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WhiteNet: A White Space Network for Campus Connectivity Using Spectrum Sensing Design Principles

Hope Mauwa & Antoine Bagula
University of the Western Cape
mhope@uwc.ac.za & *bbagula@uwc.ac.za*
Marco Zennaro
International Centre for Theoretical Physics
mzennaro@ictp.it

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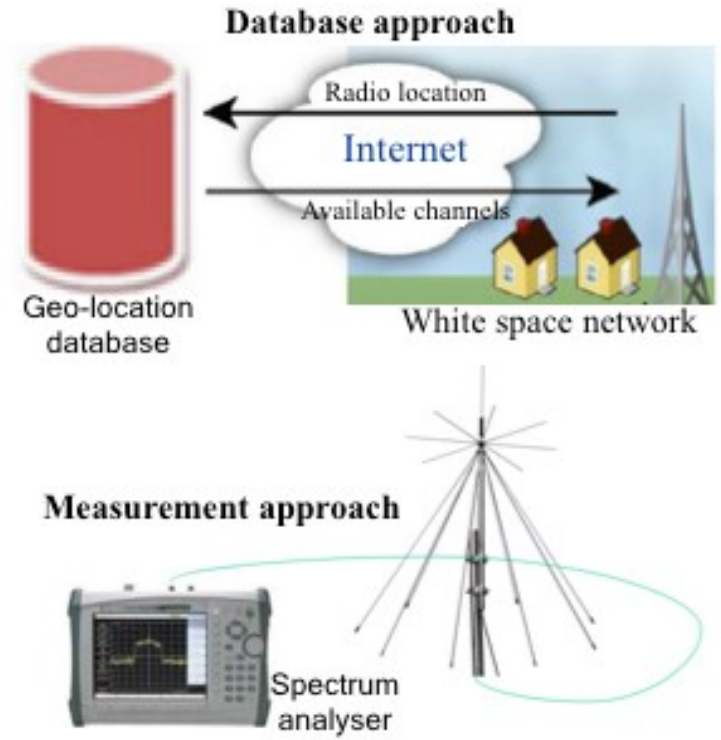
Two ways to measure TV white spaces (TVWSs)

- Database approach and measurement



- Database – preferred method.
  - Guarantees high protection.
- Not necessarily the method of choice in places where:
  - There is a lot of TVWSs.
  - There is incomplete database.
  - Access to database may be a challenge

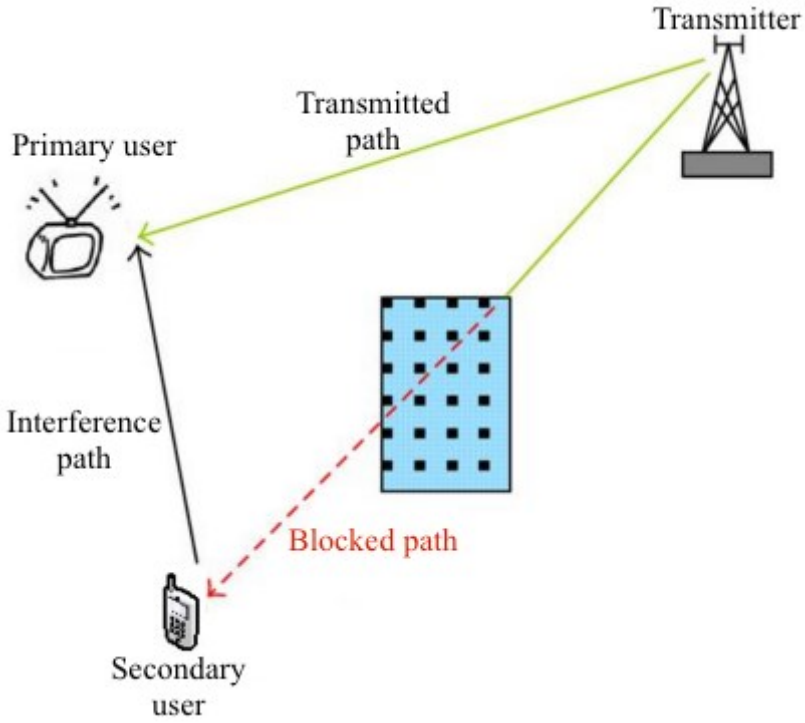
Rural areas of developing world has a lot of TVWSs

Country	White Space found (MHz)
South Africa	307
Uganda	208
Philippines	304
India	217

- White space access does not require stringent constraints.
- Spectrum sensing is as an alternative method.
- Energy detector-common spectrum sensing is the method of choice.

Energy detector has some challenges

- No standardized way of selecting detection threshold.
  - Optimal performance difficult to achieve.
- Suffers from multi-path fading or shadowing.
  - Results into *hidden user problem*.
- Some principles are being proposed.



HIDDEN USER PROBLEM

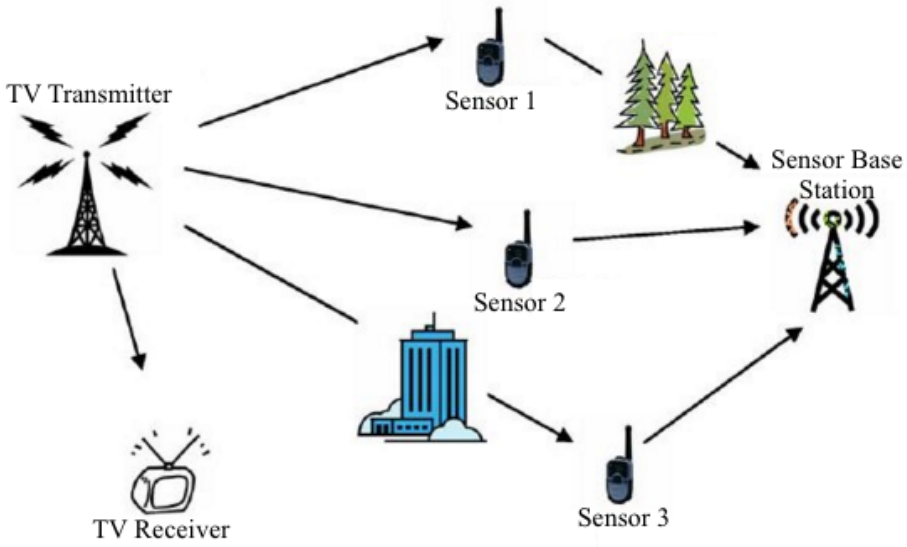
1. Using more than one detection threshold

- *-114 dBm* as mandated by FCC is conservative.
  - Leads to significant loss of TVWSs.
- On the other hand, different detection thresholds have been used.
- Therefore, using more than one detection threshold seems to a logical solution.
  - From *-114 dBm* to a value dependent on a country's TV broadcasting allocation scheme.
- TVWSs can be grouped based on thresholds used.
  - Allocation starts with TVWSs discovered with lowest/conservative threshold.
- Approach results into optimal performance.

2. Virtual pricing of TVWSs identified

- Based on some common quantity associated with all TVWSs, e.g. signal strength.
  - Highest price given to TVWS channel with strongest signal.
  - Lowest price given to TVWS channel with weakest signal.
- Allocate cheapest channels within each group first.
- In this way, probability of interference is minimized.
  - TVWS channel prices that may result into false negatives are more expensive than those that are actually TVWSs.
  - Therefore, they cannot be allocated unless the channels that are actually WSs are exhausted.

1. Cooperative Spectrum Sensing



- Solution to *hidden user problem*.
- Network of sensors have a better chance of detecting.
- Proposed principles rely on results generated from this principle as first step to minimize interference.

2. Channel-clustering and location-clustering

- Help in resource allocation, i.e. sensors.
  - Right number of sensors are deployed.
  - Sensors are strategically placed based on groups created.
- WS channels are calculated according to location clusters.
  - Secondary users are required to identify their positions first.

Short-time measurements at the University of the Western Cape, South Africa

BUILDING LAYOUT AND MEASUREMENT LOCATIONS (560 m^2)

- Environment for measurement locations – same since:
  - Same floor.
  - Covered small areas.
- Assumption – same WS channels identified.
- Hand-held RF Explorer model WSUB1G was used.

Results-TVWSs identified

Threshold (dBm)	No of WSs identified	Channel(s)
103	1	67
102.5	8	54, 57, 60, 61, 62, 65, 66, 68
102	12	43, 46, 47, 48, 49, 52, 53, 56, 57, 58, 59, 64

- Grouping of WS channels helps to allocate them sequentially.
  - Safe – allocation starts with safest group.
- Different if TVWSs are discovered with only one threshold.
  - Allocation is done randomly.
- Pricing channels within a group adds additional security within the group.

Results-Virtual prices of WS channel

WS Channel Group	Channel Prices
103 dBm	67:1.000
102.5 dBm	54:0.997, 57:0.996, 60:0.998, 61:0.998, 62:0.997, 65:0.997, 66:0.998, 68:1.000
102 dBm	43:0.998, 46:0.997, 47:1.000, 48:0996, 49:0.998, 52:0.995, 53:0.996, 56:0.999, 58:1.000, 59:0.997, 64:1.000

- Channels with stronger signals are priced higher.
  - Ones more likely to have missed detection.
- Sequence allocation starting with cheapest channels within a group adds some protection.
- E.g. in *102 dBm* group, allocating 52, 53, 48 first adds protection to expensive channels like 47, 58, 64.

Conclusion

- Results show that application of the principles can reduce the probability of interference
- Principles require:
  - Redesigning existing network management techniques to manage TVWSs.
  - Redesigning cost metrics in traffic engineering techniques to reflect WS availability under primary and secondary usage.

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