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Session 4: IMT Technologies

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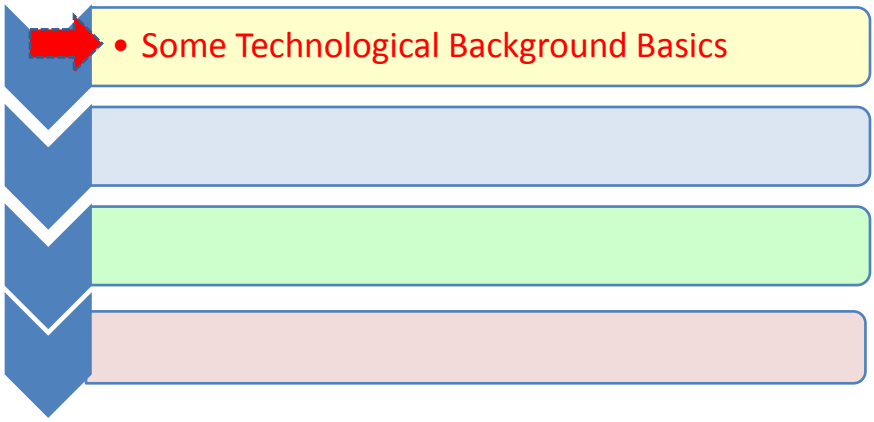
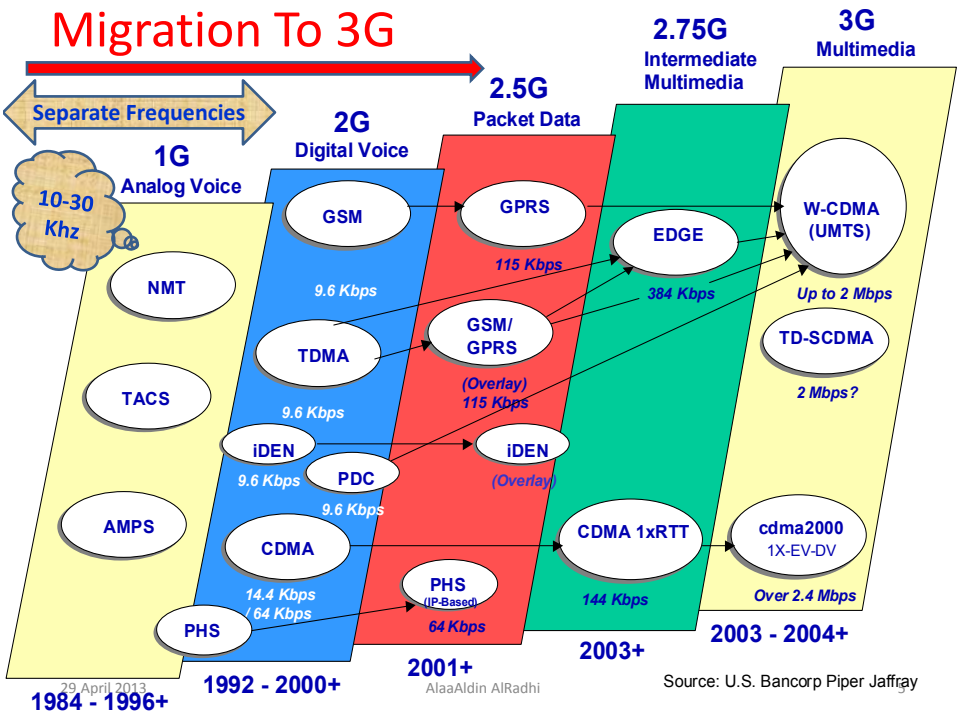
- Some Technological Background Basics
- Why IMT? IMT Standards Evolution Briefing
- & Competing Technologies
- Relevant ITU Recommendations, Reports & WRC-12 Outcome
- Additional Slides & Some References



Generations of Cellular Technologies

Generation	Year	Network	Technology	Data
1G	Early 1980s	Circuit switched	**TACS,AMPS**	Analog Voice
2G	Early 1990s	D-AMPS, GSM,CDMA	**D-AMPS, GSM,CDMA**	Digital Voice
2.5G	1996	Circuit switched or Packet switched	**GPRS, EDGE, EVDO, EVDV**	Digital Voice + Data
3G	2000	Non IP, Packet switched / Circuit switched	**W-CDMA, CDMA2000**	Digital Voice + High speed Data + video
4G	2012	IP based, Packet switched core network.	**NOT Finalized**	Digital Voice, High speed Data , Multimedia, Security



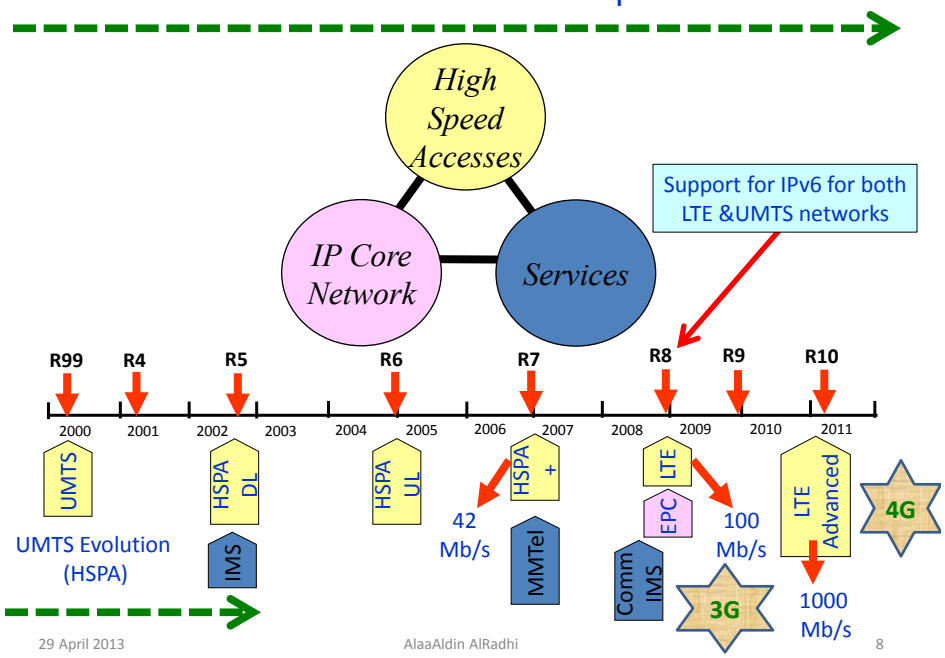
Complimentary to 3G = WLANs & WIMAX

- Faster than 3G: 11 or 56 Mbps vs. <2 Mbps for 3G when stationary
- Low cost, low barriers to entry
- Easy for Organizations to build own networks
- WLAN gives “hot spot” coverage
- WIMAX extends coverage to MANs
- 3G gives full mobility
- WLAN & WIMAX coupled/combined with 3G will offer mobile broadband for EVERYBODY & EVERYWHERE, whatever the technology and access mode

3GPP: 3rd Generation Partnership Project

- 3GPP Specified Radio Interfaces:
  - 2G radio: GSM, GPRS, EDGE
  - 3G radio: WCDMA, HSPA, LTE
  - 4G radio: LTE Advanced
- 3GPP Core Network:
  - 2G/3G: GSM core network
  - 3G/4G: Evolved Packet Core (EPC)
- 3GPP Service Layer:
  - GSM services
  - IP Multimedia Subsystem (IMS)
  - Multimedia Telephony (MMTEL)
  - Support of Messaging and other OMA functionality
  - Emergency services and public warning
  - Etc.

3GPP Release Concept



General Directions of 3GPP Evolution

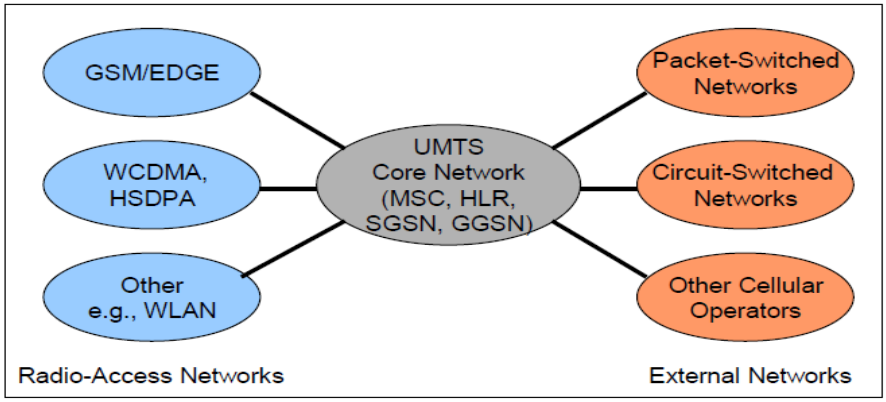
- Radio Interfaces:
  - Higher Data Throughput
  - Lower Latency
  - More Spectrum Flexibility
  - Improved CAPEX and OPEX
- IP Core Network:
  - Support of non-3GPP Accesses
  - Packet Only Support
  - Improved Security
  - Greater Device Diversity
- Service Layer:
  - More IMS Applications (MBMS, PSS, mobile TV now IMS enabled)
  - Greater session continuity

UMTS = Universal Mobile Telecom System

- The most important International Mobile Telecommunications-2000 (IMT-2000) proposals are the UMTS (W-CDMA) as the successor to 3G GSM.
- UMTS employs a wideband CDMA radio-access technology
- UMTS licenses have been awarded across Europe & Asia through 3GPP Group. For interoperability with North American networks, another group known as 3GPP2 was formed to develop global specifications for 3G networks
- Primary benefits of UMTS include high spectral efficiency for voice & data, simultaneous voice and data capability for users. So Operators can also use their entire available spectrum for both voice and high-speed data services.
- UMTS differs from GSM Phase 2+ (2.5 & 2.75 G) mostly in the new principles for air interface transmission, (W–CDMA instead of TDMA/ FDMA).

UMTS Multi-radio Network

Operators can use a common core network that supports multiple radio access networks including GSM, EDGE, WCDMA, HSPA, and evolutions of these technologies. This is called the UMTS multi-radio network, and it gives operators maximum flexibility in providing different services across their coverage areas



HSPA: High Speed Packet Access

- Is strongly positioned to be the dominant mobile-data technology for the next 5-10 years.
- HSPA+ is a series of enhancements to create “HSPA Evolution” developed by 3GPP
- HSPA+ represents a logical development of the Wideband Code Division Multiple Access (WCDMA) approach, and it is the stepping stone to an entirely new 3GPP radio platform called 3GPP LTE.
- GSM-HSPA1 has an overwhelming global position in terms of subscribers, deployment, and services.
- UMTS-HSPA & CDMA2000 are the primary 3G technologies

HSPA: Throughput Evolution

Technology	Downlink (Mbps) Peak Data Rate	Uplink (Mbps) Peak Data Rate
HSPA as defined in Release 6	14.4	5.76
Release 7 HSPA+ DL 64 QAM, UL 16 QAM	21.1	11.5
Release 7 HSPA+ 2X2 MIMO, DL 16 QAM, UL 16 QAM	28.0	11.5
Release 8 HSPA+ 2X2 MIMO DL 64 QAM, UL 16 QAM	42.2	11.5
Release 8 HSPA+ (no MIMO) Dual Carrier (2 X 10 MHz)	42.2	11.5
Release 9 HSPA+ 2X2 MIMO, Dual Carrier (2 X 10 MHz)	84.0	23.0
Release 10 HSPA + 4X4 MIMO, Quad Carrier (2 X 20 MHz)	168.0	23.0

LTE (Long Term Evolution)

- Although HSPA & HSPA+ offer a highly efficient broadband-wireless service, but LTE, a standard, defined by 3GPP, is a highly flexible radio interface for wireless communication which will allow operators to achieve even higher peak throughputs in higher spectrum bandwidth
- It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using new modulation techniques.
- Supports smooth evolution from earlier 3GPP system (TD-SCDMA, WCDMA/HSPA) & 3GPP2 systems: cdma2000.
- Also constitutes a major step towards IMT-Advanced
- Cell ranges up to:
  - 5 km; with best throughput, spectrum efficiency & mobility.
  - 30 km; Mobility with some degradation in throughput and spectrum efficiency permitted.

LTE – Advanced

- Is to provide higher bitrates in a cost efficient way, and at the same time completely fulfill the requirements set by ITU for IMT- Advanced, also referred to as 4G. So LTE-Advanced is expected to be the 1st "true" 4G system available
- So the term 4G will apply to networks that comply with the requirements of IMT-Advanced (Report ITU-R M.2134)
- Focuses on higher capacity by adding more bandwidth:
  - Increased peak data rate, DL 3 Gbps, UL 1.5 Gbps
  - Higher spectral efficiency to 30 bps/Hz
  - Increased number of simultaneously active subscribers
- Uses MIMO (Multiple Input Multiple Output) or Spatial Multiplexing, to increase the overall bitrate through transmission of two (or more) different data streams on two (or more) different antennas
- Support for scalable bandwidth up to and including 40 MHz
- Encouragement to support wider bandwidths (e.g., 100 MHz)

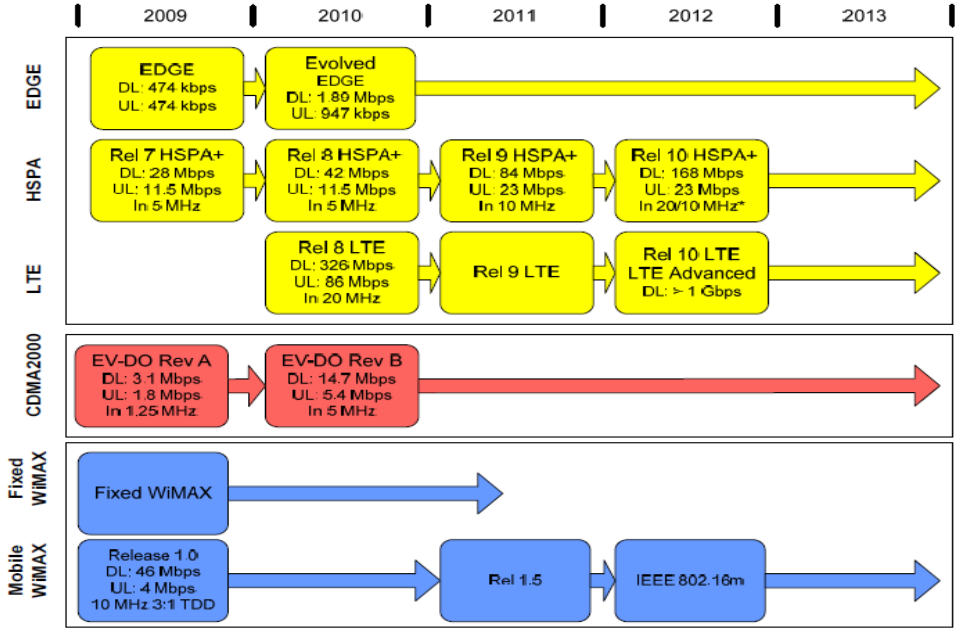
Characteristics of 3GPP Technologies

Technology Name	Type	Characteristics	Typical Downlink Speed	Typical Uplink Speed
GSM	TDMA	Most widely deployed cellular technology in the world. Provides voice and data service via GPRS/EDGE.		
EDGE	TDMA	Data service for GSM networks. An enhancement to original GSM data service called GPRS.	70 kbps to 135 kbps	70 kbps to 135 kbps
Evolved EDGE	TDMA	Advanced version of EDGE that can double and eventually quadruple throughput rates, halve latency and increase spectral efficiency.	175 kbps to 350 kbps expected (Single Carrier) 350 kbps to 700 kbps expected (Dual Carrier)	150 kbps to 300 kbps expected
UMTS	CDMA	3G technology providing voice and data capabilities. Current deployments implement HSPA for data	200 to 300 kbps	200 to 300 kbps

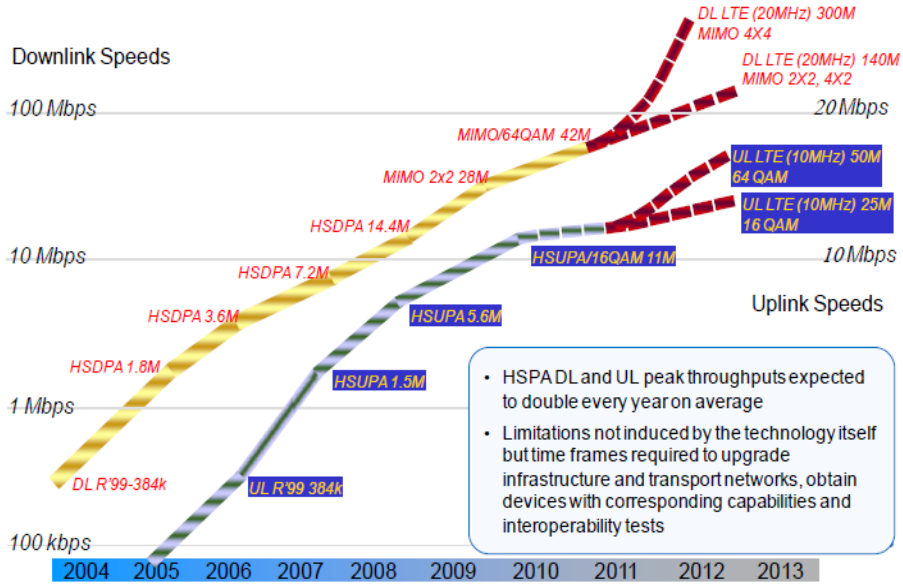
Characteristics of 3GPP Technologies

Technology Name	Type	Characteristics	Typical Downlink Speed	Typical Uplink Speed
HSPA[24]	CDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 Mbps to 4 Mbps	500 kbps to 2 Mbps
HSPA+	CDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.9 to Mbps to 8.8 Mbps	1 Mbps to 4 Mbps
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	5.9 to 21.5 Mbps in 2 X 10 MHz	
LTE-Advanced	OFDMA	Advanced version of LTE designed to meet IMT-Advanced requirements.		

Evolution of TDMA, CDMA & OFDMA Systems

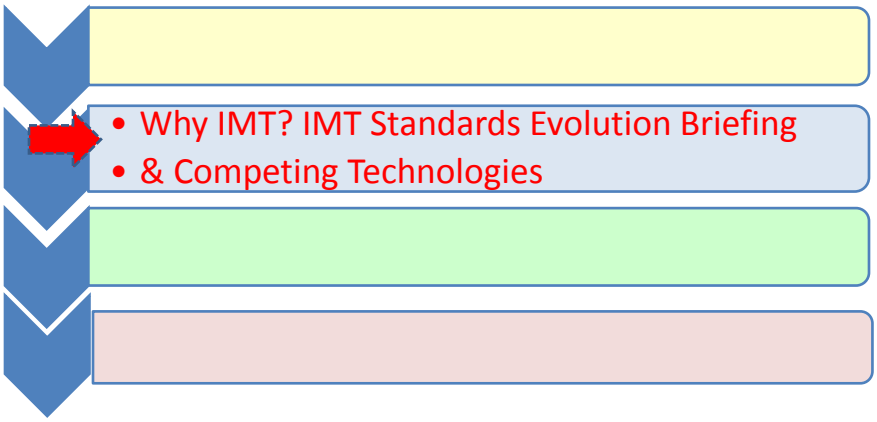


Peak DL & UL Rates Over Time



CR: Cognitive Radio = New ways of Using Spectrum

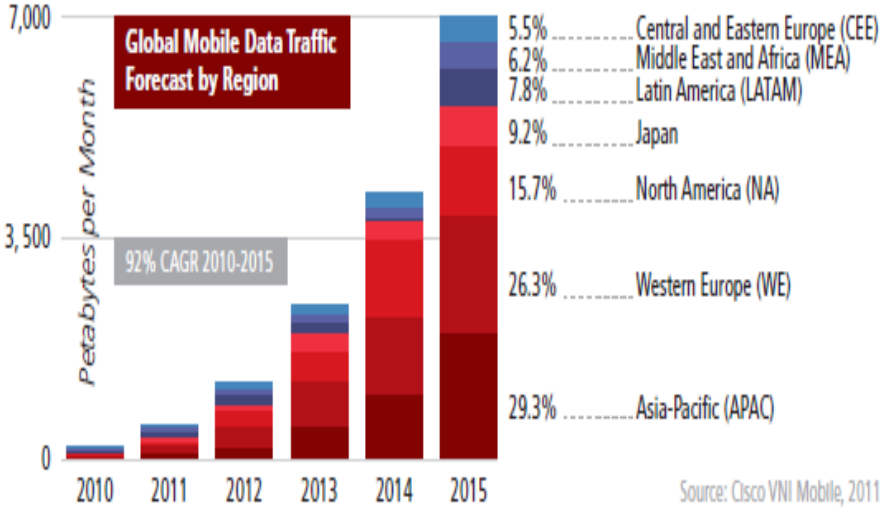
- Spectrum has been & will continue to be a scarce resource for the mobile-communication industry. So we need developed ways to use spectrum
- So CR technology allows different radio technologies to share the same spectrum efficiently by adaptively finding unused spectrum & adapting the transmission scheme to the requirements of the technologies currently sharing the spectrum.
- This dynamic radio resource management is achieved in a distributed fashion, & relies on Software-Defined Radio SDR
- SDR benefits from today's high processing power to develop multiband, multi-standard base stations & terminals.



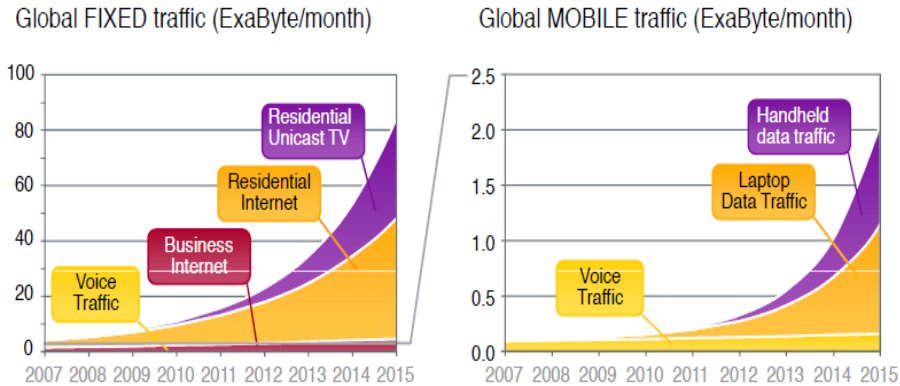
Facing up to the Mobile Data Explosion: *Stats*

- As of today there are more than:
  - 1 billion 3G subscriptions
  - 400 3GPP-family networks of HSPA technology with data speeds in the 2-14 Mbps range.
  - 140 networks of HSPA+ technology with data speeds of up to 42 Mbps
  - 50 LTE already installed networks (started commercially late 2009) with 10 million LTE subscriptions and with many foreseen operators to deploy LTE gradually

The volume of Mobile Data is Growing by Approximately 92 %, year over year



Internet Traffic Growth is Huge



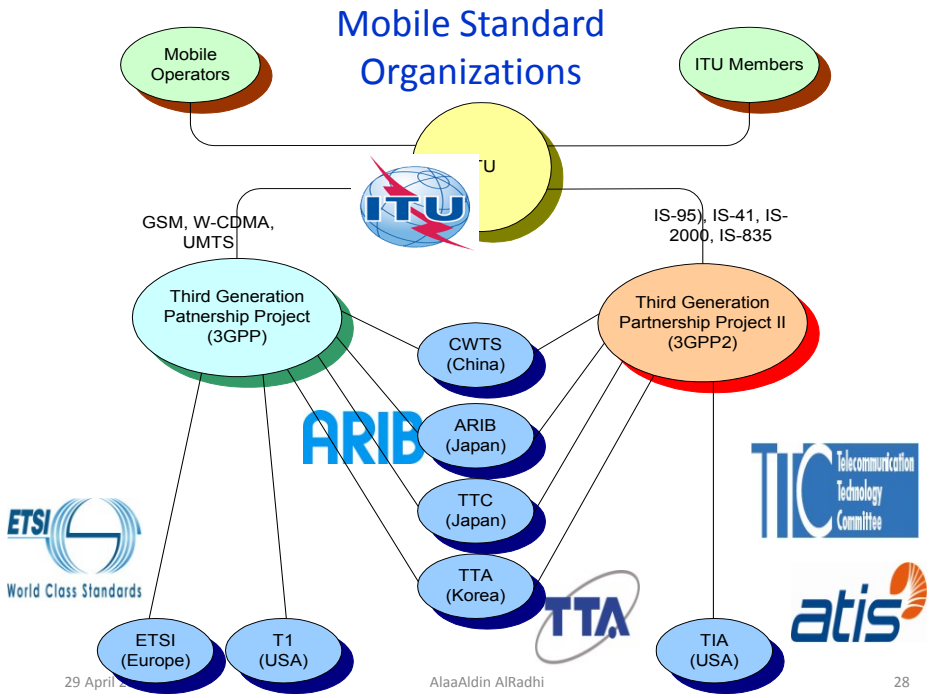
Fixed broadband traffic is 40x mobile in 2015

Mobile data traffic grows 300 fold

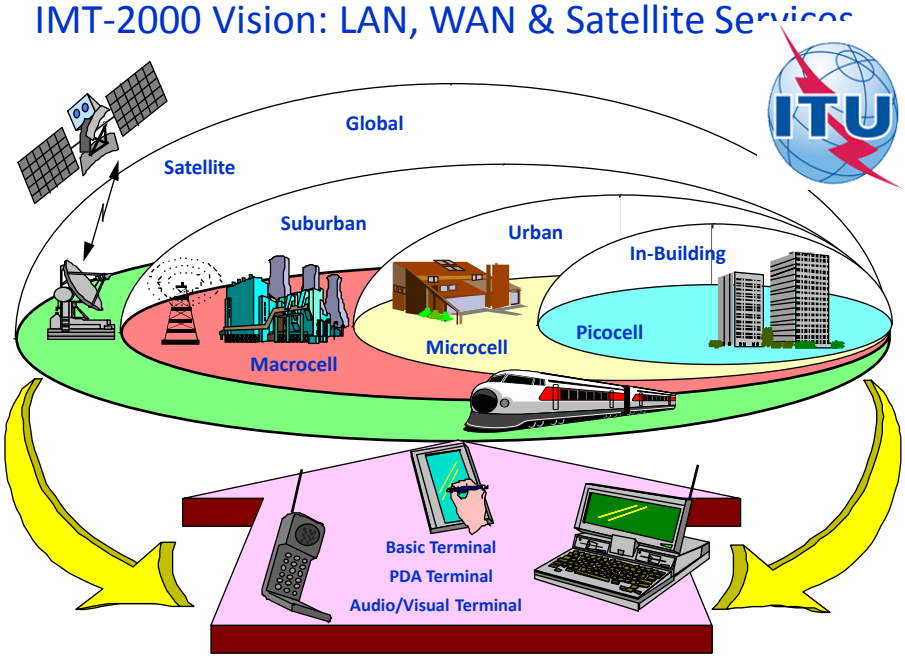
Facing up to the Mobile Data Explosion: *What is Needed?*

- *So we need:*
  - More Spectrum to support the projected growth of mobile data.
  - Less Radio Latency
  - Higher Processing Speed
  - Access to all kind of networks & interfaces

- IMT = International Mobile Telecommunications
- ITU Global Broadband Multimedia International Mobile Telecommunication System
- A family of Standards:
  - IMT-2000: ITU's umbrella name for 3G
  - IMT-Advanced"
- National & Regional standards bodies are collaborating in 3G partnership projects: TIA (US), ETSI (EU), TTC (Japan), TTA (South Korea), etc
- 3G Partnership Projects (3GPP & 3GPP2): Focused on evolution of access & core networks
- *Currently:* There Are More Than 2 Billion IMT Subscribers In The World



IMT-2000 Vision: LAN, WAN & Satellite Services



IMT-2000 Radio Access Standards

(Source: ITU)

IMT- 2000 CDMA Direct Spread	IMT- 2000 CDMA Multi - Carrier	IMT- 2000 CDMaA TDD	IMT- 2000 CDMA Single Carrier	IMT- 2000 FDMA / TDMA	IMT- 2000 OFDMA TDD WMAN

WCDMA UMTS)	CDMA 1X & 1 x EV	TRA TDD & TD-SCDMA	UWC-136 DGE	DECT	Wimax (CMR 2007)

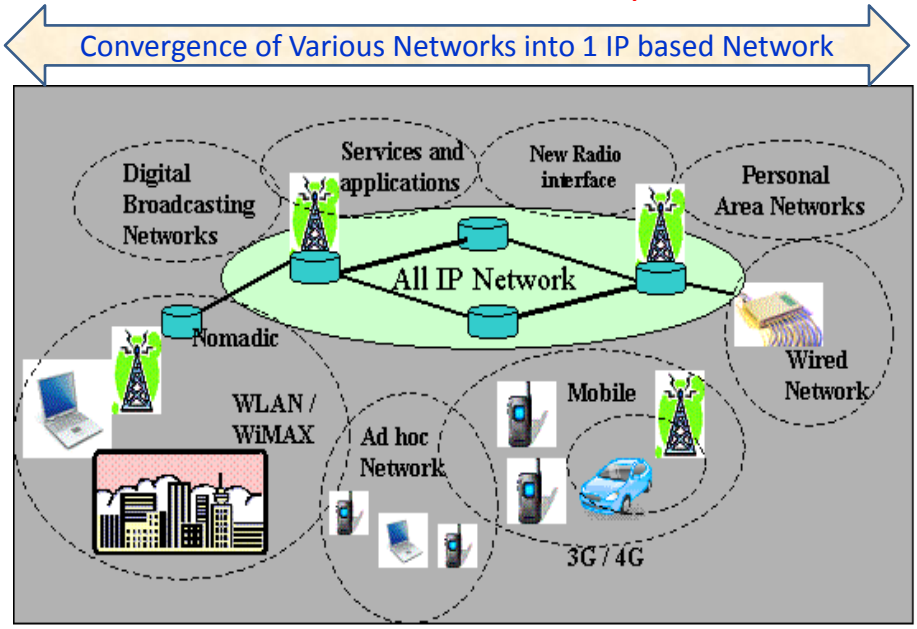
IMT – Advanced: ITU Standard for 4G

- IMT- Advanced was standardized late 2011 & agreed @ ITU Radiocommunication Assembly (RA-12), in Geneva , January 2012, consensus was reached to expand the IMT Radio Interface Family by establishing the new IMT-Advanced standard. The Recommendation ITU-R M.2012 dealing with IMT was approved by all Member States.
- During the ITU World Radiocommunication Conference (WRC-12) in Geneva, February 2012, it was agreed that additional spectrum for the mobile applications (which includes IMT) was made in Resolution 232 in the band 694 - 790 MHz in Region 1 and additionally asked the ITU-R to perform sharing studies in this band and in additional bands to be identified for IMT in preparation for WRC-15 (Resolution 233). The additional spectrum will be assigned by the next WRC-15.
- IMT-Advanced to be commercialized by 2015
- Data Rates of 1 Gbps Range

IMT – Advanced: *Summary of Major Improvements Over IMT-2000*

- Increased spectrum efficiency — supporting more users at higher data rates per radio channel. ITU recommends:
  - Operation in up-to-40 MHz radio channels with very high spectral efficiency
  - Operation in up-to-100 MHz radio channels & peak spectral efficiency of 15 bps/Hz, resulting in a theoretical throughput rate of 1.5 Gbps
- Fully packet-based architecture — meaning reduced costs, and comprehensive support for broadband wireless data;
- Improved radio resource management and control — for enhanced quality of service;
- New capabilities for the physical layer of the radio interface — including wideband radio channels, MIMO [multiple input multiple output] smart antennas and flexible deployment options.

IMT – Advanced: *Principle*



IMT – Advanced: *Key Features*

- Compatibility of services within IMT & with fixed networks
- Capability of interworking with other radio access
- Worldwide roaming capability systems
- Enhanced peak data rates to support advanced services & applications (100 Mbit/s for high and 1 Gbit/s for low mobility
- Use radio-frequency spectrum much more efficiently making higher data transfers possible on lesser bandwidth
- Less Latency
- A QoS that matches those of fixed networks

IMT – Advanced: *Requirements*

- 1 IP based global core network. Various networks (Wired PSTN, LAN, Cellular (3G), wireless (WIMAX), nomadic, ad hoc & sensor networks) will be able to communicate with this core network.
- The new Radio Channel Multiple access technologies will be backward compatible and must coexist with the IMT-2000 systems. Examples are:
  - OFDMA (Orthogonal Frequency Division Multiple Access)
  - SC-FDMA (Single Carrier- Frequency Division Multiple Access),
  - OFDM-TDMA (Orthogonal Frequency Division Multiplexing - Time Division Multiple Access)
- Radio Aspects:
  - Base station: 2 transmit & 2 receive antennas: (2 x 2)
  - Mobile Station: 1 transmit & 2 receive antennas (1 x 2)

IMT – Advanced: *Bandwidth & Spectrum Requirements 1*

Spectrum	Current Use	Advantages	Disadvantages
410 - 430 MHz	Land mobile services-public protection and disaster relief	More coverage area, good propagation characteristics	Large antennas, limited band, capabilities of IMT-Advanced could downscale
450 - 470 MHz	Land mobile services-public protection and disaster relief	More coverage area, good propagation characteristics	Large antennas, limited band, capabilities of IMT-Advanced could downscale
470 - 806 MHz	Broadcasting services (TV & Radio)	More coverage area, good propagation , upper band closer to IMT-2000. So reduced complexity of Equipment	Large antennas, limited band, capabilities of IMT-Advanced could downscale
2300 - 2400 MHz	Fixed and mobile services	Band closer to IMT-2000. Simplifies development, planning & deployment of IMT systems	Insufficient bandwidth, Used in other applications

IMT – Advanced: *Bandwidth & Spectrum Requirements 2*

Spectrum	Current Use	Advantages	Disadvantages
2700 - 2900 MHz	Radar systems, aeronautical radio navigation	Band closer to IMT-2000. Simplifies development, planning & deployment of IMT systems in this band	Not feasible for IMT-2000 systems. Lots of interference from radars
3400 - 4200 MHz	Fixed services & fixed satellite services; fixed &mobile BB wireless access systems	Large bandwidth, smaller antenna size, relatively better propagation characteristics	interference mitigation measures are required

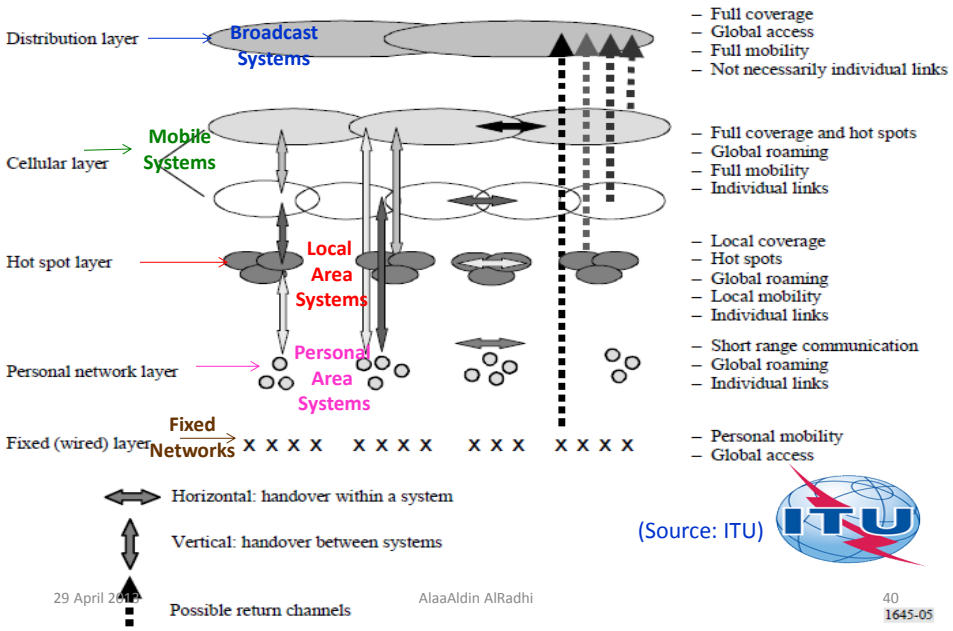
IMT – Advanced: *Bandwidth & Spectrum Requirements 3*

Spectrum	Current Use	Advantages	Disadvantages
4400 - 4990 MHz	Mobile service, FSS providing basic infrastructure telecommunication system, aeronautical mobile or for Fixed Services (FS) for long distance links, radio astronomy	Large bandwidth, smaller antenna size, multiple antenna techniques enabling high spectrum efficiency	largest frequency-dependent propagation loss adversely affecting high mobility

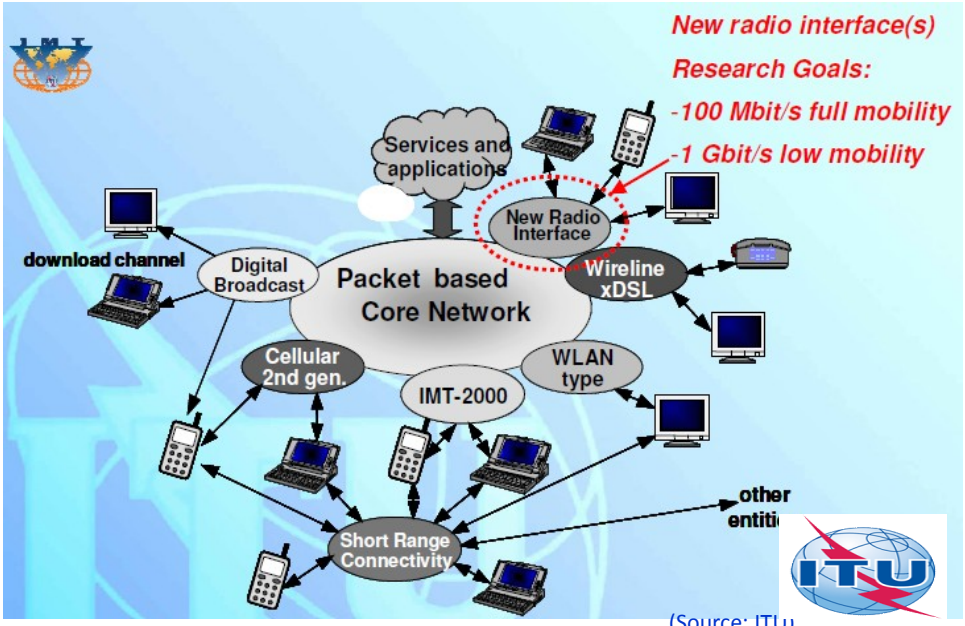
IMT-Advanced Requirements & Anticipated LTE-Advanced Capability

Item	IMT-Advanced Requirement	LTE-Advanced Projected Capability
Peak Data Rate Downlink		1 Gbps
Peak Data Rate Uplink		500 Mbps
Spectrum Allocation	Up to 40 MHz	Up to 100 MHz
Latency User Plane	10 msec	10 msec
Latency Control Plane	100 msec	50 msec
Peak Spectral Efficiency DL[127]	15 bps/Hz	30 bps/Hz
Peak Spectral Efficiency UL	6.75 bps/Hz	15 bps/Hz
Average Spectral Efficiency DL	2.2 bps/Hz	2.6 bps/Hz
Average Spectral Efficiency UL	1.4 bps/Hz	2.0 bps/Hz
Cell-Edge Spectral Efficiency DL	0.06 bps/Hz	0.09 bps/Hz
Cell-Edge Spectral Efficiency UL	0.03 bps/Hz	0.07 bps/Hz

IMT-Advanced Vision of Complementary Interconnected Access Systems

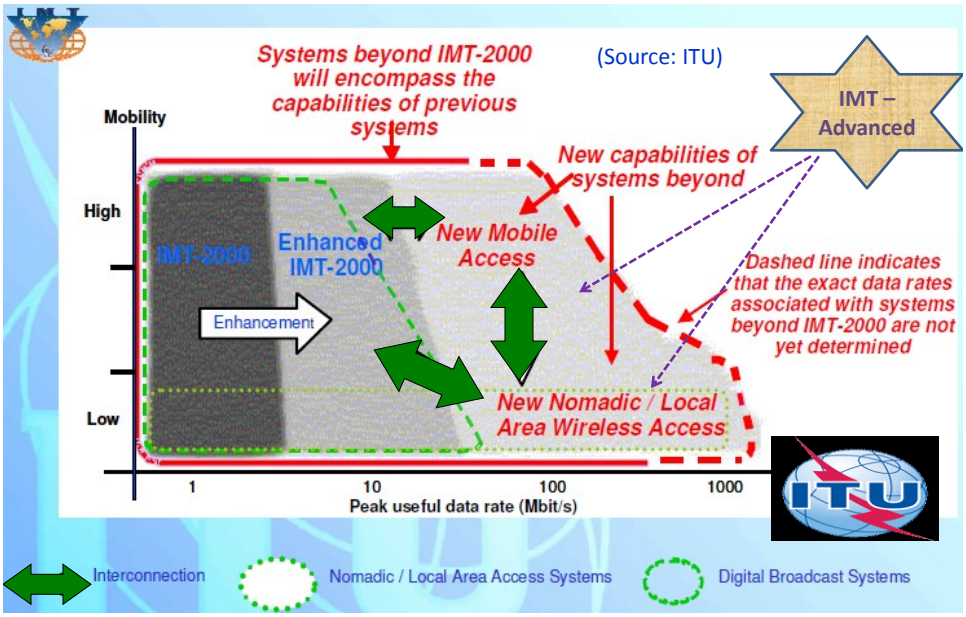


New Radio Interface(s) - Variety of Access Networks



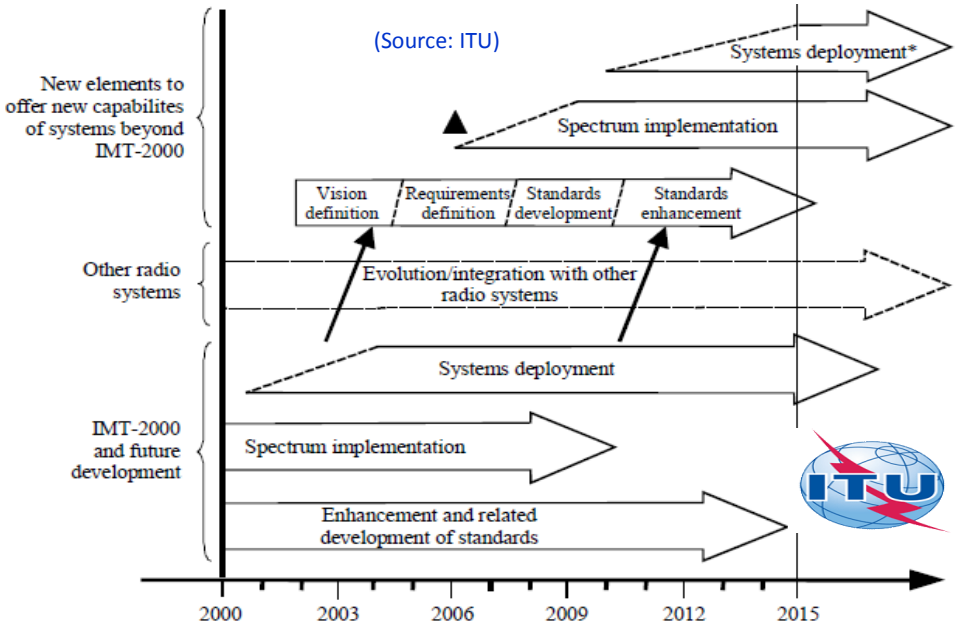
(Source: ITU)

Capabilities of IMT-2000 & IMT-Advanced: The Van

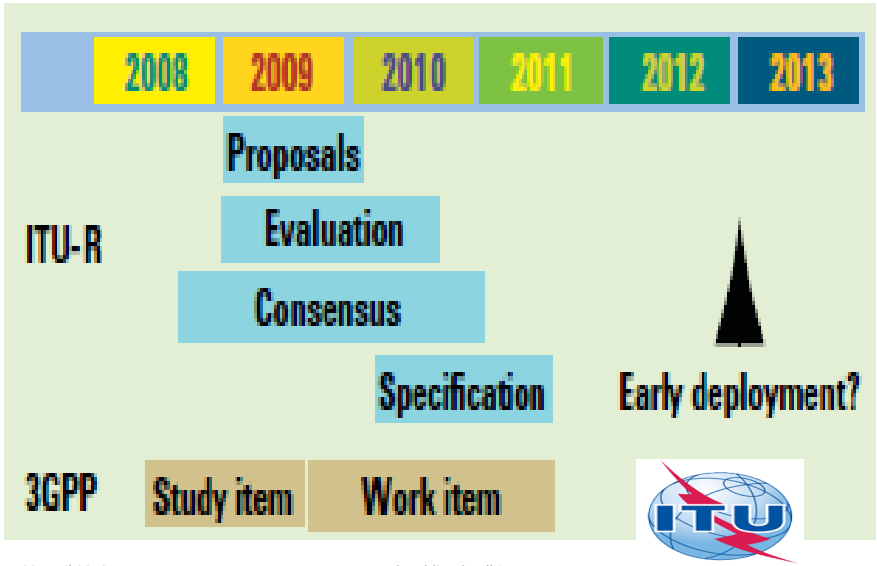


IMT – Advanced: *Timelines*

(Source: ITU)

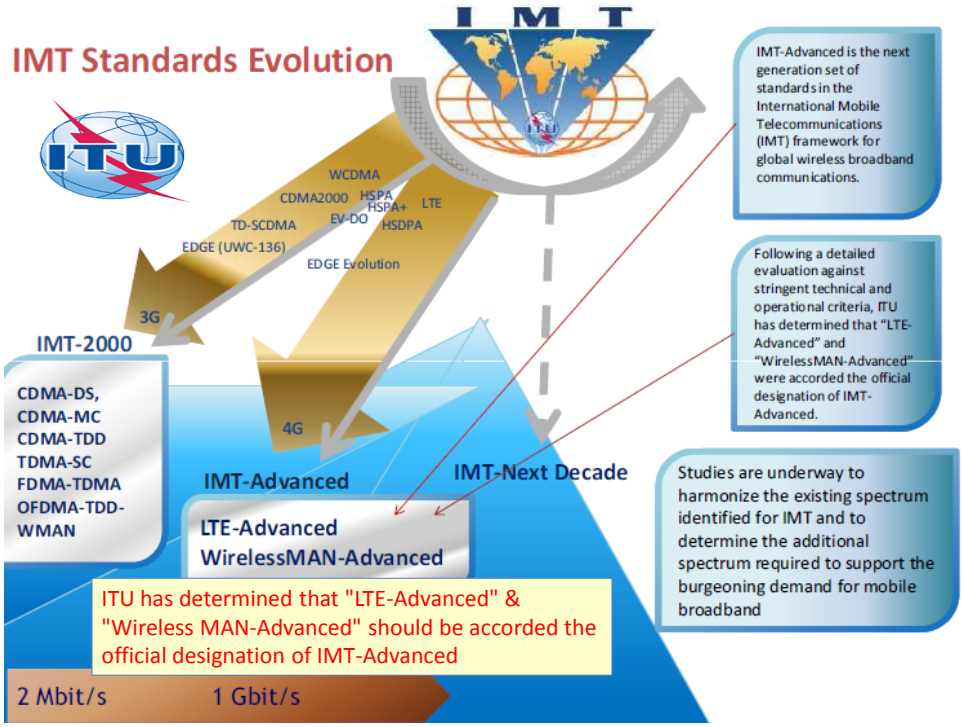


IMT – Advanced:
Projected ITU timeline & links into 3GPP

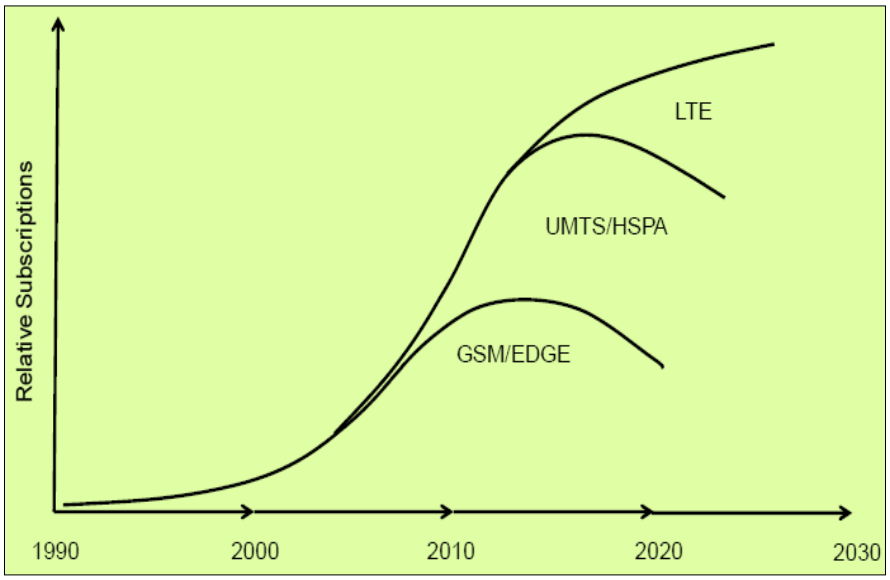


IMT – Advanced: *Summary*

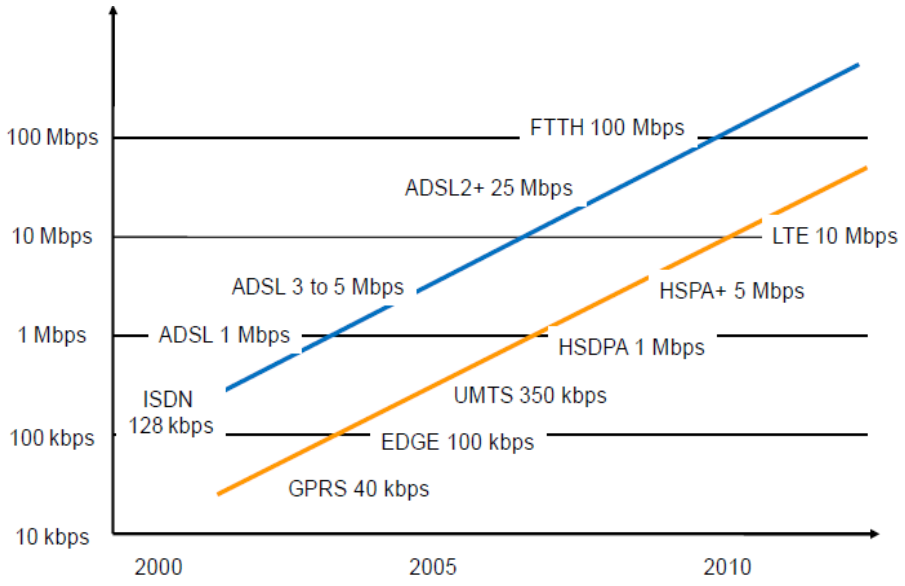
Characteristics	Technology
Deployment	2012-2015
Core networks	IP based
Band	Below 6 GHz
Data rates	100 Mbps to 1 GHz
Access methods	OFDMA, SC- FDMA, OFDM-TDMA
Radio Interface	Cognitive radios, software defined radios.
Modulation	QPSK, 16QAM, 64QAM, DAPSK
Services provided	Rich multimedia, voice, high speed data.
Duplex methods	FDD(paired, unpaired), TDD
Error control	LDPC, turbo codes, HARQ
Handover	Seamless, vertical, horizontal, hard, soft

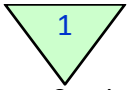


Relative Adoption of Technologies



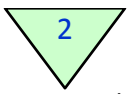
Wire-line & Wireless Advances





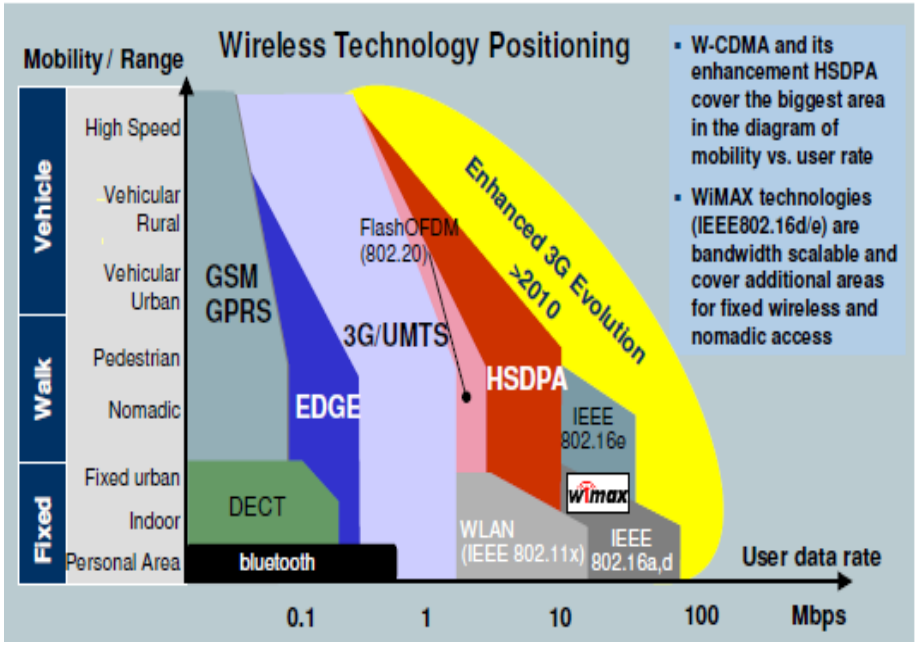
Competing Technologies: CDMA 2000

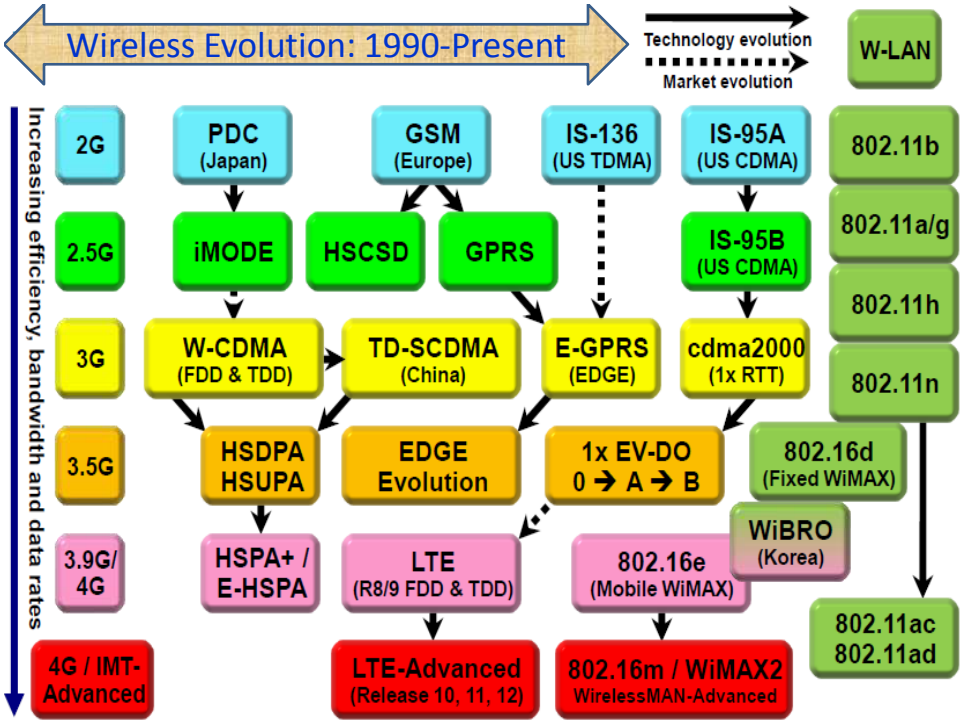
- Consisting principally of 1 Carrier Radio Transmission Technology (1xRTT) & 1 Carrier-Evolved, Data-Optimized (1xEV-DO) versions, is the other major cellular technology deployed in many parts of the world
- 1xRTT is currently the most widely deployed CDMA2000 version.
- Currently there were 114 EV-DO Rel. 0 networks & 95 EV-DO Rev. A networks deployed worldwide
- EV-DO uses many of the same techniques for optimizing spectral efficiency as HSPA including higher order modulation, efficient scheduling, turbo-coding, & adaptive modulation & coding.
- So, it achieves spectral efficiency that is virtually the same as HSPA.
- The 1x technologies operate in the 1.25 MHz radio channels, compared to the 5 MHz channels UMTS uses, resulting in lower theoretical peak rates, although average throughputs for high level network loading are similar.
- One challenge for EV-DO operators is that they cannot dynamically allocate their entire spectral resources between voice and high-speed data functions. The EV-DO channel is NOT available for circuit-switched voice



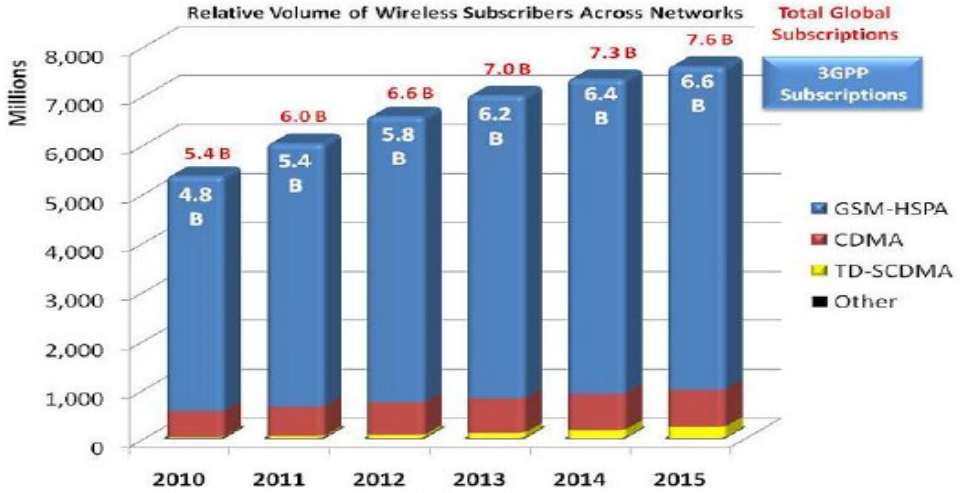
Competing Technologies: WIMAX

- Based on OFDMA & accepted by the ITU as an IMT-2000 (3G technology), WiMAX is trying to challenge existing wireless technologies by having greater capabilities & greater efficiencies than alternative approaches such as HSPA
- WiMAX has gained the greatest traction in developing countries as an alternative to wireline deployment.
- The major WiMAX technical disadvantage is cell size.
- Original specification is IEEE 802.16
- WiMAX employs many of the same mechanisms as HSPA to maximize throughput & spectral efficiency, including high-order modulation, efficient coding, adaptive modulation & coding
- The principal difference from HSPA is IEEE 802.16e use of OFDMA.
- Relative to LTE, WiMAX has the following technical disadvantage: 5 msec frames instead of 1 msec
- With respect to spectral efficiency, WiMAX is comparable to HSPA+


Wireless Technology Positioning
Mobility / Range
Vehicle
Walk
Fixed
High Speed
Vehicular Rural
Vehicular Urban
Pedestrian
Nomadic
Fixed urban
Indoor
Personal Area
GSM GPRS
EDGE
3G/UMTS
FlashOFDM (802.20)
HSDPA
Enhanced 3G Evolution >2010
IEEE 802.16e
wimax
DECT
bluetooth
WLAN (IEEE 802.11x)
IEEE 802.16a,d
User data rate
0.1
1
10
100
Mbps
W-CDMA and its enhancement HSDPA cover the biggest area in the diagram of mobility vs. user rate
WiMAX technologies (IEEE802.16d/e) are bandwidth scalable and cover additional areas for fixed wireless and nomadic access


Wireless Evolution: 1990-Present
Technology evolution
Market evolution
W-LAN
Increasing efficiency, bandwidth and data rates
2G
2.5G
3G
3.5G
3.9G/ 4G
4G / IMT-Advanced
PDC (Japan)
GSM (Europe)
IS-136 (US TDMA)
IS-95A (US CDMA)
iMODE
HSCSD
GPRS
IS-95B (US CDMA)
W-CDMA (FDD & TDD)
TD-SCDMA (China)
E-GPRS (EDGE)
cdma2000 (1x RTT)
HSDPA HSUPA
EDGE Evolution
1x EV-DO 0 → A → B
HSPA+ / E-HSPA
LTE (R8/9 FDD & TDD)
802.16e (Mobile WiMAX)
LTE-Advanced (Release 10, 11, 12)
802.16m / WiMAX2 WirelessMAN-Advanced
802.11b
802.11a/g
802.11h
802.11n
802.16d (Fixed WiMAX)
WiBRO (Korea)
802.11ac 802.11ad

Subscribers Among Different Wireless Technologies

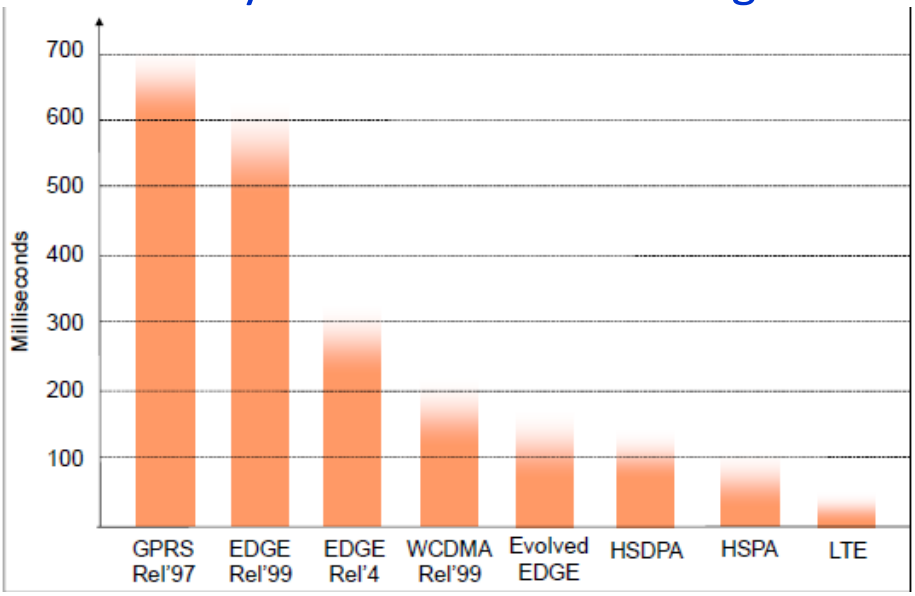


	2010	2011	2012	2013	2014	2015
WiMAX	3M	7M	16M	33M	61M	
LTE	317T	3.7M	16.6M	50M	133M	265M
HSPA	378M	633M	985M	1.4B	2.0B	2.6B

Feature	LTE	WiMAX Release 1.0	WiMAX Release 1.5	Impact
Multiple Access	OFDM in downlink, Discrete Fourier Transform (DFT)-spread OFDM in uplink	OFDM in downlink and uplink	OFDM in downlink and uplink	DFT-spread OFDM reduces the peak-to-average power ratio and reduces terminal complexity, requires one-tap equalizer in base station receiver.
Uplink Power Control	Fractional path-loss compensation	Full path-loss compensation	Full path-loss compensation	Fractional path-loss compensation enables flexible tradeoff between average and cell-edge data rates.
Scheduling	Channel dependent in time and frequency domains	Channel dependent in time domain	Channel dependent in time and frequency domains	Access to the frequency domain yields larger scheduling gains.
MIMO Scheme	Multi-codeword (horizontal), closed loop with pre-coding	Single codeword (vertical)	Single codeword (vertical), with rank-adaptive MIMO (TDD) and with closed-loop pre-coding (FDD)	Horizontal encoding enables per-stream link adaptation and successive interference cancellation receivers.
Modulation and Coding Scheme Granularity	Fine granularity (1-2 dB apart)	Coarse granularity (2-3 dB apart)	Coarse granularity (2-3 db apart)	Finer granularity enables better link adaptation precision.
Hybrid Automatic Repeat Request (ARQ)	Incremental redundancy	Chase combining	Chase combining	Incremental redundancy is more efficient (lower SNR required for given error rate).
Frame Duration	1 msec subframes	5 msec subframes	5 msec subframes	Shorter subframes yield lower user plane delay and reduced channel quality feedback delays.
Overhead / Control Channel Efficiency	Relatively low overhead	Relatively high overhead	Relatively high overhead apart from reduction in pilots	Lower overhead improves performance.

LTE & WIMAX Features

Latency of Different Technologies



1

Competitive Summary

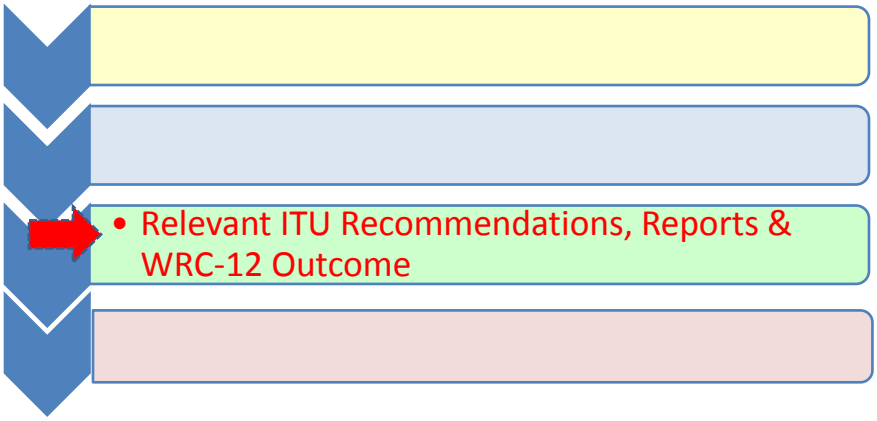
Technology	EDGE/HSPA/LTE	CDMA2000	WiMAX
Subscribers	Over 4.4 billion	518 million[85] today; slower growth expected than GSM-HSPA	61 million anticipated by 2014
Maturity	Extremely mature	Extremely mature	Emerging
Adoption	Cellular operators globally	Cellular operators globally	Limited to date
Coverage/Footprint	Global	Global with the general exception of Western Europe	Limited
Deployment	Fewer cell sites required at 700 and 850 MHz	Fewer cell sites required at 700 and 850 MHz	Many more cell sites required at 2.5 GHz

Competitive Summary

Technology	EDGE/HSPA/LTE	CDMA2000	WiMAX
Devices	Broad selection of GSM/EDGE/UMTS/ HSPA devices	Broad selection of 1xRTT/EV-DO devices	Initial devices emphasize data
Radio Technology	Highly optimized TDMA for EDGE, highly optimized CDMA for HSPA, highly optimized OFDMA for LTE	Highly optimized CDMA for Rev 0/A/B	Optimized OFDMA in Release 1.0. More optimized in Release 1.5
Spectral Efficiency	Very high with HSPA, matches OFDMA approaches in 5 MHz with HSPA+	Very high with EV-DO Rev A/B	Very high, but not higher than HSPA+ for Release 1.0, and not higher than LTE for Release 1.5
Throughput Capabilities	Peak downlink user-achievable rates of over 4 Mbps today with achievable rates of over 8 Mbps today with HSPA+	Peak downlink user-achievable rates of over 1.5 Mbps, with significantly higher rates in the future	3 to 6 Mbps typical rates with bursts to 10 Mbps

Competitive Summary

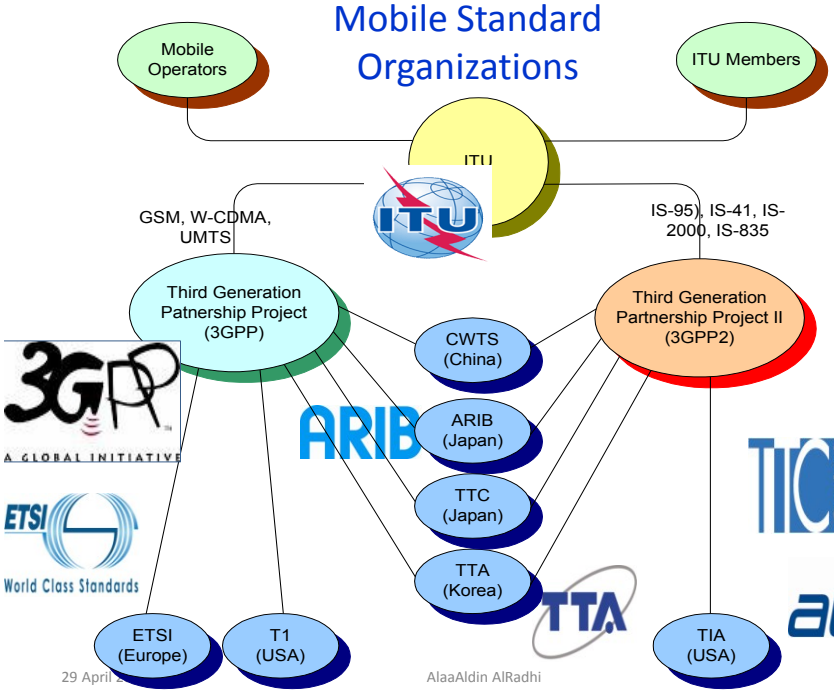
Technology	EDGE/HSPA/LTE	CDMA2000	WiMAX
Voice Capability	Extremely efficient circuit-voice available today; smoothest migration to VoIP of any technology	Extremely efficient circuit-voice available today EV-DO radio channels with VoIP cannot support circuit-voice users	Relatively inefficient VoIP initially; more efficient in later stages, but lower than LTE Voice coverage will be much more limited than cellular
Simultaneous Voice and Data	Available with GSM[86] and UMTS today	Not available today Available with VoIP and future devices	Potentially available, though initial services will emphasize data
Efficient Spectrum Usage	Entire UMTS radio channel available for any mix of voice and high-speed data	Radio channel today limited to either voice/medium speed data or high-speed data only	Currently only efficient for data-centric networks



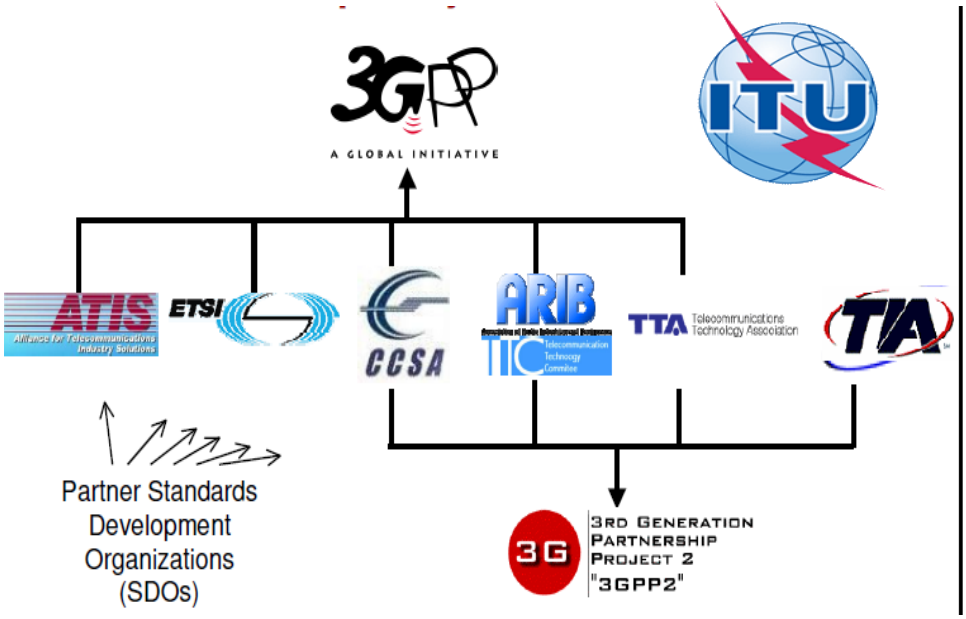
Role of ITU

- World-Wide Spectrum Efficiency Coordination & Improvements
- Policy & Regulatory Harmonization
- International Standards for Key Access and Network Interfaces
- Provide Foundation, Framework & Catalyst For 3G Convergence Across Regions & Technologies
- Harmonize Regional Input Contributions & Consensus Building
- World Radiocommunication Conference (WRCs): Reviews & revises the use of the Radio-Frequency spectrum
- Radiocommunication Assembly (RA): Sets work priorities / time-frames and approves the Recommendations in support of WRCs
- Radio Regulations Board (RRB): Approves Rules of Procedure for applying Radio Regulations and registering frequency assignments made by Member States

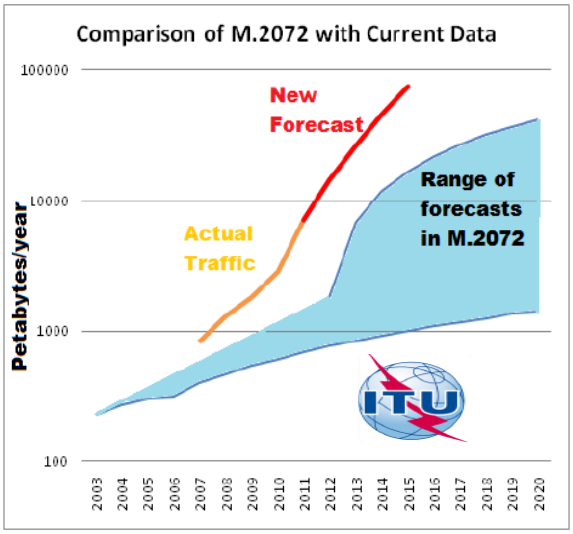
Mobile Standard Organizations



ITU & SDO Partners of the 3G Partnership Projects



ITU-R M.2072: Forecasts Vs Actual



The global estimates from Report ITU-R M.2072 (2005) were quite conservative

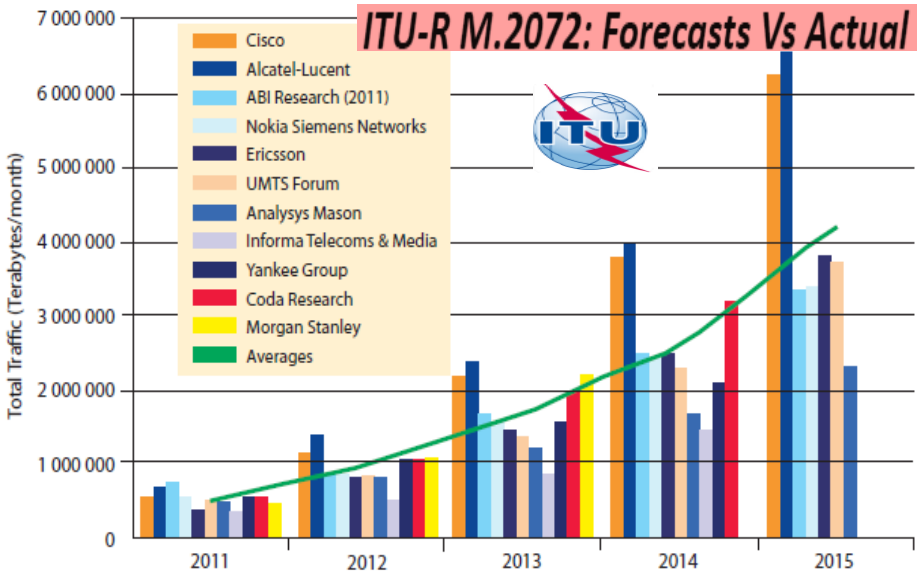
Actual data traffic is many times greater (more than 5) than some of the estimates in Report ITU-R M.2072.

Moreover, the actual traffic being experienced by the operators today is even greater than some of the forecasts in Report ITU-R M.2072 for the year 2020.

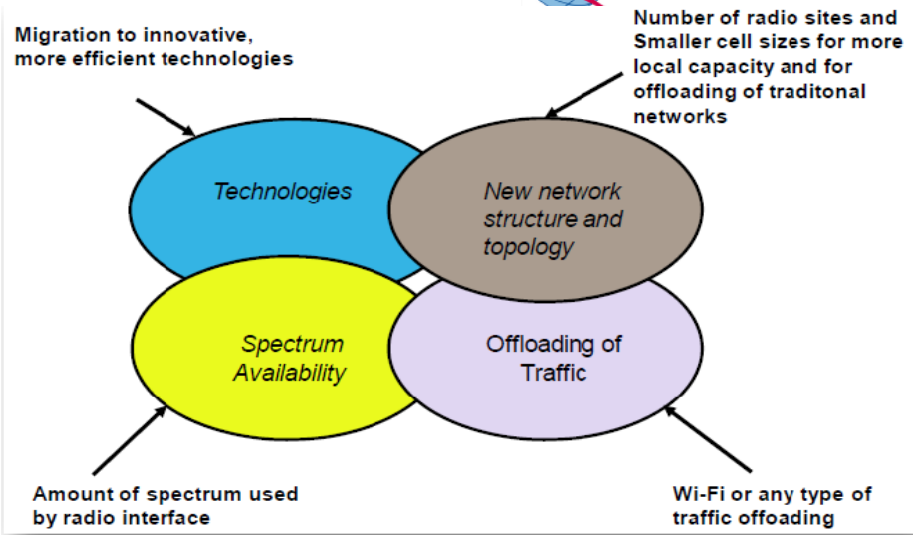
One Report ITU-R M.2072 forecast also anticipated that in 2015 data traffic would be equal to voice traffic for the first time, but, in reality, the proportion of traffic from mobile data already exceeded mobile voice in 2009.

Source: Report ITU-R M.2243 (00/2011)

ITU-R Study on IMT Forecasts: ITU-R M.2243 Report: Mobile Global Data Traffic estimates 2011-2015



Options to manage mobile demand



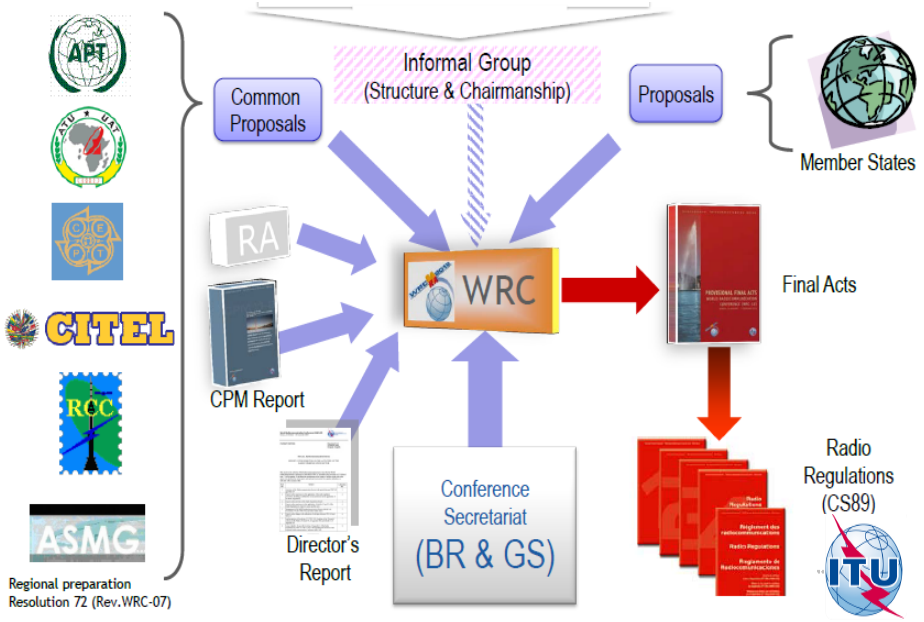
Source: Report ITU-R M.2243 (00/2011)

Ensuring Full Availability of IMT Identified Spectrum

The Amount of Typical Available Spectrum Per Region

Region		Total spectrum available for IMT (Typical country)
APT	Asia-Pacific Telecommunity	Between 330 MHz and 510 MHz
ASMG	Arab Spectrum Management Group	Between 340 MHz and 630 MHz
ATU	African Telecomm Union	370 MHz
CEPT	EU Conference of Postal &Telecomm Administrations	590 MHz
North America (CITEL)		478 MHz
Latin America (CITEL)		Between 270 MHz and 360 MHz

WRC-12: *Preparations*



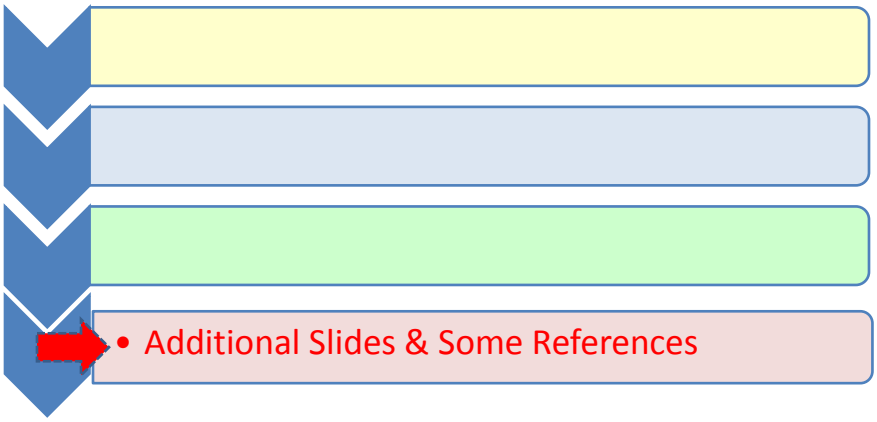
WRC-12 & IMT: *Results*

Mobile Broadband / IMT Spectrum

In addition to establishing the conditions to use of the 800 MHz band (i.e., 790-862 MHz) in Region 1 (the "first " digital dividend), WRC-12 considered further spectrum allocations to the mobile service, including International Mobile Telecommunications (IMT) to facilitate the development of terrestrial mobile broadband applications; thus the extension of the 800 MHz band, i.e., 694-790 MHz (the "second" digital dividend) in Region 1 will be available from 2015.

WRC-12 & IMT: *Results*
Spectrum Bands for IMT

- WARC-92, WRC-2000, WRC-2007, WRC-2012 identified the following bands:
  - 450-470 MHz,
  - 698-960 MHz,
  - 1710-2025 MHz,
  - 2110-2200 MHz,
  - 2300-2400 MHz,
  - 2500-2690 MHz,
  - 3400-3600 MHz
- Actual allocation may differ across Region 1, 2 and 3



List of ITU-R Recommendations on IMT: M-Series

Radiocommunication Sector (ITU-R)

Freely Available & Updated @: http://www.itu.int/ITU-R/index.asp?category=information&rlink=imt-advanced-rec&lang=en

- M.687 - International Mobile Telecommunications-2000 (IMT-2000)
- M.816 - Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
- M.817 - International Mobile Telecommunications-2000 (IMT-2000). Network architectures
- M.818 - Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
- M.819 - International Mobile Telecommunications-2000 (IMT-2000) for developing countries
- M.1034 - Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
- M.1035 - Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)
- M.1036 - Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)
- M.1078 - Security principles for International Mobile Telecommunications-2000 (IMT-2000)

- M.1079 - Performance and quality of service requirements for International Mobile Telecommunications-2000 (IMT-2000) access networks
- M.1167 - Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
- M.1168 - Framework of International Mobile Telecommunications-2000 (IMT-2000)
- M.1182 - Integration of terrestrial and satellite mobile communication
- M.1223 - Evaluation of security mechanisms for IMT-2000
- M.1224 - Vocabulary of terms for International Mobile Telecommunications (IMT)
- M.1225 - Guidelines for evaluation of radio transmission technologies for IMT-2000
- M.1308 - Evolution of land mobile systems towards IMT-2000
- M.1311 - Framework for modularity and radio commonality within IMT-2000
- M.1390 - Methodology for the calculation of IMT-2000 terrestrial spectrum requirements
- M.1391 - Methodology for the calculation of IMT-2000 satellite spectrum requirements

- M.1456 - Minimum performance characteristics & operational conditions for high altitude platform stations providing IMT-2000 in the bands 1 885-1 980 MHz, 2 010-2 025 MHz & 2 110-2 170 MHz in Regions 1 & 3 and 1 885-1 980 MHz & 2 110-2 160 MHz in Region 2
- M.1457 - Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
- M.1545 - Measurement uncertainty as it applies to test limits for the terrestrial component of International Mobile Telecommunications-2000
- M.1579 - Global circulation of IMT-2000 terrestrial terminals
- M.1580 - Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT 2000
- M.1581 - Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT 2000
- M.1635 - General methodology for assessing the potential for interference between IMT-2000 or systems beyond IMT-2000 and other services
- M.1641 - A methodology for co-channel interference evaluation to determine separation distance from a system using high-altitude platform stations to a cellular system to provide IMT-2000 service
- M.1645 - Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

- M.1646 - Parameters to be used in co-frequency sharing & pfd threshold studies between terrestrial IMT-2000 & BSS (sound) in the 2 630-2 655 MHz
- M.1654 - A methodology to assess interference from broadcasting-satellite service (sound) into terrestrial IMT-2000 systems intending to use the band 2 630-2 655 MHz
- M.1768 - Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000
- M.1822 - Framework for services supported by IMT
- M.1850 - Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
- M.2012 - Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (and 5.433A)
- M.2014 - Global circulation of IMT-2000 satellite terminals
- S.1856 - Methodologies for determining whether an IMT station at a given location operating in the band 3 400-3 600 MHz would transmit without exceeding the power flux-density limits in the Radio Regulations Nos. 5.430A, 5.432A, 5.432B and 5.433A

List of ITU-R Reports on IMT: M-Series

Radiocommunication Sector (ITU-R)

Freely Available & Updated @: http://www.itu.int/ITU-R/index.asp?category=information&rlink=imt-advanced-rep&lang=en

- BT.2247 - Field measurement and analysis of compatibility between DTTB and IMT
- F.2060 - Fixed service use in the IMT-2000 transport network
- M.1153 - Future public land mobile telecommunication systems
- M.1155 - Adaptation of mobile Radiocommunication technology to the needs of developing countries
- M.2023 - Spectrum requirements for International Mobile Telecommunications-2000 (IMT-2000)
- M.2024 - Summary of spectrum usage survey results
- M.2030 - Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geographical area
- M.2031 - Compatibility between WCDMA 1800 downlink and GSM 1900 uplink
- M.2038 - Technology trends
- M.2039 - Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses
- M.2041 - Sharing and adjacent band compatibility in the 2.5 GHz band between the terrestrial and satellite components of IMT-2000

- M.2045 - Mitigating techniques to address coexistence between IMT-2000 time division duplex and frequency division duplex radio interface technologies within the frequency range 2 500-2 690 MHz operating in adjacent bands and in the same geographical area
- M.2072 - World mobile telecommunication market forecast
- M.2074 - Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000
- M.2077 - Traffic forecasts and estimated spectrum requirements for the satellite component of IMT 2000 and systems beyond IMT-2000 for the period 2010 to 2020
- M.2078 - Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced
- M.2079 - Technical and operational information for identifying Spectrum for the terrestrial component of future development of IMT-2000 and IMT-Advanced
- M.2109 - Sharing studies between IMT Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 and 4 500-4 800 MHz frequency bands

- M.2110 - Sharing studies between Radiocommunication services and IMT systems operating in the 450-470 MHz band
- M.2111 - Sharing studies between IMT-Advanced and the radiolocation service in the 3 400-3 700 MHz bands
- M.2112 - Compatibility/sharing of airport surveillance radars and meteorological radar with IMT systems within the 2 700-2 900 MHz band
- M.2113 - Sharing studies in the 2 500-2 690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in the same geographical area
- M.2133 - Requirements, evaluation criteria and submission templates for the development of IMT-Advanced
- M.2134 - Requirements related to technical performance for IMT-Advanced radio interface(s)
- M.2135 - Guidelines for evaluation of radio interface technologies for IMT-Advanced
- M.2146 - Coexistence between IMT-2000 CDMA-DS and IMT-2000 OFDMA TDD WMAN in the 2 500-2 690 MHz band operating in adjacent bands in the same area

- M.2176 - Vision and requirements for the satellite radio interface(s) of IMT-Advanced
- M.2198 - The outcome of the evaluation, consensus building and decision of the IMT-Advanced process (steps 4-7), including characteristics of IMT-Advanced radio interfaces
- M.2241 - Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz
- M.2242 - Cognitive Radio Systems specific for IMT Systems
- M.2243 - Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications
- M.2244 - Isolation between antennas of IMT base stations in the land mobile service

Partnership Project and Forums

- ITU IMT http://www.itu.int/imt
- 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