3G Tutorial

Brough Turner & Marc Orange

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NMS COMMUNICATIONS

Preface...

- **The authors would like to acknowledgement material contributions from:**
  - **Murtaza Amiji, NMS Communications**
  - **Samuel S. May, Senior Research Analyst, US Bancorp Piper Jaffray**
  - **Others as noted on specific slides**
- **We intend ongoing improvements to this tutorial and solicit your comments at:**
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- **For the latest version go to:**
  - **http://www.nmscommunications.com/3Gtutorial**

Outline

- **History and evolution of mobile radio**
  - **Brief history of cellular wireless telephony**
  - **Radio technology today: TDMA, CDMA**
  - **Demographics and market trends today**
  - **3G vision, 3G migration paths**
- **Evolving network architectures**
  - **Based on GSM-MAP or on IS-41 today**
  - **3GPP versus 3GPP2 evolution paths**
  - **3G utilization of softswitches, VoIP and SIP**
  - **Potential for convergence**

Outline (continued)

- **Evolving services**
  - **SMS, EMS, MMS messaging**
  - **Location**
  - **Video and IP multimedia**
- **Applications & application frameworks**
  - **Is there a Killer App?**
- **Business models**
  - **What's really happening? When?**

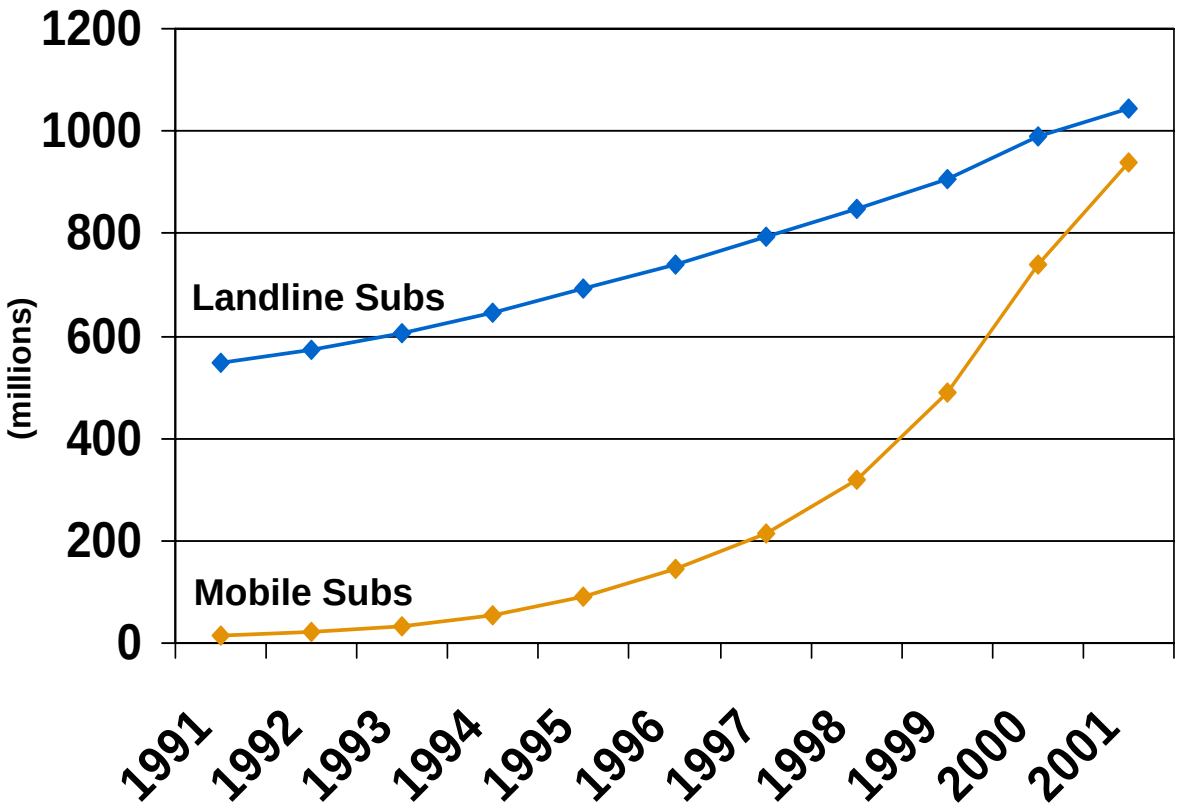
3G Tutorial

- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- Applications
- Business Models

First Mobile Radio Telephone 1924

Courtesy of Rich Howard

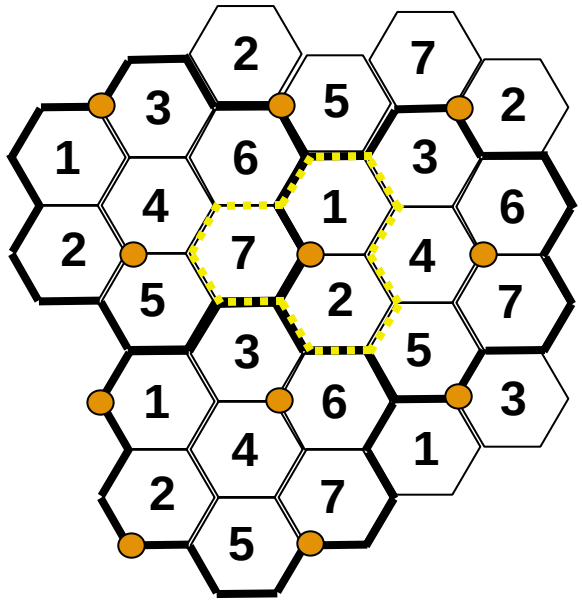
World Telecom Statistics



Crossover has happened May 2002 !

Cellular Mobile Telephony

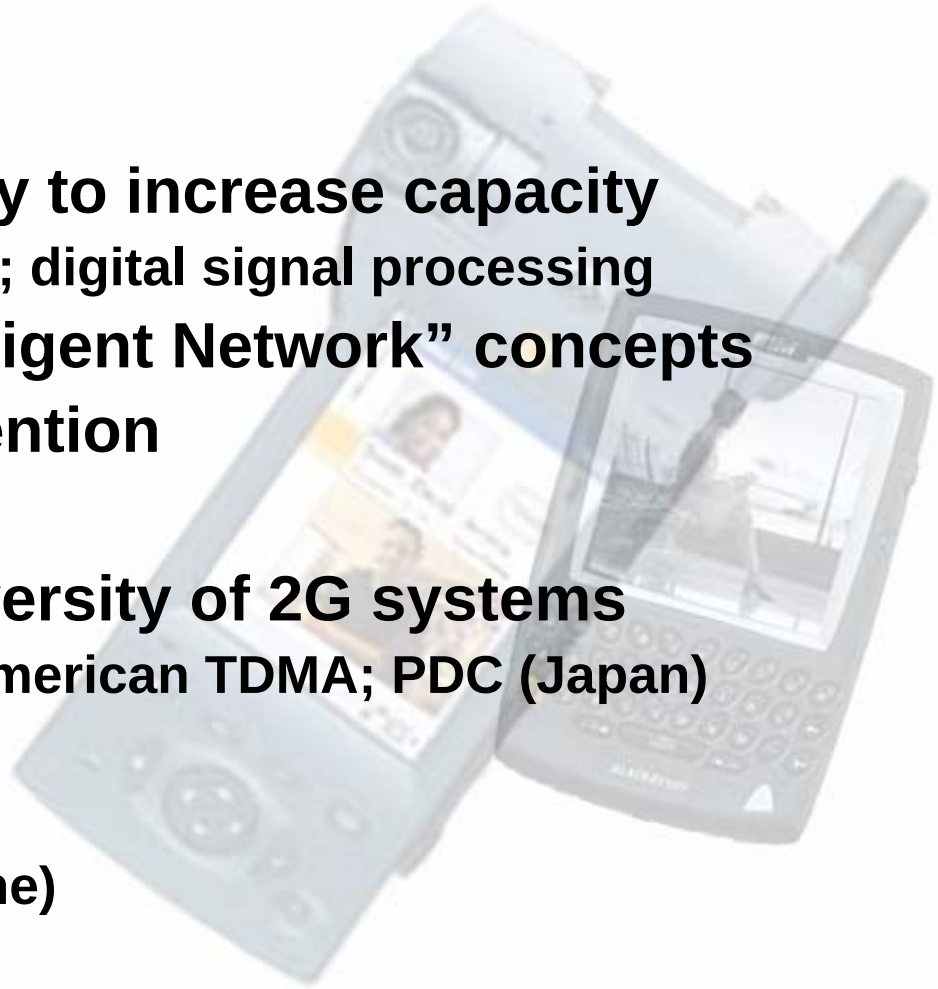
- Frequency modulation
- Antenna diversity
- Cellular concept
  - Bell Labs (1957 & 1960)
- Frequency reuse
  - Typically every 7 cells
- Handoff as caller moves
- Modified CO switch
  - HLR, paging, handoffs
- Sectors improve reuse
  - Every 3 cells possible



First Generation

- **Advanced Mobile Phone Service (AMPS)**
  - US trials 1978; deployed in Japan (’79) & US (’83)
  - 800 MHz band — two 20 MHz bands
  - TIA-553
  - Still widely used in US and many parts of the world
- **Nordic Mobile Telephony (NMT)**
  - Sweden, Norway, Demark & Finland
  - Launched 1981; now largely retired
  - 450 MHz; later at 900 MHz (NMT900)
- **Total Access Communications System (TACS)**
  - British design; similar to AMPS; deployed 1985
  - Some TACS-900 systems still in use in Europe

Second 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**
- **There are a wide diversity of 2G systems**
  - **IS-54/ IS-136 North American TDMA; PDC (Japan)**
  - **iDEN**
  - **DECT and PHS**
  - **IS-95 CDMA (cdmaOne)**
  - **GSM**

D-AMPS/ TDMA & PDC

- **Speech coded as digital bit stream**
  - **Compression plus error protection bits**
  - **Aggressive compression limits voice quality**
- **Time division multiple access (TDMA)**
  - **3 calls per radio channel using repeating time slices**
- **Deployed 1993 (PDC 1994)**
  - **Development through 1980s; bakeoff 1987**
- **IS-54 / IS-136 standards in US TIA**
- **ATT Wireless & Cingular use IS-136 today**
  - **Plan to migrate to GSM and then to W-CDMA**
- **PDC dominant cellular system in Japan today**
  - **NTT DoCoMo has largest PDC network**

iDEN

- **Used by 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 has highest APRU in US market due to “Direct Connect” push-to-talk service**

DECT and PHS

- **Also based on time division multiple access**
- **Digital European Cordless Telephony**
  - **Focus on business use, i.e. wireless PBX**
  - **Very small cells; In building propagation issues**
  - **Wide bandwidth (32 kbps channels)**
  - **High-quality voice and/or ISDN data**
- **Personal Handiphone Service**
  - **Similar performance (32 kbps channels)**
  - **Deployed across Japanese cities (high pop. density)**
  - **4 channel base station uses one ISDN BRI line**
  - **Base stations on top of phone booths**
  - **Legacy in Japan; new deployments in China today**

North American 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)**
- **Used by Verizon and Sprint in US**
- **Simplest 3G migration story today**

cdmaOne — IS-95

- **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)**

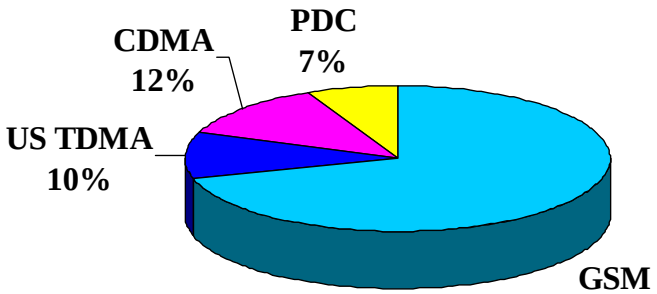
GSM

- « Groupe Special Mobile », later changed to « Global System for Mobile »
  - Joint European effort beginning in 1982
  - Focus on seamless roaming across Europe
- Services launched 1991
  - Time division multiple access (8 users per 200KHz)
  - 900 MHz band; later extended to 1800MHz
  - Added 1900 MHz (US PCS bands)
- GSM is dominant world standard today
  - Well defined interfaces; many competitors
  - Network effect (Metcalfe's law) took hold in late 1990s
  - Tri-band GSM phone can roam the world today

Distribution of GSM Subscribers

- **GSM is used by 70% of subscribers worldwide**
  - **564 M subs / 800 M subs in July 2001**
- **Most GSM deployments in Europe (59%) and Asia (33%)**
  - **ATT & Cingular deploying GSM in US today**

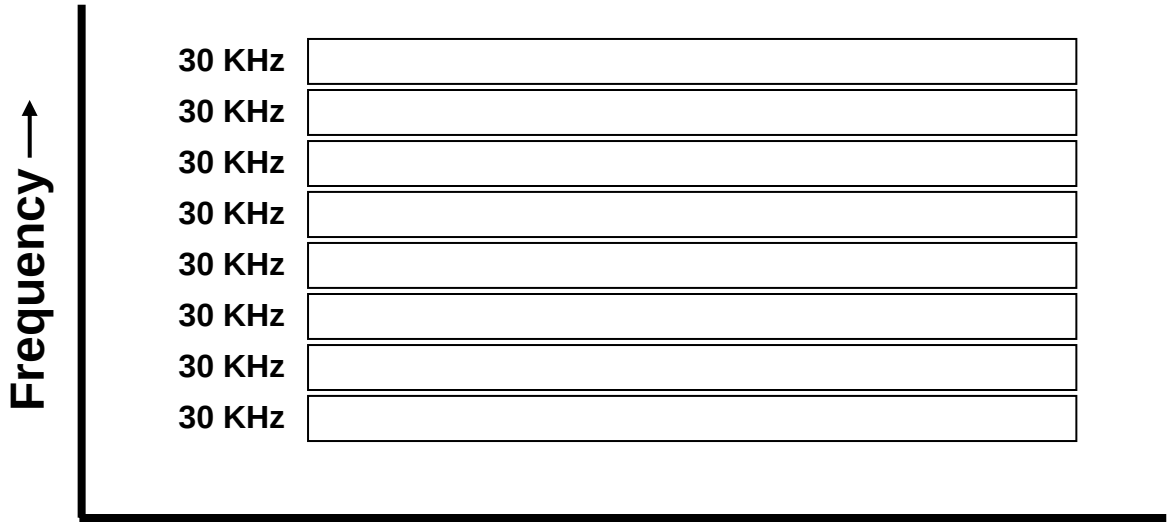
Number of subscribers in the world (Jul 2001)



Source: EMC World Cellular / GSM Association

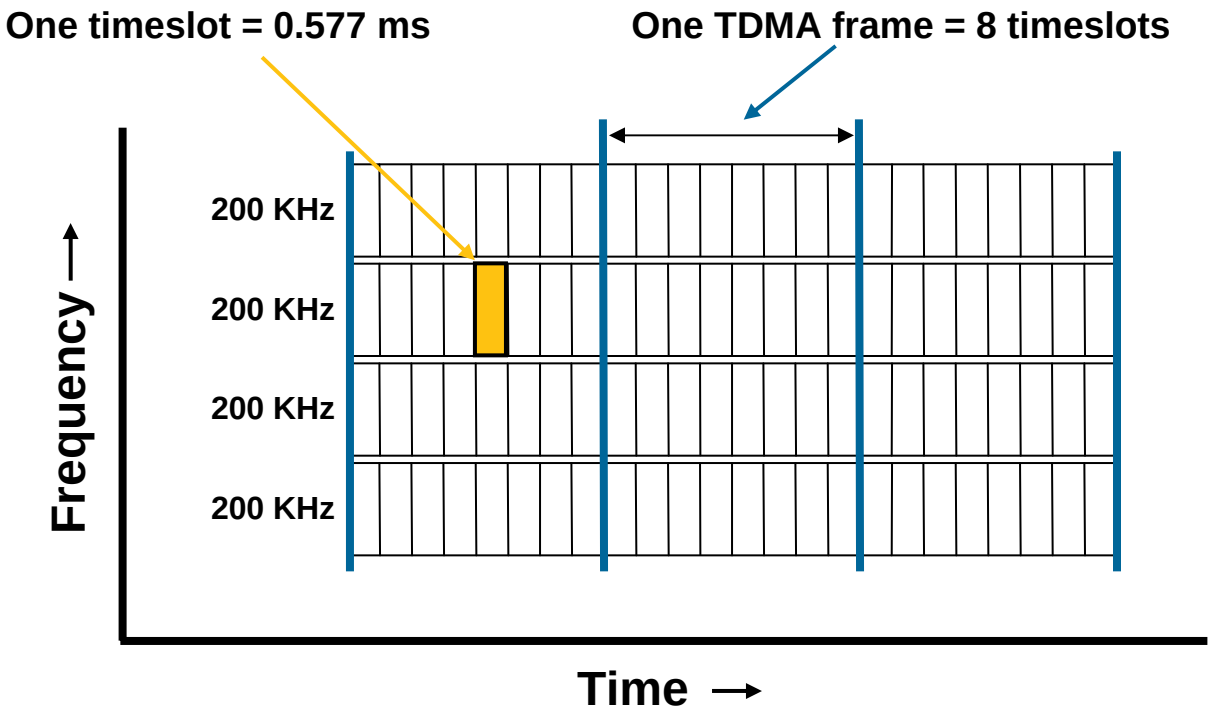
1G — Separate Frequencies

FDMA — Frequency Division Multiple Access



2G — TDMA

Time Division Multiple Access

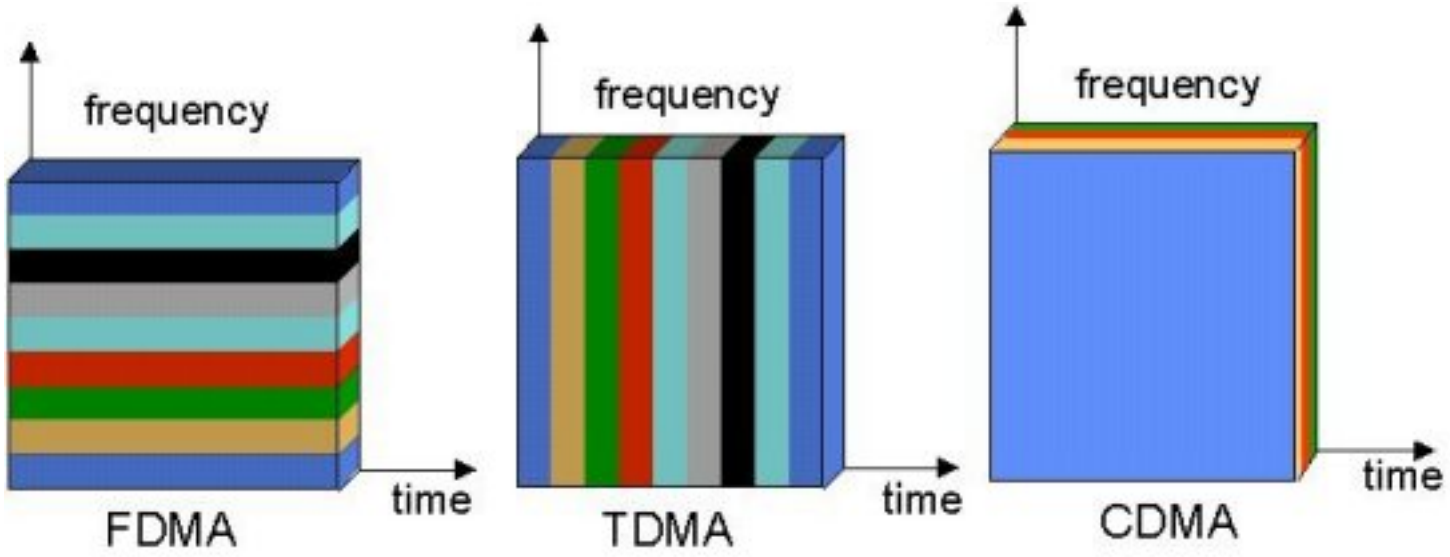


2G & 3G — CDMA

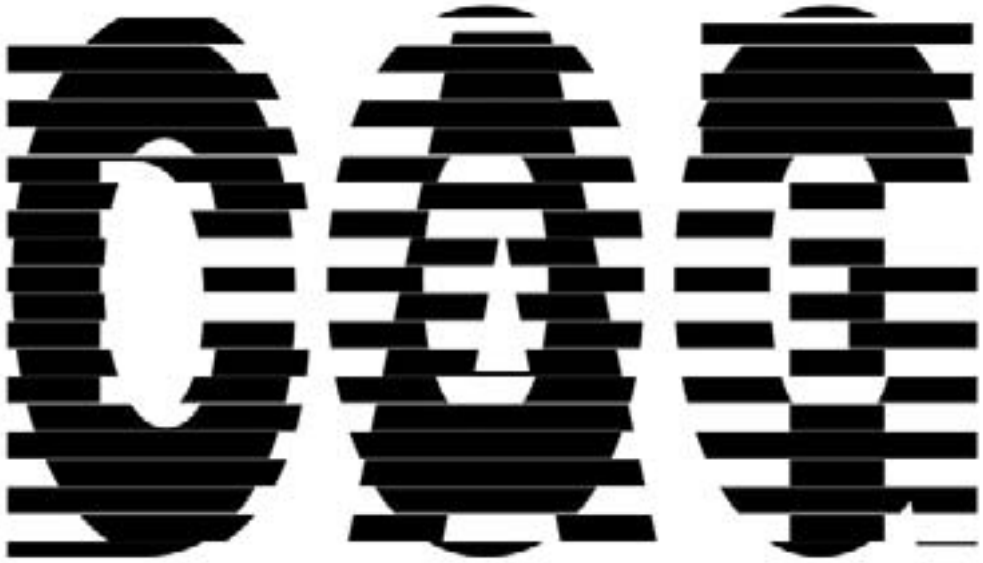
Code Division Multiple Access

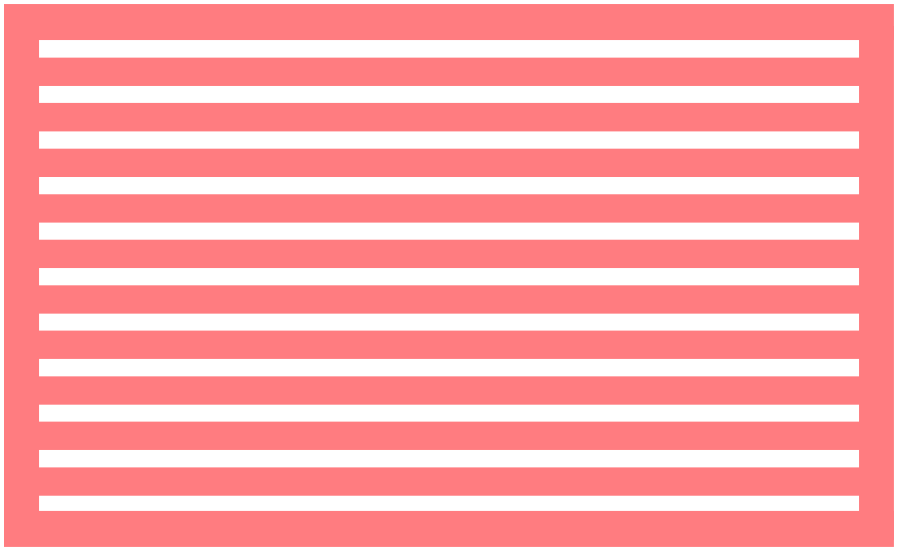
- **Spread spectrum modulation**
  - **Originally developed for the military**
  - **Resists jamming and many kinds of interference**
  - **Coded modulation hidden from those w/o the code**
- **All users share same (large) block of spectrum**
  - **One for one frequency reuse**
  - **Soft handoffs possible**
- **Almost all accepted 3G radio standards are based on CDMA**
  - **CDMA2000, W-CDMA and TD-SCDMA**

Multi-Access Radio Techniques



Courtesy of Petri Possi, UMTS World





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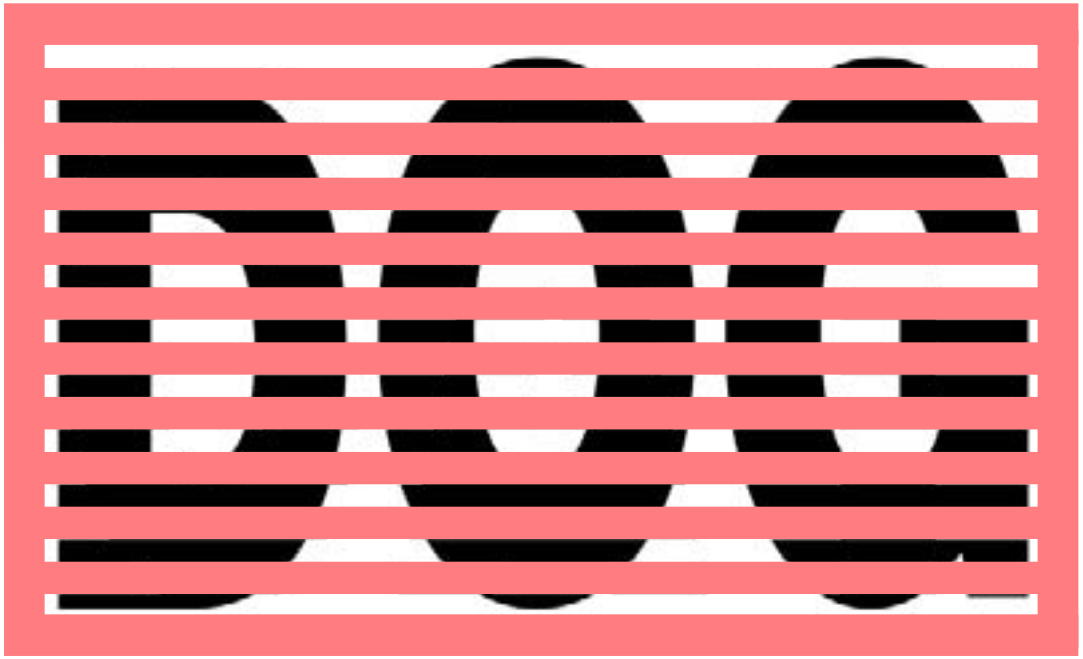
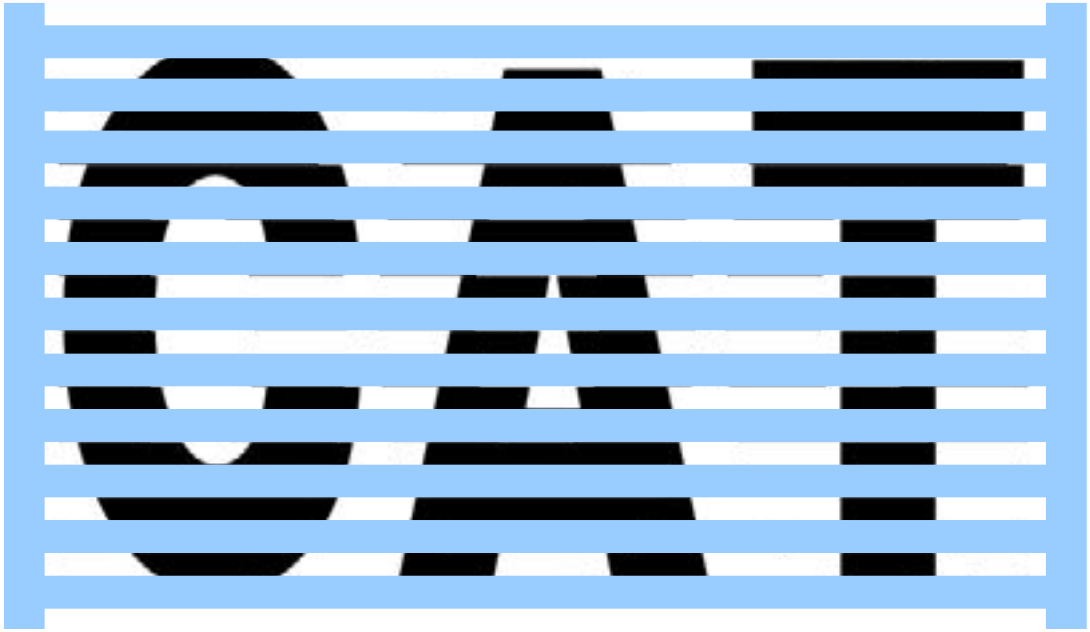
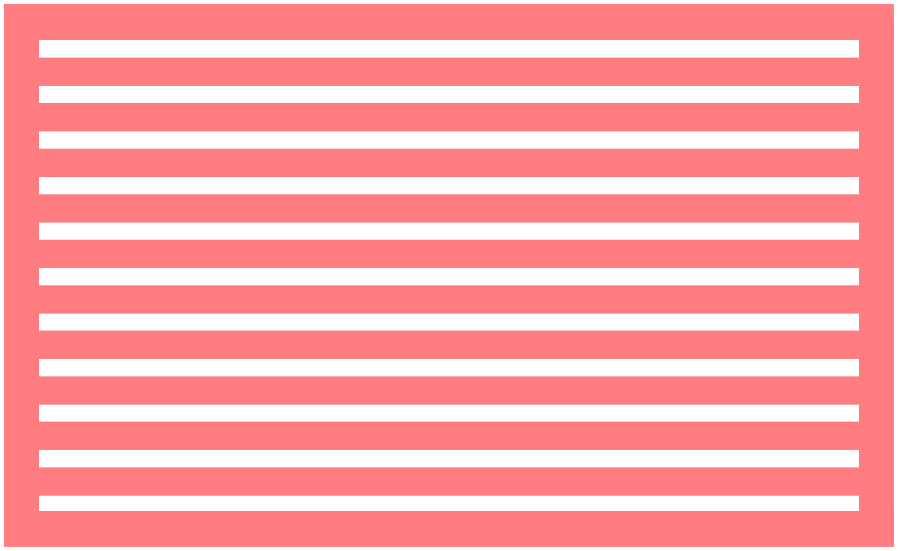
www.nmscommunications.com







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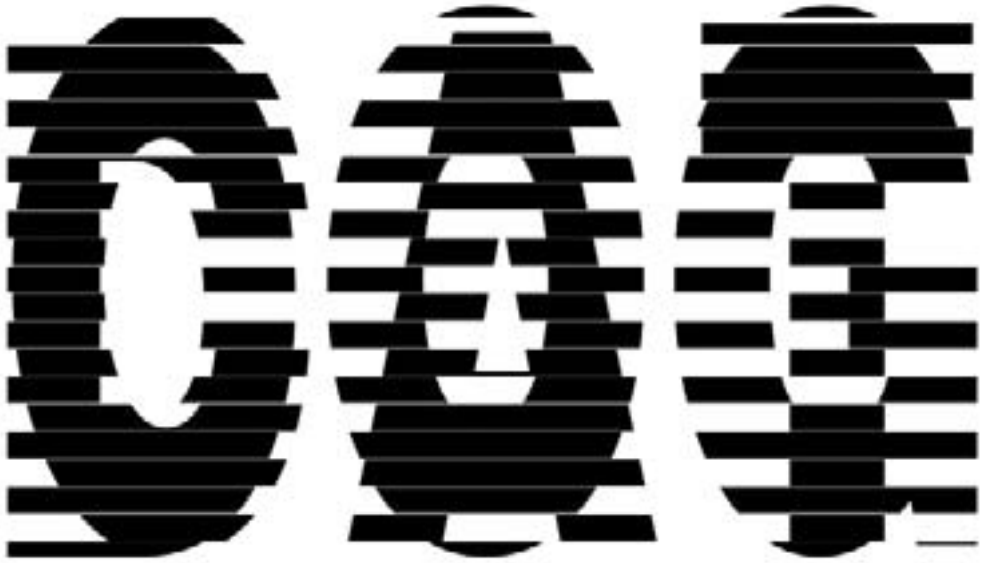
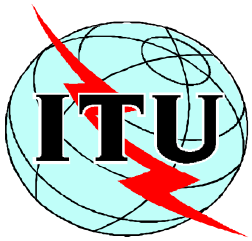


3G Vision

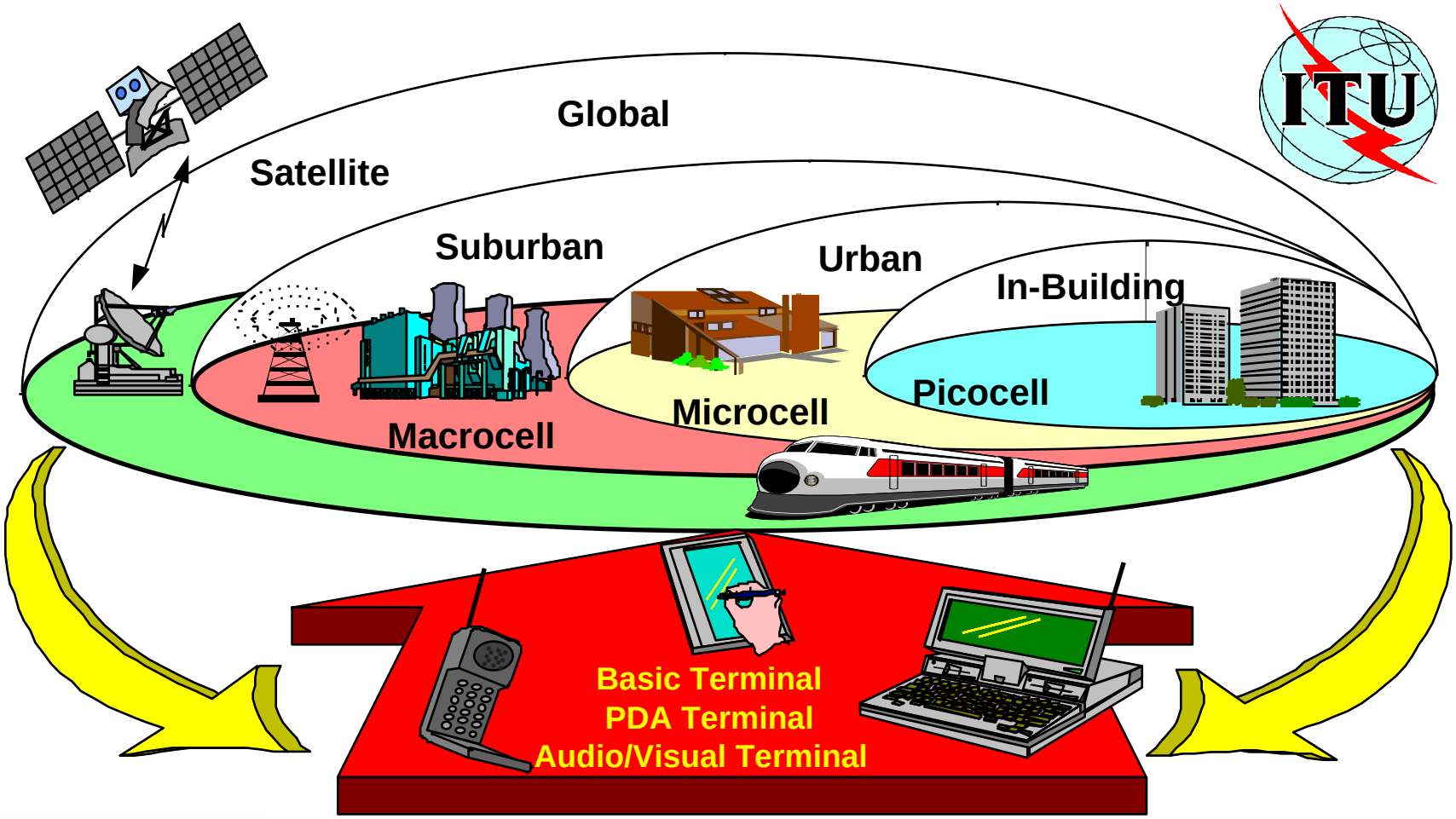
- **Universal global roaming**
- **Multimedia (voice, data & video)**
- **Increased data rates**
  - **384 kbps while moving**
  - **2 Mbps when stationary at specific locations**
- **Increased capacity (more spectrally efficient)**
- **IP architecture**
- **Problems**
  - **No killer application for wireless data as yet**
  - **Vendor-driven**

International Standardization



- **ITU (International Telecommunication Union)**
  - **Radio standards and spectrum**
- **IMT-2000**
  - **ITU's umbrella name for 3G which stands for International Mobile Telecommunications 2000**
- **National and regional standards bodies are collaborating in 3G partnership projects**
  - **ARIB, TIA, TTA, TTC, CWTS. T1, ETSI - refer to reference slides at the end for names and links**
- **3G Partnership Projects (3GPP & 3GPP2)**
  - **Focused on evolution of access and core networks**

IMT-2000 Vision Includes LAN, WAN and Satellite Services



IMT-2000 Radio Standards

- **IMT-SC* Single Carrier (UWC-136): EDGE**
  - **GSM evolution (TDMA); 200 KHz channels; sometimes called "2.75G"**
- **IMT-MC* Multi Carrier CDMA: CDMA2000**
  - **Evolution of IS-95 CDMA, i.e. cdmaOne**
- **IMT-DS* Direct Spread CDMA: W-CDMA**
  - **New from 3GPP; UTRAN FDD**
- **IMT-TC** Time Code CDMA**
  - **New from 3GPP; UTRAN TDD**
  - **New from China; TD-SCDMA**
- **IMT-FT** FDMA/TDMA (DECT legacy)**

*** Paired spectrum; ** Unpaired spectrum**

CDMA2000 Pros and Cons

- **Evolution from original Qualcomm CDMA**
  - **Now known as cdmaOne or IS-95**
- **Better migration story from 2G to 3G**
  - **cdmaOne operators don't need additional spectrum**
  - **1xEVD0 promises higher data rates than UMTS, i.e. W-CDMA**
- **Better spectral efficiency than W-CDMA(?)**
  - **Arguable (and argued!)**
- **CDMA2000 core network less mature**
  - **cmdaOne interfaces were vendor-specific**
  - **Hopefully CDMA2000 vendors will comply w/ 3GPP2**

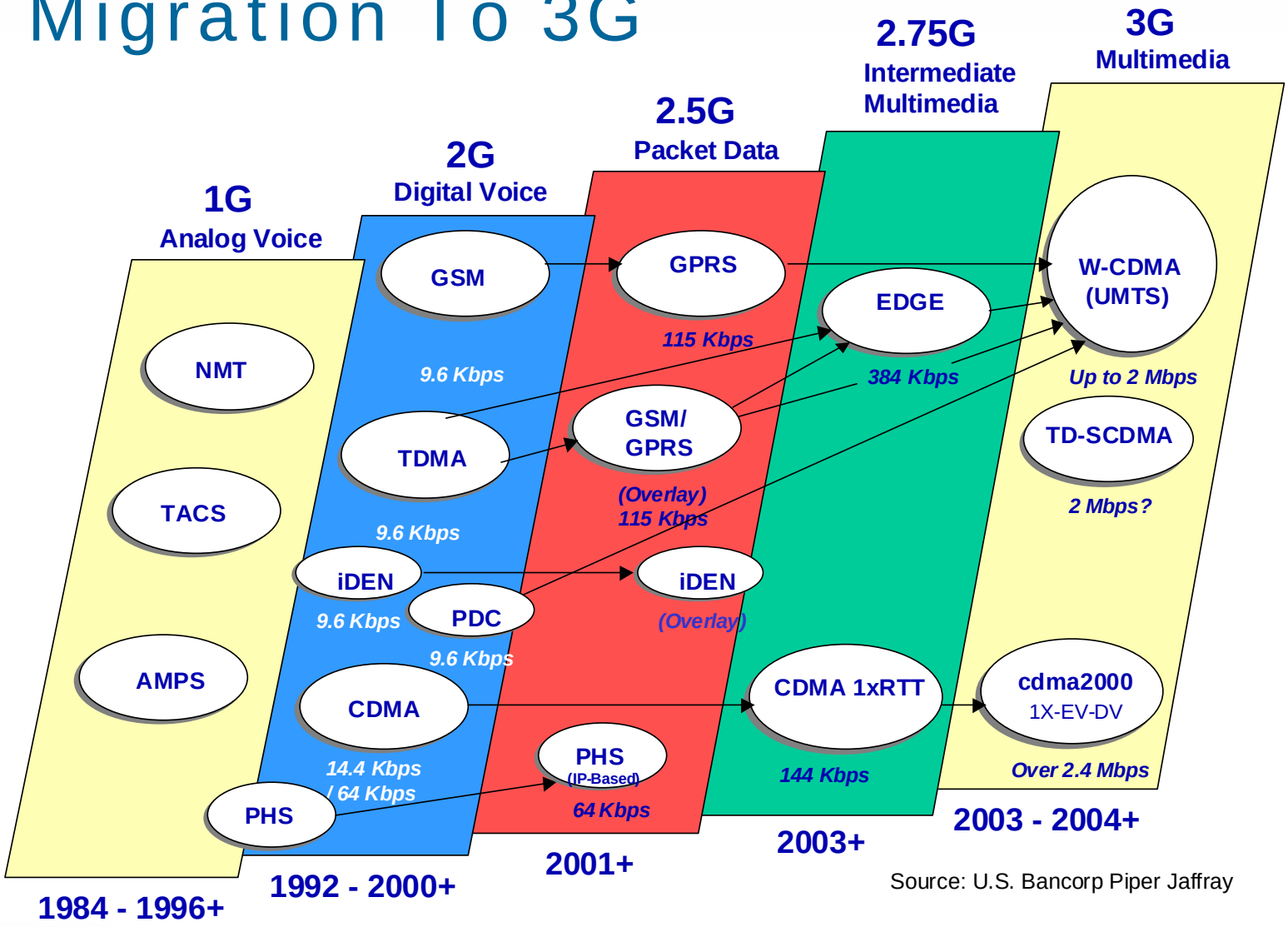
W-CDMA (UMTS) Pros and Cons

- **Wideband CDMA**
  - **Standard for Universal Mobile Telephone Service (UMTS)**
- **Committed standard for Europe and likely migration path for other GSM operators**
  - **Leverages GSM's dominant position**
- **Requires substantial new spectrum**
  - **5 MHz each way (symmetric)**
- **Legally mandated in Europe and elsewhere**
- **Sales of new spectrum completed in Europe**
  - **At prices that now seem exorbitant**

TD-SCDMA

- **Time division duplex (TDD)**
- **Chinese development**
  - **Will be deployed in China**
- **Good match for asymmetrical traffic!**
- **Single spectral band (1.6 MHz) possible**
- **Costs relatively low**
  - **Handset smaller and may cost less**
  - **Power consumption lower**
  - **TDD has the highest spectrum efficiency**
- **Power amplifiers must be very linear**
  - **Relatively hard to meet specifications**

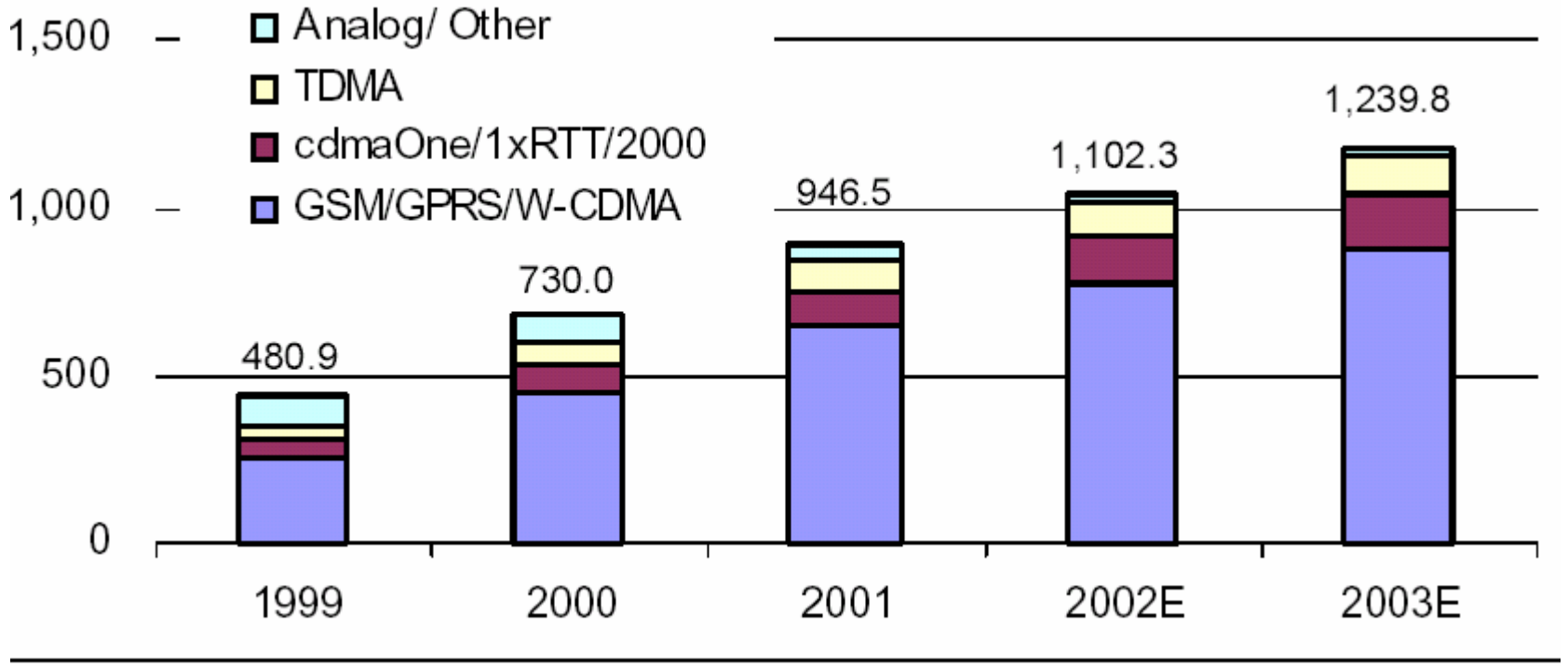
Migration To 3G



Source: U.S. Bancorp Piper Jaffray

Subscribers: GSM vs CDMA

- **Cost of moving from GSM to cdmaOne overrides the benefit of the CDMA migration path**



Source: U.S. Bancorp Piper Jaffray

Mobile Wireless Spectrum

Bands (MHz)	Frequencies (MHz)	Regions	GSM/ EDGE	WCDMA	CDMA2000
450	450-467	Europe	x		x
480	478-496	Europe	x		
800	824-894	America	x		x
900	880-960	Europe/APAC	x		x
1500		Japan PDC			x
1700	1750-1870	Korea			x
1800	1710-1880	Europe/APAC	x	x	x
1900	1850-1990	America	x	x	x
2100	1885-2025 & 2100-2200	Europe/APAC		x	x
2500	2500-2690	ITU Proposal			x

Prospects for Global Roaming

- **Multiple vocoders (AMR, EVRC, SMV,…)**
- **Six or more spectral bands**
  - **800, 900, 1800, 1900, 2100, 2500, …? MHz**
- **At least four modulation variants**
  - **GSM (TDMA), W-CDMA, CDMA2000, TD-SCMDA**

The handset approach

- **Advanced silicon**
- **Software defined radio**
- **Improved batteries**

Two cycles of Moore's law? i.e. 3 yrs?

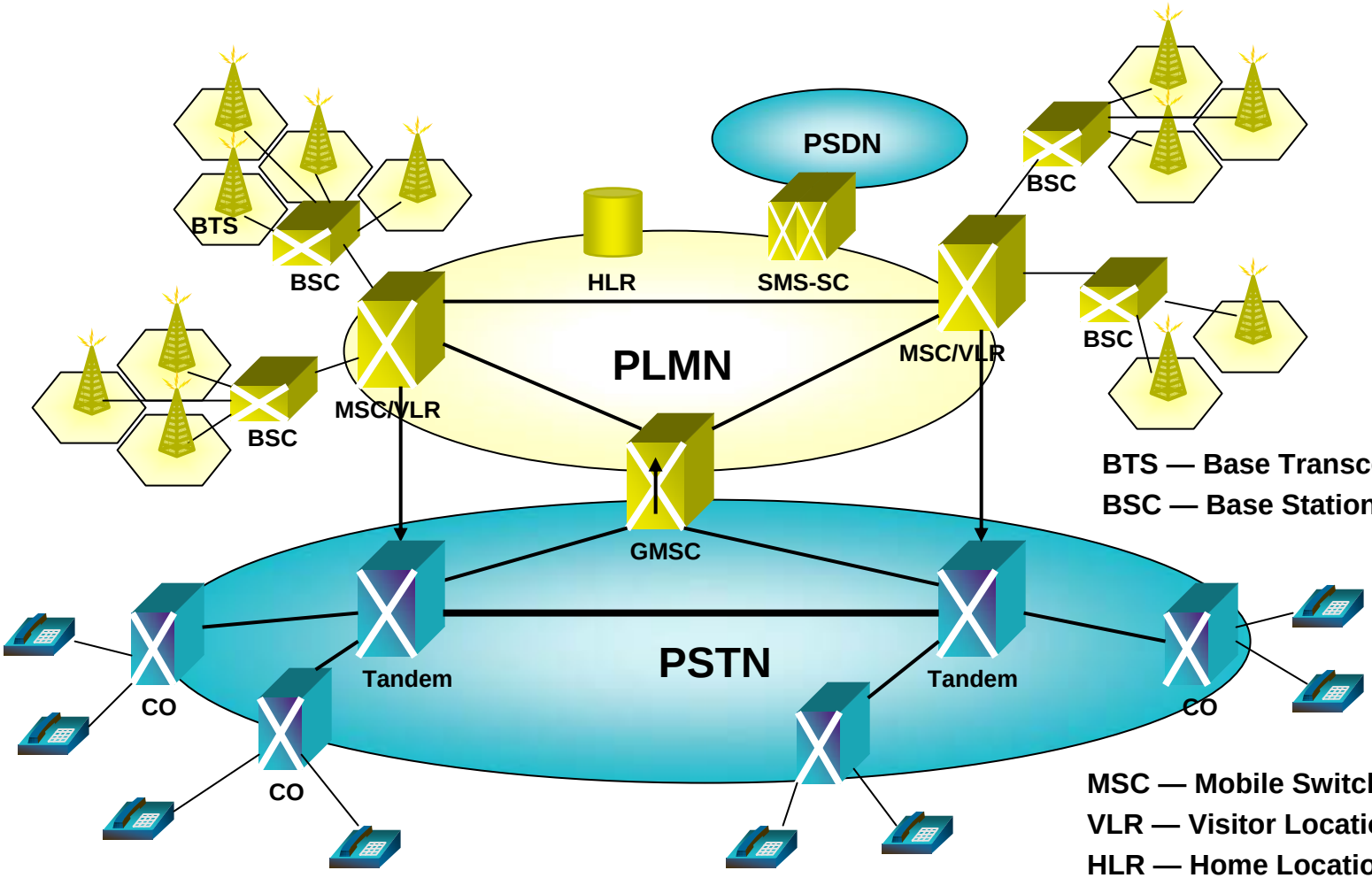
3G Tutorial

- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- Applications
- Business Models

Evolving CN Architectures

- **Two widely deployed architectures today**
- **GSM-MAP — used by GSM operators**
  - **“Mobile Application Part” defines extra (SS7-based) signaling for mobility, authentication, etc.**
- **ANSI-41 MAP — used with AMPS, TDMA & cdmaOne**
  - **TIA (ANSI) standard for “cellular radio telecommunications inter-system operation”**
- **Each evolving to common “all IP” vision**
  - **“All IP” still being defined — many years away**
  - **GAIT (GSM ANSI Interoperability Team) provides a path for interoperation today**

Typical 2G Architecture

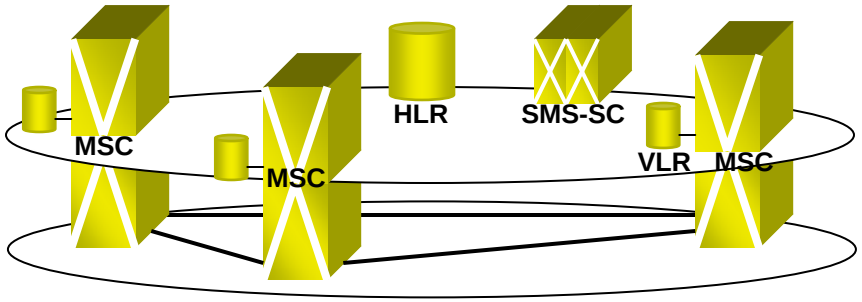


BTS — Base Transceiver Station
BSC — Base Station Controller

MSC — Mobile Switching Center
VLR — Visitor Location Register
HLR — Home Location Register

Network Planes

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



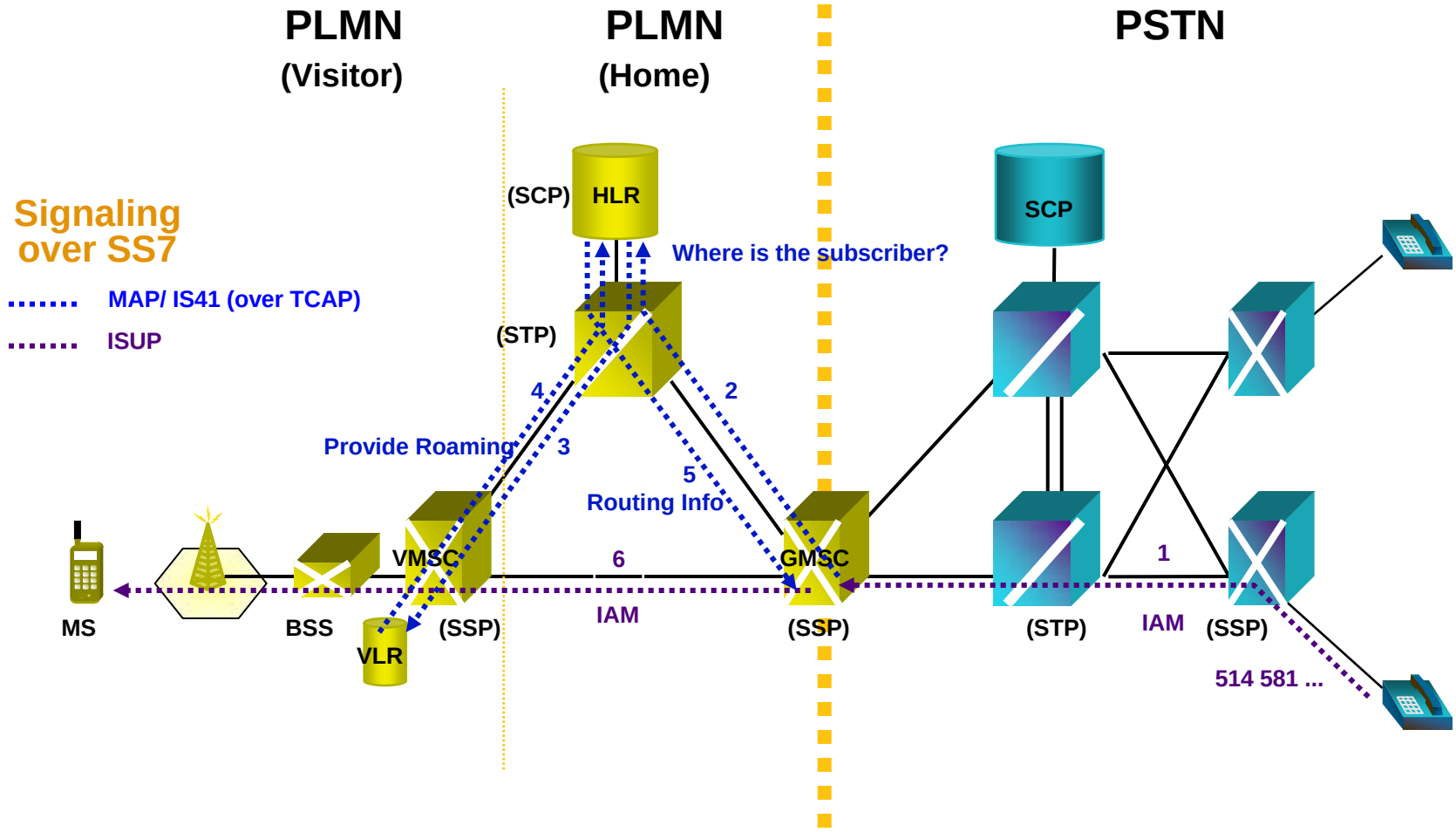
Signaling Plane (SS7)

Transport Plane (Voice)

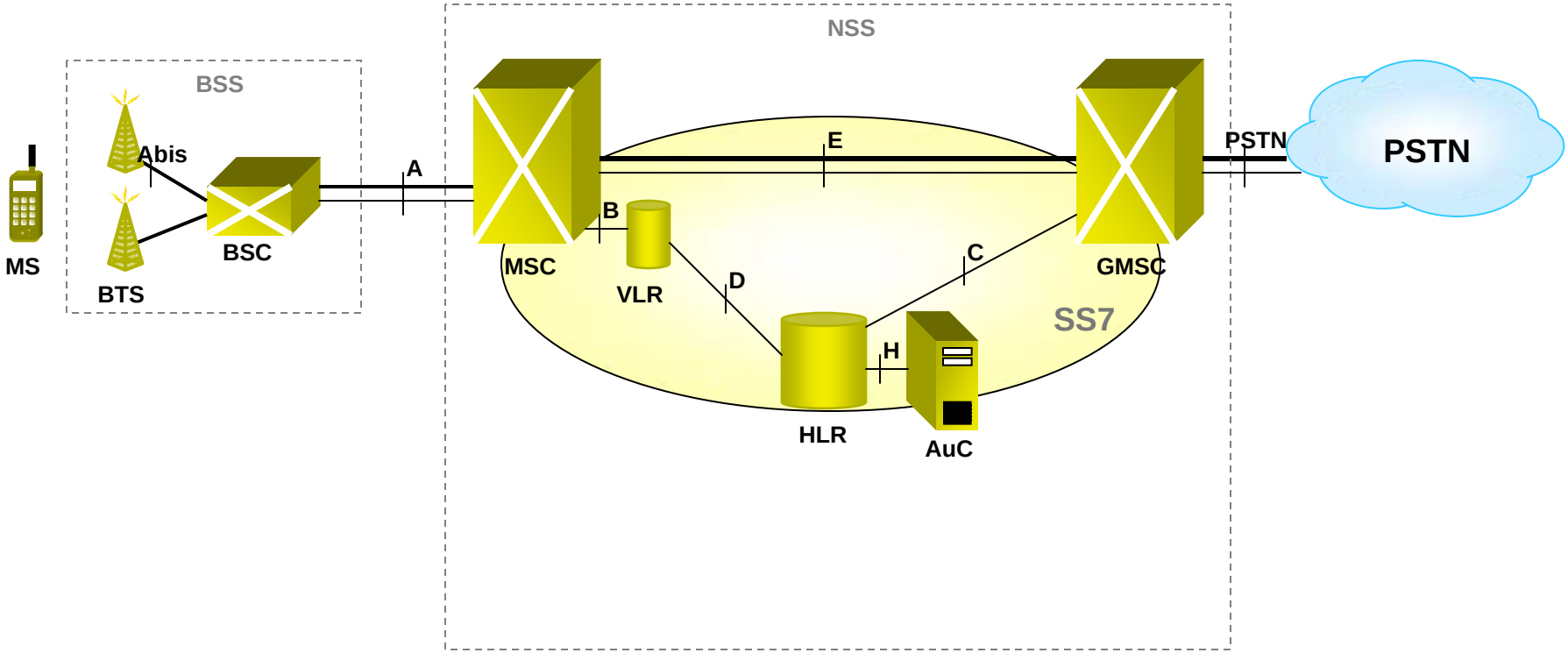
Signaling in Core Network

- **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 keeps local copy for roamers**

PSTN-to-Mobile Call



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

Enhancing GSM

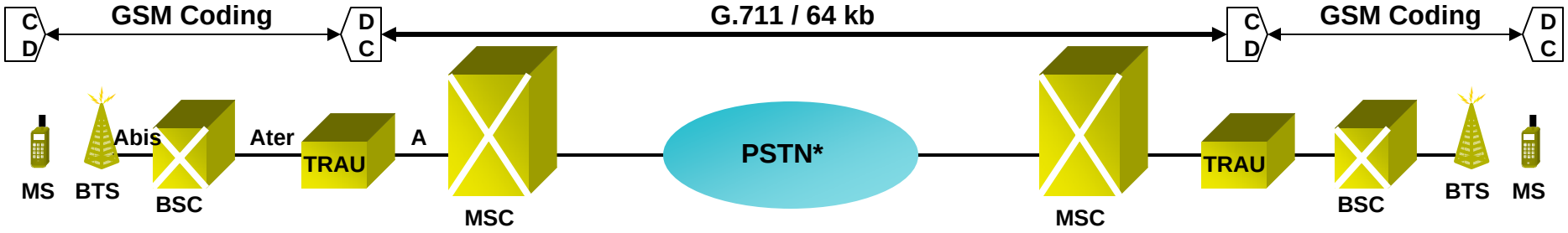
- **New technology since mid-90s**
- **Global standard — most widely deployed**
  - **significant payback for enhancements**
- **Frequency hopping**
  - **Overcome fading**
- **Synchronization between cells**
  - **DFCA: dynamic frequency and channel assignment**
    - **Allocate radio resources to minimize interference**
  - **Also used to determine mobile's location**
- **TFO — Tandem Free Operation**

TFO Concepts

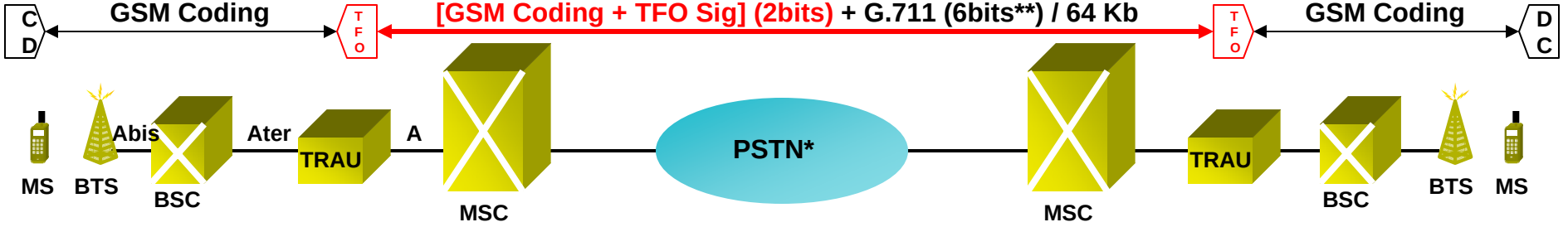
- **Improve voice quality by disabling unneeded transcoders during mobile-to-mobile calls**
- **Operate with existing networks (BSCs, MSCs)**
  - **New TRAU negotiates TFO in-band after call setup**
  - **TFO frames use LSBits of 64 Kbps circuit to carry compressed speech frames and TFO signaling**
  - **MSBits still carry normal G.711 speech samples**
- **Limitations**
  - **Same speech codec in each handset**
  - **Digital transparency in core network (EC off!)**
  - **TFO disabled upon cell handover, call transfer, in-band DTMF, announcements or conferencing**

TFO – Tandem Free Operation

- **No TFO : 2 unneeded transcoders in path**



- **With TFO (established) : no in-path transcoder**



(*) or TDM-based core network

(**) or 7 bits if Half-Rate coder is used

New Vocoders: AMR & SMV

- **AMR: Adaptive multi-rate**
  - **Defined for UMTS (W-CDMA)**
  - **Being retrofitted for GSM**
- **SMV: Selectable mode vocoder**
  - **Defined by 3GPP2 for CDMA2000**
- **Many available coding rates**
  - **AMR 8 rates: 12.2, 10.2, 7.95, 7.4, 6.7, 5.9, 5.15 & 4.75bps, plus silence frames (near 0 bps)**
  - **SMV 4 rates: 8.5, 4, 2 & 0.8kbps**
- **Lower bit rates allow more error correction**
  - **Dynamically adjust to radio interference conditions**

Enhancing GSM

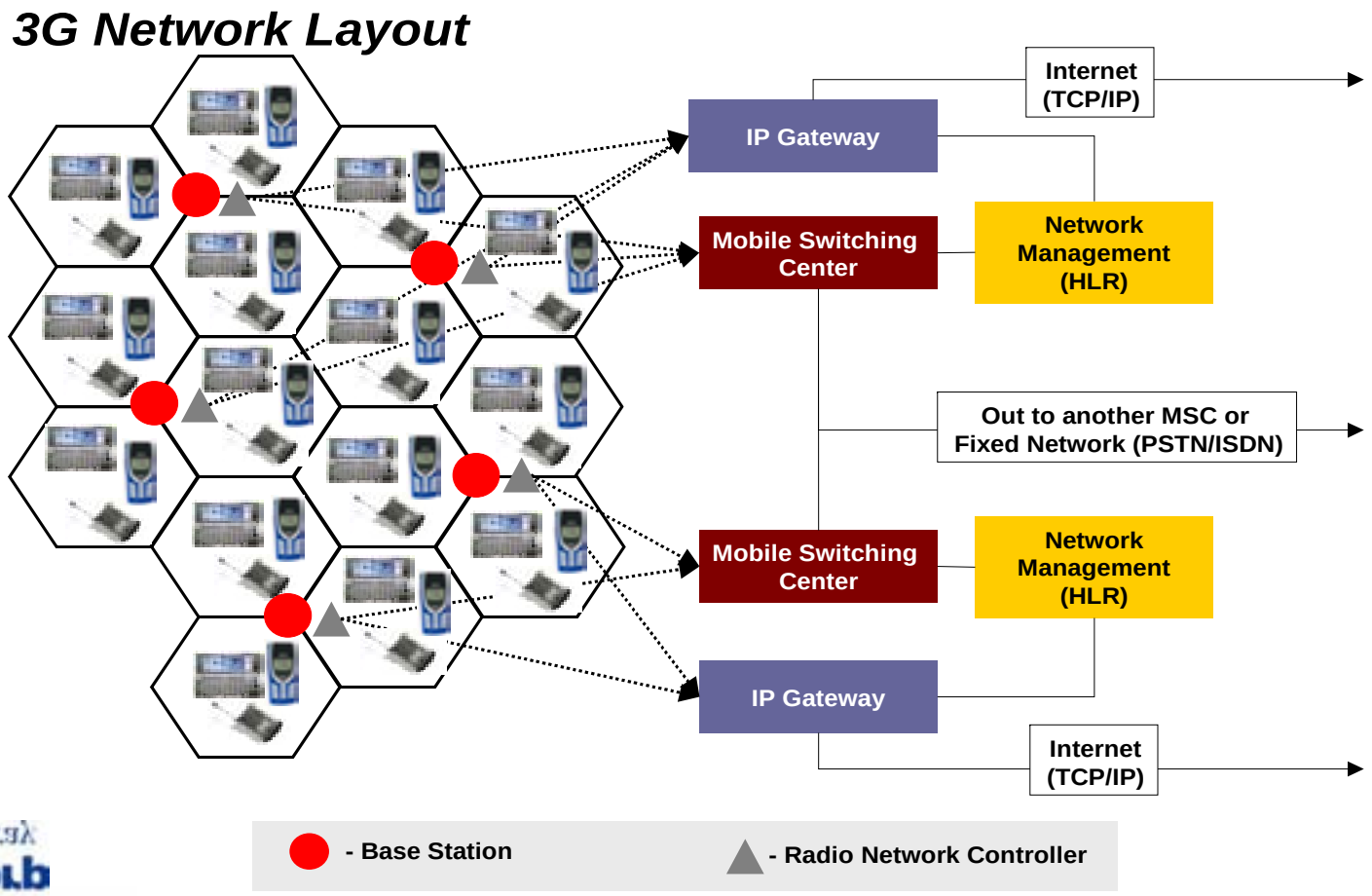
- **AMR speech coder**
  - **Trade off speech and error correction bits**
  - **Fewer dropped calls**
- **DTX — discontinuous transmission**
  - **Less interference (approach 0 bps during silences)**
  - **More calls per cell**
- **Overlays, with partitioned spectral reuse**
  - **3x in overlay (cell edges); 1x reuse in underlay**
- **HSCSD — high speed circuit-switched data**
  - **Aggregate channels to surpass 9.6 kbps limit (→50k)**
- **GPRS — general packet radio service**

GPRS — 2.5G for GSM

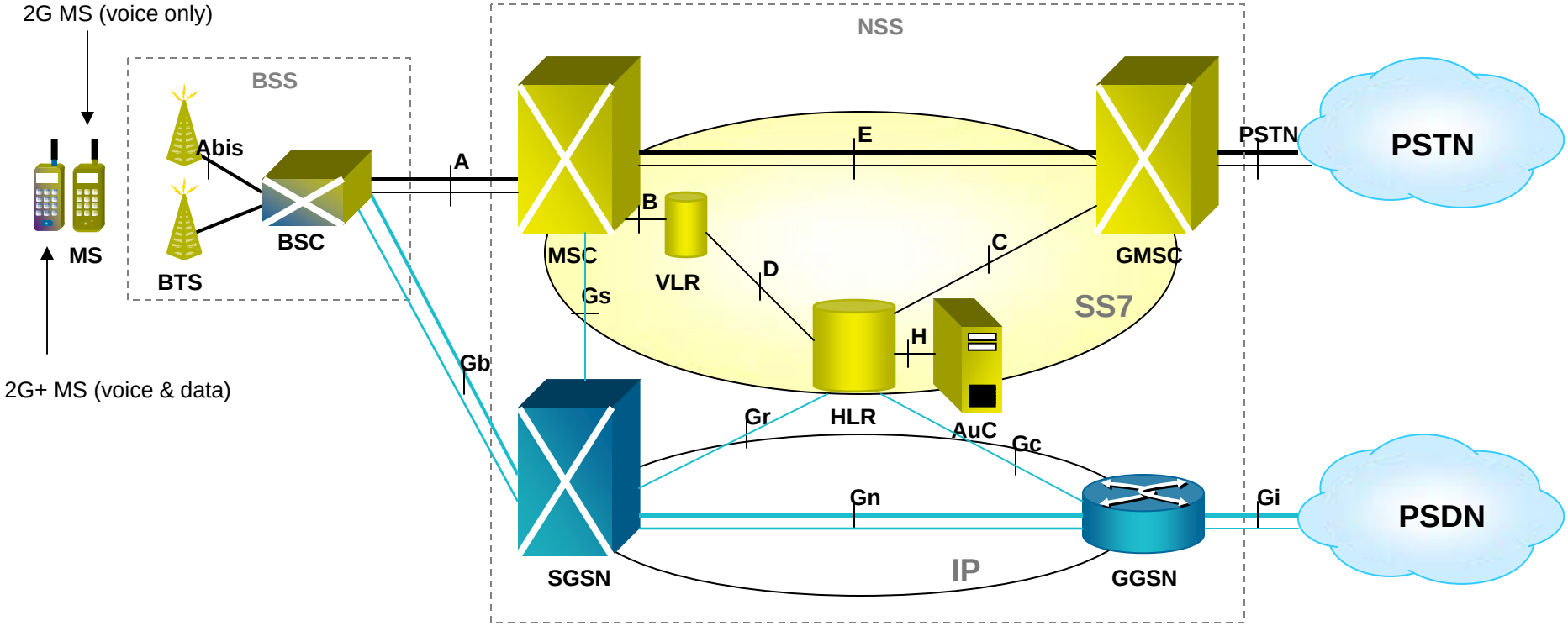
- **General packet radio service**
  - **First introduction of packet technology**
- **Aggregate radio channels**
  - **Support higher data rates (115 kbps)**
  - **Subject to channel availability**
- **Share aggregate channels among multiple users**
- **All new IP-based data infrastructure**
- **No changes to voice network**

2.5G / 3G Adds IP Data

No Changes for Voice Calls



2.5G Architectural Detail



BSS — Base Station System

BTS — Base Transceiver Station

BSC — Base Station Controller

NSS — Network Sub-System

MSC — Mobile-service Switching Controller

VLR — Visitor Location Register

HLR — Home Location Register

AuC — Authentication Server

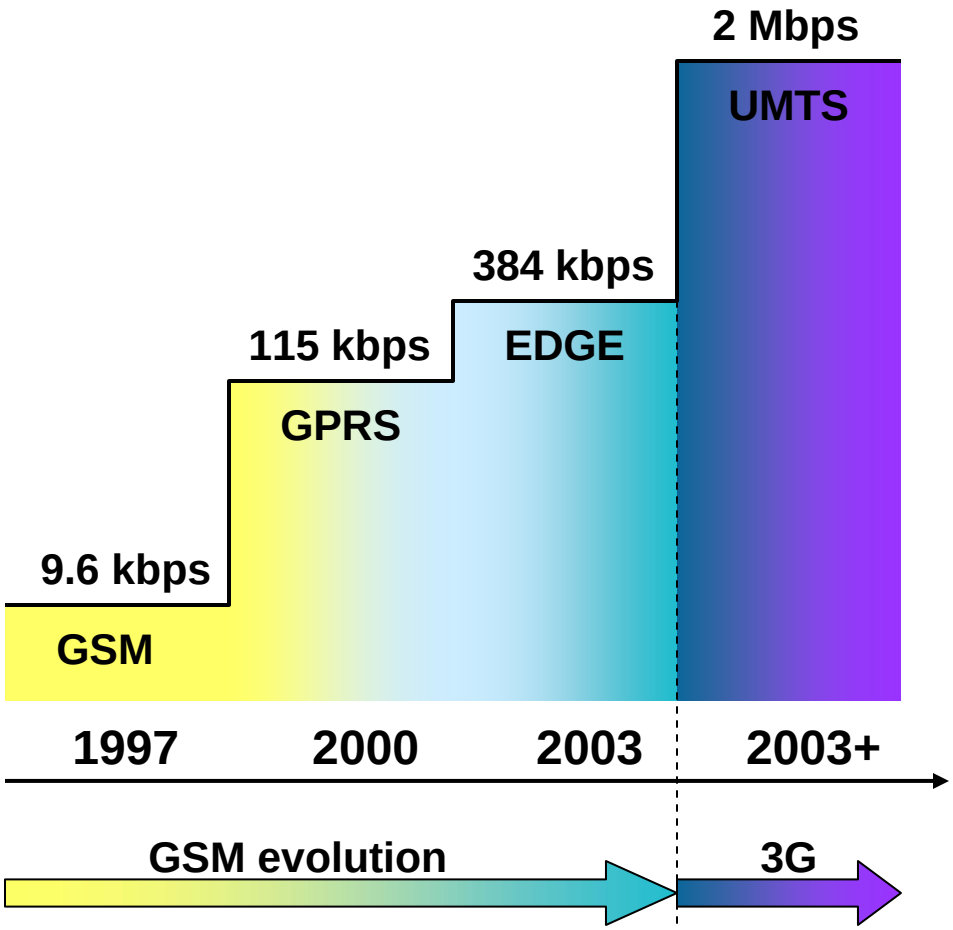
GMSC — Gateway MSC

SGSN — Serving GPRS Support Node

GGSN — Gateway GPRS Support Node

GPRS — General Packet Radio Service

GSM Evolution for Data Access



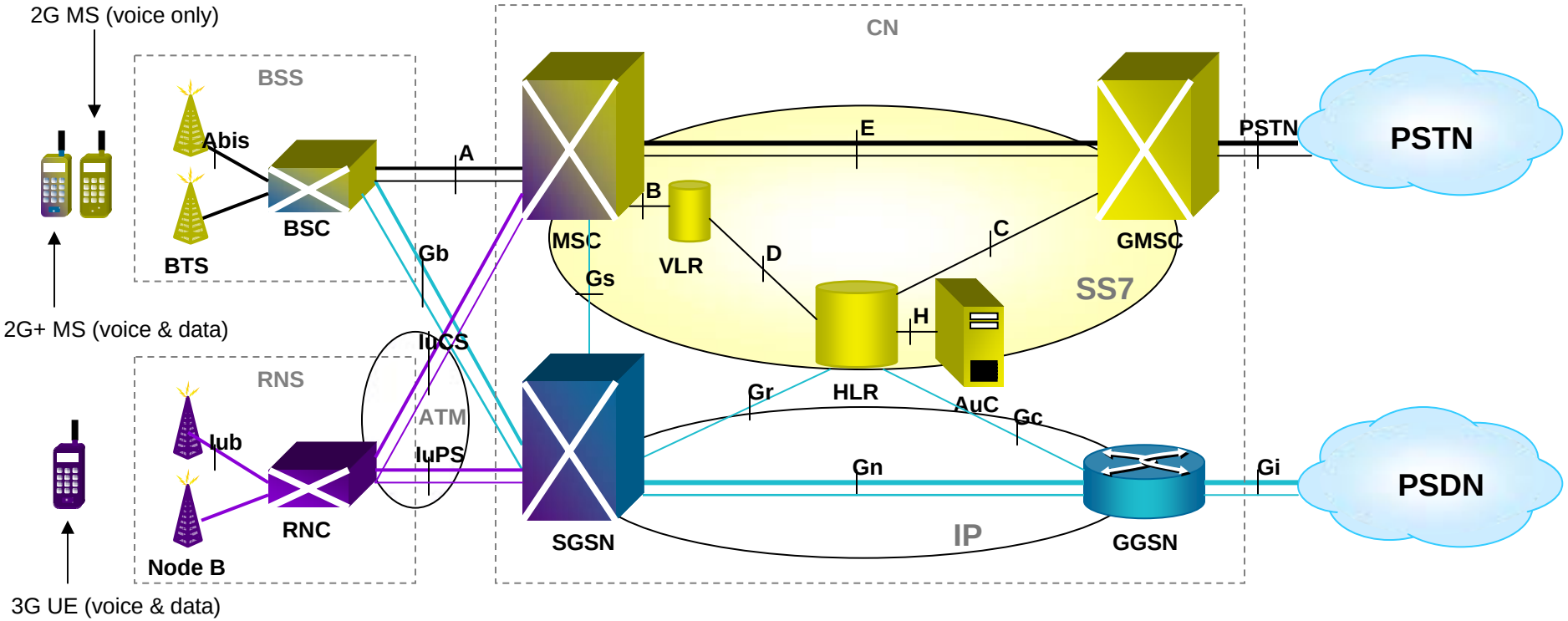
EDGE

- **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)**
- **GAIT — GSM/ANSI-136 interoperability team**
  - **Allows IS-136 TDMA operators to migrate to EDGE**
  - **New GSM/ EDGE radios but evolved ANSI-41 core network**

3G Partnership Project (3GPP)

- **3GPP defining migration from GSM to UMTS (W-CDMA)**
  - **Core network evolves from GSM-only to support GSM, GPRS and new W-CDMA facilities**
- **3GPP Release 99**
  - **Adds 3G radios**
- **3GPP Release 4**
  - **Adds softswitch/ voice gateways and packet core**
- **3GPP Release 5**
  - **First IP Multimedia Services (IMS) w/ SIP & QoS**
- **3GPP Release 6**
  - **“All IP” network; contents of r6 still being defined**

3G rel99 Architecture (UMTS) — *3G Radios*



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BTS — Base Transceiver Station

BSC — Base Station Controller

RNS — Radio Network System

RNC — Radio Network Controller

CN — Core Network

MSC — Mobile-service Switching Controller

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HLR — Home Location Register

AuC — Authentication Server

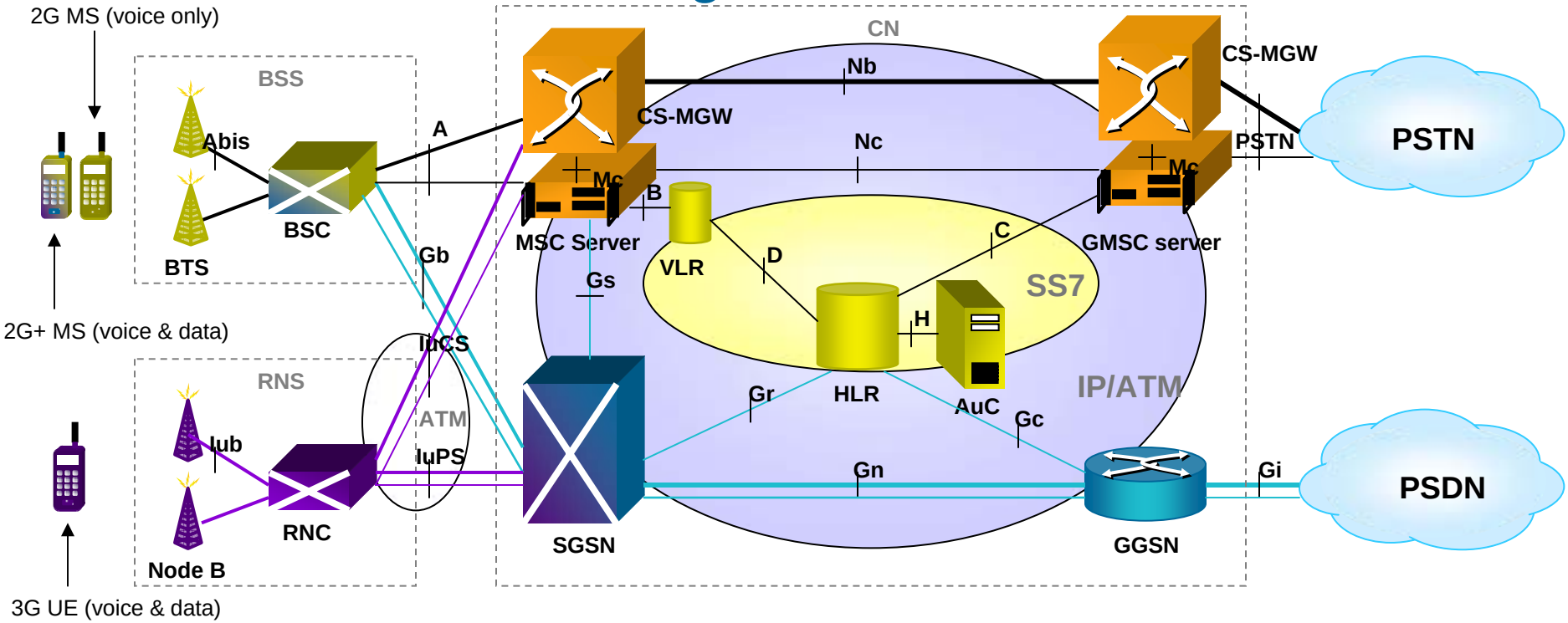
GMSC — Gateway MSC

SGSN — Serving GPRS Support Node

GGSN — Gateway GPRS Support Node

UMTS — Universal Mobile Telecommunication System

3G rel4 Architecture (UMTS) — *Soft Switching*



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GMSC — Gateway MSC

SGSN — Serving GPRS Support Node

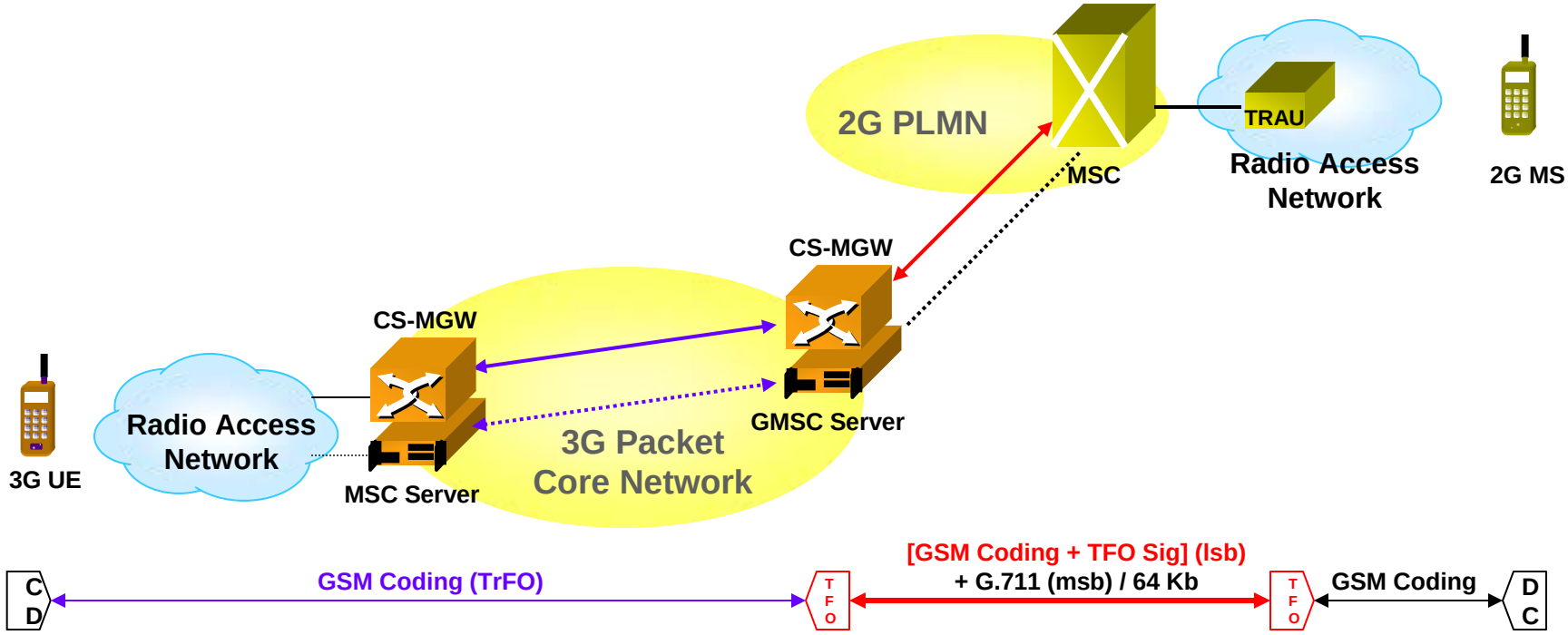
GGSN — Gateway GPRS Support Node

Transcoder Free Operation (TrFO)

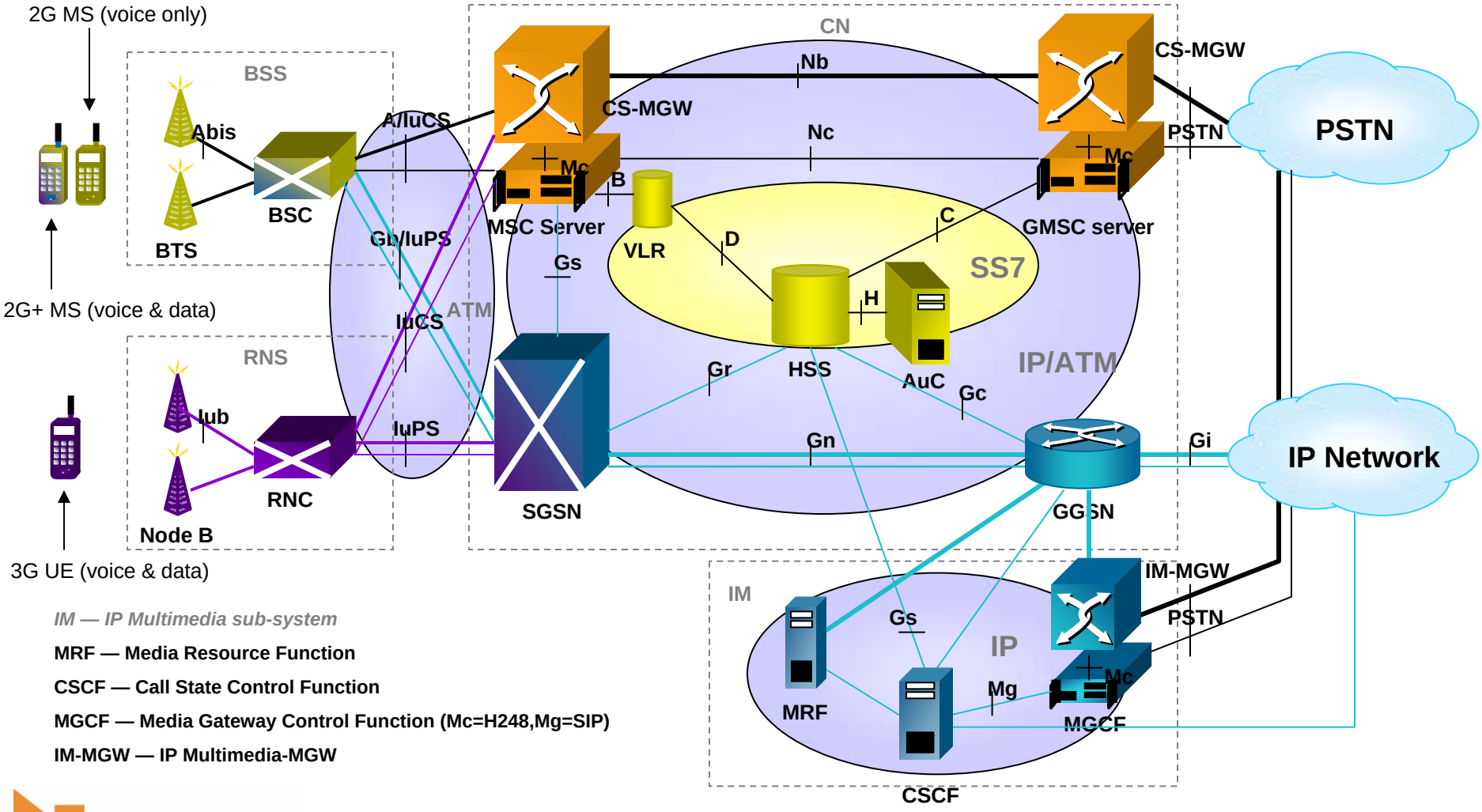
- **Improve voice quality by avoiding unneeded transcoders**
  - **like TFO but using packet-based core network**
- **Out-of-band negociation**
  - **Select same codec at both ends during call setup**
  - **Supports sudden channel rearrangement (handovers, etc.) via signaling procedures**
  - **When TrFO impossible, TFO can be attempted**
    - **e.g. transit between packet-based and circuit-based core networks**

TrFO + TFO Example

- **2G handset to 3G handset: by combining TrFO and TFO, in-path transcoders can be avoided**



3G rel5 Architecture (UMTS) — *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

3GPP Rel.6 Objectives

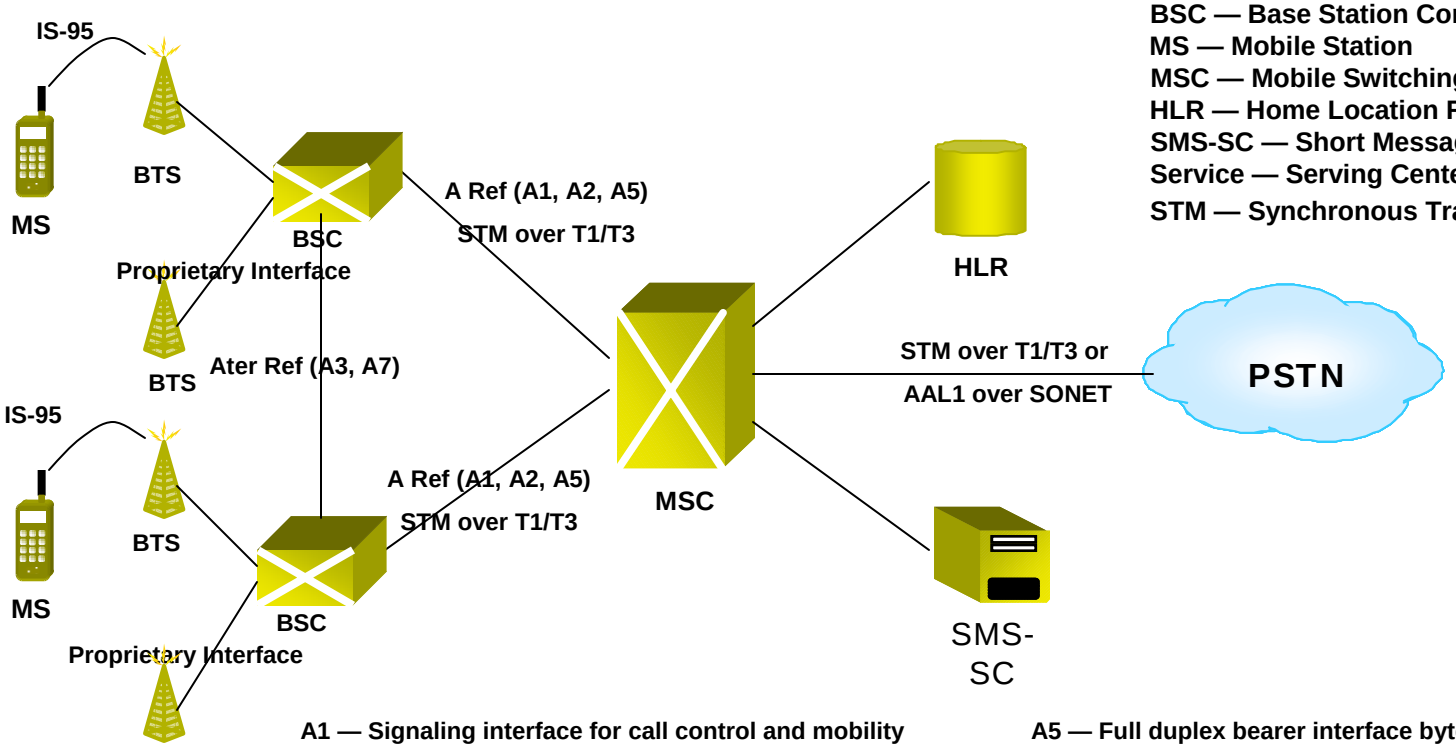
- **IP Multimedia Services, phase 2**
  - **IMS messaging and group management**
- **Wireless LAN interworking**
- **Speech enabled services**
  - **Distributed speech recognition (DSR)**
- **Number portability**
- **Other enhancements**

- **Scope and definition in progress**

3GPP2 Defines IS-41 Evolution

- **3rd Generation Partnership Project "Two"**
  - **Separate organization, as 3GPP closely tied to GSM and UMTS**
  - **Goal of ultimate merger (3GPP + 3GPP2) remains**
- **Evolution of IS-41 to "all IP" more direct but not any faster**
  - **Skips ATM stage**
- **1xRTT — IP packet support (like GPRS)**
- **1xEVDV — adds softswitch/ voice gateways**
- **3x — triples radio data rates**

2G cdmaOne (IS-95 + IS-41)



BTS — Base Transceiver Station
BSC — Base Station Controller
MS — Mobile Station
MSC — Mobile Switching Center
HLR — Home Location Registry
SMS-SC — Short Message Service — Serving Center
STM — Synchronous Transfer Mode

A1 — Signaling interface for call control and mobility Management between MSC and BSC

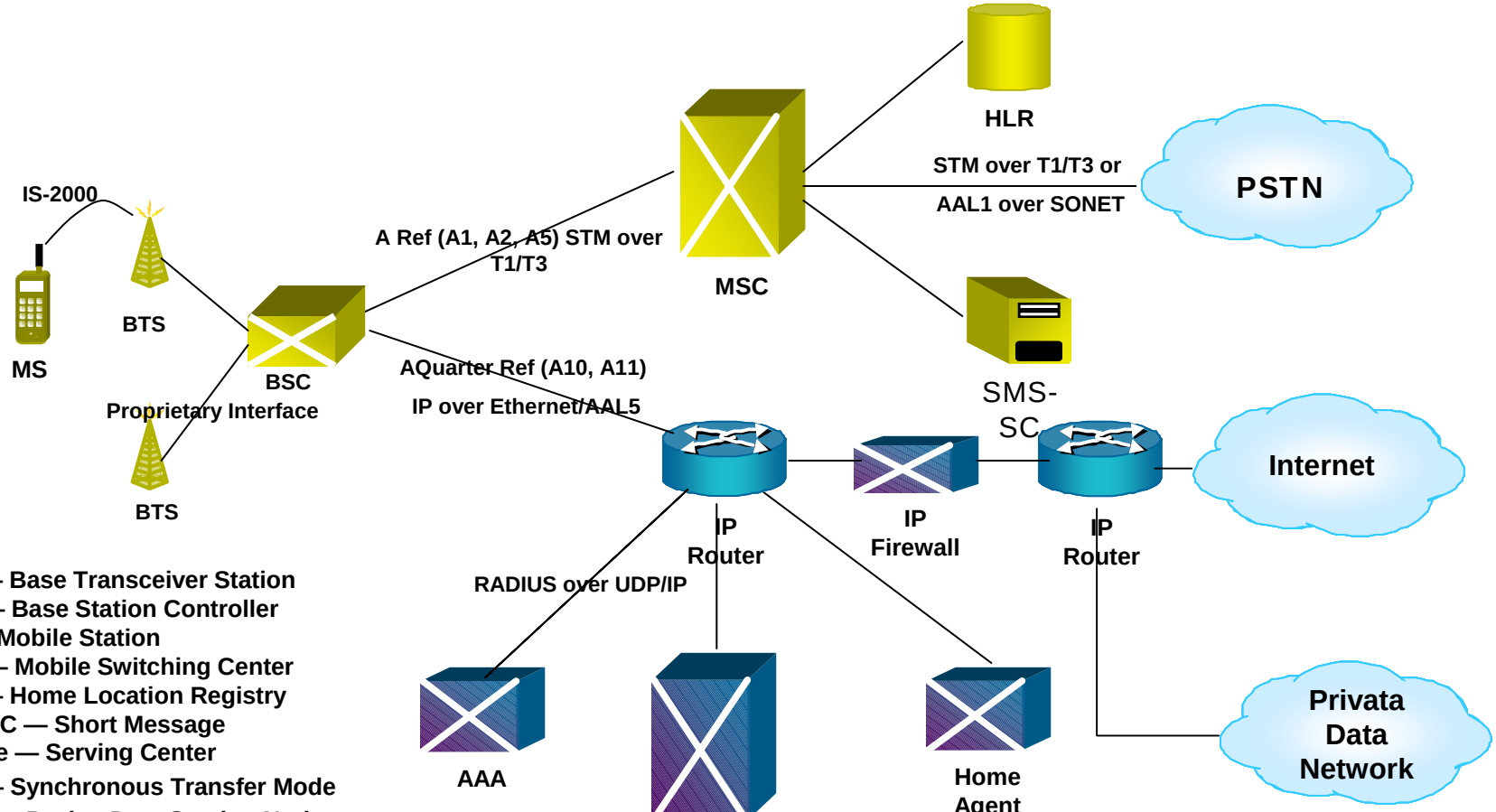
A2 — 64 kbps bearer interface for PCM voice

A3 — Signaling interface for inter-BSC mobile handoff

A5 — Full duplex bearer interface byte stream (SMS ?)

A7 — Bearer interface for inter-BSC mobile handoff

CDMA2000 1x Network



BTS — Base Transceiver Station
BSC — Base Station Controller
MS — Mobile Station
MSC — Mobile Switching Center
HLR — Home Location Registry
SMS-SC — Short Message
Service — Serving Center
STM — Synchronous Transfer Mode
PDSN — Packet Data Serving Node
AAA — Authentication, Authorization, and Accounting
Home Agent — Mobile IP Home Agent

A10 — Bearer interface between BSC (PCF) and PDSN for packet data
A11 — Signaling interface between BSC (PCF) and PDSN for packet data

Packet Data Serving Node (PDSN)

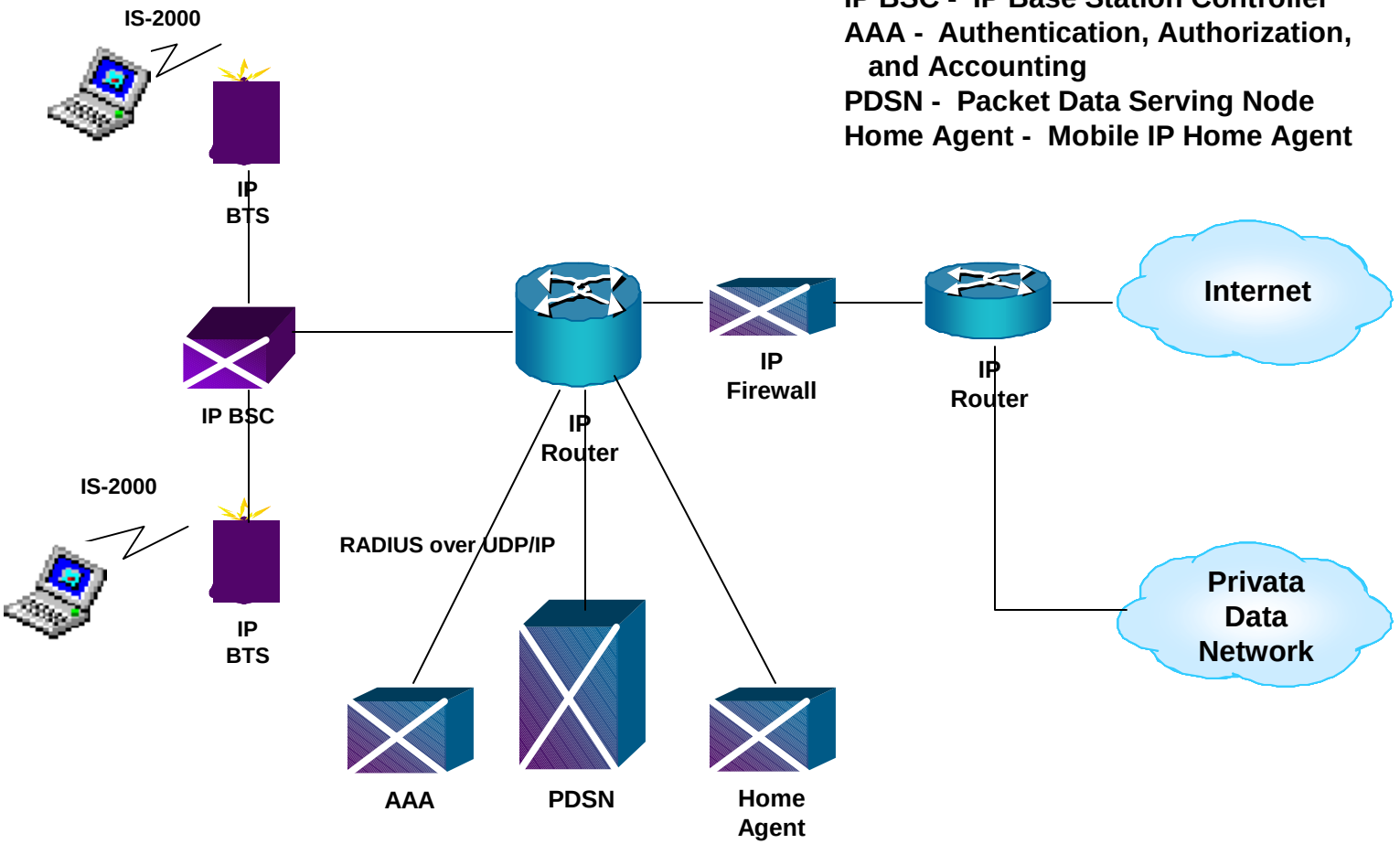
- **Establish, maintain, and terminate PPP sessions with mobile station**
- **Support simple and mobile IP services**
  - **Act as mobile IP Foreign Agent for visiting mobile station**
- **Handle authentication, authorization, and accounting (AAA) for mobile station**
  - **Uses RADIUS protocol**
- **Route packets between mobile stations and external packet data networks**
- **Collect usage data and forward to AAA server**

AAA Server and Home Agent

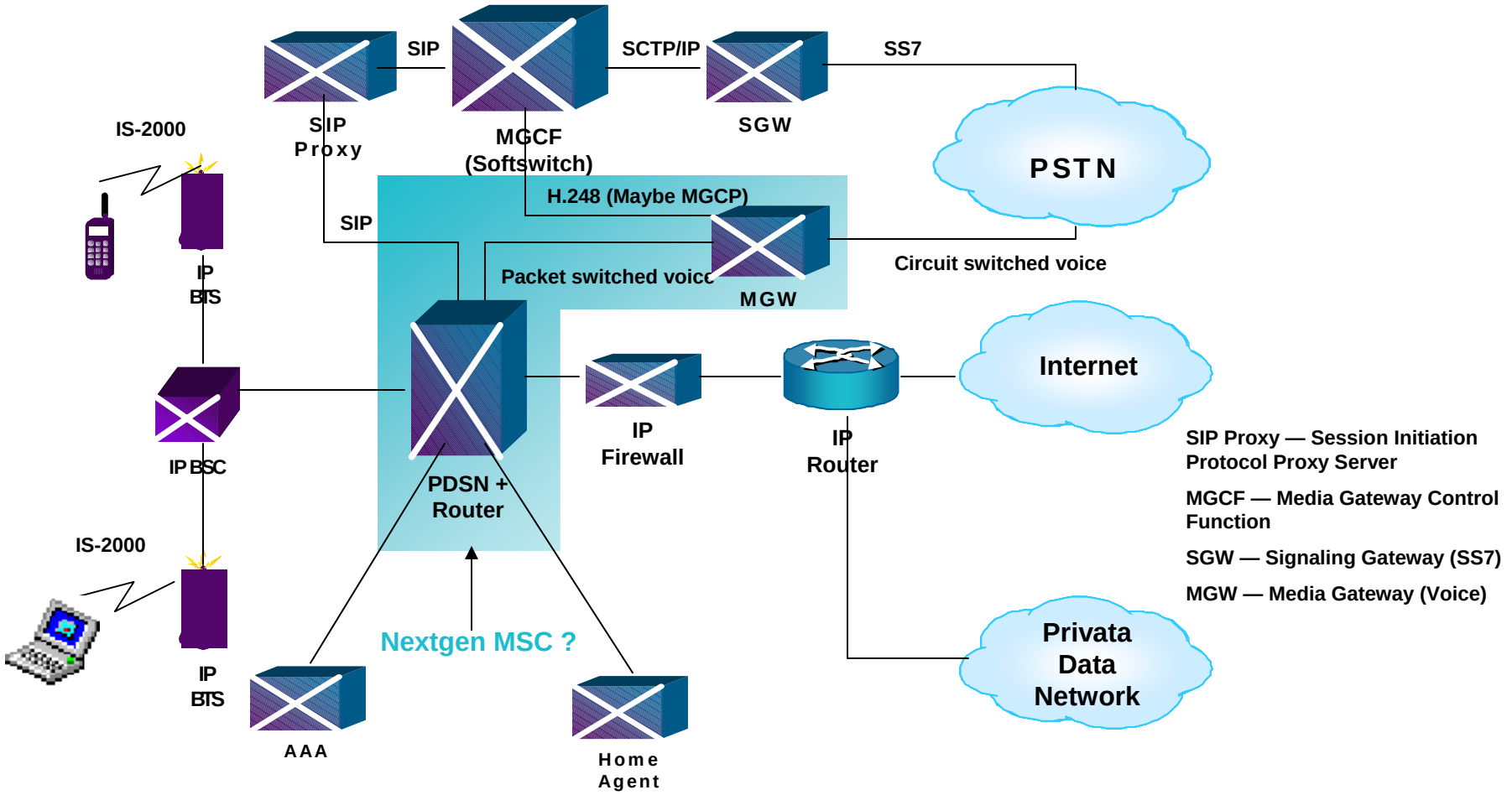
- **AAA server**
  - **Authentication: PPP and mobile IP connections**
  - **Authorization: service profile and security key distribution and management**
  - **Accounting: usage data for billing**
- **Mobile IP Home Agent**
  - **Track location of mobile IP subscribers when they move from one network to another**
  - **Receive packets on behalf of the mobile node when node is attached to a foreign network and deliver packets to mobile's current point of attachment**

1xEVDO — IP Data Only

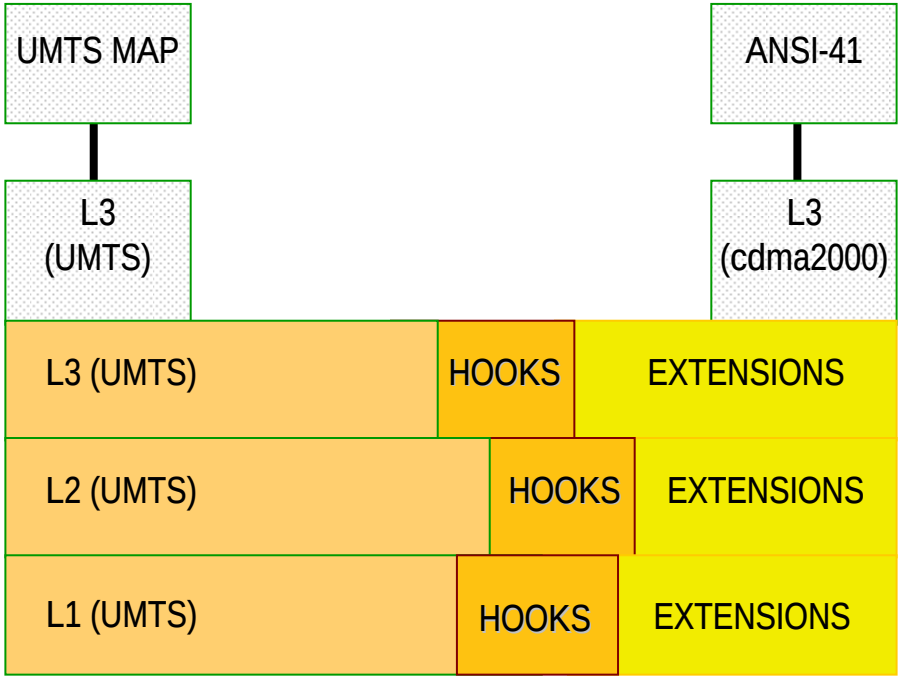
IP BTS - IP Base Transceiver Station
IP BSC - IP Base Station Controller
AAA - Authentication, Authorization, and Accounting
PDSN - Packet Data Serving Node
Home Agent - Mobile IP Home Agent



1XEVDV — IP Data and Voice



Approach for Merging 3GPP & 3GPP2 Core Network Protocols

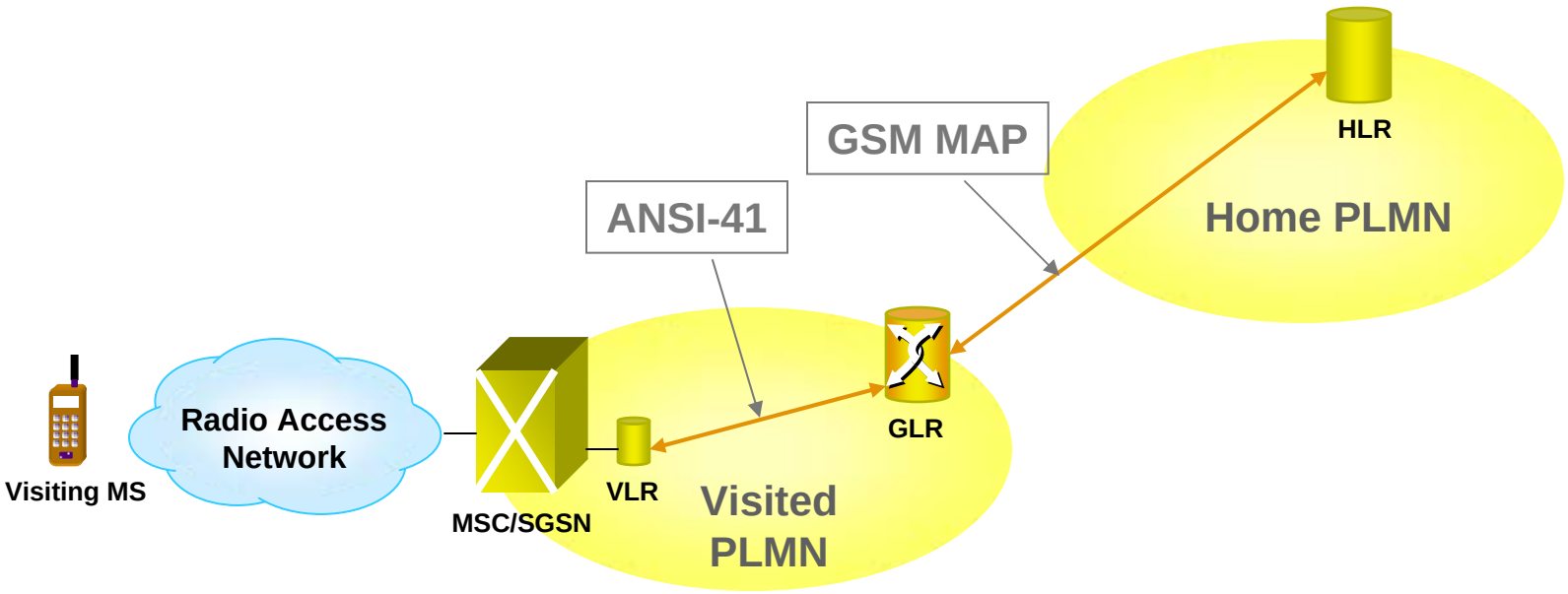


Gateway Location Register

- **Gateway between differing LR standards**
- **Introduced between VLR/SGSN and HLR**
  - **Single point for “hooks and extensions”**
  - **Controls traffic between visited mobile system and home mobile system**
- **Visited network’s VLR/SGSN**
  - **Treats GLR as roaming user’s HLR**
- **Home network’s HLR**
  - **Treats GLR as VLR/SGSN at visited network**
- **GLR physically located in visited network**
  - **Interacts with all VLRs in visited network**

Gateway Location Register Example

- **Mobile Station roaming in a PLMN with a different signaling protocol**



3GPP / 3GPP2 Harmonization

- **Joint meetings address interoperability and roaming**
  - **Handsets, radio network, core network**
- **« Hooks and Extensions » help to converge**
  - **Near term fix**
- **Target all-IP core harmonization**
  - **Leverage common specifications (esp. IETF RFCs)**
  - **Align terms, interfaces and functional entities**
  - **Developing Harmonization Reference Model (HRM)**
- **3GPP's IP Mutilmedia Services and 3GPP2's Multi-Media Domain almost aligned**

3G Tutorial

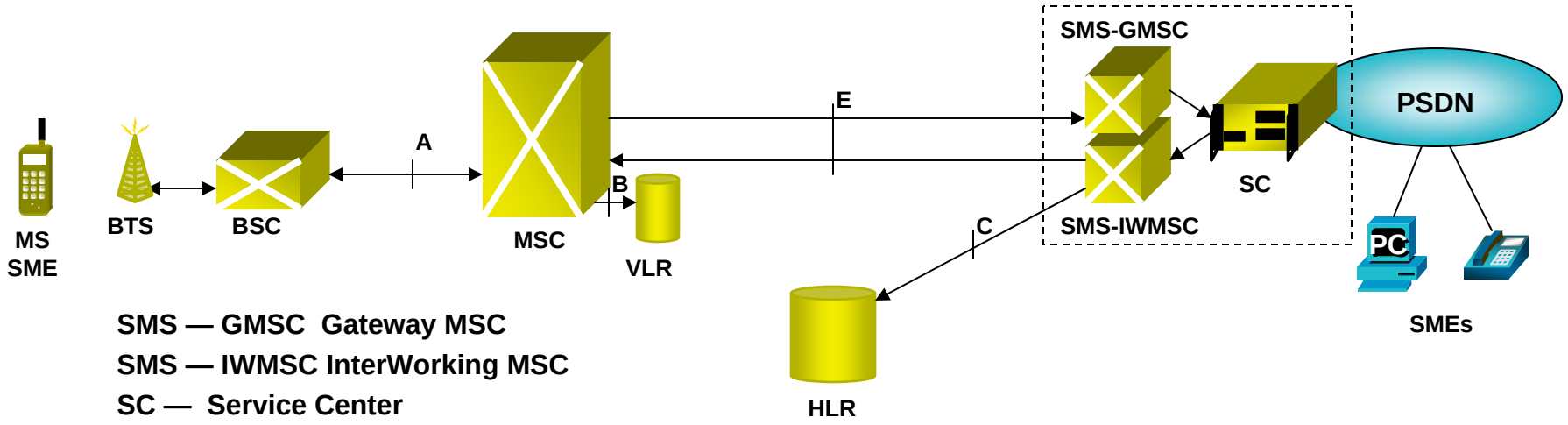
- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- Applications
- Business Models

Up and Coming Mobile Services

- **SMS, EMS, MMS**
- **Location-based services**
- **3G-324M Video**
- **VoIP w/o QoS; Push-to-Talk**
- **IP Multimedia Services (w/ QoS)**
- **Converged “All IP” networks — the Vision**

Short Message Service (SMS)

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

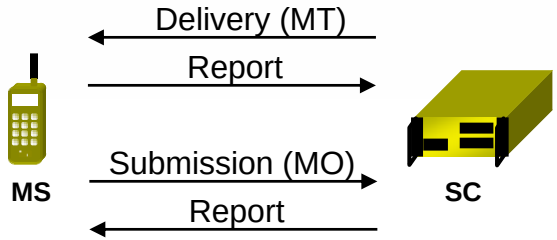


SMS — GMSC Gateway MSC
SMS — IWMSC InterWorking MSC
SC — Service Center
SME — Short Messaging Entity

SMS Principles

- **Basic services**
  - **SM MT (Mobile Terminated)**
  - **SM MO (Mobile Originated)**
  - **(3GPP2) SM MO can be cancelled**
  - **(3GPP2) User can acknowledge**
- **SM Service Center (3GPP) aka Message Center (3GPP2)**
  - **Relays and store-and-forwards SMSs**
- **Payload of up to 140 bytes, but**
  - **Can be compressed (MS-to-MS)**
  - **And/or segmented in several SMs**

SMS Transport



- **Delivery / Submission report**
  - **Optional in 3GPP2**
- **Messages-Waiting**
  - **SC 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 have IP option**

EMS Principles

- **Enhanced Message Service**
- **Leverages SMS infrastructure**
- **Formatting attributes in payload allow:**
  - **Text formatting (alignment, font size, style, colour…)**
  - **Pictures (e.g. 255x255 color) or vector-based graphics**
  - **Animations**
  - **Sounds**
- **Interoperable with 2G SMS mobiles**
  - **2G SMS spec had room for payload formatting**
  - **2G MS ignore special formats**

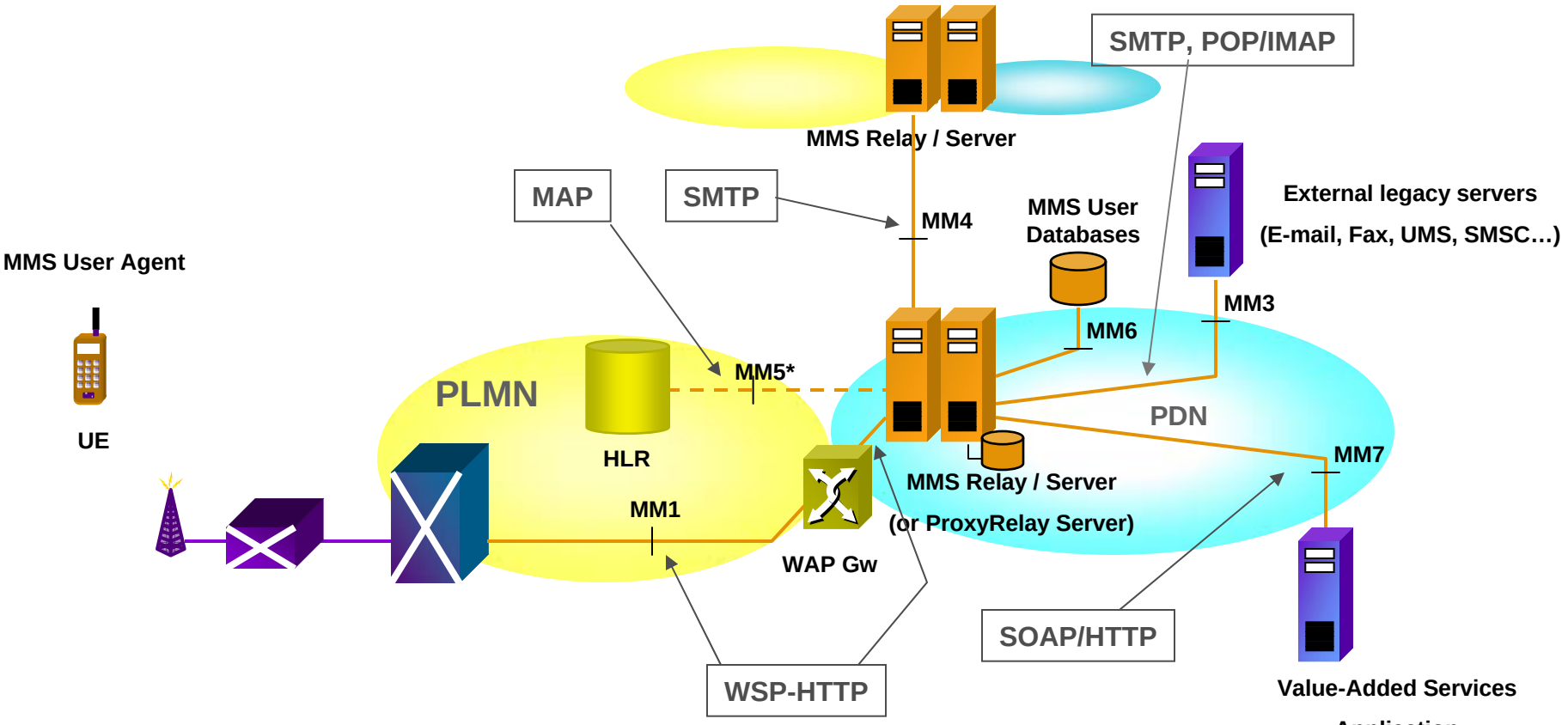
MMS Principles (1)

- **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 (2)

- **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 MMBox, i.e. a mail box**
- **Optional support of media streaming (RTP/RTSP)**

MMS Architecture



(*) Optional

Location

- **Driven by e911 requirements in US**
  - **FCC mandated; not yet functioning as desired**
  - **Most operators are operating under “waivers”**
- **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**
- **Significant privacy issues**

Location Technology

- **Cell identity: crude but available today**
- **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**

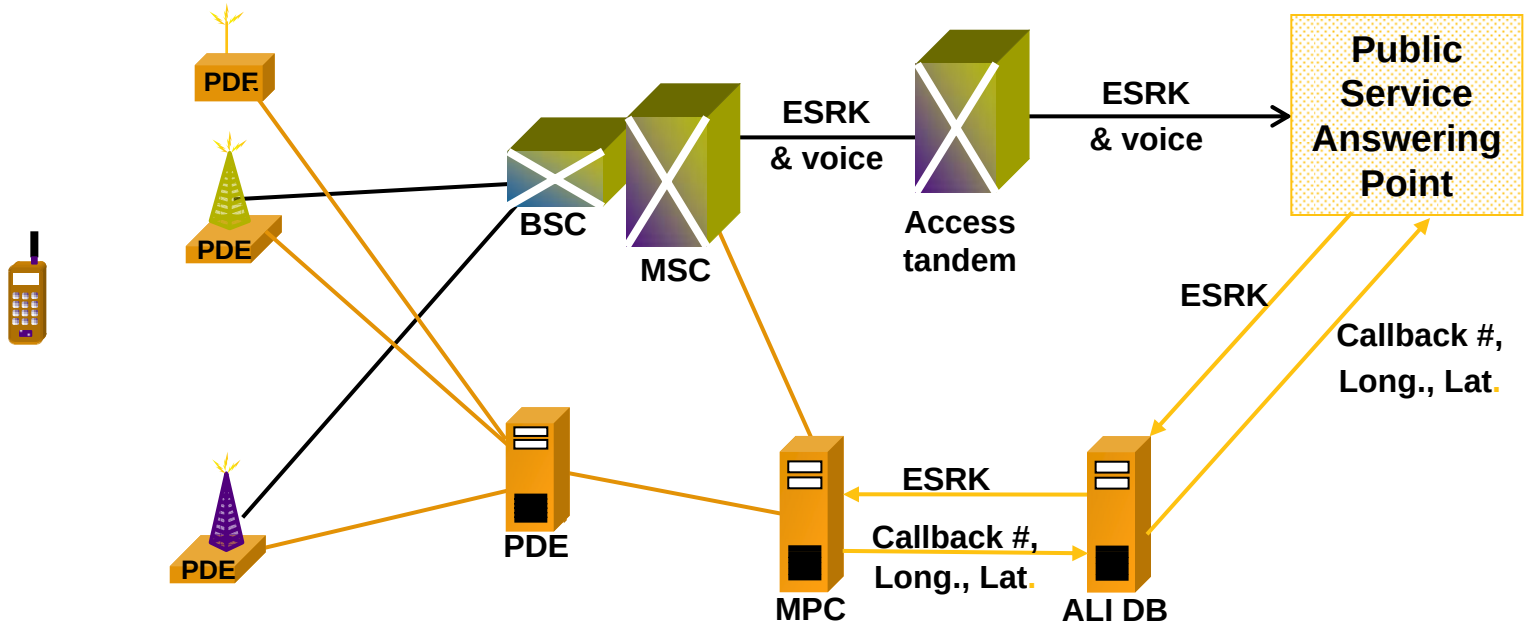
Location-Based Services

- **Emergency services**
  - **E911 - Enhanced 911**
- **Value-added personal services**
  - **friend finder, directions**
- **Commercial services**
  - **coupons or offers from nearby stores**
- **Network internal**
  - **Traffic & coverage measurements**
- **Lawful intercept extensions**
  - **law enforcement locates suspect**

Location Information

- **Location (in 3D), speed and direction**
  - **with timestamp**
- **Accuracy of measurement**
- **Response time**
  - **a QoS measure**
- **Security & Privacy**
  - **authorized clients**
  - **secure info exchange**
  - **privacy control by user and/or operator**

US E911 Phase II Architecture

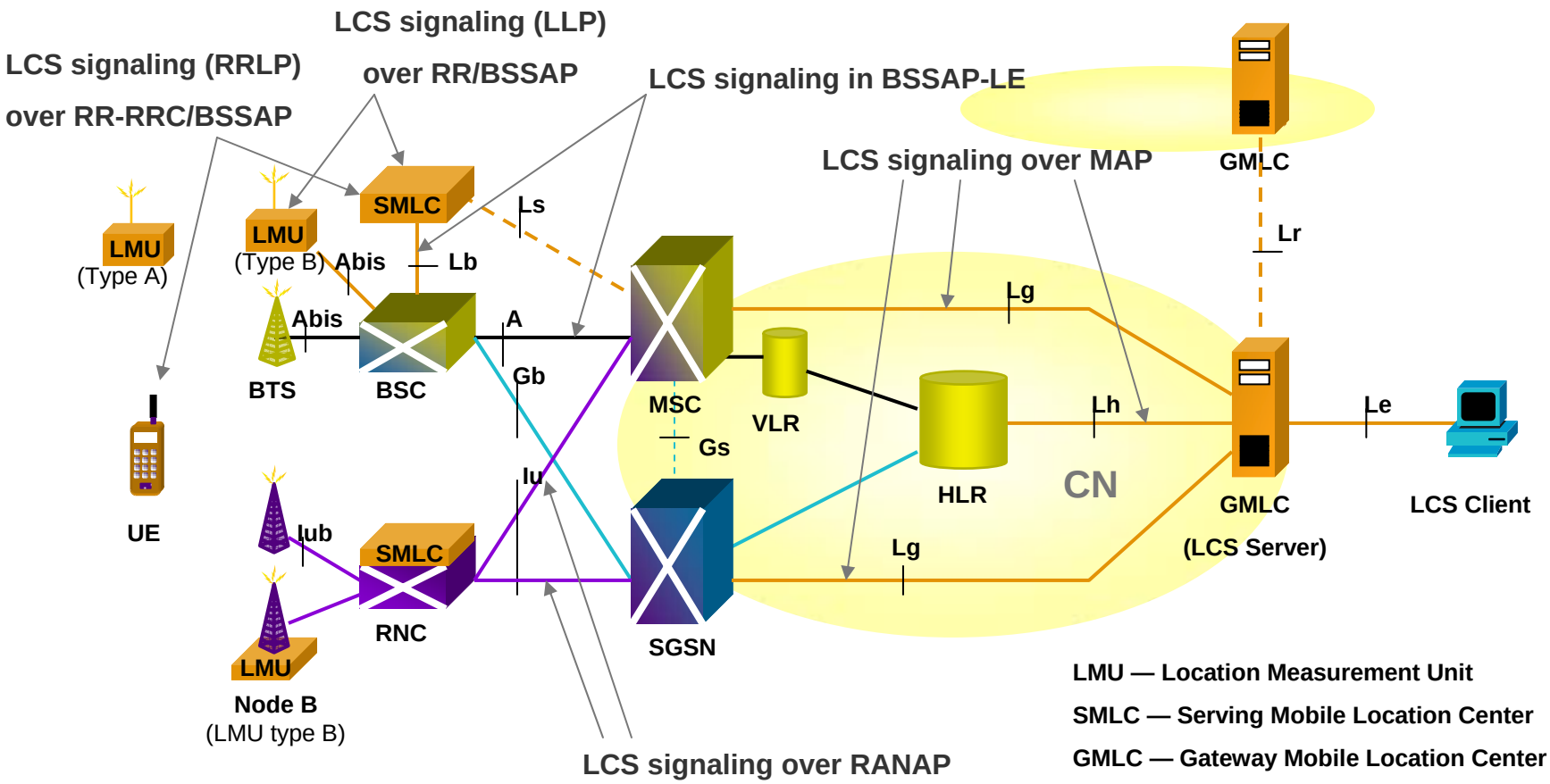


PDE — Position Determining Entity
MPC — Mobile Positioning Center
ESRK — Emergency Service Routing Key
ALI DB — Automatic Location Identification Data Base

3GPP Location Infrastructure

- **UE (User Entity)**
  - **May assist in position calculation**
- **LMU (Location Measurement Unit)**
  - **distributed among cells**
- **SMLC (Serving Mobile Location Center)**
  - **Standalone equipment (2G) or integrated into BSC (2G) or RNC (3G)**
- **Leverages normal infrastructure for transport and resource management**

LCS Architecture (3GPP)



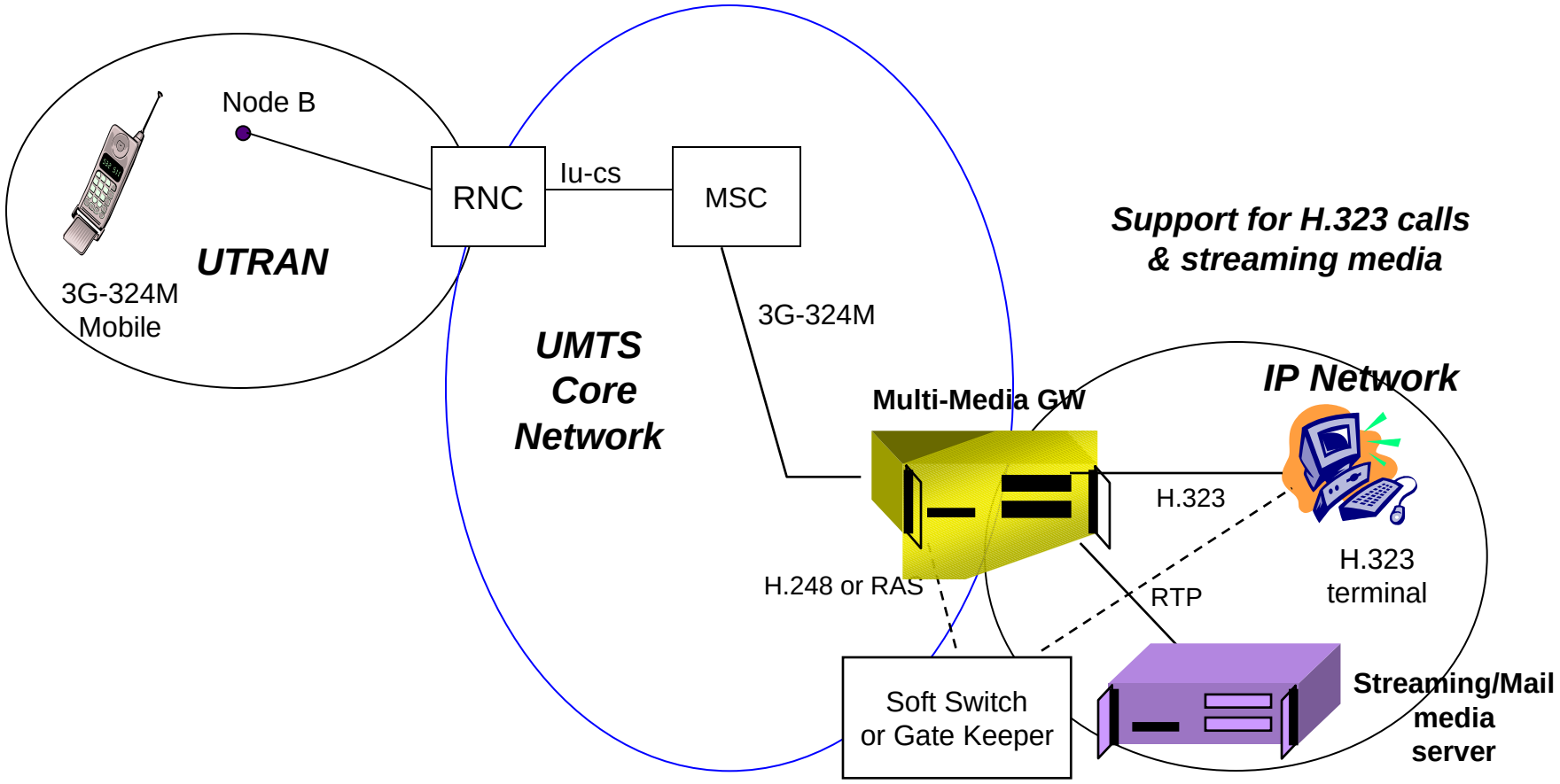
Location Request

- **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**

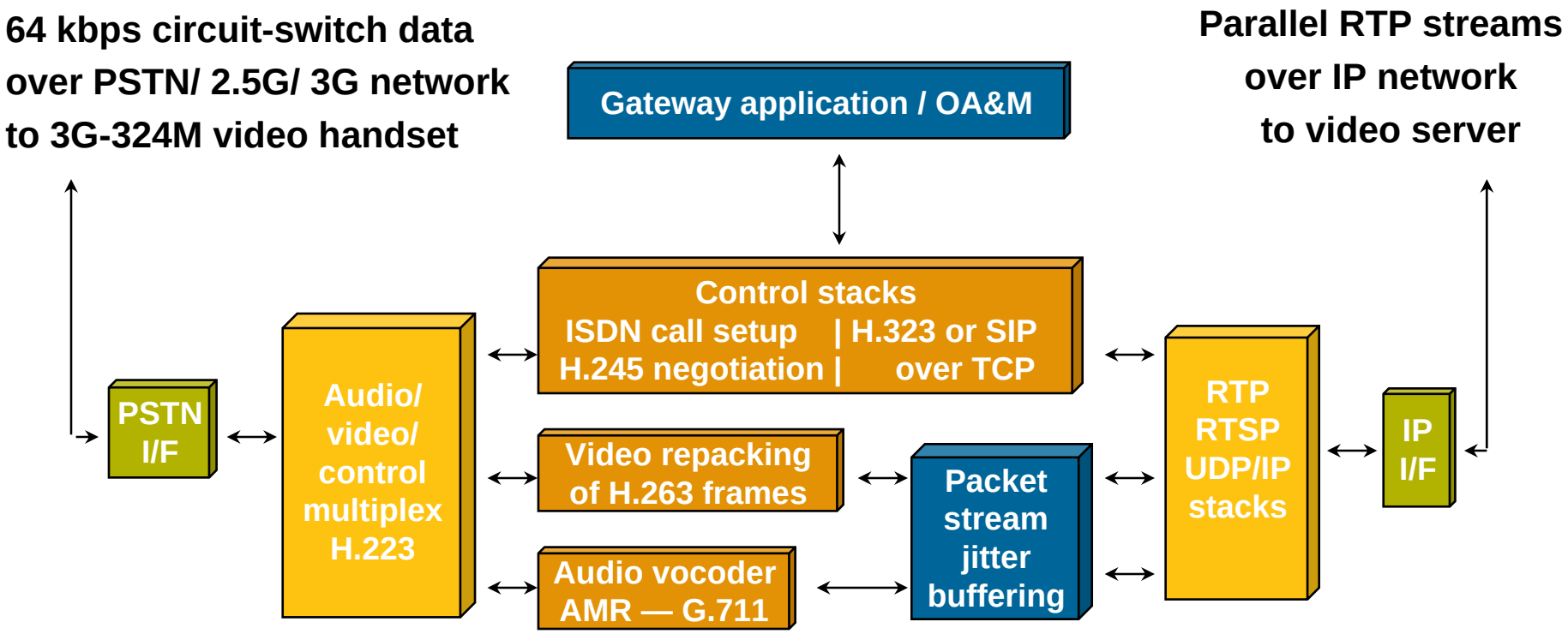
3G-324M Video Services

- **Initial mobile video service uses 3G data bandwidth w/o IP multimedia infrastructure**
  - **Deployed by DoCoMo in Japan today**
- **Leverage high speed circuit-switch data path**
  - **64 kbps H.324 video structure**
  - **MPEG 4 video coding**
  - **AMR audio coding**
- **Supports video clips, video streaming and live video conversations**
  - **MS to MS**
  - **MS to Internet or ISDN with gateways**

Common Technology Platform for 3G-324M Services

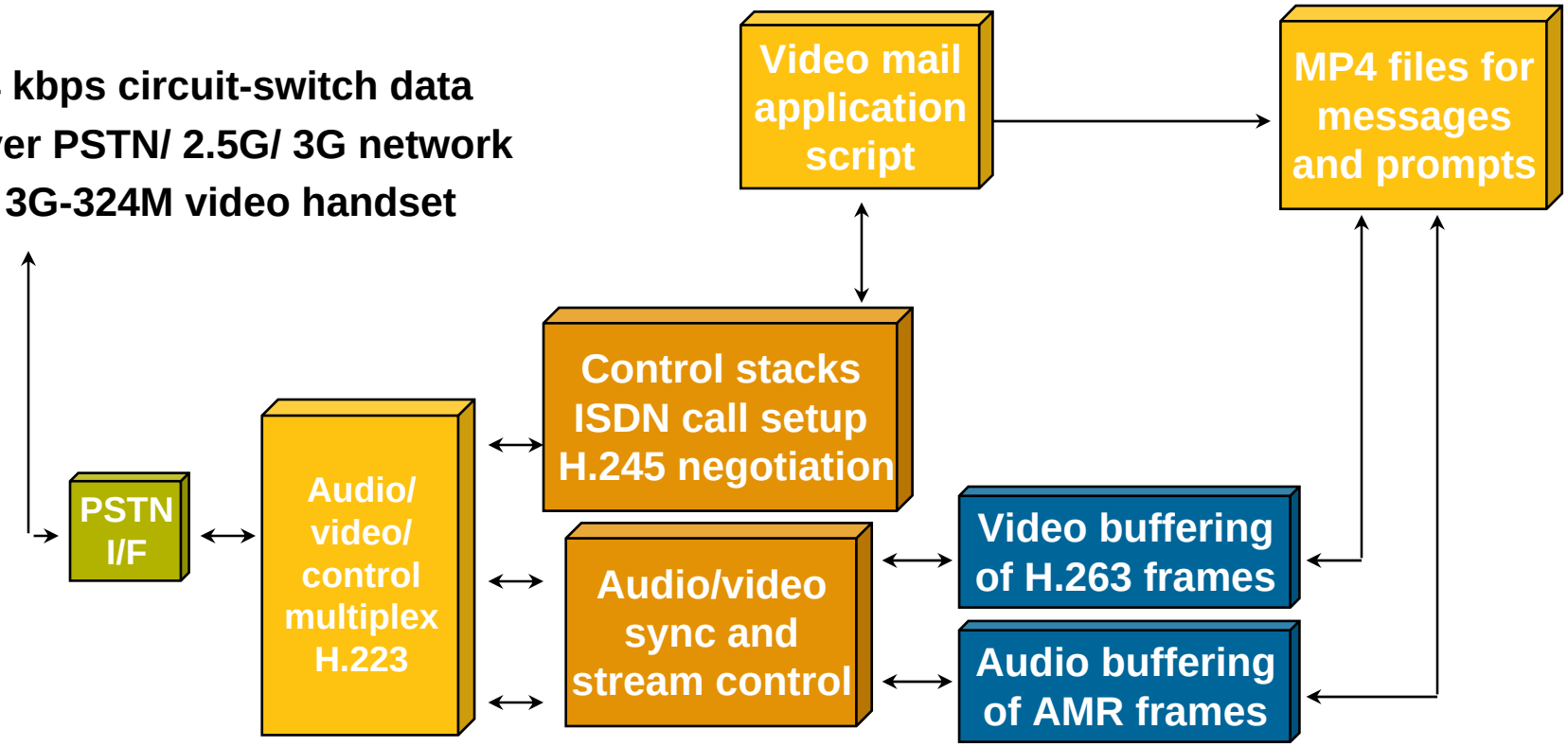


Gateway: 3G-324M to MPEG4 over RTP



Video Messaging System for 3G-324M

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



Push-toTalk

VoIP before QoS is Available

- **Nextel's "Direct Connect" service credited with getting them 20-25% extra ARPU**
  - **Based on totally proprietary iDEN**
  - **Other carriers extremely jealous**
- **Push-to-talk is half duplex**
  - **Short delays OK**
- **Issues remain**
  - **Always on IP isn't always on; radio connection suspended if unused; 2-3 seconds to re-establish**
- **Sprint has announced they will be offering a push-to-talk service on their 1xRTT network**

«All IP» Services

- **IP Multimedia Subsystem (IMS) — 3GPP**
- **Multi-Media Domain (MMD) — 3GPP2**

- **Voice and video over IP with quality of service guarantees**
  - **Obsoletes circuit-switched voice equipment**

- **Target for converging the two disparate core network architectures**

IMS / MMD Services

- **Presence**
- **Location**
- **Instant Messaging (voice+video)**
- **Conferencing**
- **Media Streaming / Annoucements**
- **Multi-player gaming with voice channel**

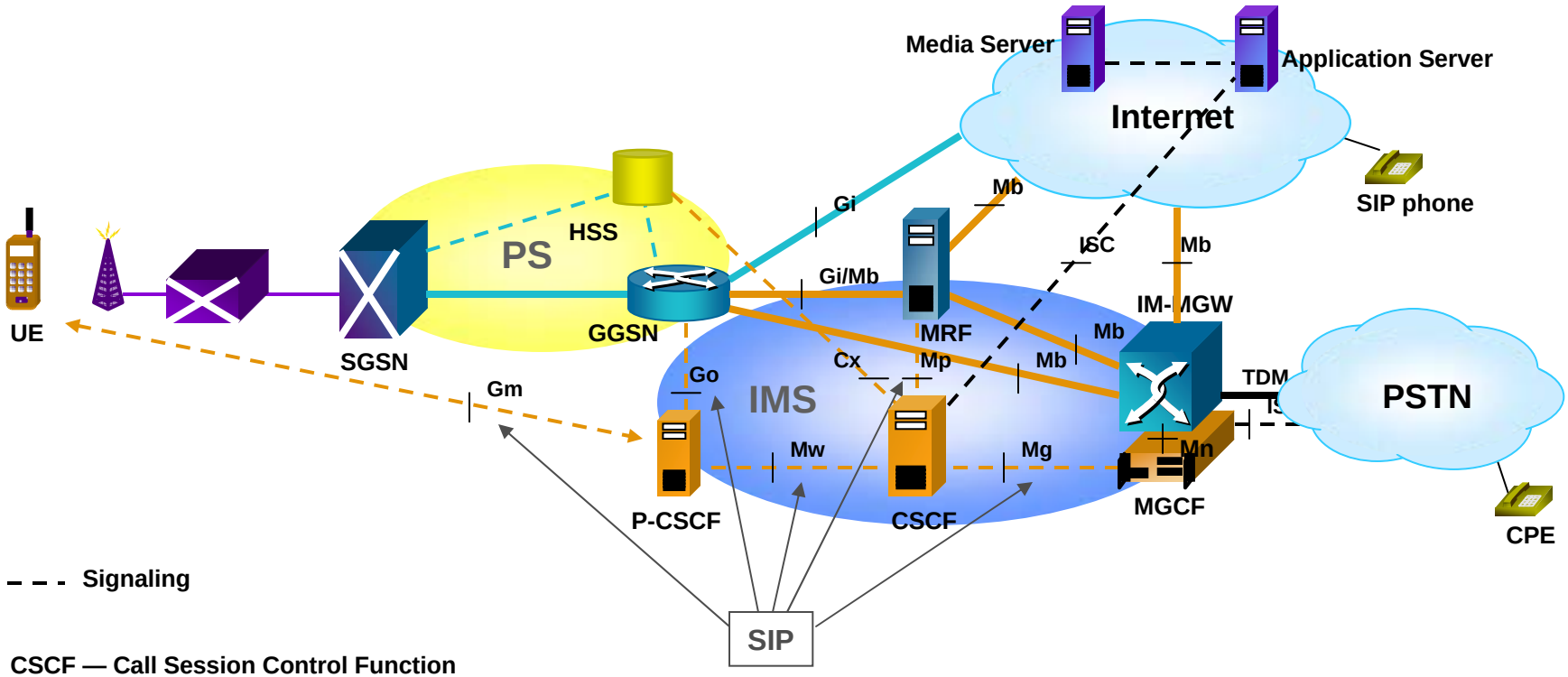
3G QoS

- **Substantial new requirements on the radio access network**
- **Traffic classes**
  - **Conversational, streaming, interactive, background**
- **Ability to specify**
  - **Traffic handling priority**
  - **Allocation/retention priority**
  - **Error rates (bits and/ or SDUs)**
  - **Transfer delay**
  - **Data rates (maximum and guaranteed)**
  - **Deliver in order (Y/N)**

IMS Concepts (1)

- **Core network based on Internet concepts**
  - **Independent of circuit-switched networks**
  - **Packet-switched transport for signaling and bearer traffic**
- **Utilize existing radio infrastructure**
  - **UTRAN — 3G (W-CDMA) radio network**
  - **GERAN — GSM evolved radio network**
- **Utilize evolving handsets**

IMS Architecture



CSCF — Call Session Control Function

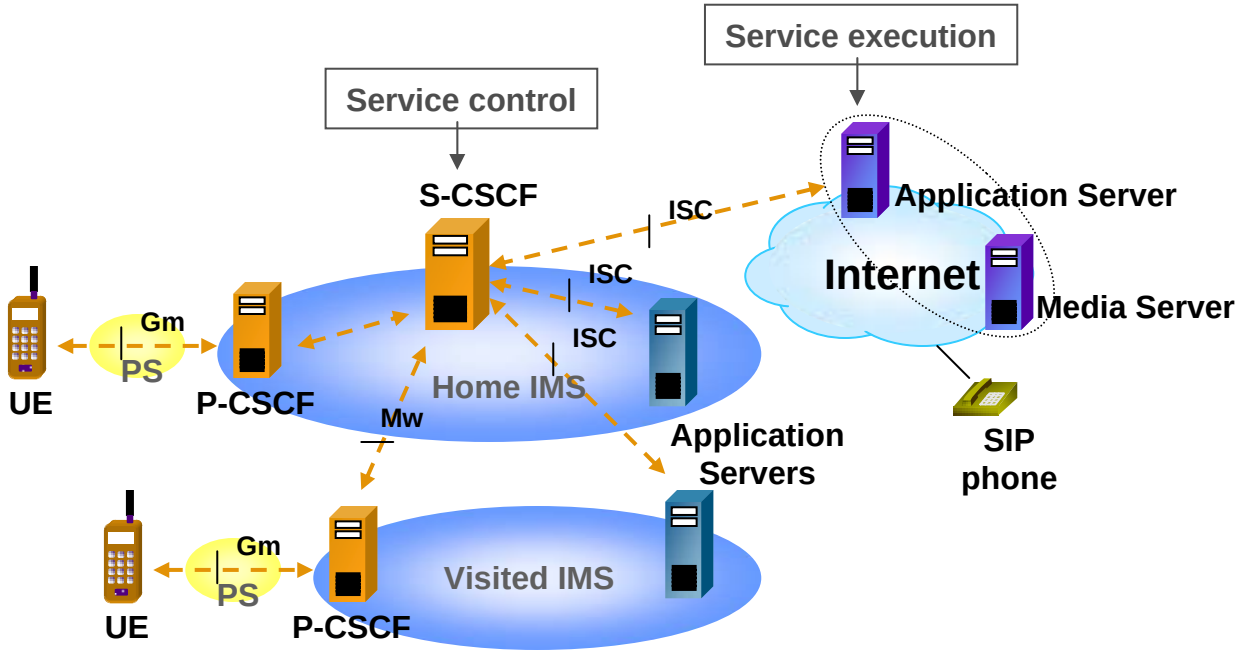
IM-MGW — IM-Media Gateway

MGCF — Media Gateway Control Function

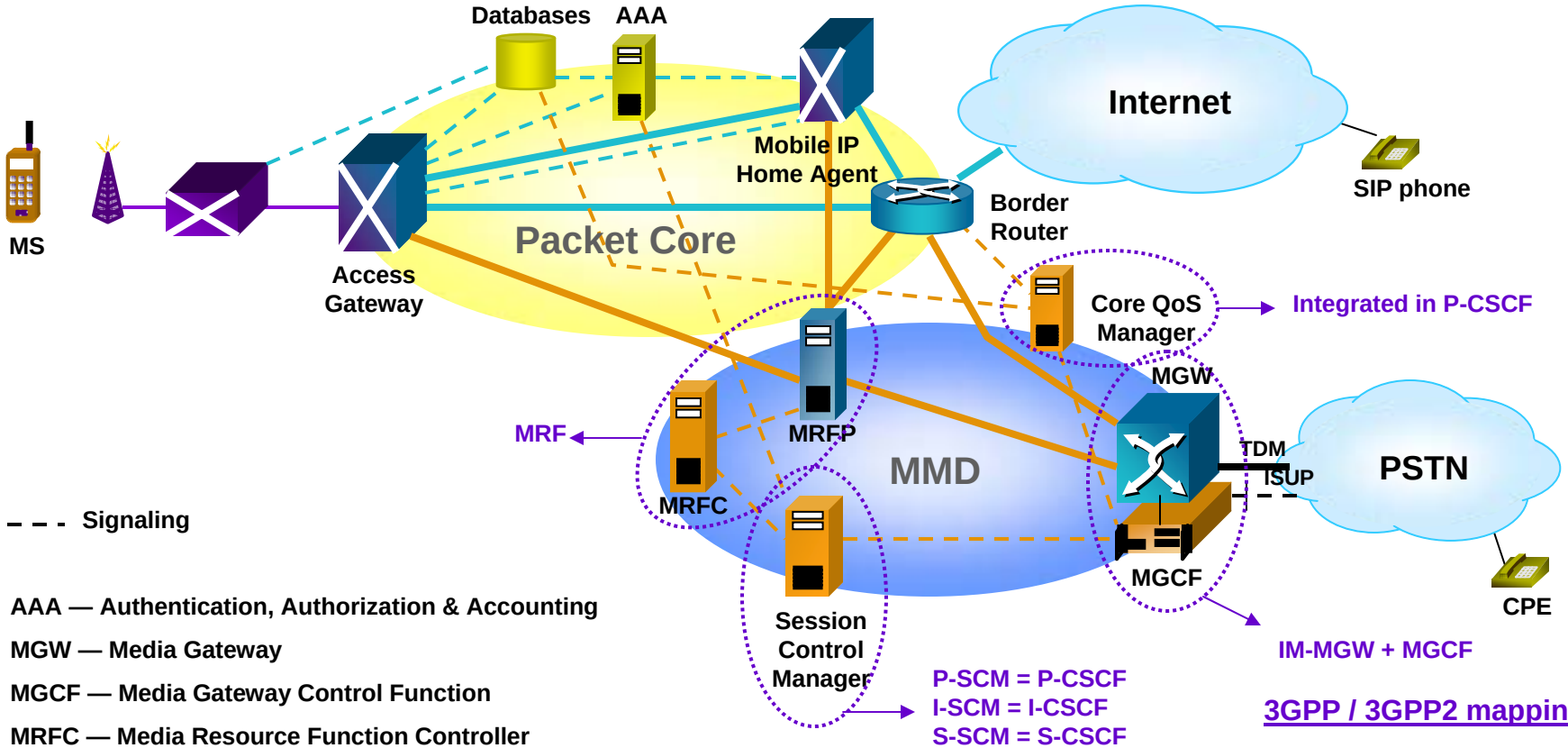
MRF — Media Resource Function

IMS Concepts (2)

- **In Rel.5, services controlled in home network (by S-CSCF)**
  - **But executed anywhere (home, visited or external network) and delivered anywhere**



MMD Architecture —
3GPP2 MultiMedia Domain



AAA — Authentication, Authorization & Accounting

MGW — Media Gateway

MGCF — Media Gateway Control Function

MRFC — Media Resource Function Controller

MRFP — Media Resource Function Processor

3G Tutorial

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- Applications
- Business Models

Killer Applications

- **Community and Identity most important**
  - **Postal mail, telephony, email, instant messaging, SMS, chat groups — community**
  - **Designer clothing, ring tones — identity**
- **Information and Entertainment also**
  - **The web, TV, movies**
- **Content important, but content is not king!**
  - **Movies $63B (worldwide) (1997)**
  - **Phone service $256B (US only)**
  - **See work by Andrew Odlyzko; here: http://www.dtc.umn.edu/~odlyzko/doc/recent.html**

2.5G & 3G Application Issues

- **No new killer apps**
  - **Many potential niche applications**
- **Voice and data networks disparate**
  - **“All IP” mobile networks years away**
- **Existing infrastructure “silo” based**
  - **Separate platforms for voice mail, pre-paid,**
  - **Deploying innovative services difficult**
- **Billing models lag**
  - **Poor match for application-based services**

Multimodal Services and Multi-Application Platforms

- **Combined voice and data applications**
  - **Today, without “all IP” infrastructure**
  - **Text messaging plus speech recognition-enabled voice services**
  - **Evolve from as new services become available**
- **Multi-application platform**
  - **Integrate TDM voice and IP data**
  - **Support multiple applications**
  - **Flexible billing and provisioning**

Sample Multimodal Applications

- **Travel information**
  - Make request via voice
  - Receive response in text
- **Directions**
  - Make request via voice
  - Receive initial response in text
  - Get updates while traveling via voice or SMS or rich graphics
- **One-to-many messaging**
  - Record message via voice or text
  - Deliver message via voice, SMS, WAP, or email

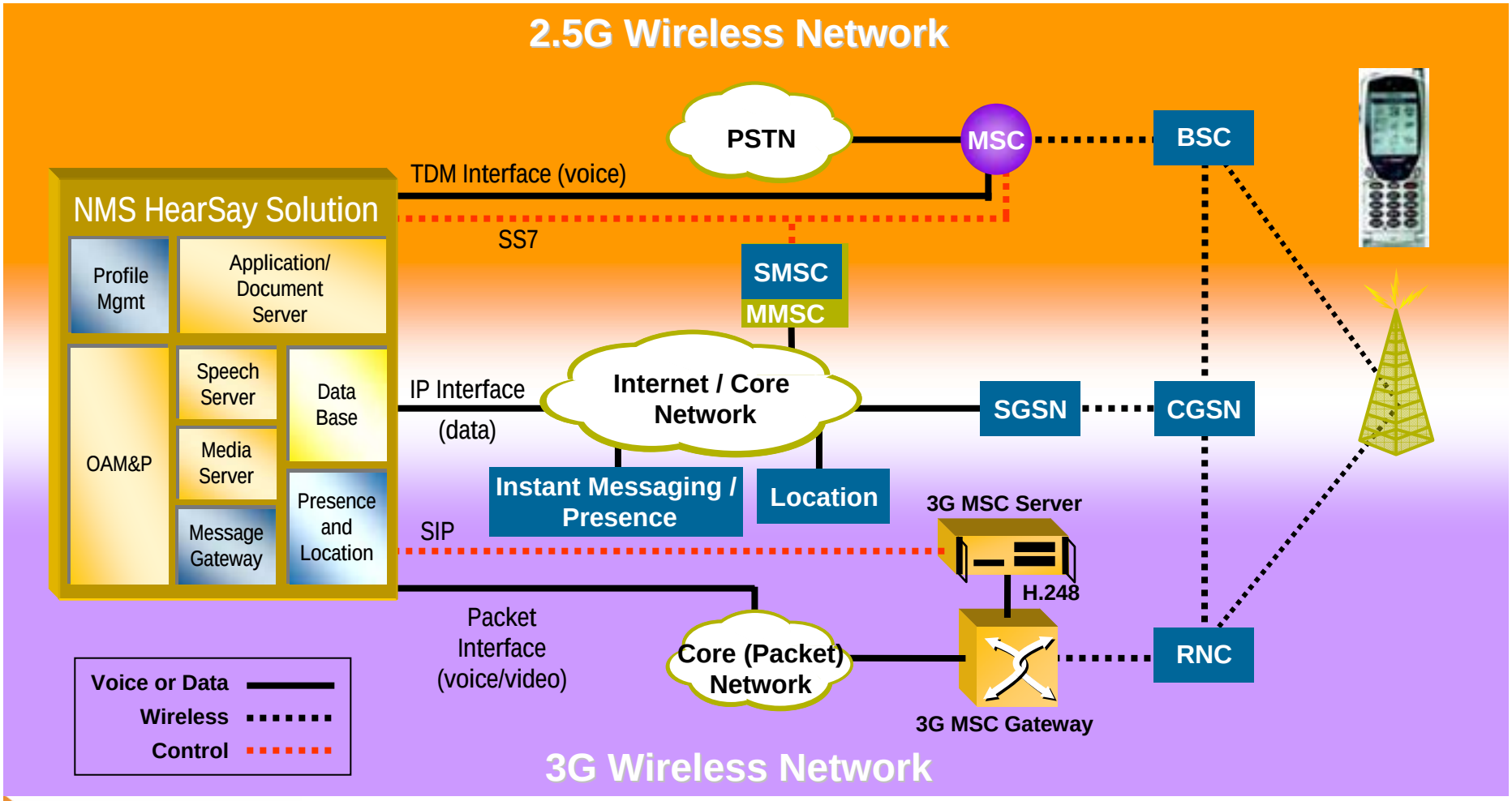
More Multimodal Examples

- **Purchasing famous person's voice for your personal answering message**
  - **Text or voice menus**
  - **Voice to hear message**
  - **Voice or text to select (and authorize payment)**
- **Unified communications**
  - **While listening to a voice message from a customer, obtain a text display of recent customer activity**
- **Emergency response team**
  - **SMS and voice alert**
  - **Voice conference, and text updates, while traveling to site of emergency**

Early Deployments

- **Cricket matches (Hutchinson India)**
  - **SMS alert at start of coverage**
  - **Live voice coverage or text updates**
- **Information delivery (SFR France)**
  - **SMS broadcast with phone # & URL**
  - **Choice of text display or voice (text-to-speech)**
- **Yellow pages (Platinet Israel)**
  - **Adding voice menus to existing text-based service**
  - **Voice flattens menus, eases access**

Multimodal Applications in the Evolving Wireless Network



3G Tutorial

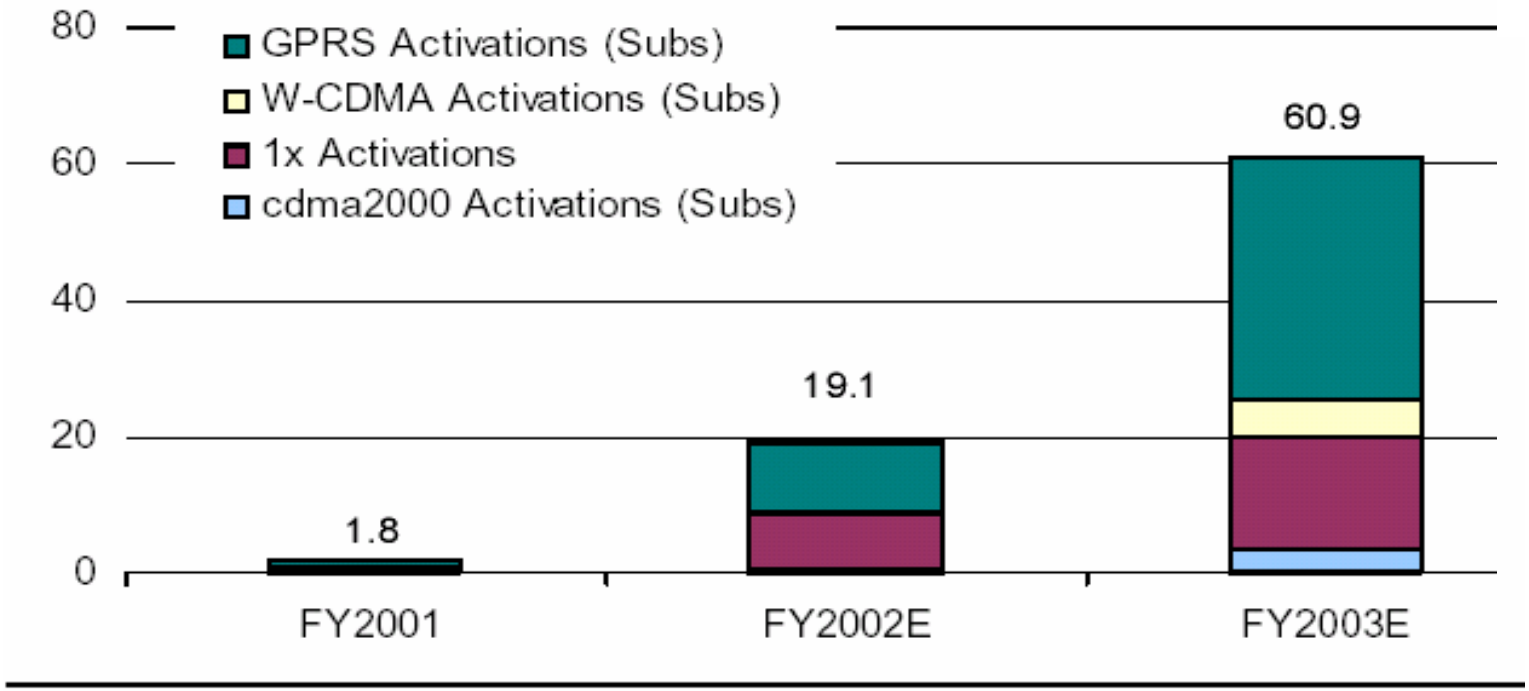
- History and Evolution of Mobile Radio
- Evolving Network Architectures
- Evolving Services
- Applications
- Business Models

Upgrade Cost, By Technology

2G	GSM	CDMA	TDMA
2.5G / 2.75G	GPRS	CDMA 1x	GSM/GPRS/EDGE
Software/Hardware	Software-based	Hardware-based	Hardware and software
Cost	Incremental	Substantial	Middle of the road
3G	W-CDMA	cdma2000	W-CDMA
Software/Hardware	Hardware-based	Software-based	Hardware-based
Cost	Substantial	Incremental	Middle of the road

- **CDMA upgrade to 2.75G is expensive; to 3G is cheap**
- **GSM upgrade to 2.5G is cheap; to 3G is expensive**
- **TDMA upgrade to 2.5G/3G is complex**
- **Takeaway: AT&T and Cingular have a difficult road to 3G**

2.5G & 3G Uptake



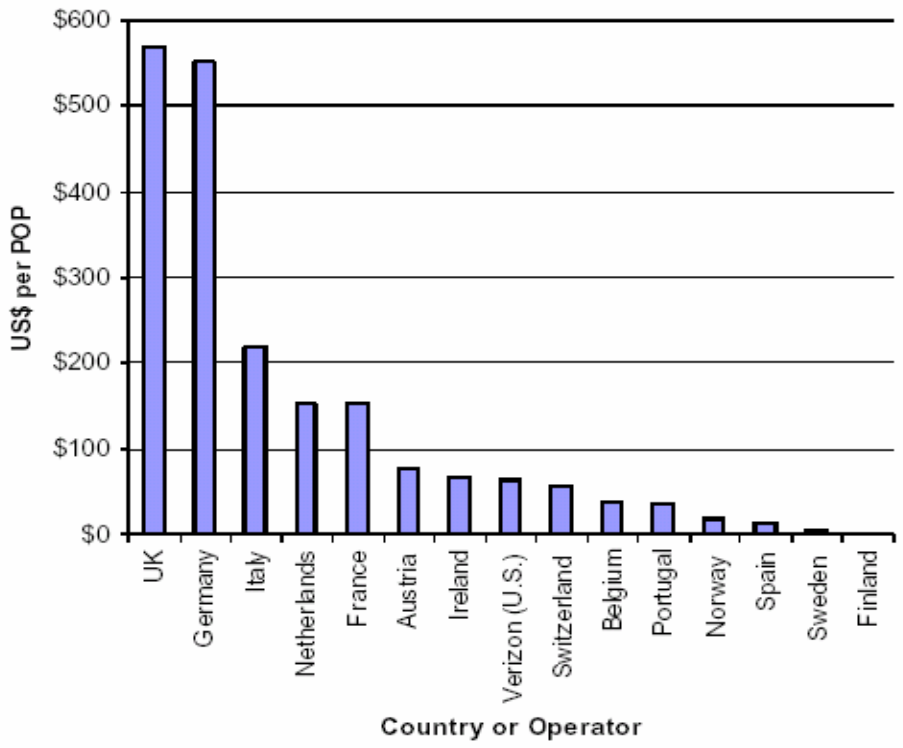
Handsets and subscribers are not cumulative
Source: U.S. Bancorp Piper Jaffray

3G Spectrum Expensive

Exhibit 1.11

COST OF 3G FREQUENCY PER POP

Country or Operator	Spectrum Cost / POP
UK	$570
Germany	$551
Italy	$218
Netherlands	$153
France	$152
Austria	$77
Ireland	$65
Verizon (U.S.)	$63
Switzerland	$55
Belgium	$39
Portugal	$36
Norway	$18
Spain	$12
Sweden	$5
Finland	$0



Source: Spectrum Strategy Consultants and QUALCOMM

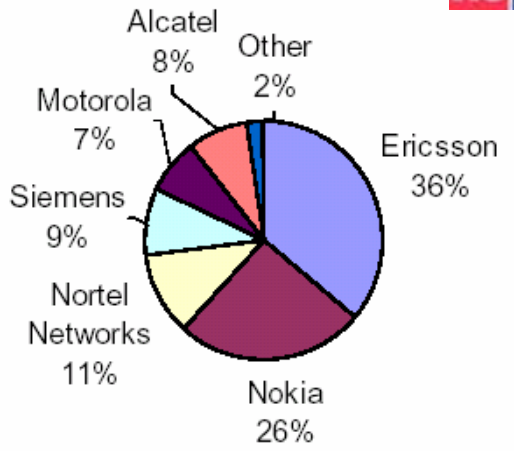
GPRS (2.5G) Less Risky

Exhibit 4.6

CUMULATIVE GPRS CONTRACTS BY VENDOR

(As Of January 1, 2002)

	Share	Contract Wins
Ericsson	36.1%	78
Nokia	25.5%	55
Nortel Networks	11.1%	24
Siemens	9.3%	20
Motorola	7.4%	16
Alcatel	8.3%	18
Other	2.3%	5
TOTAL	**100.0%**	**216**



Source: U.S. Bancorp Piper Jaffray

- **Only $15k~$20k per base station**
- **Allows operators to experiment with data plans**

… But falls short because:

- **Typically 30~50 kbps**
- **GPRS decreases voice capacity**

EDGE Cheaper and Gives Near-3G Performance

Exhibit 1.5

DATA THROUGHPUT SPEEDS OVER FIXED LINE VS. WIRELESS NETWORKS

Modem	Technology	Throughput	1 MB File Download Speed
GSM/TDMA	2G Wireless	<9.6 Kbps	~20 min
Analog Modem	Fixed Line Dial-up	9.6 Kbps	16 min
GPRS	2.5G Wireless	30-40 Kbps	4.5 min
ISDN	Fixed Line Digital	128 Kbps	1.1 min
CDMA 1x	2.75G Wireless	144 Kbps	50 sec
EDGE	2.75G Wireless	150 - 200 Kbps	36 to 47 sec
DSL	Fixed Line DSL	0.7 - 1.5 Mbps	1 to 3 sec
W-CDMA	3G Wireless	1.0 Mbps	1.5 sec
Cable	Fixed Line Cable	1.0 - 2.0 Mbps	0.8 to 1.5 sec

- **EDGE is 2.75G, with significantly higher data rates than GPRS**
- **Deploying EDGE significantly cheaper than deploying W-CDMA**
- **Takeaway: Look for EDGE to gain traction in 2002/2003+**

Long Life for 2.5G & 2.75G

"We believe the shelf life of 2.5G and 2.75G will be significantly longer than most pundits have predicted. Operators need to gain valuable experience in how to market packet data services before pushing forward with the construction of new 3G networks."

- **Sam May, US Bancorp Piper Jaffray**

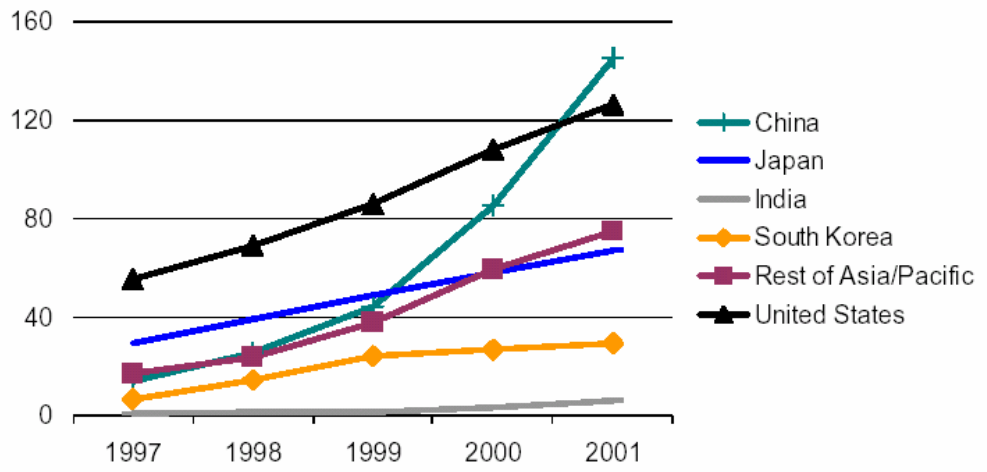
- **Operators need to learn how to make money with data**
- **Likely to stay many years with GPRS/EDGE/CDMA 1x**
- **Bottom line: wide-scale 3G will be pushed out**

Critical For 3G — Continued Growth In China

Exhibit 3.5

WIRELESS SUBSCRIBERS—MAJOR GEOGRAPHIES

(In Millions)



Source: U.S. Bancorp Piper Jaffray, Global Mobile

Likely 3G licensing outcomes:

- **China Unicom — cdma2000**
- **China Mobile — W-CDMA**
- **China Telecom — W-CDMA/ TD-SCDMA?**
- **China Netcom — W-CDMA/ TD-SCDMA?**

Risk:

- **CDMA IS-95 (2G) has been slow to launch in China**
  - **Why would the launch of 3G be any different?**
- **PHS (2G) with China Telecom/Netcom is gaining momentum**

Business Models

Walled Garden or Wide Open?

- **US and European carriers want to capture the value — be more than just transport**
  - **Cautious partnering; Slow roll out of services**
- **DoCoMo I-Mode service primitive**
  - **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" available for 9% share**
- **I-Mode big success in less than 24 months**
  - **55,000 applications, 30M subscribers !**

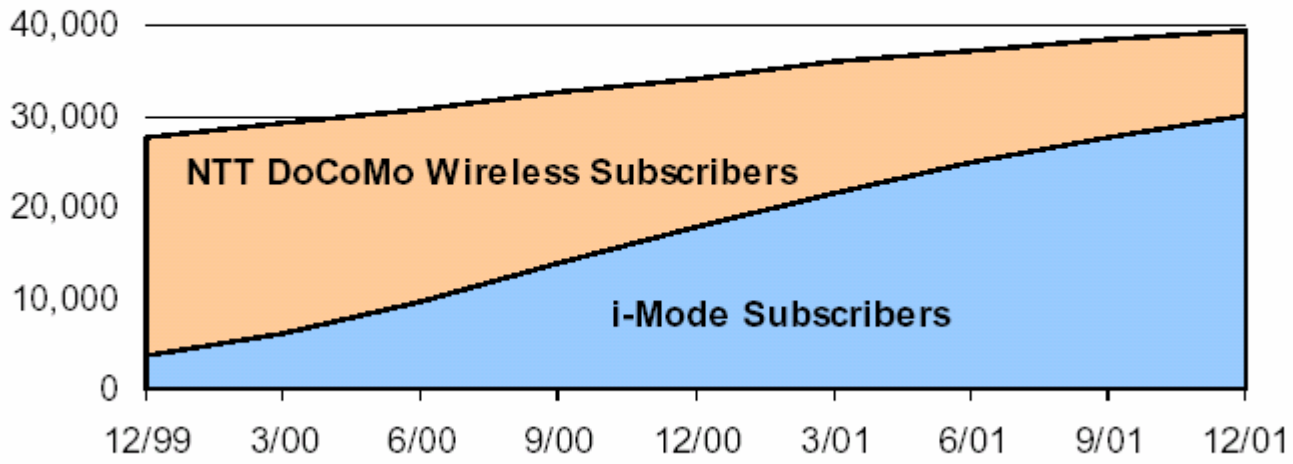
DoCoMo Has The Right Model

When will the others wake up?

Exhibit 3.13

ADOPTION OF I-MODE DATA SERVICES IN JAPAN

(Subscribers In Thousands)



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

Biggest Threat to Today's 3G — Wireless LANs

- **Faster than 3G**
  - **11 or 56 Mbps vs. <2 Mbps for 3G when stationary**
- **Data experience matches the Internet**
  - **With the added convenience of mobile**
  - **Same user interface (doesn't rely on small screens)**
  - **Same programs, files, applications, Websites.**
- **Low cost, low barriers to entry**
- **Organizations can build own networks**
  - **Like the Internet, will grow virally**
- **Opportunity for entrepreneurs!**
- **Opportunity for wireless operators?**

NMS COMMUNICATIONS

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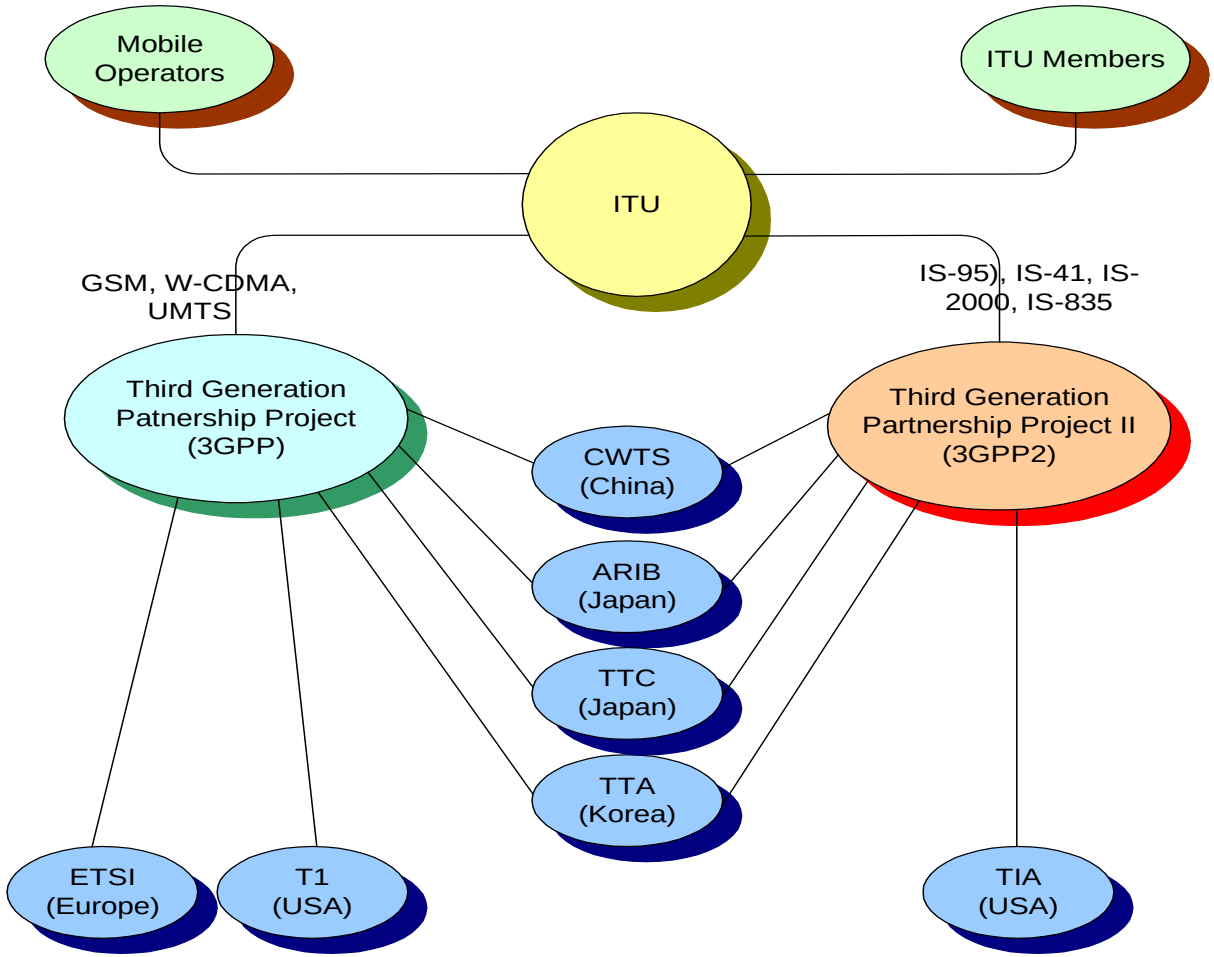
Additional Reference Material

Mobile Standard Organizations



Partnership Project and Forums

- **ITU IMT-2000** http://www.itu.int/imt2000
- **Mobile Partnership Projects**
  - **3GPP:** http://www.3gpp.org
  - **3GPP2:** http://www.3gpp2.org
- **Mobile Technical Forums**
  - **3G All IP Forum:** http://www.3gip.org
  - **IPv6 Forum:** http://www.ipv6forum.com
- **Mobile Marketing Forums**
  - **Mobile Wireless Internet Forum:** http://www.mwif.org
  - **UMTS Forum:** http://www.umts-forum.org
  - **GSM Forum:** http://www.gsmworld.org
  - **Universal Wireless Communication:** http://www.uwcc.org
  - **Global Mobile Supplier:** http://www.gsacom.com

Mobile Standards Organizations

- **European Technical Standard Institute (Europe):**
  - http://www.etsi.org
- **Telecommunication Industry Association (USA):**
  - http://www.tiaonline.org
- **Standard Committee T1 (USA):**
  - http://www.t1.org
- **China Wireless Telecommunication Standard (China):**
  - http://www.cwts.org
- **The Association of Radio Industries and Businesses (Japan):**
  - http://www.arib.or.jp/arib/english/
- **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

Location-Related Organizations

- **LIF, Location Interoperability Forum**
  - **http://www.locationforum.org/**
  - **Responsible for Mobile Location Protocol (MLP)**
  - **Now part of Open Mobile Alliance (OMA)**
- **OMA, Open Mobile Alliance**
  - **http://www.openmobilealliance.org/**
  - **Consolidates Open Mobile Architecture, WAP Forum, LIF, SyncML, MMS Interoperability Group, Wireless Village**
- **Open GIS Consortium**
  - **http://www.opengis.org/**
  - **Focus on standards for spatial and location information**
- **WLIA, Wireless Location Industry Association**
  - **http://www.wliaonline.com**

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