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An Overview of Wireless Standards & Technology

Past, Present and Future

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President

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Agenda

- History of Wireless
- Basic Frequency Usage
- Overview of Types of Networks
- WPAN Technologies – Bluetooth, UWB
- WLAN Technologies – WiFi
- WMAN Technologies – WiMax
- WWAN Technologies – Cellular and Related WWAN
  - Generations
  - 3GPP, 3GPP2
- Summary

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Mark Hoffman - Background

- Founded ***ACETEC*** in 1995
- Penstock, Now Avnet
- Comstream
  - RF Design Engineer
- McDonnell Douglas Technologies Inc.
  - Microwave Design Engineer
- BSEE, MSEE, University of Wisconsin , 1987

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Wireless History

- EM Wireless Communications started with the work of Hertz (1860's) and Maxwell (1860's).
- In 1893 Nikola Tesla demonstrated the transmission of information over EM waves.
- In 1898 Guglielmo Marconi demonstrated wireless telegraphy from a boat to the Isle of Wight in the English Channel.
- Tesla was really the first to "invent" the radio but Marconi had better public relations.
- Marconi shared with Karl Ferdinand Braun the 1909 Nobel Prize in Physics for their contributions to the development of wireless telegraphy.

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First Systems

- Very first systems were Spark Gap Transmitters with a Tank Circuit operating below 500 KHz. Very Noisey. Rx Antenna with Detector.
- Most Early systems were unidirectional, First Station was KDKA in Pittsburg, PA in 1915, Built by Westinghouse
- Amateur (HAM) radio started in the early 1900's. ARRL formed by 1914. My call is WB9VSG
- WWI - mostly Morse Code. Human can received -10 dB SNR, HAM's taken off the air
- By 1930's many Police had Radio's in their cars
- 1932 Radio ACT was basically the start of the FCC

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First Systems - Continued

- WWII, Korea - Still Morse Code. Some AM and FSK Teletype
- 1946 First VHF mobile system installed in St. Louis, MO
  - used operators and had 6 channels
  - ran out of capacity quickly
- AT&T's Bell Labs found answer: The Cellular Principal with Hand off's.
- In 1979 NTT in Japan made the first cellular systems
- AT&T decided not to get into the cellular phone market on the advice of consultants
- Later on AT&T bought McCaw Cellular for over $10 billion

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Approximate Frequency Allocation

- ***Below 100 MHz:*** CB radio, HAM radio, pagers, analog cordless phones, AM radio
- ***100-800 MHz:*** Mainly for broadcast (TV and FM radio). 700 MHz, MediaFlo and DVB-H Mobile TV
- ***400-500 MHz:*** Trunking radio and some cellular systems (good coverage with low user density)
- ***800-1000 MHz:*** Cellular and some emergency communication systems, 915 MHz cordless phones
- ***1.8-2.0 GHz:*** 2G cellular systems
- ***2.4-2.5 GHz:*** ISM (Industrial, Scientific, Medical) band, cordless phones, WLAN, WPAN, Bluetooth, WiMax

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Approximate Frequency Allocation Continued

- ***3.3-3.8 GHz:*** Fixed wireless and WiMax, UWB
- ***4.8-5.8 GHz:*** WLAN, fixed wireless, and WiMax, UWB
- ***7/8, 11, 13, 15, 18, 23, 26, 28, 32, 38 GHz*** Pt-Pt microwave back haul
- ***11-15 GHz:*** Most popular satellite TV service
- ***14-14.5 GHz Uplink,*** 11.7-12.2 GHz Downlink, Ku band, VSAT

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Classification of Wireless Networks

- **WPAN (<10m)** – Wireless Personal Area Networks - UWB, Bluetooth, Zigbee 802.15.4
- **WLAN (<100m)** – Wireless Local Area Networks - WiFi 802.11x
- **WMAN (~1 city)** – Wireless Metropolitan Area Network – WiMax
- **WWAN (>1 city)** – Wireless Wide Area Network – Cellular

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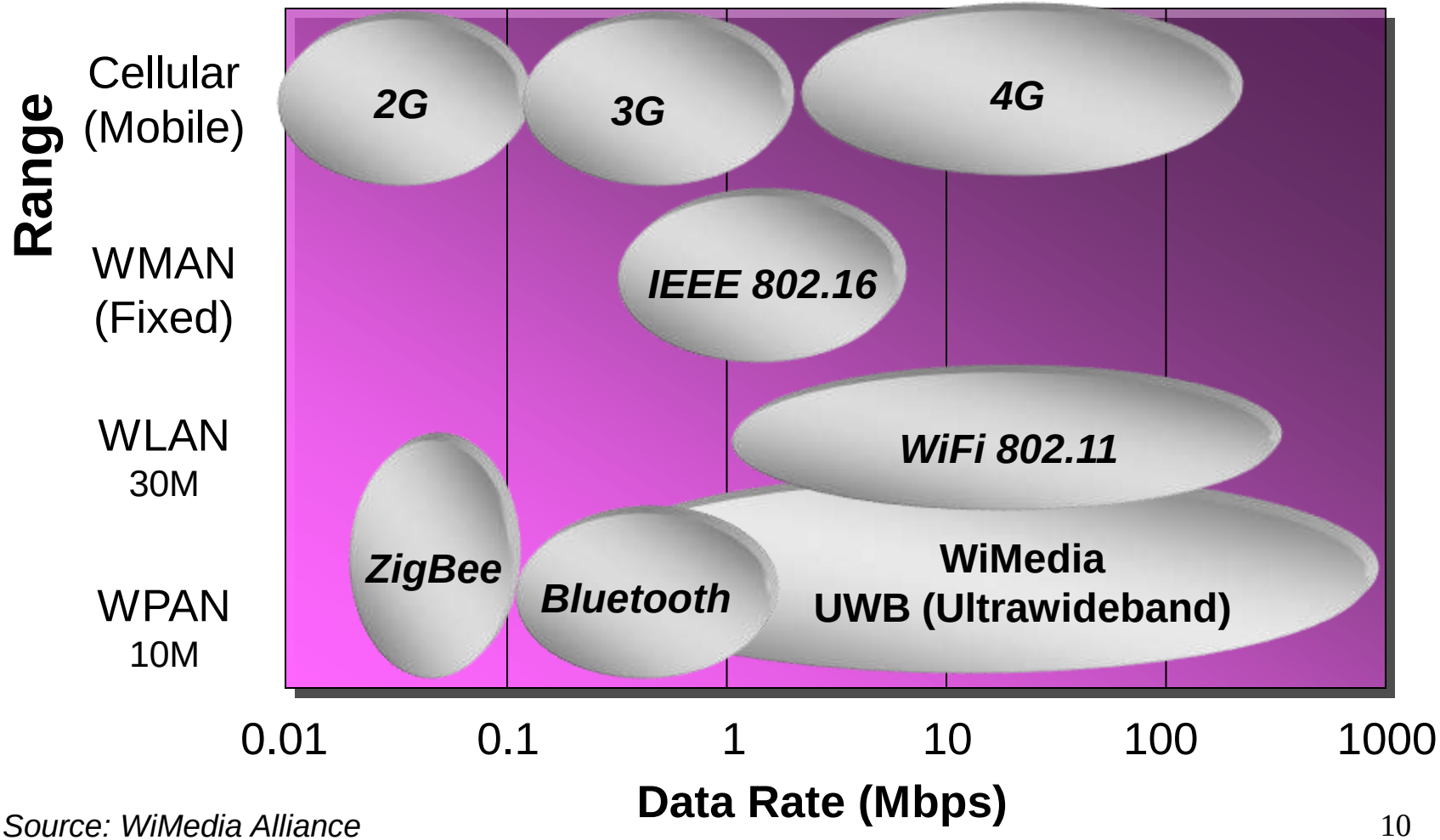
Wireless Technology Comparison



Source: WiMedia Alliance

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WPAN Technologies - Bluetooth

What it stands for: Nothing – Bluetooth was the internal project name at Ericsson.

What it is: Low power, low cost, short range communication, IEEE 802.15.3

Where: All over the world. Frequency 2.45 GHz

Who: Ericsson and others started the technology

Why: For Wireless headsets, cable free connections, etc. Consumes very little power (~1mw), cell phones consume about 200mw, low cost at about $4-$6

When: Late 1990s but did not take off until around 2003

How it works: Frequency hopping spread spectrum (FHSS)

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Other WPAN Technologies

- Zigbee IEEE 802.15.4
  - Uses ISM bands, 868 MHz in Europe, 915 and 2.4 GHz
  - Used for Sensing and M2M (Machine to Machine).
- NFC – Near Field Communication
  - For payment and other close in applications
  - Uses magnetic field induction at ~10cm
- RFID

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WPAN Technologies - UWB

What it stands for: Ultra Wide Band, AKA Wireless USB, High-speed USB

What it is: IEEE 802.15.3a, short range, low cost IC wireless radio standard. For distances <15m. Note: Two competing standards are slowing the standard process: WiMedia Alliance vs. UWB Forum.

Where it is used: Worldwide at different frequencies.

Who: Intel, Sony, Microsoft, TI, Motorola, Staccato, PulseLink, General Atomics.

Why it was used: Creates a robust, fast, and low cost WPAN communications system. May replace numerous cables around computers and entertainment centers.

How it works: Extremely wide spread spectrum signal. Uses 3.1-10.6 GHz with max speeds of ~110Mbps (~10M) and 480 Mbps (L2M)

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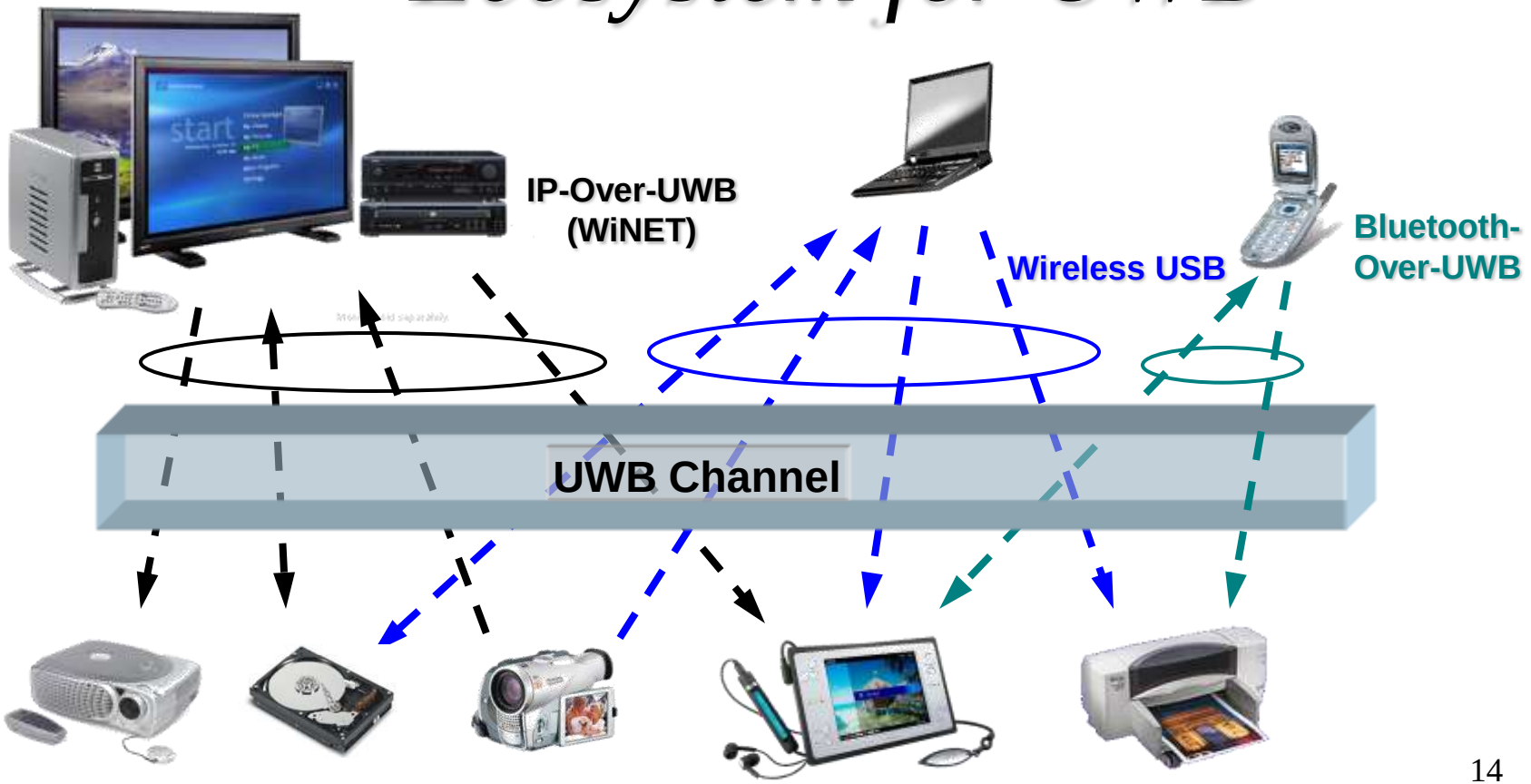
Multi-Protocol Application Ecosystem for UWB



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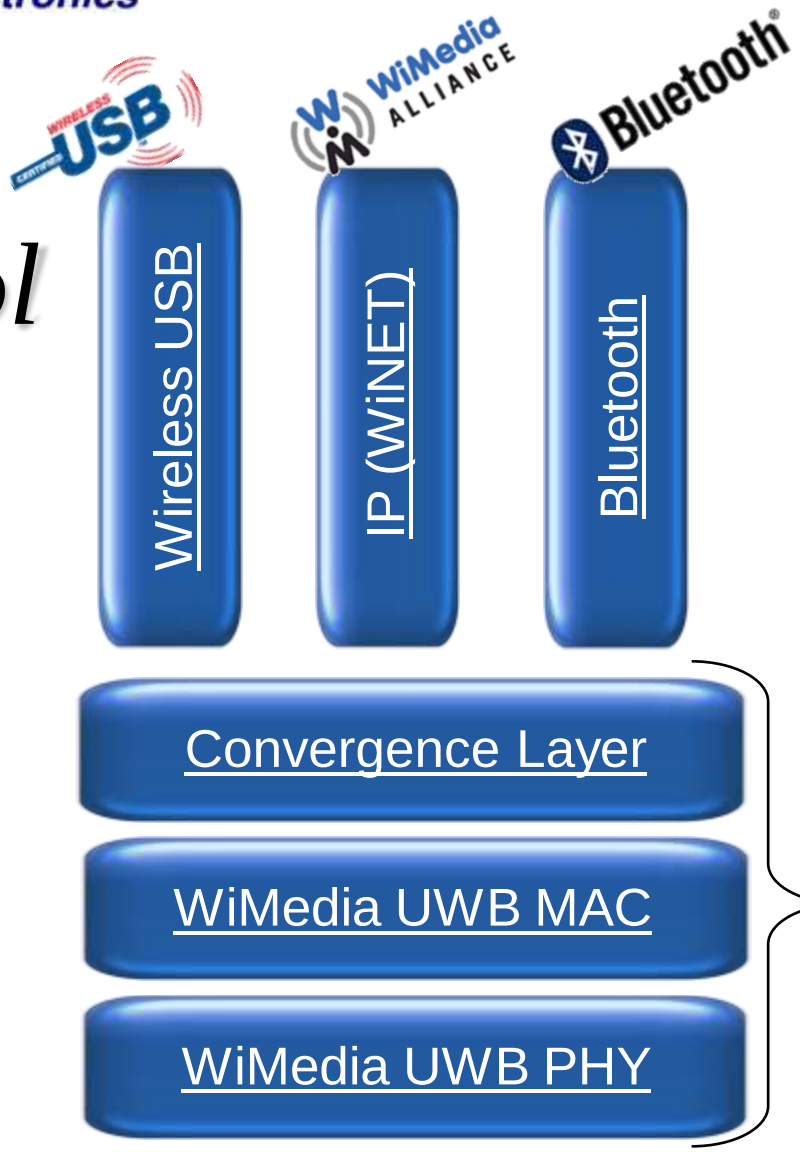
UWB Protocol Relationships



Multiple protocols running over a common platform

WiMedia ALLIANCE

Single Radio Platform

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Wired USB vs Wireless USB

vs

Physical Medium	Cable	Air
Communication Model	One Host, Multiple Devices	One Host, Multiple Devices
Topology	Tiered Star	Hub and Spoke
Number of Devices	127	127
Max Data Rate	480 Mbps	480 Mbps
Software Protocol	Class Drivers	Class Drivers
Traffic Protocol	Token, Data, Handshake	Token, Data, Handshake

Only WiMedia UWB is support by Certified W-USB by the USB-IF

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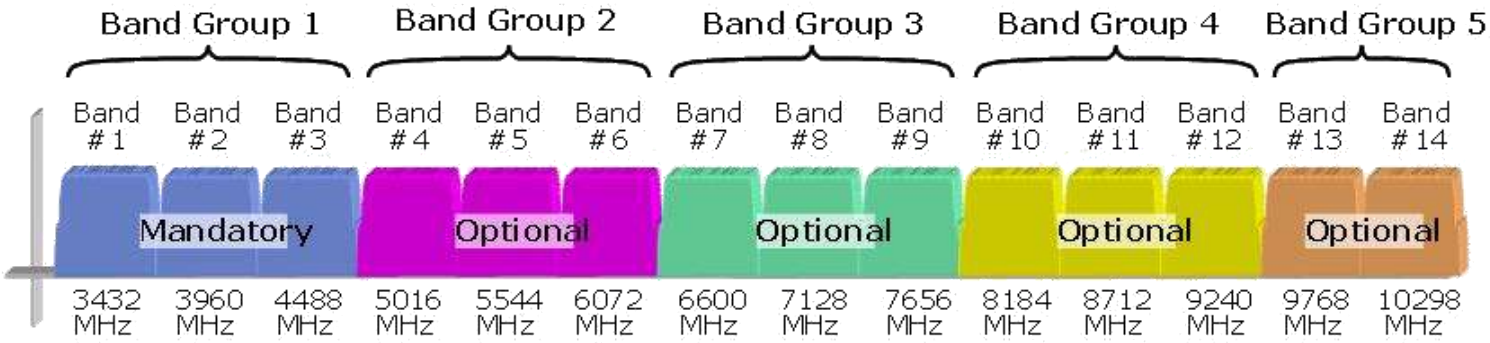
MultiBand-OFDM



- Number of band groups (BG) = 5
  - BG 1-4 consists of three 528 MHz bands
  - BG 5 consists of two 528 MHz bands
- Band subcarriers
  - 128 tone OFDM
  - Tone width = 4.125MHz
  - Tone modulation = QPSK
- Channels
  - TFI (Time Frequency Interleaving)
  - FFI (Fixed Frequency Interleaving)
- WiMedia PHY Specification v1.1
  - Band Switching within BG #1 (3.168 – 4.752 GHz)

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Regulatory Status

USA
- ***Issued ruling in 2002***
  - Unlicensed allocation
  - 3.1GHz-10.6 GHz
  - Emission level: -41.3dBm/MHz
- ***Waiver granted in Mar '05 for power measurement procedures***

Europe
- Decision – Dec'06
  - 4.2GHz-4.8GHz (no DAA until Dec 2010)
  - 6GHz-8.5GHz (no restrictions)
  - In-band Emission level: same as FCC
- ***Under consideration***
  - DAA 3.1-4.2GHz Mid'07
  - 9GHz extension Mid'07
- ***ECMA adopts WiMedia specs (Dec '05)***
  - ECMA to liaise with ETSI for UWB specs

Regulatory Approval

Intermediary Stance

Japan
- ***MIC issued ruling in Aug'06***
  - 3.4-4.8GHz (DAA)
  - 4.2-4.8GHz (no DAA until Dec'08)
  - 7.25-10.25GHz (no restrictions)
  - In-band Emission level: same as FCC
  - Indoor use only

Australia/New Zealand
- UWB trial allowed on interim licenses

Hong Kong/Singapore
- UWB trials allowed
- Emission levels higher than FCC

China
- Working towards regulations in 2007
- WiMedia China chapter opened in Oct'08

Korea
- ***MIC approved spectrum use in Jul'06, ruling expected in 1H'2007***
  - 3.1-4.8GHz (DAA)
  - 4.2-4.8GHz (no DAA until June'10)
  - 7.2-10.2GHz (no restrictions)
  - Emission level: same as FCC
  - Indoor and outdoor use

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WLAN Technology - WiFi

What it stands for: Wireless Fidelity

What it is: IEEE 802.11x for wireless internet access in unlicensed spectrum.

Where it is used: Worldwide.

Who uses it: Many chip manufacturers and equipment makers.

Why it is used: For high-speed internet connection within 100m

When was it used: Started in the late 90s

How it works: 802.11a - 5.2 GHz, 54Mbps (max), OFDM

802.11b/g - 2.4 GHz, 11Mbps/54Mbps (max), DSSS/OFDM

802.11i – Address security flaws 100mw max output power

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WMAN Technologies – WiMax 802.16e

What it stands for: Worldwide Interoperability for Microwave Access Standard

What it is: Low cost "Last Mile" and mobile broadband high-speed internet connectivity

Where it is used: Worldwide at various frequencies. Fixed WiMax: 10 GHz-66 GHz, theoretical max speed of 70 Mbps per sector LOS (Line of Sight). Mobile WiMax: 2-11 GHz, theoretical max speed of 63 Mbps DL/28 Mbps UP/sector in a 10 MHz channel with 2x2 MIMO (<5km) NLOS (Non Line of Sight).

Who uses it: Sprint is deploying at 2.5 GHz across the US. Motorola and Samsung are making the hardware. Intel is pushing hard for WiMax as well. Many other suppliers. Clearwire with Craig McCaw.

When: Started around early 2000, first for fixed wireless.

How it works: OFDM/OFDMA orthogonal frequency division multiplexing access.

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Wireless Generations

1980
1G
AMPS, NMT

Voice mobility

1990
2G
IS-95
GSM
IS-136 (TDMA)
Added voice and data mobility

2000
3G
CDMA2000
UMTS/CDMA
Added voice capacity and high speed data

2005+
4G
WiMax
FlashOFDM
UMB
LTE

Voice and Very High speed data

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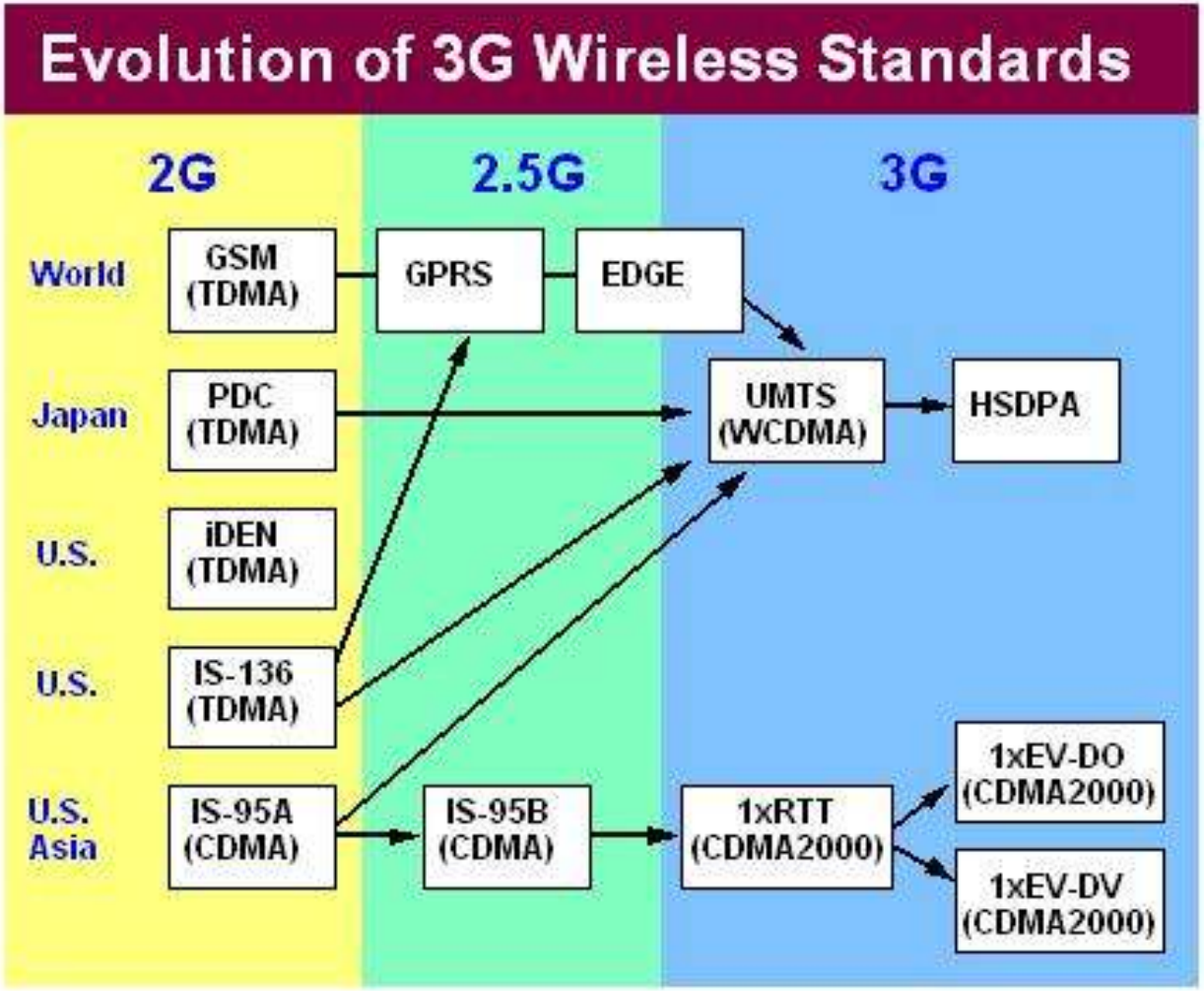

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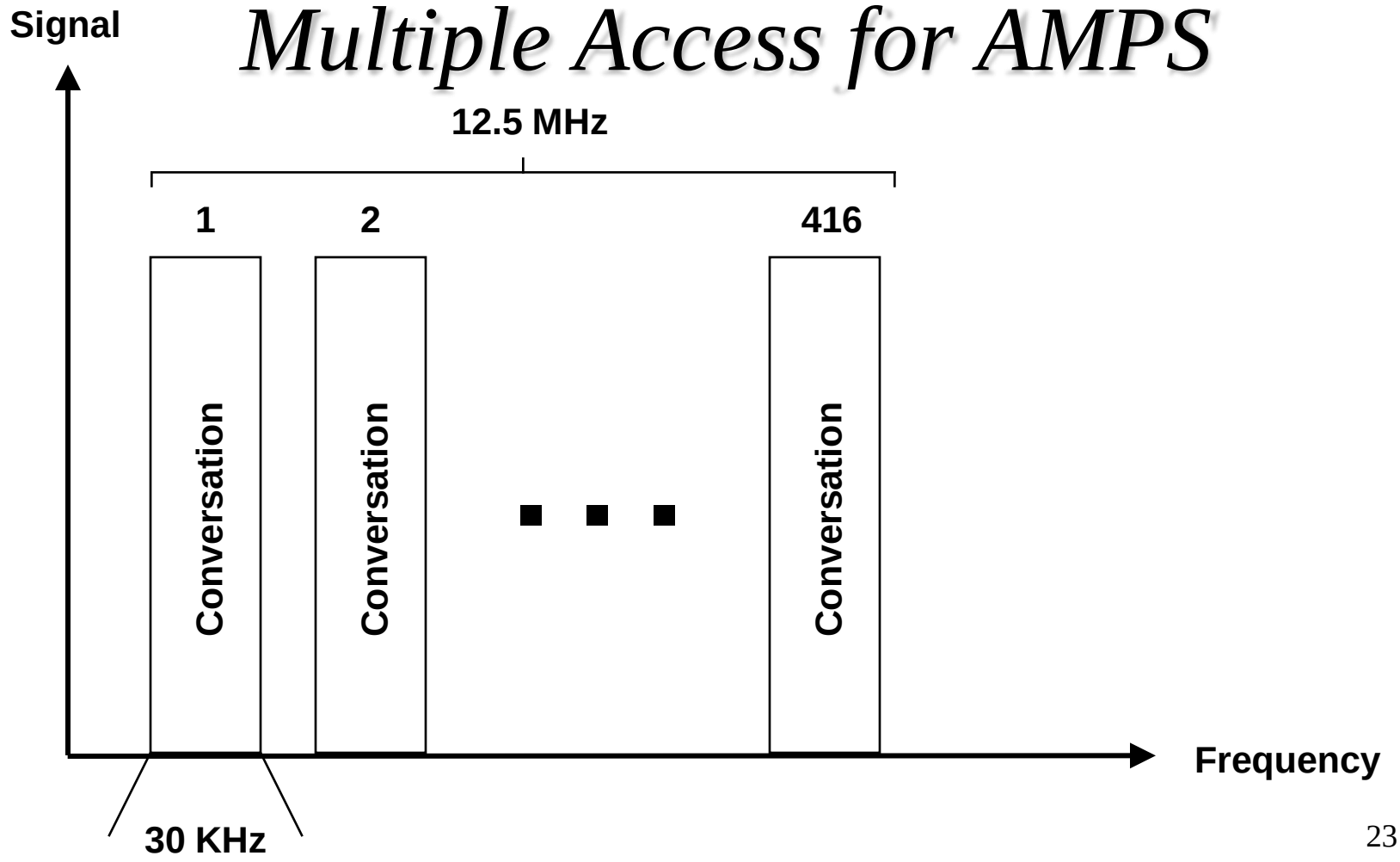
FDMA-Frequency Division Multiple Access for AMPS



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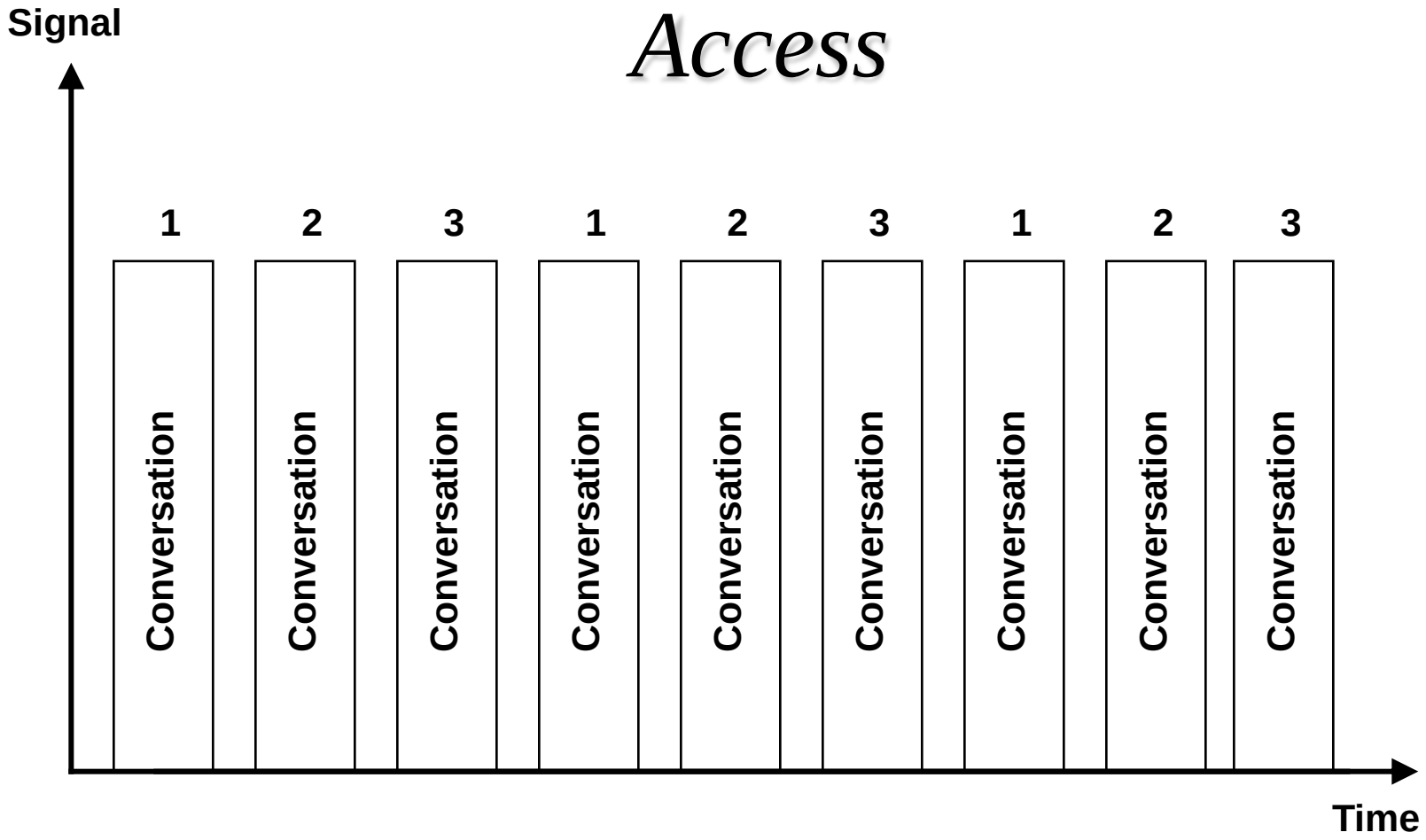
TDMA-Time Division Multiple Access



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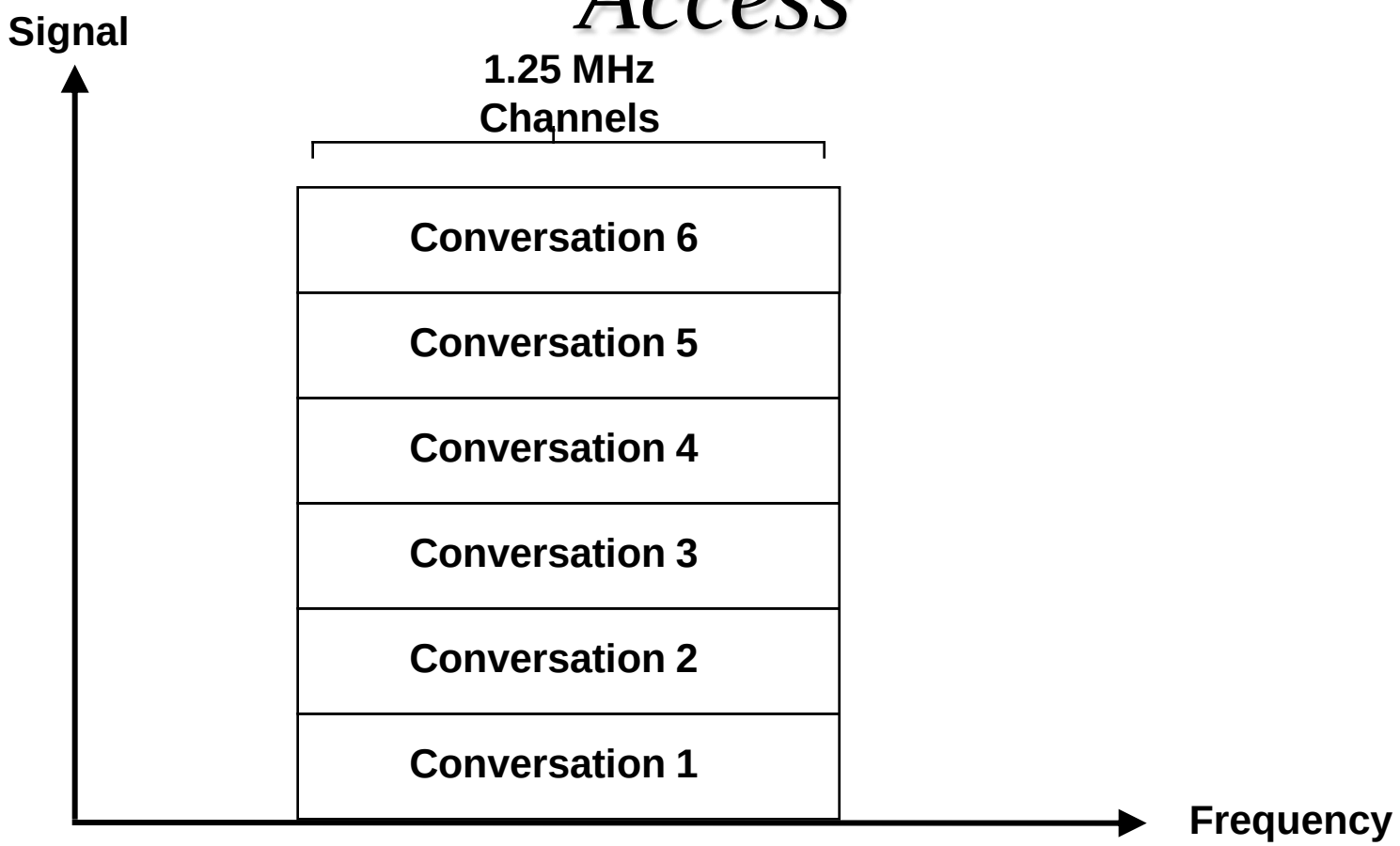
CDMA-Code Division Multiple Access



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Cellular WWAN Technology - AMPS

What it stands for: Advance Mobile Phone System

What it is: First US standard

Why it was used: It was easy to implement and used existing FM technology

Who used it: AT&T and Motorola created the first systems

When it was used: Early 1980s

How does it work: FDMA with analog FM modulation

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NMT

What it stand for: Nordic Mobile Telephone

What it is: A Swedish system created by Ericsson AB

Why it was used: It was Sweden's entrance into cell phones

Who used it: Ericsson AB and other in Nordic countries

When it was used: 1980s

How does it work: Analog system with digital switching

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GSM

What it stand for: Global System for Mobile communications

What it is: A second generation phone system in which both signaling and speech channels are Digital call quality

Why it was used: Has higher digital voice quality and more capacity

Who uses it: Ericsson, Nokia, Siemens, Alcatel and others in Europe

When it was used: 1990s

How does it work: TDMA with digital switching

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UMTS

What it stands for: **Universal Mobile Telecommunication Standard**

What it is: **European standard that continues GSM under 3GPP.**

Where it is used: **Worldwide**

Who uses it: **Major carriers in Europe and Cingular in the US.**

How it works: **WCDMA, 5 MHz channels (1900 MHz UL/2100 MHz DL in many parts of the world).**

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HSDPA/HSUPA/HSPA/HSPA+/LTE

What it stands for: High Speed Downlink Packet Access, High Speed Uplink Access, High Speed Packet Access, Long Term Evolution

What it is: UMTS/WCDMA 3GPP Roadmap

Why it is important: Brings DL rates to 14-42 Mbps peak with 2x2 MIMO. Brings UL rates to 11 Mbps peak. LTE: DL up to 150 Mbps, UL 50 Mbps peak.

When: 2006 HSDPA, 2007 HSUPA, 2009 HSPA+, 2010 LTE

How it works: Better maximizes data through put by using entire channel BW with only data within the channel.

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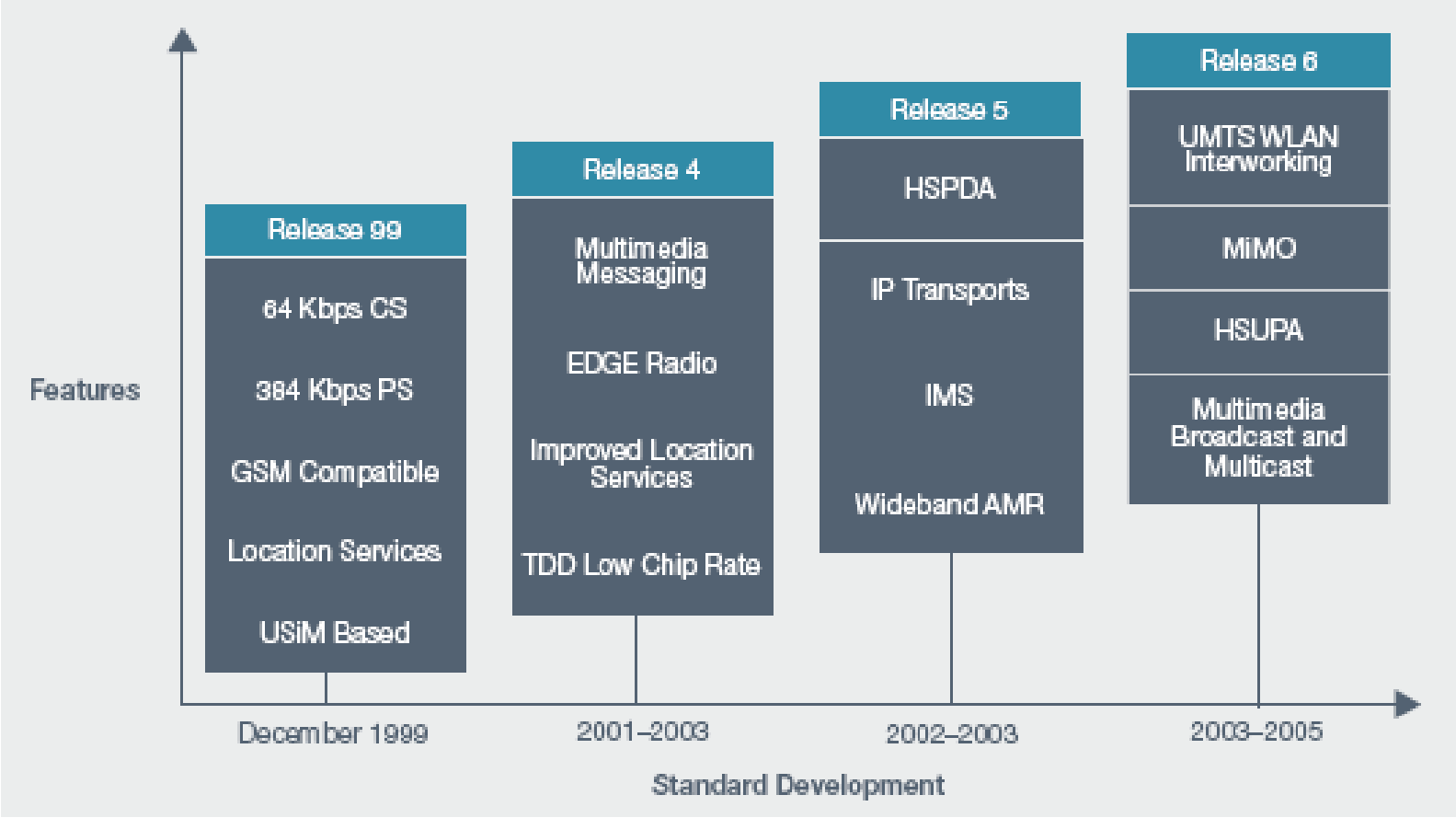
UMTS WCDMA 3GPP Evolution



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UMTS Band Classes

Index	Operating band/ Band class	AKA	Region	UL Frequency Tx	DL Frequency Rx	Duplex spacing	<REF Ior>	Tx BW	Rx BW	Band Gap	1x equivalent
1	I	IMT band	Europe, Japan, China & Korea	2045MHz 1950MHz 1920-1980MHz	2140MHz 2110-2170MHz	190MHz	-106.7dBm	60	60	130	BC6
2	II	PCS1900 band	USA	1920MHz 1880MHz 1850-1910MHz	1960MHz 1930-1990MHz	80MHz	-104.7dBm	60	60	20	BC1
3	III	DCS1800 band	Europe, Japan & China	1795MHz 1748MHz 1710-1785MHz	1843MHz 1805-1880MHz	95MHz	-103.7dBm	75	75	20	BC8
4	IV	AWS 17/21 band	USA	1933MHz 1733MHz 1710-1755MHz	2133MHz 2110-2155MHz	400MHz	-106.7dBm	45	45	355	BC15
5	V	GSM850 band	USA	859MHz 836.5MHz 824-849MHz	881.5MHz 869-894MHz	45MHz	-104.7dBm	25	25	20	BC0
6	VI		Japan	857.5MHz 835MHz 830-840MHz	880MHz 875-885MHz	45MHz	-106.7dBm	10	10	35	
7	VII	UMTS2600	Europe	2595MHz 2535MHz 2500-2570MHz	2655MHz 2620-2690MHz	120MHz	-104.7dBm	70	70	50	BC13
8	VIII	EGSM900 band	Europe, Japan & China	920MHz 897.5MHz 880-915MHz	942.5MHz 925-960MHz	45MHz	-104.7dBm	35	35	10	BC9
9	IX	UMTS1700	Japan	1815MHz 1767MHz 1749.9-1784.9MHz	1862MHz 1844.9-1879.9MHz	95MHz	-105.7dBm	35	35	60	
10	X	?	?	1940MHz 1740MHz 1710-1770MHz	2140MHz 2110-2170MHz			60	60	340	
??	??	JCDMA2000 J-1x	Japan, (KDDI 20MHz)	2025MHz 1930MHz 1920-1940MHz	2120MHz 2110-2130MHz	190MHz		20	20	170	

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Flash OFDM

What it stands for: Fast Low-latency Access with Seamless Handoff Orthogonal Frequency Division Multiplexing.

What it is: High-speed wireless standard and future CDMA2000 standard.

Where it is used: US and Europe

Who : Flarion (bought by Qualcomm), Vodafone, T-Mobile, Siemens, Digita, and others are using the technology.

Why it is important: Qualcomm bought Flarion for the technology and patent portfolio for $600 million. OFDMA is the technology of the future. Most new Standards use version of OFDM.

How it works: OFDMA takes advantage of the latest DSP technology to make OFDMA work. Very good for high data rates and multi-path.

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CDMA "3GPP2" – 1x EV-DO Rev 0, A, B/UMB

What it stands for: Code Division Multiple Access, 1x Evolution-Data Only Revision 0, A, B, Ultra Mobile Broadband

What it is: CDMA (3GPP2) high-speed data road map. UMB has potential to get to Forward Link:280 Mbps peak, Reverse Link:68 Mbps peak.

Where it is used: USA, Korea, Japan, China, India, and South America, Some in Europe

Why it is used: CDMA high speed road map peak rates given:

CDMA2000 1x, 307Kbps FL, 153 Kbps RL

EVDO Rev 0, 2400 Kbps FL, 153 Kbps RL

EVDO Rev A, 3100 Kbps FL, 1800 Kbps RL

EVDO Rev B, 6.2-73.5 Mbps FL, 3.6-27 Mbps RL

When : 1x 1999, Rev 0 ~2002, Rev A present, Rev B 2010

How it works: Better maximizes data through put by using entire channel. Uses multi-carrier, 1.25x2 or 3 channels.

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CDMA2000 Terminology

- **CDMA2000** – Trademarked name for IMT-2000 CDMA Multi-Carrier.
- **CDMA2000 1X** – 3G technology which offers 2 times increase in voice capacity and provides data speeds up to 625 Kbps on a single (1.25 MHz, or 1X) carrier in new or existing spectrum.
- **CDMA2000 1xEV** – Evolution of CDMA2000 1X. 1xEV-DO (Data-Only) uses a separate 1.25 MHz carrier for data and offers peak data rates of 2.4 Mbps. 1xEV-DV (Data-Voice) integrates voice and data on the same carrier.
- **CDMA2000 3X** – 3G technology which offers voice and data on a 5 MHz carrier (or 3 times [3X] the 1.25 MHz carrier).

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CDMA 1x, Band Classes:

Band Class (Sub-class)	System	Mobile transmit frequency band. (MHz)	Base station transmit frequency band. (MHz)
0	North American Cellular	824 - 849	869 – 894
1	North American PCS	1850 - 1910	1930 – 1990
2	Total Access Communications System	872 - 915	917 – 960
3	Japan Total Access Communications System (A1)	887 - 889	832 – 834
3	Japan Total Access Communications System (A3)	893 - 898	838 – 843
3	Japan Total Access Communications System (A2)	898 - 901	843 - 846
3	Japan Total Access Communications System (A)	915 - 925	860 – 870
4	Korean PCS	1750 - 1780	1840 – 1870
5(0)	Nordic Mobile Telephone 450 (A)	452.500 – 457.475	462.500 – 467.475
5(1)	Nordic Mobile Telephone 450 (B)	452.000 – 456.475	462.000 – 466.475
5(2)	Nordic Mobile Telephone 450 (C)	450.000 – 454.800	460.000 – 464.800
5(3)	Nordic Mobile Telephone 450 (D)	411.675 – 415.850	421.675 – 425.850
5(4)	Nordic Mobile Telephone 450 (E)	415.500 – 419.975	425.500 – 429.975
5(5)	Nordic Mobile Telephone 450 (F)	479.000 – 483.480	489.000 – 493.480
5(6)	Nordic Mobile Telephone 450 (G)	455.230 – 459.990	465.230 – 469.990
5(7)	Nordic Mobile Telephone 450 (H)	451.310 – 455.730	461.310 – 465.730

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CDMA 1x, Band Classes (continued):

6	IMT-2000	1920 - 1980	2110 – 2170
7	North American 700	776 - 794	746 – 764
8	1800 MHz	1710 - 1785	1805 – 1880
9	900 MHz	880 - 915	925 - 960
10	Secondary 800 MHz Band	806 - 901	851 - 940
11	400 MHz European PAMR Band	452 - 484	462 - 494
12	800 MHz PAMR Band	870 - 876	915 - 921
13	2.5 GHz IMT-2000 Extension Band	2500 - 2570	2620 - 2690
14(A)	US PCS 1.9GHz Band (A)	1850 -1865	1930 -1945
14(D)	US PCS 1.9GHz Band (D)	1865 -1870	1945 -1950
14(B)	US PCS 1.9GHz Band (B)	1870 -1885	1950 -1965
14(E)	US PCS 1.9GHz Band (E)	1885 -1890	1965 -1970
14(F)	US PCS 1.9GHz Band (F)	1890 -1895	1970 -1975
14(C)	US PCS 1.9GHz Band (C)	1895 -1910	1975 -1990
14(G)	US PCS 1.9GHz Band (G)	1910 -1915	1990 -1995
14(H)	US PCS 1.9GHz Band (H)	1915 - 1920	1995 - 2000
15	AWS Band	1710 - 1755	2110 - 2155

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3GPP

- Stands for 3rd Generation Partnership Project
- Also known as the GSM “European” Partnership Project
- Current organization partners are: ARIB (Japan), ATIS) North America) CCSA (China), ETSI(Europe), TTA (Korea), TTC (Japan)

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3GPP2

- Also known as the next generation of CDMA2000.
- 3GPP2 is a collaborative effort between five officially recognized SDOs:
- ARIB (Japan), CCSA (China), TIA (North America), TTA (Korea), TTC (Japan).
- These SDOs are known as the Project's Organizational Partners (OPs).

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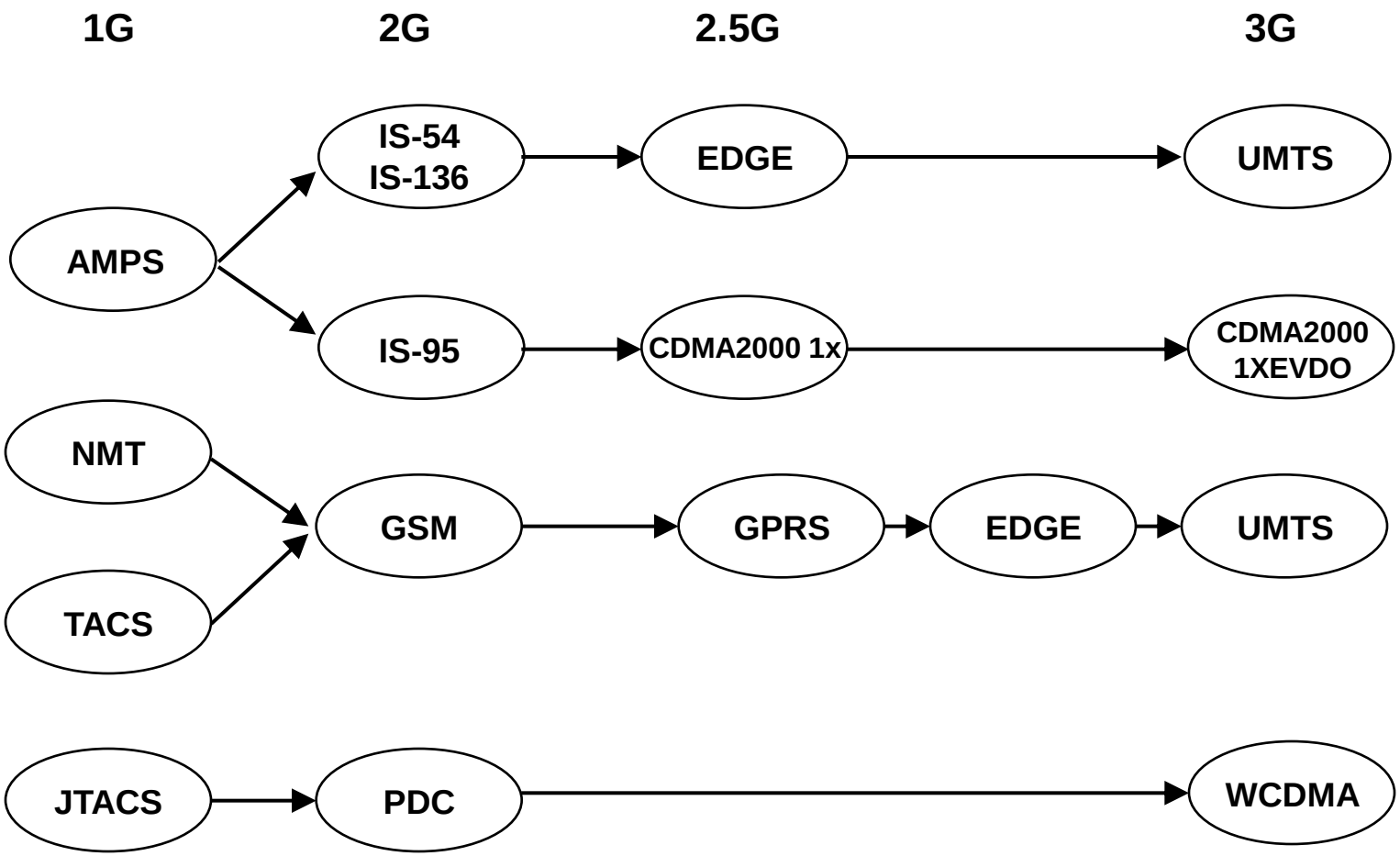
Cellular Standard Roadmaps



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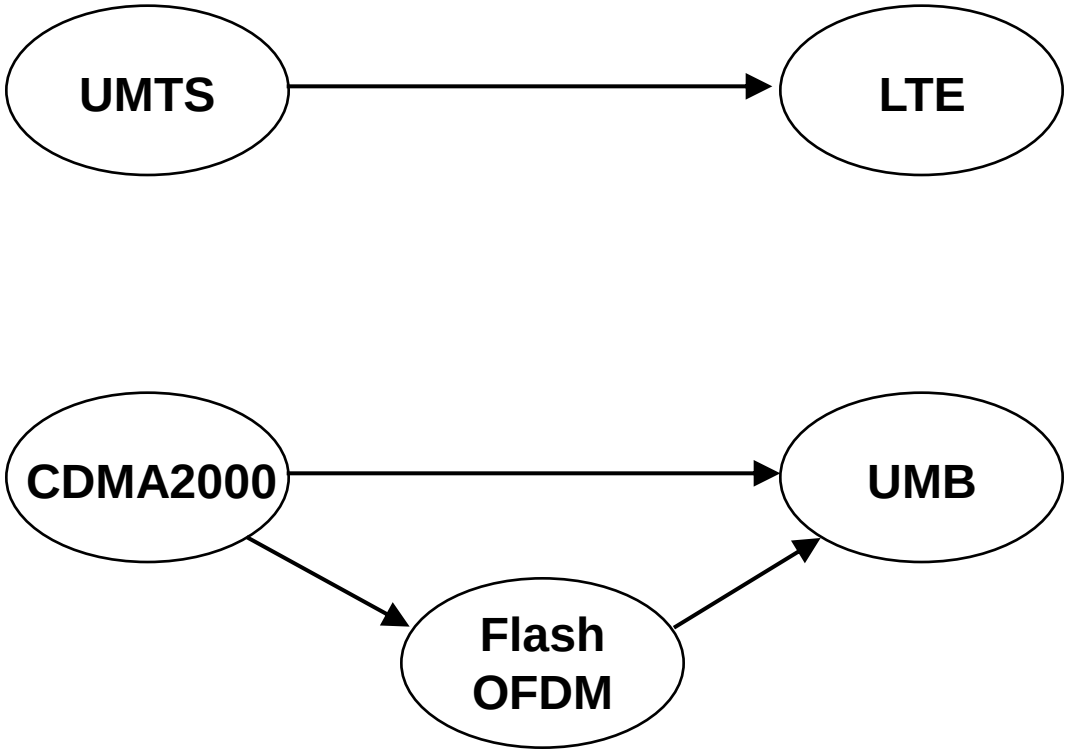
Future Cellular Standards Roadmap



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Other Technologies

Satellite Radio: Code-OFDM

DBS Direct Broadcast Satellite: Ku Band, 8PSK with Coding

MediaFlo: Mobile TV, Channel 55, Qualcomm Technology

DVB-H: Mobile TV, European Standard, Completing with MediaFlo

GlobalStar: Satcom phone, Qualcomm designed and built

Iridium: Satcom phone, Motorola designed and built

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Thank you!

- Stay tuned…..
- New changes happening daily.
- Cellular(UMB and LTE) vs. Wimax 802.16e
- Feel free to contact me if you have any questions:
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- E-mail: mhoffman@acetec.com