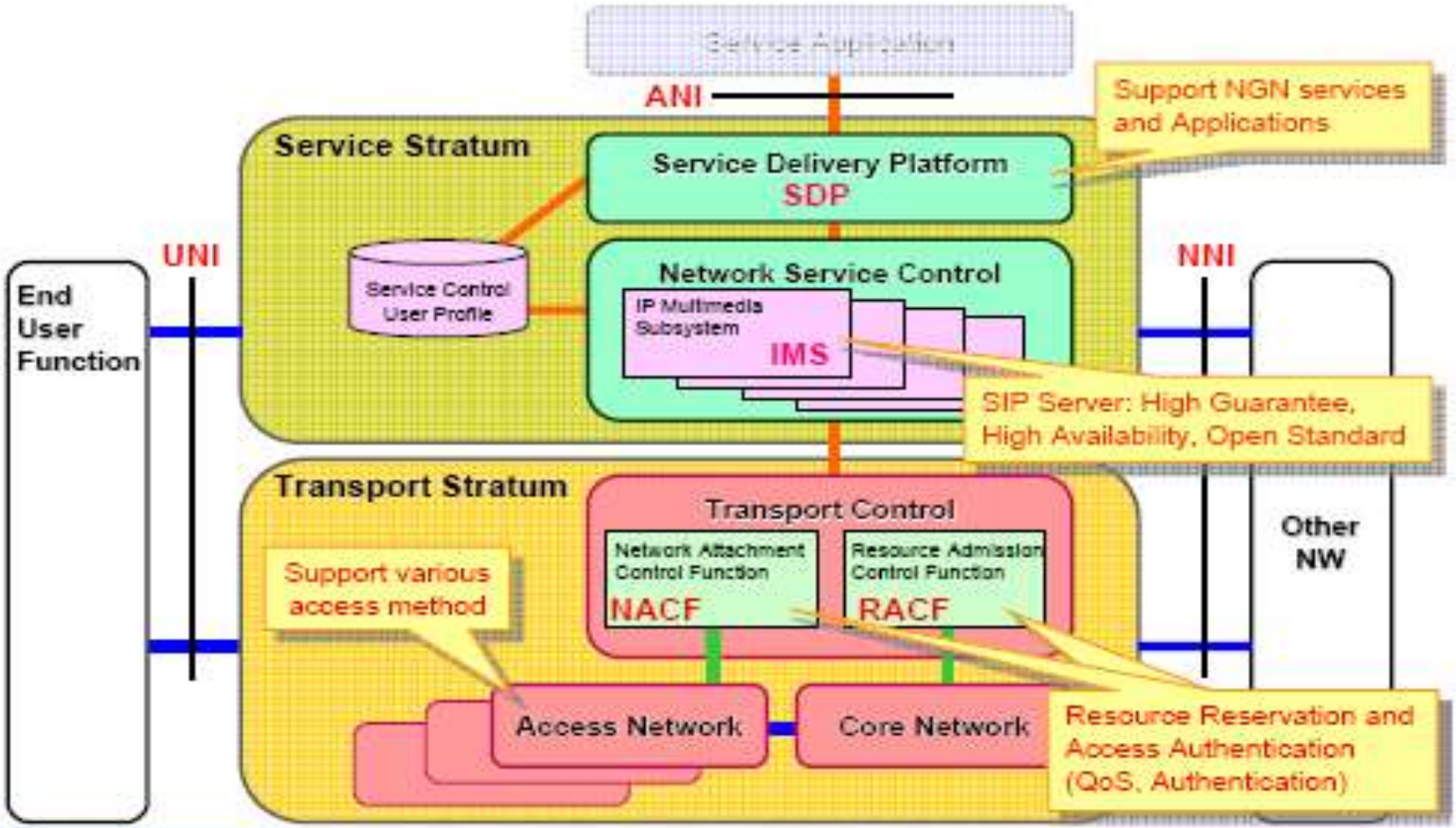
Providing "Service Platform(*)" and "Application" used it

(*) Service Platform:
Platform to provide Common Services (accounting, authentication, etc) that support Applications



U can change.

Key Technology of NGN Architecture



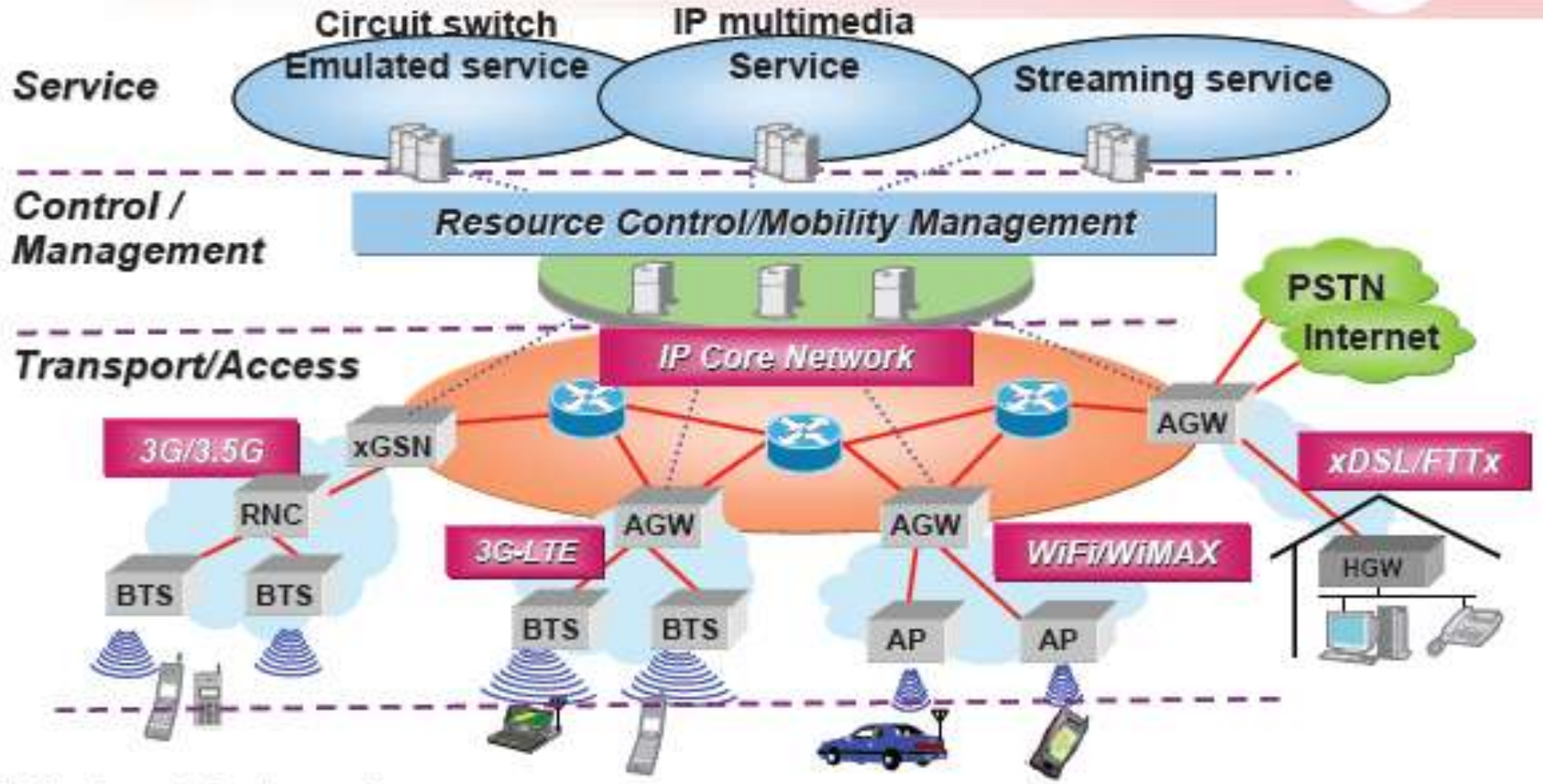
U can change.

Expectation for NGN

IP based multi-service platform capable of any traffic type and services on an architecture.

8

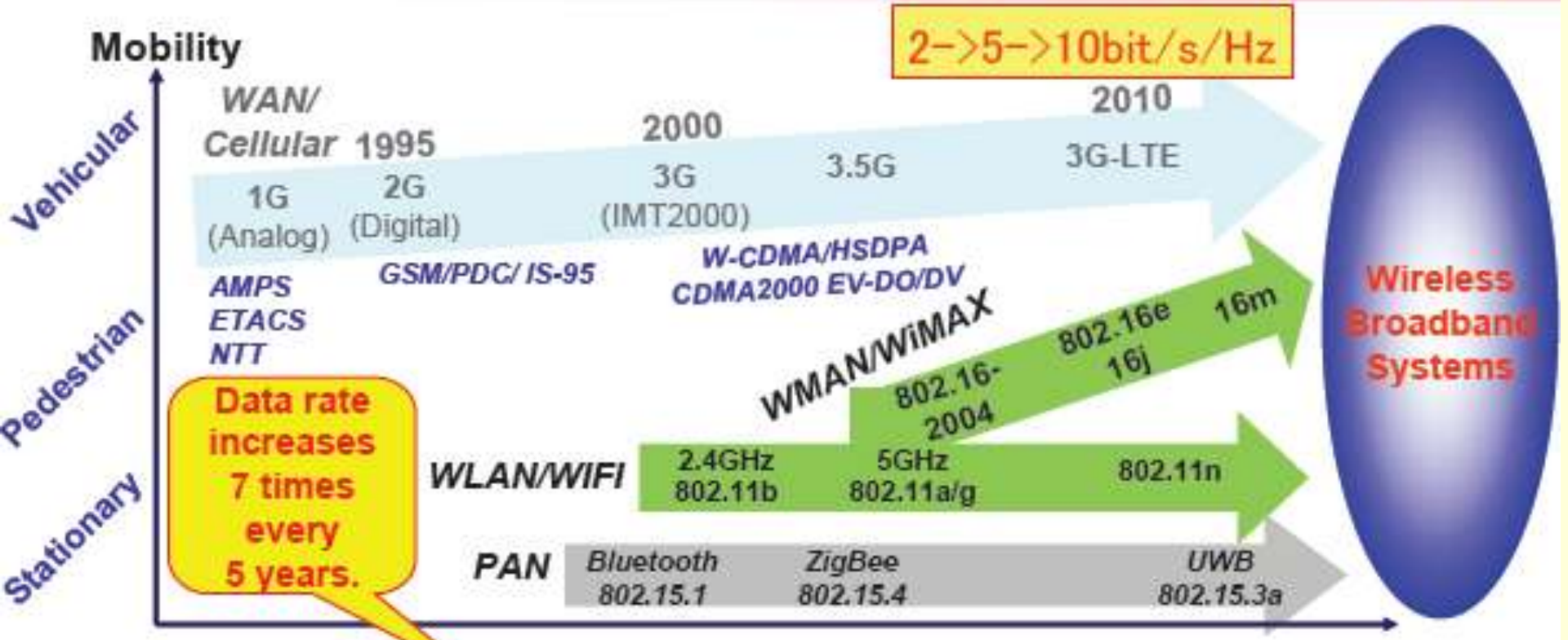
Next Generation Packet-based Network



BTS: Base station transceiver
RNC: Radio Network Controller
xGSN: Serving/ Gateway GPRS Support Node

AGW: Access Gateway
AED: Access edge Device
LTE: Long Term Evolution

Wireless Technology Trend



Data Rates	~40kbps	2Mbps	14Mbps	54Mbps	100Mbps	1Gbps
Spectral Efficiency (bit/s/Hz)	0.4	0.4	2.8	2.7	5	10
Radio Access	TDMA QPSK	DS-CDMA MC-CDMA	Adaptive QAM	OFDM/QAM Adaptive Coding		MIMO Adaptive Array

8

Beyond 3G Packet-based Wireless Systems

	3.5G		3G-LTE (3.9G)	IMT-Advanced (4G)	WiMAX	
	(1x-EVDO Rev.A)	(HSDPA,HSUPA)			802.16e	802.16m
Access method	DL: CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: OFDMA UL: SC-FDMA	DL: OFDMA(?) UL: (?)	DL: SOFDMA UL: SOFDMA	DL: SOFDMA UL: SOFDMA
Bandwidth	1.25 MHz	5 MHz	20 MHz	>100 MHz	20 MHz	>20 MHz
Modulation	BPSK,QPSK 8PSK,16QAM	HPSK,QPSK 16QAM	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.
Data rate (max.)	DL: 3.1Mbps UL: 1.8Mbps	DL: 14.4Mbps UL: 5.7Mbps	DL: 100Mbps UL: 50Mbps	DL: ~1Gbps UL: >50Mbps	DL+UL: 75Mbps	DL: >130Mbps UL: >56Mbps
Service-in	Year 2006	Year 2006	Expected in 2009	Expected in next decade	Expected in 2007	Expected in next decade
Features	Enhancement of data rate and QoS	Enhancement of packetised data rate	Great improvement of data rate and latency	Further improvement of data rate and mobility	Great improvement of data rate and latency	Further improvement of data rate and latency

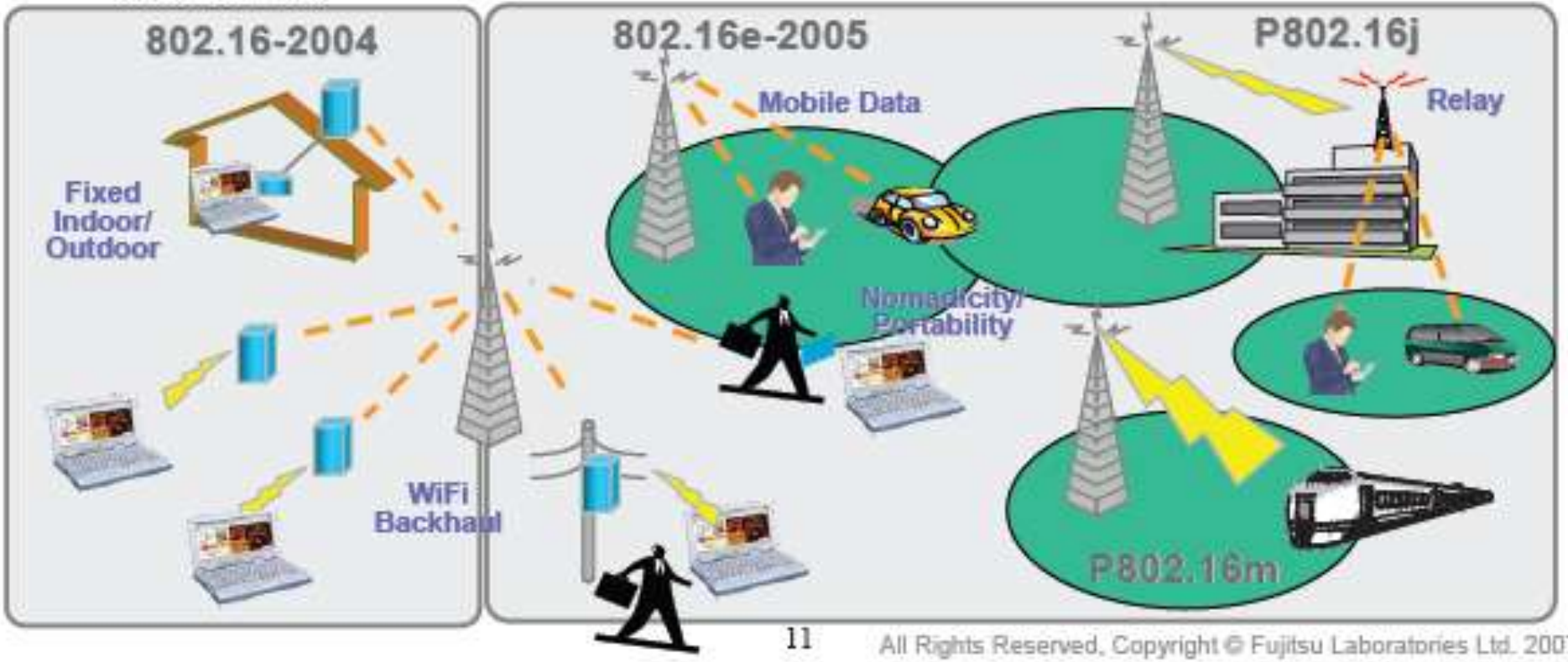
3G-LTE: 3G Long Term Evolution

802.16 Series Wireless MAN Specifications

Fixed → Nomadic/Portable → Simple Mobile/ Full Mobile → Relay / High speed

- Alternative to ADSL
- Business Access
- WiFi Backhaul

Complements Cellular System



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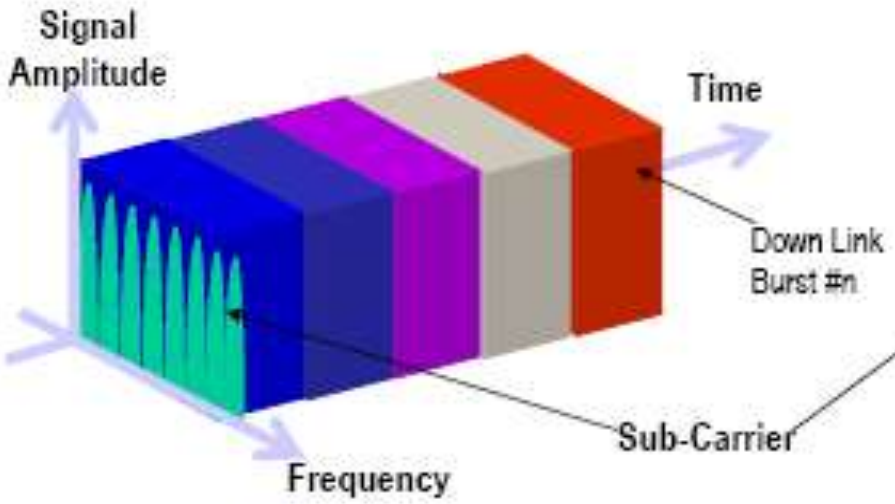
Specification of WiMAX

		Fixed (802.16-2004)	Mobile (802.16e-2005)	802.16m
Freq.	Frequency band	< 11GHz	< 6GHz	< 6GHz
	Bandwidth	1.25～20MHz	1.25～20MHz	1.25～20MHz
Peak Data Rate		75Mbps (DL+UL)	75Mbps (DL+UL)	> 130Mbps(DL) > 56Mbps(UL)
Cell Radius		2-10km（max. 50km)	2-3km	Up to 5km*
Modu-lation	Primary (AMC)	BPSK/QPSK/16QAM/64 QAM	QPSK/16QAM/ 64QAM	QPSK/16QAM/ 64QAM
	Secondary	OFDMA	SOFDMA	SOFDMA
Technology for higher data speed		AAS, STC, MIMO	AAS, STC, MIMO	AAS, STC, MIMO
Mobility		Fix, Nomadic	Max. 120km/h	Max. 350km/h

AMC: Adaptive Modulation and Coding, SC: Single Carrier,
AAS: Adaptive Antenna System, STC: Space Time Coding
MIMO: Multiple Input Multiple Output
*: some members propose "functionally up to 100km" for rural area application

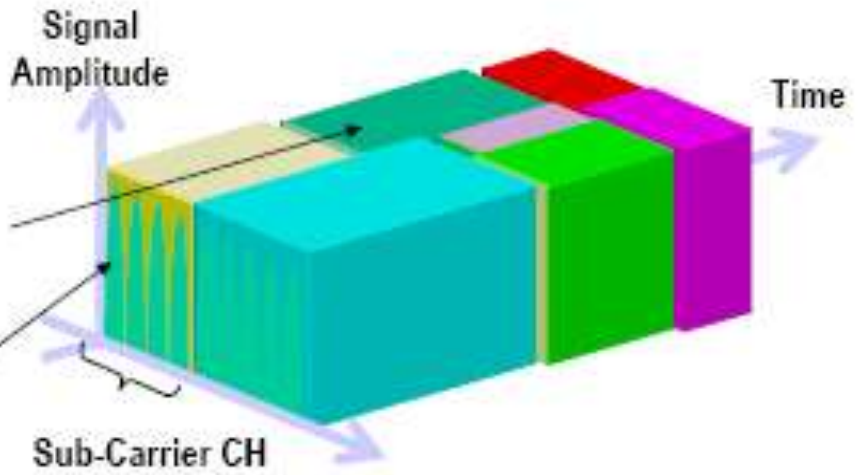
OFDM and OFDMA

Transmission by OFDM (Orthogonal Frequency Division Multiplexing)



- All sub carriers are allocated to one user.
- Used in 802.16-2004

Transmission by OFDMA (Orthogonal Frequency Division Multiple Access)



- Sub carriers are flexibly allocated to one or more users depending to their radio condition.
- Used in 802.16e-2005 and 802.16m

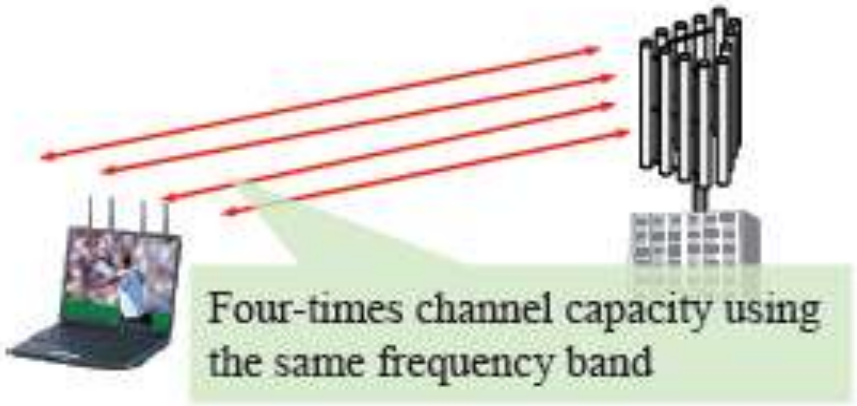
Multi-Antennas for Higher Capacity

➢AAA (Adaptive Array Antennas)

- Space division to reduce interference at both terminal and base station
- Optimal antenna directivity is best calculated on real-time basis.

➢MIMO (Multi Input Multi Output)

- Space Division Multiplexing in the same space using the same frequency band
- Expected capacity increase of number-of-antenna-fold
- Adaptive signal processing required to establish each independent channel



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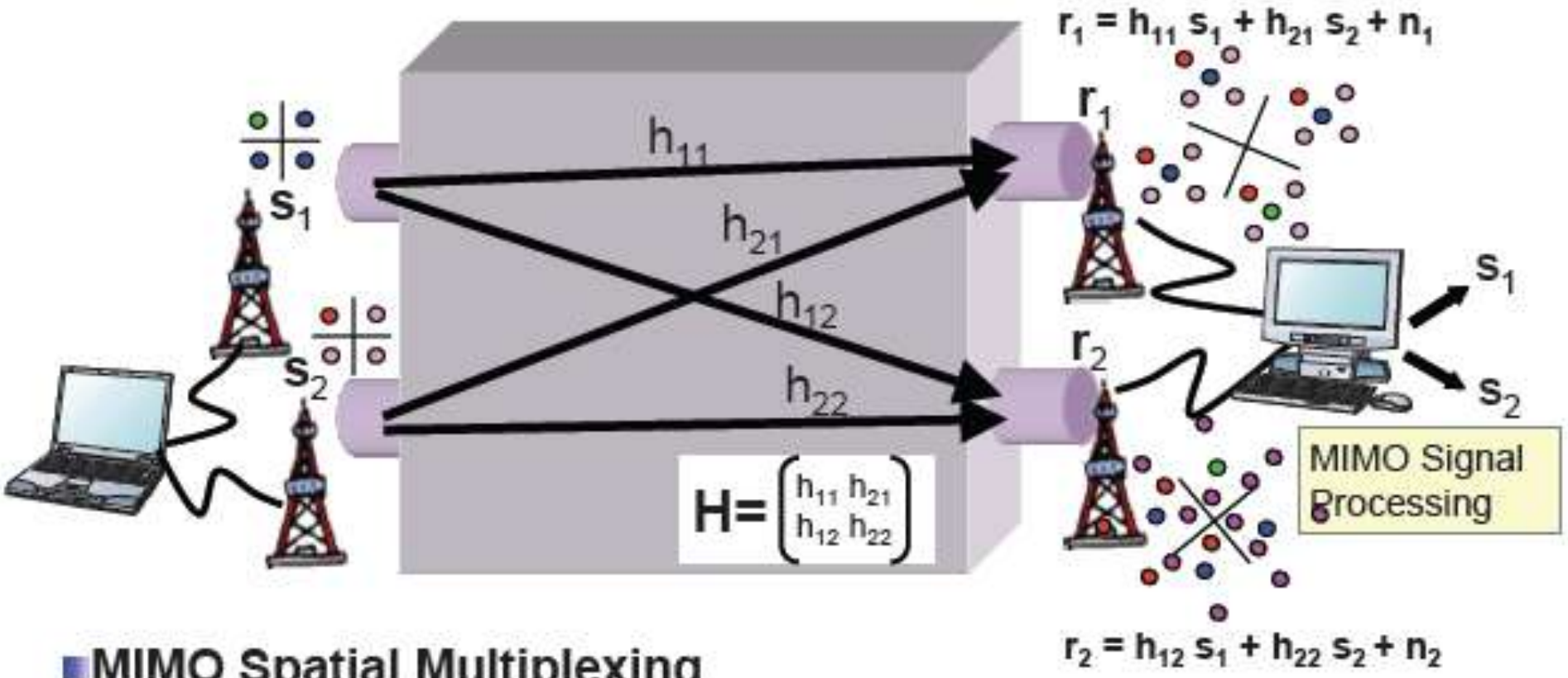
MIMO: Multiple Input Multiple Output

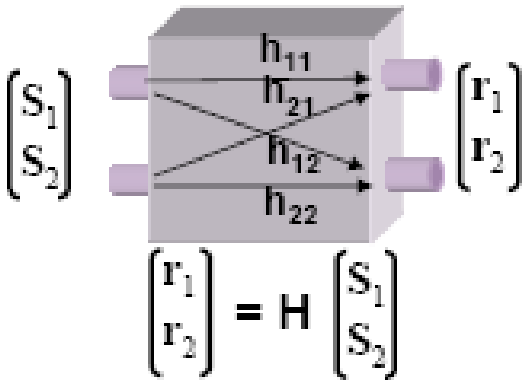


MIMO Spatial Multiplexing

Multiple data streams are transmitted through multiple antennas

⇨ Data rate can be increased proportional to the number of antennas (min. of Tx and Rx)

MIMO Signal Processing Schemes



$$r_1 = h_{11}\, s_1 + h_{21}\, s_2$$
$$r_2 = h_{12}\, s_1 + h_{22}\, s_2$$

ZF: Matrix Inverse

$$\begin{bmatrix} \hat{s}_1 \\ \hat{s}_2 \end{bmatrix} = \hat{H}^{-1} \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

$$h_{22} r_1 = h_{22} h_{11}\, s_1 + h_{22} h_{21}\, s_2$$
$$h_{21} r_2 = h_{21} h_{12}\, s_1 + h_{21} h_{22}\, s_2$$

$$h_{22} r_1 - h_{21} r_2 = (h_{22} h_{11} - h_{21} h_{12})\, s_1$$

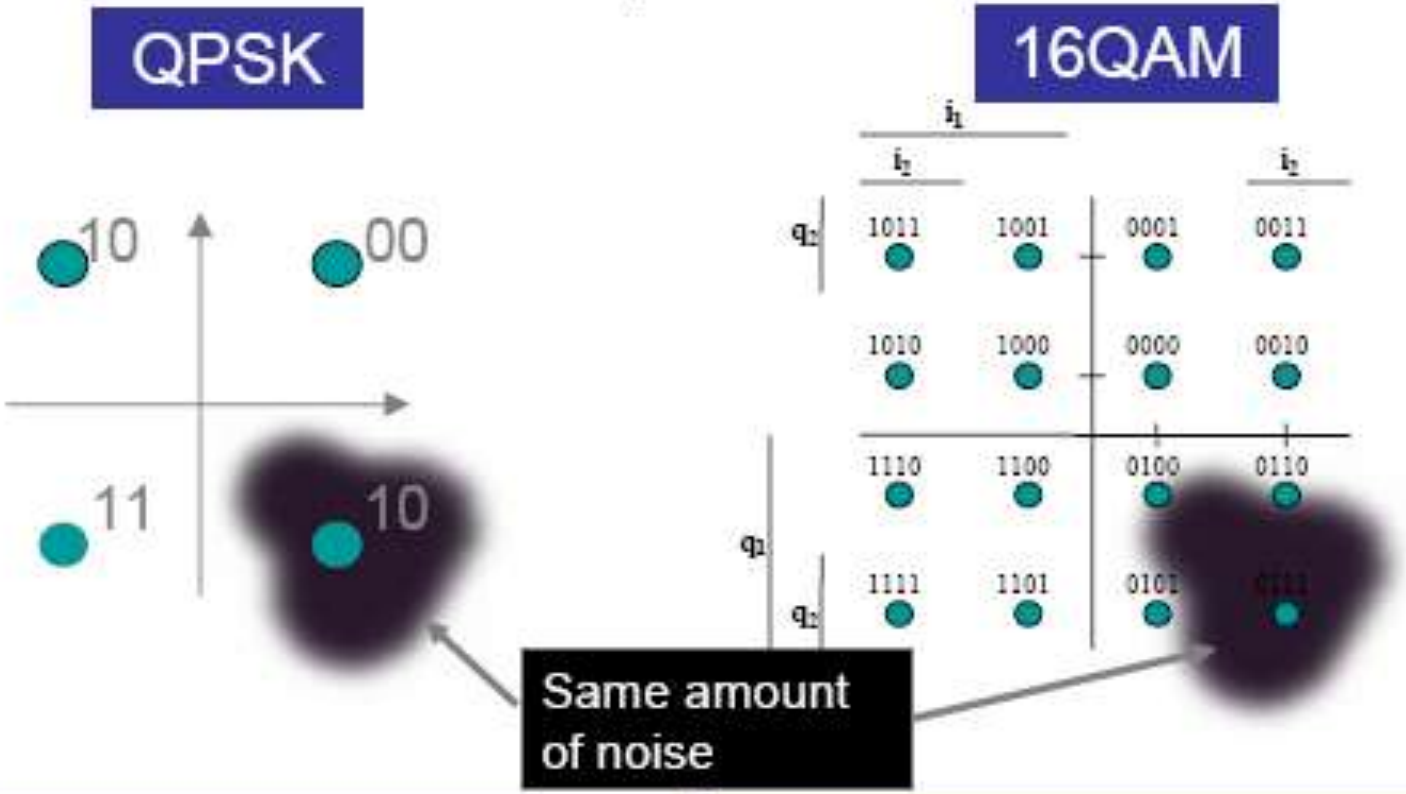
$$s_1 = \frac{h_{22} r_1 - h_{21} r_2}{h_{22} h_{11} - h_{21} h_{12}} \qquad s_2 = \frac{h_{12} r_1 - h_{11} r_2}{h_{12} h_{21} - h_{11} h_{22}}$$

Other schemes

- **MMSE:** Wiener Filter
- **BLAST:** Serial Interference Canceller
- **MLD:** Maximum Likelihood Detection
- **Eigen-mode precoding:** with feedback

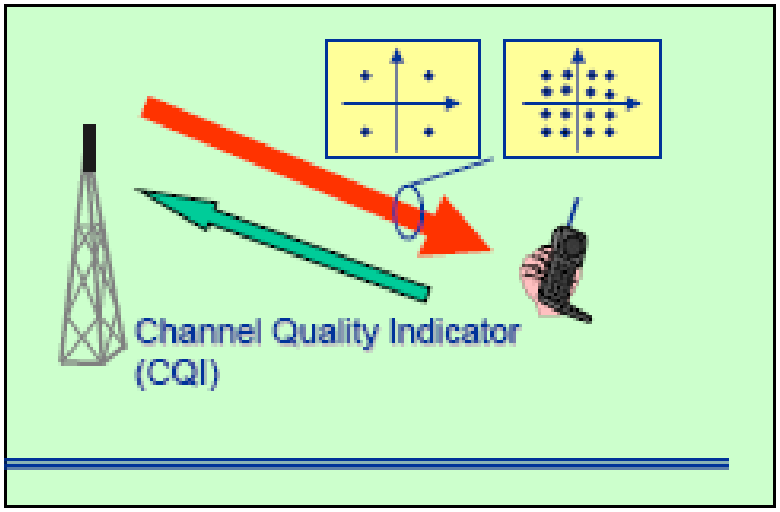
Quadrature Amplitude Modulation

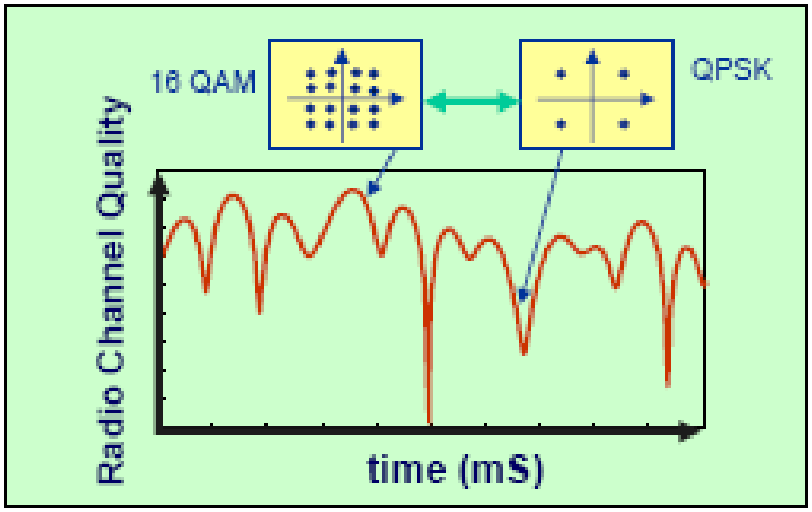
- Modulation Phase and Amplitude



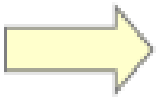
2 bits per symbol Robust	4 bits per symbol Requires high S/N

Adaptive Modulation and Coding (AMC)





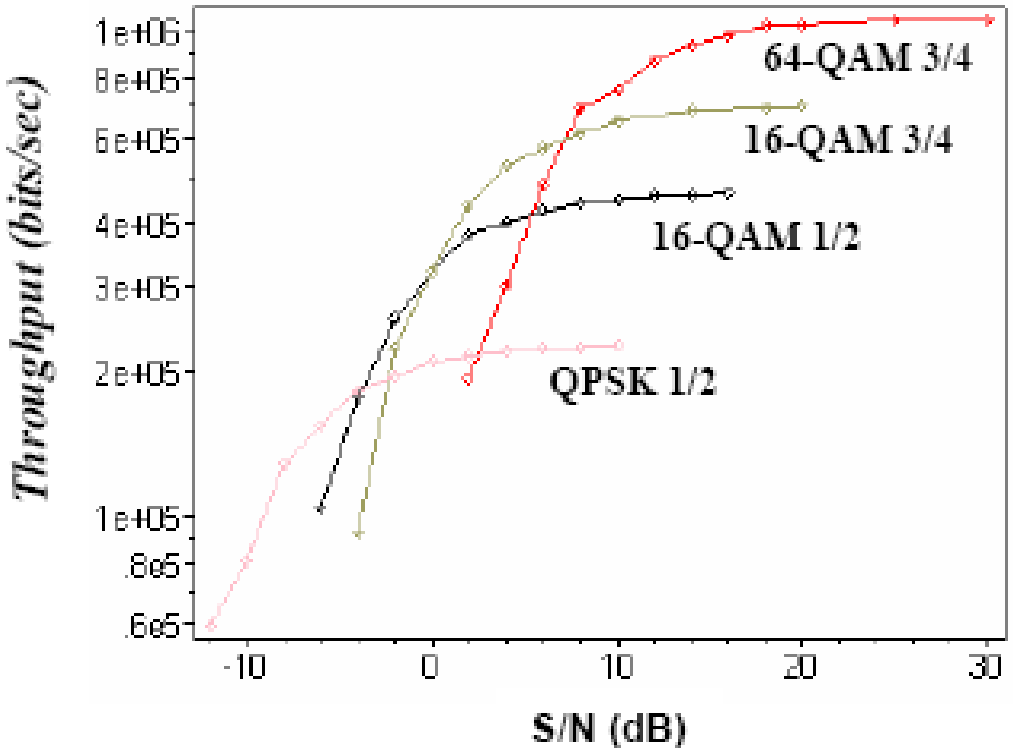
- Use high level modulation and coding rate when channel condition is good



Data Throughput can be increased

Adaptive Modulation and Coding (AMC)

- Throughput Performance

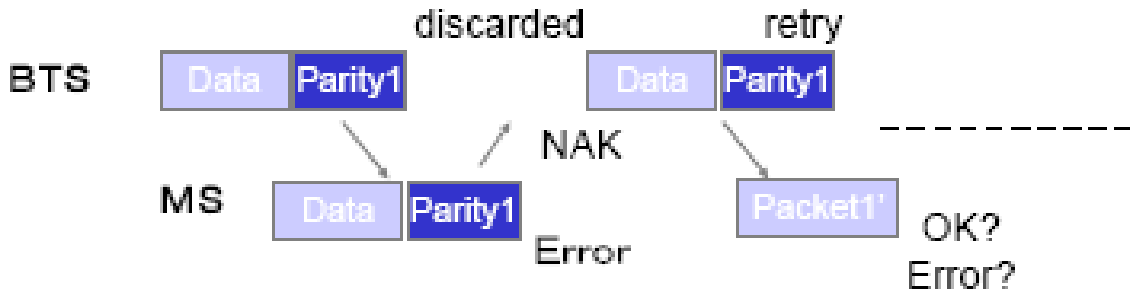


Single path
Rayleigh Fading
Fd = 5.555 Hz

Hybrid ARQ

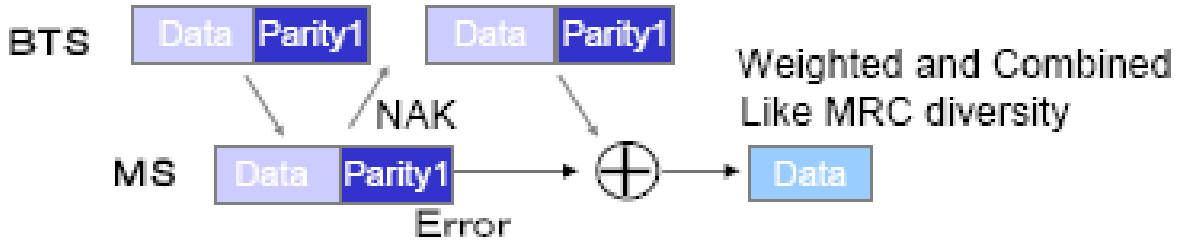
<Conventional ARQ>

- Discard error packet
- Retry

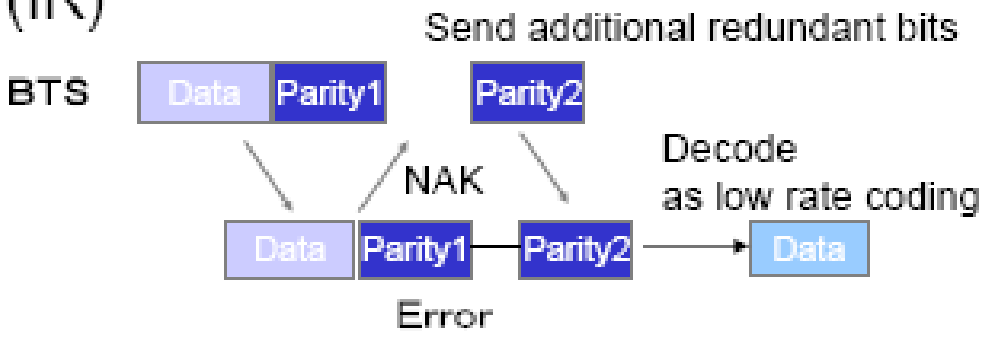


<Hybrid ARQ>

- Chase Combining (CC)
  - Store
  - Resend
  - Combine



- Incremental Redundancy (IR)
  - Store
  - Send
    Additional redundant bits



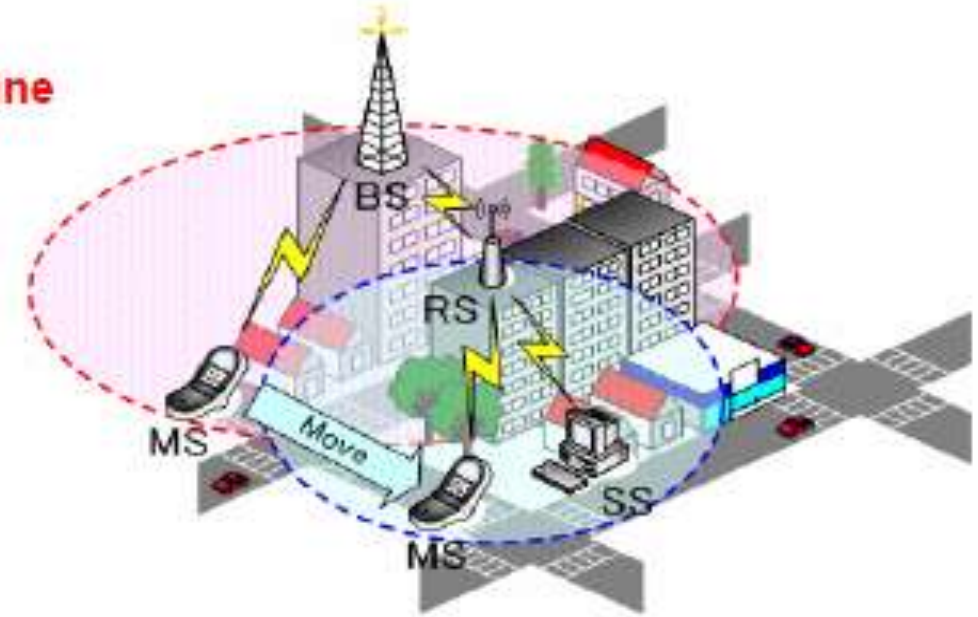
ARQ: Automatic Repeat Request
MRC: Maximum Ratio Combining

Critical Problems to Solve

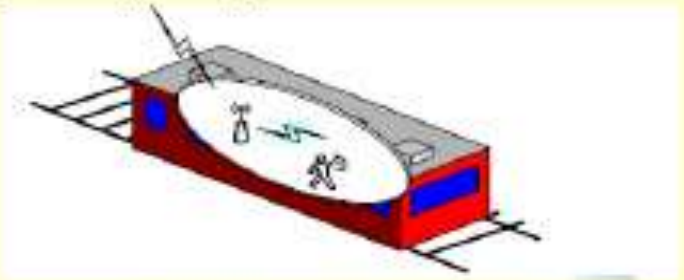
- Single Frequency Network (SFN) operation
  - Fractional Frequency Reuse (FFR)
  - Antenna diversity (STC)
  - Other-cell interference mitigation: Scheduling algorithm
- Peak-to-Average Power Ratio (PAPR) in Uplink (UL)
  - Linearization for terminal: high-linearity PA, Digital Pre-Distortion (DPD)
  - 3G-LTE employs Single-Carrier (SC) approach
- Control channel quality in Time Division Duplex (TDD): Data/C-ch mixed frame structure
  - Circular-Shifted Transmit Diversity (CSTD) for 2-Tx antennas
  - Repetition Coding

Multi-hop Relay (802.16j)

- Add the repeater function:
  - -Wider coverage without backhaul line
  - -Higher throughput
- Two Relay modes:
  - •Transparent relay
    - •Two hop simple relay
    - •Centralized scheduling
  - •Non-transparent relay
    - •Multiple Relay
    - •For expanding coverage
    - •Centralized/Distributed scheduling



Sample Application

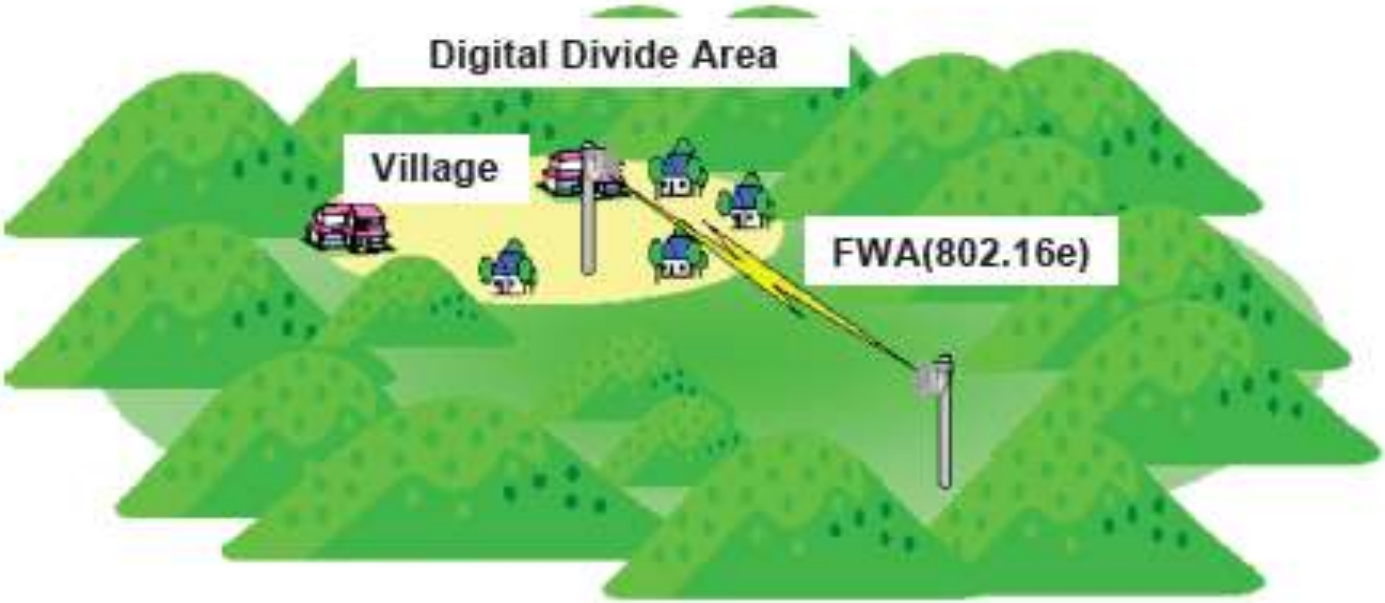


Passengers in a train

Train/vehicles in a tunnel

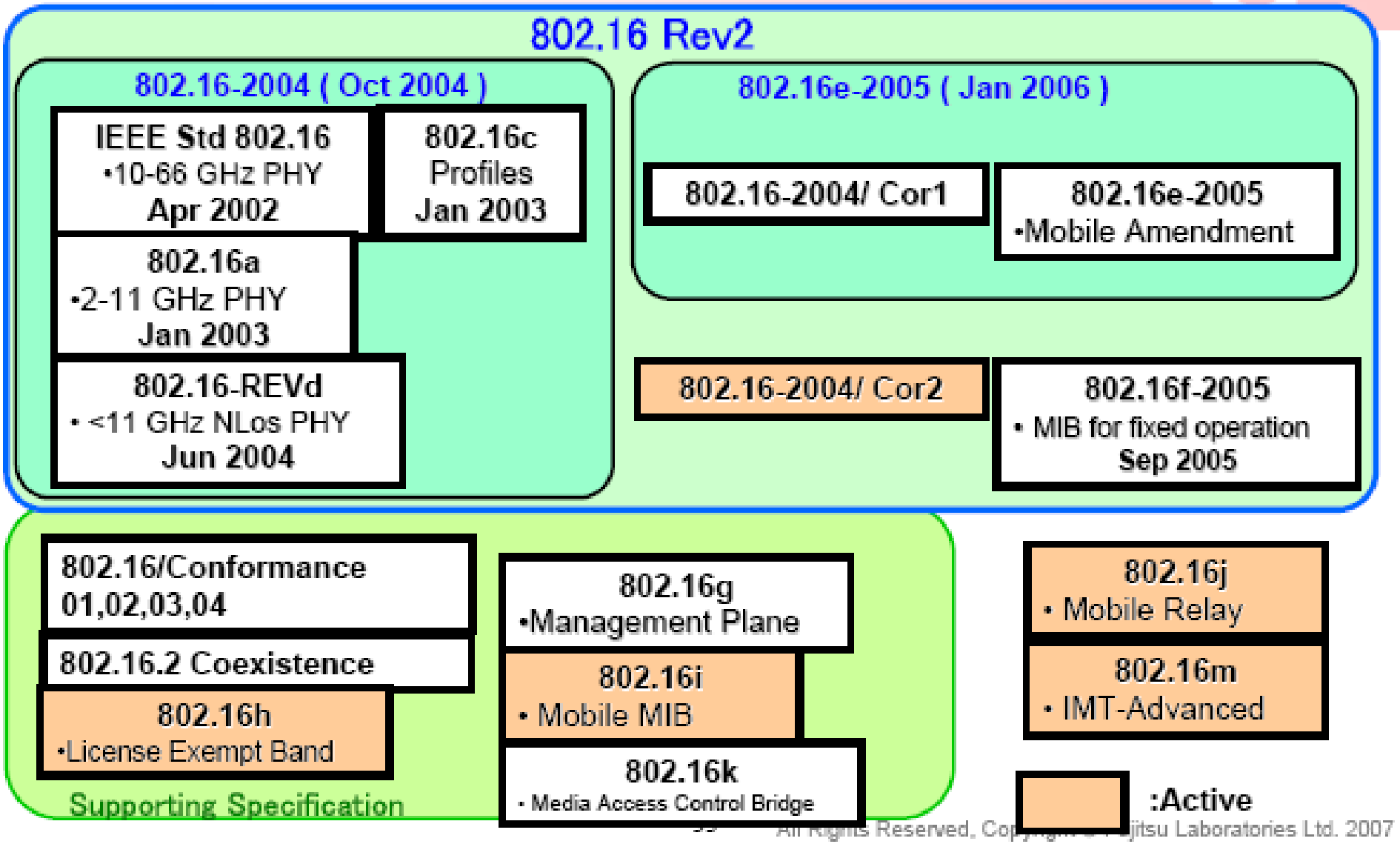
Fixed Wireless Access (FWA)

- 802.16e usage according to application:
  - -FWA for digital divide area
  - -MWA for dense urban area

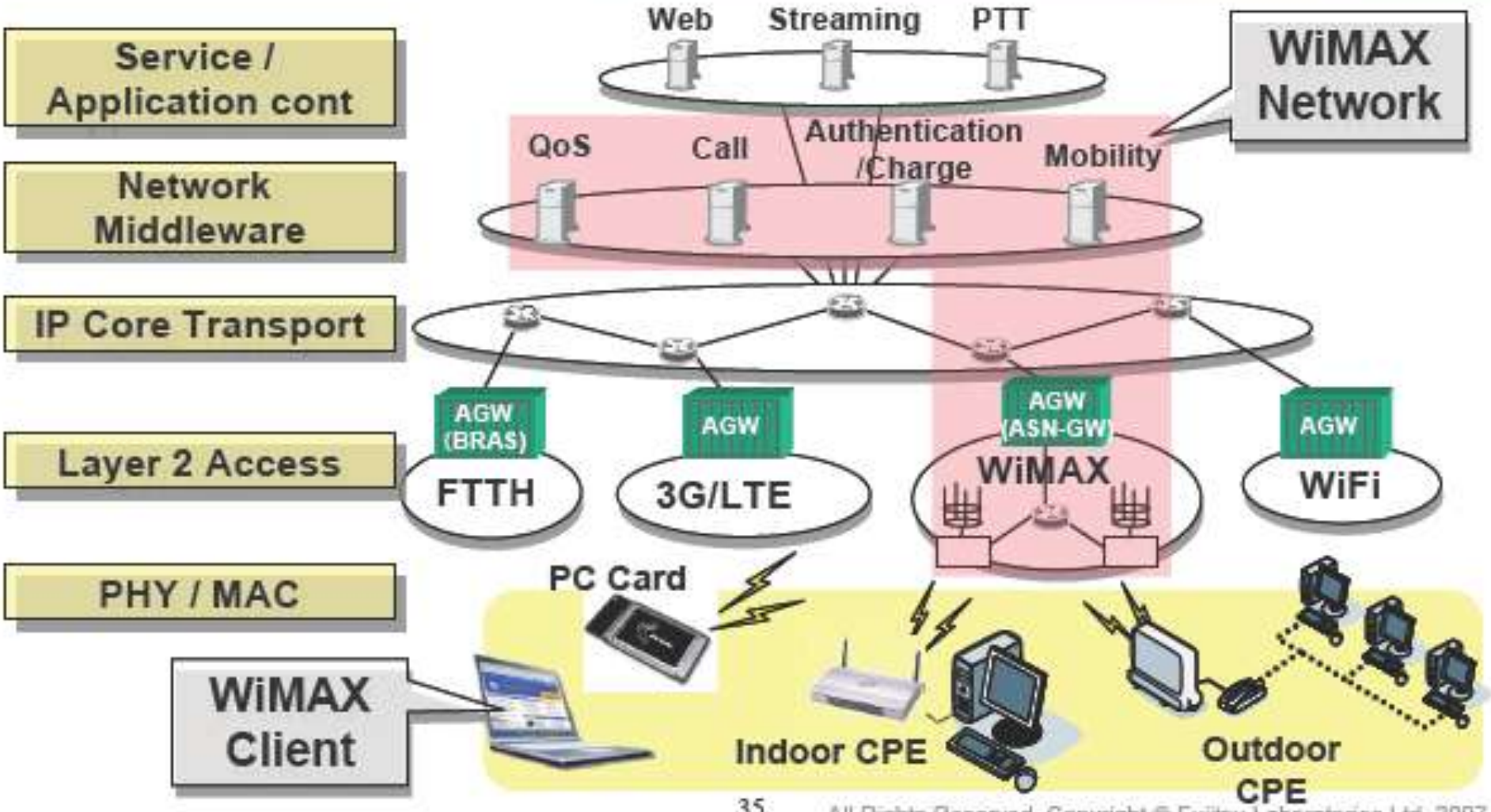


MWA: Mobile Wireless Access

IEEE802.16 Standard Family

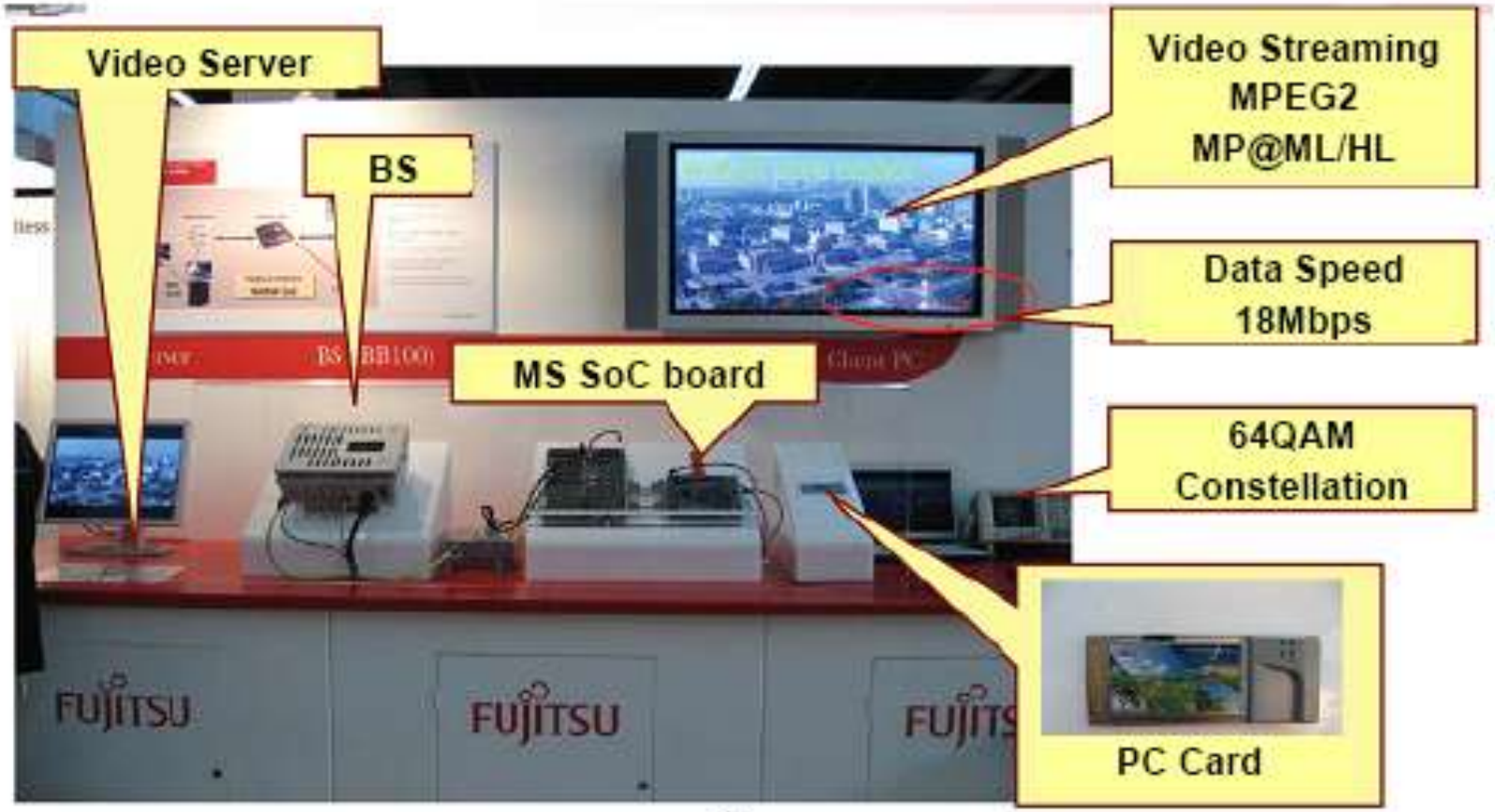


WiMAX System Structure



Mobile WiMAX System

3GSM World Congress
2007/2/13 – 2/16, Barcelona, Spain



ITU-R: IMT-2000

- IMT-2000
  - 3G mobile communications systems
  - Aimed at the global standard for up to 2Mbps (in stationary) in 2000
- IMT-2000 terrestrial family (2000/05) defined in ITU-R M.1457
  1. CDMA direct spread ... WCDMA
  2. CDMA multicarrier CDMA-2000
  3. CDMA TDD ... TD-SCDMA
  4. TDMA single carrier ... EDGE
  5. FDMA/TDMA ....DECT
- IMT-2000 frequency band
  - 806-960 MHz
  - 1710 – 1885 MHz
  - 1885 – 2025 MHz
  - 2110 – 2220 MHz
  - 2500 – 2690 MHz

Trends for the next generations

- Support for advanced and wideband multimedia services
- Extended coverage area, enhanced system capacity
- High data rate, over 100 Mbps in some cases
- High speed, low delay
- Software defined radio (SDR)
- Seamless mobility and internetworking in hybrid networks.
- Digital Convergence of the Telecommunication and Multimedia Broadcasting
- All-IP system such as Mobile IPTV

Key Technologies of Advanced Communication methods are as following

- Orthogonal Frequency Division Multiplexing (OFDM)
- Advanced channel coding techniques (Turbo codes, LDPC codes)
- Multi-antenna signal processing (MAS)
- Multiple-Input, Multiple-output (MIMO)
- Smart antennas
- Space-time coding
- Ad-hoc operation

Effective dynamic power reduction technologies are

- Clock gating (20%-40% dynamic power reduction)
- Dynamic/Adaptive Voltage Scaling (20% - 50% dynamic power reduction)
- Variable Threshold CMOS(VTCMOS)
- Combinations of Adaptive Voltage Scaling and VTCMOS

Some critical Innovations with glorious past and promise of shining future

- Mobile Telecommunications
- IC Revolution – Digital Electronics – Processor and Memory
- The Internet and Web Technologies

Dreams, Challenges and Achievements

1. Space Exploration – Humans in Space
2. Robots
3. Nano Technology
4. Security

Mass Appeal – Far Reaching Applications

1. Medicine and Health Care
2. Transportation – Intelligent Transport Service/ System
3. Sports and Games

Path to 4G Mobile – Long Term Evolution (LTE)

Issues and Requirements for NGN

1. Evolution of cellular Network
   - Circuit to Packet Switching
   - Voice to Voice & Data – to Multimedia
2. Terminals moving between wired (Cable, Fibre, DSL) and Wireless
3. Sessions originate, terminate and to be maintained during movement

….continued

LTE continued….

4. Important Parameters : Bandwidth and Quality of Service
5. Protection – Authentication, Encryption, Other Security Mechanisms at Access, Network Layers
6. Radio Technology with improved performance and reduced complexity
7. Service Architecture Evolution

….continued

LTE continued….

8. Long Term Evolution

   (i) Evolved Packet Core (EPC) and

   (ii) Evolved Universal Terrestrial Radio Access Network (e-UTRAN)

LTE continued….

Desirable

1. Core Network should be based on IP
2. Core should be same for 3GPP Radio Acess (LTE, 3G & 2G), non – 3GPP Radio Access (HRPD, WLAN, WiMAX) and Fixed Access (Ethernet, DSL, Cable, Fibre)

LTE continued….

EPC (Evolved Packet Core) Paradigms

- Mobility
- Policy Management
- Security
- EPC should provide User Terminals with Optimized Hand Over Schemes Between Different Radio Technology (LTE and HRPD)

LTE continued….

LTE Radio Access Based on

1. Orthogonal Frequency Division Multiplexing (OFDM)
   - To support different Bandwidths (1.4 - 20 MHz) in both FDD and TDD Mode
2. Shared Channel Access providing Peak Data Rate of 75 Mbps in Uplink and 300 Mbps in Downlink

Thus LTE offers a 4G Solution with Key holes of improved coverage and long battery life

LTE continued….

- Recently demand for Mobile Data is Skyrocating – causing Challenges.
- Capacity of existing Networks is constrained
- Reasons for Mobile Data Explosion leading to Mobile Broadband
  - Advent of Web 2.0
  - Graphically rich Internet
  - Video Based content
  - Unabated use of Consumer Electronics Gadgets such as Digital Camera, MP3 Players, Camcoders, online games
  - Mobile Media : Follow me content

LTE continued….

LTE Network Solution should offer

- Lower Cost Per Bit
- Higher Capacity
- Faster Data Speeds

LTE continued….

LTE – Features, Attributes, Promises…

1. Popularly called 4G Technology
2. All-IP, based on OFDM (spectrally efficient – more bits/Hz)
3. Technology of choice for 3GPP and 3GPP2 mobile operators
4. Provides economy of scale and spectrum reuse

LTE continued….

5. Offers a smooth integration and Handover to and from existing 3GPP and 3GPP2 Networks, supporting full mobility and Global Roaming
6. LTE can be deployed in a gradual manner as per the demand
7. Brings to subscriber True Mobile Broadband (~ 5 ~ 10 Mbps ~ 15 ms latency) resulting in quality video experience and media mobility

LTE continued….

8. Very flexible LTE standard – deployable in all current existing and future spectrum (as little as 1.4 MHz or as much as 20 MHz and grow the network with demand)
9. Different spectrum bands around the world including the new 2.6 GHz band (2x20 MHz virgin spectrum) also deployable in reframed 900 MHz and 1800 MHz GSM bands
10. Brings improvement in capacity, speed, latency, faster access to applications, wealth of new applications similar to wired internet

LTE continued….

11. Wall between wired and wireless comes down with LTE
12. Allows watching latest TV series recorded on a DVR automatically transferred to 4G Net as one walks out door
13. Allows unloading content one's social network profile for friends' information
14. Power point files saved on laptop are instantaneously available on smart phone

LTE continued….

- Latest pictures from LTE enabled Digital Camera can be uploaded onto Home Server or Social Networking site for family to see

LTE continued….

Operator Investment / Migration

1. 2G & 3G Operators ⟶ Leap frog to LTE
2. TDD Operators can go for FDD LTE
3. 3G & HSPA ⟶ HSPA+ , but only near the cell user get improvement in peak rate. Thus HSPA+ is an interiem solution. Better to migrate to LTE straight

LTE continued….

- For HSPA+ 2X2 MIMO requires new hardware
- HSPA+ may face tough competition with early LTE operators

LTE continued….

Market Predictions

1. More than 20 Operators committed to LTE enabling 1.8 billion out of 3.5 billion users on LTE
2. 32 million LTE subscribers by 2013
3. LTE not before 2010

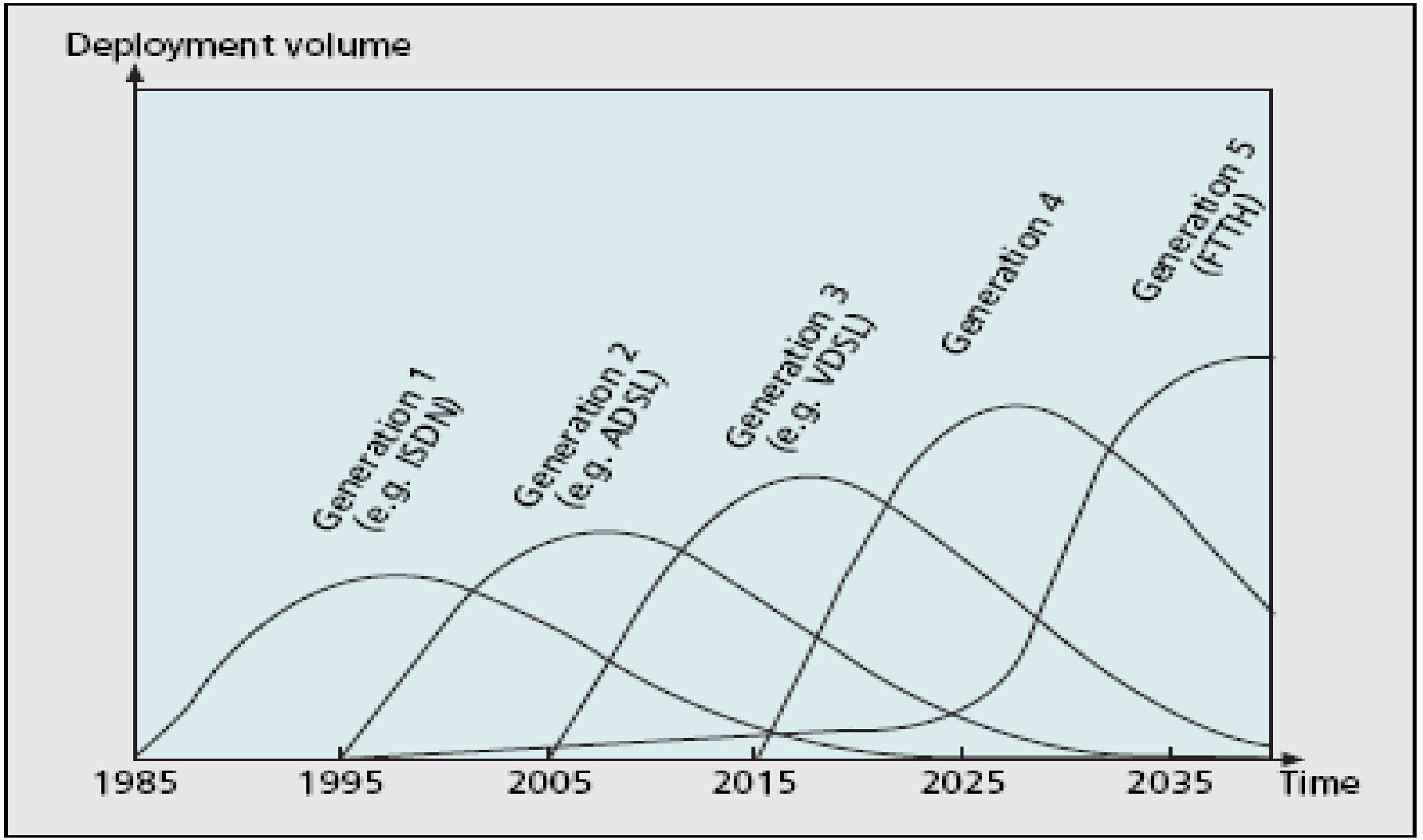


Figure 1. *A sketch of deployment volumes of broadband access techniques (number of new installations or upgrades per time unit). The time axis is based on historical data (up to present time), while the y-axis is no more than an illustration of trends.*

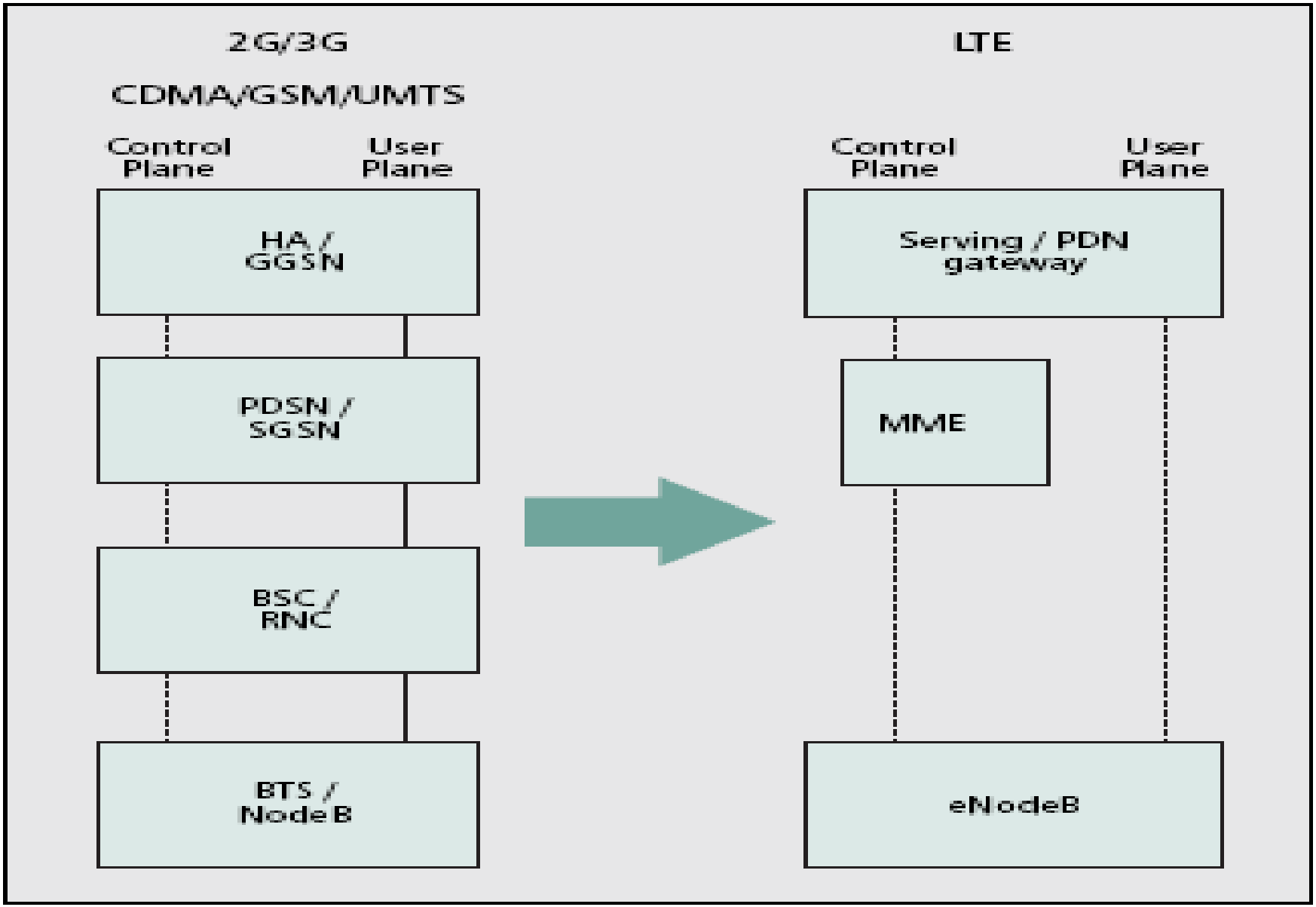


Figure 1. *From hierarchical to a simpler, flatter network.*

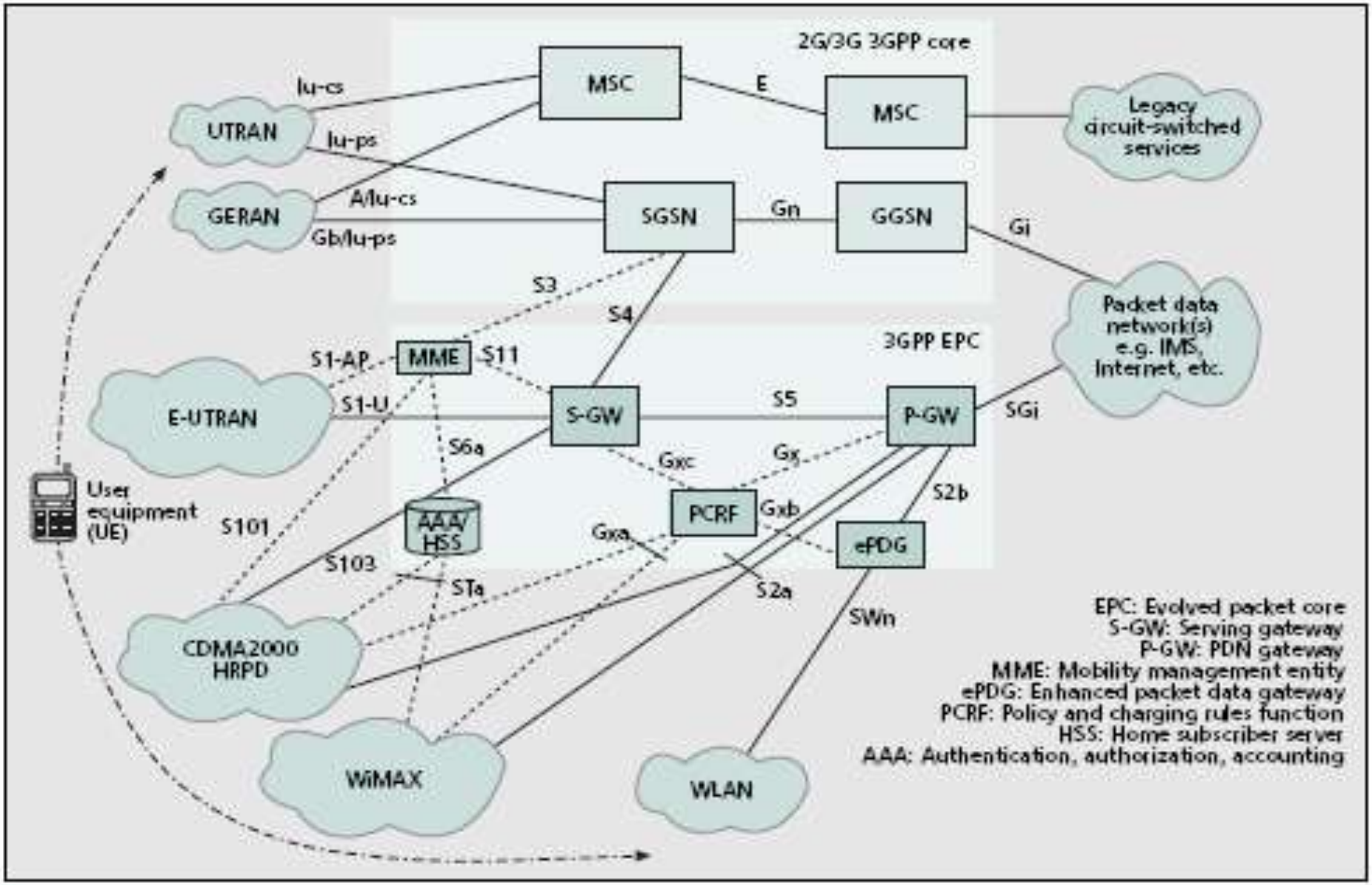


Figure 1. *Simplified architecture of the evolved 3GPP network.*

Figure 5. *a) IMS service continuity architecture based around the SCC-AS*

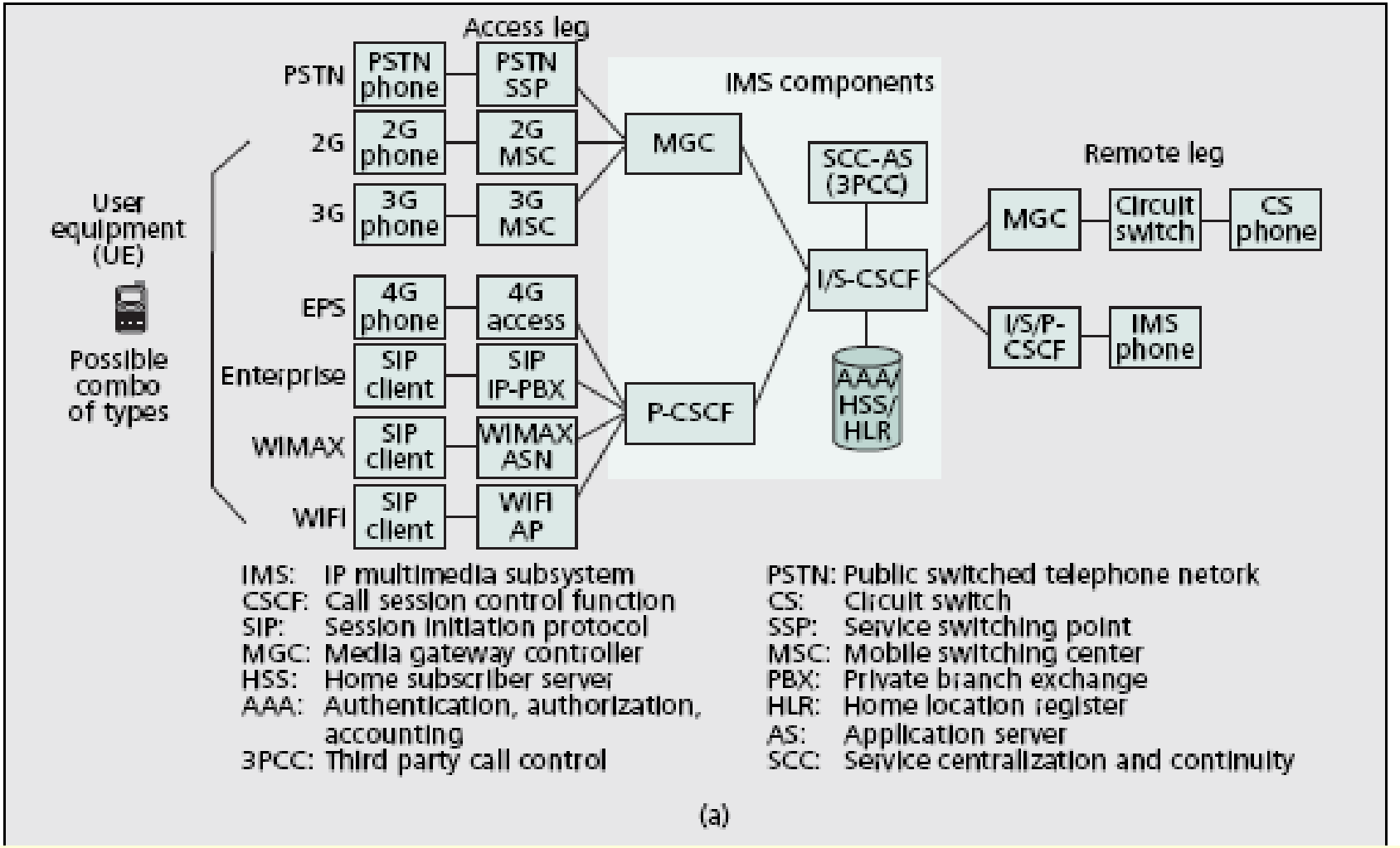
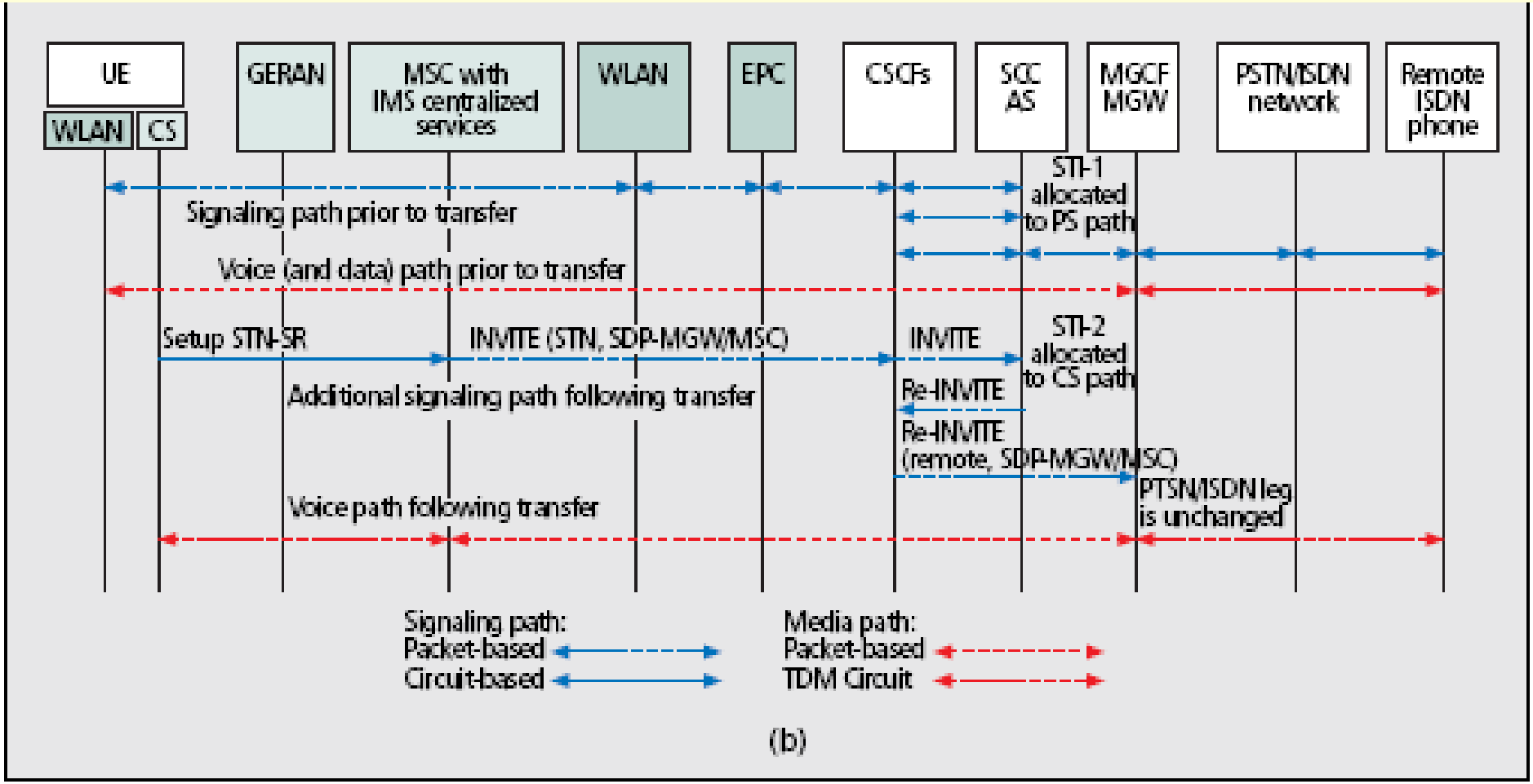


Figure 5. *b) simplified message flow diagram for voice call transfer with IMS service continuity mechanisms.*



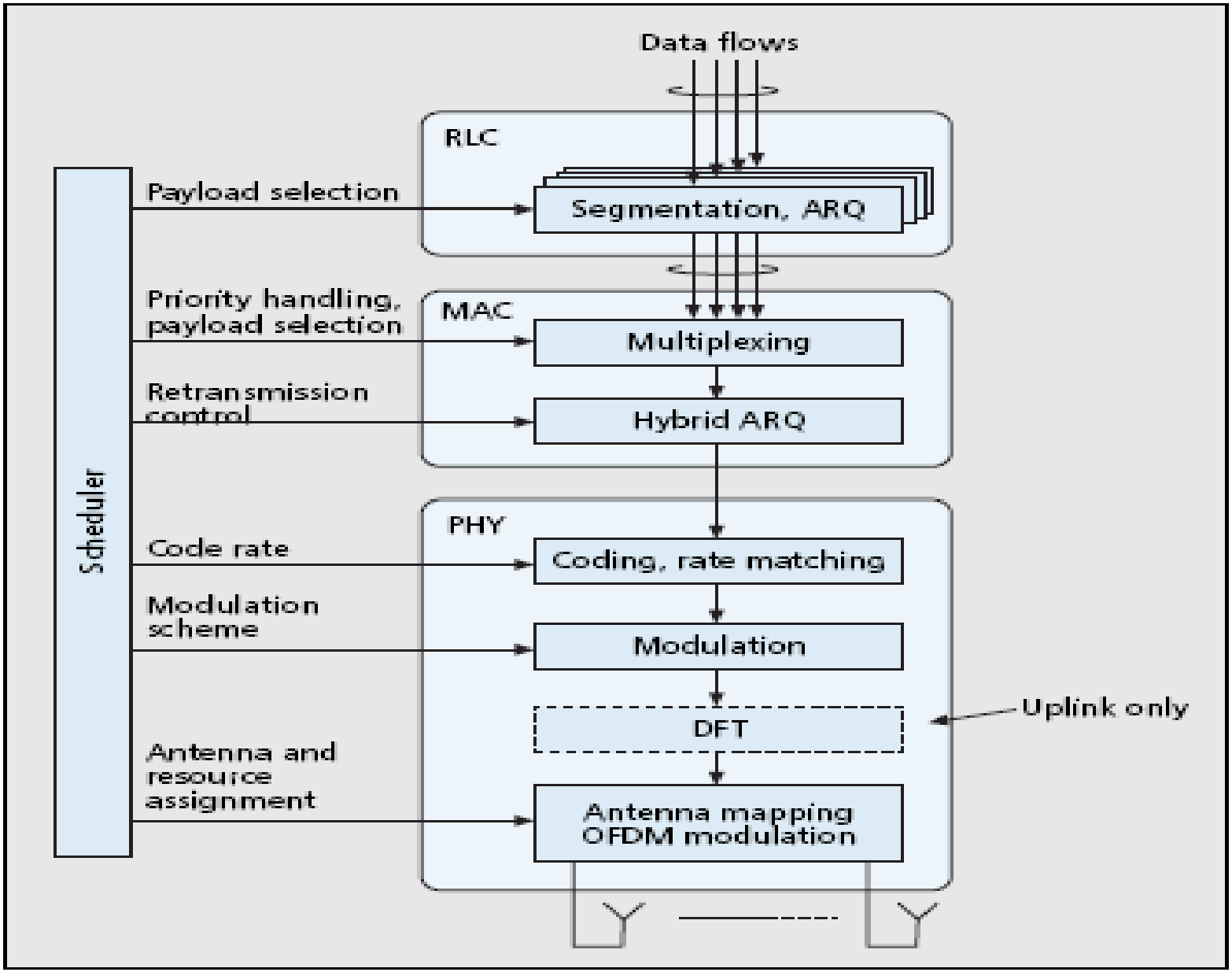


Figure 1. *LTE protocol structure (simplified).*

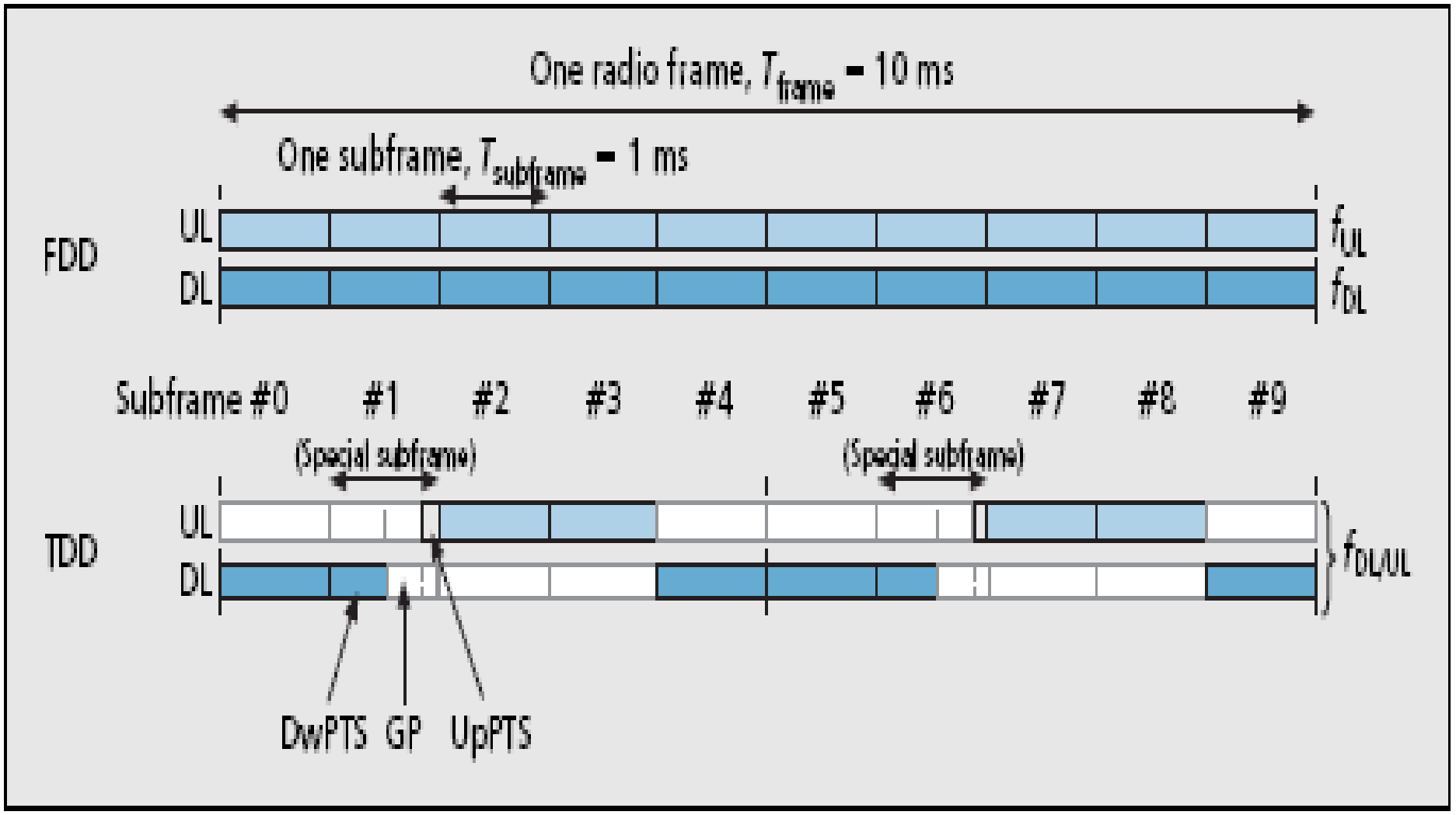


Figure 2. *LTE frame structure.*

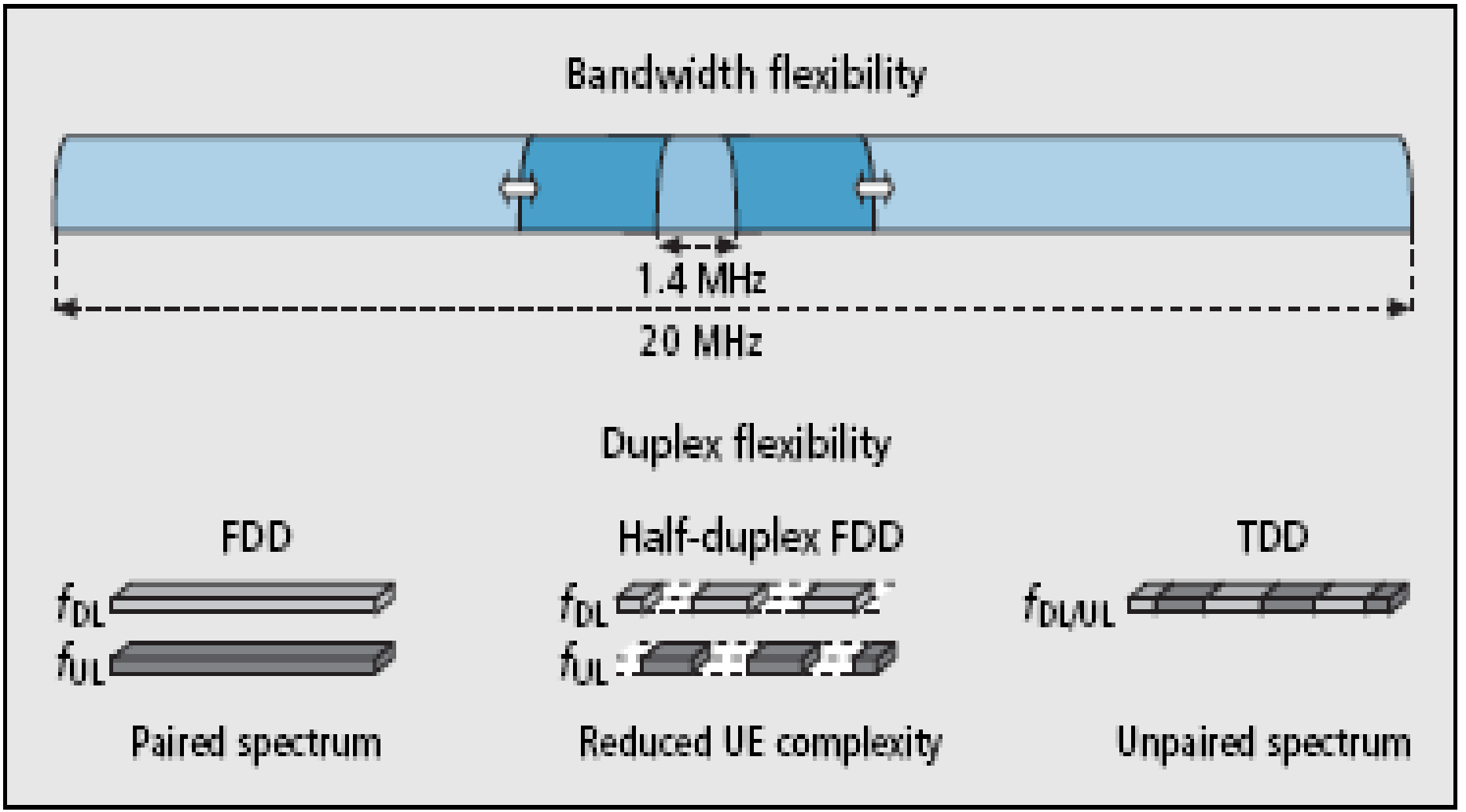


Figure 4. *LTE spectrum (bandwidth and duplex) flexibility. Half duplex FDD is seen from a terminal perspective.*

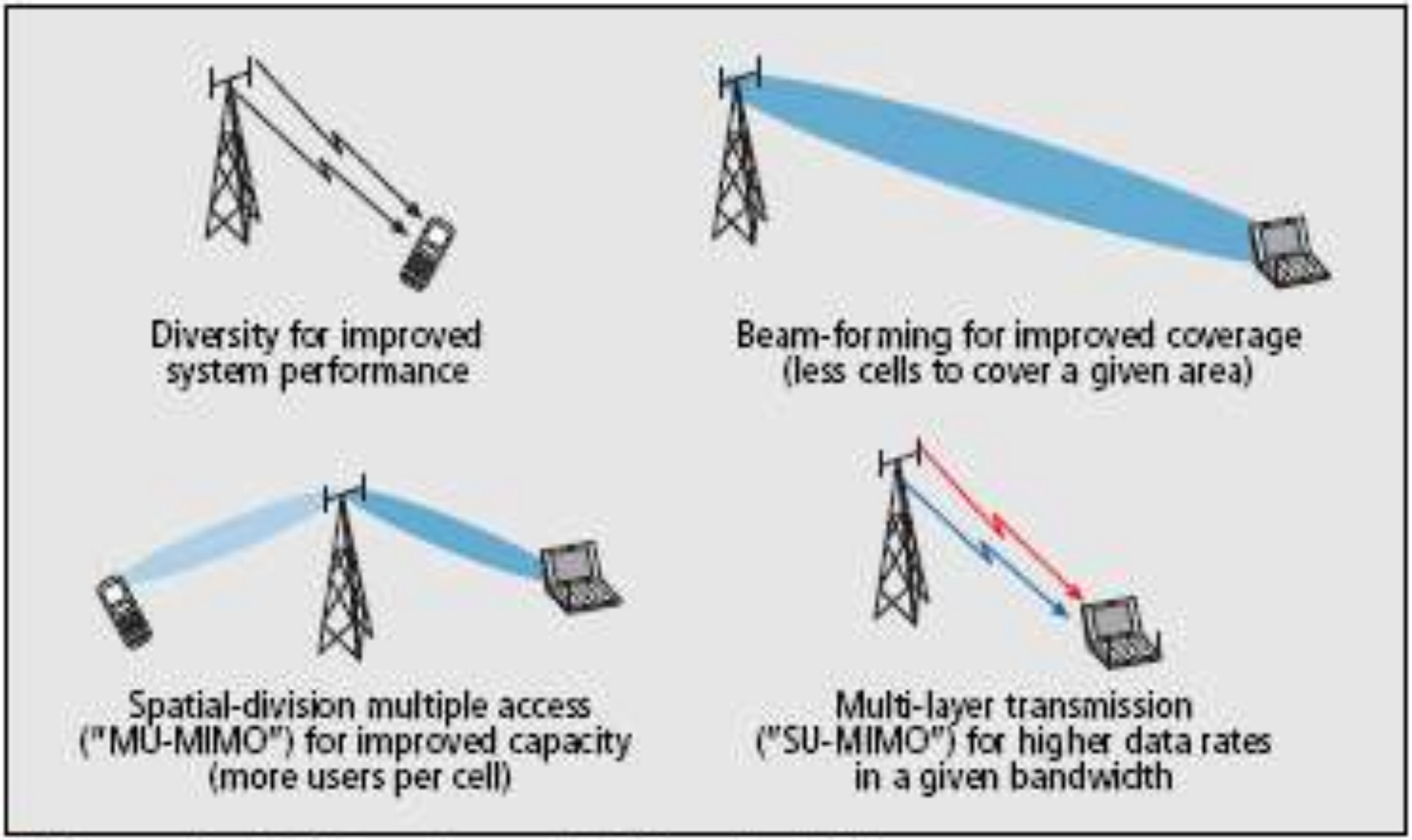


Figure 5. *Multiple-antenna techniques in LTE.*

Optical Network Research Issues

by

Vincent Chan

1. Is the direction that optical network development heading the right one to give us lots more data rate and much lower cost?
2. What applications will demand more data rates? Is it SOA, Service-Oriented-Architecture, that has distributed data storage, distributed processing, etc.?
3. Will we ever use the many THz of bandwidth in a fiber?
4. Should we use all the bandwidth in a fiber?

….continued

Optical Network Research Issues continued…

5. Can we trade bandwidth for lower cost?
6. Should cost be the only and ultimate performance metric for a network?
7. Why are we still using an optical network architecture developed originally for electronic networks?
8. Are the properties of optical devices different enough for optical networks to benefit by different architectures from electronic networks?

….continued

Optical Network Research Issues continued…

9. Is packet switching architecture the ultimate universal transport?
10. Is optical packet switching the right transport for fiber networks?
11. Will optical logic gates ever be competitive with CMOS gates in power consumption, size and cost?
12. How can we make massive scale photonic circuits like CMOS?

….continued

Optical Network Research Issues continued…

13. What about burst switching? Is the throughput and delay acceptable?
14. Is flow switching a good alternative? If so when? What physical and higher-layer network architecture is right for flow switching?
15. Is coherent system the right choice for ultra-high rate systems?
16. Should we invest more efforts on the development of lower loss (< 0.01db/Km) fiber?
17. What is the role of “carrier-class Ethernet”?

….continued

Optical Network Research Issues continued…

18. Will fiber networks always use higher network layer protocols that are IP based?
19. Is TCP/IP the right protocol for very high bandwidth services (>1Gbps)? What is the throughput efficiency? What is the delay characteristic?
20. Is the increase in offered user data rates of optical networks ever going to beat Moore's Law?
21. When do power consumption and cooling become the dominant network cost?

….continued

Optical Network Research Issues continued…

22. Are there network architectures that use substantially less power?
23. Should users have direct optical access to the core network? Or should there be an electronic isolation at the Metro-access network interface?
24. Are all (and near-all) optical networks secure against denial of service attacks?

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THANK YOU

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