Better Broadband for All

The Future of White Spaces & TV Band Devices (TVBD)
The **global village** is real... but not fully inclusive

- **2 billion** internet connected consumers
- **555 million** wired broadband subscribers
- **943 million** wireless broadband subscribers
- **5 billion** cell phones

But 4.8B are not connected
But 3.9B could not afford
But 2.6B could not afford
Still some 2.2B have-not's

*2010 Estimates: ITU World Telecommunications/ ICT Indicators database*
“Traffic from wireless devices will exceed traffic from wired devices by 2016. In 2016, wired devices will account for 39 percent of IP traffic, while Wi-Fi and mobile devices will account for 61 percent of IP traffic. In 2011, wired devices accounted for the majority of IP traffic at 55 percent.”
Dynamic Spectrum Access (DSA)

**Query** the availability database

**Transmit** in “available frequencies”

**Detect** if primary user appears

**Move** to new frequencies

**Adapt** bandwidth and power levels

http://whitespaces.msresearch.us
TV white spaces: “super Wi-Fi” for digital inclusion

Broadcast TV channels are “allotted” to serve the local area
- Other licensed and unlicensed services also operate in the TV bands
- “White spaces” are unused channels at a given location

Spectrum below 1 GHz is ideal “real estate”
- Propagation characteristics mean easier coverage for large areas
- Simplifies broadband delivery to unserved/underserved communities
- Supports M2M communication

http://whitespace.i2r.a-star.edu.sg

Asia Development Bank Demo (Manila)

Cambridge, UK Trial Report
Key Conclusions

Devices can successfully co-exist with broadcasters and other licensees

Could be used for a variety of applications

The trial participation and attention evidences growing industry interest and readiness

This and other trial results will aid regulatory decisions around the world

Cambridge White Space Consortium Trial
Singapore White Spaces Pilot Group

http://whitespace.i2r.a-star.edu.sg
Formulation of Regulatory Framework for White Space Technology (New)
In 2010,IDA had developed a preliminary regulatory framework for trial purposes. With the escalating interest from the industry on white space technology, IDA will be formulating the appropriate regulatory framework to facilitate the adoption of white space technology in Singapore.

As part of the process to finalise the regulations for white space technology, IDA will be initiating a consultation to seek views and comments from the industry and members of the public by 2012. In this consultation, IDA will also be consulting on the approach and requirements to implement the geolocation database method. For more information, please contact Mr Henry Foo (henry_foo@ida.gov.sg) or Ms Michelle Ho (michelle_xm_ho@ida.gov.sg).

Industry Readiness
IDA had organised several industry engagement forums with the intent to generate discussions on the regulations that would facilitate white space technology adoption and to explore possible collaborative efforts amongst the industry.

In April 2012, several organisations (I2R, StarHub and Microsoft) had confirmed that they would lead the formation of a "Singapore White Spaces Pilot Group" to leverage on the CRAVE trials to establish Singapore as an innovation zone for white space technology. The CRAVE trials were designed as a proof-of-concept, to validate that TV Band Devices (TVBD) could be deployed without causing any impact on traditional broadcast television. With the Singapore White Spaces Pilot Group, the group is to undertake commercial pilot deployments to explore how white space technology could supplement the existing wireless infrastructures and develop innovative consumer and business applications.

The Pilot Group would look into ways to foster close collaboration between its members to promote Singapore as a test-bed for White Spaces pilot trials with a view to maximise the value of White Spaces to end users. IDA encourages participation from both local and international organisations. For more information, interested parties may contact the pilot group at whitespace@i2r.a-star.edu.sg.
TV Band White Spaces trials & demos
**Industry readiness**

**First Certified Databases**
Spectrum Bridge & Telcordia

**First Certified Radios**
Adaptrum & KTS

**First Commercial Network**
Wilmington, NC, USA

**Volume Devices**
Based on proprietary implementations as early as YE2012

**Mass Market Availability**
Standards-based (802.11af/ac) Wi-Fi devices from 2014

---

**2012**
IEEE 801.11af/ac draft spec first letter ballot approved in 3Q CY2012

**2013**
The IEEE 801.11af/ac published spec in CY2013

**2014**

---

**PROGRESSING**
A Wi-Fi Alliance certification program
Standards efforts focused on machine-to-machine and rural broadband
By end of 2012, A+B+C becomes D

A = prototype TVWS radio client (FPGA-based)
B = Laptop running configuration software
C = Off-shelf 802.11n Wi-Fi AP (D-Link)
D = Production TVWS Radio Client from Adaptrum

Size comparison of first-gen commercial TVWS Radio Client (bottom, from Adaptrum) and a off-shelf 802.11n Wi-Fi Access Point (top, from D-Link)

As the industry and market develop, TVWS radio will become even smaller and eventually become built-in in mobile devices and sensors.
Example: Neul Product Roadmap 2011-2013

**Prove Technology**

**Network operators**
- **NeulNET 1 Basestation**
  - Installed now on three continents

**Network users**
- **NeulNET 1 Terminal**
  - Powering the largest white space radio trial in the world

**WISPs**
- **horizon**
  - 16Mbps broadband
  - Up to 10km range
  - No line of sight required

**Build the ecosystem**

**Network operators**
- **Cloudbase 1**
  - Automatic network planning
  - Online data aggregation
  - Discreet (50cm) omni antennas

**Network users**
- **Neultrino Dev Kit**
  - Link any device to Neul’s Network
  - Simple PHP/JavaScript coding

**WISPs**
- **_horizon v2_**
  - >24Mbps broadband
  - US, UK and worldwide markets

**Roll out International Networks**

**Network operators**
- **Cloudbase 2**
  - Macro and femtocell variants
  - Multi channel operation
  - High gain, multi element antennas

**Network users**
- **Iceni Custom ASIC**
  - Interface identical to Neultrino
  - Multi year battery life
  - <$5 chip cost

2011 | H1 2012 | H2 2012 | 2013
Greater spectrum sharing opportunities should be pursued

Database-enabled sharing will evolve from simple look up tables to real time arbiters of spectrum access and usage (e.g., accounting for the cost of interference, filtering capabilities, power limits, geolocation and mobility, prioritization, and duration).

<table>
<thead>
<tr>
<th>Today</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who I am?</td>
<td>My willingness to pay/be paid for interference?</td>
</tr>
<tr>
<td>What I am?</td>
<td>My out-of-band emission mask?</td>
</tr>
<tr>
<td>Where I am?</td>
<td>My spectrum tuning range?</td>
</tr>
<tr>
<td></td>
<td>Am I moving &amp; where am I going?</td>
</tr>
<tr>
<td></td>
<td>When I will get there?</td>
</tr>
<tr>
<td></td>
<td>My desired power output?</td>
</tr>
<tr>
<td></td>
<td>My geolocation accuracy?</td>
</tr>
<tr>
<td></td>
<td>My desired quality of service?</td>
</tr>
<tr>
<td></td>
<td>My knowledge of nearby transmissions (sensing)?</td>
</tr>
<tr>
<td></td>
<td>How long I will be there?</td>
</tr>
</tbody>
</table>

Additional variables will be considered
A growing White Space technology ecosystem...

<table>
<thead>
<tr>
<th>Database Providers (United States)</th>
<th>Hardware Providers (today)</th>
<th>Other Potential Players (growing interest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comsearch</td>
<td>6Harmonics</td>
<td>Alcatel-Lucent</td>
</tr>
<tr>
<td>Frequency Finder, Inc.</td>
<td>Adaptrum</td>
<td>Atheros (Qualcomm)</td>
</tr>
<tr>
<td>Google</td>
<td>Airspan</td>
<td>ARM</td>
</tr>
<tr>
<td>Key Bridge</td>
<td>Carlson</td>
<td>Broadcom</td>
</tr>
<tr>
<td>LS Telcom AG</td>
<td>KTS</td>
<td>CSR</td>
</tr>
<tr>
<td>Microsoft</td>
<td>Lyrtech</td>
<td>Dell</td>
</tr>
<tr>
<td>Neustar</td>
<td>MLED</td>
<td>Hewlett Packard</td>
</tr>
<tr>
<td>Spectrum Bridge (Approved)</td>
<td>Neul</td>
<td>Intel</td>
</tr>
<tr>
<td>Telcordia Technologies (Ericsson)</td>
<td>Shared Spectrum</td>
<td>LG Electronics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marvell Semiconductor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nokia, Inc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Research in Motion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Samsung . . .</td>
</tr>
</tbody>
</table>
Wi-Fi - its impact after 10 years

<table>
<thead>
<tr>
<th>Year</th>
<th>Wi-Fi Homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>alliance founded</td>
</tr>
<tr>
<td>2012</td>
<td>439M homes using a Wi-Fi router</td>
</tr>
<tr>
<td>2016</td>
<td>800M homes projected to deploy Wi-Fi</td>
</tr>
</tbody>
</table>

- Currently 25% of all households worldwide use Wi-Fi
- 85% penetration in homes with fixed broadband
- By making fixed broadband more valuable, Wi-Fi:
  - generates $46 to $87 billion of consumer surplus each year.
  - maintains 49 to 101 million fixed broadband subscriptions globally.
Traffic carried by different channels for different types of device (PB per month) (global estimates)

- **Smartphones & Tablets**
  - Cellular: 236
  - Wi-Fi: 105

- **Traditional PCs & Laptops**
  - Cellular: 8,949
  - Wi-Fi: 350

The aggregate spectral efficiency of the 2.4GHz band is at least 30 times greater than the overall efficiency of any cellular band.
Number of extra sites needed worldwide absent Wi-Fi

This year 140,000 to 450,000 extra sites would be needed (an additional 8 – 20% sites worldwide)

At a cost of $30 - $90 billion (very conservative)

As traffic levels are rapidly rising this number could escalate substantially in the coming 5 years
Where we are going...

1. **R&D**
   - Basic research
   - Lab trials

2. **Regulatory Trials**
   - Technology feasibility
   - Prototype devices
   - Field test & measurements

3. **Commercial Pilots**
   - Device & database certification
   - Use case experimentation
   - Vertical industries

4. **Commercial Deployments**
   - Volume devices
   - Rural broadband
   - Campus networking
   - Smaller form factors
   - Standards-based devices
Singapore: An Intelligent Nation, A Global *Smart* City

Smart Radio, Smarter City