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IEEE 802.22 WG on Cognitive Radio Based Wireless Regional Area Networks

IEEE 802.22 WG is the recipient of the IEEE SA Emerging Technology Award

IEEE 802.22 Standard – Wireless Regional Area Networks: Cognitive Radio based Access in TVWS: Published in July 2011

802.22.1 – Std for Enhanced Interference Protection using beaconing: Published in Nov. 2010
802.22.1a – Advanced Beaconing

802.22.2 – Std for Recommended Practice for Deployment of 802.22 Systems: Expected completion - Dec 2012


802.22b Enhancement for Broadband Services and Monitoring Applications

www.ieee802.org/22
Providing cost-effective RURAL broadband is a significant opportunity

• Today, 73% of the people in the world (5.1 Billion people) do not have access to internet. More than half the population in the world live in rural areas with hardly any access to broadband.

• It is expensive to lay fiber / cable in rural and remote areas with low population density.

• Wireless broadband powered by license exempt or lightly licensed spectrum can help.

• Backhaul / backbone internet access for rural areas is very expensive (50% of the cost). Hence long distance communications technologies are very useful as well.

• This has created a DIGITAL DIVIDE / OPPORTUNITY
Relative Cost and Complexity of Various Technologies for Rural and Regional Area Broadband Service

Population density (per km²)

Relative Complexity and Cost (%)

- **Mobile broadband**
- **Satellite**
- **ADSL**
- **Cable modem**
- **Optical fiber**

Population per density bin (Million)

- **Fixed broadband at lower frequency**

FCC Definition of ’Rural’

4 W Base Station
100 W Base Station
4 W User terminal

Satellite
WRAN
ADSL, Cable, ISM and UNII Wireless and Optical Fiber

www.crc.ca

Courtesy: Gerald Chouinard: gerald.chouinard@crc.ca

IEEE 802.22: WhiteSpace Enabled Rural Broadband to Cognitive M2M
Spectrum: Optimum frequency range for large area Non-Line-of-sight Broadband Access

Optimum frequency range for large area Non Line of Sight (NLoS) operation falls within the TV Band spectrum.

Courtesy: Gerald Chouinard: gerald.chouinard@crc.ca
IEEE 802.22 Cognitive Radio based Wireless Regional Area Networks for Broadband over Long Distances

Southern Ontario Canada

Many Channels Available in Rural Areas

Rural Areas

Urban Areas

TV Channel Availability for Broadband

Source: Gerald Chouinard, CRC and Industry Canada

• VHF / UHF bands traditionally have highly favorable propagation characteristics. Penetrating through foliage and structures, they reach far and wide

• IEEE 802.22 Cognitive radio based Wireless Regional Area Networks provide broadband solutions for large areas and long range
IEEE 802.22 (Wi-FAR) WhiteSpace Applications

Before

Now

Rural Broadband and Backhaul
IEEE 802.22 WhiteSpace Applications

Tripple play

Cellular offload

Critical infrastructure monitoring

Border protection

Emergency broadband infrastructure

Environment monitoring
IEEE 802.22 WhiteSpace Applications

Archipelago and marine broadband service.
Servicing oil rigs

Remote medical service

C. W. Pyo, A. Mody et al. Use Cases for IEEE 802.22 (Wi-FAR(TM)) Smart Grid and Critical Infrastructure Monitoring

IEEE 802.22 used for Backhaul
TV Channel Modeling – IEEE 802.22 (Wi-FAR™ supports large multi-path delay absorption)

- Long distance communication in the VHF/ UHF Band needs to deal with severe multipath and delay spread conditions
- Frequency selective with large excessive delay
  - Excessive delay (measurements in US, Germany, France*)
    - Longest delay: >60 μsec
    - 85% test location with delay spread ~35 μsec
  - Low frequency (54~862 MHz)
  - Long range (up to 100 km)
  - Slow fading
    - Small Doppler spread
    - (up to a few Hz)

* WRAN Channel Modeling, IEEE802.22-05/0055r7, Aug 05
Information provided by TV Broadcasters
IEEE 802.22 (Wi-FAR™) – Cognitive Radio Capability

Channel Set Management

Subscriber Station Registration and Tracking

Policies

Geo-location

Incumbent Database Service

Incumbent Database

Spectrum Manager

Self Co-existence

Spectrum Sensing

Channel Set Management

Subscriber Station Registration and Tracking

Incumbent Database Service

Incumbent Database

Spectrum Manager

Self Co-existence

Spectrum Sensing
IEEE 802.22 (Wi-FAR™) – Frame Structure

- Time Division Duplex (TDD) frame structure Super-frame: 160 ms, Frame: 10 ms
- OFDM/OFDMA Transport
- QPSK up to 64 QAM modulation supported
- Convolutional codes and other advanced codes supported
- Throughput: 22-29 Mbps per TV channel WITH NO MIMO. MIMO and channel bonding increase the throughput
- Spectral Efficiency: 0.624 – 3.12 bits/sec/Hz
- Distance: 10 km minimum. Upto 30 km and even 100 kms
- MAC supports Cognitive Radio features
- Self-coexistence Window (SCW): BS commands subscribers to send out CBPs for 802.22

IEEE 802.22 prototypes are being announced
Cognitive Machine to Machine (CM2M)

50 Billion machine to machine devices will be deployed by 2020
IEEE 802.22.1 Advanced Beaconing: Radar and Commercial Comms Spectrum Sharing in 3550-3650 bands

• **How will it Work:** The designed beacon will contain *Peace Time* temporal patterns of the radars which when combined with some universal time clock such as GPS can help commercial communications systems to use the empty time slots for their operation.

• During *Emergency Situations*, the beacon will send Urgent Co-existence request, to ask all the commercial systems to shut down immediately. Security features for such beacons are very important. IEEE Std, 802.22.1-2010 has incorporated many such security mechanisms that may be applied to the 3550-3650 band relatively readily.

**Current IEEE 802.22.1 beacon protocol contains many security Features already**

**This approach can open as much as 600 MHz of Spectrum in the S-Band**
IEEE 802.22 (Wi-FAR™) Unique Proposition

- **First** IEEE Standard for operation in Television Whitespaces
- **First** IEEE Standard that is specifically designed for rural and regional area broadband access aimed at removing the digital divide
- **First** IEEE Standard that has all the Cognitive Radio features
- IEEE 802.22 (Wi-FAR™) provides Broadband Wireless Access to Regional, Rural and Remote Areas Under Line of Sight (LoS) and Non Line of Sight (NLoS) Conditions using Cognitive Radio Technology (*without causing harmful interference to the incumbents*).
- Cognitive Radio technology added to a simple and optimized OFDMA waveform (similar to the OFDMA technology used in other broadband standards)
- Each IEEE 802.22 (Wi-FAR™) cell can provide 22 to 29 Mbps per TV Channel and provide support for 512 devices.
- Enhancements to the IEEE 802.22 are currently under way in several amendments.
References

- United Kingdom Office of Communications (OfCom) - [www.ofcom.org.uk](http://www.ofcom.org.uk)
- UK OfCom presentation on Geolocation issues - [https://mentor.ieee.org/802.18/dcn/10/18-10-0042-00-0000-ofcom-presentation-on-gelocation-issues.pptx](https://mentor.ieee.org/802.18/dcn/10/18-10-0042-00-0000-ofcom-presentation-on-gelocation-issues.pptx)
- UK OfCom update on TVWS issues [https://mentor.ieee.org/802.18/dcn/09/18-09-0118-00-0000-ofcom-update-on-the-tv-white-space-issues.ppt](https://mentor.ieee.org/802.18/dcn/09/18-09-0118-00-0000-ofcom-update-on-the-tv-white-space-issues.ppt)
Backups
IEEE 802.22 (Wi-FAR™) provides three mechanisms for incumbent protection:

- Sensing
- Database Access
- Specially Designed Beacon

Security sub-layers are introduced to protect non-cognitive as well as cognitive functions.

Cognitive Plane is used to control the Cognitive Radio Operation. Security Sublayer 2 is introduced for protection against Cognitive Threats.