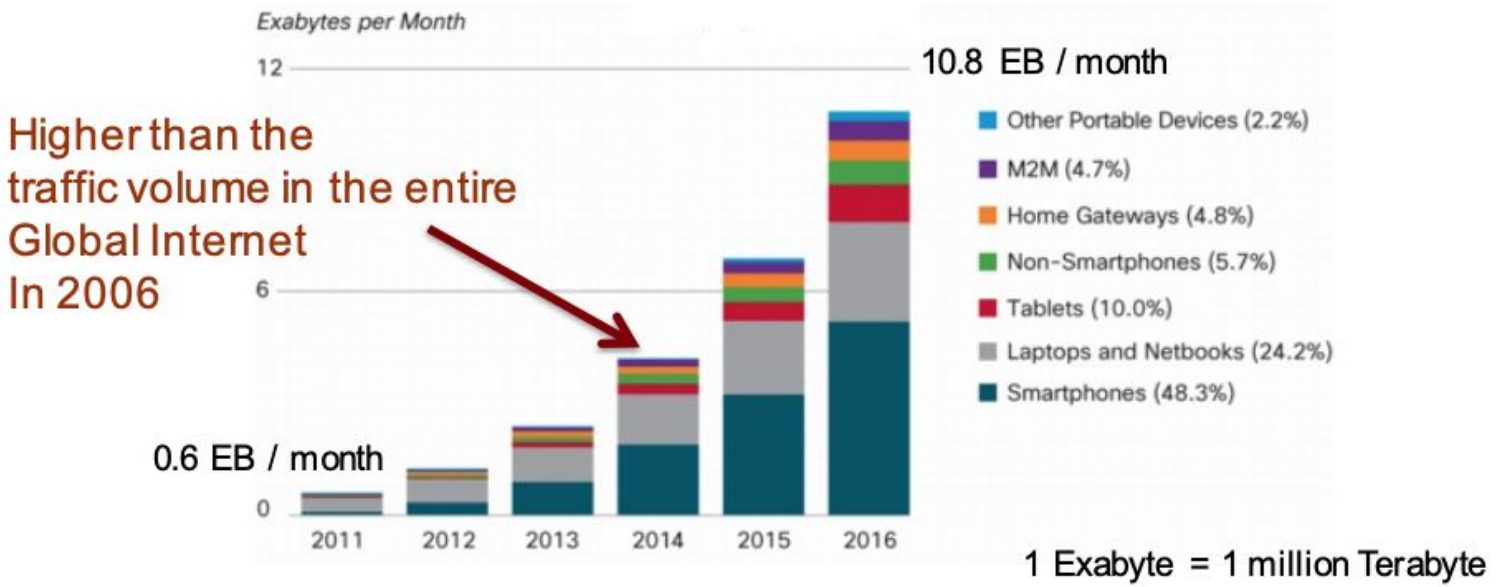
CSE570 Spring 2020
Wireless and Mobile Networks

White Space Spectrum

Mallesham Dasari

Mobile Data Usage



1 Exabyte = 1 million Terabyte

Forecast of Global Mobile Data Traffic

Source: CISCO VNI Mobile

Exponential growth in mobile traffic. Need for additional spectrum. But no significant spectrum unallocated.


3 kHz
300 kHz
300 kHz
3 MHz
3 MHz
30 MHz
30 MHz
300 MHz
300 MHz
3 GHz
3 GHz
30 GHz
30 GHz
300 GHz
* EXCEPT AERO MOBILE (R)
** EXCEPT AERO MOBILE
THE RADIO SPECTRUM
MAGNIFIED ABOVE
VERY LOW FREQUENCY (VLF)
LF
MF
HF
VHF
UHF
SHF
EHF
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA-RAY
COSMIC-RAY
PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUMSEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

Opportunity: TV Bands

- Significant amount of RF spectrum allocated for over-the-air (OTA) TV broadcasting are not efficiently used.
- TV broadcasts use VHF/UHF bands roughly 50-800MHz (not continuous).
  - This spectrum provides very good propagation quality for wireless communications. Thus, attractive.
- Not all TV channels are used at every location at all times. Also, after the recent analog to digital transition TV broadcasts use less spectrum.
  - Part of the previously used TV spectrum has already been consolidated and auctioned off (channels 52-69, 698-806MHz).
  - But a large amount of ill-utilized TV spectrum still available: Lower VHF channels 2-6 (54-72, 76-88 MHz), upper VHF channels 7-13 (174-216 MHz) and UHF channels 14-51 (470- 698MHz) with the exception of channel 37 reserved for radio astronomy.

TV White Space (TVWS)

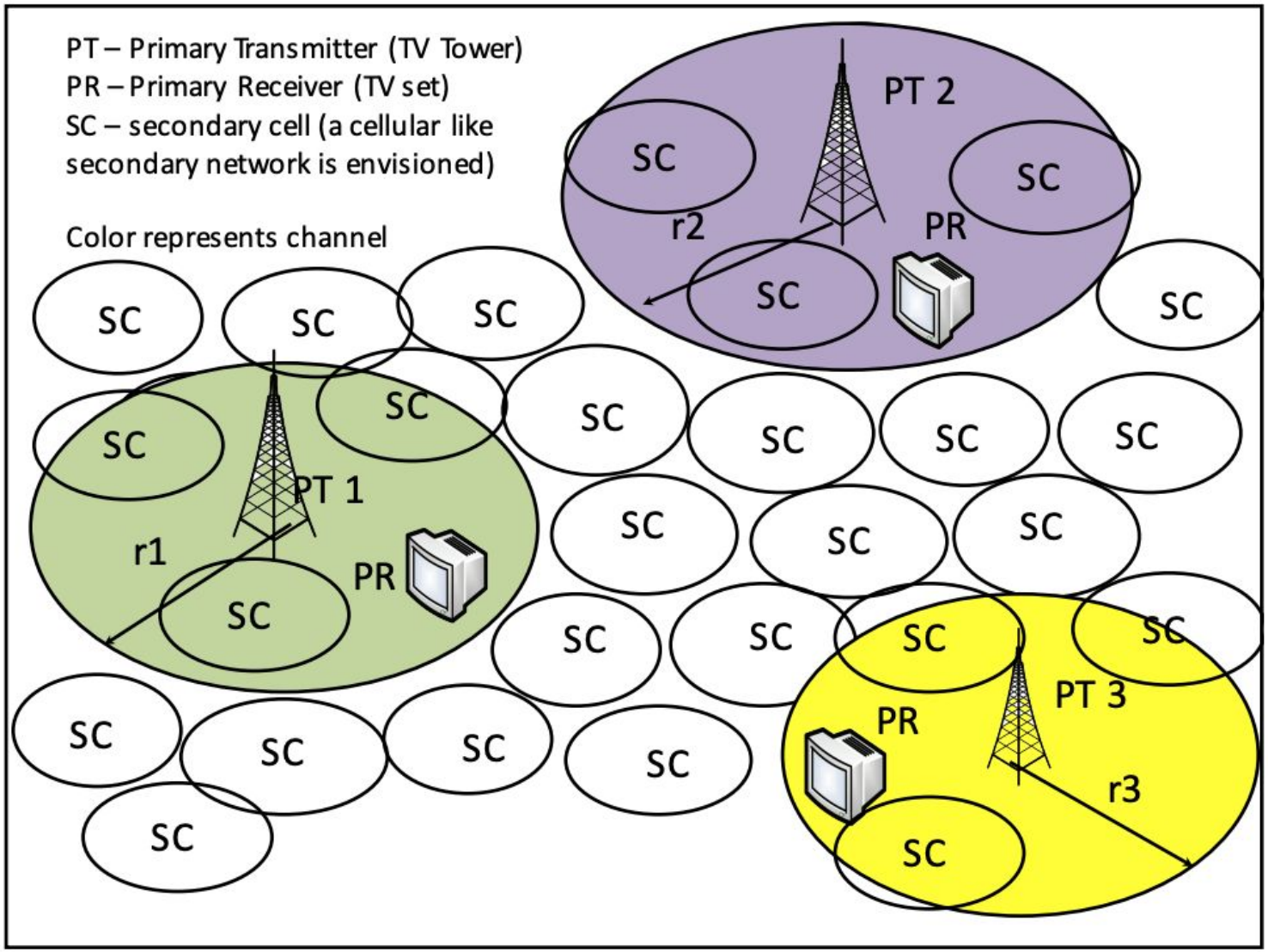
- TVWS = Unused TV spectrum over time and space.
- TVWS spectrum is still legally licensed to TV broadcasters.
  - Similar situation all over the world (not a US centric issue).
- Similar situation exists for other ill-utilized spectrum, e.g., various radar bands (e.g., 2.7-3.6GHz)

Opportunity and Challenge

- *Opportunity*: Large amount of fallow spectrum attractive for wireless communication.
- *Challenge*: It is already licensed. How to create new regulations and technologies to support wireless communications in this spectrum band that do not interfere with TV reception.

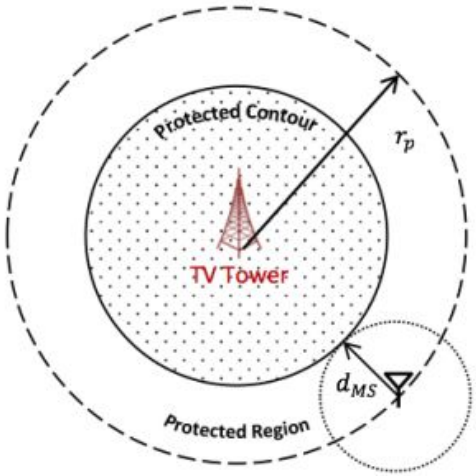
De-Regulation

- Regulators worldwide (e.g., FCC in USA, Ofcom in UK) are promoting a new form of unlicensed use in the TVWS.
  - e.g., FCC ruling in 2008 in USA.
- Unlicensed use, but incumbent protected.
  - Not exactly "free for all" like WiFi.
  - Sometimes called "lightly licensed."
- Incumbents are the licensees. They are called "primaries." Unlicensed devices are called "secondaries."
- Basic access rule: secondary communications cannot interfere with primaries (i.e., TV reception).


PT – Primary Transmitter (TV Tower)
PR – Primary Receiver (TV set)
SC – secondary cell (a cellular like secondary network is envisioned)
Color represents channel
PT 2
r2
PR
PT 1
r1
PR
PT 3
PR
r3
SC

Secondary Operation in TVWS

- Secondary operation permitted so long as no interference at the TV receivers.
- Define a *primary protection region.* (Roughly the coverage area of the TV tower, plus some – depending on the signal strength of the secondary transmitters.)
- General rule: Do not operate in the same TV channel within the protection region.



Determination of Protection Region

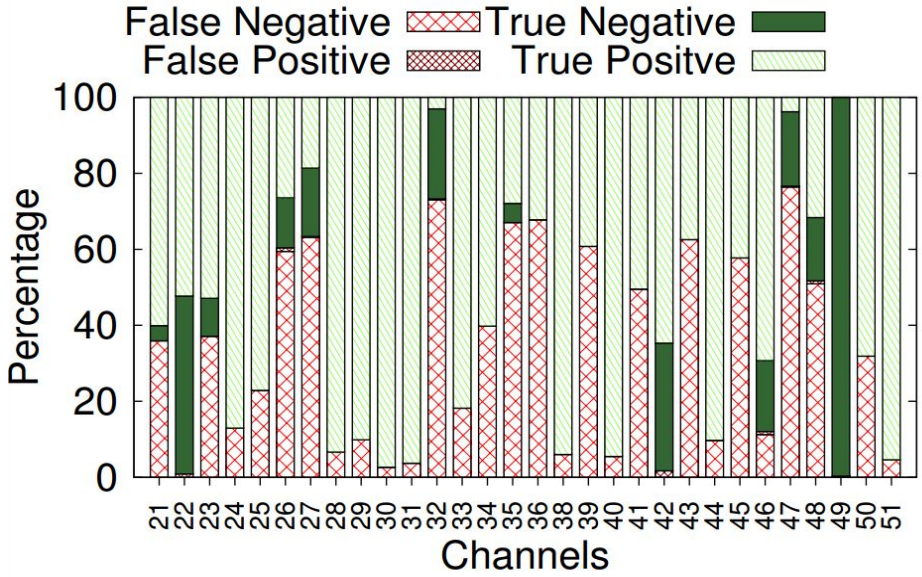
- TV transmitter location, channel, tx power, antenna characteristics (height, gain) are known.
- This provides a coverage contour defined by a distance within which TV signals are received at a power higher than a specified threshold.
  - This distance could be computed via path loss modeling.
- Add to that an additional no-talk distance d_{MS} such that interference produced by any secondary transmitter will be below a specified threshold.
  - This can again be computed via similar modeling.

TVWS Spectrum Database

- These databases use sophisticated propagation models and terrain data to estimate whether a specific TV channel is available for secondary use at a given location.
  - In other words, whether this location is outside the protection region of all TV transmitters operating in that channel.

Creating Spectrum Databases

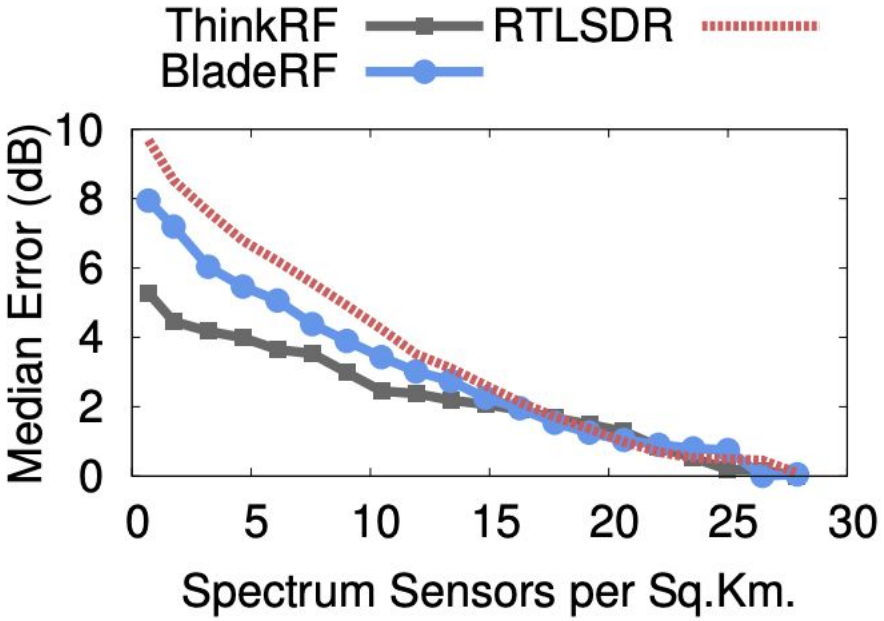
- Propagation models
  - Accuracy problem
- Use spectrum analyzers
  - Cost



http://conferences.sigcomm.org/co-next/2014/CoNEXT_papers/p67.pdf

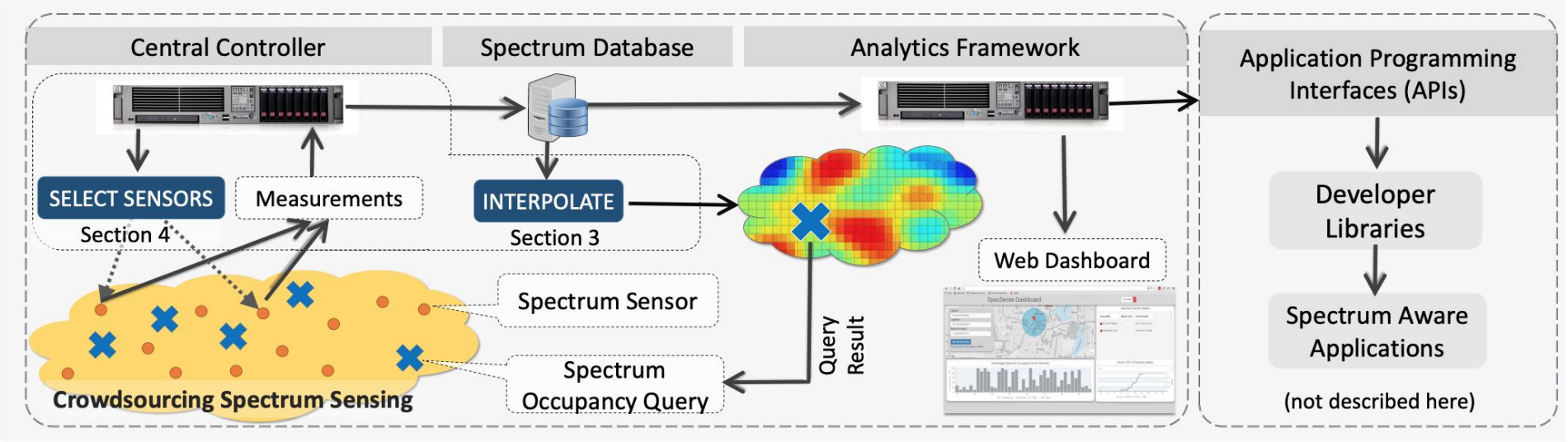
Low Cost Spectrum Monitoring

- Software Defined Radio
- Crowd Sourced spectrum monitoring



https://www3.cs.stonybrook.edu/~aychakrabort/files/specsense_infocom17.pdf

Low Cost Spectrum Monitoring



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Low Cost Spectrum Monitoring

- Challenges
  - Cheap sensing -> not accurate
  - Device capacity
  - Network cost – massive spectrum data

Summary

- Problem: Spectrum crunch
- Opportunity: White spaces
- Challenge: De-regulation
- Current Solution: Spectrum Databases