4GWE
4G WIRELESS EVOLUTION

octoScope

The Evolving Standards

Fanny Mlinarsky
President
octoScope, Inc.

13-Sep-11

Presented by: TMC crossfire media

Long Ago…

BBC broadcast 1935

Today

Over the last 5 years wireless bandwidth deployed in the US has increased 553-fold.

George Gilder
Chairman, Gilder Technology Group

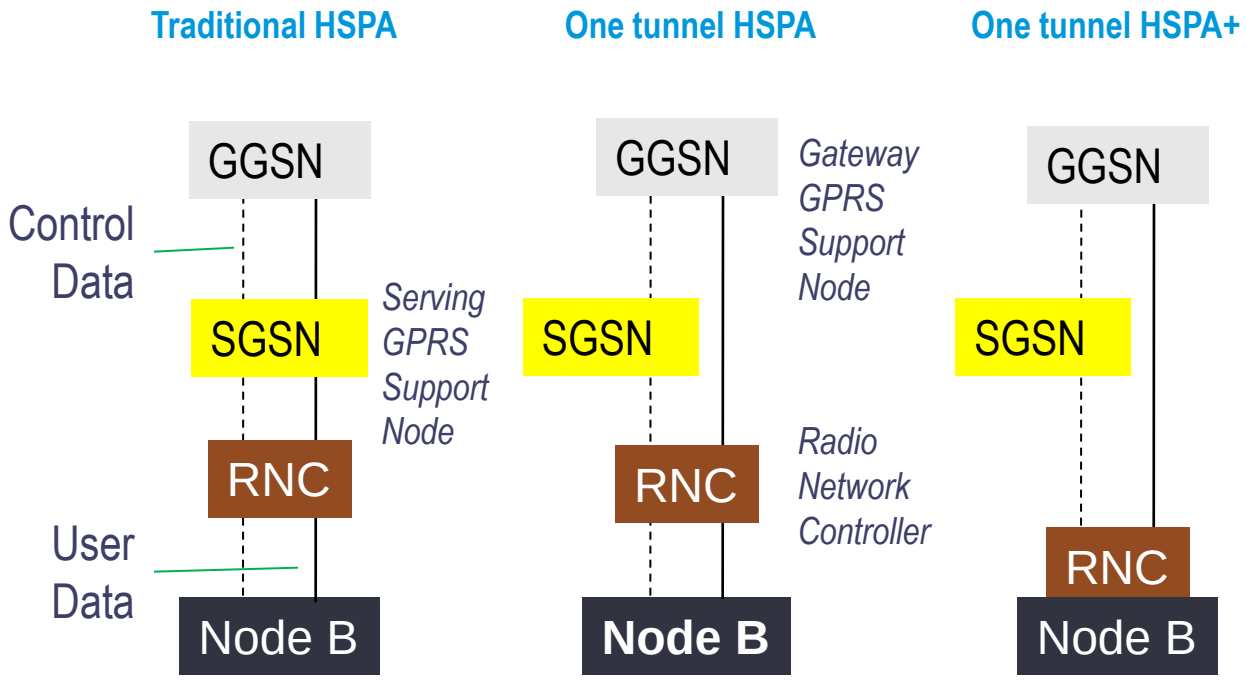
G	The G's	Peak Data Rate (Mbps)	
		Downlink	Uplink
1	Analog	19.2 kbps	
2	Digital – TDMA, CDMA	14.4 kbps	
3	Improved CDMA variants (WCDMA, CDMA2000)	144 kbps (1xRTT); 384 kbps (UMTS); 2.4 Mbps (EVDO)	
3.5	HSPA (today)	14 Mbps	2 Mbps
3.75	HSPA (Release 7) DL 64QAM or 2x2 MIMO; UL 16QAM	28 Mbps	11.5 Mbps
	HSPA (Release 8) DL 64QAM and 2x2 MIMO	42 Mbps	11.5 Mbps
3.9	WiMAX Release 1.0 TDD (2:1 UL/DL ratio), 10 MHz channel	40 Mbps	10 Mbps
	LTE, FDD 5 MHz UL/DL, 2 Layers DL	43.2 Mbps	21.6 Mbps
	LTE CAT-3	100 Mbps	50 Mbps

Maximum LTE data rates in the 20 MHz channel are 326 Mbps DL (4 streams), 172 Mbps UL (2 streams)

OFDM

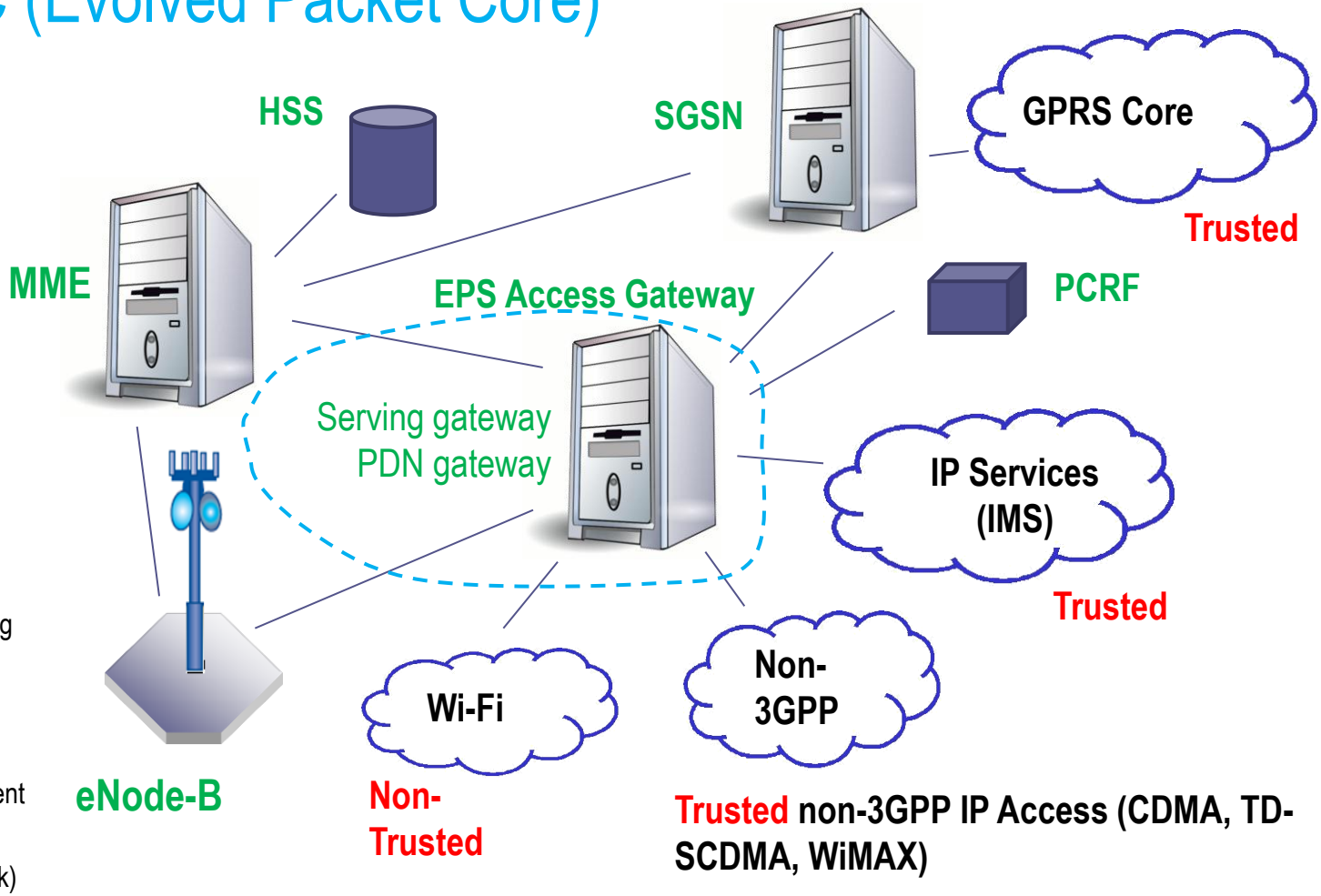
HSPA and HSPA+

- HSPA+ is aimed at extending operators' investment in HSPA
  - 2x2 MIMO, 64 QAM in the downlink, 16 QAM in the uplink
  - Data rates up to 42 MB in the downlink and 11.5 MB in the uplink.



One-tunnel architecture flattens the network by enabling a direct transport path for user data between RNC and the GGSN, thus minimizing delays and set-up time

LTE EPC (Evolved Packet Core)



SGSN (Serving GPRS Support Node)

PCRF (policy and charging rules function)

HSS (Home Subscriber Server)

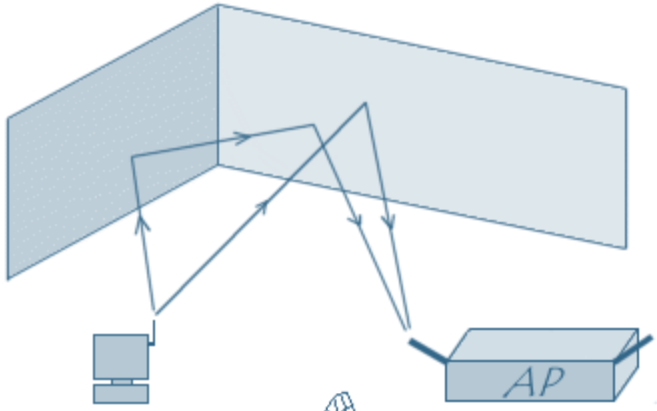
MME (Mobility Management Entity)

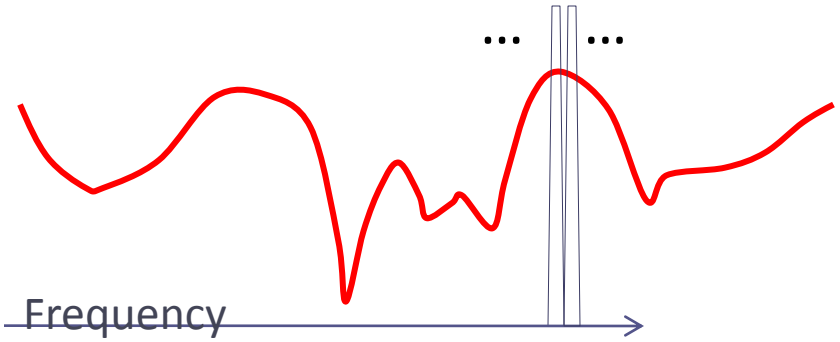
PDN (Public Data Network)

Flat, low-latency architecture

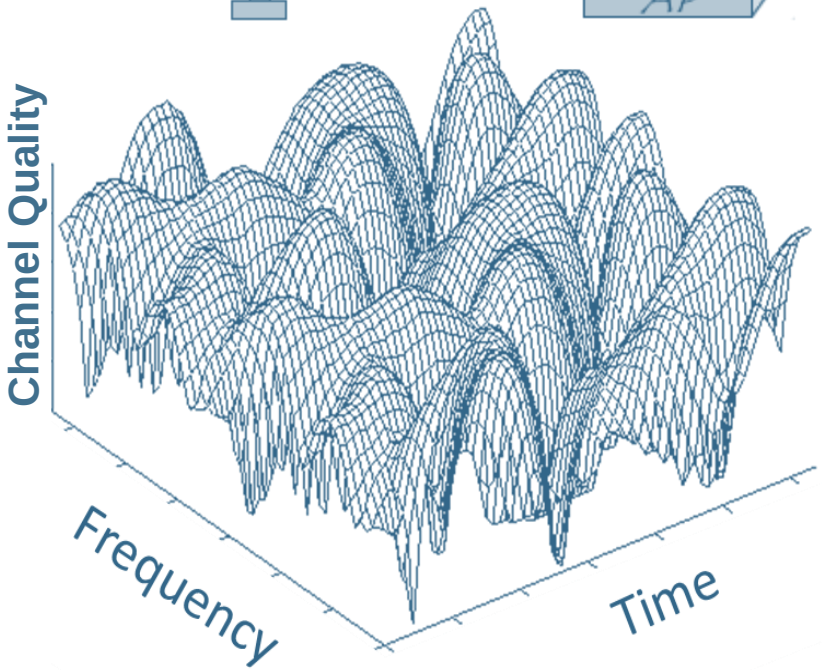
OFDM and MIMO

- OFDM transforms a frequency- and time-variable fading channel into parallel correlated flat-fading channels, enabling wide bandwidth operation





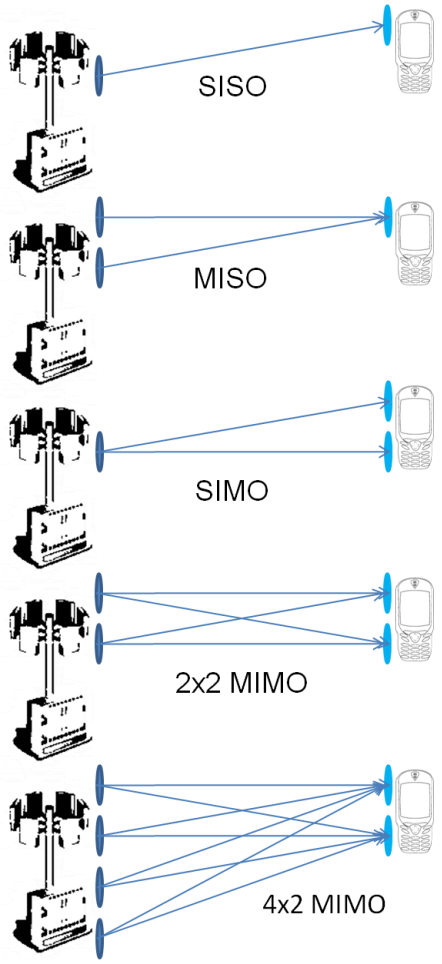
Frequency-variable channel appears flat over the narrow band of an OFDM subcarrier.



OFDM = orthogonal frequency division multiplexing
MIMO = multiple input multiple output

Multiple Antenna Techniques

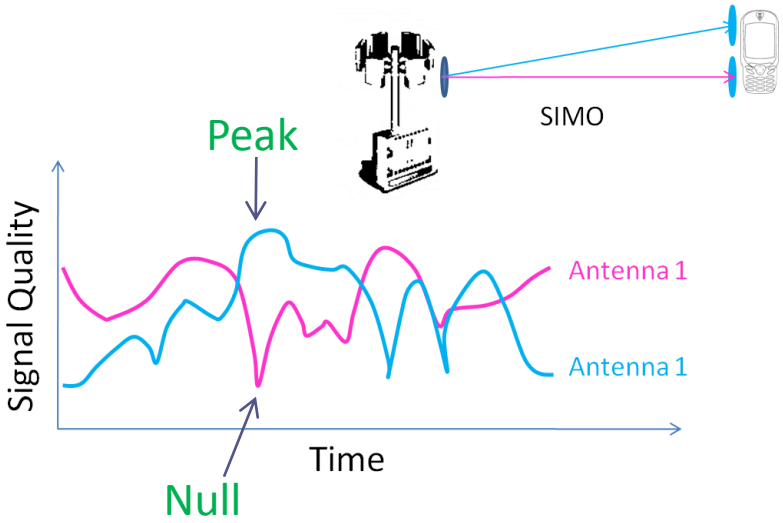
- SISO (Single Input Single Output)
  - Traditional radio
- MISO (Multiple Input Single Output)
  - Transmit diversity (STBC, SFBC, CDD)
- SIMO (Single Input Multiple Output)
  - Receive diversity, MRC
- MIMO (Multiple Input Multiple Output)
  - SM to transmit multiple streams simultaneously; can be used in conjunction with CDD; works best in high SNR environments and channels de-correlated by multipath
  - TX and RX diversity, used independently or together; used to enhance throughput in the presence of adverse channel conditions
- Beamforming

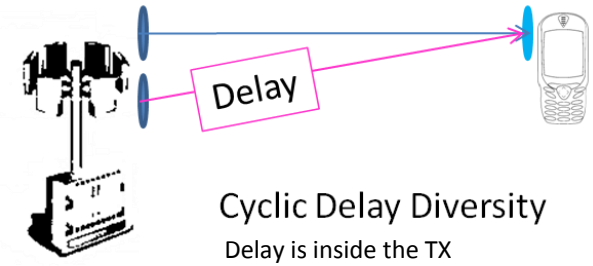


SM = spatial multiplexing
SFBC = space frequency block coding
STBC = space time block coding
CDD = cyclic delay diversity
MRC = maximal ratio combining
SM = Spatial Multiplexing
SNR = signal to noise ratio

MIMO Based RX and TX Diversity

- When 2 receivers are available in a MIMO radio MRC can be used to combine signals from two or more antennas, improving SNR
- MIMO also enables transmit diversity techniques, including CDD, STBC, SFBC
- TX diversity spreads the signal creating artificial multipath to decorrelate signals from different transmitters so as to optimize signal reception





Cyclic Delay Diversity

Delay is inside the TX

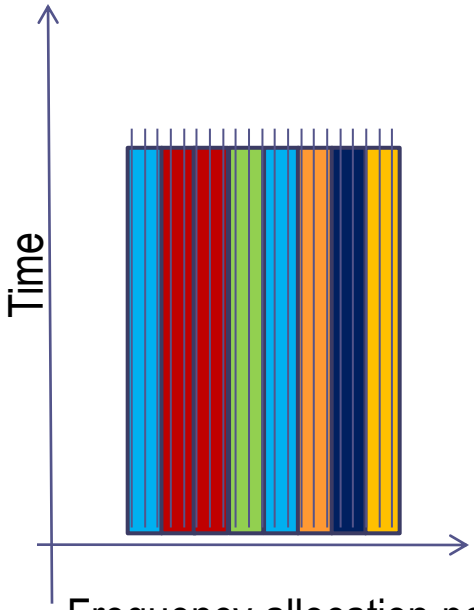
MIMO = multiple input multiple output
SIMO = single input multiple outputs
SM = spatial multiplexing
SFBC = space frequency block coding
STBC = space time block coding
CDD = cyclic delay diversity
MRC = maximal ratio combining
SM = Spatial Multiplexing
SNR = signal to noise ratio

OFDMA

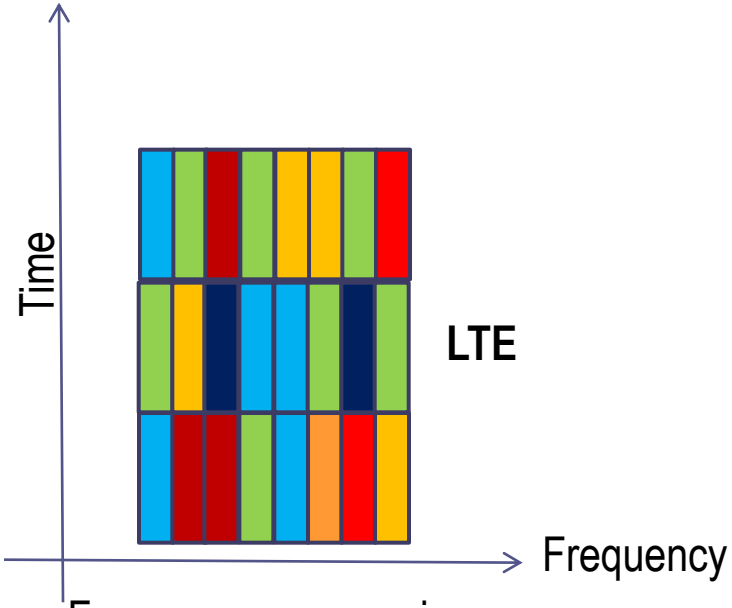
OFDM is a modulation scheme

OFDMA is a modulation and access scheme

Multiple Access



Frequency allocation per user is continuous vs. time

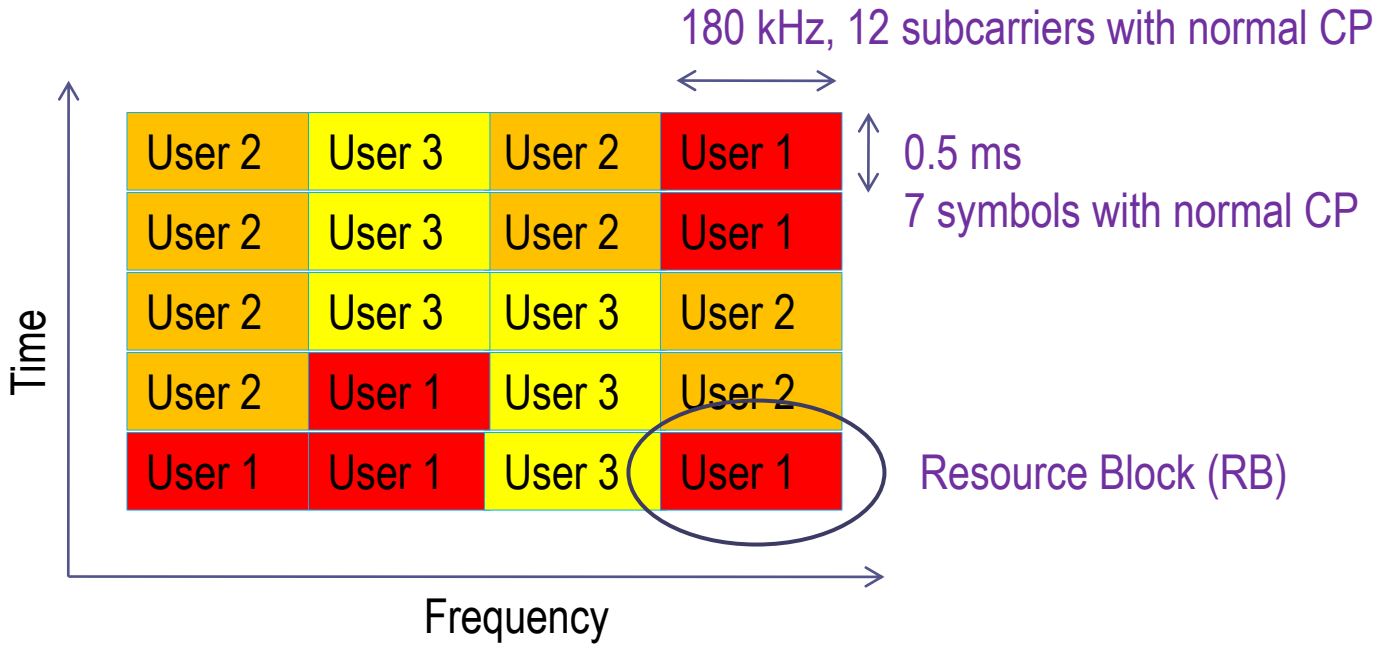


Frequency per user is dynamically allocated vs. time slots

User 1 | User 2 | User 3 | User 4 | User 5

OFDM = orthogonal frequency division multiplexing
OFDMA = orthogonal frequency division multiple access

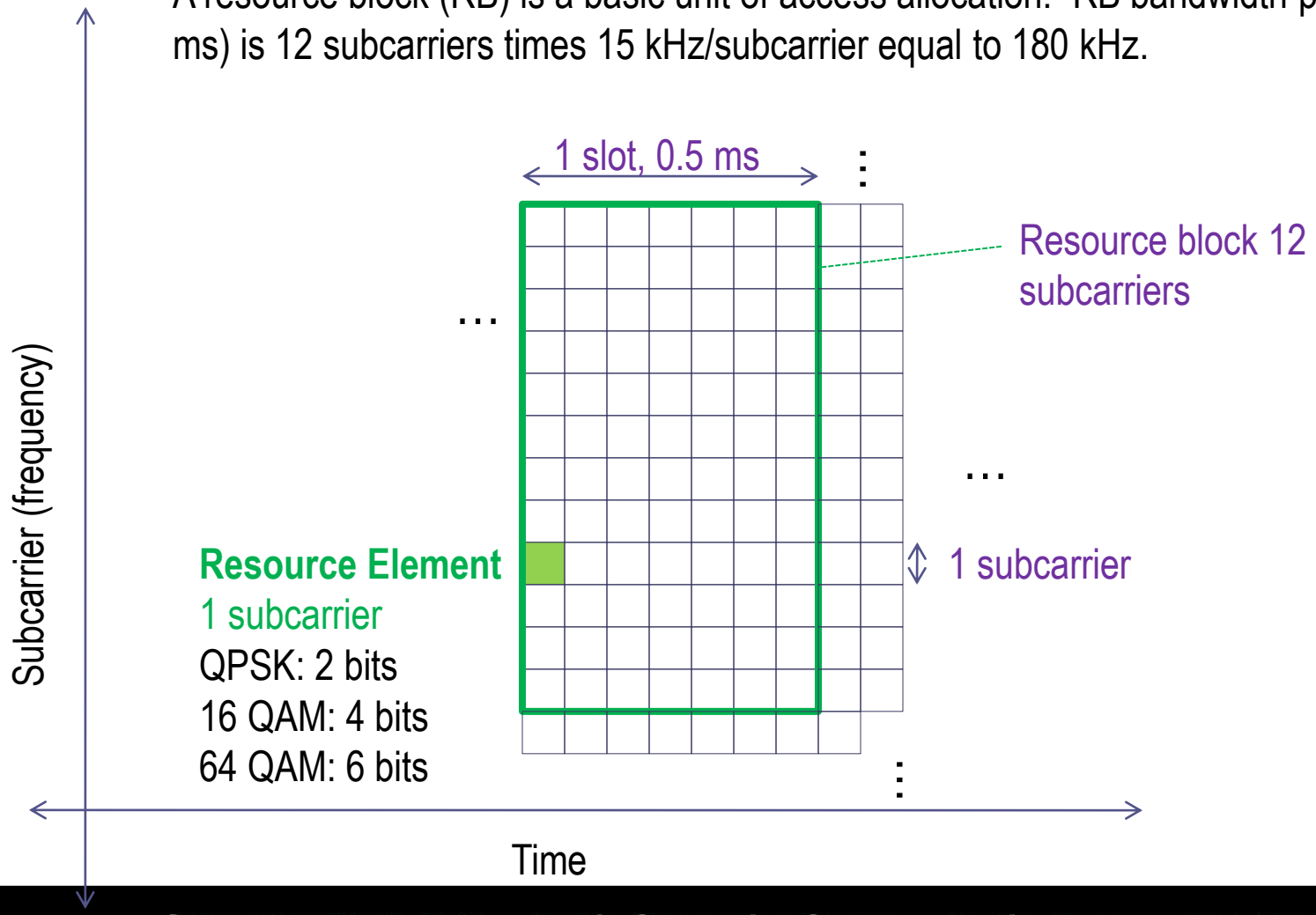
LTE Resource Allocation



- Resources are allocated per user in time and frequency. RB is the basic unit of allocation.
- RB is 180 kHz by 0.5 ms; typically 12 subcarriers by 7 OFDM symbols, but the number of subcarriers and symbols can vary based on CP

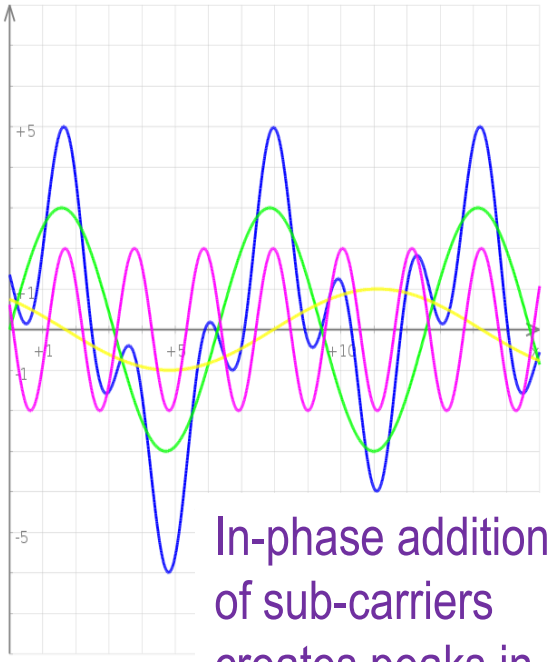
Resource Block

A resource block (RB) is a basic unit of access allocation. RB bandwidth per slot (0.5 ms) is 12 subcarriers times 15 kHz/subcarrier equal to 180 kHz.



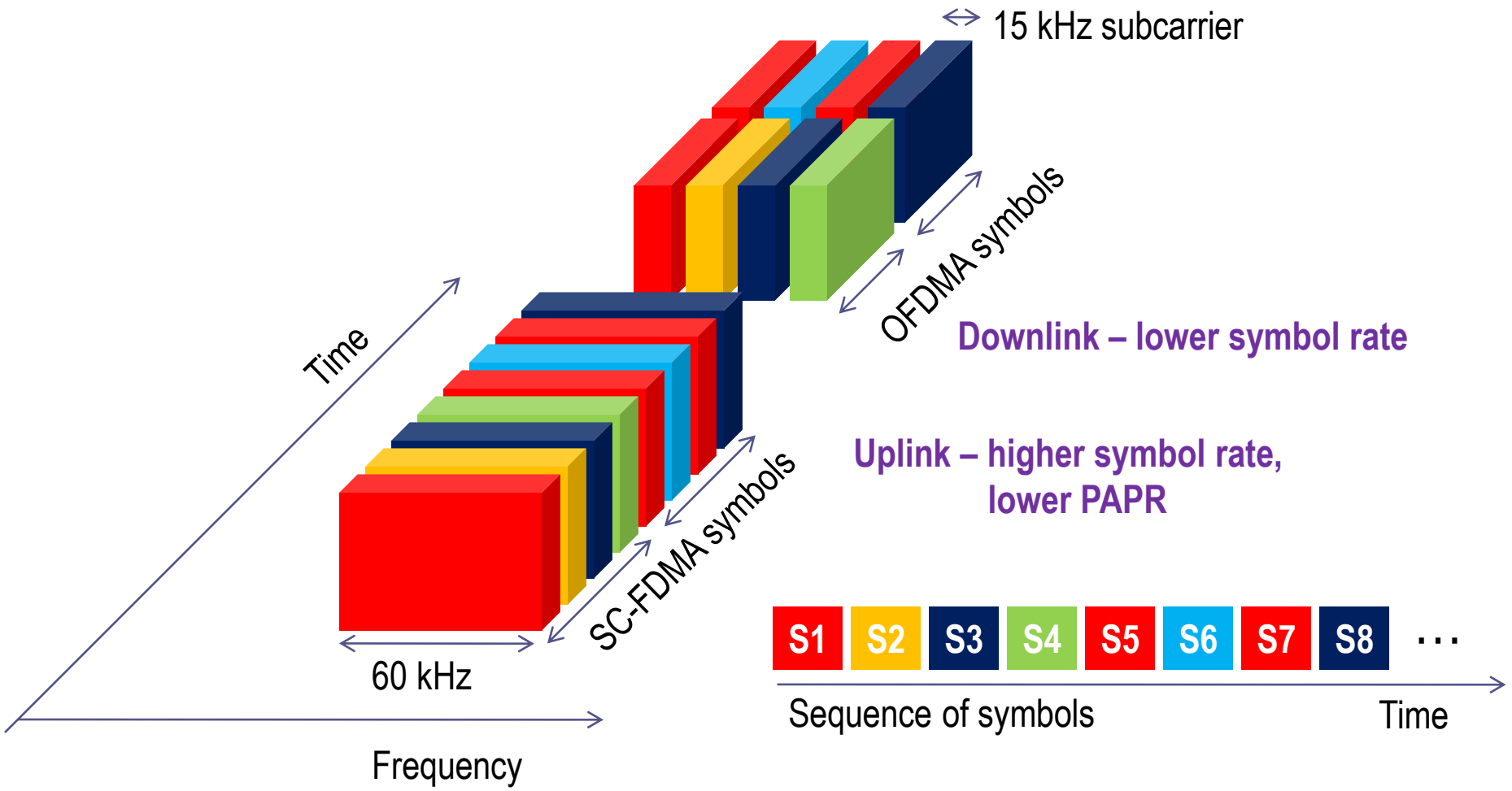
OFDMA vs. SC-FDMA (LTE Uplink)

- Multi-carrier OFDM signal exhibits high PAPR (Peak to Average Power Ratio) due to in-phase addition of subcarriers.
- Power Amplifiers (PAs) must accommodate occasional peaks and this results low efficiency of PAs, typically only 15-20% efficient. Low PA efficiency significantly shortens battery life.
- To minimize PAPR, LTE has adapted SC-FDMA (single carrier OFDM) in the uplink. SC-FDMA exhibits 3-6 dB less PAPR than OFDMA.

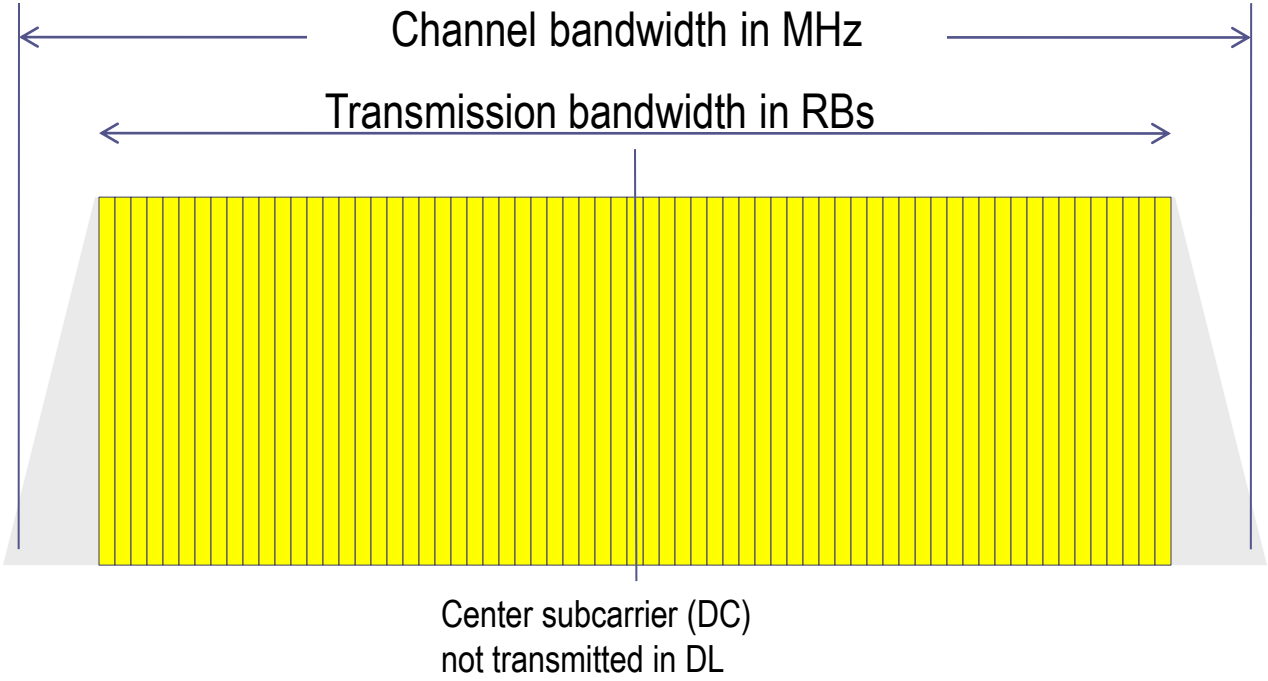


In-phase addition of sub-carriers creates peaks in the OFDM signal

SC-FDMA vs. OFDMA



LTE Scalable Channel Bandwidth

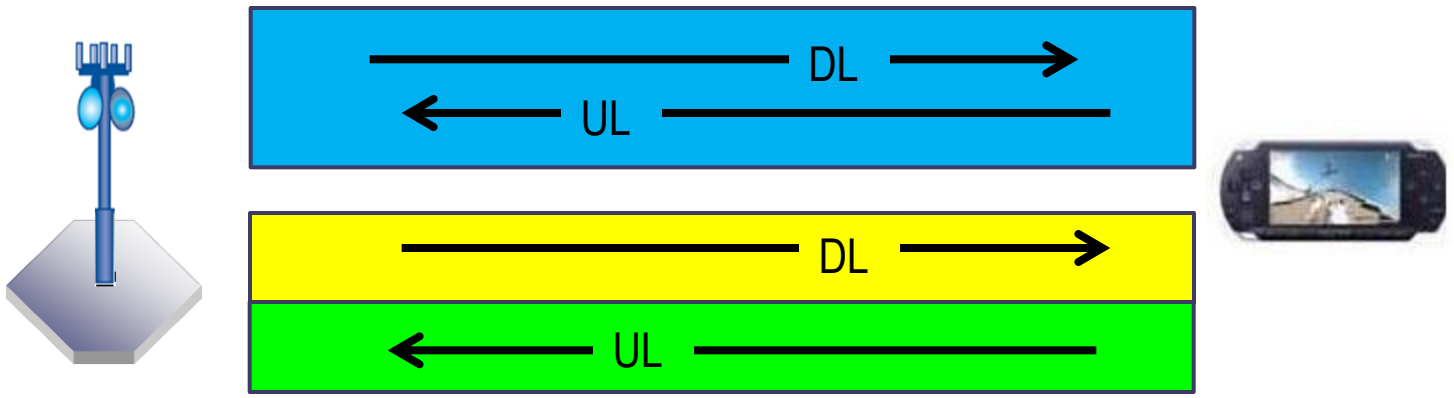


Channel bw	1.4	3	5	10	15	20	MHz
Transmission bw	1.08	2.7	4.5	9	13.5	18	
# RBs per slot	6	15	25	50	75	100	

FDD vs. TDD

- FDD (frequency division duplex)
  - Paired channels
- TDD (time division duplex)
  - Single frequency channel for uplink an downlink
  - Is more flexible than FDD in its proportioning of uplink vs. downlink bandwidth utilization
  - Can ease spectrum allocation issues

TD-LTE

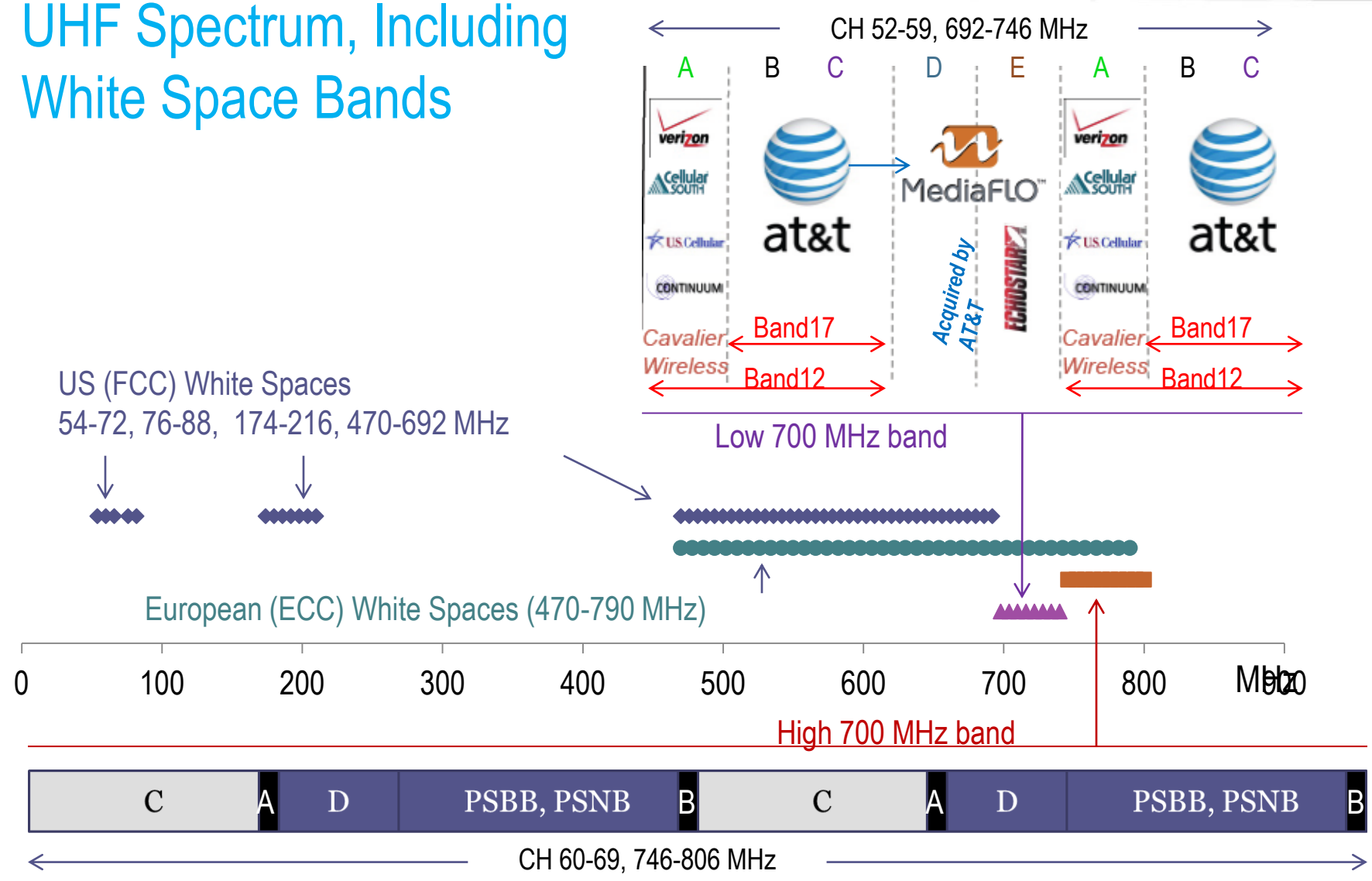


LTE Frequency Bands - FDD

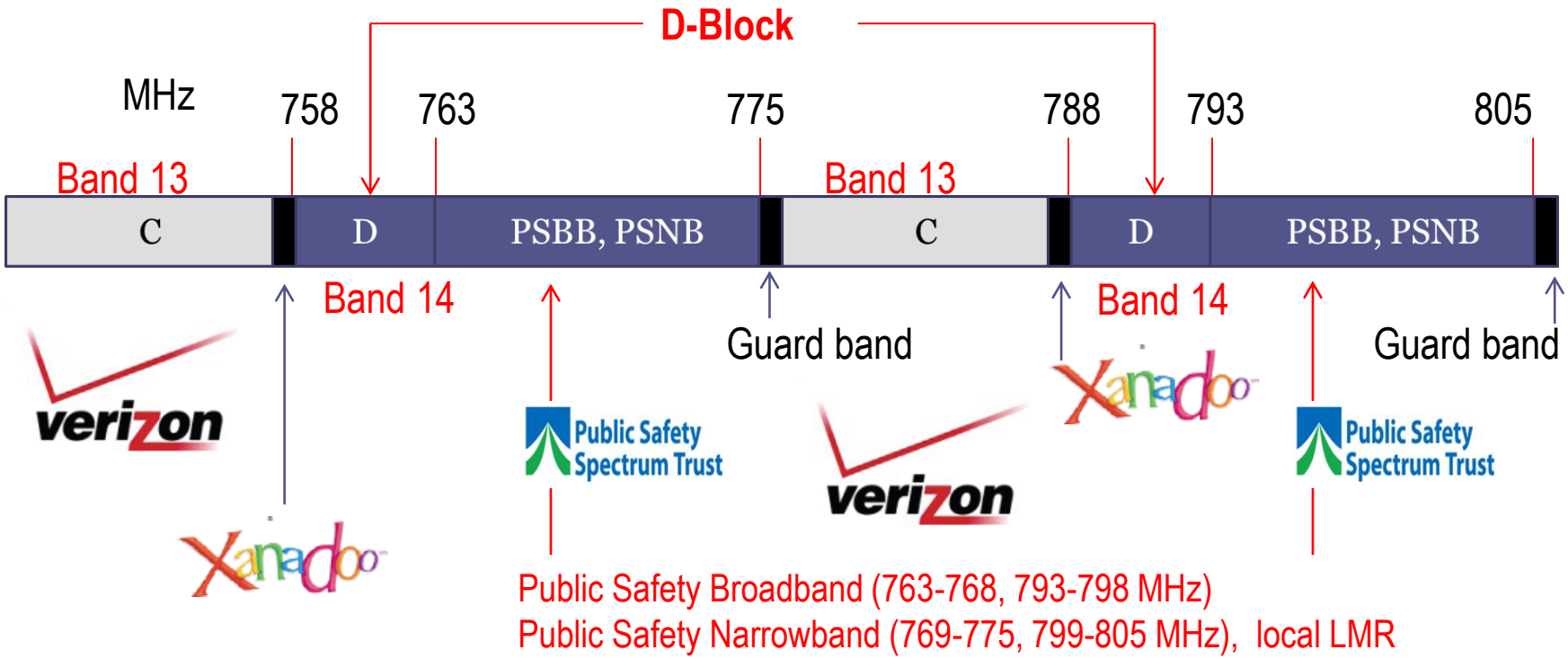
Source: 3GPP TS 36.104; V10.1.0 (2010-12)

Band	Uplink (UL)	Downlink (DL)	Regions
1	1920 -1980 MHz	2110 - 2170 MHz	Europe, Asia
2	1850 -1910 MHz	1930 - 1990 MHz	Americas, Asia
3	1710 -1785 MHz	1805 -1880 MHz	Europe, Asia, Americas
4	1710 -1755 MHz	2110 - 2155 MHz	Americas
5	824-849 MHz	869 - 894 MHz	Americas
6	830 - 840 MHz	875 - 885 MHz	Japan
7	2500 - 2570 MHz	2620 - 2690 MHz	Europe, Asia
8	880 - 915 MHz	925 - 960 MHz	Europe, Asia
9	1749.9 - 1784.9 MHz	1844.9 - 1879.9 MHz	Japan
10	1710 -1770 MHz	2110 - 2170 MHz	Americas
11	1427.9 - 1452.9 MHz	1475.9 - 1500.9 MHz	Japan
12	698 - 716 MHz	728 - 746 MHz	Americas
13	777 - 787 MHz	746 - 756 MHz	Americas (Verizon)
14	788 - 798 MHz	758 - 768 MHz	Americas (D-Block, public safety)
17	704 - 716 MHz	734 - 746 MHz	Americas (AT&T)
18	815 – 830 MHz	860 – 875 MHz	
19	830 – 845 MHz	875 – 890 MHz	
20	832 – 862 MHz	791 – 821 MHz	
21	1447.9 – 1462.9 MHz	1495.9 – 1510.9 MHz	

UHF Spectrum, Including White Space Bands



High 700 MHz Band



TV Channels and White Space Allocation

US – FCC

	Channel #	Frequency Band	
Fixed TVBDs only	2-4	54-72 MHz	VHF
	5-6	76-88 MHz	
	7-13	174-216 MHz	
	14-20	470-512 MHz**	UHF
White Spaces	21-51*	512-692 MHz	

*Channel 37 (608-614 MHz) is reserved for radio astronomy
**Shared with public safety

Transition from NTSC to ATSC (analog to digital TV) in June 12, 2009 freed up channels 52-69 (above 692 MHz)

http://www.fcc.gov/mb/engineering/usallochrt.pdf

Europe – ECC

	Channel #	Frequency Band	
	5-12	174-230 MHz	VHF
White Spaces	21-60	470-790 MHz	UHF
	61-69	790-862 MHz	

LTE Frequency Bands - TDD

TD-LTE

Band	UL and DL	Regions
33	1900 - 1920 MHz	Europe, Asia (not Japan)
34	2010 - 2025 MHz	Europe, Asia
35	1850 - 1910 MHz	
36	1930 - 1990 MHz	
37	1910 - 1930 MHz	
38	2570 - 2620 MHz	Europe
39	1880 - 1920 MHz	China
40	2300 – 2400 MHz	Europe, Asia
41	2496 – 2690 MHz	Americas (Clearwire LTE)
42	3400 – 3600 MHz	
43	3600 – 3800 MHz	

Source: 3GPP TS 36.104; V10.1.0 (2010-12)

WiMAX Frequency Bands - TDD

Band Class	(GHz) BW (MHZ)	Bandwidth Certification Group Code (BCG)
1	**2.3-2.4**	
	8.75	1.A
	5 AND 10	1.B
2	**2.305-2.320, 2.345-2.360**	
	3.5	2.A (Obsolete, replaced by 2.D)
	5	2.B (Obsolete, replaced by 2.D)
	10	2.C (Obsolete, replaced by 2.D)
	3.5 AND 5 AND 10	2.D
3	**2.496-2.69**	
	5 AND 10	3.A
4	**3.3-3.4**	
	5	4.A
	7	4.B
	10	4.C
5	**3.4-3.8**	
	5	5.A
	7	5.B
	10	5.C
7	**0.698-0.862**	
	5 AND 7 AND 10	7.A
	8 MHz	7.F

WiMAX Forum Mobile Certification Profile v1.1.0

A universal frequency step size of 250 KHz is recommended for all band classes, while 200 KHz step size is also recommended for band class 3 in Europe.

WiMAX Frequency Bands - FDD

Band Class	(GHz)BW (MHZ)	Duplexing Mode BS	Duplexing Mode MS	MS Transmit Band (MHz)	BS Transmit Band (MHz)	Bandwidth Certification Group Code
2	**2.305-2.320, 2.345-2.360**					
	2x3.5 AND 2x5 AND 2x10	FDD	HFDD	2345-2360	2305-2320	2.E**
	5 UL, 10 DL	FDD	HFDD	2345-2360	2305-2320	2.F**
3	**2.496-2.690**					
	2x5 AND 2x10	FDD	HFDD	2496-2572	2614-2690	3.B
5	**3.4-3.8**					
	2x5 AND 2x7 AND 2x10	FDD	HFDD	3400-3500	3500-3600	5.D
6	**1.710-2.170 FDD**					
	2x5 AND 2x10	FDD	HFDD	1710-1770	2110-2170	6.A
	2x5 AND 2x10 AND Optional 2x20 MHz	FDD	HFDD	1920-1980	2110-2170	6.B
	2x5 AND 2x10 MHz	FDD	HFDD	1710-1785	1805-1880	6.C
7	**0.698-0.960**					
	2x5 AND 2x10	FDD	HFDD	776-787	746-757	7.B
	2x5	FDD	HFDD	788-793 AND 793-798	758-763 AND 763-768	7.C
	2x10	FDD	HFDD	788-798	758-768	7.D
	5 AND 7 AND 10 (TDD), 2x5 AND 2x7 AND 2x10 (H-FDD)	TDD or FDD	Dual Mode TDD/H-FDD	698-862	698-862	7.E*
	2x5 AND 2x10 MHz	FDD	HFDD	880-915	925-960	7.G
8	**1.710-2.170 TDD**					
	5 AND 10	TDD	TDD	1785-1805, 1880-1920, 1910-1930, 2010-2025	1785-1805, 1880-1920, 1910-1930, 2010-2025	8.A

Unlicensed Bands and Services

Frequency range	Bandwidth	Band	Notes
433.05 – 434.79 MHz	1.74 MHz	ISM	Europe
420–450 MHz	30 MHz	Amateur	US
868-870 MHz	2 MHz	ISM	Europe
902–928 MHz	26 MHz	ISM-900	Region 2
2.4–2.5 GHz	100 MHz	ISM-2400	International allocations (see slides 7, 8 for details)
5.15–5.35 GHz	200 MHz	UNII-1,2	
5.47–5.725 GHz	255 MHz	UNII-2 ext.	
5.725–5.875 GHz	150 MHz	ISM-5800 UNII-3	
24–24.25 GHz	250 MHz	ISM	US, Europe
57-64 GHz 59-66 GHz	7 GHz	ISM	US Europe

Medical devices
Remote control

RFID and other unlicensed services

Smart meters, remote control, baby monitors, cordless phones

802.11b/g/n, Bluetooth
802.15.4 (Bluetooth, ZigBee), cordless phones

802.11a/n, cordless phones

Emerging 802.11ad
802.15.3c, ECMA-387
WirelessHD

TVB

Americas, including US and Canada; Australia, Israel

European analog of the ISM-900 band

ISM = industrial, scientific and medical
UNII = unlicensed national information infrastructure

Unlicensed Bands and Services

IEEE 802.11 (Wi-Fi) operates in the ISM-2400 and ISM-5800 bands and in the 5800 UNII band; recently standardized for 3650-3700 contention band

IEEE 802.16 (WiMAX) operates in the UNII/ISM band and in the 3500-3700 MHz contention band

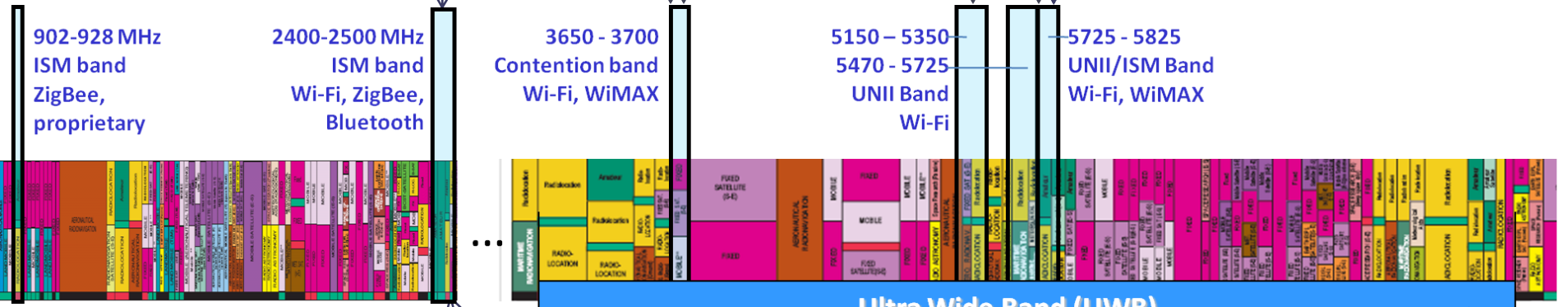
902-928 MHz
ISM band
ZigBee, proprietary

2400-2500 MHz
ISM band
Wi-Fi, ZigBee, Bluetooth

3650 - 3700
Contention band
Wi-Fi, WiMAX

5150 – 5350
5470 - 5725
UNII Band
Wi-Fi

5725 - 5825
UNII/ISM Band
Wi-Fi, WiMAX



Ultra Wide Band (UWB)

Most UWB products operate here

3100

4900

10,600

ISM-900 traditionally used for consumer devices such as cordless phones, garage openers and baby monitors, now also used on smart meters

Cordless phones

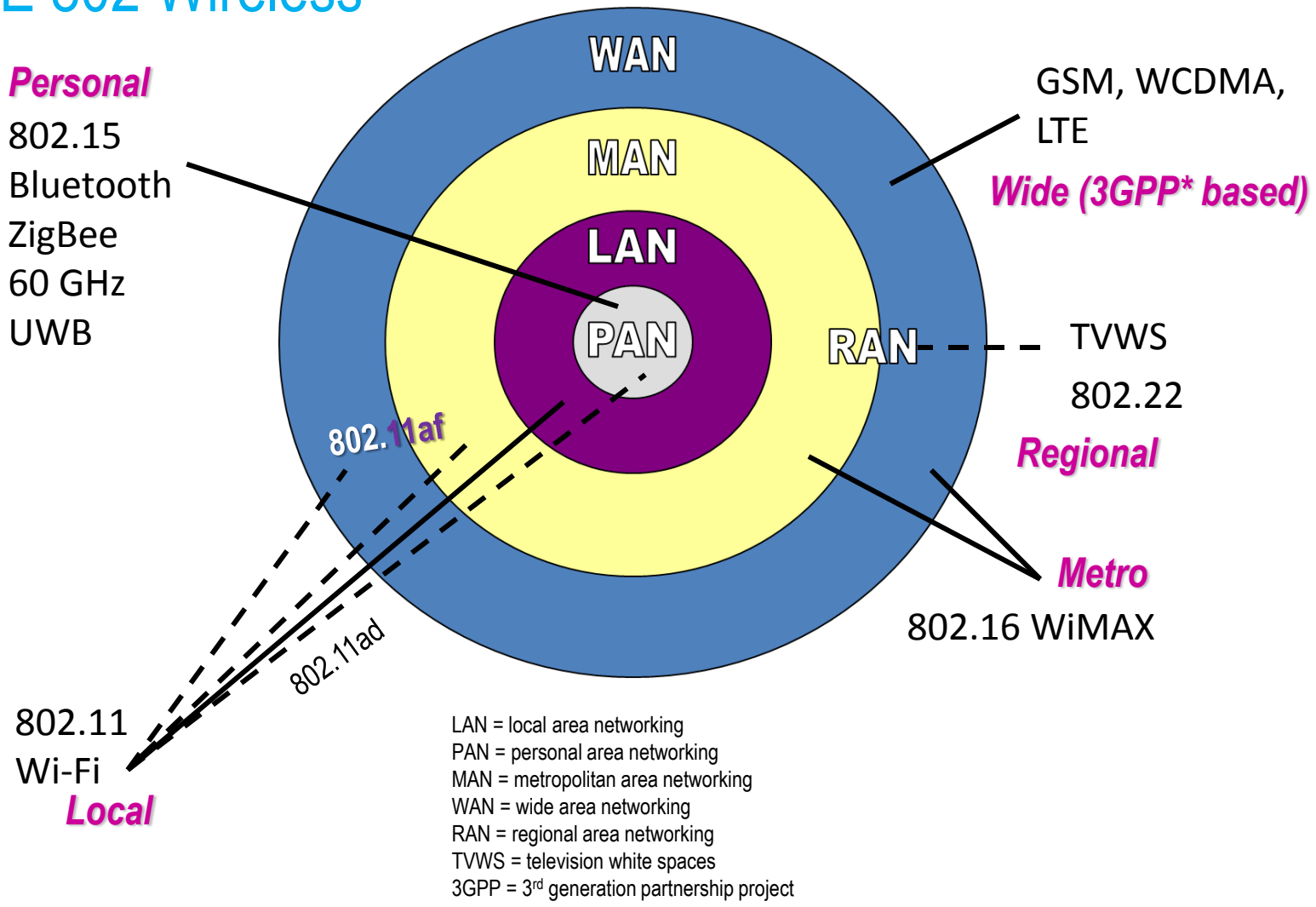
UWB based WiMedia is a short-range network operating in the noise floor of other services

Standards-based

proprietary

FCC spectrum allocation chart
http://www.ntia.doc.gov/osmhome/allochrt.PDF

IEEE 802 Wireless



LAN = local area networking
PAN = personal area networking
MAN = metropolitan area networking
WAN = wide area networking
RAN = regional area networking
TVWS = television white spaces
3GPP = 3rd generation partnership project

Growing WLAN Market

- Worldwide wireless LAN market reached record revenues in 2010, growing 25% to surpass $5 billion
  - SOHO segment >$3 billion in revenues
  - Enterprise segment >$2 billion; 7 straight quarters of revenue growth
- Alcatel-Lucent, Aruba, Belkin, Netgear, Tropos, and ZyXel each posted full-year 2010 WLAN revenue growth >40%
- Source: Dell'Oro Group
  - http://www.fiercetelecom.com/press_releases/wireless-lan-market-reached-record-level-2010-revenues-jump-25-percent-acco

IEEE 802.11 Active Task Groups

IEEE 802.11

http://grouper.ieee.org/groups/802/11

- **TGmb** – Maintenance
- **TGs** – Mesh networking
- **TGv** – Wireless network management
- **TGaa** – Robust streaming of AV Transport Streams
- **TGac** – VHTL6 (very high throughput < 6 GHz)
- **TGad** – VHT 60 GHz
- **TGae** – Prioritization of management frames
- **TGaf** – TV Band operation
- **TGah** – Sub 1 GHz
- **TGai** – Fast initialization
- **Smart Grid SG** – smart grid
- **WNG SC** – Wireless Next Generation

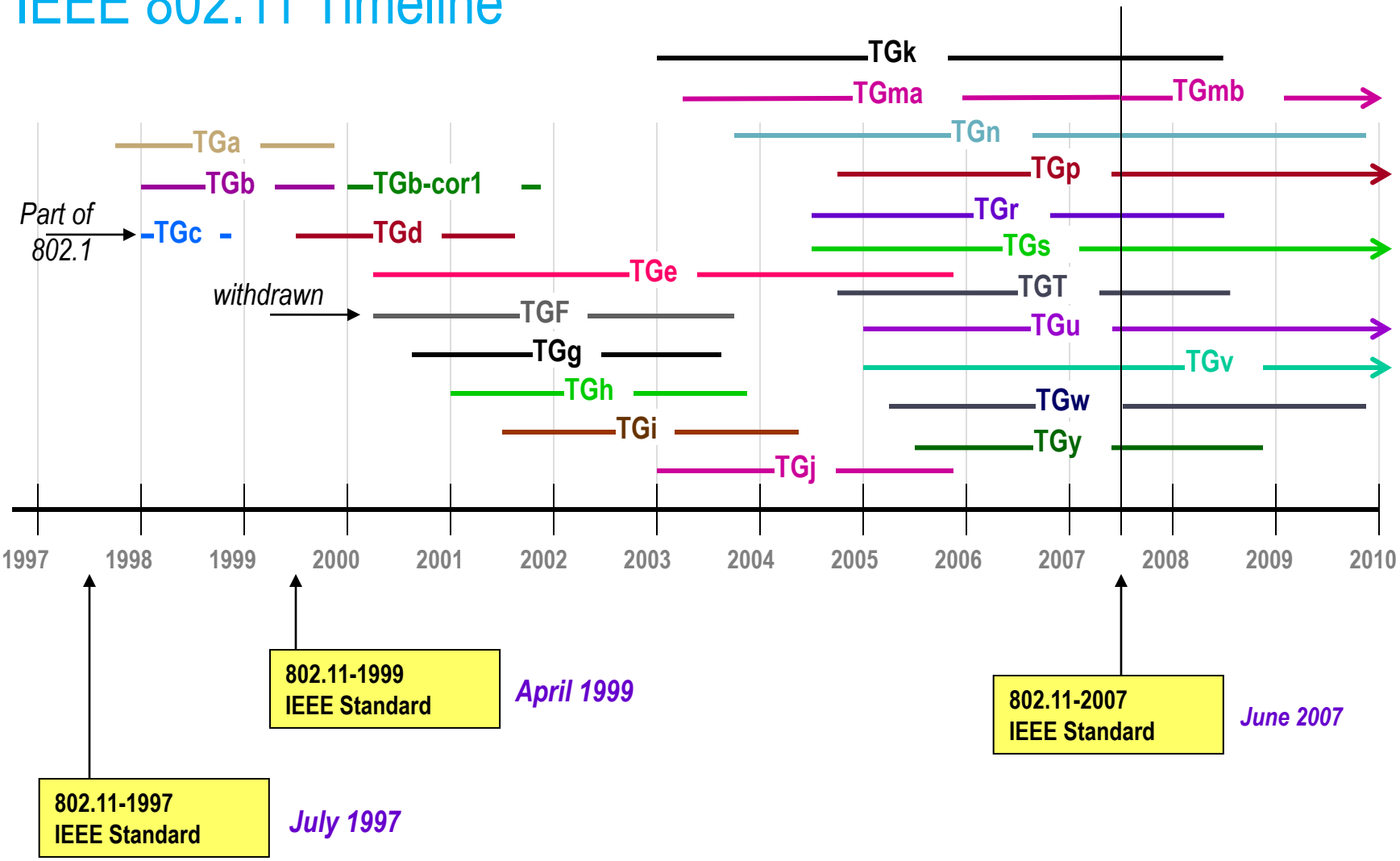
TG = task group

802.11 Past Task Groups

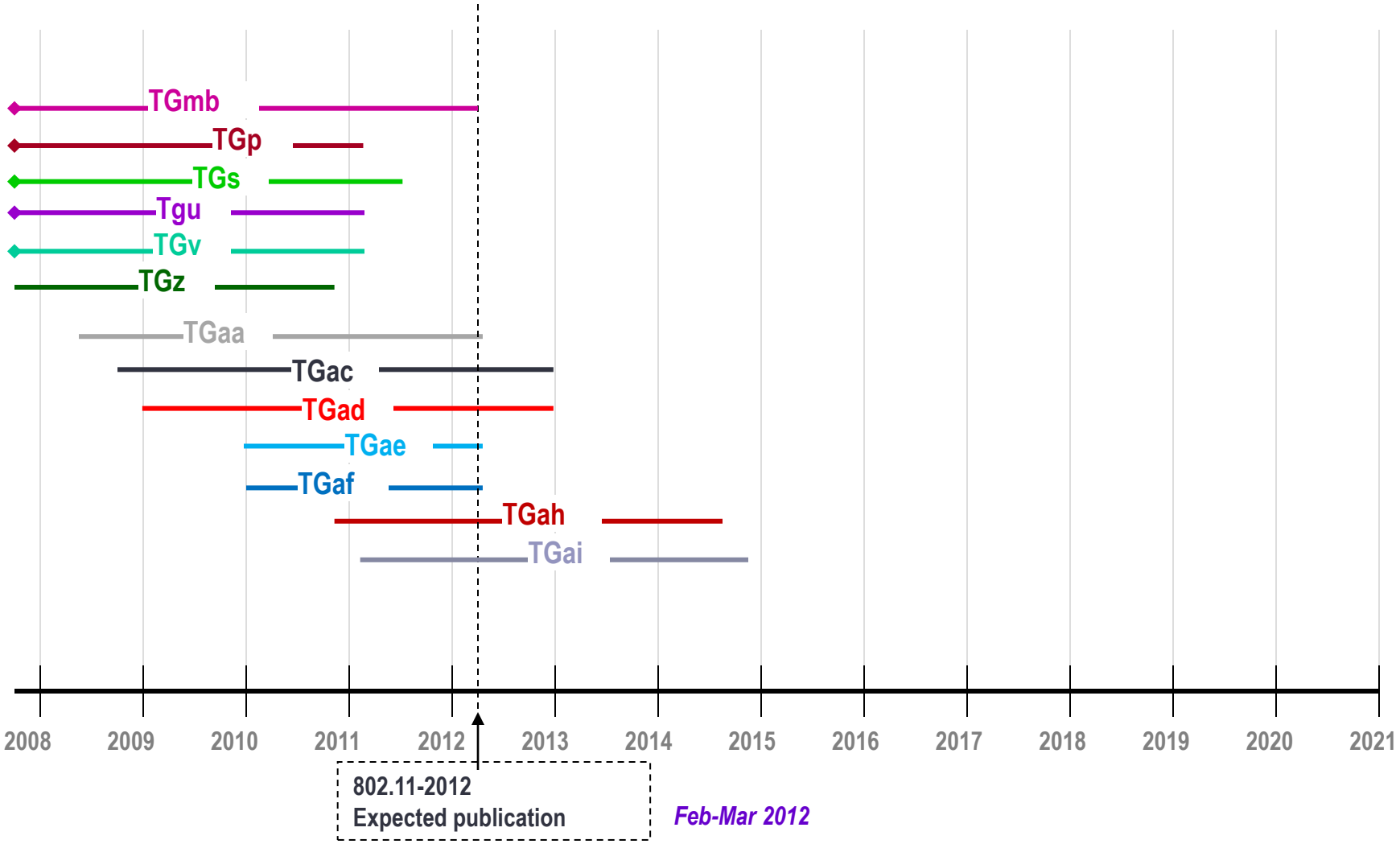
- ✓ **TGma** – Maintenance
- ✓ **TGa –** 5 GHz OFDM PHY
- ✓ **TGb** – 2.4 GHz 11 Mbps; DSSS PHY
- ✓ **TGc** – Bridging (part of 802.1)
- ✓ **TGd –** Additional regulatory domains
- ✓ **TGe –** Quality of Service
- ✓ **TGf –** Inter-AP protocol
- ✓ **TGg –** 2.4 GHz OFDM PHY
- ✓ **TGh –** Radar avoidance (DFS, TPC)
- ✓ **TGi –** Security
- ✓ **TGk** – Radio Resource Measurements
- ✓ **TGn** – High Throughput; MIMO
- ✓ **TGp** – Vehicular ITS networks (WAVE/DSRC)
- ✓ **TGr** – Fast Roaming
- ✓ **TGT** – IEEE 802 Performance
- ✓ **TGu** – InterWorking with External Networks
- ✓ **TGw** – Protected Management Frames
- ✓ **TGy** – 3650-3700 MHz Operation in US
- ✓ **TGz** – Direct Link Setup

OFDM = orthogonal frequency division multiplexing
DSSS = direct sequence spread spectrum
DSRC = dedicated short range communications
WAVE = wireless access vehicular environment
ITS = intelligent transportation systems
MIMO = multiple input multiple output
DFS = dynamic frequency selection
TPC = transmit power control

IEEE 802.11 Timeline



IEEE 802.11 Timeline (continued)



Outline

- IEEE 802 wireless background
- HT - High Throughput (802.11n)
- VHT - Very High Throughput (802.11ac/ad)
- White Space (802.11af)
- Under 1 GHz (802.11ah)
- Streaming of AV transport streams (802.11aa)
- Fast initialization (802.11ai)
- Smart Grid SG (Study Group)
- Regulatory Ad Hoc

802.11n Throughput Enhancements

802.11n throughput enhancement	Description	Throughput enhancement over legacy
Spatial multiplexing	With 2 spatial streams throughput can be double that of a single stream.	100%
40 MHz channel width	Doubling the channel width over the legacy 20 MHz channel can double the throughput.	100%
More efficient OFDM	With 52 data sub-carriers vs. 48 for the legacy networks, the highest data rate per stream is 65 Mbps vs. the 802.11a/g 54 Mbps	20%
Shorter GI (guard interval)	The short GI of 400 ns allowed by 802.11n reduces the symbol time from 4 microseconds to 3.6 microseconds increasing the symbol rate by 10%.	10%
Frame aggregation and Block ACK	64k bytes A-MPDU; 8k bytes A-MSDU	Up to 100%

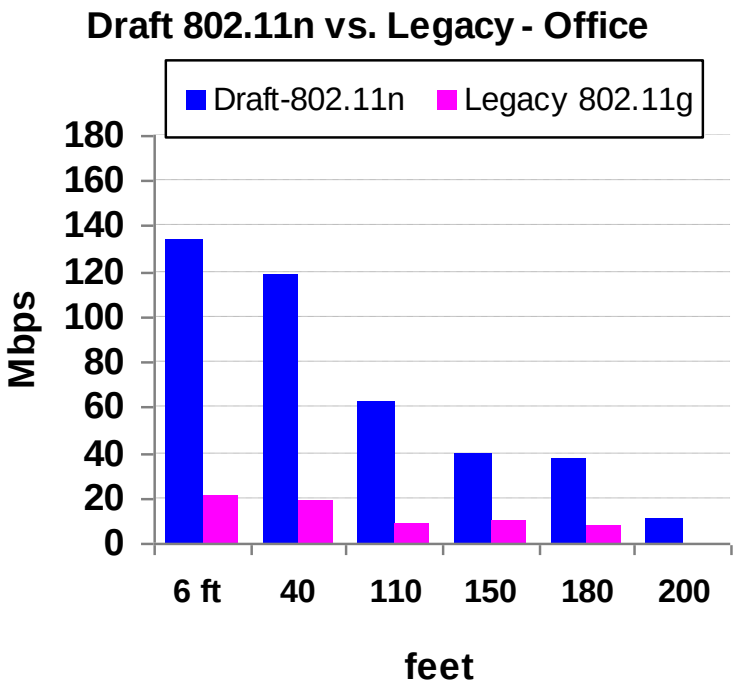
A-MPDU = Aggregated Mac Protocol Data Unit
A-MSDU = Aggregated Mac Service Data Unit

IEEE 802.11a,b,g,n Data Rates

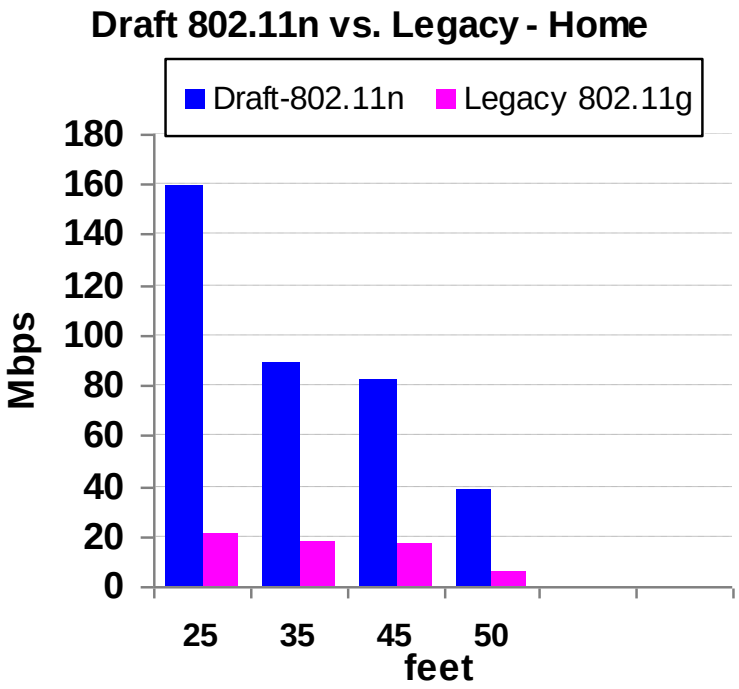
	20 MHz Channel				40 MHz Channel			
	1 stream	2 streams	3 streams	4 streams	1 stream	2 streams	3 streams	4 streams
	Data Rate, in Mbps							
802.11b 2.4 GHz	1, 2, 5.5, 11							
802.11a 5 GHz	6, 9, 12, 18, 24, 36, 48, 54							
802.11g 2.4 GHz	1, 2, 6, 9, 12, 18, 24, 36, 48, 54							
802.11n 2.4 and 5 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130	19.5, 39, 58.5, 78, 117, 156, 175.5, 195	26, 52, 78, 104, 156, 208, 234, 260	13.5, 27, 40.5, 54, 81, 108, 121.5, 135	27, 54, 81, 108, 162, 216, 243, 270	40.5, 81, 121.5, 162, 243, 324, 364.5, 405	54, 108, 162, 216, 324, 432, 486, 540
802.11n, SGI enabled 2.4 and 5 GHz	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2	14.4, 28.9, 43.3, 57.8, 86.7, 115.6, 130, 144.4	21.7, 43.3, 65, 86.7, 130, 173.3, 195, 216.7	28.9, 57.8, 86.7, 115.6, 173.3, 231.1, 260, 288.9	15, 30, 45, 60, 90, 120, 135, 150	30, 60, 90, 120, 180, 240, 270, 300	45, 90, 135, 180, 270, 360, 405, **450**	60, 120, 180, 240, 360, 480, 540, **600**

Top rate commercially available today

MIMO vs. SISO Throughput Performance



Vendor 1



Vendor 2

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IEEE 802.11 Very High Throughput

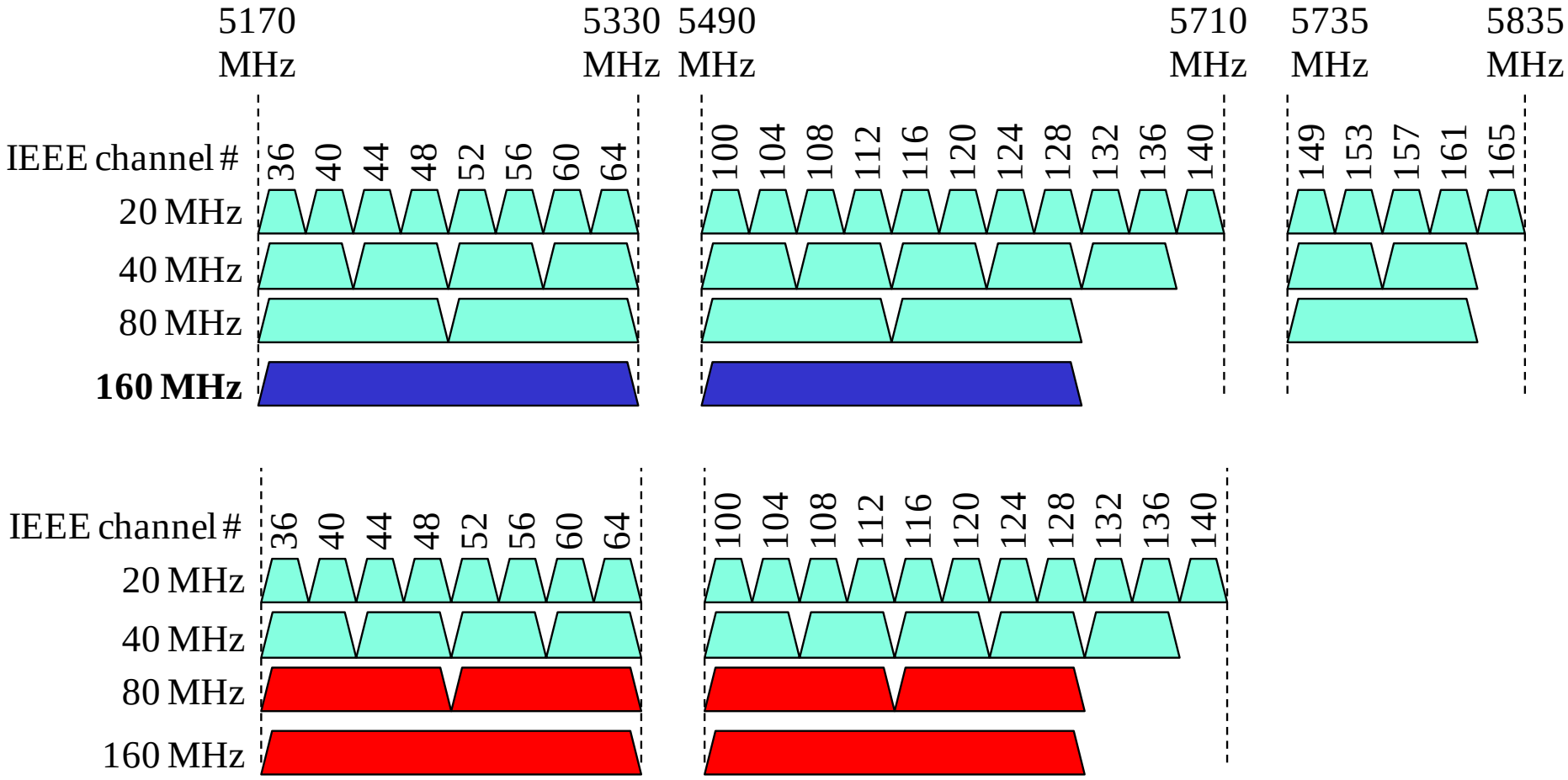
- The goal of the 802.11 VHT effort is to achieve 1 Gbps throughput at nomadic (walking speeds) to support HD video transmission and high speed data applications and to satisfy the IMT-Advanced requirements
- The work is ongoing at TGac and TGad
- TGac
  - Under 6 GHz (2.4 and 5 GHz bands)
- TGad
  - 60 GHz band
  - Capitalize on work already done by 802.15.3c in the 60 GHz band

TGac

- Up to 6.9 Gbps of PHY data rate (draft 0.1)
- Higher order MIMO (> 4x4)
- 8 spatial streams
- Multi-user (MU) MIMO
  - Up to 4 users; up to 4 streams per user
- Higher bandwidth channels (20, 40, 80, 80+80 and 160 MHz)

OFDMA = orthogonal frequency division multiple access

TGac Channels – US Region



802.11ad 60 GHz Frequency Bands

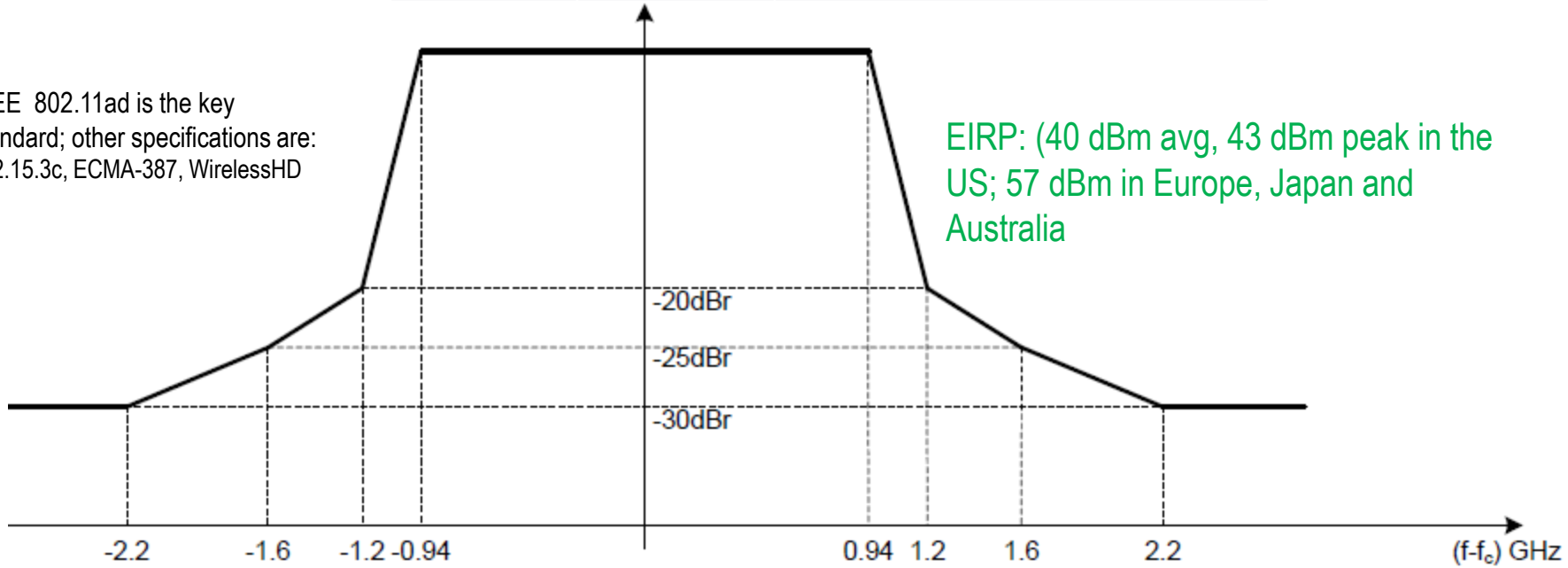
Channel	f_c (GHz)	Country
1	58.32	US
2	60.48	US, Japan, EU, Australia
3	62.64	US, Japan, EU
4	64.80	Japan, EU

Channel 2 must be supported →

Up to 6.8 Gbps of PHY throughput (draft 1.2)

IEEE 802.11ad is the key standard; other specifications are: 802.15.3c, ECMA-387, WirelessHD

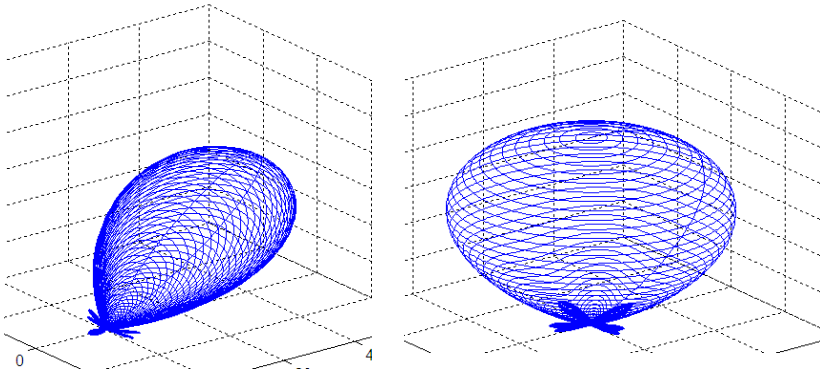
EIRP: (40 dBm avg, 43 dBm peak in the US; 57 dBm in Europe, Japan and Australia

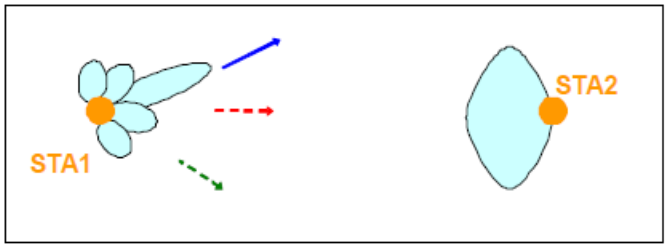


Channel spacing = 2160MHz

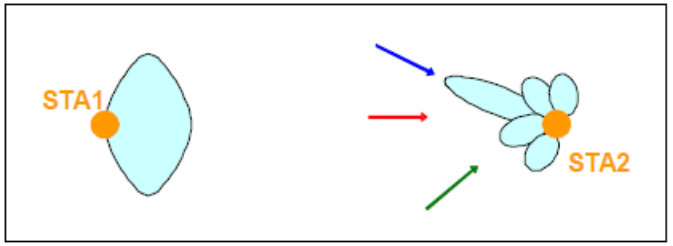
802.11ad Beam Steering

- Beam steering, central to 802.11ad, optimizes the range by focusing the energy between transmitting and receiving nodes
  - Involves two-way channel sounding, sector sweeping and beamforming to make optimum use of a lossy 60 GHz channel

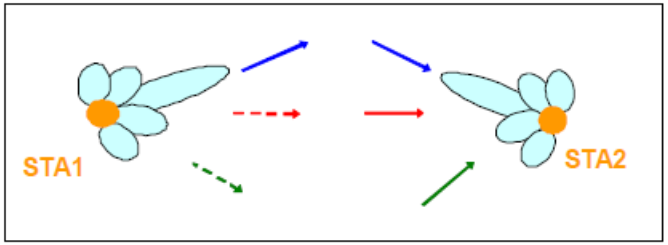




(a) I-TXSS in SLS



(b) I-MID



(c) I-BC (Beam Combining)

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TV Band Spectrum Utilization

- Spectrum under 3 GHz has significant unused capacity
  - Average occupancy over various locations studied is 5.2% and the maximum occupancy is 13.1% (in New York City)
  - Shared Spectrum Company, NSF funded measurements, 9/2009 http://www.sharedspectrum.com/measurements
- Only 8% of Americans receive broadcast TV
  - Consumer Electronics Association (CEA) survey, 2011
  - http://www.cesweb.org/shared_files/ECD-TOC/CEACordCuttingAnalysis.pdf
- The economic potential for the TV white spaces was estimated at $100 billion
  - R. Thanki, "The economic value generated by current and future allocations of unlicensed spectrum", 9/2009 http://www.ingeniousmedia.co.uk/websitefiles/Value_of_unlicensed_-_website_-_FINAL.pdf

White Spaces – Brief History

- NPRM in May 2004
  - http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-113A1.pdf
- November 4, 2008 FCC approved Report & Order 08-260, allowing unlicensed use of TV band spectrum
  - http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-01-260A1.pdf
- February 17, 2009, the FCC released the final rules for "Unlicensed Operation in the TV Broadcast Bands"
  - http://edocket.access.gpo.gov/2009/pdf/E9-3279.pdf
- Sep 23, 2010 The FCC reaffirmed a 2008 decision to open the broadcast airwaves


THE WALL STREET JOURNAL.
WSJ.com
SEPTEMBER 24, 2010
FCC to Open Unused TV Airwaves, Extending Wi-Fi's Possibilities

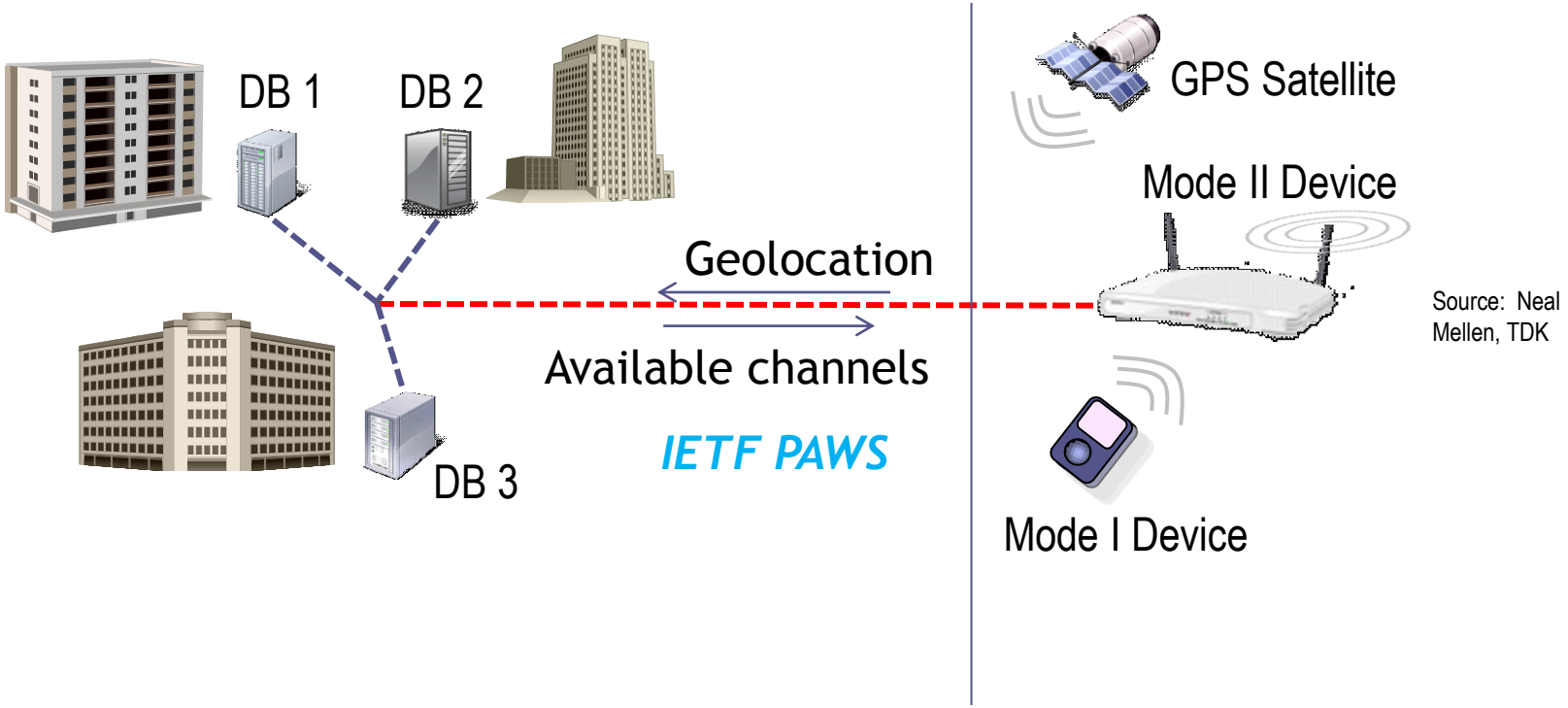
NPRM = Notice of Proposed Rule Making

European White Space Regulation

- Ofcom (UK) is in the process of making this Digital Dividend band available
  - https://mentor.ieee.org/802.18/dcn/09/18-09-0059-00-0000-ofcom-update-on-the-digital-dividend.ppt
  - http://stakeholders.ofcom.org.uk/consultations/geolocation/summary
- ECC of CEPT in Europe has published a report on White Spaces in Jan 2011
  - http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP159.PDF
- China TV band regulations expected in 2015

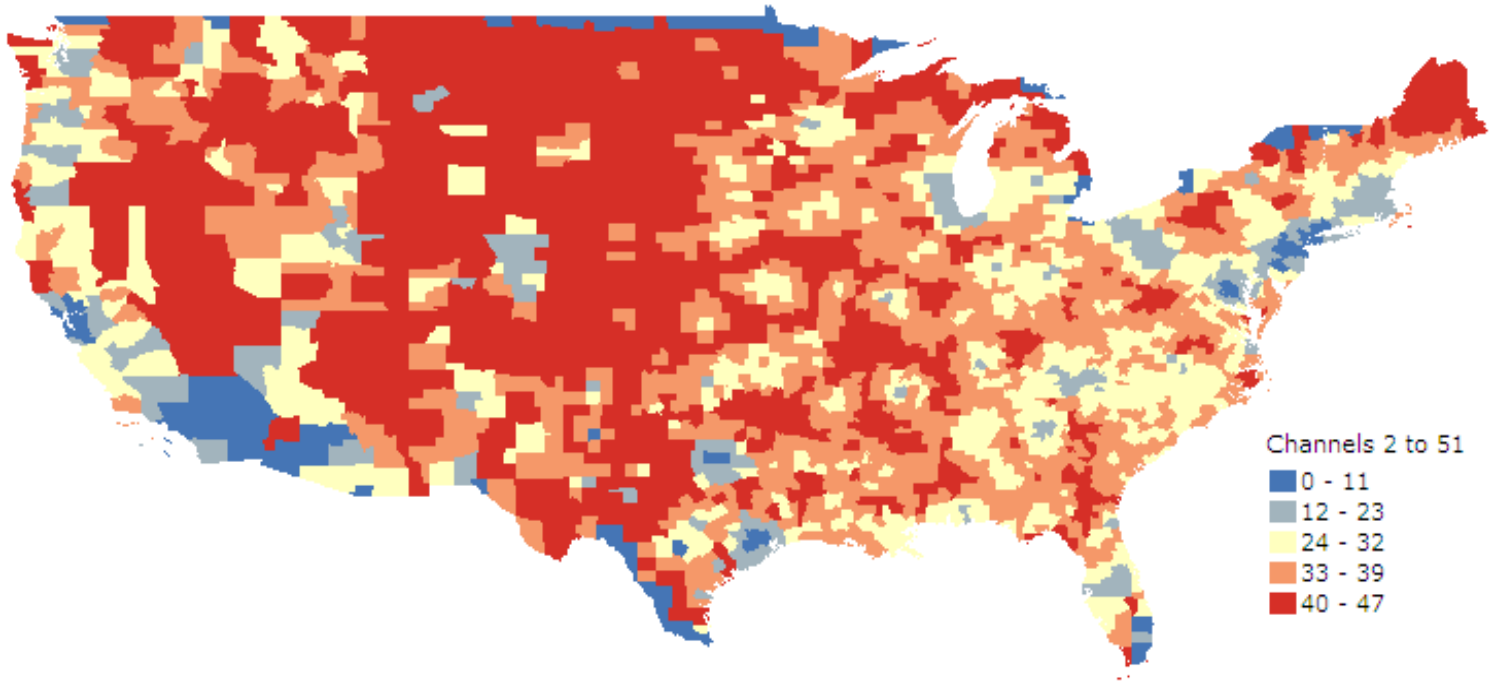
ECC = Electronic Communications Committee
CEPT = European Conference on Postal and Telecommunications

White Space Spectrum Access



TV Band Channel Availability

- Channel availability based on the geolocation query of TV band internet database



Source: Rick Tornado, Spectrum Bridge

TV Channels and White Space Allocation

US – FCC

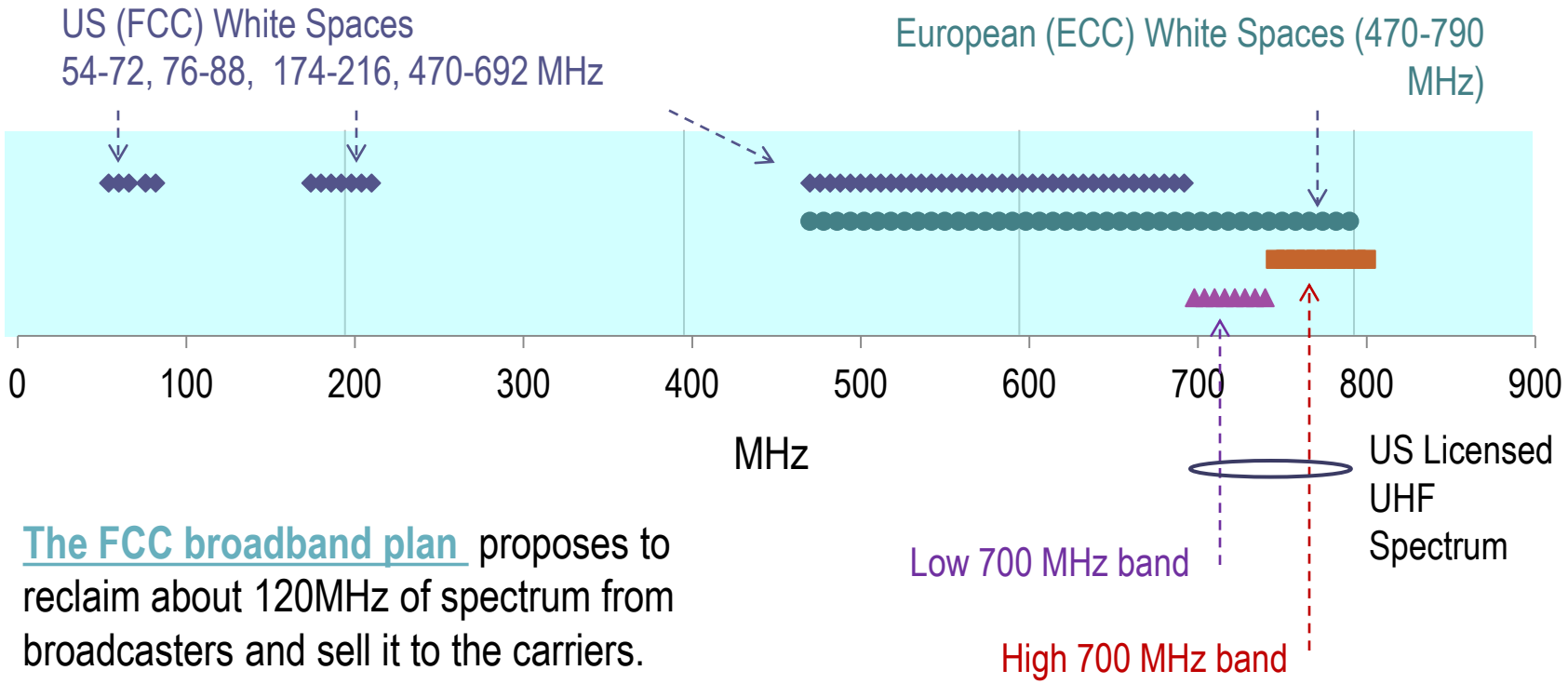
	Channel #	Frequency Band	
Fixed TVBDs only	2-4	54-72 MHz	VHF
	5-6	76-88 MHz	
	7-13	174-216 MHz	
	14-20	470-512 MHz**	UHF
White Spaces	21-51*	512-692 MHz	

Transition from NTSC to ATSC (analog to digital TV) June 12, 2009 freed up channels 52-69 (above 692 MHz)

Europe – ECC

	Channel #	Frequency Band	
	5-12	174-230 MHz	VHF
White Spaces	21-60	470-790 MHz	UHF
	61-69	790-862 MHz	

TV Band Spectrum



The FCC broadband plan proposes to reclaim about 120MHz of spectrum from broadcasters and sell it to the carriers.

This move may serve to discourage investment into white spaces.

IEEE TV Band Related Standards

- **802.11af** – formed in January 2010 to adapt 802.11 to TV band operation
- **802.16h** – originally organized to adapt 802.16 to the 3650-3700 MHz contention band now working on TV band operation of 802.16
- **802.22** – Regional Area Networks
  - Guided the FCC in the recent TV band regulations
  - Introduced spectrum sensing and location information to determine whether given transmit frequencies and power levels will cause harmful interference to licensed services
- **802.18** TAG – regulatory
- **802.19** TAG – coexistence among dissimilar networks in the TV band
- **SCC 41** – defines layers above the MAC and PHY for dynamic spectrum access networks
  - http://grouper.ieee.org/groups/scc41/crinfo/
  - 1900.7 is the relevant group under SCC 41

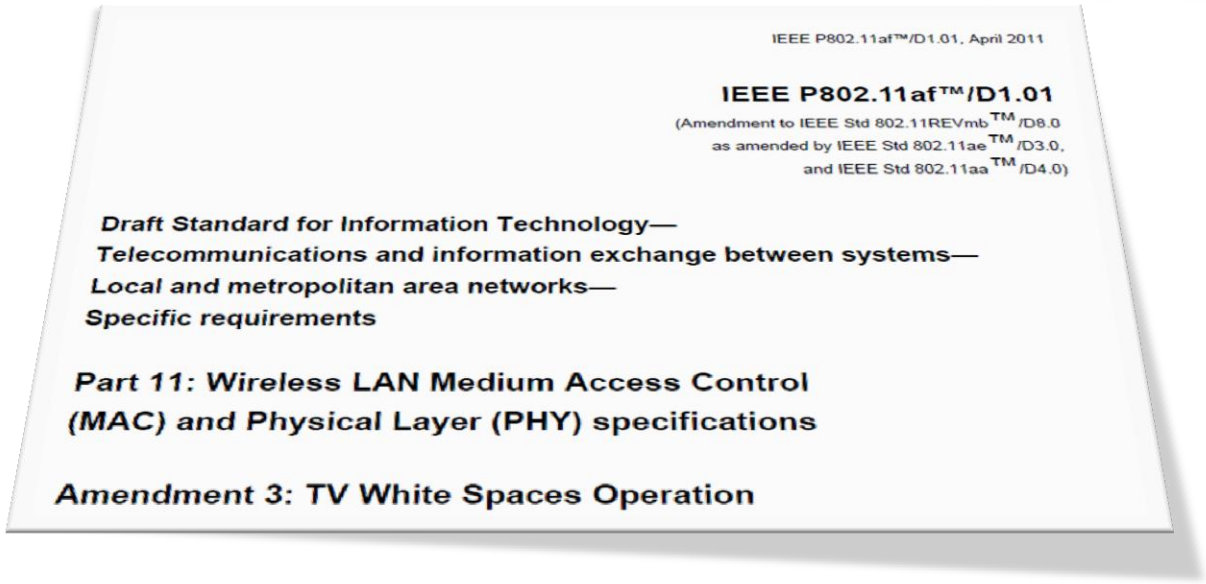
Ecma and CogNeA TV Band Standard

- Ecma TC48-TG1 standard for Personal/Portable devices in TV White Spaces
  - Physical (PHY) and Medium Access Control (MAC) layers including a protocol and mechanisms for coexistence
  - http://www.ecma-international.org/publications/standards/Ecma-392.htm
- Sponsor Organization: CogNeA (http://www.cognea.org)
  - Industry alliance formed in 2008 to develop a specification for white spaces

802.11af

Database is out of scope of 802.11af

Being defined by IETF PAWS


IEEE P802.11af™/D1.01, April 2011

IEEE P802.11af™/D1.01

(Amendment to IEEE Std 802.11REVmb™/D8.0
as amended by IEEE Std 802.11ae™/D3.0,
and IEEE Std 802.11aa™/D4.0)

Draft Standard for Information Technology—
Telecommunications and information exchange between systems—
Local and metropolitan area networks—
Specific requirements

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

Amendment 3: TV White Spaces Operation

- Re-band the popular 802.11 systems; capitalize on work already done for 802.11y and 802.11h
  - Use 5, 10, 20 and 40 MHz wide channels
  - FCC EIRP: 4 W, 100 mW, 50 mW
- Possible deployment scenarios
  - Indoor (< 100 m): like present WLAN
  - Outdoor (< 5 km): comparable to the range of typical urban model

White Spaces Standards

Most cost-effective **if** 802.11 chipsets support the band

802.11af

Most promising IEEE White Spaces standard with 802.11 chipset vendors evaluating the business opportunity; fast moving; Wi-Fi Alliance expects to certify in 2012

802.22

Based on 802.16d Fixed WiMAX; no chipset vendors involved yet; small group dominated by broadcasters who oppose White Spaces

No products expected in the near-future

Products already announced

Ecma-based or proprietary

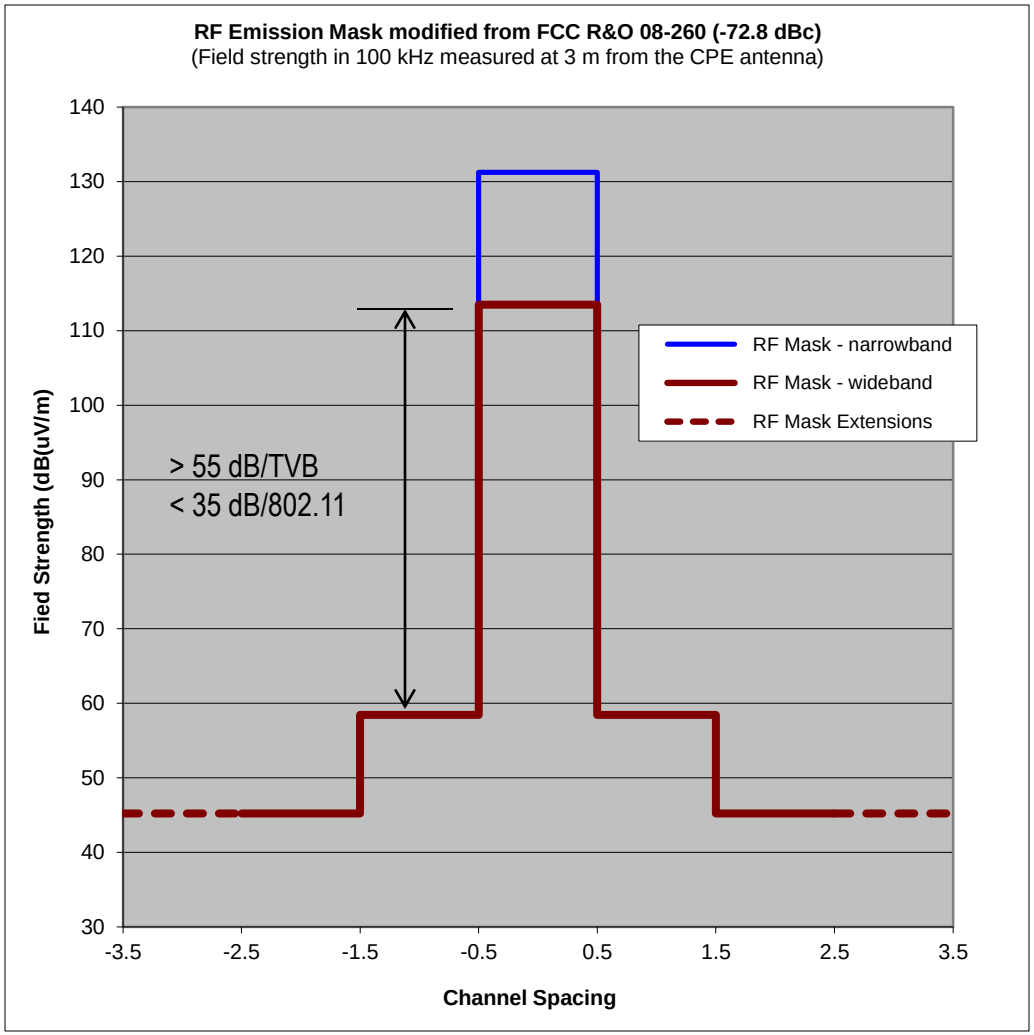
Proprietary implementation is already on the market (e.g. www.carlsonwireless.com) ; potential to disrupt 802.11 service since access protocol is unknown

SCC41

Higher layer cognitive radio algorithms, such as Dynamic Spectrum Access; academic group; no near-term products expected

TV Band Technical Issues

- Biggest roadblock to 802.11af adaptation is the stringent spectrum mask mandated by the FCC for the TV Band
  - 20 dB more stringent than the most stringent 802.11 devices support today
- Another issue is the limit on antenna elevation, which limits the range of TV Band data service
  - Antennas no higher than 90 feet



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AV Streaming

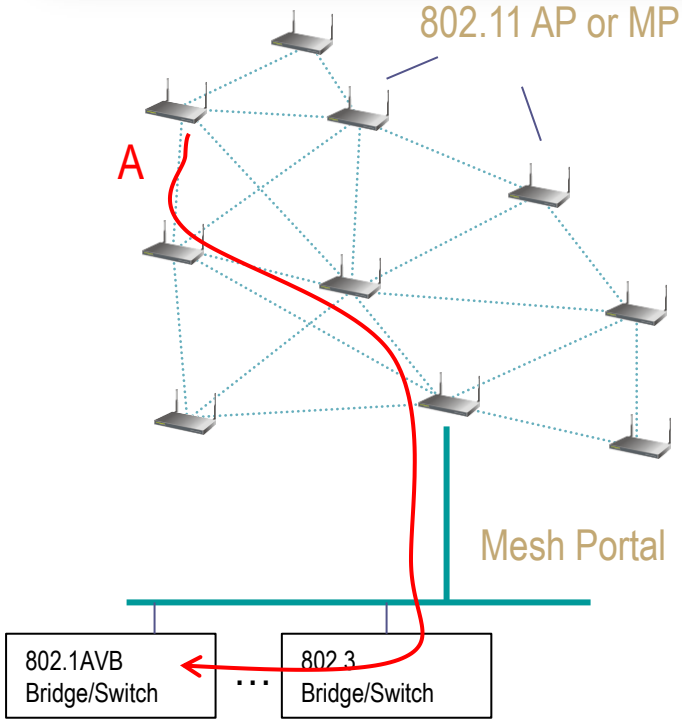
- 802.11aa is being developed collaboratively with 802.1AVB working group (audio-visual bridging)
- MAC layer protocol to 'open-up' a passage through multiple MAC layer bridges from point A to point B in the network
- The goal is to optimize and prioritize the transport of AV streams through multiple bridging devices at the network level
  - Bridging is incorporated into wired and wireless devices, including 802.3 and 802.11
  - MAC layer bridge is built into an 802.11 AP, 802.11s MP, 802.3 switch and the emerging 802.1AVB device

IEEE P802.11aa/D3.01, March 2011

IEEE P802.11aa™/D3.01
Draft STANDARD for
Information Technology-
Telecommunications and information exchange between systems-
Local and metropolitan area networks-
Specific requirements-

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

Amendment 3: MAC Enhancements for Robust Audio Video Streaming



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Fast Initialization

- Common use case: crowd of users trying to connect simultaneously to one AP (e.g. passengers passing in a train or getting off a train)
- Use case reference list:
  - https://mentor.ieee.org/802.11/dcn/11/11-11-0326-01-00ai-use-case-ref-list-doc-discussion.pptx
- Too much time currently being spent in 802.11 link set-up on functions including
  - AP/network discovery
  - Security authentication
  - Higher layer (IP address) assignment
- Biggest potential for performance improvement:
  - AP discovery & “parallelization of message exchanges” for higher layer protocols
  - Security: pre-conditions for security scheme
- This is likely to result in microcode upgrades only – no new silicon

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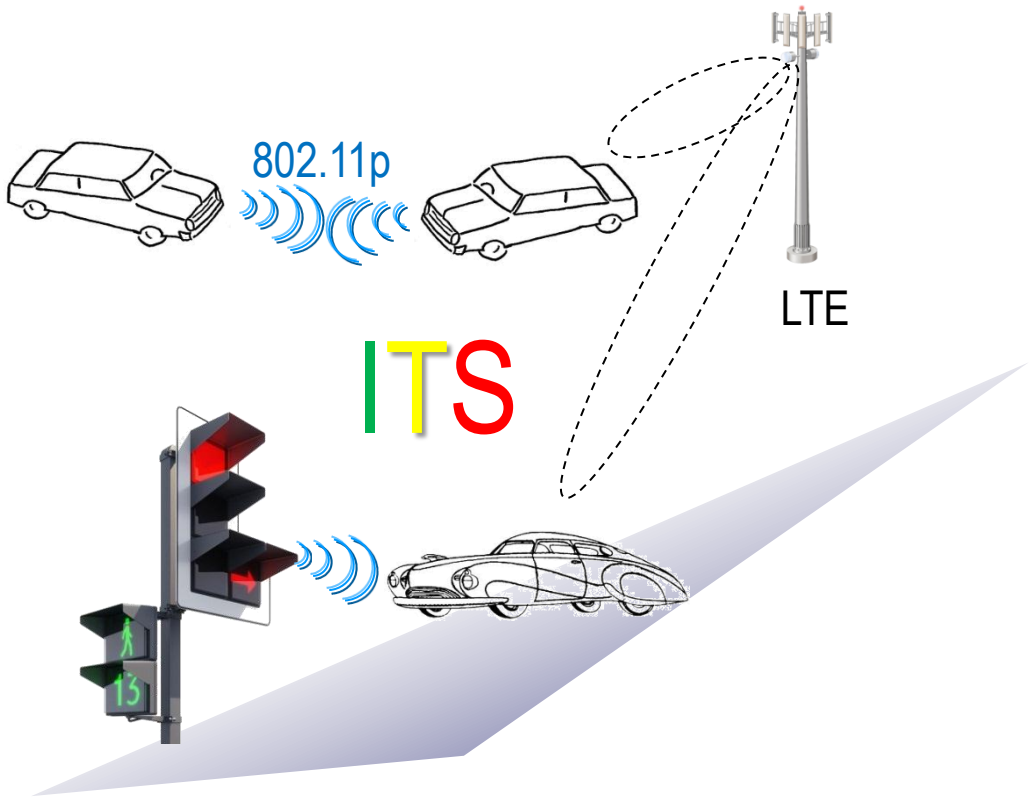
Smart Grid Study Group

- NIST coordinating work on smart grid standards
- Many organizations involved
- Overview presentation
  - https://mentor.ieee.org/802.11/dcn/11/11-11-0133-00-0000-smart-grid-ad-hoc-january-2011.ppt
- ITU-R WP1A is developing a Preliminary Draft New Report (PDNR) dealing with Smart Grid power management systems.
  - https://mentor.ieee.org/802.18/dcn/11/18-11-0002-00-0000-itu-r-wp1a-draft-report-on-smart-grid-power-management-systems.docx

Intelligent Transportation Systems (ITS)

- Big emerging market
- Embracing 802.11p and LTE with sophisticated software stacks on top



Summary

- Wireless broadband industry is based on Wi-Fi and LTE
  - Wi-Fi indoors
  - LTE outdoors
- Wi-Fi and LTE are also now being embraced by
  - Military and Public Safety markets
  - Intelligent Transportation Systems also embracing 802.11p and LTE
  - Possibly Smart Grid
- MIMO and OFDM/OFDMA are going to be with us for some time to come

For More Information

- White papers, presentations, articles and test reports on a variety of wireless topics

www.octoscope.com