- WCA White Space update
  October 2011

- Peter Ecclesine,  petere@cisco.com

# Agenda

- White Space topics

- Dynamic Spectrum Access

- US FCC and OFCOM TVWS

- TVWS in Other Countries

- Technologies and Markets

- Spectrum Politics

- IEEE 802.11af Operation in TV White Spaces

- Scaling the 802.11ac radio for Sub 1 GHz operation

# White Space topics

- Coexistence – Broadcast towers, News Gathering, Cellular/mobile, legacy broadcast band applications

- Countries – Canada, Finland, Japan, Korea, Singapore, U.K., USA

- Markets – indoor, up to a few km outdoors, long range

- Regulatory – Cognitive Radios, DySPAN, exclusive use, geo-location databases, Joint Select Committee on Deficit Reduction, radar bands

- Standards – cellular/mobile, regional, best effort

- Technologies – LTE, 802.22, 802.11, 802.19.1, PAWS, geo-location database and sensing

# Dynamic spectrum access applies to both TV white space and other bands

- Goal – "While geographic sharing of spectrum is well-established, we are only just now seeing the emergence of technologies that enable 'dynamic' sharing – that is, the ability to identify slices of spectrum that are available at that location, **whether for a few seconds, a few minutes, a few hours, or a few days.**"

- At the time of radio deployment, the future available frequencies and transmit power limits are unknown.

- All protected spectrum users want quicker resolution of interference. Geolocation databases of spectrum users is quite helpful.
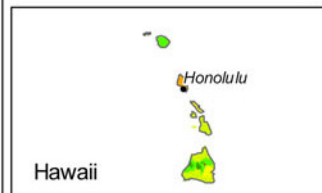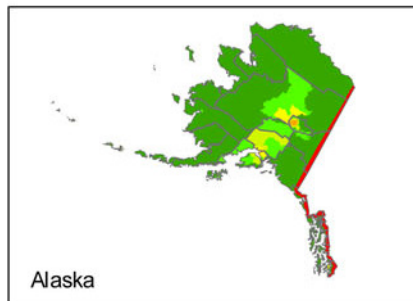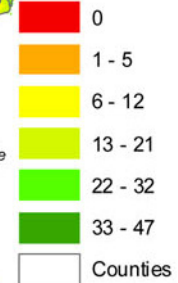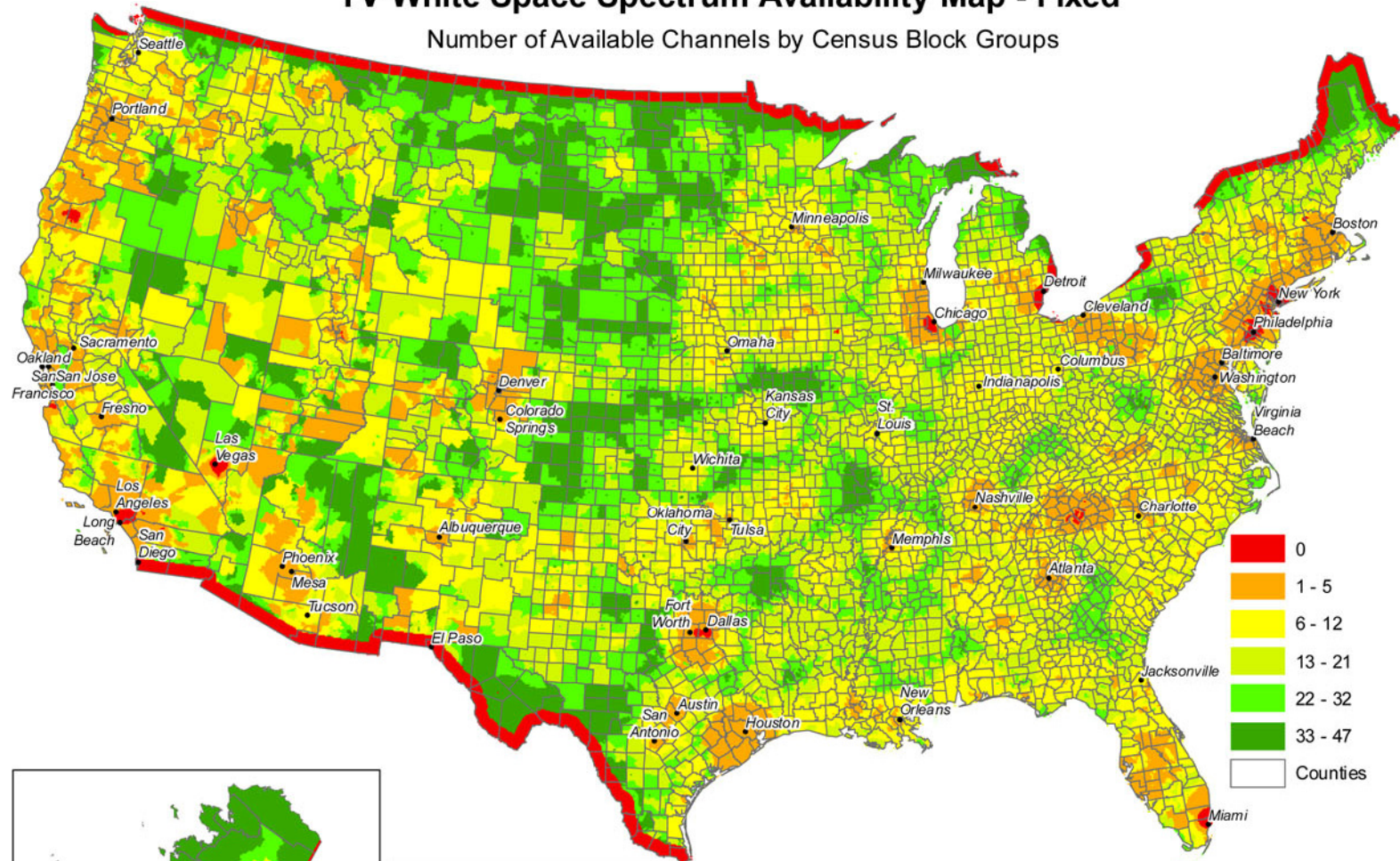
# U.S. TV white spaces takes a decade

- 2002 ET Docket No. 02-380 Additional Spectrum for Unlicensed Devices below 900 MHz

- 2003 ET Docket No. 03-108 Cognitive Radio NPRM

- 2004 ET Docket No. 04-186 Unlicensed Operation in the TV Broadcast Bands

- 2008 FCC 08-260 2nd Report and Order and Memorandum Opinion and Order (17 petitions for reconsideration, one court appeal by MSTV/NAB)

- 2010 FCC 10-174 2nd Memorandum Opinion and Order ( received 5 petitions for reconsideration)

- 2011 Sept 19 begin 45-day trial of SpectrumBridge TV bands database (absent privacy)

# White Space spectrum in the USA?

- FCC Part 15 Subpart H TVWS rules
  http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol1/pdf/CFR-2010-title47-vol1-part15.pdf

- FCC terminology
  https://mentor.ieee.org/802.11/dcn/11/11-11-0175-02-00af-fcc-tvws-terminology.ppt

- Showmywhitespace.com 445 N. Mary Ave, Sunnyvale
  http://spectrumbridge.com/whitespaces.aspx

- Calculations   http://fjallfoss.fcc.gov/ecfs/document/view?id=7021713432

- US Metro white space April and September 2011
  https://mentor.ieee.org/802.11/dcn/11/11-11-0499-03-00af-us-metro-mhzpops.xls

# TV White Space Spectrum Availability Map - Fixed

## Number of Available Channels by Census Block Groups



Legend:
- 0 (red)
- 1 - 5 (orange)
- 6 - 12 (yellow)
- 13 - 21 (yellow-green)
- 22 - 32 (green)
- 33 - 47 (dark green)
- Counties (white)

Alaska

Hawaii

Puerto Rico & US Virgin Islands

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# TV White Space Spectrum Availability Map - Mode II

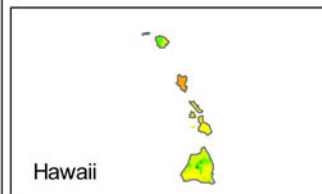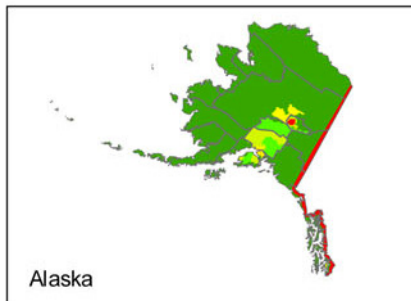## Number of Available Channels by Census Block Groups



**Legend:**
- 0 (red)
- 1 - 5 (orange)
- 6 - 10 (yellow)
- 11 - 16 (light green)
- 17 - 23 (green)
- 24 - 30 (dark green)
- Counties (white)

Alaska

Hawaii

**COMSEARCH**
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Puerto Rico & US
Virgin Islands
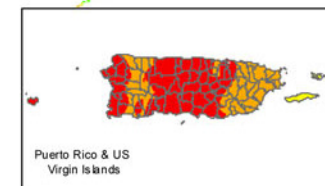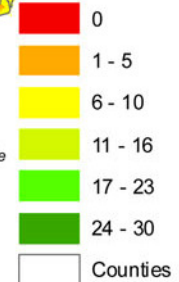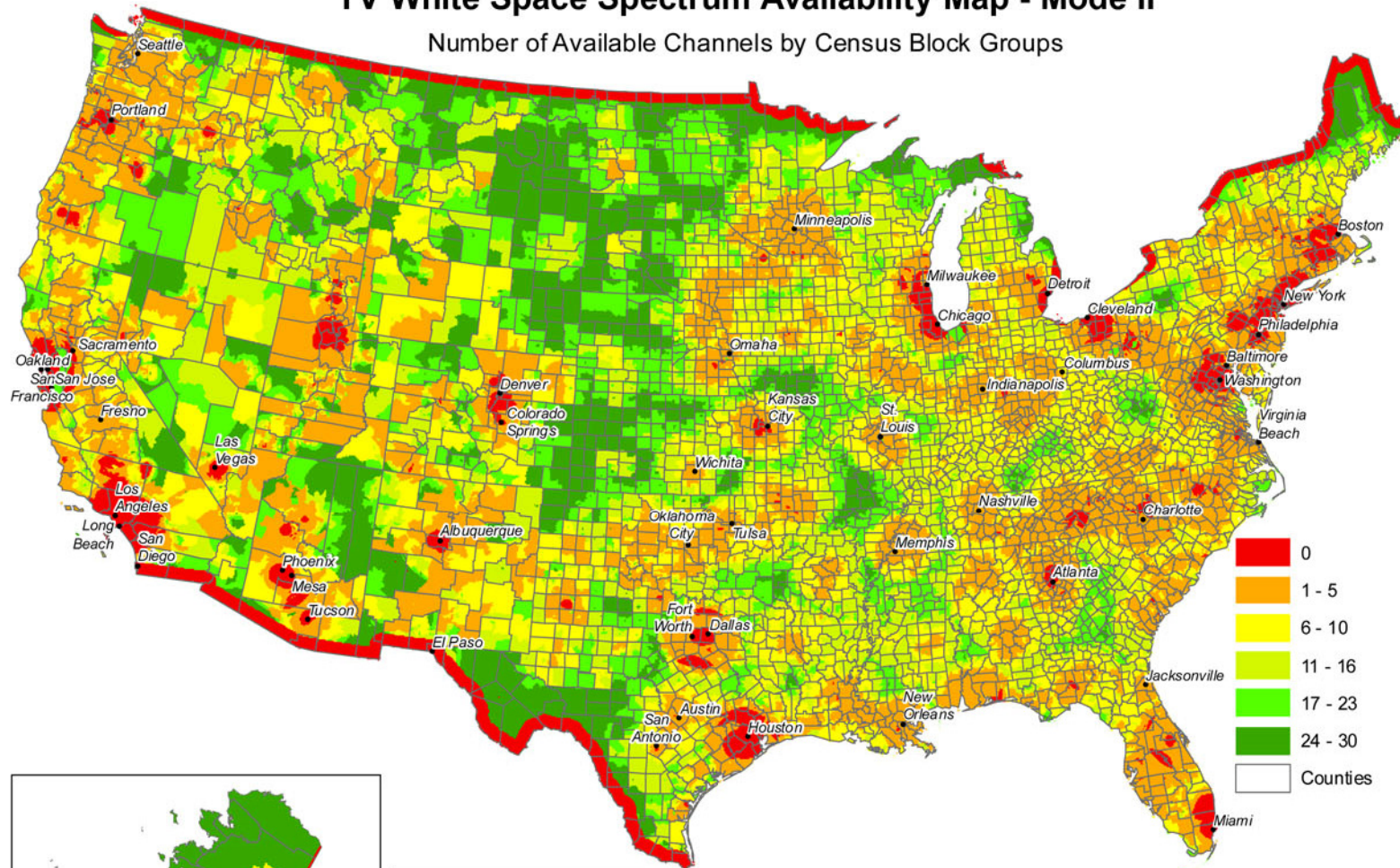
# FCC TV White Spaces Spectral Mask



-72.78 dB means less than 1/18,967,059 of peak power
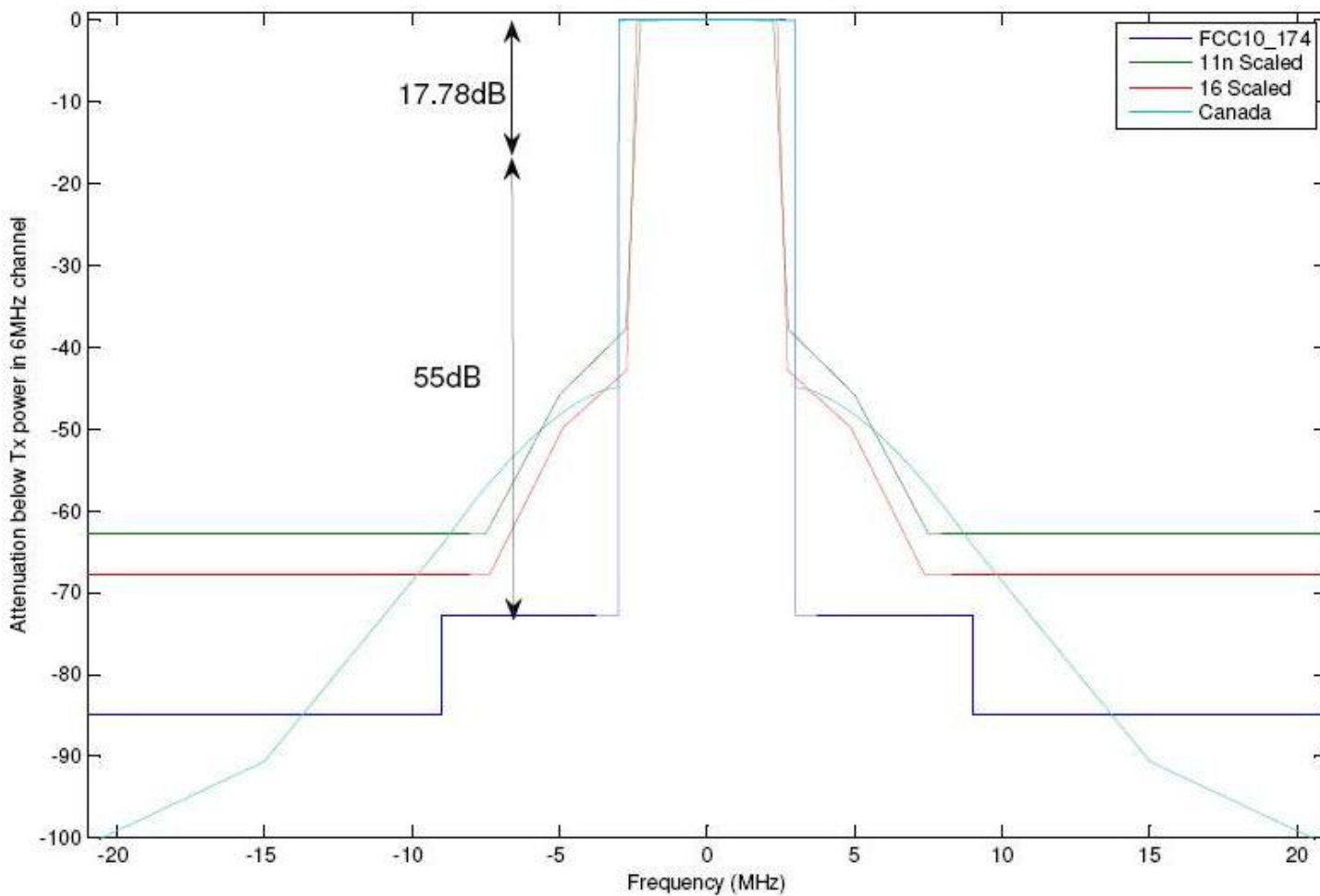
# OFCOM TV white spaces

- About 128 MHz of interleaved spectrum is available in nearly every household.

- Lower UHF 470-550 MHz, Upper UHF 614-790 MHz
    Analogue TV to be switched off October 24, 2012

- OFCOM TV white space Technical Working Group working on the rules, and OFCOM expect to issue a Statutory Instrument in 2012 – pushing back 4G spectrum auction to 4Q12 pushes back TVWS rules

- Database calculates white spaces depending on accuracy of location, device radio characteristics. To protect mobile uses, database must be checked every hour

# Other countries

- Canada allows Remote Rural Broadband Systems licensed use with up to 500W, has consultation SMSE-012-11 to align unlicensed use with FCC TVWS rules

- Finland, Singapore had TVWS trials in 2010, 2011

- Japan, Korea, South Africa expect to trial TVWS services in 2012

- ECC Report 159 sets technical and operational requirements for using TVWS by cognitive radios in EU

- CEPT SE43 Cognitive Radio Systems – White Space
  http://www.cept.org/ecc/groups/ecc/wg-se/se-43

# Coexistence with broadcast band uses

- Coexistence considerations from easy to hard

  Broadcast towers, (they don't move, but radio propagation models have changed from R-6602 surface roughness)

  http://www.fcc.gov/dtv/markets/maps_current/San_Francisco-Oakland-San_Jose_CA.pdf  ('FCC KBCW')

  Community TV repeaters/translators

  Electronic News Gathering (<10,000 microphones in the field)

  Commercial Mobile Radio Services in metro areas (TV 14-20)

  Cellular/mobile in adjacent channels (lower 700 MHz)

# Broadcast Band Technologies

- LTE cellular, licensed band exclusive use

- IEEE 802.22-2011, Regional area network (40-50 km)

- IEEE 802.19.1, Wireless Coexistence in the TV Bands

- IETF PAWS, Protocol to Access White Space database

  Asserting Who I am, What I am, Where I am, What I will permit, Receiving grants of what is permitted at my location

- Proprietary cognitive radios – 6Harmonics, Adapt4, Adaptrum, Aviacomm/Carlson Wireless/Neul, ...

- Geo-location database and sensing progress (ECC SE43)

# TVWS Markets

- Indoor for greater range and coverage – people spend most of their time indoors, the wafer starts are here

- Outdoor short range – Internet of Things

- Long range – regional area networks (the Outback, Yukon Territory), WISPA.org

# Spectrum Politics

- Lawmakers tell regulators what to do

    The FCC reports to the US Congress, not to the Executive Branch

- Many European countries are under financial pressure

- Many 3rd world countries sell spectrum licenses to cover regulatory expenses

- US Joint Select Committee on Deficit Reduction has a $24B goal for auctioned spectrum

    Entirely likely will recommend consolidating DTV broadcasters on fewer TV channels and auction off unused spectrum

    Once Congressional Budget Office approves the auction, the projected proceeds can be spent (no waiting for the auction)

    Broadcast Broadband Plan $125B
    http://coalitionforfreetvandbroadband.org/?page_id=504

# Marginal Flexibility of Spectrum per POP
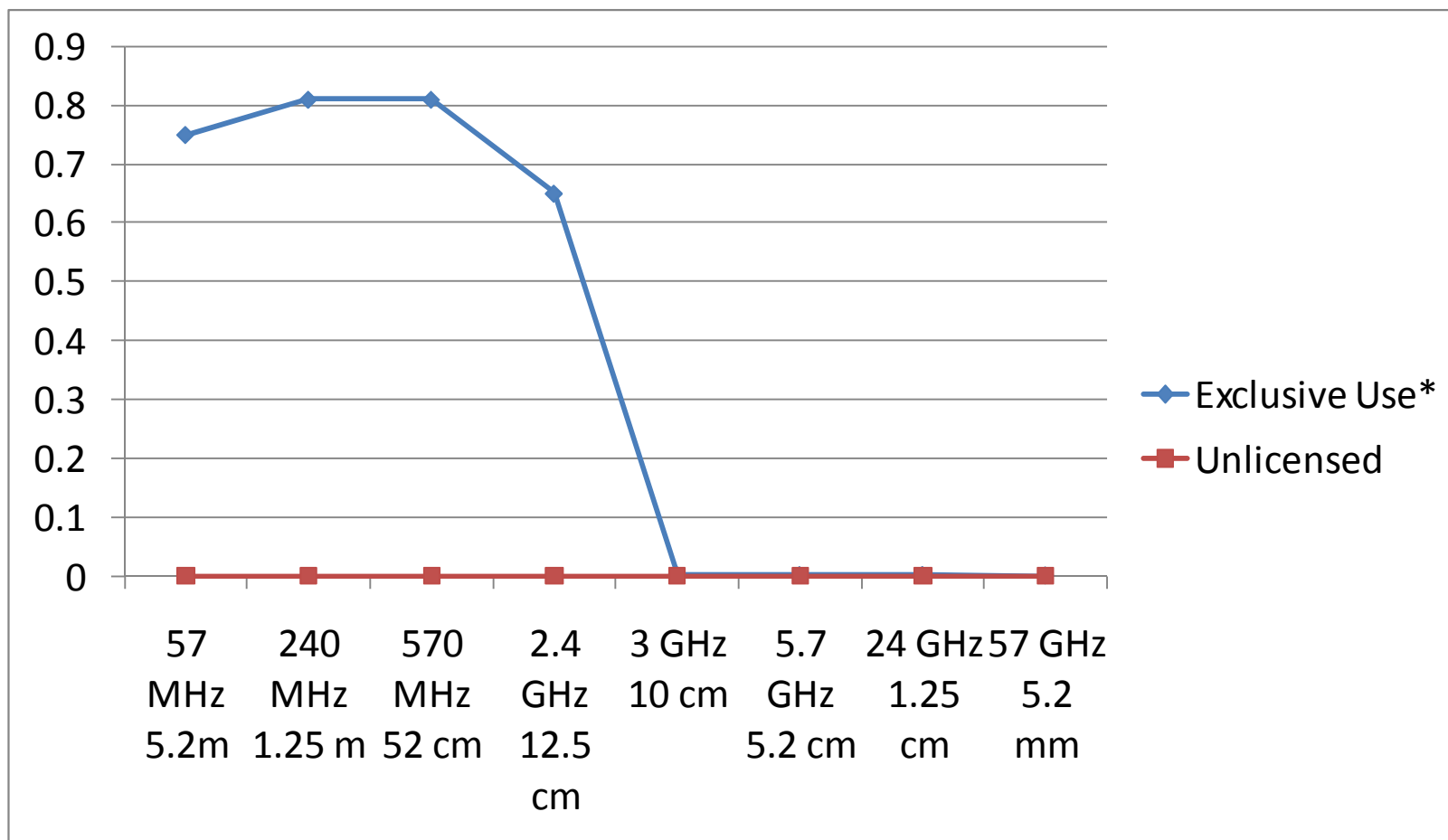


Highest Value Use of Spectrum, Citizens Guide to the Airwaves

* http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=73

# 802.11af TV band defined elements
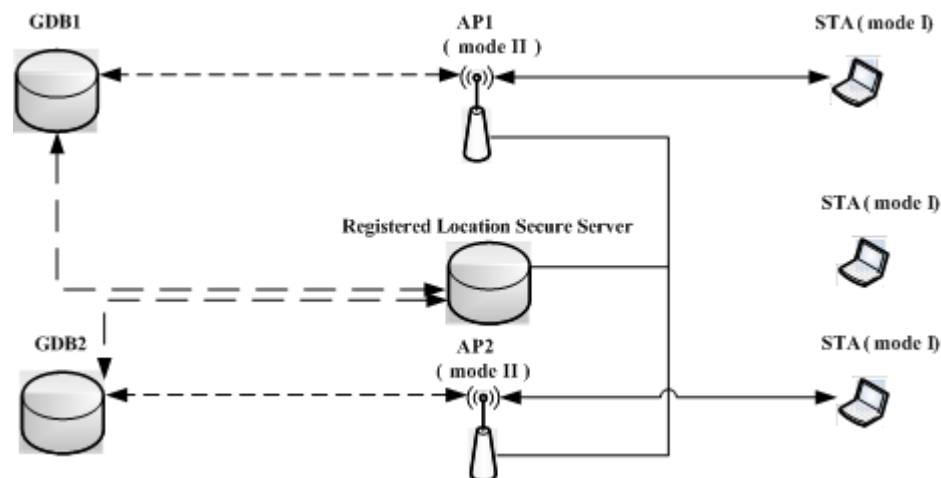


Others define the Authorized database protocols that APs and Fixed devices shall use, and each AP is certified to operate with a specific Authorized TV bands database. A Registered Location Secure Server accesses the Authorized databases with protocols that others define, and may provide a persistent internet address to the databases. APs and 802.11 stations access a Registered Location Secure Server with radio protocols that IEEE 802.11 defines.

# Wi-Fi Sub 1 GHz Range

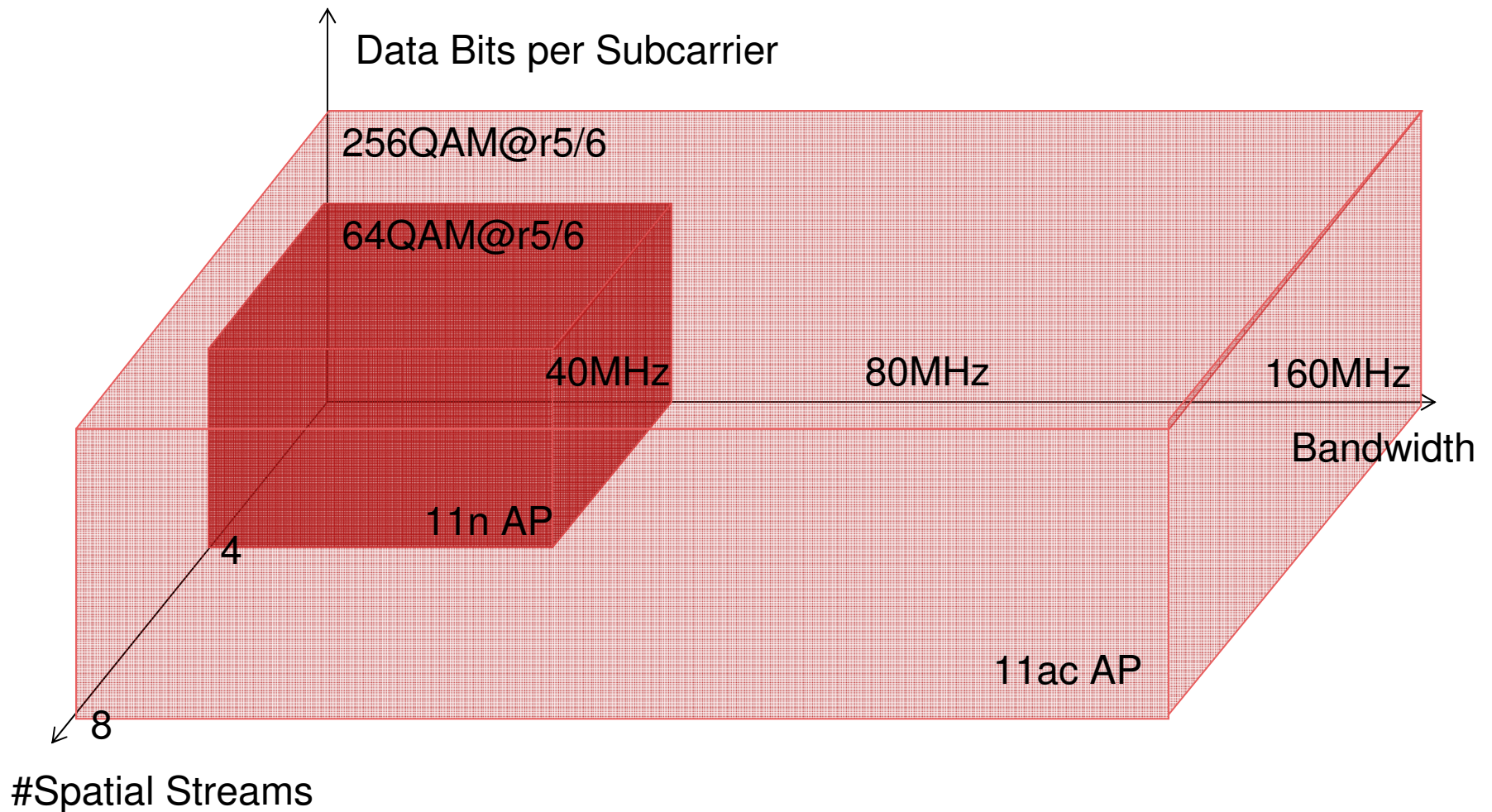- 3 times the range

# Wi-Fi Sub 1 GHz Range

- 10 times the coverage

# Wi-Fi Sub 1 GHz Rate

- Up to One tenth the speed

1/54, 1/40, 1/30, 1/20, . . . 1/10

# 802.11ac VHT<6 11ac, Making 11n Go Faster

Data Bits per Subcarrier

256QAM@r5/6

64QAM@r5/6

40MHz          80MHz          160MHz

Bandwidth

11n AP

4

8

11ac AP

#Spatial Streams

Acknowledge Brian Hart, Cisco

# Important 802.11ac VHT<6 Numbers

- For battery-powered APs and clients, only the yellow row is mandatory

- Gigabit rates for some product configurations (orange rows)

| BW (MHz) | #Spat Strm | MCS (QAMr5/6) | PHY rate (Mbps) | MAC thruput (Mbps)* | BW (MHz) | #Spat Strm | MCS (QAMr5/6) | PHY rate (Mbps) | MAC thruput (Mbps)* |
|---|---|---|---|---|---|---|---|---|---|
| 40 | 3 | 64 | 450 | 315 | 40 | 4 | 64 | 600 | 420 |
| 80 | 1 | 64 | 325 | 227 | 160 | 1 | 64 | 650 | 455 |
| 80 | 1 | 256 | 433 | 303 | 160 | 1 | 256 | 867 | 607 |
| 80 | 2 | 64 | 650 | 455 | 160 | 2 | 64 | 1300 | 910 |
| 80 | 2 | 256 | 867 | 607 | 160 | 2 | 256 | 1733 | 1213 |
| 80 | 3 | 64 | 975 | 683 | 160 | 3 | 64 | 1950 | 1365 |
| 80 | 3 | 256 | 1300 | 910 | 160 | 3 | 256 | 2600 | 1820 |
| 80 | 4 | 64 | 1300 | 910 | 160 | 4 | 64 | 2600 | 1820 |
| 80 | 4 | 256 | 1733 | 1213 | 160 | 4 | 256 | 3467 | 2427 |
| 80 | 8 | 256 | 3467 | 2427 | 160 | 8 | 256 | 6933 | 4853 |

*Assuming 70% efficiency

Acknowledge Brian Hart, Cisco
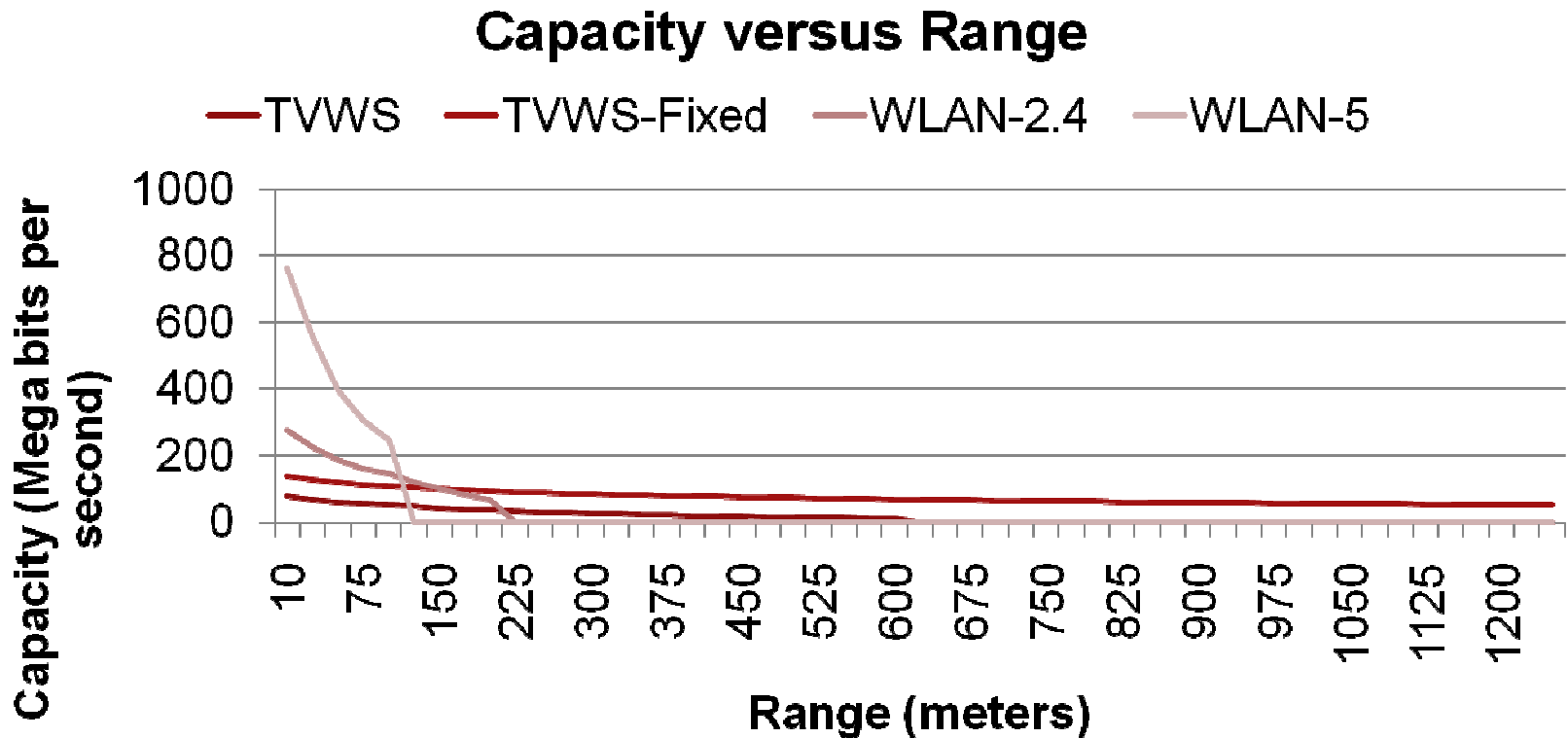
# Relations between 802.11ac and 11af

- Expect 11ac PHY to be 'frozen' by Christmas, 2011, and WFA to certify devices by Spring 2013

- Expect 11af to take PHY decisions by Thanksgiving, 2011 and WFA to certify devices starting Spring, 2013

- Expect TV frequencies to affect spatial streams more than any other WLAN PHY technology.

   Long wavelengths 5.2m-1.4m (VHF) and 63 cm-43 cm (UHF) mean for the same size devices MIMO is less effective than at shorter wavelengths

   TV channel bandwidths of 6 MHz, 7 MHz and 8 MHz have to be supported by world client radios

   Expect Interference Alignment and Cancellation to be used in the home

# US FCC TVWS compared to 2.4 GHz and 5 GHz



## Capacity versus Range

Legend: TVWS — TVWS-Fixed — WLAN-2.4 — WLAN-5

Y-axis: Capacity (Mega bits per second) — 0, 200, 400, 600, 800, 1000

X-axis: Range (meters) — 10, 75, 150, 225, 300, 375, 450, 525, 600, 675, 750, 825, 900, 975, 1050, 1125, 1200

# Link budgets US TVWS v 2.4 GHz v 5 GHZ

| | TVWS | TVWS-Fixed | WLAN-2.4 | WLAN-5 |
|---|---|---|---|---|
| Tx Power (mW) | 40 | 4000 | 40 | 40 |
| Tx Power (dBm) | 16.02 | 36.02 | 16.02 | 16.02 |
| Tx Antenna Gain | 0 | 0 | 0 | 0 |
| Rx Antenna Gain | -3 | 12 | 0 | 0 |
| Frequency (MHz) | 518 | 192 | 2437 | 5500 |
| Bandwidth (MHz) | 4 | 4 | 20 | 80 |
| Wavelenth (meters) | 0.5791 | 1.5625 | 0.1231 | 0.0545 |
| Path-loss Exponent | 4 | 4 | 4 | 4 |
| Fade margin | 10 | 10 | 10 | 10 |
| BD | 100 | 100 | 100 | 100 |
| Noise Figure | 5 | 5 | 5 | 5 |
| Noise Power | -107.97 | -107.97 | -100.99 | -94.96 |
| 1st meter loss | -26.72 | -18.10 | -40.17 | -47.24 |
| BD Free Space Loss | -66.72 | -58.10 | -80.17 | -87.24 |
| Minimum SNR* | 8 | 8 | 8 | 8 |

\* Minimum SNR required to be able to decode packets
Breakpoint Distance BD >> SQRT($h_t h_r$)

# TVWS References

- Cognitive RadioTechnologies https://mentor.ieee.org/802.18/dcn/04/18-04-0004-00-0000-cognitive-radio-technologies.ppt

- wikipedia https://secure.wikimedia.org/wikipedia/en/wiki/White_spaces_(radio)

- IEEE 802.11 http://www.ieee802.org/11/

- Wi-Fi Alliance http://www.wi-fi.org/connection/

- IEEE 802.22 http://www.ieee802.org/22/

- Cognitive radio in ECC http://www.wonderlandwpa.com/dev/ecc_newsletter_june/june-2011/index.html

- ECC Report 159 http://www.erodocdb.dk/docs/doc98/official/Pdf/ECCRep159.pdf

- FCC TVWS ECFS Proceeding 02-380, 04-186 http://fjallfoss.fcc.gov/ecfs/

- FCC Part 15 Subpart H TVWS rules http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol1/pdf/CFR-2010-title47-vol1-part15.pdf

- FCC terminology https://mentor.ieee.org/802.11/dcn/11/11-11-0175-02-00af-fcc-tvws-terminology.ppt

- IETF PAWS  http://palgronsund.com/tag/ietf/

- Showmywhitespace.com http://spectrumbridge.com/whitespaces.aspx

- US Metro white space https://mentor.ieee.org/802.11/dcn/11/11-11-0499-03-00af-us-metro-mhzpops.xls

- 802.11ah sub 1 GHz channel models  https://mentor.ieee.org/802.11/dcn/11/11-11-0968-01-00ah-channel-model-text.docx

# Q and A