octoScope

Interop/Vegas
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Off the Hook: Advances in Wireless LAN Technologies

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Agenda

- Fanny Mlinarsky
  - President, octoScope
  - Advances in WLAN technology
- Matthew Gast
  - Director, Product Management, Aerohive
  - Wi-Fi Alliance
  - Focus on Very High Throughput
- Dave Borison
  - Vice President, Marketing, Ralink
  - 802.11 for ever faster multimedia
- Q&A

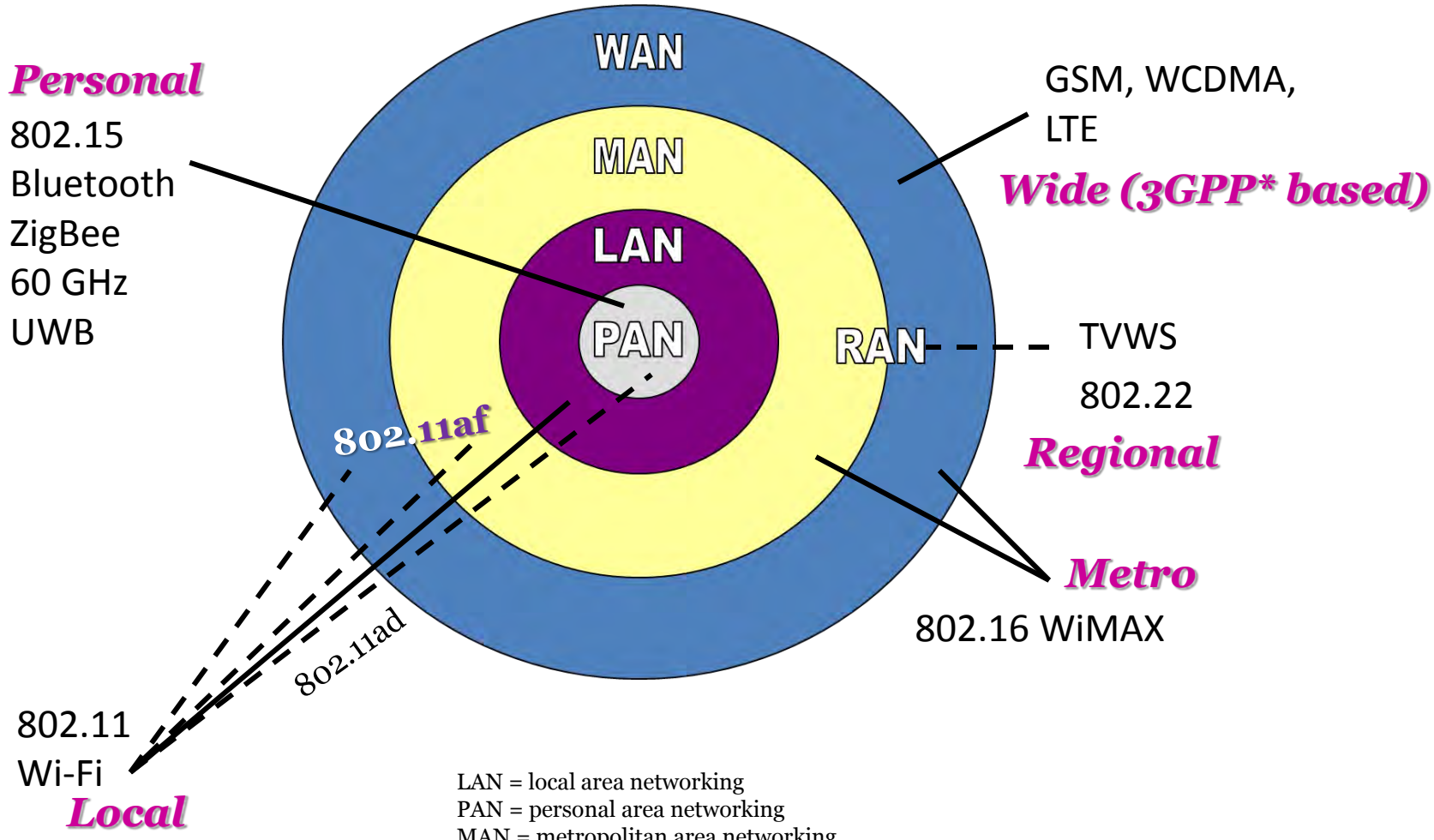
Matthew Gast

- Matthew Gast is the Director of Product Management at Aerohive Networks, where he leads development of the core software technologies in Aerohive's fully distributed Wi-Fi network system.
- He currently serves as chair of both the Wi-Fi Alliance's security task groups and the Wireless Network Management Marketing task group, and is the past chair of the IEEE 802.11 revision task group.
- Matthew is also the author of 802.11 Wireless Networks: The Definitive Guide (O'Reilly), which is now in its second edition and has been translated into six languages.

Dave Borison

- Dave Borison is VP of Marketing for Ralink, a developer of wired and wireless networking solutions. Before joining Ralink, Dave was Director of Product Management at Airgo Networks (now Qualcomm), where he managed 802.11n chipsets, reference designs, and software solutions. Prior to Airgo, Dave held Product Management positions at Atheros where he was responsible for the company's 802.11a/b/g solutions, and at 3Com where he managed Fast Ethernet and Gigabit Ethernet products.
- Dave holds a BS in Mechanical Engineering from the MIT and an MBA from MIT's Sloan School of Management

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

IEEE 802.11 Active Task Groups

- **TGmb** – Maintenance
- **TGs** – Mesh networking
- **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

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

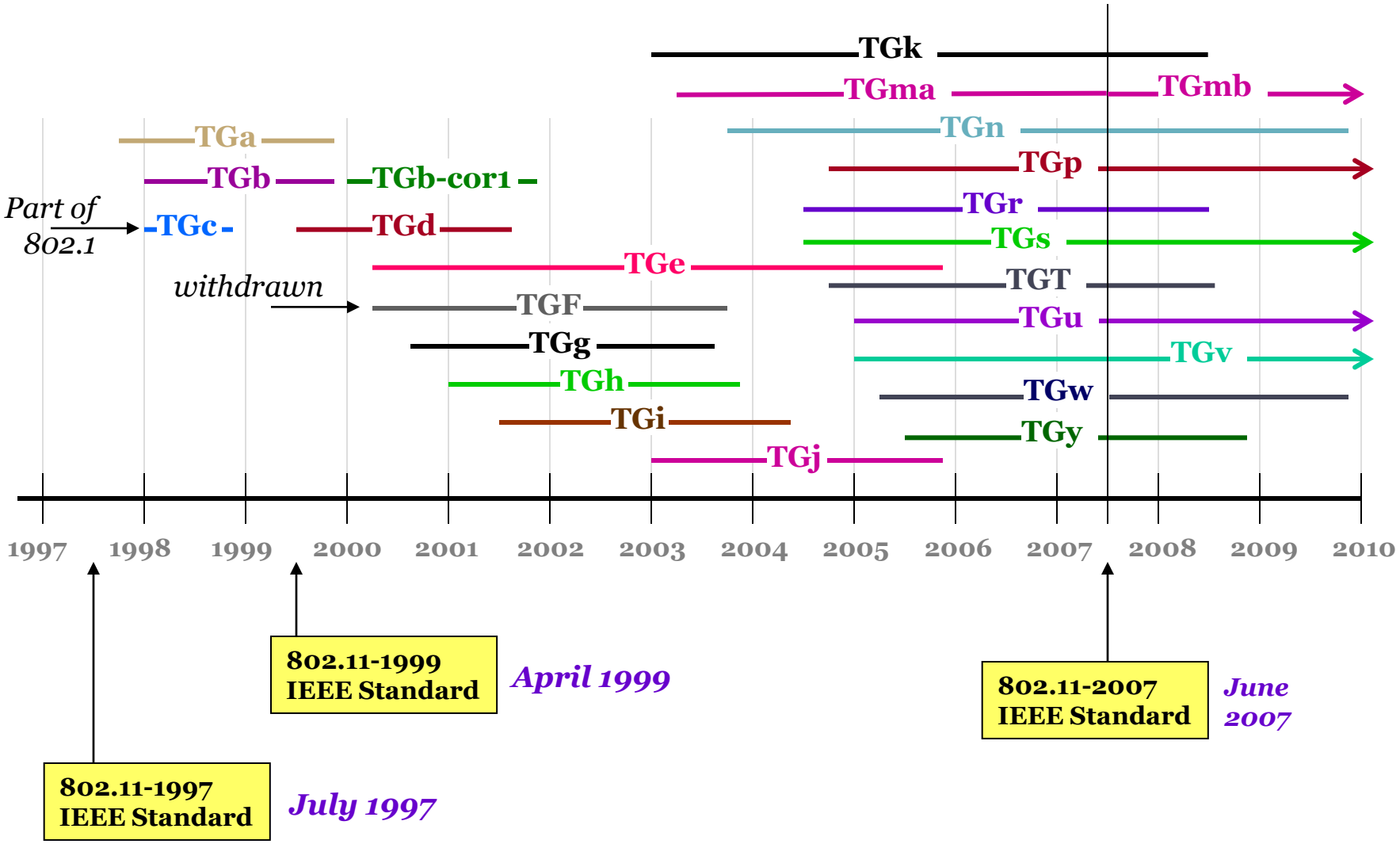
TG = task group
SG = study group
SC = standing committee

802.11 Past Task Groups

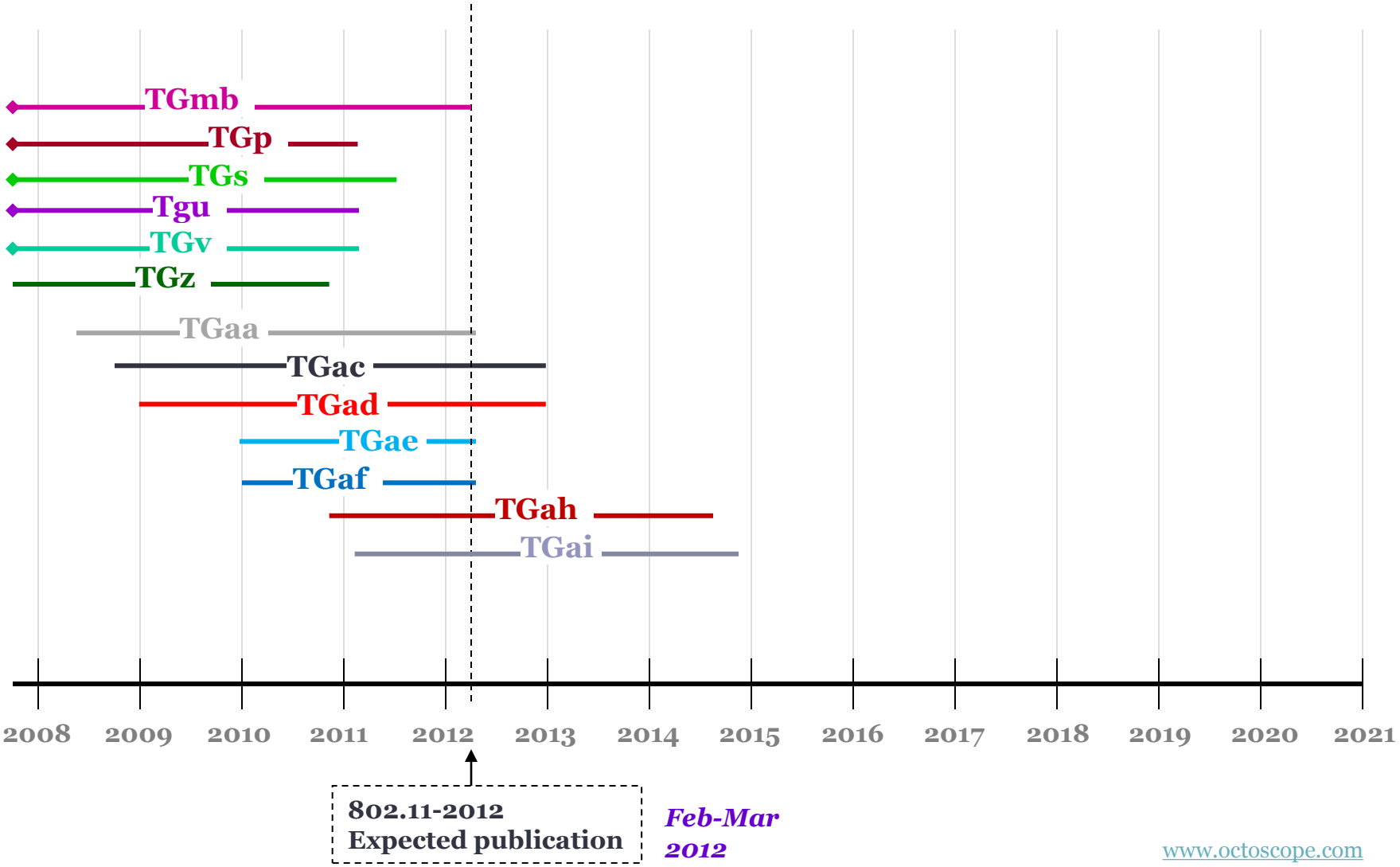
- ✓ **TGma** – Maintenance
- ✓ **TGa –** 5 GHz OFDM PHY
- ✓ **TGb** – 2.4 GHz 11 Mbps; DSSS PHY
- ✓ **TGc** – Bridging (part of 802.1)
- ✓ **TGd –** Additional regulatory domains
- ✓ **TGe –** Quality of Service
- ✓ **TGf –** Inter-AP protocol
- ✓ **TGg –** 2.4 GHz OFDM PHY
- ✓ **TGh –** Radar avoidance (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
- ✓ **TGv** – Wireless network management
- ✓ **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

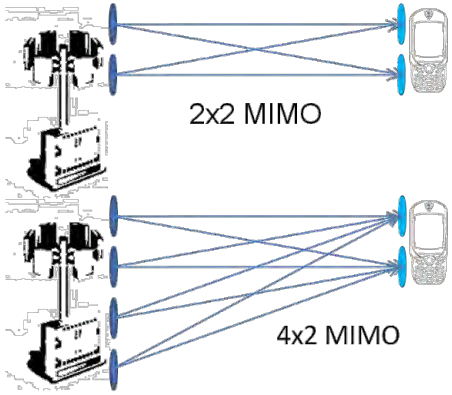


IEEE 802.11 Timeline (continued)



802.11n MIMO Technology

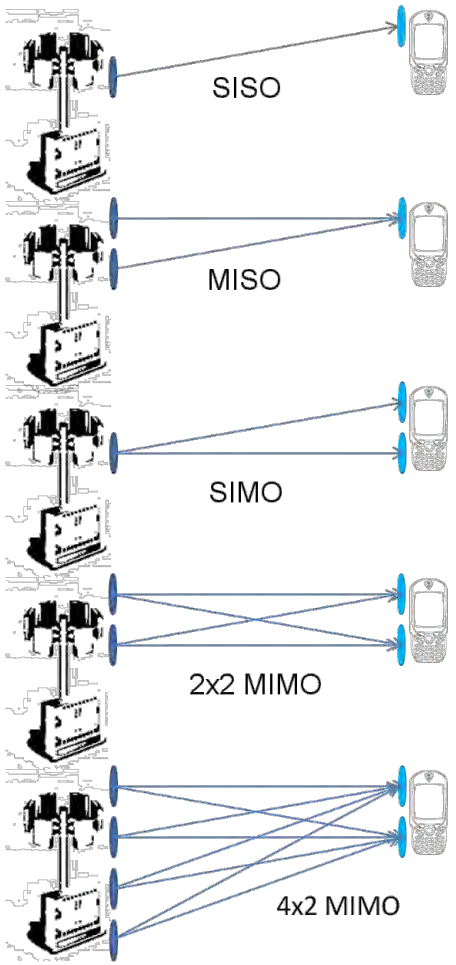
- > 100 Mbps of IP layer throughput; data rate up to 600 Mbps with 4 spatial streams in a 40 MHz channel
- PHY improvements
  - MIMO – Spatial Multiplexing, Beamforming, up to 4x4 MIMO, 40 MHz channels
- MAC improvements
  - Frame aggregation, block acknowledgements
- Battery life improvements for handsets
  - PSMP protocol – sleep mode with scheduled packet delivery



PSMP = Power Save Multi-Poll

Multiple Antenna Techniques

- **SISO (Single Input Single Output)**
  - Traditional radio
- **MISO (Multiple Input Single Output)**
  - Transmit diversity
  - Space Time Block Coding (STBC) or Cyclic Delay Diversity (CDD)
- **SIMO (Single Input Multiple Output)**
  - Receive diversity
  - Maximal Ratio Combining (MRC)
- **MIMO (Multiple Input Multiple Output)**
  - Spatial Multiplexing (SM) to transmit multiple streams simultaneously; can be used in conjunction with Cyclic Delay Diversity (CDD); works best in high SNR environments and channels de-correlated by multipath
  - TX and RX diversity can be used independently or together to enhance throughput in the presence of adverse channel conditions



STBC = Space Time Block Coding
CDD = Cyclic Delay Diversity
MRC = Maximal Ratio Combining
SM = Spatial Multiplexing

SISO = Single Input Single Output
MISO = Multiple Input Single Output
SIMO = Single Input Multiple Output
MIMO = Multiple Input Multiple Output

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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

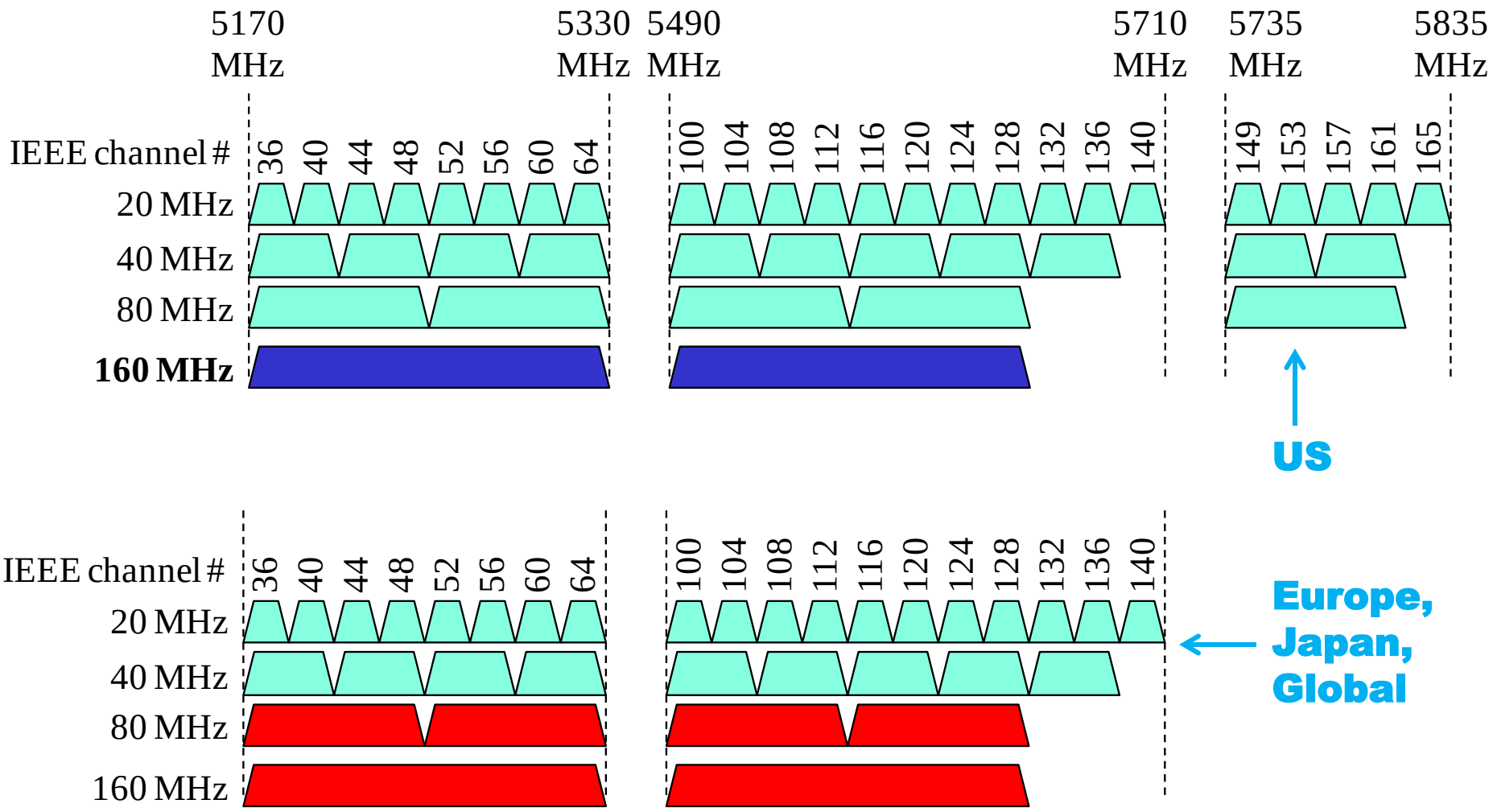
IEEE 802.11 Very High Throughput

- 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
- TGac and TGad
- TGac
  - Under 6 GHz (2.4 and 5 GHz bands)
  - Up to 6.9 Gbps
  - Higher order MIMO (> 4x4)
  - 8 spatial streams
  - Multi-user (MU) MIMO

- TGad
  - 60 GHz band
  - Up to 6.8 Gbps
  - Capitalize on work already done by 802.15.3c in the 60 GHz band
  - Beamforming

VHT = very high throughput

TGac Channels



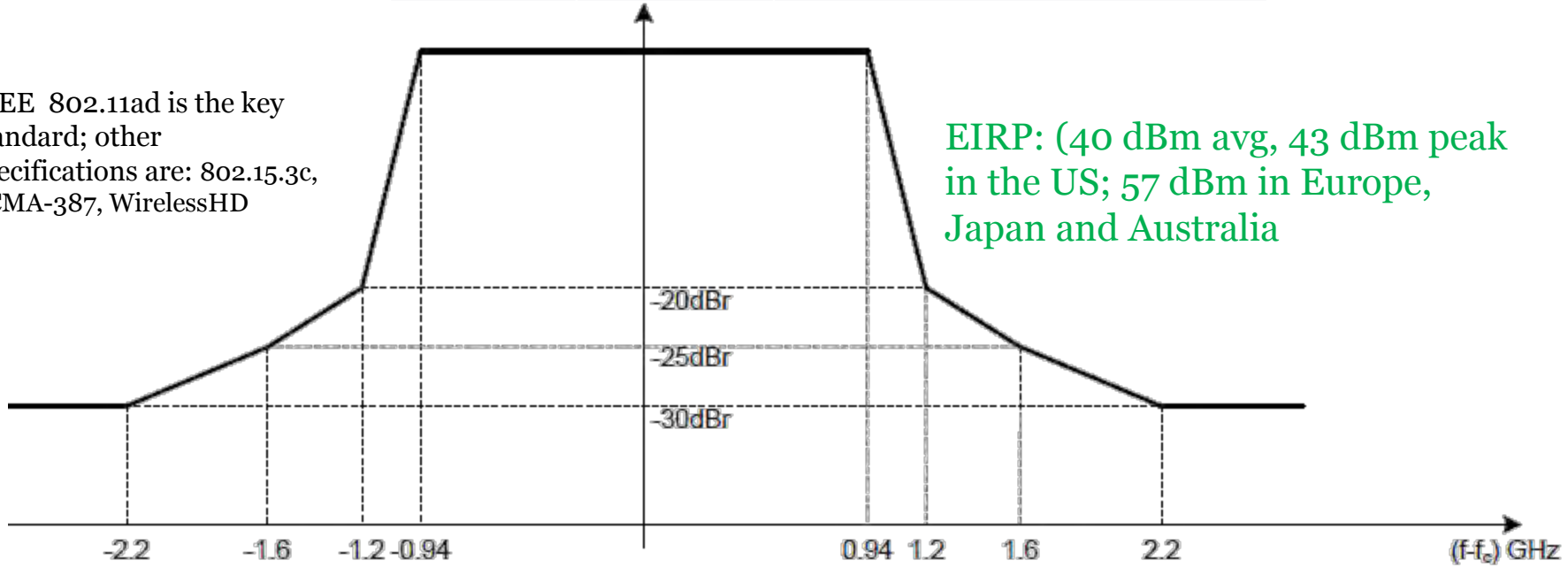
802.11ad 60 GHz Channels

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 →

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

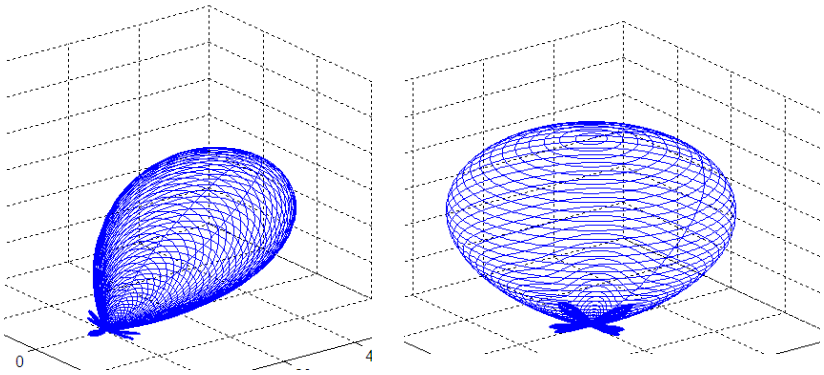
EIRP: (40 dBm avg, 43 dBm peak in the US; 57 dBm in Europe, Japan and Australia

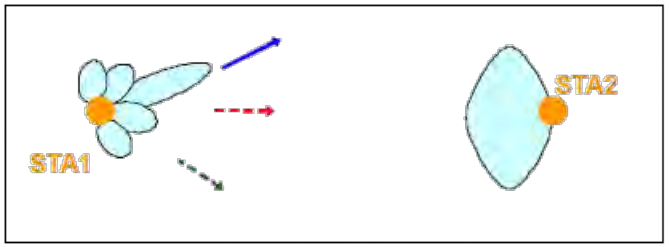


Channel spacing = 2160MHz

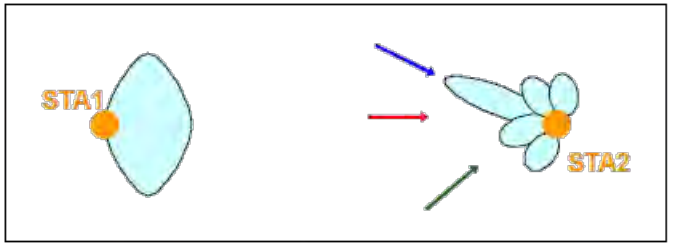
802.11ad Beam Steering

- 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

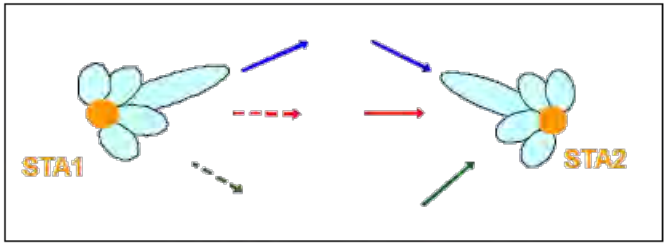




(a) I-TXSS in SLS



(b) I-MID



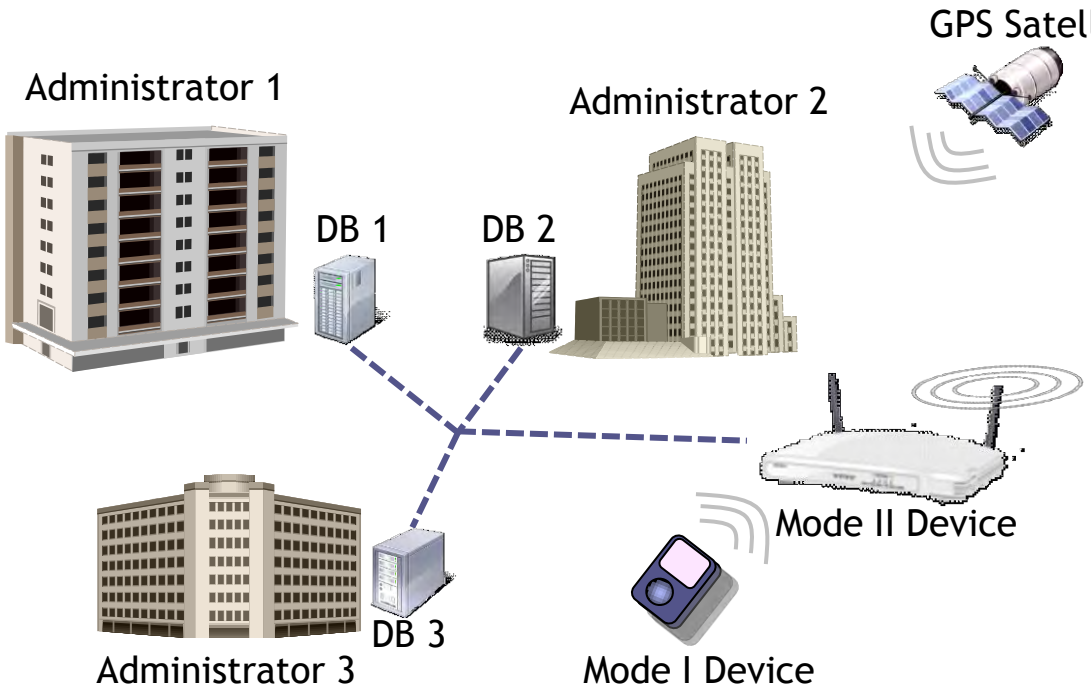
(c) I-BC (Beam Combining)

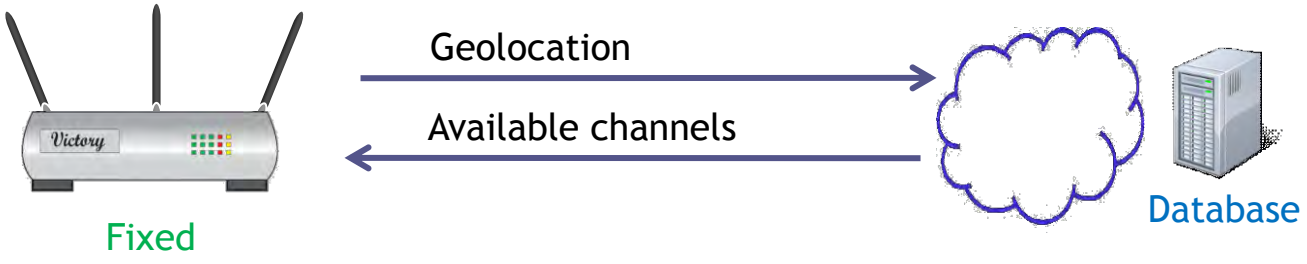
802.11af – TV White Spaces

- 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
- Database is out of scope of 802.11af; being developed by IETF

Database

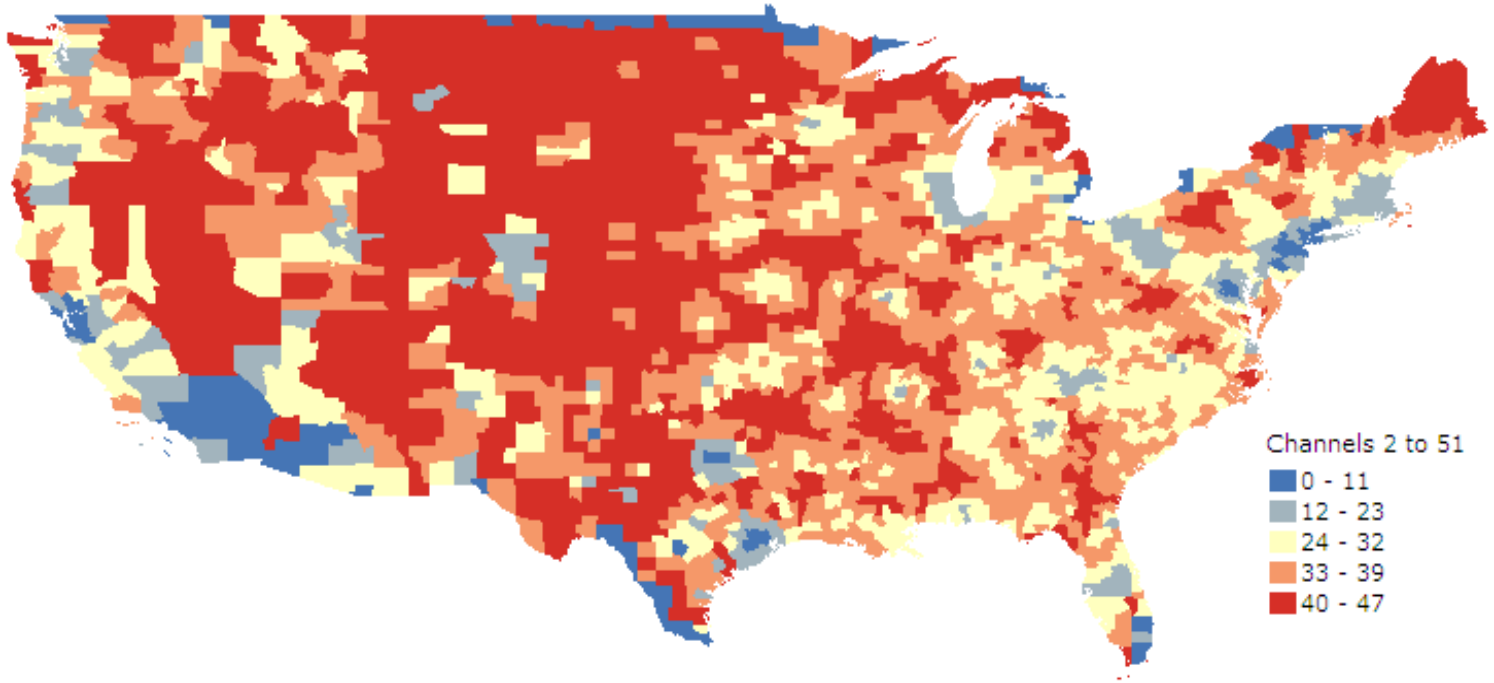
- Fixed TVBDs require geolocation capability and Internet access to a database of protected radio services.
- An 802.11af AP can use the 2.4 GHz band to get to the database and find out the available TVB channels and then switch operation to TVB





Taking Advantage of TV White Spaces

- 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	

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

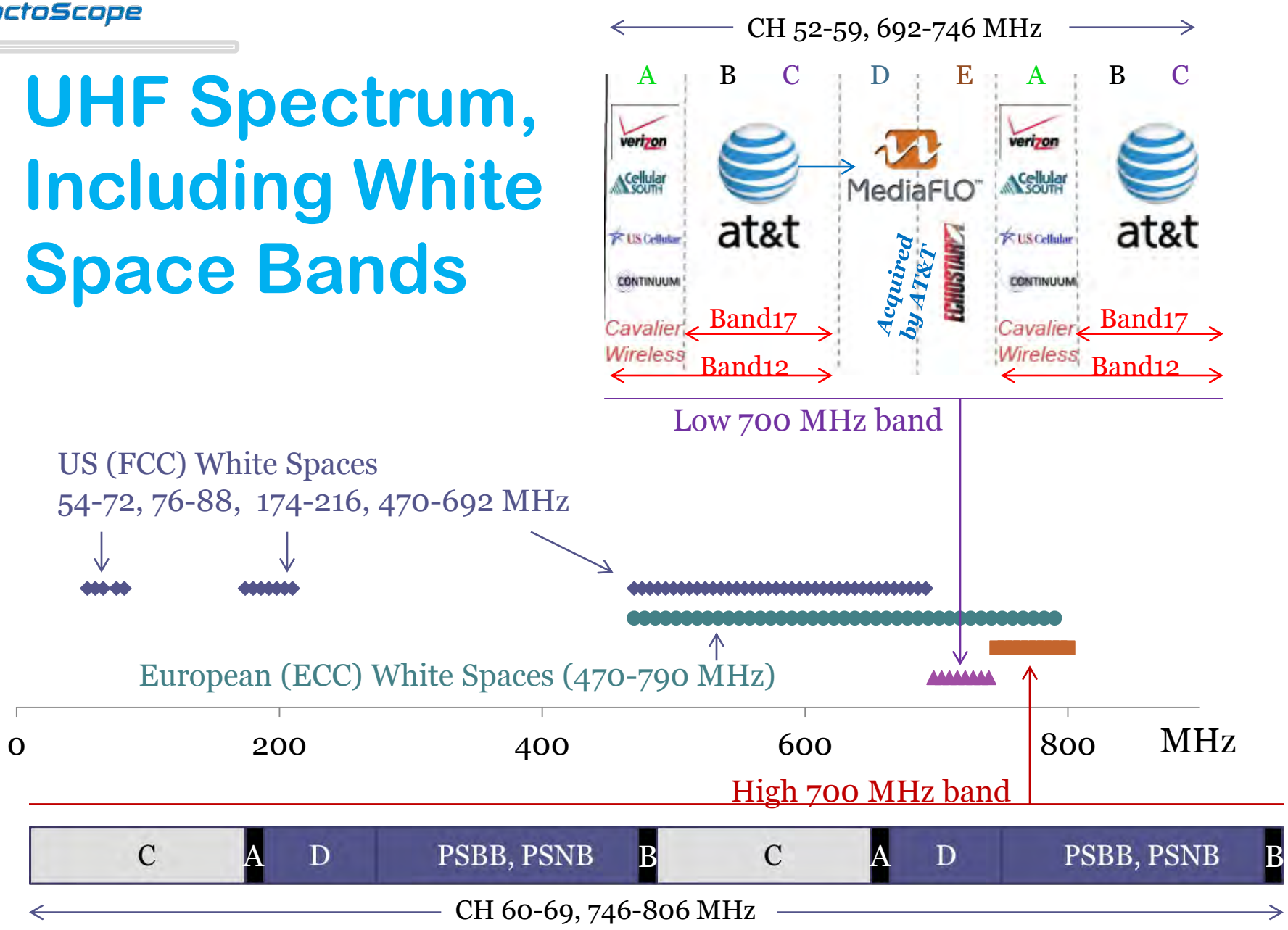
*Channel 37 (608-614 MHz) is reserved for radio astronomy
**Shared with public safety

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

Europe – ECC

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

UHF Spectrum, Including White Space Bands



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ECC = Electronic Communications Committee

Thank you!

- For more information and white papers please visit www.octoscope.com

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Back-up

Operation in TV Bands – Latest Rules

Access based on *geo-location & database* or *spectrum sensing*

Fixed

For fixed TVBDs max output power < 4 Watts EIRP

Must access a TV bands database over the Internet to determine channel availability

Personal /portable

For PP TVBDs max output power < 100 mW EIRP on non-adjacent channels and < 40 mW EIRP on adjacent channels

Mode I: obtain a list of available channels from a master device

Mode II: incorporate geo-location capability

PP = personal/portable