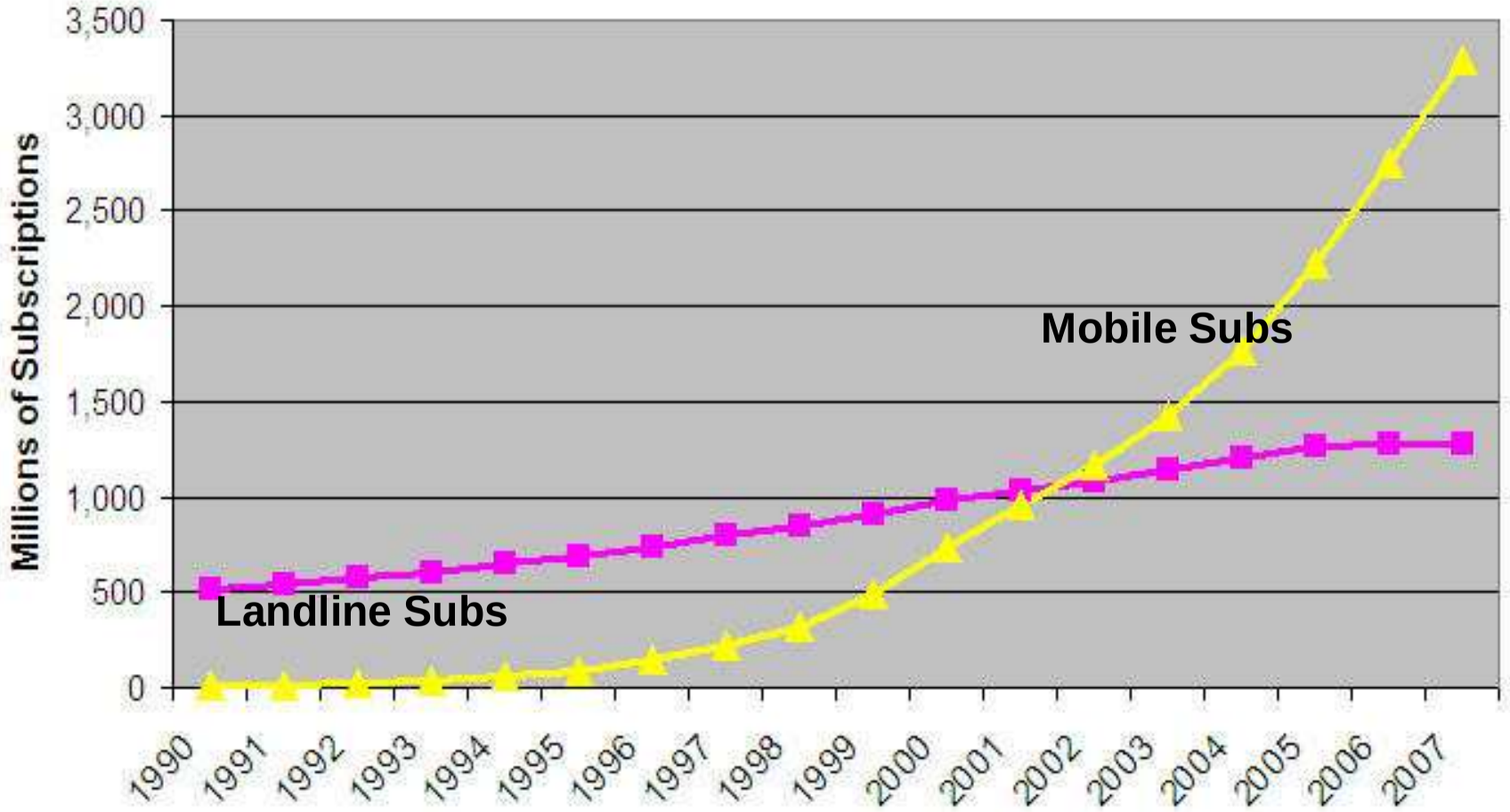
Wireless Tutorial

Brough Turner
NMS Communications

October 9, 2008

Mobiles over take fixed phones



Source: ITU World ICT Indicators, June 2008

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The author would like to acknowledge material contributions from:

- Marc Orange, Interphase
  - Formerly with NMS Communications
- Murtaza Amiji, Tellme (A Microsoft Subsidiary)
  - Formerly with NMS Communications
- Samuel S. May, Price Waterhouse Coopers
  - Formerly with US Bancorp Piper Jaffray

many others, as noted on specific slides

Outline

- History and evolution of mobile radio
  - Brief history of cellular wireless telephony
  - Radio technology today: TDMA, CDMA, OFDMA, …
  - Demographics and market trends today
  - 3G, 3.5G, WiMAX, LTE & 4G migration paths
- Evolving network architectures
  - GSM-MAP (EU) and IS-41 (US) origins
  - Softswitches, VoIP and SIP in NextGen Networks (NGN)
  - 3GPP & NGN convergence: releases, features and schedules

Outline (continued)

- Evolving services
  - SMS, MMS, location, rich presence, video
  - IP multimedia subsystem (IMS) vs. “dumb pipe”
- Applications and business models
  - Killer applications & killer platforms
  - 2-sided business models
- Related technology, Issues and Futures
  - WiMAX, Backhaul, Bluetooth, NextGen WiFi
  - Mobile device diversity / application environments

Wireless Tutorial

- **History and Evolution of Mobile Radio**
- Evolving Network Architectures
- Evolving Services
- Applications and Business Models
- Related technology, Issues and Futures

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Origins of Wireless Communications

- 1864: James Clark Maxwell
  - Predicts existence of radio waves
- 1886: Heinrich Rudolph Hertz
  - Demonstrates radio waves
- 1895-1901: Guglielmo Marconi

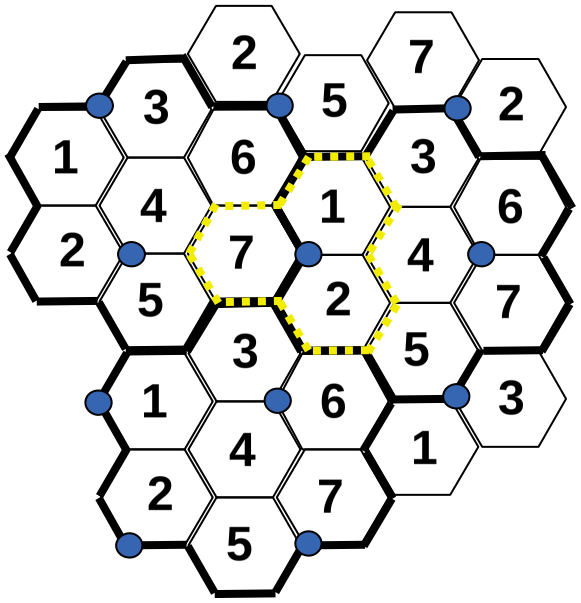
  - Demonstrates wireless communications over increasing distances
- Also in the 1890s
  - Nikola Tesla, Alexander Stepanovich Popov, Jagdish Chandra Bose and others, demonstrate forms of wireless communications

First Mobile Radio Telephone, 1924

Courtesy of Rich Howard

Cellular Mobile Telephony

- Antenna diversity
- Cellular concept
  - Bell Labs (1957 & 1960)
- Frequency reuse
  - typically every 7 cells
- Handoff as caller moves
- Modified CO switch
  - HLR, paging, handoffs
- Sectors improve reuse
  - every 3 cells possible



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First Generation (nearly all retired)

- Advanced Mobile Phone Service (AMPS)
  - US trials 1978; deployed in Japan (’79) & US (’83)
  - 800 MHz; two 20 MHz bands; TIA-553
- Nordic Mobile Telephony (NMT)
  - Sweden, Norway, Demark & Finland
  - Launched 1981
  - 450 MHz; later at 900 MHz (NMT900)
- Total Access Communications System (TACS)
  - British design; similar to AMPS; deployed 1985

2nd Generation "2G" – digital systems

- Leverage technology to increase capacity
  - Speech compression; digital signal processing
- Utilize/extend "Intelligent Network" concepts
  - Improve fraud prevention; Add new services
- Wide diversity of 2G systems
  - IS-54/ IS-136 North American TDMA; & PDC (Japan)
  - DECT and PHS; iDEN
  - IS-95 CDMA (cdmaOne)
  - GSM

D-AMPS (usually called "TDMA") & PDC

- IS-54 / IS-136 standards in US TIA
  - Speech coded as digital bit stream; aggressive compression limits voice quality
  - Development through 1980s; bakeoff 1987
  - Deployed 1993 (PDC 1994)
- ATT Wireless & Cingular used D-AMPS initially
  - Migrated to GSM; D-AMPs now largely retired
- PDC dominant 2G cellular system in Japan
  - Migration to 3GSM (W-CDMA, …) well advanced; PDC likely to be phased out in 2009-2010

iDEN (primary user was Nextel)

- Motorola proprietary system
  - time division multiple access technology; based on GSM architecture
- 800 MHz private mobile radio (PMR) spectrum
  - just below 800 MHz cellular band
- Special protocol supports fast “Push-to-Talk”
  - digital replacement for old PMR services
- Nextel had highest APRU in US market due to “Direct Connect” push-to-talk service

DECT and PHS

- Also uses time division multiple access
- Digital European Cordless Telephony
  - focus on business use, i.e. wireless PBX
  - very small cells (in building)
  - wide bandwidth (32 Kbps channels)
  - high quality voice and/or ISDN data
- Personal Handiphone Service
  - Similar technology, but high density urban deployments
  - 4 channel base station uses one ISDN BRI line
  - legacy in Japan; still widely deployed in China today

2G "CDMA" (cdmaOne)

- Code Division Multiple Access
  - all users share same frequency band
  - discussed in detail later as CDMA is basis for 3G
- Qualcomm demo in 1989
  - claimed improved capacity & simplified planning
- First deployment in Hong Kong late 1994
- Major success in Korea (1M subs by 1996)
- Adopted by Verizon and Sprint in US
- Easy migration to 3G (same modulation)

2G "CDMA" (cdmaOne)

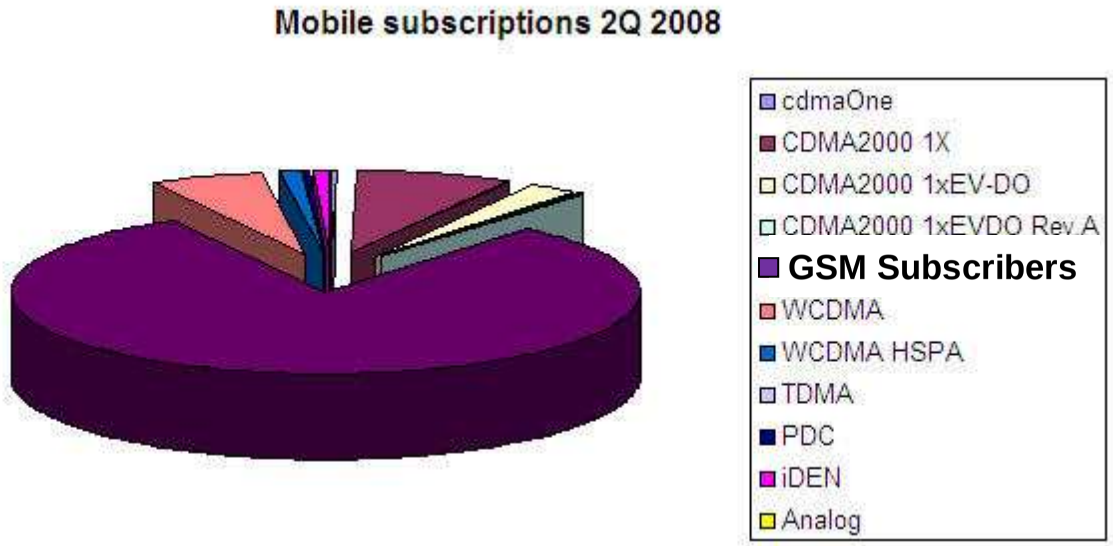
- TIA standard IS-95 (ANSI-95) in 1993
- IS-95 deployed in the 800 MHz cellular band
  - J-STD-08 variant deployed in 1900 MHz US "PCS" band
- Evolution fixes bugs and adds data
  - IS-95A provides data rates up to 14.4 kbps
  - IS-95B provides rates up to 64 kbps (2.5G)
  - Both A and B are compatible with J-STD-08.
- All variants designed for TIA IS-41 core networks (ANSI 41)

GSM – Global System for Mobile

- Originally "*Groupe Spécial Mobile* "
  - joint European effort beginning in 1982 focused on seamless roaming across Europe
- Services launched 1991
  - time division multiple access (8 users per 200KHz)
  - 900 MHz band; later extended to 1800 MHz; then 1900 MHz
  - Quad-band "world phones" support 850/900/1800/1900 MHz
- GSM – dominant world standard today
  - well defined interfaces; many competitors; lowest cost to deploy
  - network effect (Metcalfe's law) took hold in late 1990s

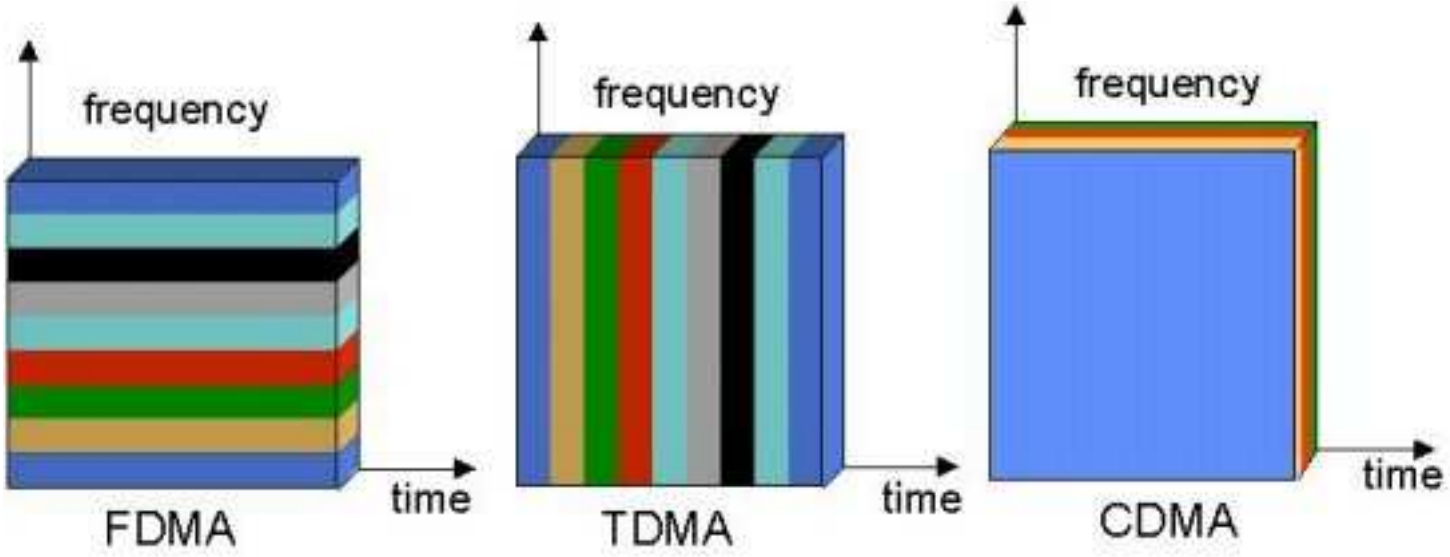
Distribution of GSM Subscribers

- GSM is used by 81% of subscribers worldwide
  - GSM plus 3GSM accounts for 88% of all mobile subscriptions
- Asia dominates with 42% of all mobile subscriptions
  - ATT & T-Mobile USA use GSM/3GSM in US today



Source: Wireless Intelligence / GSM Association

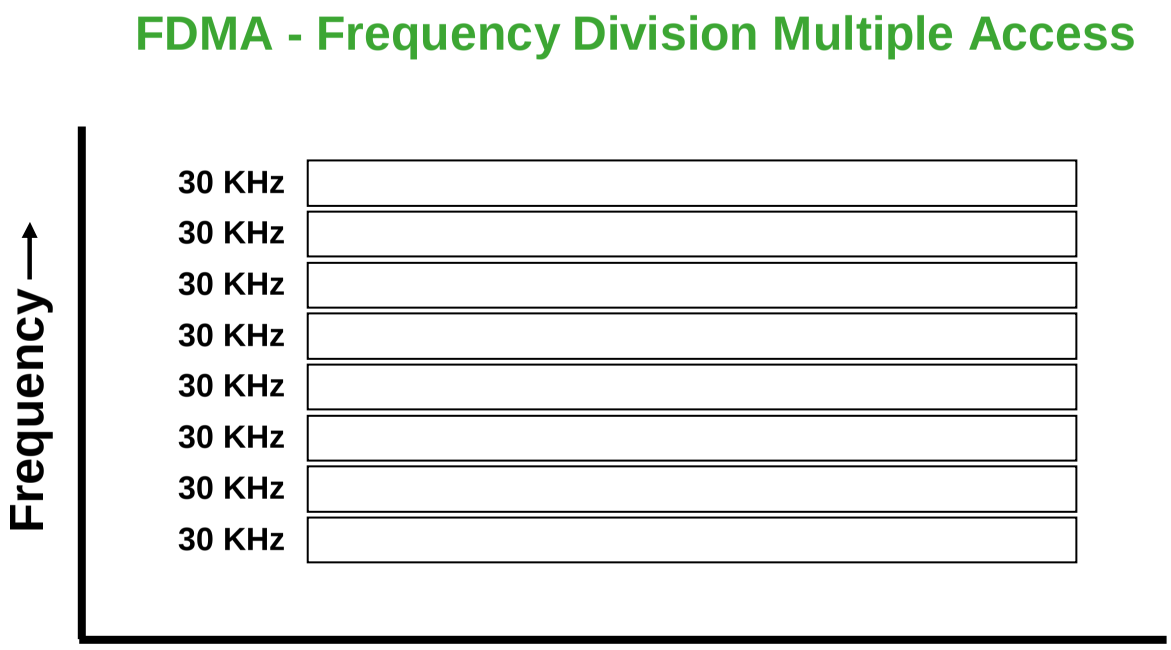
1G, 2G, 3G Multi-Access Technologies



Courtesy of Petri Possi, UMTS World

3.5G, 4G and future wireless systems optimize a combination of frequency, time and code multiplexing

1G – Separate Frequencies



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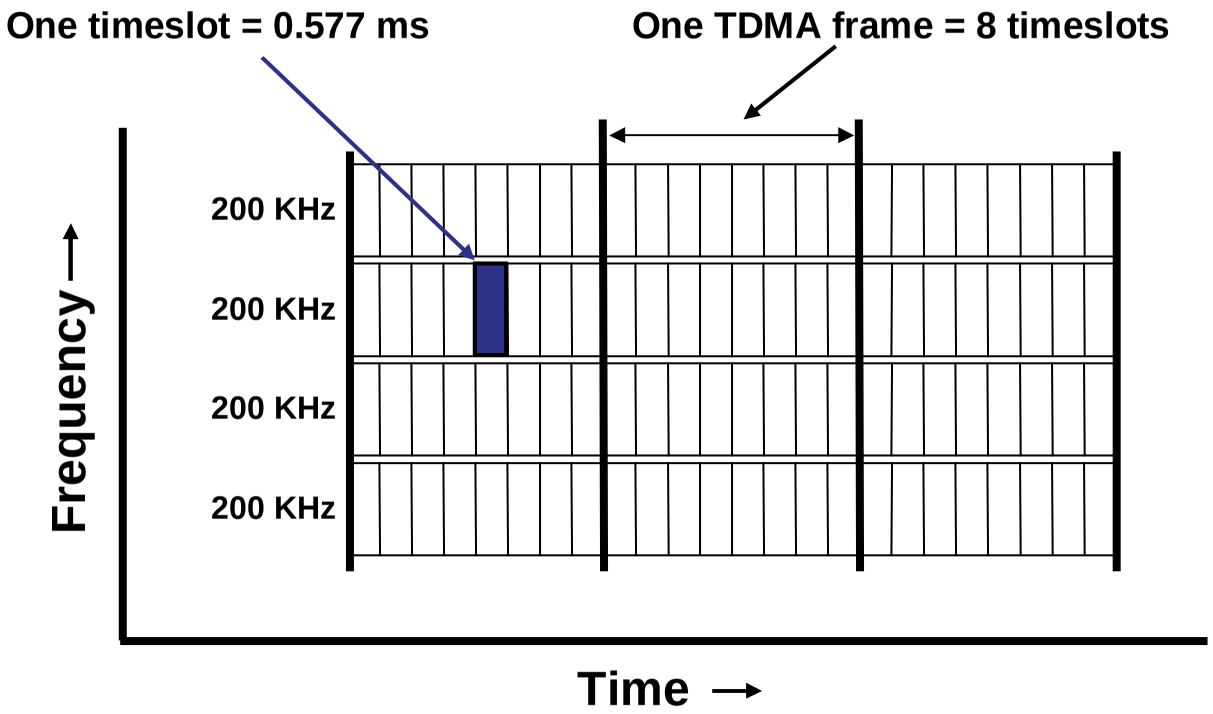
2G – Time Division Multiple Access (TDMA)



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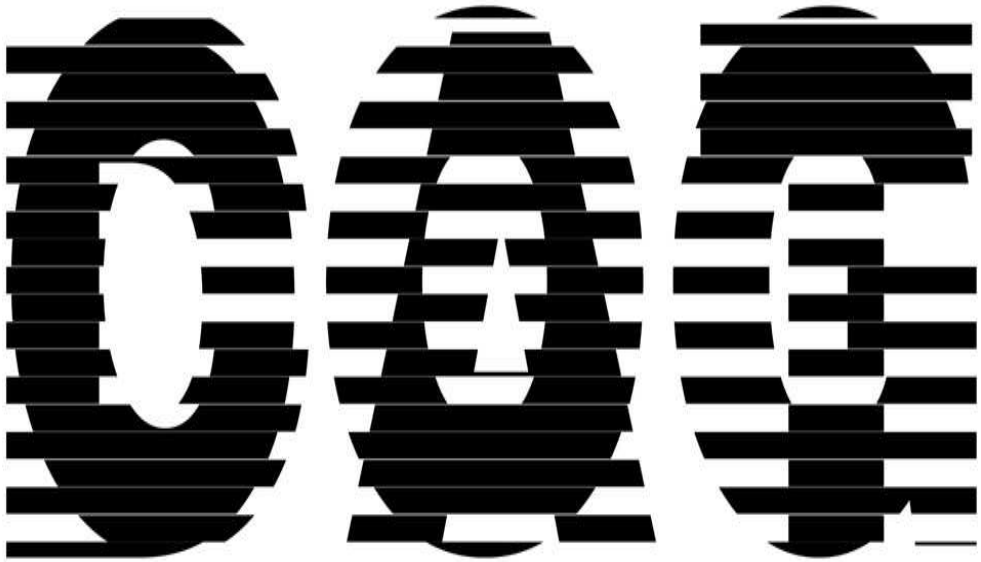
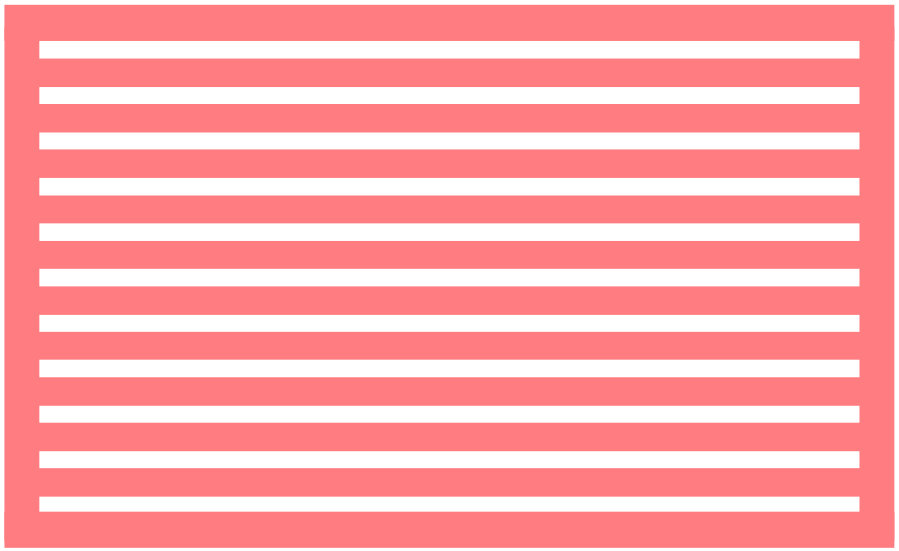
2G & 3G – Code Division Multiple Access

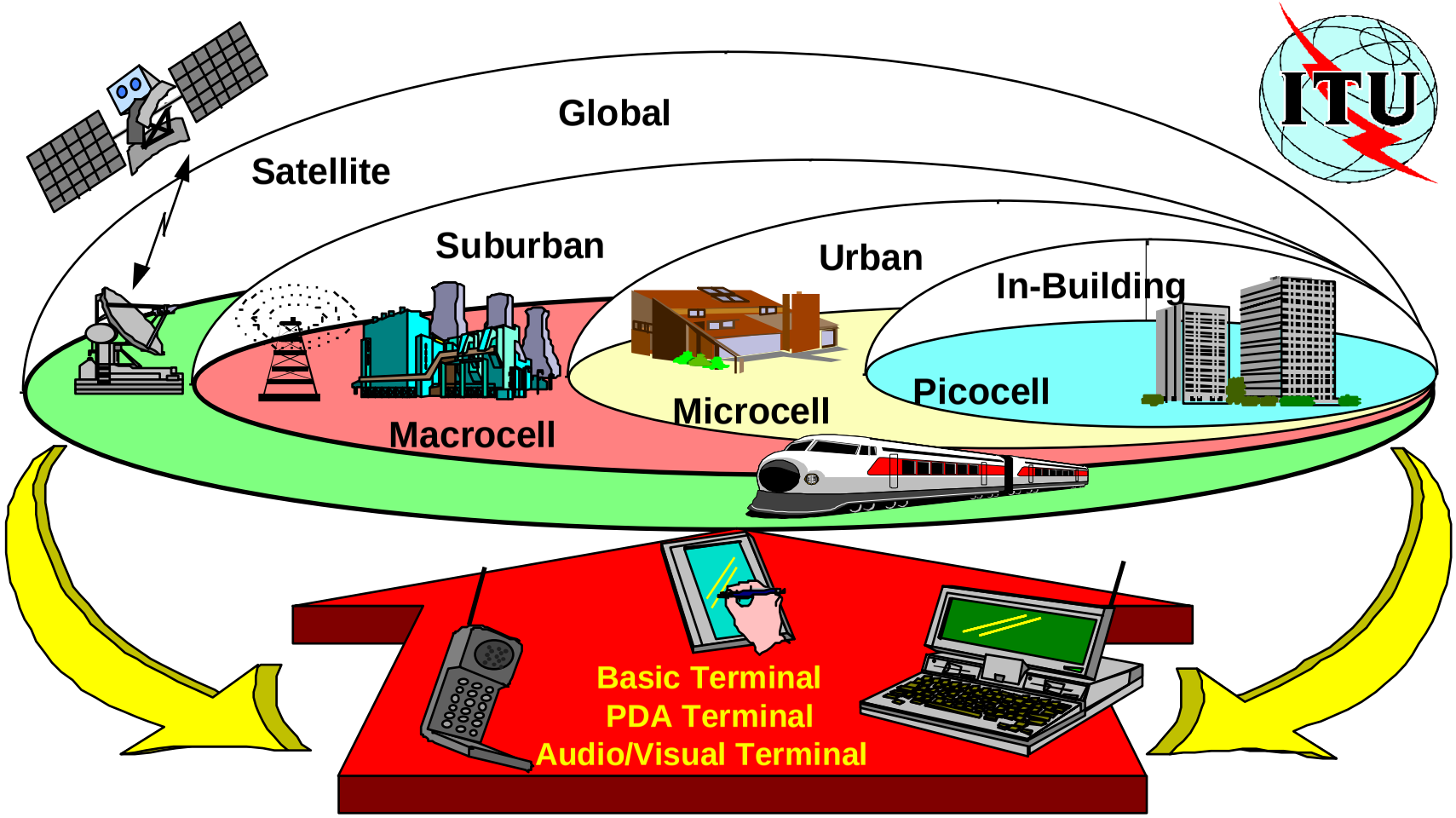
- Spread spectrum modulation
  - originally developed for the military
  - resists jamming and many kinds of interference
  - coded modulation hidden from those w/o the code
- All users share same (large) block of spectrum
  - one for one frequency reuse
  - soft handoffs possible
- All 3G radio standards based on CDMA
  - CDMA2000, W-CDMA and TD-SCDMA





Courtesy of Suresh Goyal & Rich Howard

IMT-2000 Vision (from 1992) included LAN, WAN and Satellite Services



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The 3G Vision

- Universal global roaming (1 standard, not 7)
  - 3GSM leads, but with CDMA 2000 & China TD-SCDMA
- Multimedia (voice, data & video)
- Increased data rates (384 Kbps to ? Mbps)
- Increased capacity (more spectrally efficient)
- Data-centric architecture (ATM at first, then IP)

But deployment took longer than expected

- No killer data app; new spectrum costly; telecom bubble burst; much of the vision was vendor-driven

Original GSM substantially enhanced

- Widely deployed so significant payback for enhancements
- Frequency hopping (to overcome fading)
- Synchronization between cells (minimize interference)
  - DFCA: dynamic frequency and channel assignment
  - Also used to determine mobile's location
- AMR: Adaptive multi-rate vocoder
  - trade off speech and error correction bits for fewer dropped calls
  - 8 coding rates: 12.2, 10.2, 7.95, 7.4, 6.7, 5.9, 5.15 & 4.75 bps, plus silence frames (near 0 bps)
  - dynamically adjust to radio interference conditions

GSM enhancements (continued)

- DTX – discontinuous transmission
  - less interference (approach 0 bps during silences)
  - more calls per cell
- Overlays with reuse partioning
  - 3x in overlay (cell edges); 1x reuse in underlay
- HSCSD - high speed circuit-switched data
  - aggregate channels to surpass 9.6 Kbps limit ($\rightarrow$64k)
- GPRS - general packet radio service

GPRS - 2.5G for GSM

- General packet radio service
  - first introduction of packet technology
- Aggregate radio channels
  - support higher data rates (115 Kbps)
  - subject to channel availability
- Share aggregate channels among multiple users
- All new IP-based data infrastructure
- No changes to voice network

3G Standardization

- ITU (International Telecommunication Union)
  - Radio standards and spectrum
- IMT-2000
  - ITU's umbrella name for 3G which stands for International Mobile Telecommunications 2000
- 3G Partnership Projects (3GPP & 3GPP2)
  - focused on evolution of access and core networks
  - National and regional standards bodies collaborating, i.e., ARIB, TIA, TTA, TTC, CWTS. T1, ETSI

3G Radio technology deployed today

- EDGE – GSM evolution, i.e. TDMA
  - Legacy; sometimes referred to as 2.75G
- CDMA 2000 – Multi Carrier CDMA
  - Evolution of IS-95 CDMA **Paired spectrum bands**
- UMTS/3GSM (W-CDMA, HSPA) – Direct Spread CDMA
  - Defined by 3GPP **Paired spectrum bands**
- TD-SCDMA – Time Division Synchronous CDMA
  - Defined by Chinese Academy of Telecommunications Technology under the Ministry of Information Industry

Single spectral band with time division duplexing

UMTS (3GSM) now market leader

- GSM evolution path: W-CDMA, HSDPA, HSPA, …
  - leverages GSM's dominant position
- Legally mandated in Europe and elsewhere
  - 5 MHz each way (symmetric)
- Requires substantial new spectrum
- Slow start (behind CDMA 2000) but now leading
  - Network effect builds on GSM's 80% market share

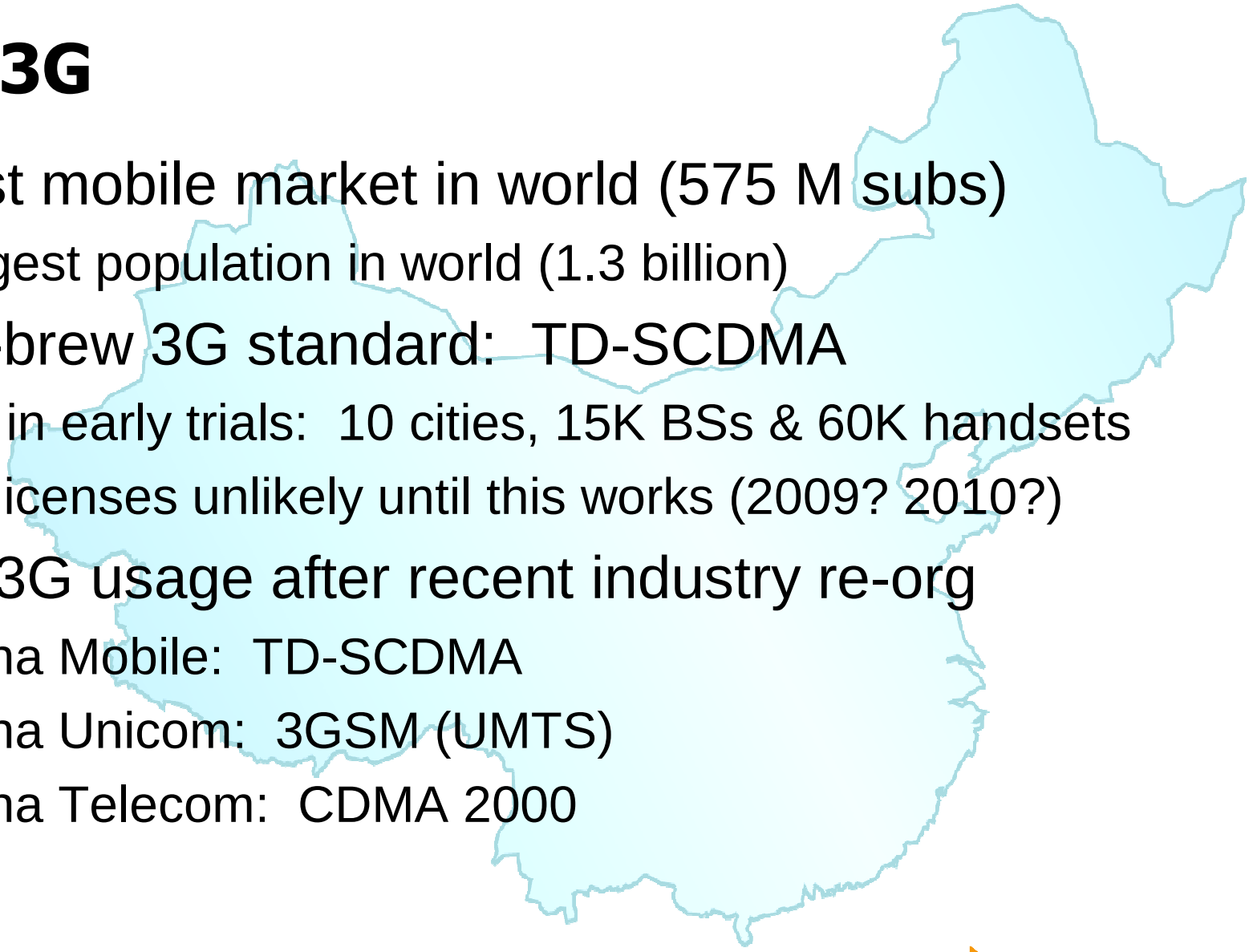
CDMA 2000 Pros and Cons

- Evolution from original Qualcomm CDMA (IS-95)
- Better migration story from 2G to 3G
  - cdmaOne operators don't need additional spectrum
  - Higher data rates than UMTS, at least at first
- Couldn't compete with GSM's critical mass
  - Even Verizon Wireless has decided to jump ship for 4G by moving to 3GSM's Long Term Evolution (LTE)

TD-SCDMA (Time division synchronous CDMA)

- Chinese development (IPR bargaining tool with West?)
  - Late to market, but big deployment plans
- Single spectral band
  - unpaired spectrum; as little as 1.6 MHz; time division duplex (TDD) with high spectral efficiency
  - Good match for asymmetrical traffic!
- Power amplifiers must be very linear
  - relatively hard to meet specifications
- In trials in ten cities but only 60K handsets so far

China 3G



- Largest mobile market in world (575 M subs)
  - Largest population in world (1.3 billion)
- Home-brew 3G standard: TD-SCDMA
  - Still in early trials: 10 cities, 15K BSs & 60K handsets
  - 3G licenses unlikely until this works (2009? 2010?)
- Likely 3G usage after recent industry re-org
  - China Mobile: TD-SCDMA
  - China Unicom: 3GSM (UMTS)
  - China Telecom: CDMA 2000

3G Adoption – DoCoMo Japan (UMTS)

Subscriber Growth:

2G: mova

3G: FOMA

Potential to discontinue 2G services in 2010 …

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3G Subscribers (2Q 2008)

- 18% on 3G; 82% on 2G; 0.01% on 1G
- EU & US 3G penetration rates approaching 30%
- US penetration overtaking EU penetration rate

3-month average ending June 2008 & June 2007

All mobile subscribers ages 13+

Country	Subscribers June 2007	Subscribers June 2008	Growth Year/Year
Germany	7,021	11,732	67.1%
Spain	7,207	12,640	75.4%
France	5,616	7,958	41.7%
Italy	14,462	18,008	24.5%
United Kingdom	8,964	13,100	46.1%
European Total (5 countries)	43,270	**63,438**	46.6%
United States	35,651	**64,207**	**80.1%**

Source: comScore MobiLens

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3G data-only subscribers

- Soaring adoption of 3G “USB Data Modems” in EU
  - Account for 92% of all 3G data bytes in Finland in 2H07
- Informa’s EU data from May 2008 on all 3G devices
  - 101.5M 3G devices out of 910.8 M mobile subscribers
  - If ~64 M are handsets, then 37M are 3G data modems
- In-Stat/ ABI Research
  - In-Stat: 5M cellular modems in 2006
  - ABI Research 300% growth in 2007, i.e. 20M?
- *Enormous growth here, but from a small base…*

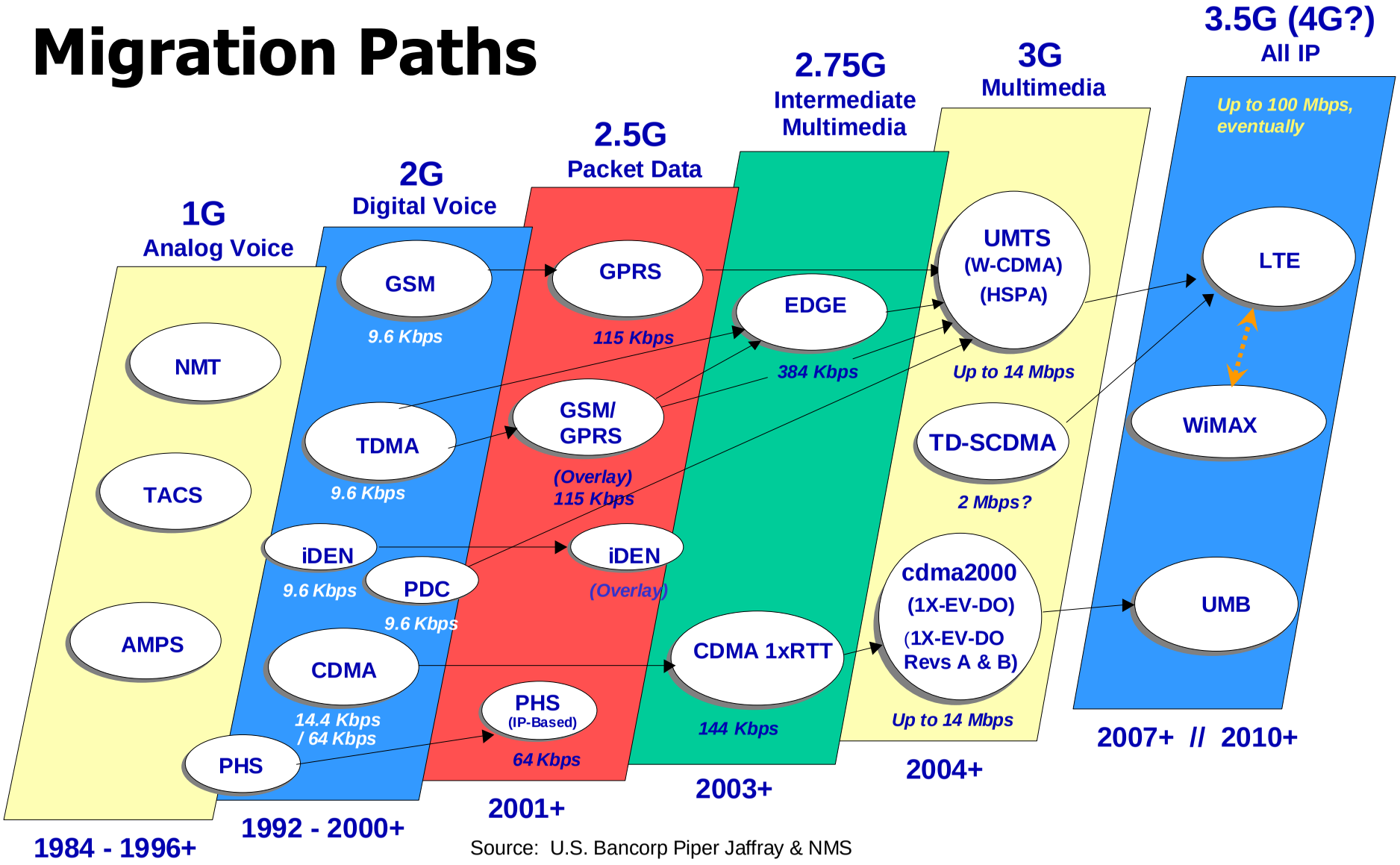
Diverse Mobile Wireless Spectrum

Bands	Frequencies (MHz)	Regions	GSM/ EDGE	UMTS/ 3GSM	CDMA 2000	TD-SCDMA
NMT/CDMA 450	460-493	EU, global			X	
GSM 450	450-467	EU, global	X			
GSM480	478-496	EU, global	X			
GSM 850 & CDMA 850	869-894	US	X		X	
GSM 900	925-960	EU, global	X			
DCS 1800	1805-1880	EU, global	X			
PCS 1900	1930-1990	US	X	X	X	
IMT 2000	1920-1980 & 2110-2170	EU, global		X		
China 3G	1880-1920 & 2010-2025 & 2300-2400	China				X
AWS	1710-1755 & 2110-2155	US		X	X	
700 MHz	746-764 & 776-794	US		X	X	
ITU Proposal	2500-2690	EU, global		X		

Global Roaming Issues

- Multiple vocoders (AMR, EVRC, SMV, …, WB?)
- Many spectral bands
  - 450, 800, 900, 1700, 1800, 1900, 2100, 2500, …? MHz
- At least four modulation variants
  - GSM (TDMA), W-CDMA, CDMA2000, TD-SCMDA
- "Universal" handset prospects
  - Advanced silicon; software defined radio
  - Still need: multiple antennas; improved batteries

Migration Paths



Source: U.S. Bancorp Piper Jaffray & NMS

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3.5G and 4G

- 4G not formally defined, projected to provide
  - 100 Mbps (moving) & 1 Gbps (stationary)
  - Seamless roaming across heterogeous networks
- Pre-4G standards sometimes promoted as “4G”
  - WiMAX – ~6 million units by 12/2008?
  - Flash-OFDM - ~13 million subscribers in 2010 ?
  - 3GPP Long Term Evolution (LTE) – 2010 launch
  - UMB in 3GPP2 – extent of adoption is uncertain
  - IEEE 802.20 - adoption uncertain

LTE highlights

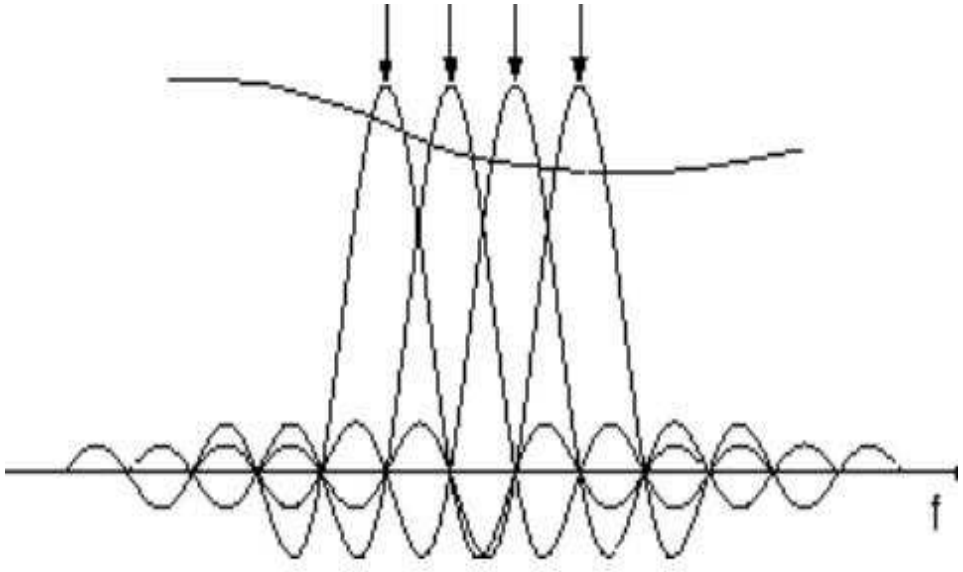
- Sophisticated multiple access schemes
  - DL: OFDMA with Cyclic Prefix (CP)
  - UL: Single Carrier FDMA (SC-FDMA) with CP
- Adaptive modulation and coding
  - QPSK, 16QAM, and 64QAM
  - 1/3 coding rate, two 8-state constituent encoders, and a contention-free internal interleaver
- Advanced MIMO spatial multiplexing techniques
  - (2 or 4) x (2 or 4) downlink and uplink

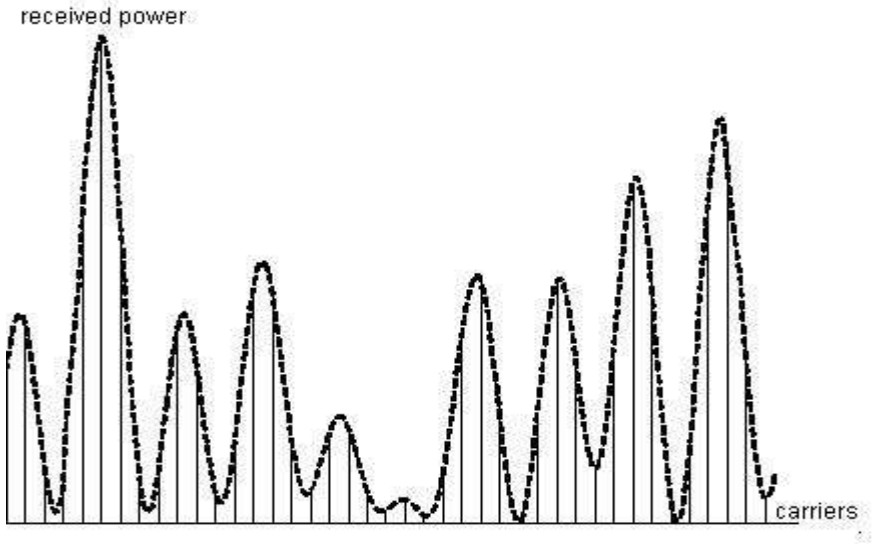
4G Technology – OFDMA

- Orthogonal Frequency Division Multiple Access
  - Supercedes CDMA used in all 3G variants
- OFDMA = Orthogonal Frequency Division Multiplexing (OFDM) plus statistical multiplexing
  - Optimization of time, frequency and code multiplexing
- Already deployed in 802.11a & 802.11g WiFi
  - Ups WiFi from 11 Mbps to 54 Mbps & beyond

OFDM – Orthogonal Frequency Division Multiplexing

- Many closely-spaced sub-carriers, chosen to be orthogonal, thus eliminating cross-talk & guard bands
- Vary bits per sub-carrier based on instantaneous received power





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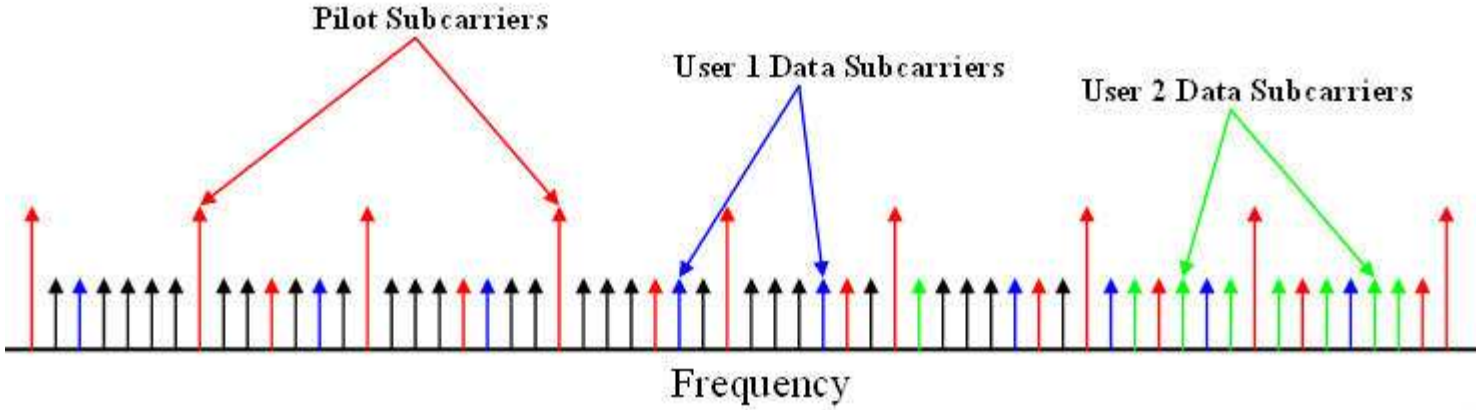
Statistical Multiplexing (in OFDMA)

- Dynamically allocate user data to sub-carriers based on instantaneous data rates and varying sub-carrier capacities
- Highly efficient use of spectrum
- Robust against fading, e.g. during mobile operation



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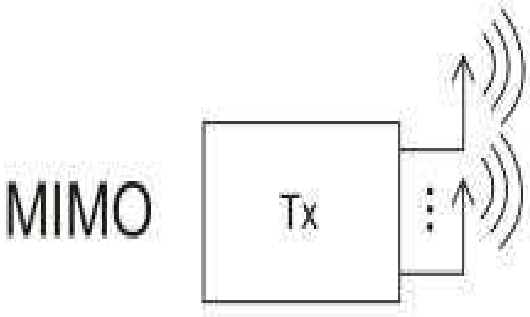
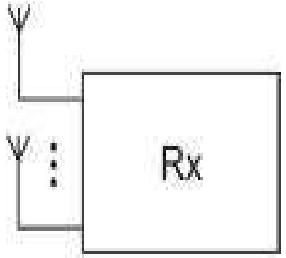
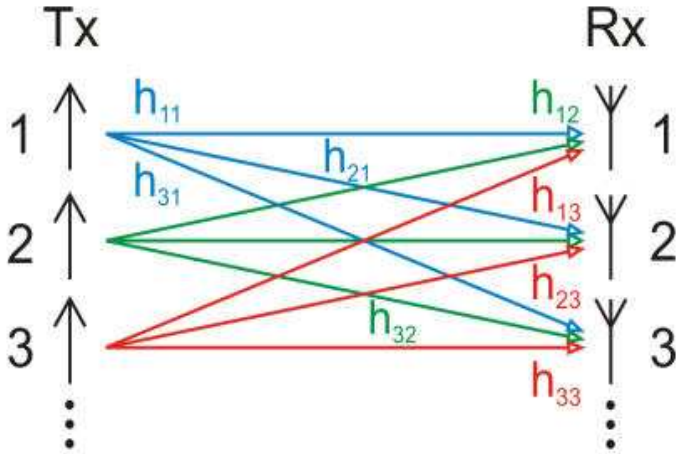
4G Technology - MIMO

- Multiple Input Multiple Output smart antenna technology
- Multiple paths improve link reliability and increase spectral efficiency (bps per Hz), range and directionality







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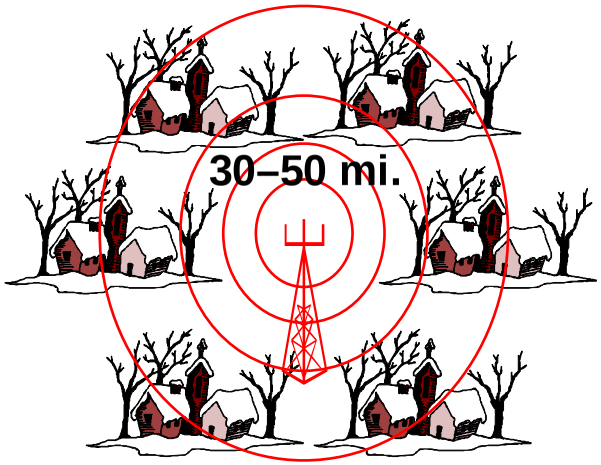
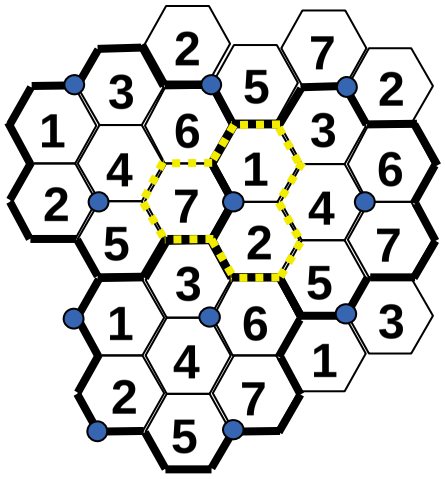
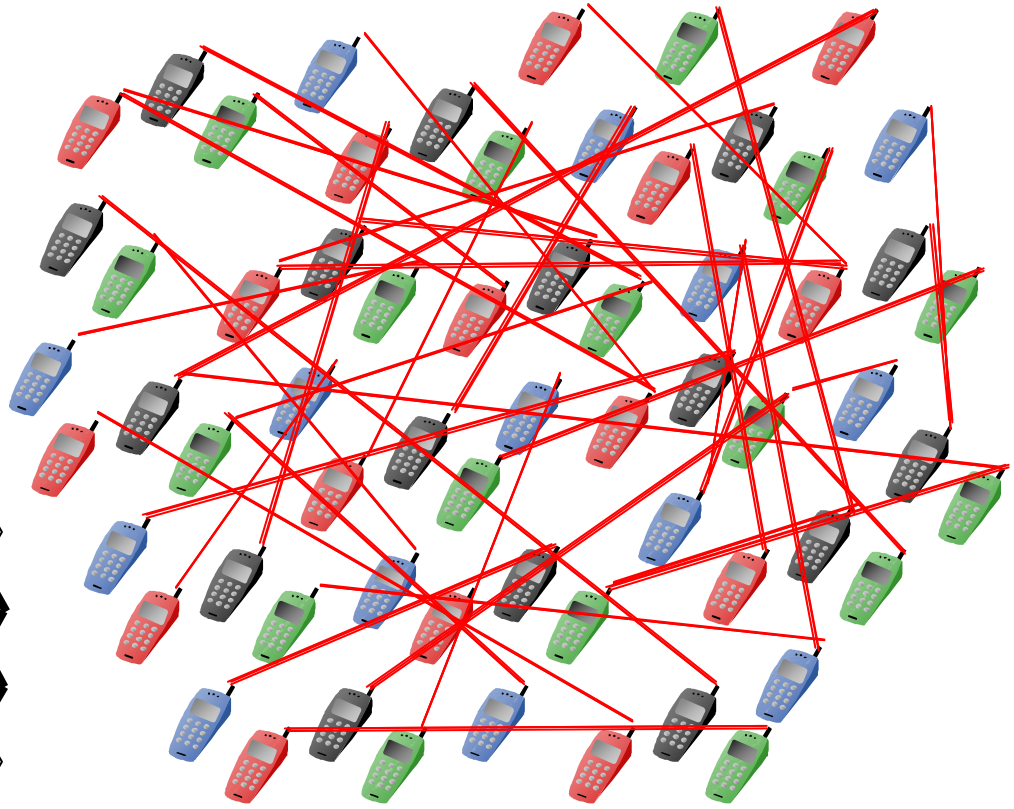
4G Technology – SC-FDMA

- Single carrier multiple access
  - Used for LTE & UMB uplinks
  - Being considered for 802.16m uplink
- Similar structure and performance to OFDMA
  - Single carrier modulation with DFT-spread orthogonal frequency multiplexing and FD equalization
- Lower Peak to Average Power Ratio (PAPR)
  - Improves cell-edge performance
  - Transmit efficiency conserves handset battery life

The Ultimate metric:
bps per Hertz per acre per watt







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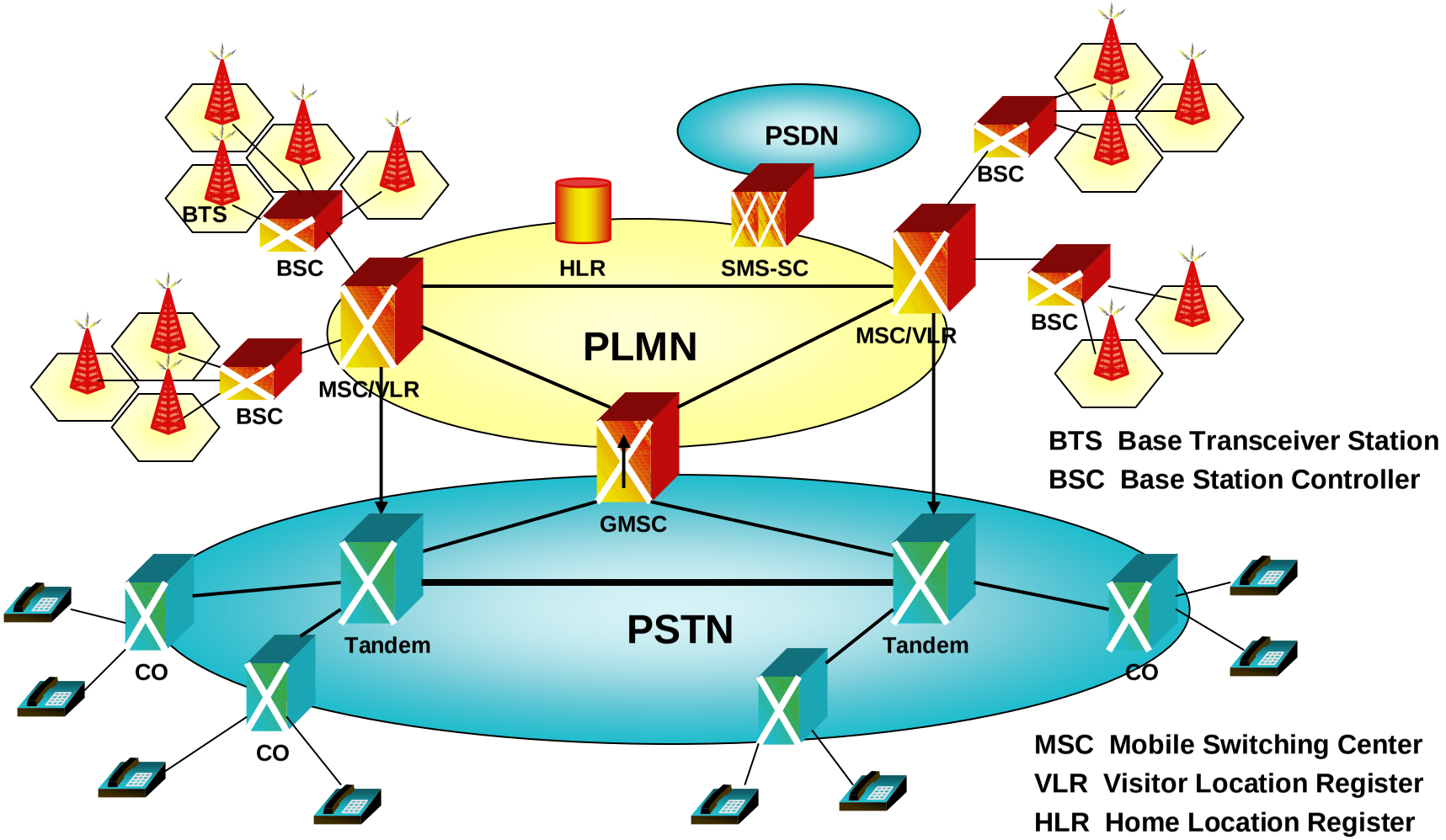
Wireless Tutorial

- History and Evolution of Mobile Radio
- **Evolving Network Architectures**
- Evolving Services
- Applications and Business Models
- Related technology, Issues and Futures

Evolving Core Network Architectures

- Two widely deployed architectures today
- 3GPP evolved from GSM-MAP
  - Used by GSM & 3GSM operators *(87% of subs globally)*
  - "Mobile Application Part" defines signaling for mobility, authentication, etc.
- 3GPP2 evolved from ANSI-41 MAP
  - ANSI-41 used with AMPS, TDMA & CDMA 2000
  - GAIT (GSM ANSI Interoperability Team) allowed interoperation, i.e., roaming
  - Evolving to common "all IP" vision based on 3GPP

Typical 2G Mobile Architecture



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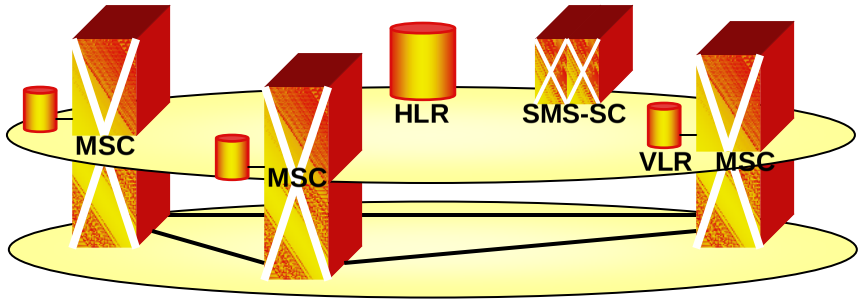
Separation of Signaling & Transport

- Like PSTN, 2G mobile networks have one network plane for voice circuits and another network plane for signaling
- Some elements reside only in the signaling plane
  - HLR, VLR, SMS Center, …



Signaling Plane (SS7)

Transport Plane (Voice)

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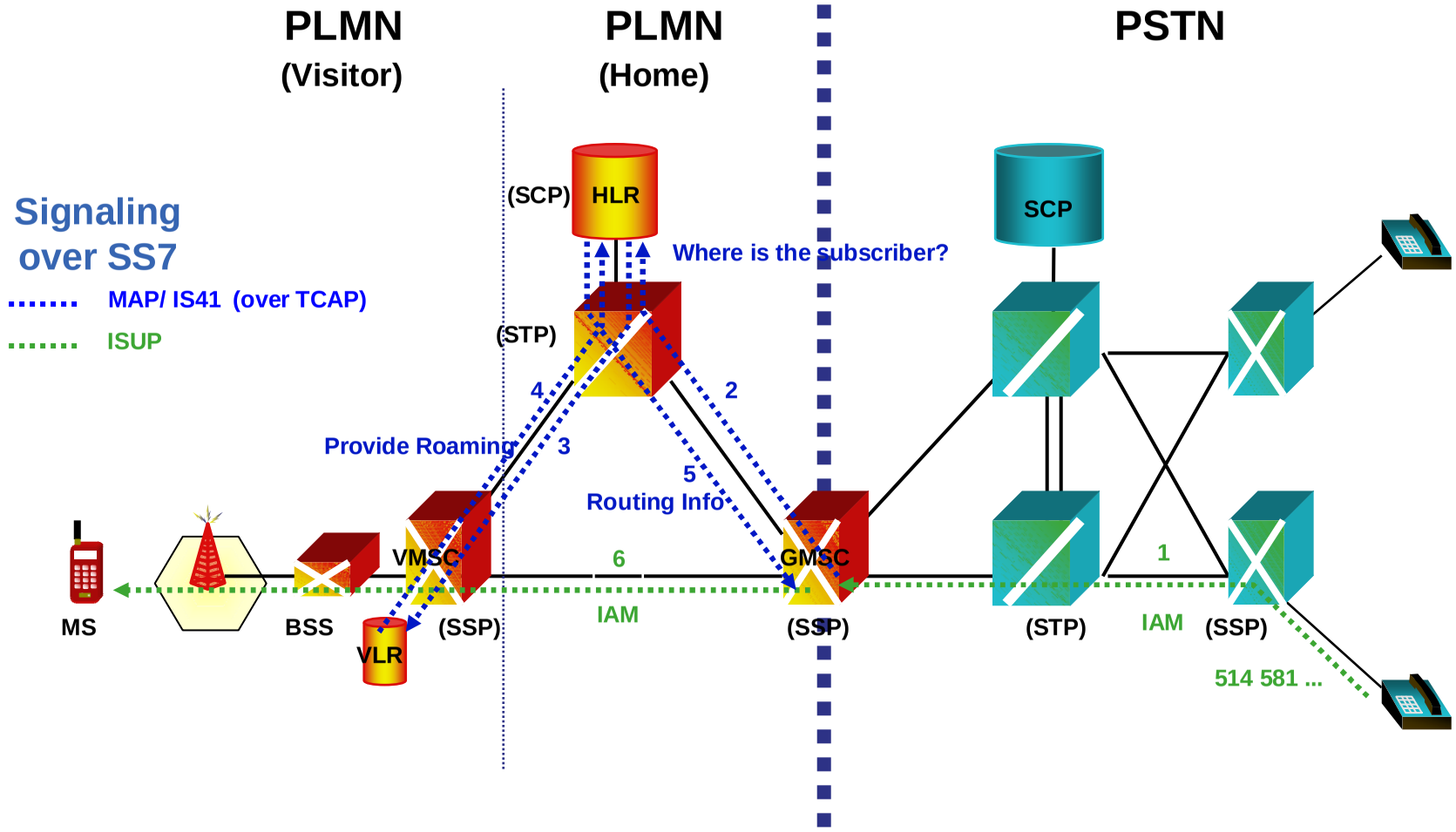
Signaling in Core Network

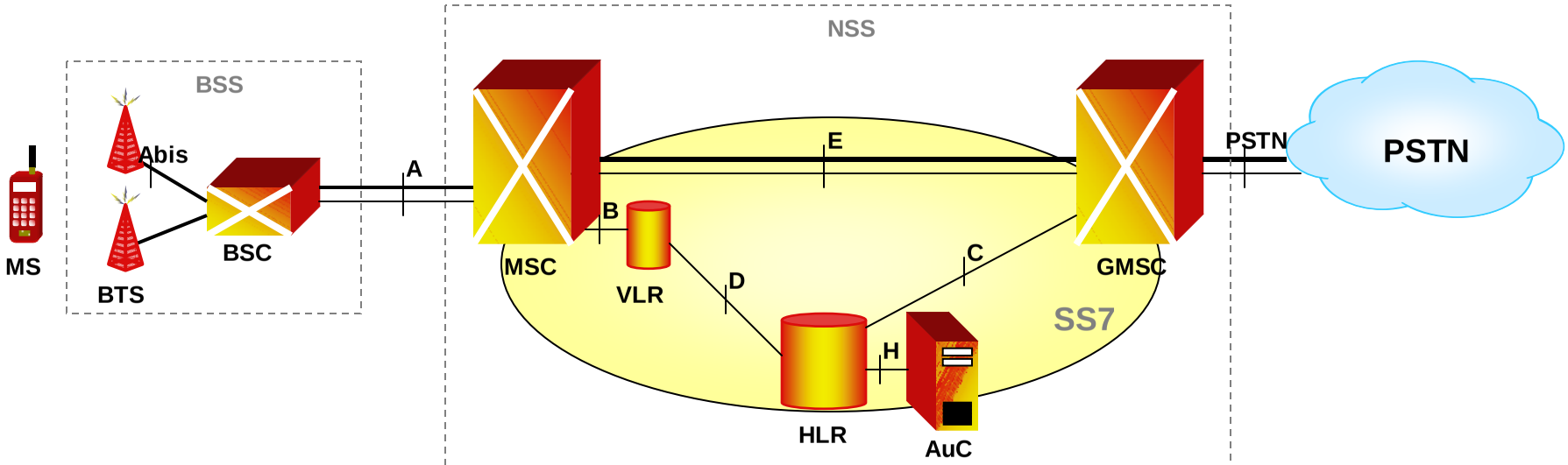
- Based on SS7
  - ISUP and specific Application Parts
- GSM MAP and ANSI-41 services
  - mobility, call-handling, O&M, authentication, supplementary services, SMS, …
- Location registers for mobility management
  - HLR: home location register has permanent data
  - VLR: visitor location register – local copy for roamers

PSTN-to-Mobile Call



NMS COMMUNICATIONS

GSM 2G Architecture



BSS Base Station System

BTS Base Transceiver Station

BSC Base Station Controller

MS Mobile Station

NSS Network Sub-System

MSC Mobile-service Switching Controller

VLR Visitor Location Register

HLR Home Location Register

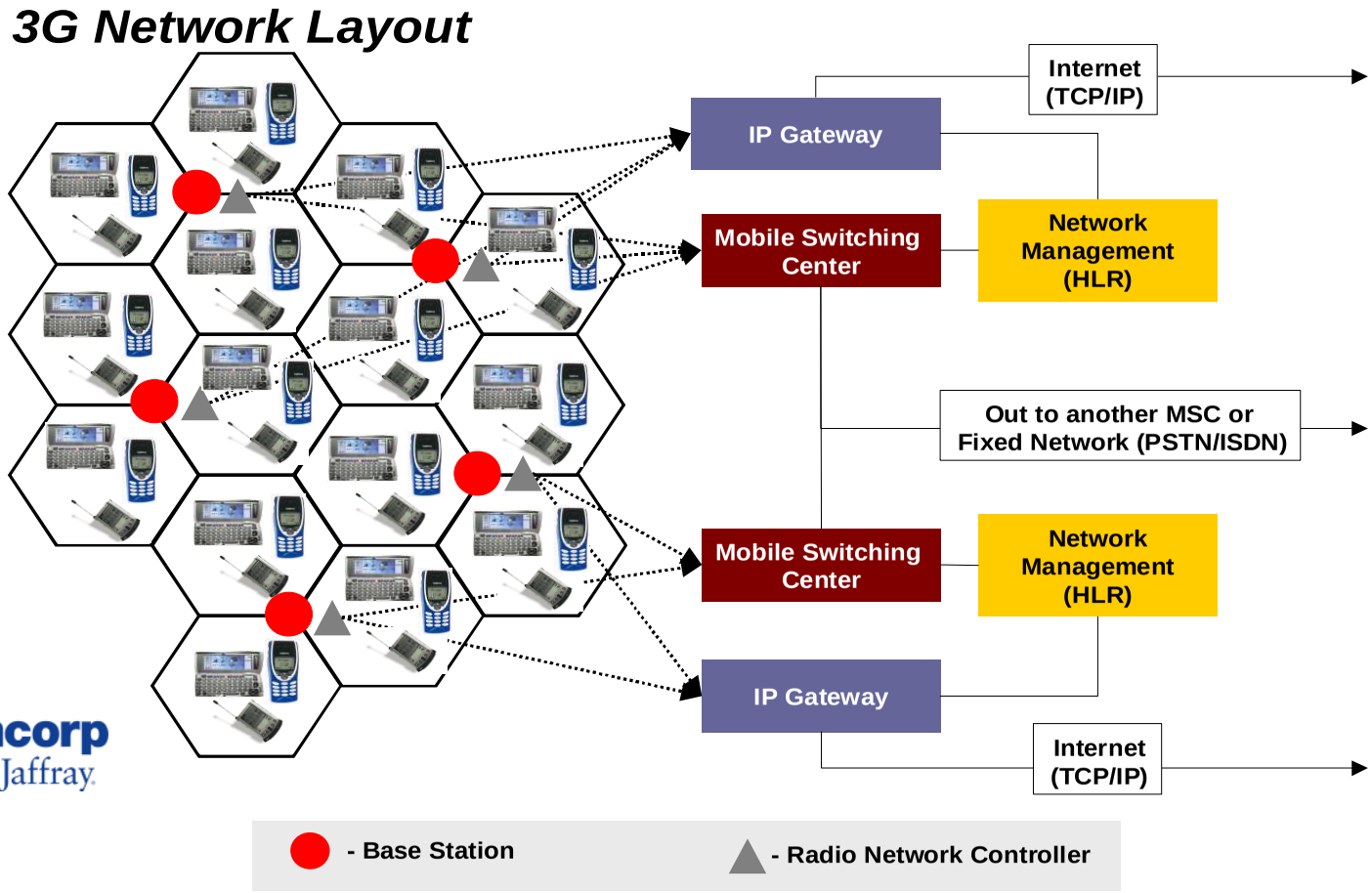
AuC Authentication Server

GMSC Gateway MSC

GSM Global System for Mobile communication

NMS COMMUNICATIONS

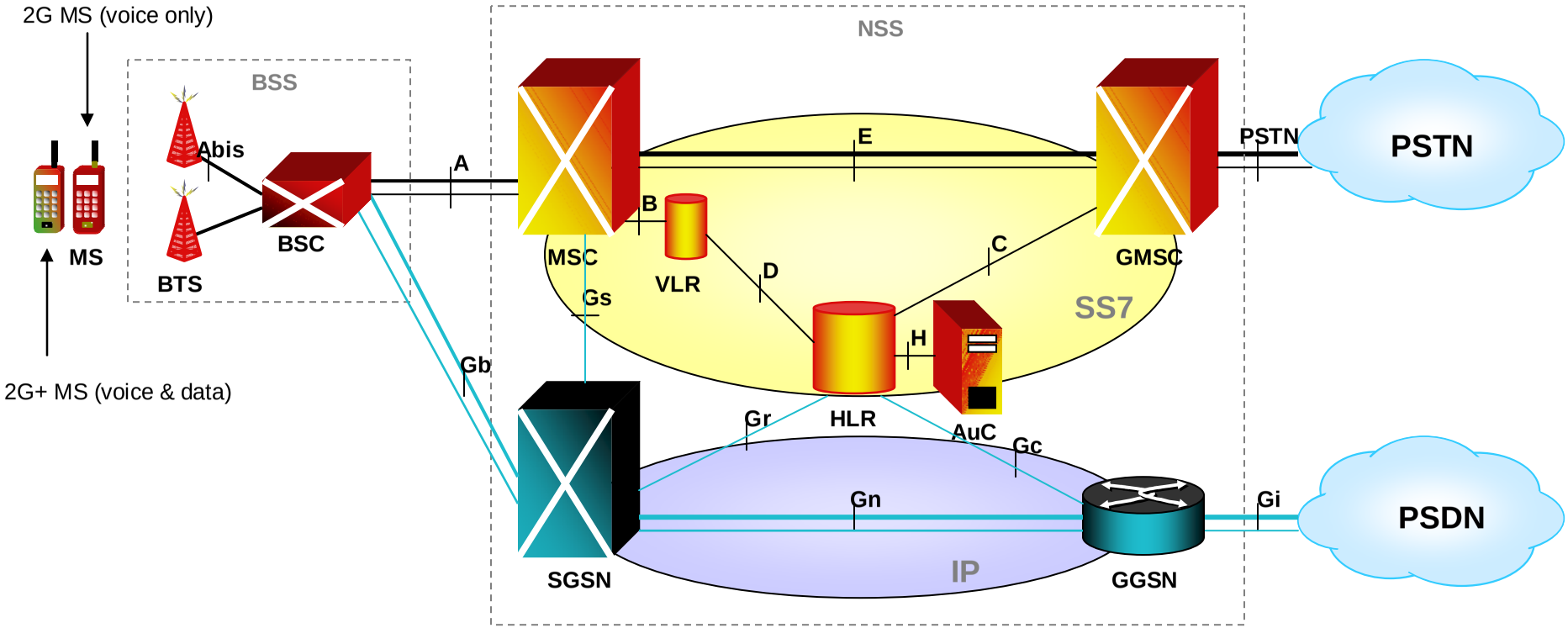
2.5G/3G Adds IP Data – voice unchanged



usbancorp Piper Jaffray

NMS COMMUNICATIONS

2.5G Architectural Detail



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AuC Authentication Server

GMSC Gateway MSC

SGSN Serving GPRS Support Node

GGSN Gateway GPRS Support Node

GPRS General Packet Radio Service

NMS COMMUNICATIONS

EDGE

- Enhanced Data rates for Global Evolution
- Increased data rates with GSM compatibility
  - still 200 KHz bands; still TDMA
  - 8-PSK modulation: 3 bits/symbol give 3X data rate
  - shorter range (more sensitive to noise/interference)
- Migration path: IS-136 TDMA to GSM/EDGE
  - GAIT - GSM/ANSI-136 interoperability team
  - Allowed operators like AT&T and Cingular to migrate to GSM/EDGE using an evolved ANSI-41 core network

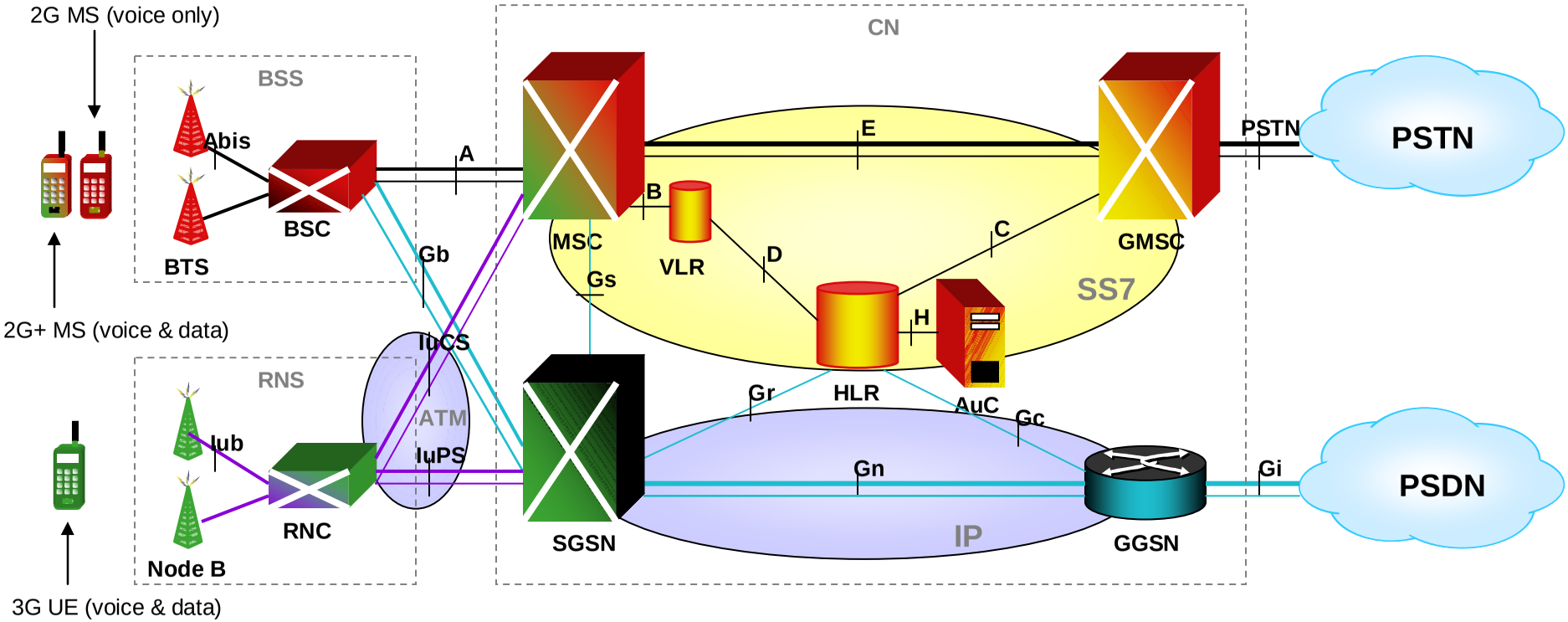
3G Partnership Project (3GPP)

Defines migration from GSM to UMTS/ 3GSM

Release	Specs complete	First deployed	Major new features defined
98	1998		Last purely 2G GSM release
99	1Q 2000	2003	W-CDMA air interface
4	2Q 2001	2004	Softswitching IP in core network
5	1Q 2002	2006	HSDPA & IP Multimedia System (IMS)
6	4Q 2004	2007	HSUPA, MBMS, GAN, PoC & WLAN integration
7	4Q 2007	future	HSPA+, Better latency & QoS for VoIP
8	? 2009 ?	future	LTE, All-IP

W-CDMA – Wideband CDMA modulation
HSxPA – High Speed (Download/Upload) Packet Access
MBMS – Multimedia Broadcast Multicast Service
GAN – Generic Access Network
PoC – Push-to-talk over Cellular
LTE – Long Term Evolution, a new air interface based on OFDN modulation

3G rel99 Architecture (UMTS) - 3G Radios



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RNS Radio Network System

RNC Radio Network Controller

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HLR Home Location Register

AuC Authentication Server

GMSC Gateway MSC

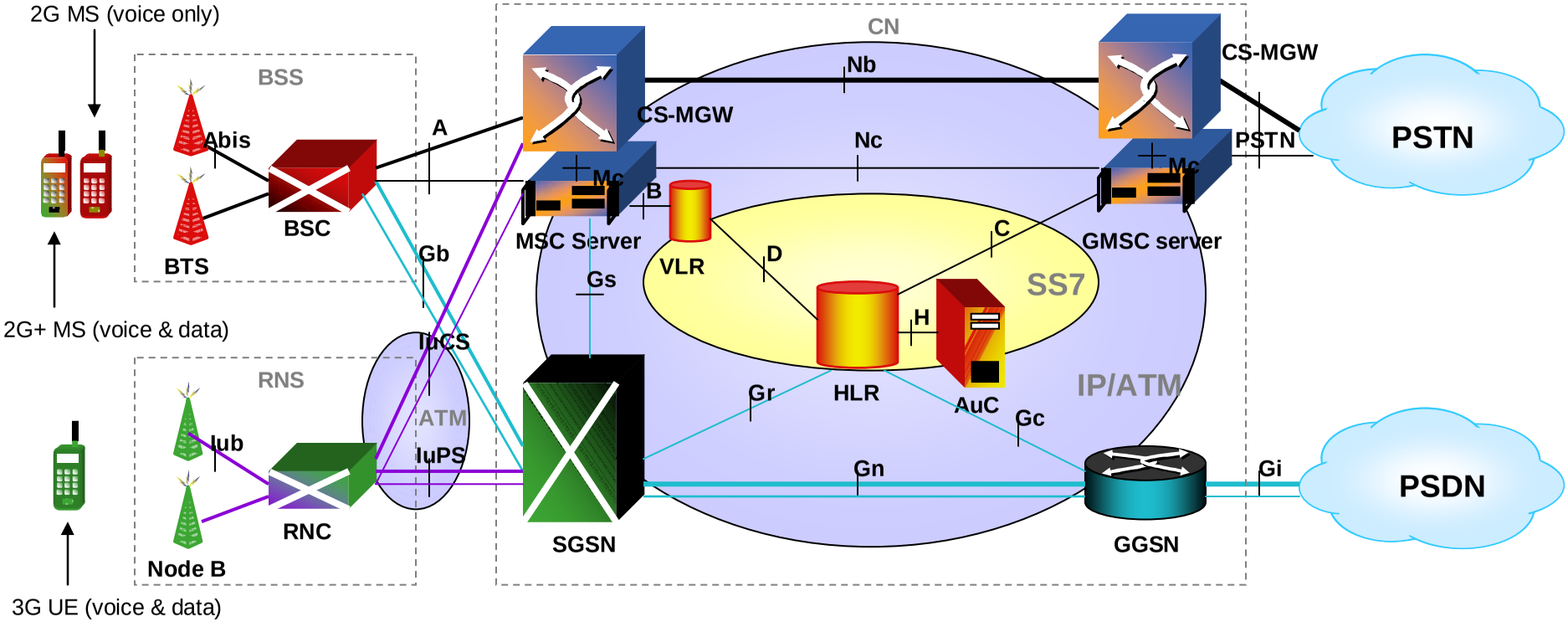
SGSN Serving GPRS Support Node

GGSN Gateway GPRS Support Node

UMTS Universal Mobile Telecommunication System

NMS COMMUNICATIONS

3G rel4 Architecture (UMTS) - Soft Switching



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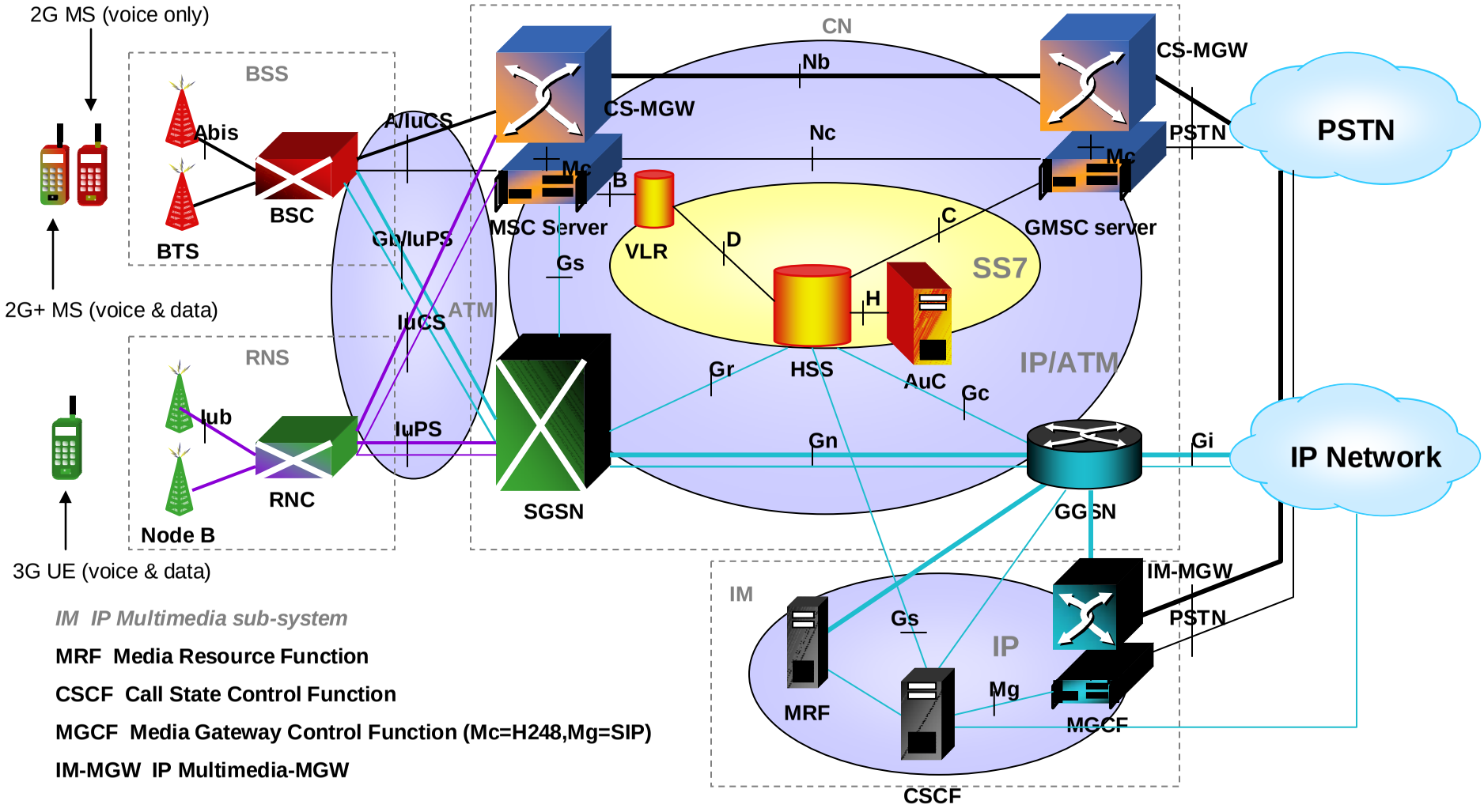
GGSN Gateway GPRS Support Node

NMS COMMUNICATIONS

3GPP rel5 Architecture - IP Multimedia



IM IP Multimedia sub-system

MRF Media Resource Function

CSCF Call State Control Function

MGCF Media Gateway Control Function (Mc=H248,Mg=SIP)

IM-MGW IP Multimedia-MGW

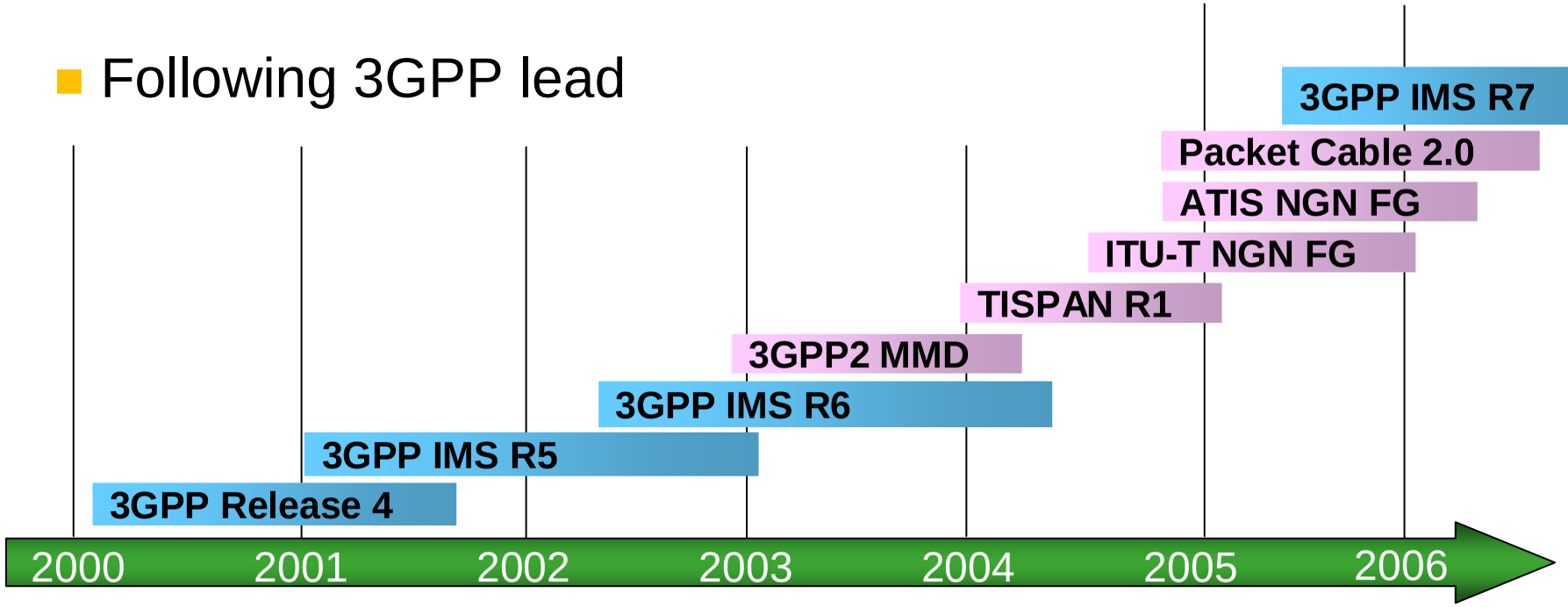
NMS COMMUNICATIONS

3GPP2 Defines IS-41 Evolution

- 3rd Generation Partnership Project “Two”
  - Evolution of IS-41 to “all IP” more direct (skips ATM stage), but not any faster
  - Goal of ultimate merger (3GPP + 3GPP2) remains
- 1xRTT – IP packet support (like GPRS)
- 1xEVDO – Evolution data-optimized
- 1xEVDV – *abandoned*
- 3x – Triples radio data rates
- Universal Mobile Broadband (UMB) is 3.5G/4G plan

NextGen Networks (NGN) Converging

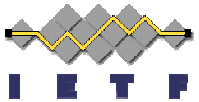
- Following 3GPP lead



- 3GPP2 — CDMA2000 multi-media domain (MMD) based on 3GPP IMS R5
- TISPAN — evolves NGN architecture for fixed networks based on 3GPP IMS
- ITU-T NGN Focus Group — venue to make TISPAN NGN a global spec
- ATIS NGN Focus Group — formally collaborating with ETSI as of April 2005
- PacketCable Release 2.0 — aligning with portions of 3GPP

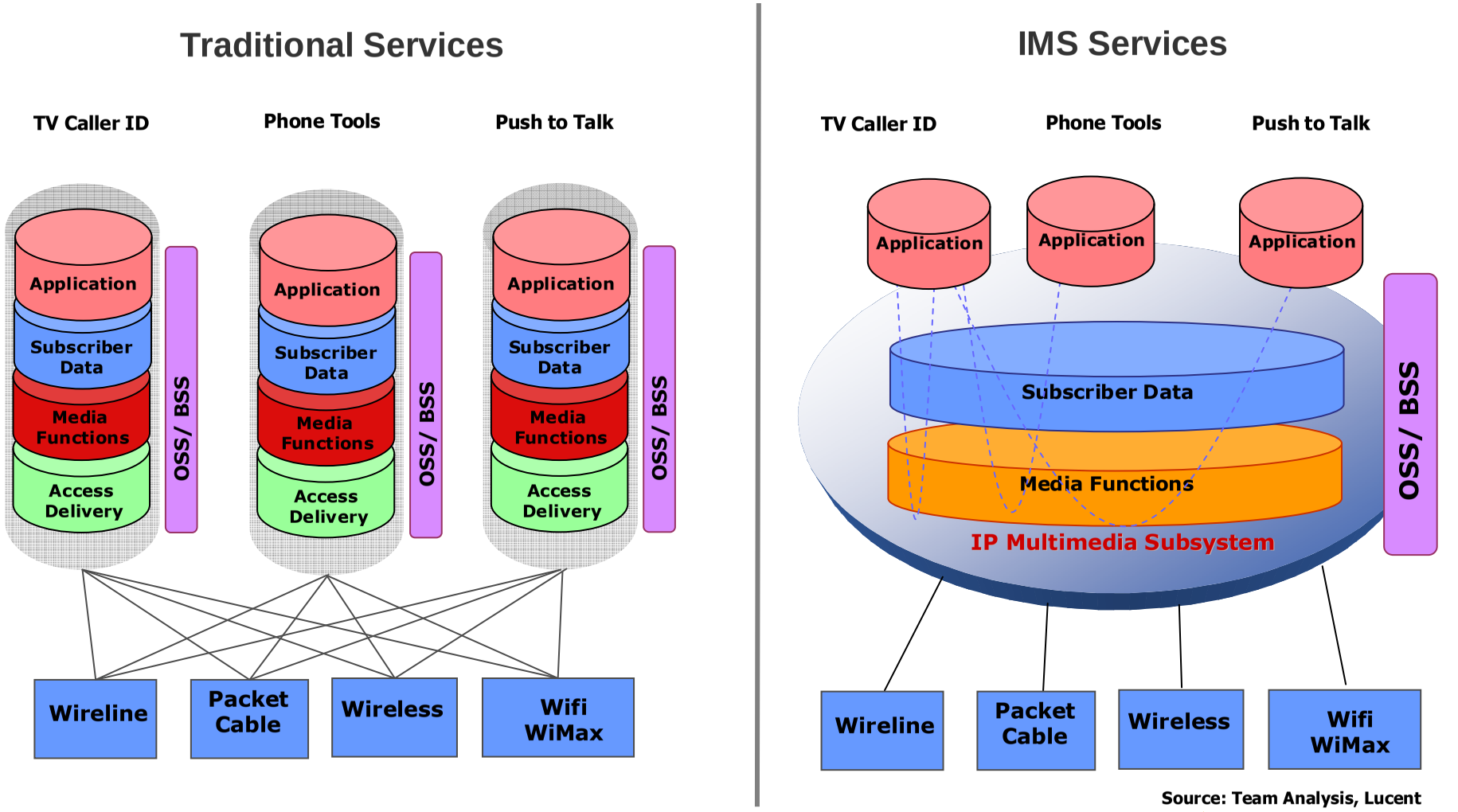
NMS COMMUNICATIONS

IMS / NGN Vision



- One core network for “any access”
  - Based on IP
  - Wireline and wireless transparency
  - Based on IETF standards, with extensions
- Access and bandwidth will be commodities; services are the differentiator
  - Per-session control supports per-application quality of service (QoS) guarantees and *per-application billing*
- Voice is just application
  - “Easily” integrated with other applications…

IMS Story: Convergence



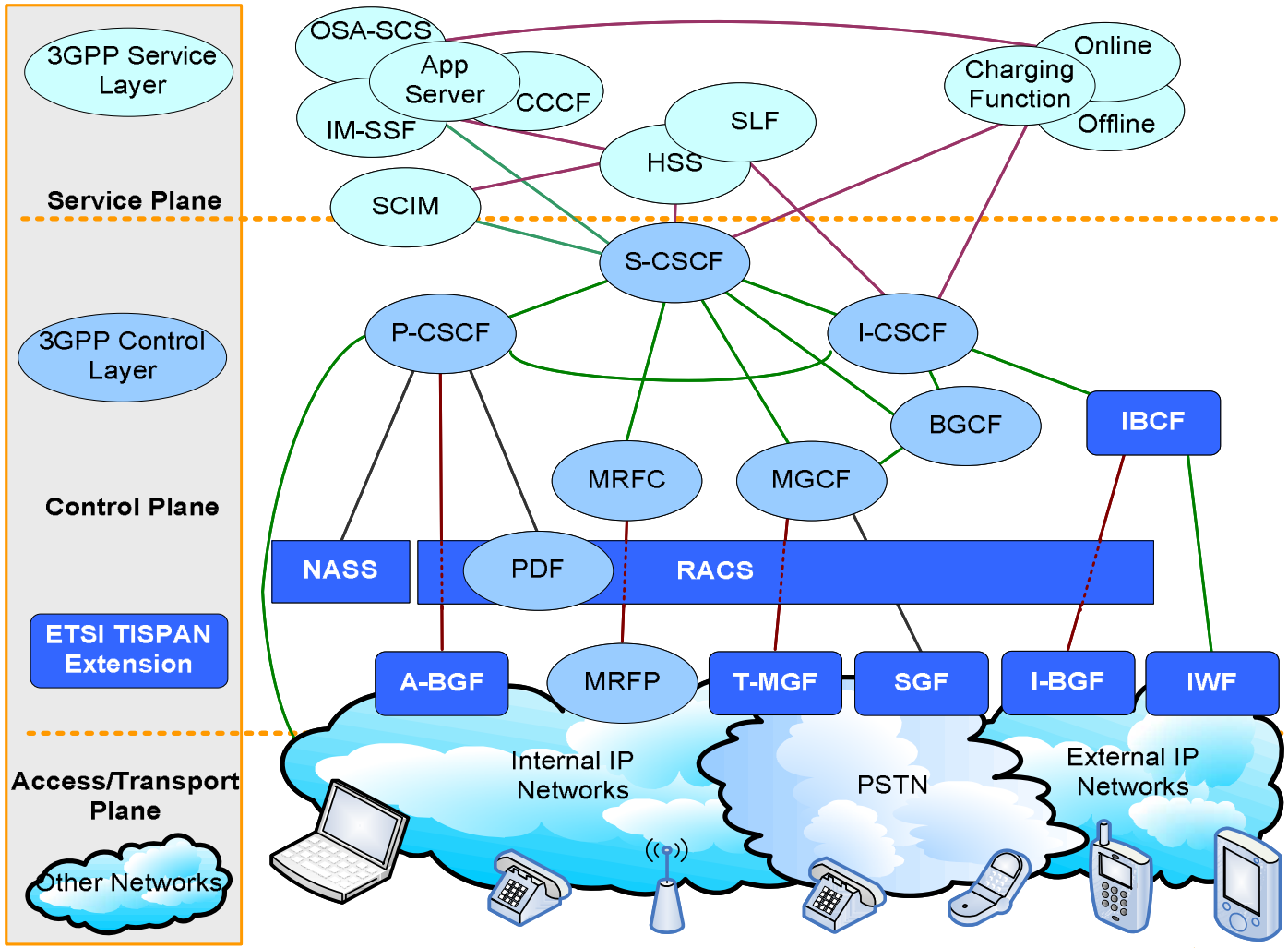
Source: Team Analysis, Lucent

NMS COMMUNICATIONS

IMS / NGN Value Proposition

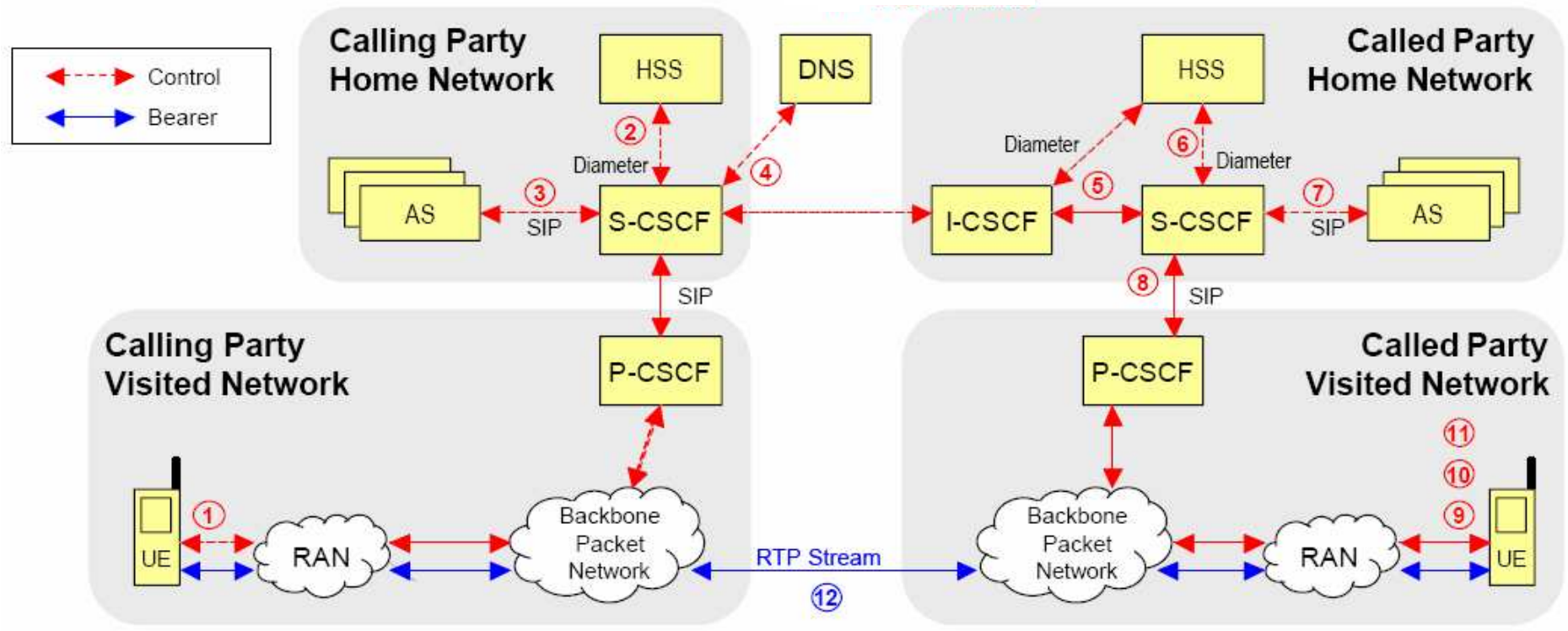
- Generate new revenue from new services
  - Per-session control allows IMS to guarantee QoS for each IP session, and enables ***differential billing*** for applications & content
- Reduce capital spending
  - Converge all services on common infrastructure
  - Focus limited resources on core competencies

3GPP R7/TISPAN IMS Architecture



NMS COMMUNICATIONS

IMS Session (i.e. Call) Control



So far, only for New Applications !

- Most major mobile operators have deployed a SIP infrastructure of some sort
  - CSCFs per strict IMS or otherwise
  - In use for new applications like Push to Talk (PTT)
- Fixed operators moving to softswitches for conventional voice, but
- Mobile voice calls still use circuit switching

Long Term Parallels: IN & IMS

Intelligent Network — IP Multimedia System

- Free operators from equipment provider lock-in
- Separate applications from basic call control
- Open protocols and APIs for applications

Intelligent Network Application Successes

- FreePhone, Mobile (HLR), Pre-paid, Voice mail, …
- 10 year summary:

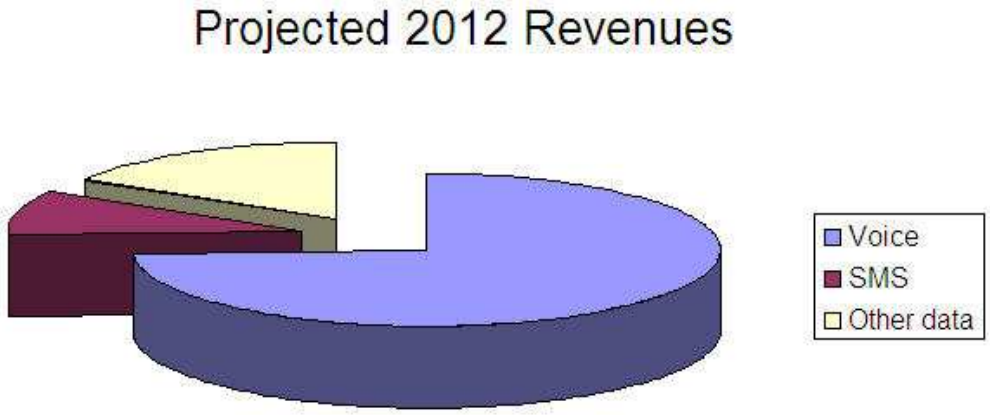
  A few applications, very widely deployed

Wireless Tutorial

- History and Evolution of Mobile Radio
- Evolving Network Architectures
- **Evolving Services**
- Applications and Business Models
- Related technology, Issues and Futures

Mobile Service Revenues

- > $800 billion in 2007, growing 6%-7% per year
  - > $1 trillion by 2012
- Voice services dominate: 81%
- SMS services: 9.5% ; All other non-voice services: 9.5%



Source: Portio Research

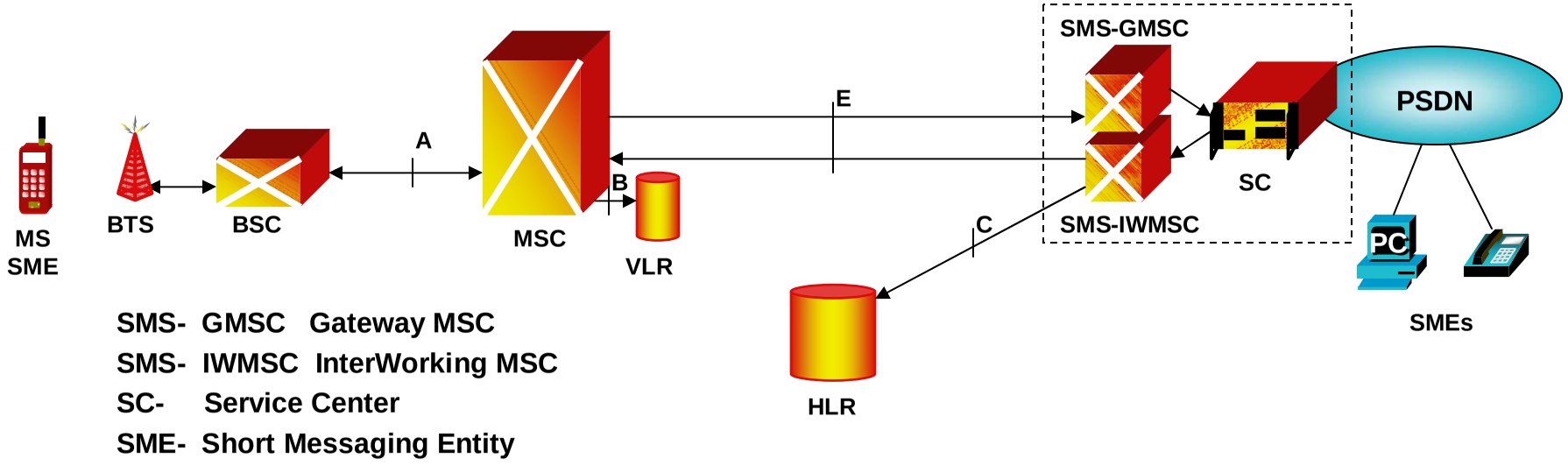
Images courtesy of Jon Stern

Non-Voice Mobile Services

- SMS; Multimedia Message Service (MMS)
- 3G-324M Video telephony
- Location-based services
- Push-to-Talk (VoIP w/o QoS)
- Rich presence (instant messaging)
- Fixed-mobile convergence (FMC)
- IP Multimedia Services (w/ QoS)
  - Video sharing (conversational video over IP)
- Converged “All IP” networks – the Vision

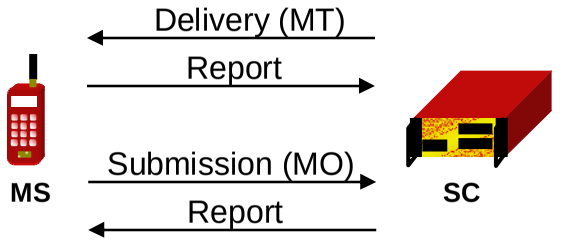
Short Message Service (SMS)

- Point-to-point, short, text message service
- 160 byte messages over signaling channel (MAP or IS-41)
- SMSC stores-and-forwards SMSs; delivery reports
- SME is any data terminal or Mobile Station



SMS Transport

- Delivery / Submission report
  - Optional in 3GPP2



- Messages-Waiting
  - SMS Service Center informs HLR/VLR that a message could not be delivered to MS
- Alert-SC
  - HLR informs SC that the MS is again ready to receive
- All messages over signaling channels
  - usually SS7; SMSC may also have IP option, i.e., a connection to the Internet or a private IP network

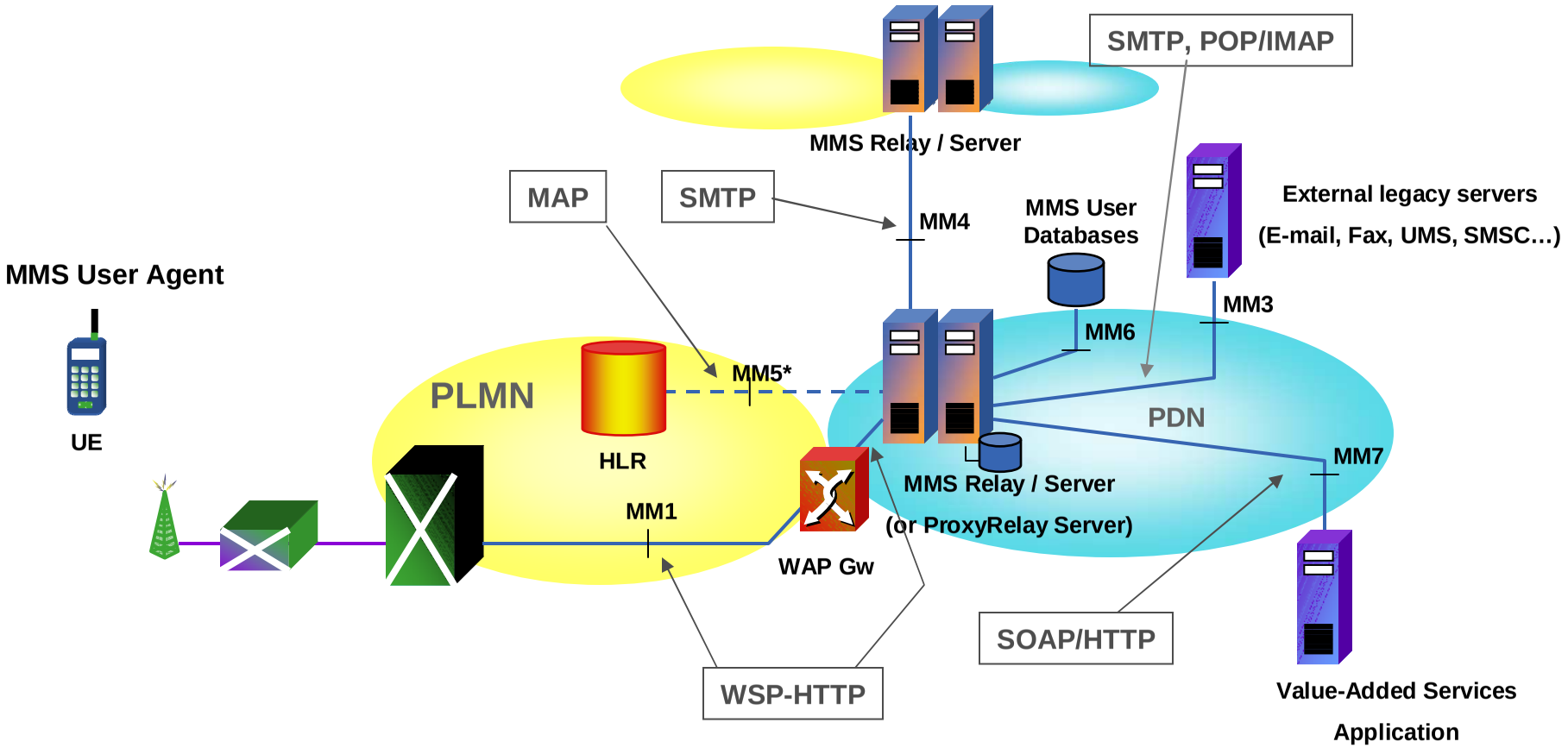
Multimedia Message Service Principles

- Non-real-time, multi-media message service
  - Text; Speech (AMR coding)
  - Audio (MP3, synthetic MIDI)
  - Image, graphics (JPEG, GIF, PNG)
  - Video (MPEG4, H.263)
  - Will evolve with multimedia technologies
- Uses IP data path & IP protocols (not SS7)
  - WAP, HTTP, SMTP, etc.
- Adapts to terminal capabilities
  - media format conversions (JPEG to GIF)
  - media type conversions (fax to image)
  - SMS (2G) terminal inter-working

MMS Principles (continued)

- MMs can be forwarded (w/o downloading), and may have a validity period
- One or multiple addressees
  - Addressing by phone number (E.164) or email address (RFC 822)
- Extended reporting
  - submission, storage, delivery, reading, deletion
- Supports an MM Box, i.e. a mail box
- Optional support of media streaming (RTP/RTSP)

MMS Architecture

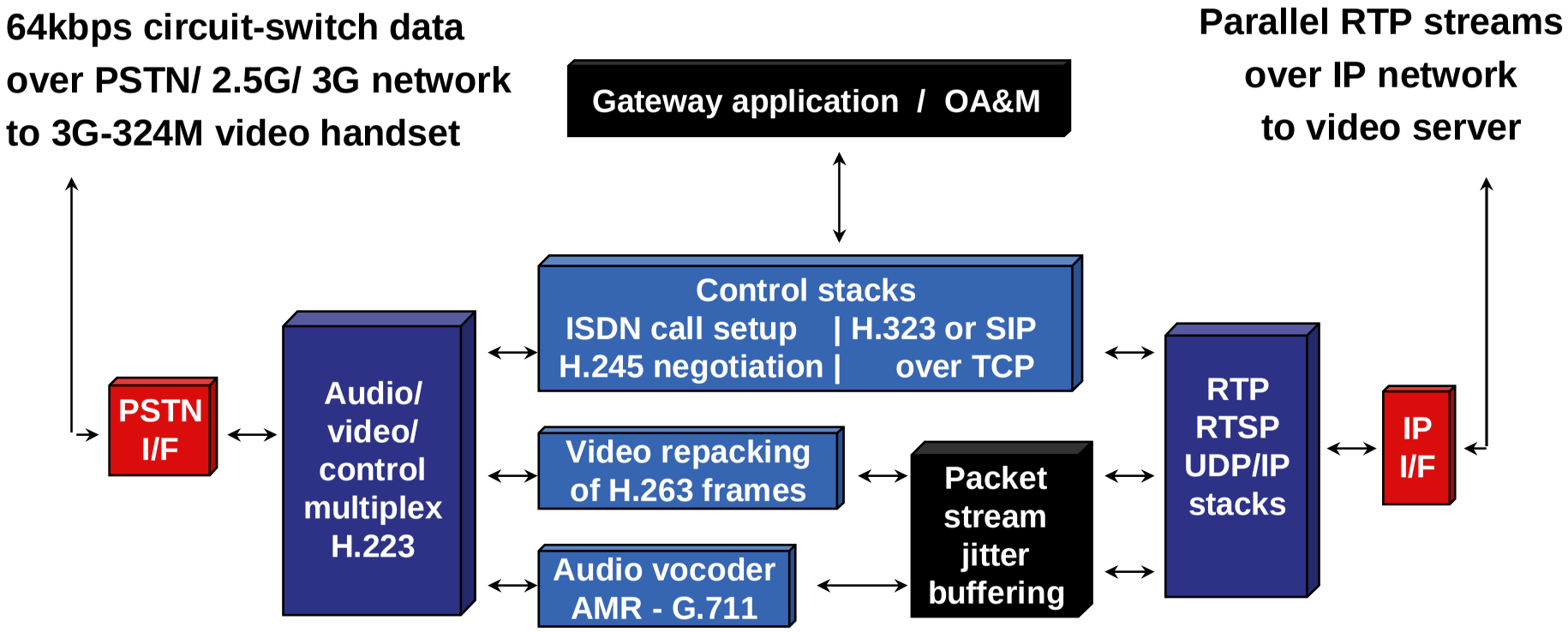


(*) Optional

3G-324M Video Services

- Uses 3G data bandwidth w/o IMS or IP
- Leverages high speed circuit-switch data path
  - 64 Kbps H.324 video structure
  - H.263 or MPEG-4 video coding; AMR audio coding
- Live video conversations, but also video clips, video streaming and Interactive Voice & Video Response
  - MS to MS; MS to Internet or ISDN via gateways;
    MS to/from Servers
- Designed for video telephony, but mostly used for Interactive Voice & Video Response (IVVR)

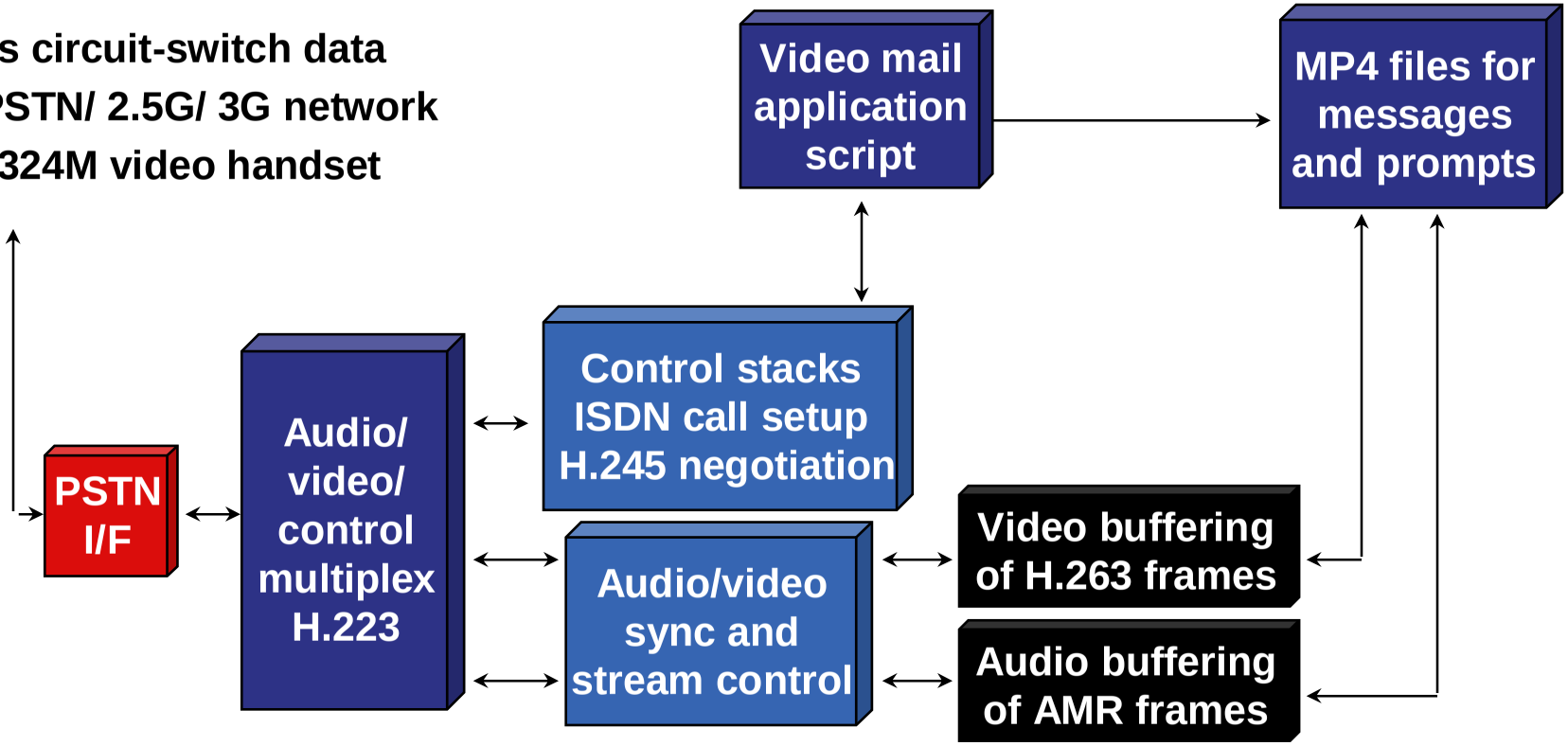
Gateway: 3G-324M to MPEG4 over RTP



NMS COMMUNICATIONS

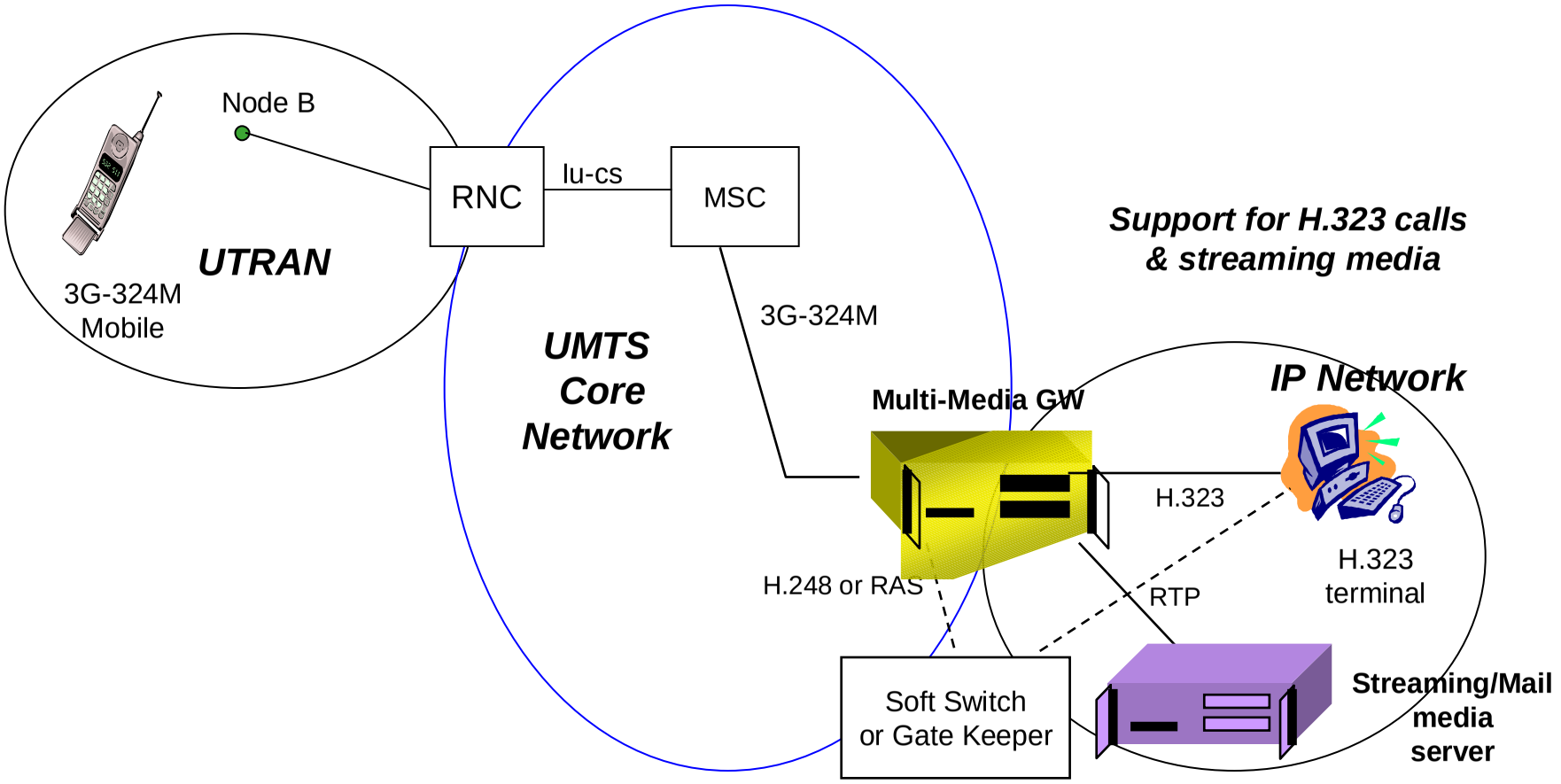
Video messaging system for 3G-324M

64kbps circuit-switch data
over PSTN/ 2.5G/ 3G network
to 3G-324M video handset



NMS COMMUNICATIONS

Typical Platform for 3G-324M Services



NMS COMMUNICATIONS

Location

- Originally driven by e911 requirements in US
  - Several years late but finally delivered ~2004-2005
- Potential revenue from location-based services
- Several technical approaches
  - In-network technologies (measurements at cell sites)
  - Handset technologies
  - Network-assisted handset approaches
- Plus additional core network infrastructure
  - location computation and mobile location servers
- Operators perceive significant privacy issues

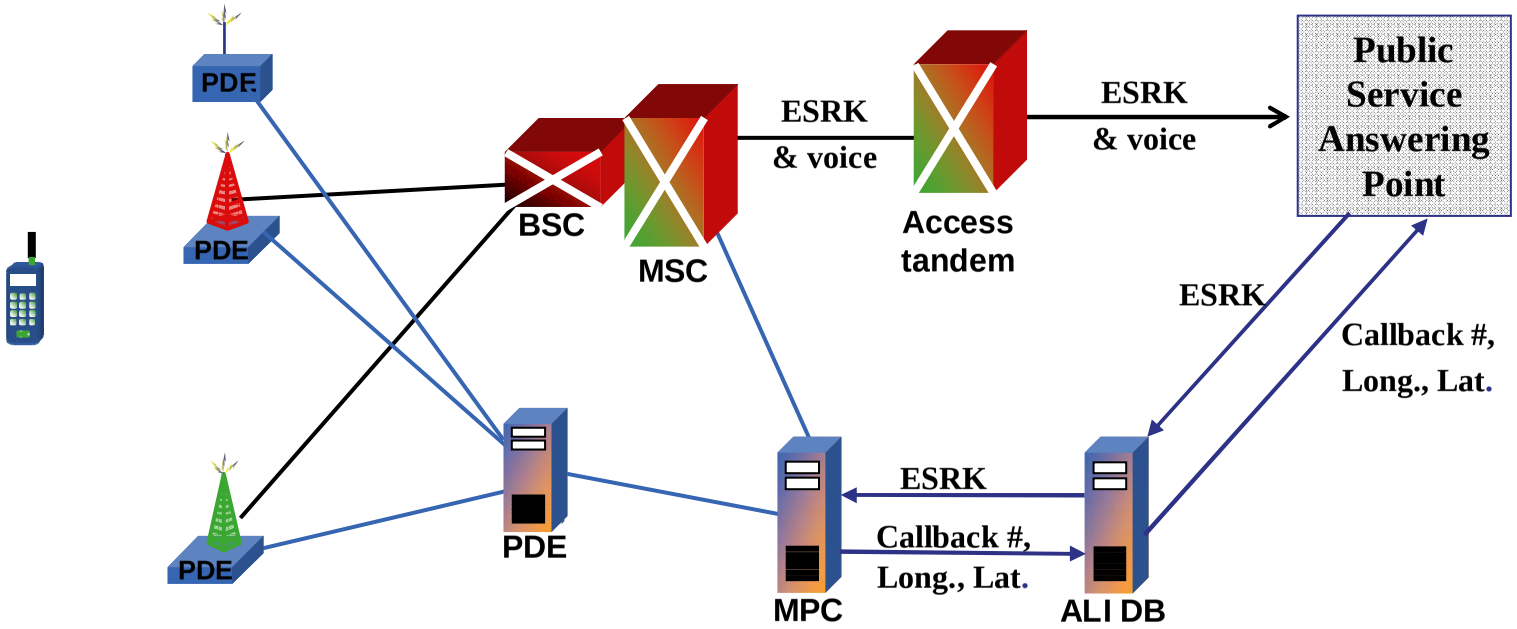
Location Technology

- Cell identity: crude but available w/o operator involvement
- Based on timing
  - TA: Timing Advance (distance from GSM BTS)
- Based on timing and triangulation
  - TOA: Time of Arrival
  - TDOA: Time Difference of Arrival
  - EOTD: Enhanced Observed Time Difference
  - AOA: Angle of Arrival
- Based on satellite navigation systems
  - GPS: Global Positioning System
  - A-GPS: Assisted GPS

Location-Based Services

- Emergency services: E911 - Enhanced 911
- Lawful intercept, i.e., locate suspect
- Network internal
  - Traffic & coverage measurements
- Still largely theoretical (at least via operators)
  - Value-added personal services: friend finder; directions
  - Commercial services: coupons from nearby stores
- Independent of operators (using cell ID, …)
  - Mapping, directions (Google) and open APIs foster many new services and service experiments

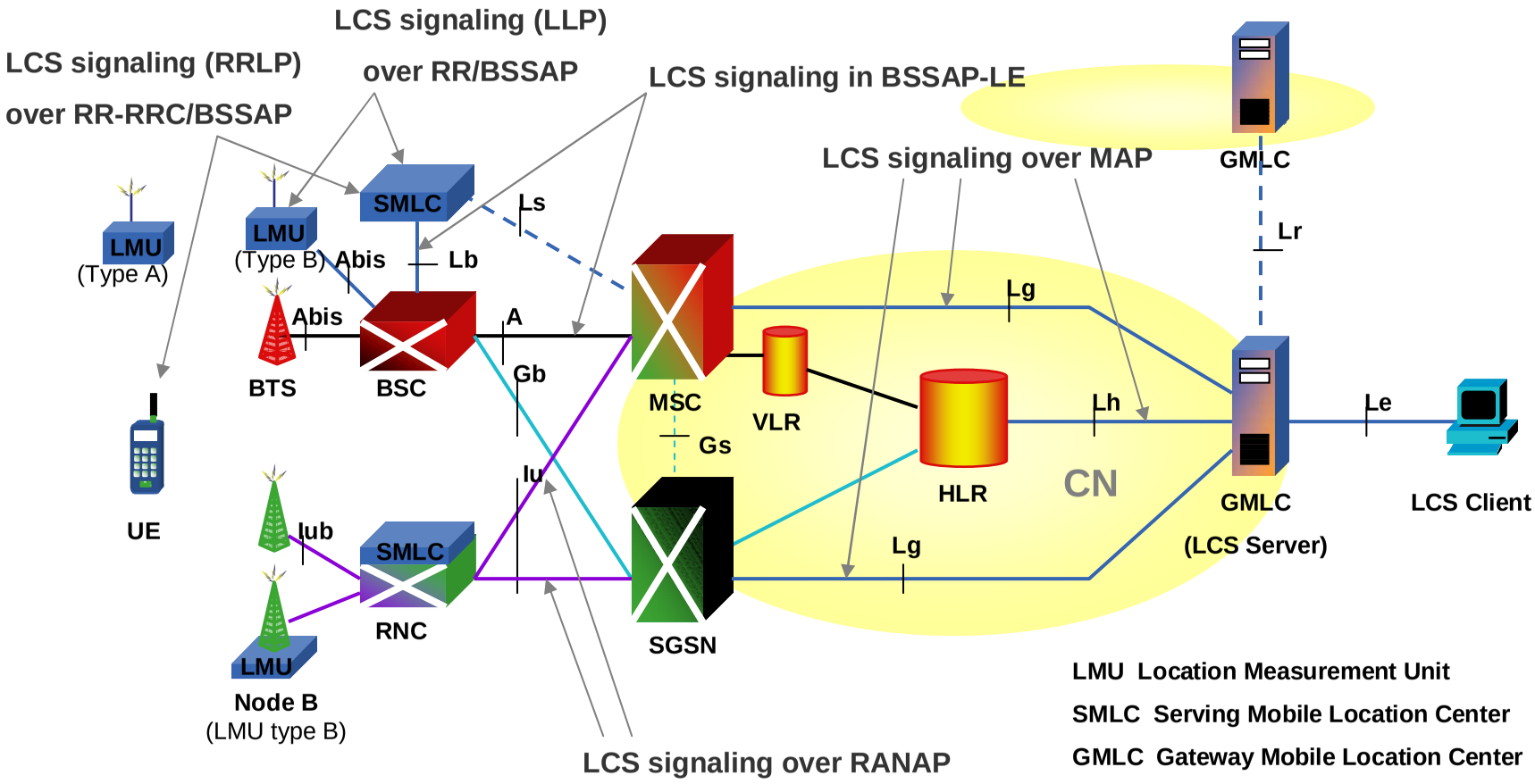
US E911 Phase II Architecture



PDE - Position Determining Entity
MPC - Mobile Positioning Center
ESRK - Emergency Service Routing Key
ALI DB - Automatic Location Identification Data Base

NMS COMMUNICATIONS

3GPP LoCation Service (LCS) Architecture



NMS COMMUNICATIONS

Making Location Requests

- MLP – Mobile Location Protocol
  - from Location Interop Forum
  - based on HTTP/SSL/XML
  - allows Internet clients to request location services
- GMLC is the Location Server
- Interrogates HLR to find visited MSC/SGSN
  - Roaming user can be located
  - UE can be idle, but not off !
- Immediate or deferred result

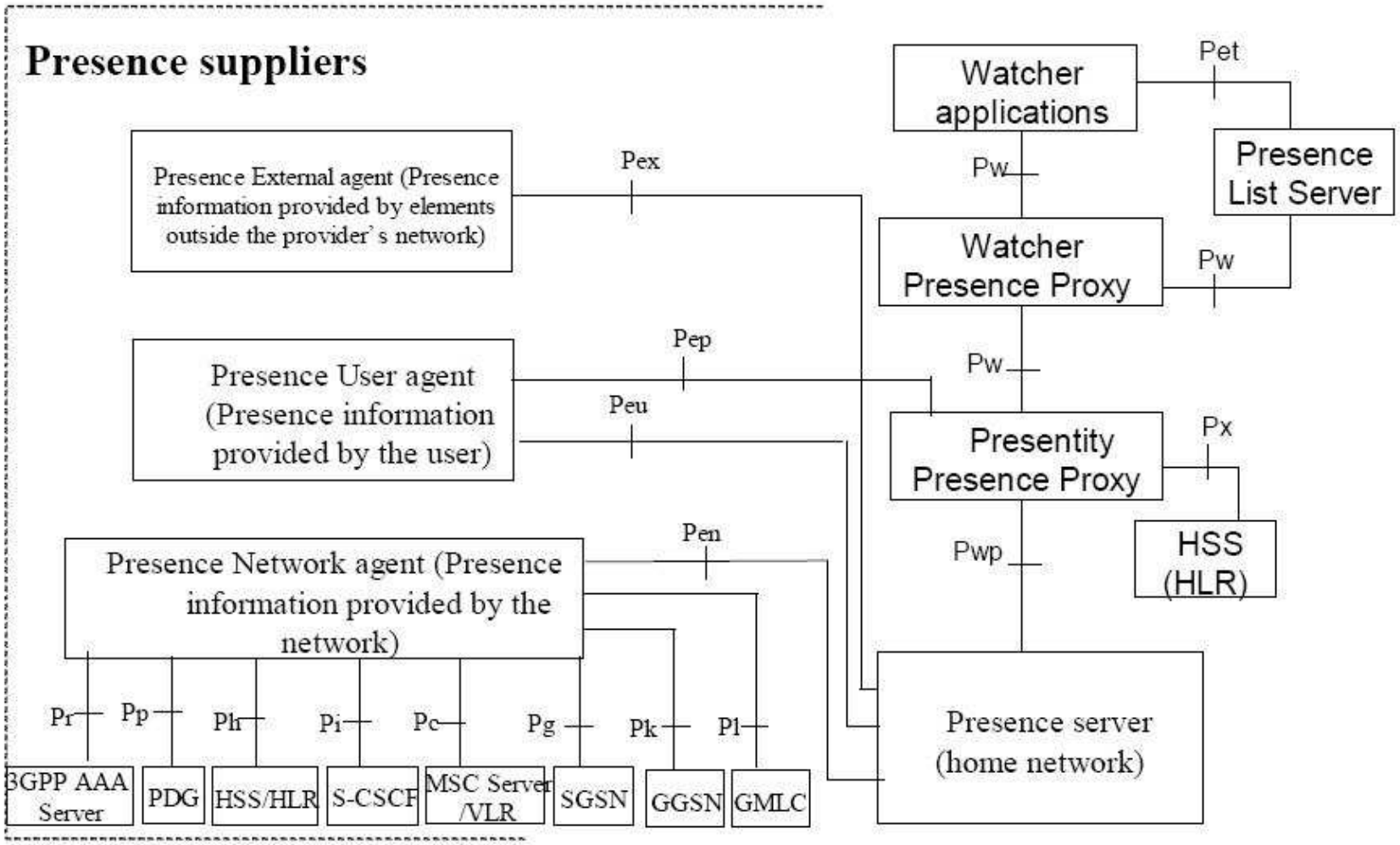
Push-to-Talk: VoIP w/o need for QoS

- Nextel's "Direct Connect" got 20-25% extra ARPU
  - Based on proprietary iDEN; Others extremely jealous
- Push-to-talk is half duplex so short delays OK
- Issues remain
  - Always on IP, isn't always on; radio connection suspended if unused; 2-3 seconds to re-establish
- Cingular (now AT&T) launched PoC service 2005
  - Initial latencies not competitive; HSPA much better
  - Multiple others have launched
  - Sprint-Nextel planning to convert to PoC beginning 2008

Instant Messaging & Rich Presence

- IMS to support rich presence in support of IM
- Pre-IMS, GSMA's "Personal IM" initiative
  - Announced Feb 2006
  - GSMA claims 38 operators now live (8/2008)
  - Services country specific or operator specific, so far
- Operators still cutting deals with popular Internet-based IM services
  - QQ (China); Windows Live Messenger, AIM, Yahoo, …
- Popular IM services used directly on smartphones

3GPP Presence Service Architecture

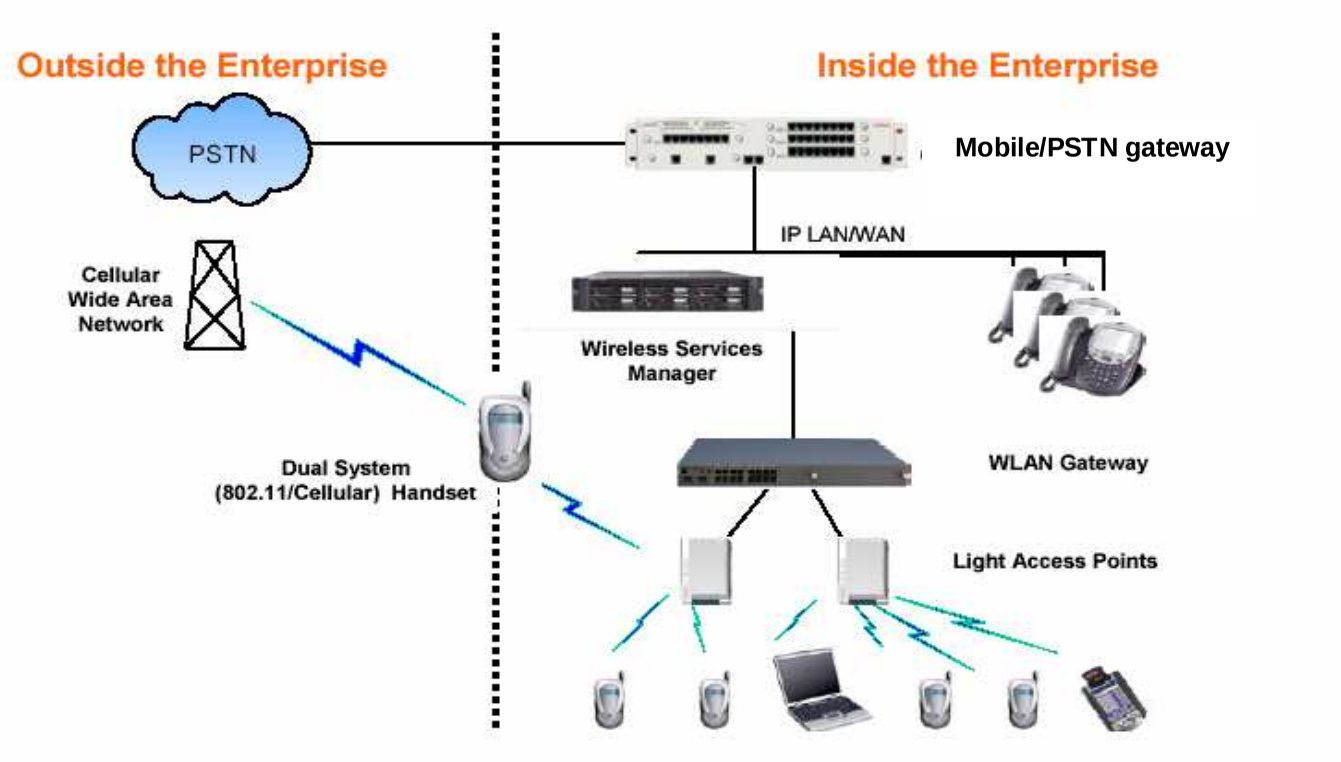


NMS COMMUNICATIONS

Fixed Mobile Convergence (FMC)

- IP-PBX, mobile gateway & dual mode handset client
  - IP-PBX is in control
- Unlicensed Mobile Access (UMA)
  - GSM & GPRS services over WiFi or Bluetooth
  - Traditional MSC is in control
- Voice Call Continuity (VCC), pre-IMS approach
  - 3GPP spec on how to maintain calls that move between circuit and packet domains
- IP Multimedia Subsystem (IMS)
  - Future all-IP solution

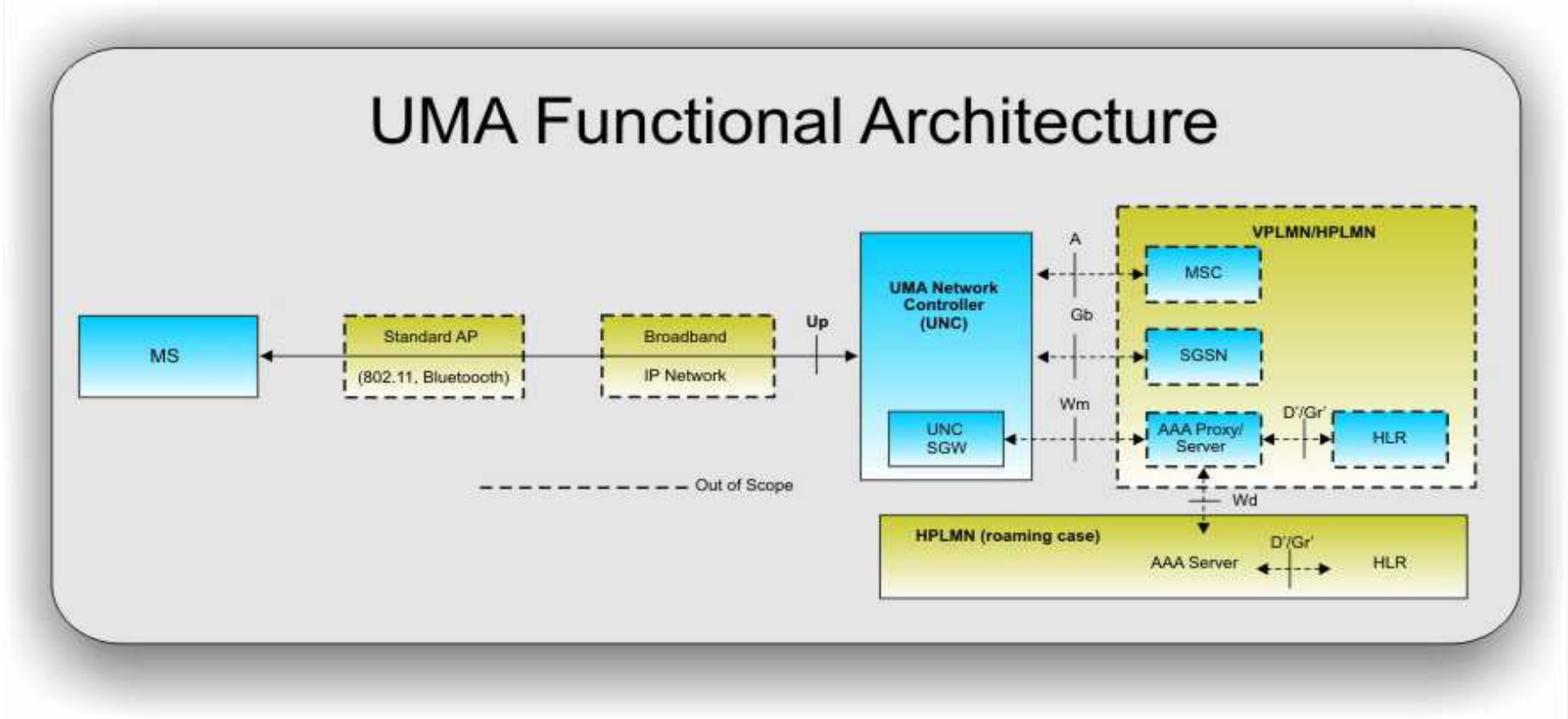
IP-PBX/Softswitch & Mobile Gateway



- IP-PBX is in charge
- Hands off to mobile when out of WiFi range

NMS COMMUNICATIONS

Unlicensed Mobile Access (UMA)



- Tunnels GSM & GPRS over IP to mobile core network

NMS COMMUNICATIONS

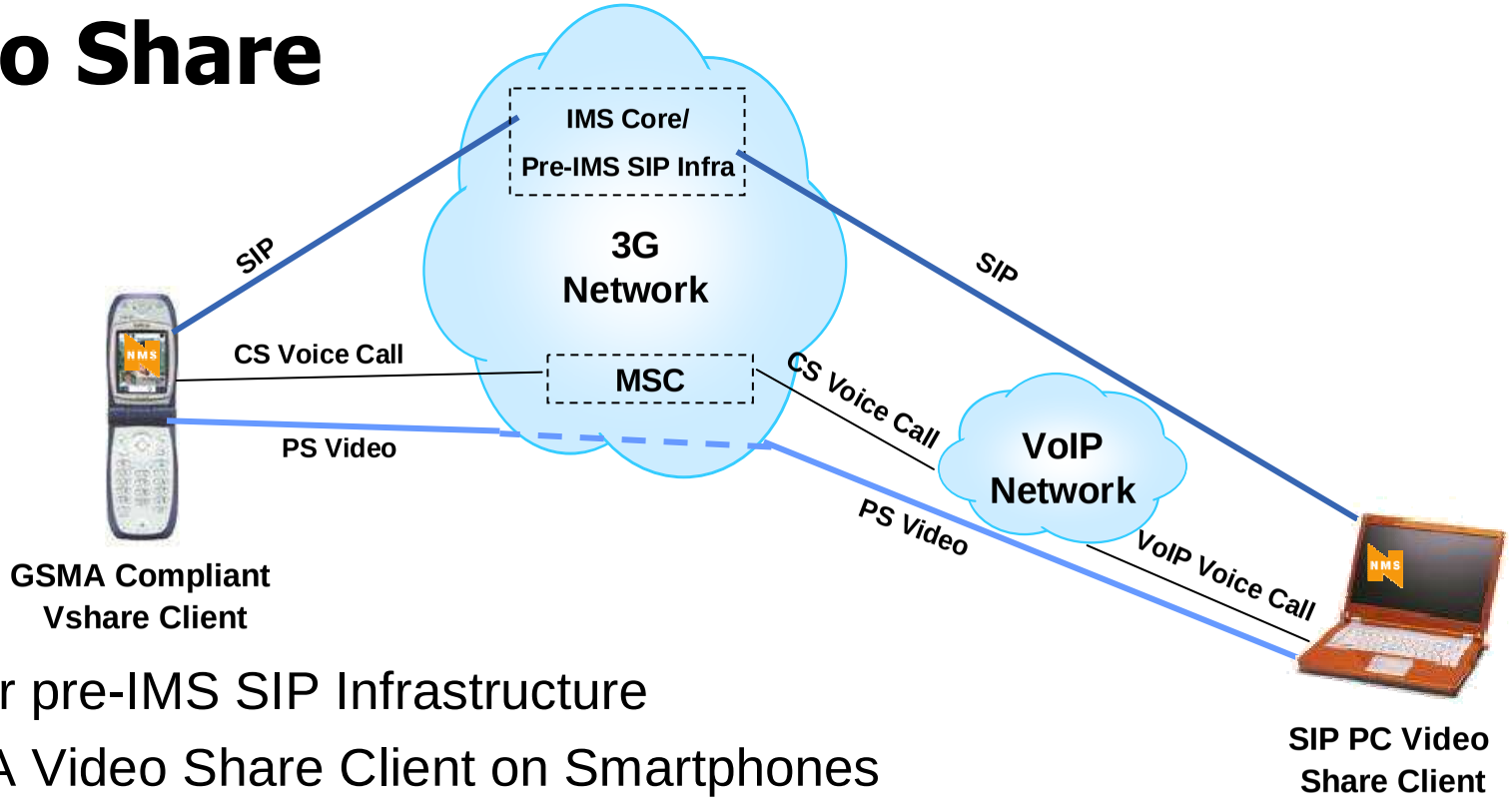
"All IP" Services based on IMS

- 3GPP vision of "All IP" NextGen network (NGN)
  - Voice/video over IP with QoS guarantees
  - Eventually to replace circuit-based voice services
- All sessions initiated via central servers allowing per-session QoS guarantee (& per-session billing)
- QoS traffic classes
  - conversational, streaming, interactive, background
- Many partial IMS implementations deployed
  - But circuit domain still carries conventional voice traffic

Early IMS (or at least SIP) Applications

- Push-to-Talk
  - Being deployed today, performance improving
- Video sharing
  - Add IP-based video session to circuit-based voice call
  - “See what I see” using 2-way voice & 1-way video
- Instant messaging and presence
  - But can mobile initiated communities compete with AIM, Yahoo, Skype, etc.?
- Fixed-mobile convergence (FMC)
  - VCC deployed; full IMS still in the future

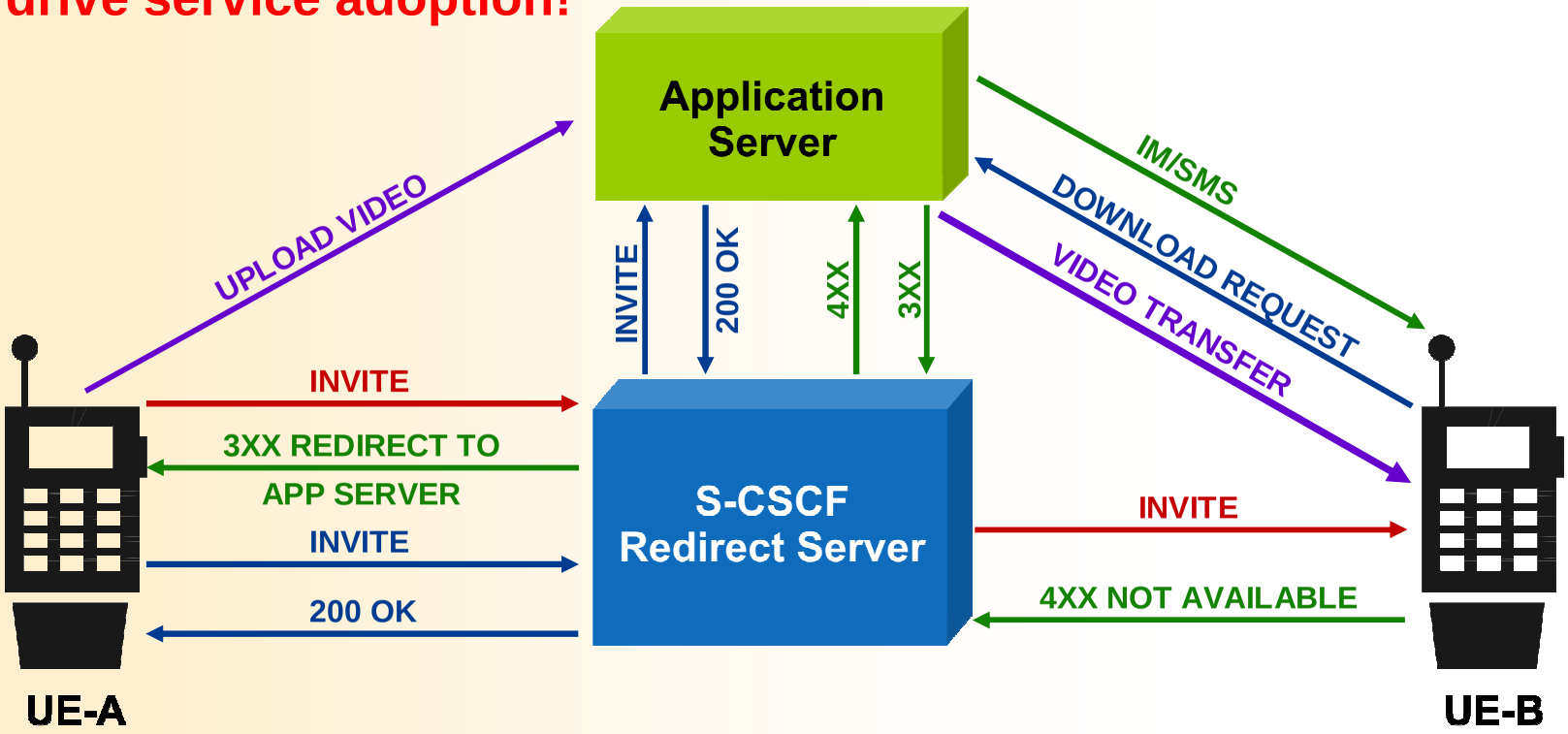
Video Share



- IMS or pre-IMS SIP Infrastructure
- GSMA Video Share Client on Smartphones
- SIP Video Share Client on PCs
- SIP PC Client addressable by reserved DN
- PC Client streams content from camera or stored content with option to change stream during a session

Redirect to complete P2P Video Share

and drive service adoption!



Upload to Server on Session Failure (Not Available/Capable)
Notification to UE-B inviting him to download video
Click to download and play → and sign up for service!

NMS COMMUNICATIONS

Wireless Tutorial

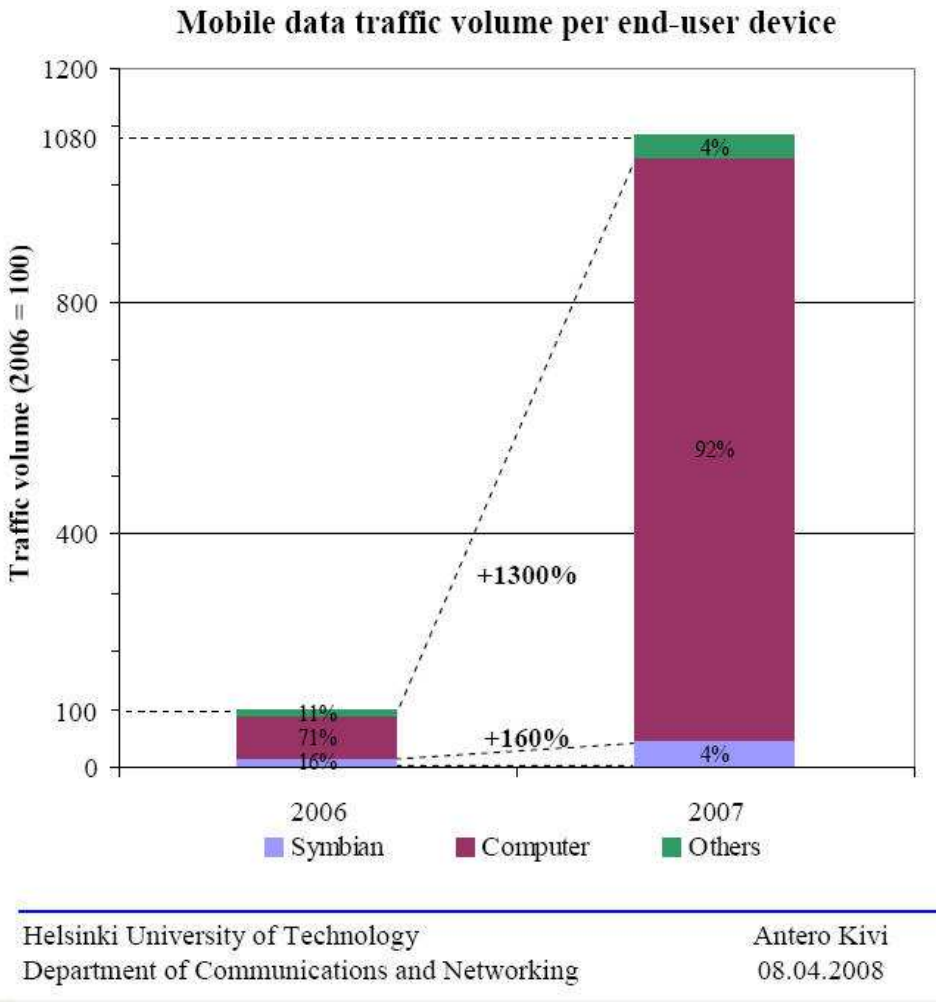
- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- **Applications and Business Models**
- Related technology, Issues and Futures

Killer Applications

- Community and Identity most important
  - Community: postal mail, telephony, email, instant messaging, SMS, chat, picture mail, “see-what-I-see” video sharing…
  - Identity: designer accessories, wallpaper, ring tones, ringback tones, …
- Content important but **content is not king!**
  - Voice revenues far exceed those from the sum of TV + movies + newspapers + magazines
  - Classic analysis by Andrew Odlyzko: http://www.dtc.umn.edu/~odlyzko/doc/recent.html

NMS COMMUNICATIONS

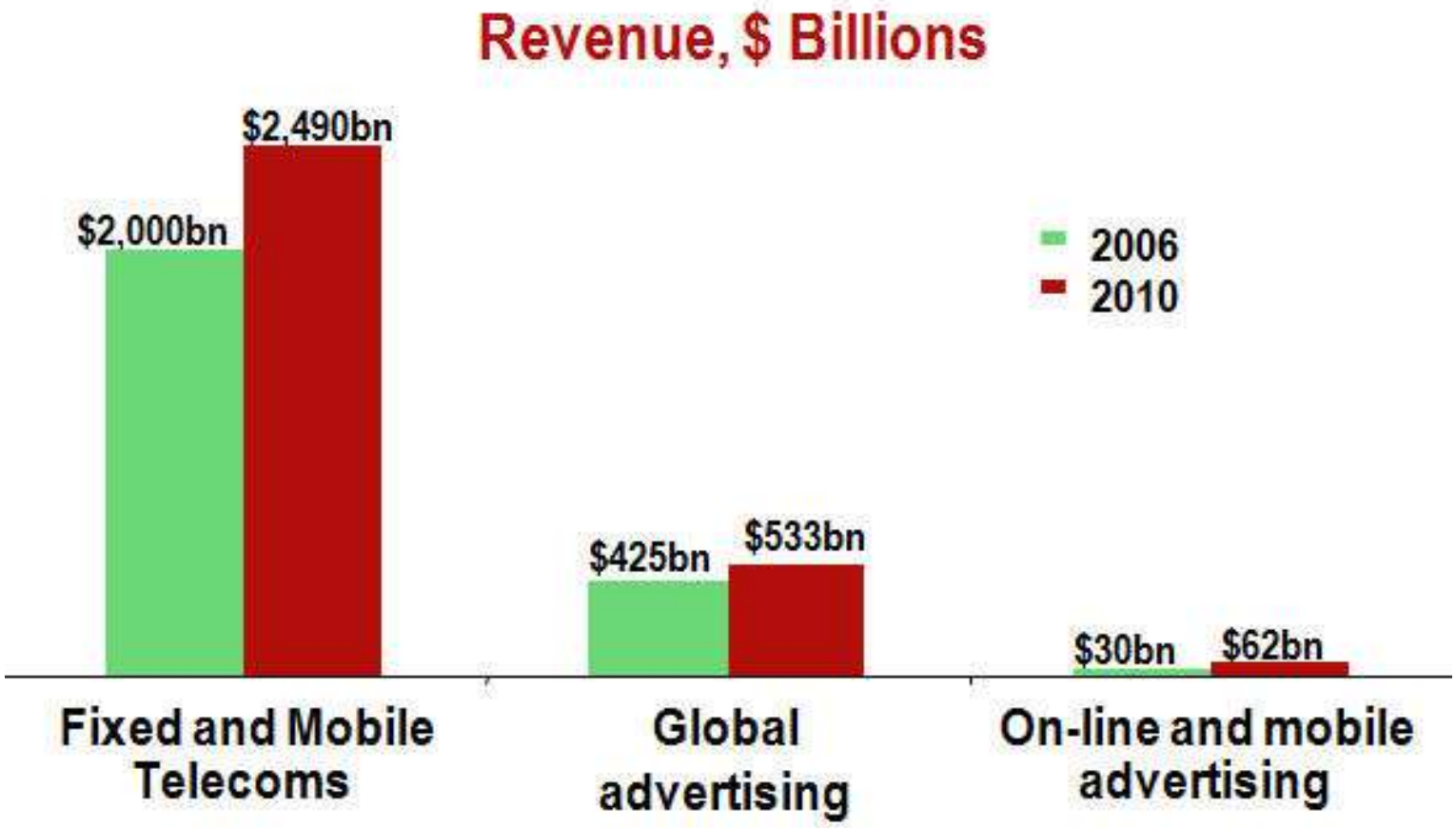
The Internet is the killer platform



- Mobile Internet access driving 3G data usage
- Future business models an open question
  - Walled garden ?
  - Advertising ?
  - Other 2-sided business models ?

NMS COMMUNICATIONS

Advertising won't cover lost voice $



Source: Telco 2.0 Manifesto, STL Partners Ltd.

NMS COMMUNICATIONS

"Open" success story – DoCoMo i-mode

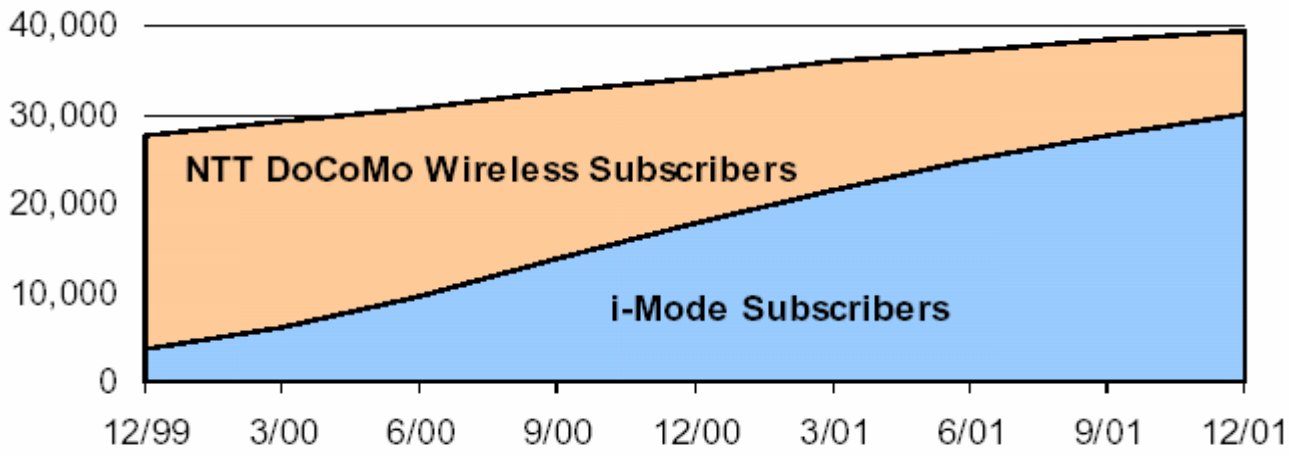
- Most operators capture value – avoid dumb pipe
  - Very cautious partnering; Slow roll out of services
- DoCoMo i-mode 2G data service launched 1999
  - Small screens, slow (9.6 kbps) data rate
- i-mode business model wide open
  - Free development software; No access restrictions
  - DoCoMo's "bill-on-behalf" based on 9% revenue share
- i-mode big success in first 24 months
  - 55,000 applications, 30M subscribers !

DoCoMo I-Mode: 2-sided business model

Exhibit 3.13

ADOPTION OF I-MODE DATA SERVICES IN JAPAN

(Subscribers In Thousands)



Source: U.S. Bancorp Piper Jaffray and company reports

- Subscribers pay for data access (flat rate monthly bundles)
- Application providers pay DoCoMo for billing services

Wireless Tutorial

- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- Applications and Business Models
- **Related technology, Issues and Futures**

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WiMAX

- Two year lead (or more) on 3GSM's LTE
  - Comparable or faster speeds at any point in time
- Can't match volumes of GSM/ 3GSM/ LTE
  - 100M's of GSM chips vs. 10M's WiMAX chips (at best)

1. May be as successful as CDMA 2000
2. Could merge with LTE
   - Radio technology very similar
   - Both assuming 3GPP IMS core network

Backhaul

- Major 3G-4G data services expense is “backhaul” e.g. connecting cell sites to the core network
  - Fixed facilities owned by local monopoly
  - Restricted &/or expensive to access rights-of-way
  - Point-to-point wireless links expensive
  - Wireless operators deployinging fiber and/or P-to-P radios on cellsite-by-cellsite basis
- Femtocells
  - Get subscribers to use their DSL, cable or fiber links for cellular backhaul

Bluetooth

- Short range, low cost and low power!
  - Personal area networks (PANs)
  - 1-2 Mbps peak data rates (today)
- Built-in discovery protocols and device-specific communications protocols; not IP
- Large installed base; roadmap to ultra-wideband
  - 480 Mbps eventually
- Unlikely to extend beyond PANs
  - But also unlikely to be displaced for PANs

WiFi as threat to 3G-4G

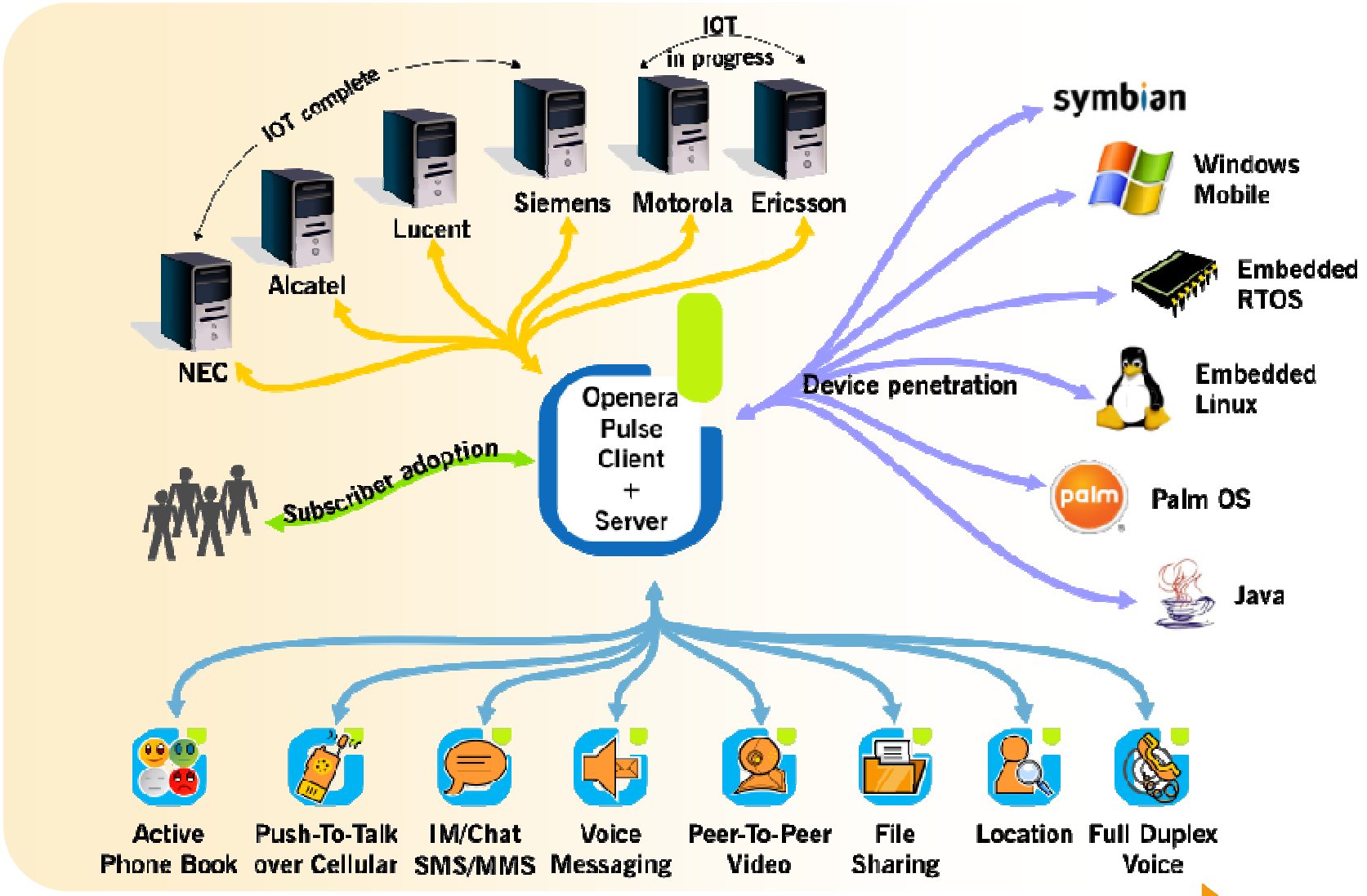
- Faster than 3G – 4G
- IEEE 802.11 spec evolving rapidly
  - “n” for MIMO (higher speeds); “r” for faster (VoIP) handoffs; “y” for beacon operation (in 3650-3700 MHz band initially – other bands later)
- Data experience can match that of the Internet
  - with nomadic convenience (and true mobility coming)
  - same user interface (doesn’t rely on small screens); same programs, files, applications, websites
- Low cost, low barriers to entry
  - Individuals and organizations build own networks

Mobile device diversity - indefinitely

- Application development environments…

Source: Andrea Constantinou, VisionMobile

Significant inter-operability issues



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Telecom Opportunity

- Internet plus mobile phones driving global economic, social, and political benefits
- Underlying technologies improving exponentially
- 6.7 B people; 3.6B mobiles; 1.6B Internet users
- 3G/4G to deliver phone & Internet to everyone

Enormous opportunity ahead!

Have fun, help mankind, make money !

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http://blogs.nmss.com/communications

http://www.nmscommunications.com

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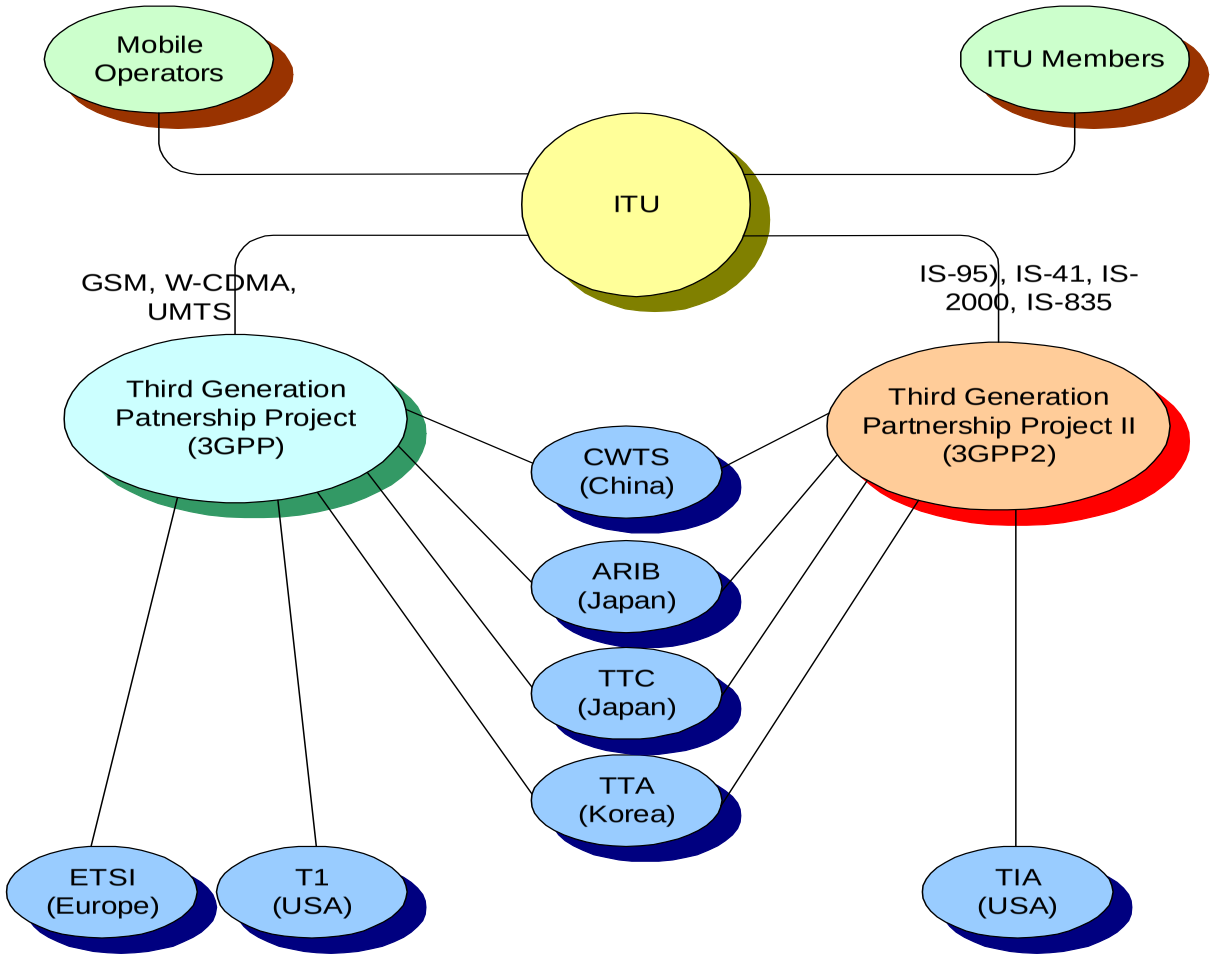
Additional Reference Material

Mobile Standard Organizations



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Partnership Projects and Forums

- ITU IMT-2000: http://www.itu.int/home/imt.html
- Mobile Partnership Projects
  - 3GPP : http://www.3gpp.org
  - 3GPP2 : http://www.3gpp2.org
- Mobile marketing alliances and forums
  - GSM Association: http://www.gsmworld.com/index.shtml
  - UMTS Forum : http://www.umts-forum.org
  - CDMA Development Group: http://www.cdg.org/index.asp
  - Next Generation Mobile Networks Alliance: http://www.ngmn.org/
  - Global Mobile Suppliers Association: http://www.gsacom.com
  - CTIA: http://www.ctia.org/
  - 3G Americas: http://www.uwcc.org

Mobile Standards Organizations

- European Technical Standard Institute (Europe):
  - http://www.etsi.org
- Telecommunication Industry Association (USA):
  - http://www.tiaonline.org
- Alliance for Telecommunications Industry Solutions (USA) (formerly Committee T1):
  - http://www.t1.org & http://www.atis.org/
- China Communications Standards Association (China):
  - http://www.cwts.org
- The Association of Radio Industries and Businesses (Japan):
  - http://www.arib.or.jp/english/index.html
- The Telecommunication Technology Committee (Japan):
  - http://www.ttc.or.jp/e/index.html
- The Telecommunication Technology Association (Korea):
  - http://www.tta.or.kr/english/e_index.htm

Other Industry Consortia

- OMA, Open Mobile Alliance: http://www.openmobilealliance.org/
  - Consolidates Open Mobile Architecture, WAP Forum, Location Interoperability Forum, SyncML, MMS Interoperability Group, Wireless Village

- Lists of wireless organizations compiled by others:
  - http://www.wipconnector.com/resources.php
  - http://focus.ti.com/general/docs/wtbu/wtbugencontent.tsp?templateId=6123&contentId=4602
  - http://www.wlana.org/pdf/wlan_standards_orgs.pdf

Wireless MAN, LAN and PAN Links

- WirelessMAN – Broadband Access (WiMAX)
  - IEEE 802.16: http://www.ieee802.org/16/
  - WiMAX Forum: http://www.wimaxforum.org/home/
- Wireless LAN (WiFi)
  - IEEE 802.11: http://www.ieee802.org/11/
  - WiFi Alliance: http://www.wi-fi.org/
  - Wireless LAN Association: http://www.wlana.org/
- Wireless WPAN (Bluetooth)
  - IEEE 802.15: http://www.ieee802.org/15/
  - Bluetooth SIG: https://www.bluetooth.org/ and http://www.bluetooth.com/

Sources of Market & Subscriber Statistics

Free:

- http://en.wikipedia.org/wiki/List_of_mobile_network_operators
  - http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_Europe
  - http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_the_Americas
  - http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_the_Asia_Pacific_region
  - http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_the_Middle_East_and_Africa
- http://www.gsmworld.com/roaming/gsminfo/index.shtml
- http://www.cdg.org/worldwide/cdma_world_subscriber.asp
- http://www.gsacom.com/news/statistics.php4

Nominal cost:

- http://www.itu.int/ITU-D/ict/publications/world/world.html

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