White Space Networking Status Update

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Joint work with Paula Boyd, Ranveer Chandra, Paul Garnett, Thomas Moscibroda, and MSR Interns (Rohan Murty, George Nychis, Xiaohui Wang, Yuan Yuan)
A Comprehensive Approach

- Work with regulators to nail down sensible specifications
- Help achieve world-wide harmonization
- Engage with silicon vendors & system integrators

Strategy & Policy

- Gather requirements, nail down specs
- Help create industry Standards
- Harden research code, develop & test on Windows

Product

- Identify & solve technical problems
- Build proof-of-concept prototypes
- Help policy teams with recommendations based on solid science
- Build community mindshare

Research

- Develop business models
- Identify Applications & Services
- Build alliances for greater connectivity

Business
Microsoft's Cognitive Networking Research Program (2005-...)

Version 1: Ad hoc networking in white spaces
- 700 MHz operation, TV sensing capability, one-to-one opportunistic networking, control-channel based MAC, varying channel width operation, multi-radio design, design analysis through simulations

Version 2: Infrastructure based networking (WhiteFi)
- White Space freq. operation, TV sensing Capability, limited microphone sensing, one-to-many opportunistic networking, Wi-Fi MAC, time-domain analysis (SIFT), demo-ed at Microsoft events (e.g. TechFest 2009)

Version 3: Campus-wide backbone network (WhiteFi with Geolocation)
- All of V2 + geolocation DB, Windows network stack improvements, bridging between Wi-Fi and WhiteFi, coverage in MS Shuttles
**FCC Experimental License** (Granted: July 6, 2009)

- Centered at (47.6442N, 122.1330W)
- Area of 1 square mile
- Perimeter of 4.37 miles
- WSD on 5-10 campus buildings
- Fixed BS operate at 2 W EIRP
- WSD inside shuttles at 63 mW

**Goal:** Deploy a white space network that provides corp. net access in Microsoft shuttles
Range Experiments

MSR’s Redmond Campus
Route taken by the shuttle (0.95 miles x 0.75 miles)

~4x range compared to 2.4 GHz (Wi-Fi) with same transmit power and receiver sensitivity

Raw received power at different Distances from the transmitter
Propagation Modeling

TV/MIC data (FCC CDBS, others)

Location (Latitude, Longitude)

Terrain Data (Globe, SRTM)

Shuttle Radar Topography Mission (SRTM)

Irregular Terrain Model (ITM) Longley-Rice (1968)
- 20 MHz to 20 GHz

The Egli model is formally expressed as:

\[ L = G_B G_M \left( \frac{h_B h_M}{d^2} \right)^2 \left( \frac{40}{f} \right)^2 \]

John Egli (1957)

Globe

The Global Land One-km Base Elevation Project

Joint Project between NASA and NIMA
Microsoft’s Database Service

TV/MIC data (FCC CDBS, others) → Propagation Modeling → Location (Latitude, Longitude) → Terrain Data (Globe, SRTM)

ASP.NET implementation using SOAP extensions

Checking for Accuracy

![Graph showing CDF of Fraction of white spaces lost (%)]

> 1000 miles
57 points

Downtown
Suburbs
Towns
Mountains
Valley
Forests
Highways

Fewer White Spaces lost with Longley-Rice + SRTM
WhiteSpaceFinder Announcement

http://whitespaces.msresearch.us

Dan Reed, announces availability of MS White Space DB for the research community

Features

- Configurable parameters
  - Propagation models: L-R, Free Space, Egli
  - Detection threshold (-114 dBm by default)

- Includes analysis of white space availability
- (forthcoming) Internationalization of TV tower data

<primary user[], signal strength[] at location>
Windows 7 Software Stack Improvements
First Urban White Space Network in the World

White Space Network Setup

Shuttle Deployment

WS Antenna on Bldg 42

WS Antenna on MS Shuttle

Data packets over UHF

Oct. 16, 2009

Microsoft Research
India
Oct. 22, 2009

China
Jan. 11, 2010

Brazil
( Feb. 2, 2010)

USA
Apr. 28, 2010

Office of Communications (UK)
June 10, 2010

Singapore
Apr. 8, 2010

Fisher Communications Inc.
Jan. 14, 2010

Industry Partners
Jan. 5, 2010

NSF Workshop on Future Wireless Communication Networks
US Research Funding
Nov. 9, 2009

Singapore
Apr. 8, 2010

China
Jan. 11, 2010

Brazil
( Feb. 2, 2010)

USA
Apr. 28, 2010

Office of Communications (UK)
June 10, 2010
WhiteFi and Broadcast TV

WhiteFi Antenna
TV Antennas

KOMO (Ch. 38)
KIRO (Ch. 39)
WhiteFi (Ch. 40)

WhiteFi transmitting at 40 mW
Co-existing with Microphones

Subcarrier Suppression setup

Microphone recording in Anechoic Chamber

Results

Original

Without SCS

With SCS
Looking Internationally (Europe)

Digital Conversion in Europe
- UK: End of 2012 – London region is the last to convert
- Finland – Complete
- Spain – Complete
- Germany – Complete
- France – End of 2011

United Kingdom (Ofcom)
- Geo-location OR sensing permitted.
- Consultations on enabling legislation and geolocation-database services expected this fall.

Other Countries
- European Commission’s CEPT SE43 group addressing technical issues.
- Finland’s Ministry of Transport and Communications has invited proposals for white space trials.
- Sweden’s National Post and Telecoms Agency is looking into enabling access to TV white spaces.
Looking Internationally (Others)

- **Singapore, IDA**
  - 7 April 2010, IDA announced the 'White Space Technology Information Package and Test Plan'
  - July 31, announced white space trials, named Cognitive Radio Venues ("CRAVE")
  - Investigating WS applications to show commercial value

- **Brazil, Ministry of Communications and Anatel**
  - Considering pilot projects, along the lines of Microsoft's WhiteFi Campus deployment

- **Japan, Ministry of Internal Affairs and Communications**
  - Considering proposals for white spaces trials. 103 proposals received.
**Goal:** Align industry towards a commercially feasible solution
- Develop usage models & marketing requirements
- Agree on a technical solution

**Participants:** Diverse group of network operators, chip vendors, device manufacturers, and others.

**Direction**

**IEEE 802.11af:** Task Group Formed
- Define the PHY
- Minimum MAC enhancements

**Wi-Fi Alliance:** TV White Spaces Marketing Task Group Formed
- Develop roadmap for a certification program
- MAC enhancements + database specifications
IEEE 802.22: Wireless Regional Area Network (WRAN) utilizing white spaces

- Point to multi-point operation (star topology)
- Clients are homes equipped with antennas (EIRP @ BS 4W - Range about 30 km)
- Distributed Sensing - CPEs share sensing information with BS

IEEE 802.11af Task Group:

- Want to adapt 802.11 for TV white space
- OFDM PHYs with 5-, 10- and 20-MHz channel widths to specify the basis for a system that the regulators can approve
- Working closely with WS Alliance

ECMA – 392 (CogNEA Group) Edition 1, December 2009

- New MAC and PHY for Operation in TV White Space
- BT, Cambridge Consultants, ETRI, Philips, Samsung Electro-Mechanics, MaxLinear, Georgia Electronic Design Center (GEDC) and Motorola

Global Standardization Status
Status of Industry Products

Hardware OEMs
Have some operational hardware


Potential Database Providers
Have filed with the FCC

- Google, Comsearch, Frequency Finder, KB Enterprises, Neustar, Spectrum Bridge, Telecordia, White Spaces DB, LLC.
Our Contributions to Standards

- Fast discovery mechanism
  - Enable clients to quickly discover an AP over all \(<channel, width>\) pairs

- Fast recovery mechanism on disconnection
  - Re-connects quickly on a new available channel upon sensing a primary user on existing channel

- Spectrum assignment algorithm
  - Enables AP to pick a channel that is free for all clients AND pick the best possible channel width
Open about identifying problems and sharing research results

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<th>Research Results &amp; Technology</th>
<th>Publication Venue</th>
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<td>1. Co-existence with wireless microphones</td>
<td>In-preparation</td>
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<td>2. Harmonious operation in heterogeneous environment</td>
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<td>3. Enhancements to the software stack</td>
<td>White paper (Tech Report)</td>
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<td>4. Fast discovery &amp; connectivity in ad hoc mode</td>
<td>In-preparation</td>
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<td>5. Secure collaborative sensing</td>
<td>IEEE DySPAN 2010</td>
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<td>6. Temporal analysis (SIFT) &amp; Spectrum assignment for AP Operation (MCham)</td>
<td>ACM SIGCOMM 2009 (Best paper)</td>
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<td>7. Dynamic channel width operation</td>
<td>ACM SIGCOMM 2008</td>
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<td>8. Load aware spectrum distribution</td>
<td>IEEE ICNP 2008</td>
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<tr>
<td>10. Control channel medium access protocol</td>
<td>IEEE DySPAN 2007</td>
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<td>11. Spectrum leasing</td>
<td>IEEE DySPAN 2006</td>
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<td>12. Separation of control &amp; data</td>
<td>IEEE BroadNets 2006</td>
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Our Contributions to the Community (2)

- Founding Member & Steering Committee Member *IEEE DySPAN* (since inception in 2005)
- Organizer of MSR Cognitive Wireless Networking Summit 2008, June 2008 (Snoqualmie, WA)
- Guest Editor, IEEE Journal on Selected Areas in Communications, Special Issue on Advances in Cognitive Radio Networking and Communications
- Tutorial on White Space Networking, Summer School in Networking, Bangalore, India (June 2009)
- General Co-Chair of IEEE *Workshop on Cognitive Wireless Communications and Networking*
- General Chair of IEEE DySPAN 2012 (*Committed*)
- Program Committee Member, IEEE DySPAN 2005, 2007, 2008, 2010
Our Collaborations with Universities

- **Chanel occupancy database design & related issues**
- **White space mesh networks for rural communities**
- **Harmonization between heterogeneous white space networks**
- **Security & privacy in white space networks**
- **Smart antennas, interference mitigate & internationalization**
- **The SORA Program**
Sharing Vision and Research Directions

Keynotes on WS Networking

- The 7th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing (EUC 2009), Vancouver, Canada, August 31, 2009
- The Fifth Euro-NGI Conference on Next Generation Internet Networks, July 2, 2009
- The Sixth International Conference on Wireless On-demand Network Systems and Services, Salt Lake City, Utah, February 2, 2009
- Workshop on Wireless Broadband Access for Communities and Rural Developing Regions, December 11, 2008
- Second IFIP International Symposium on Wireless Communications and Information Technology in Developing Countries, October 7, 2008
- First International Workshop on Cognitive Dynamic Systems and Their Applications, May 27, 2008
- Intel’s Communications Internal Senior Leadership Conference (ICOMM 2008), April 9, 2008
- The Third International Conference on Communication System Software and Middleware (COMSWARE 2008), January 8, 2008
- The Ninth International Conference on Distributed Computing and Networking (ICDCN), January 6, 2008
Over 50 articles (that we have tracked)
The project, dubbed “White Fi,” is one of the most advanced in the field, both dealing with the hardware side but also creating the networking protocols to handle the specific challenges.

Softpedia (Aug. 19, 2009)

Microsoft researchers have taken a step closer to finally turning unused analogue TV spectrum, known as “white spaces”, into unlicensed spectrum that can be used to deliver new wireless broadband service

CNET.COM (Aug. 19, 2009)

The Microsoft Research team has addressed many of these issues with WhiteFi. —that early promise of "WiFi on steroids" might turn out to be surprisingly accurate, after all.

Nate Anderson, Ars technica, August 27, 2009

The actual engineering requirements to accomplish this frequency switch are non-trivial. Microsoft Research’s "KNOWS" project has taken up the task and made some pretty remarkable advances.

Scott Merrill, Crunchgear, August 28, 2009

One of the best prospects for the future is the opening up of “white spaces,” unused parts of the spectrum. One of the most advanced research projects......

Lucian Parfeni, Web News, August 18, 2009

Microsoft researchers have taken the next step toward turning old UHF analog TV spectrum into rural wireless broadband networks that would operate like Wi-Fi but with greater range.

Simon Juran, GigaOm, August 18, 2009-09-02
To Succeed

Multimodal radios integrated into devices
Geo-location databases available
Software Support

Industry standards complete
World-wide harmonization progresses

FCC finalizes rules
2-3 SFF hardware devices available

Wi-Fi + WhiteFi
Thanks