IEEE 802.22 Basics

Wireless standards

Software Defined Radio

Cognitive Radio

802.22 coverage

Dynamic Spectrum usage

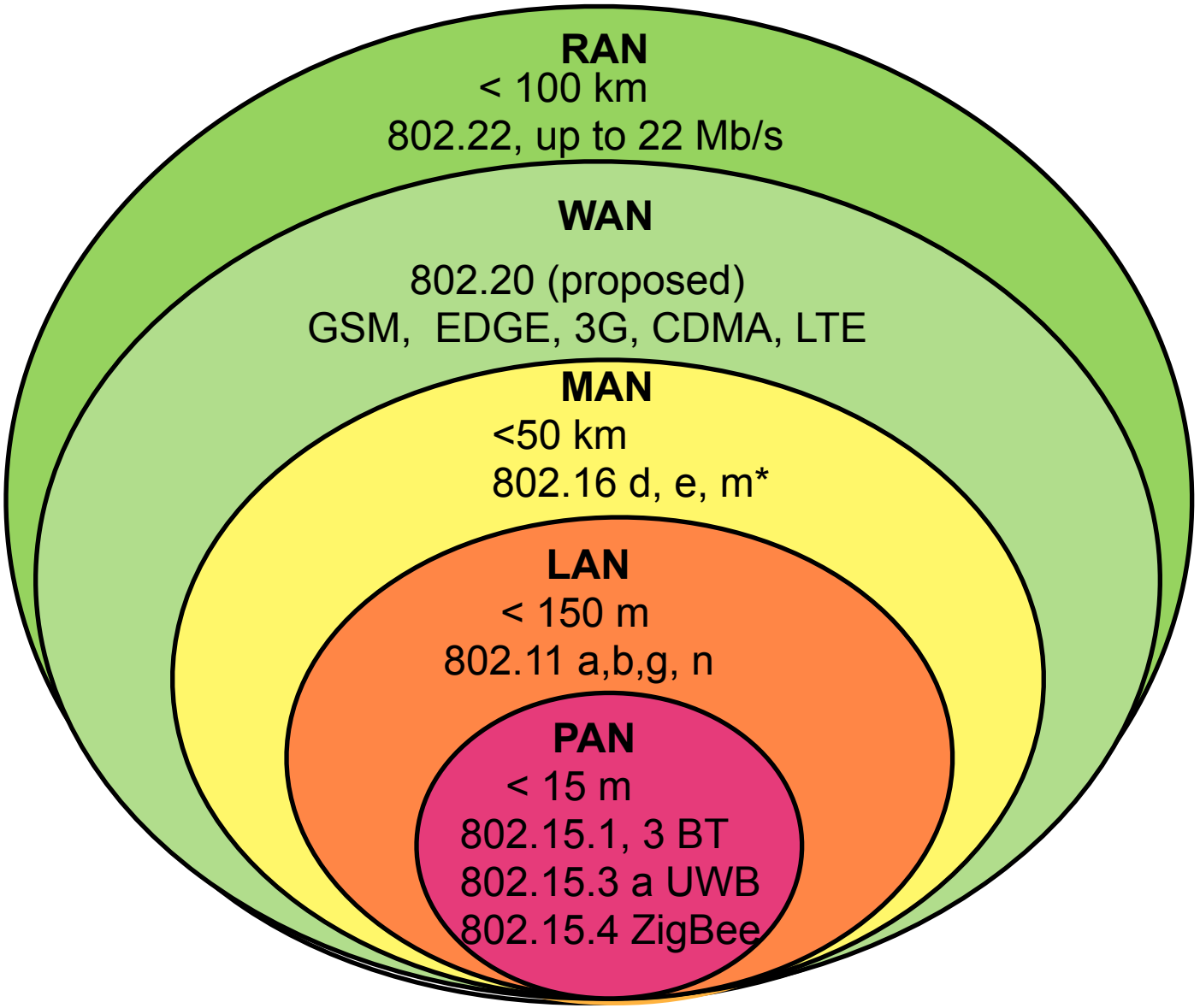
Regulatory Issues

Some regional Initiatives

Examples of currently available equipment

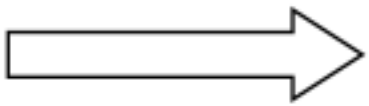
Ermanno Pietrosemoli, Trieste, 2010

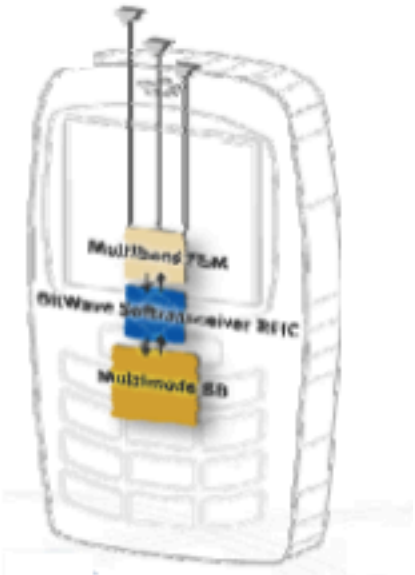
Wireless Standards



Software Defined Radio (SDR)

- Each radio interface is implemented through Integrated Circuits conceived for a set of specific functions
- Wireless device characteristics are fixed





Software Radio approach:

- the wireless terminal is reconfigurable via software
- It can be easily updated to ne or later versions of the air interface and allows multiple interfaces to be supported

ITU approved SDR definition

Software-defined radio is a radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard."

Source: Report ITU-R SM.2152.

ITU approved Cognitive Radio definition

"Cognitive radio system is a radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained."

Source: Report ITU-R SM.2152.

Capabilities of Cognitive Radio

Spectrum Sensing

- Spectrum Sharing (by agreement or compulsory)

Location Identification by the Mobile

Network/System/Service Discovery

Frequency Agility

Dynamic Frequency Selection

- Avoid co-channel operation

Adaptive Modulation/Coding

Transmit Power control

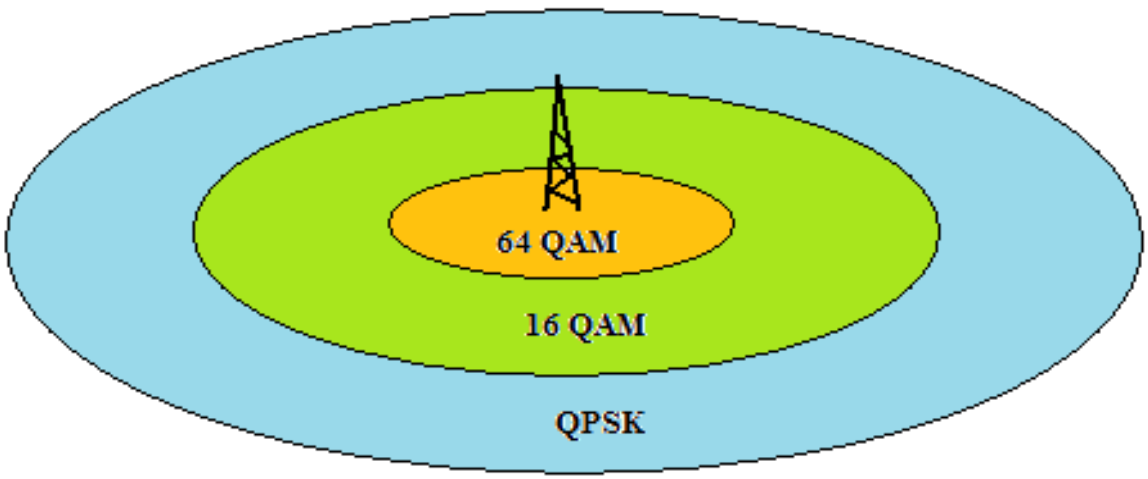
Dynamic System/Network Access

Mobility and Connection Management

Security Management

802.22 Coverage

- BS can reach a CPE up to 100 km away at 22 Mb/s.
- From the CPE the range is 33 km if the EIRP is 4W
- TV frequency bands from 54 to 862 MHz
- Ideally suited for rural areas
- Modulation: 64 QAM, 16 QAM, QPSK, distance dependent



1	Frequency Range	54 MHz to 862 MHz
	Channel Bandwidth	6, 7, 8 MHz
	Data Rate	4.54 to 22.69 Mbps
	Spectrum Efficiency	0.76 to 3.78 bits/(s*Hz)
	Modulation	QPSK, 16-QAM, 64-QAM
	EIRP (Tx)	4 W max BS or CPE Local regulator dependent
	Media ACCES	OFDMA
	Cyclic Prefix	1/4, 1/8, 1/16, 1/32
	Duplexing Technique	TDD (Time Division Duplex)
	Number of CPE supported by BS	512

With 12 simultaneous users the minimum data rate for CPE would be 1.5 Mbps downlink and 384 kbps uplink

Regulatory Issues

On September 23, 2010 the FCC released a Memorandum Opinion and Order for the use of white space for unlicensed wireless devices. The new rules removed mandatory sensing requirements which greatly facilitates the use of the spectrum with geolocation based channel allocation. The final rules adopt a proposal from the White Spaces Coalition for very strict emission rules that prevent the direct use of IEEE 802.11 (Wi-Fi) in a single channel effectively making the new spectrum unusable for Wi-Fi technologies

Regulatory Issues

On November 4, 2008, the FCC voted 5-0 to approve the unlicensed use of white space devices must both consult an FCC-mandated database to determine which channels are available for use at a given location, and must also monitor the spectrum locally once every minute to confirm that no legacy wireless microphones, video assist devices or other emitters are present. If a single transmission is detected, the device may not transmit anywhere within the entire 6 MHz channel in which the transmission was received

Regulatory Issues

- Target performance

Items	Requirements
Service Coverage	Typical 33 km ~ Max 100 km
Active subscribers	Minimum 12 users
Minimum Peak Throughput at Cell Edge	Forward link : 1.5 Mbps / subscriber (18 Mbps in total) Reverse link : 384 kbps / subscriber
Spectral Efficiency	Minimum : 0.5 bps/Hz Typical : 3 bps/Hz ➔ 18 Mbps for 6 MHz BW
Service Availability	50% of locations & 99.9% of time

Example of Television channels allocation in Ecuador Nominal Bandwidth: 6 MHz

Channel	Lower f MHz	Center f MHz	Upper f MHz
2	54	57	60
3	60	63	66
4	66	69	72
5	76	79	82
6	82	85	88
7	174	177	180
8	180	183	186
9	186	189	192
10	192	195	198
11	198	201	204
12	204	207	210
13	210	213	216
21	512	515	518
22	518	521	524
23	524	527	530
24	530	533	536
25	536	539	542
26	542	545	548
27	548	551	554
28	554	557	560
29	560	563	566
30	566	569	572
31	572	575	578
32	578	581	584
33	584	587	590
34	590	593	596
35	596	599	602
36	602	605	608
38	614	617	620
39	620	623	626
40	626	629	632
41	632	635	638
42	638	641	644
43	644	647	650
44	650	653	656
45	656	659	662
46	662	665	668
47	668	671	674
48	674	677	680
49	680	683	686

White Spaces

Protection of TV broadcasting

Protection of Part 74 wireless microphones

802.22.1 wireless microphone beacon

Quiet periods for sensing

Self-coexistence among WRAN systems

Main features of IEEE 802.22

Spectrum Reuse, White Spaces, combatting the spectrum crunch

Lower frequencies, greater range

thanks to less attenuation by walls, greater diffraction and lower free space loss

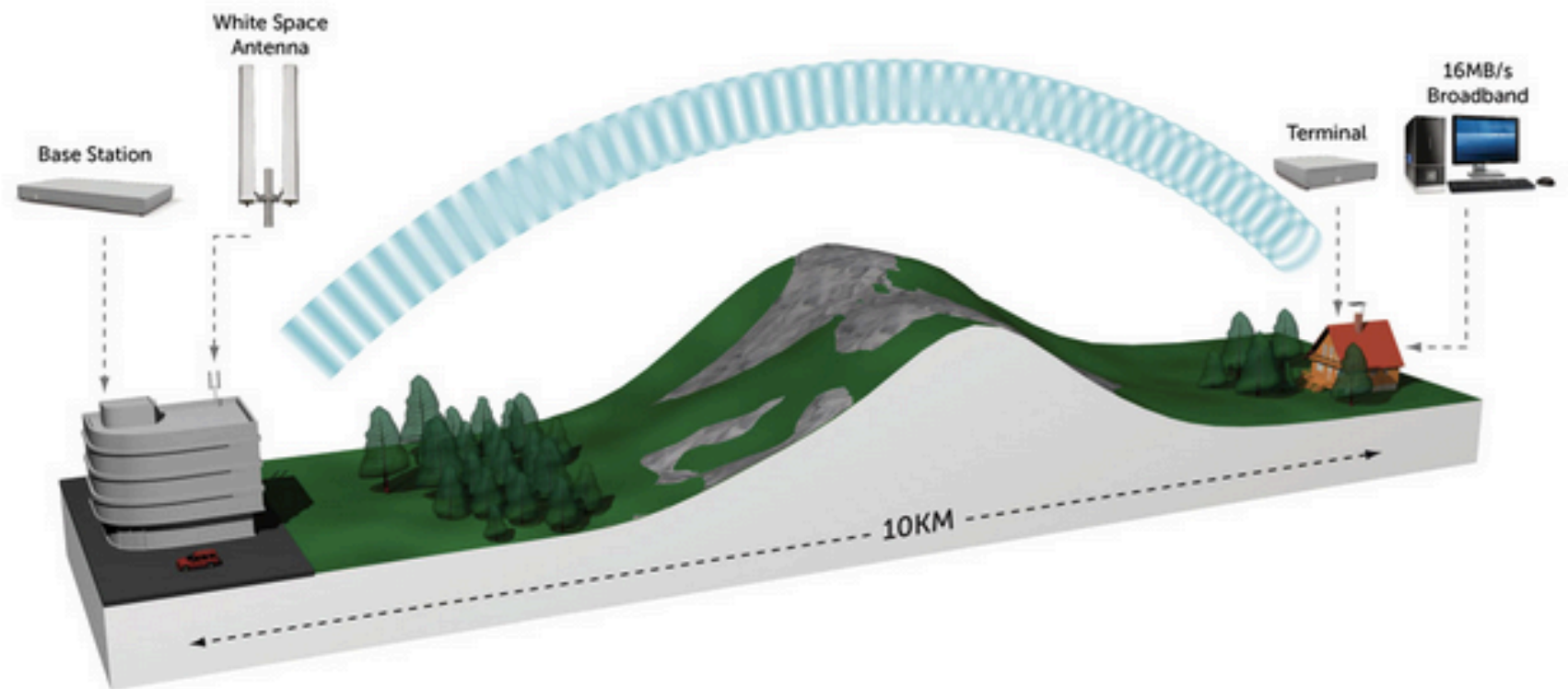
Lower frequencies can result in lower energy consumption as compared with WiFi or ZigBee

Non Line Of Sight propagation

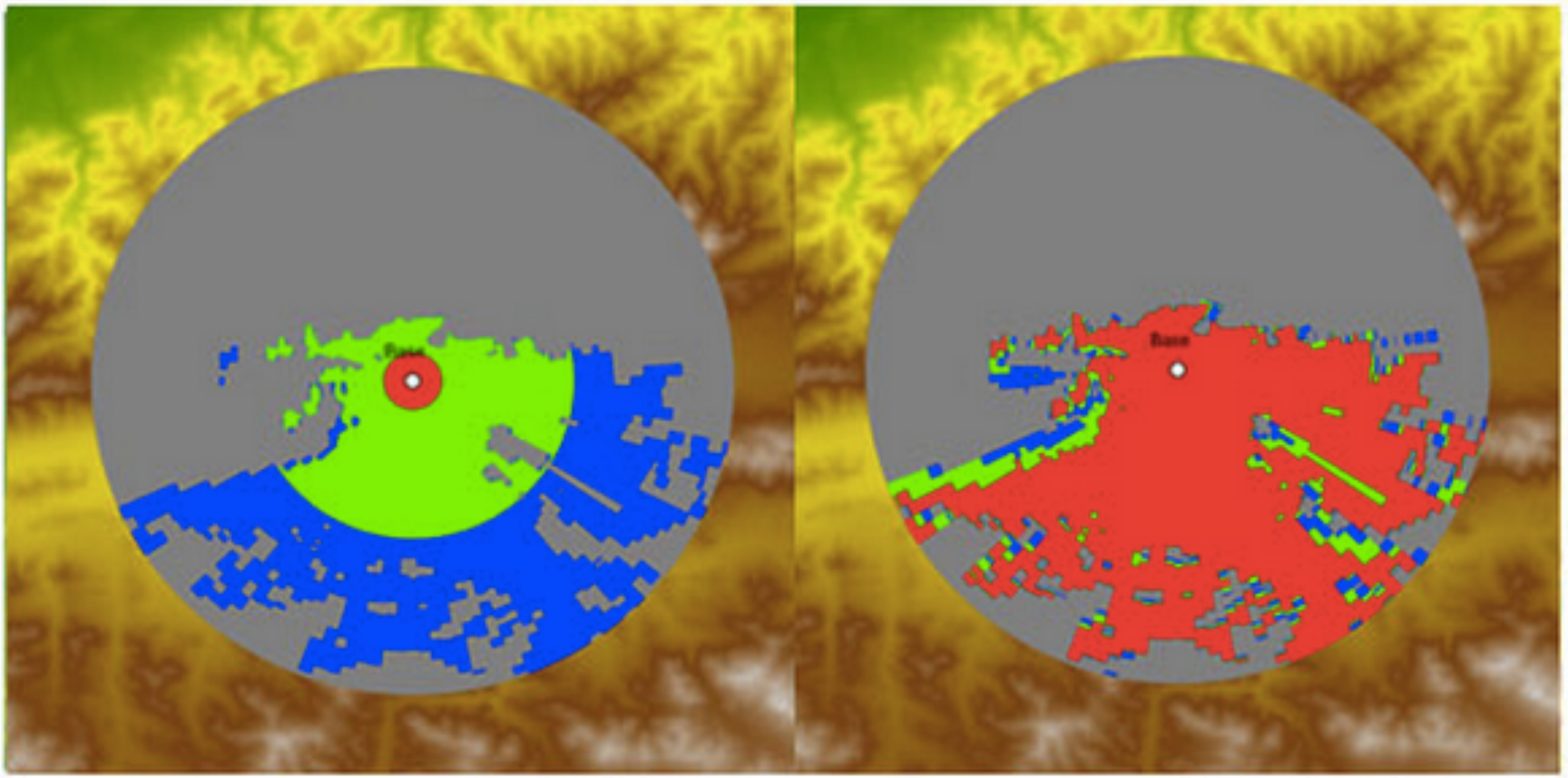
High spectrum efficiency

Use of software defined radio (SDR) as a stepping stone towards Cognitive Radio (CR)

Greater range because of lower frequency



Area of Coverage Comparison
40 km radius



Coverage with 5 GHz

Coverage with 470 MHz

http://www.carlsonwireless.com/products/ruralconnect-ip.html

Data Base Query

In the U.S. radios authorized and operating as white space devices (**TVBDs**) are required to provide their geographic location, by means of a secure Internet connection, to a TV band database system authorized by the Commission. The database will return a list of authorized channels available for operation by the TVBD for its reported location.

Base Station

To use the system, a device first supplies its location to the database, using a frequency that is known to be permanently free in that area
The system then tells the device which other chunks of spectrum are available to use at that time

802.22 parameters

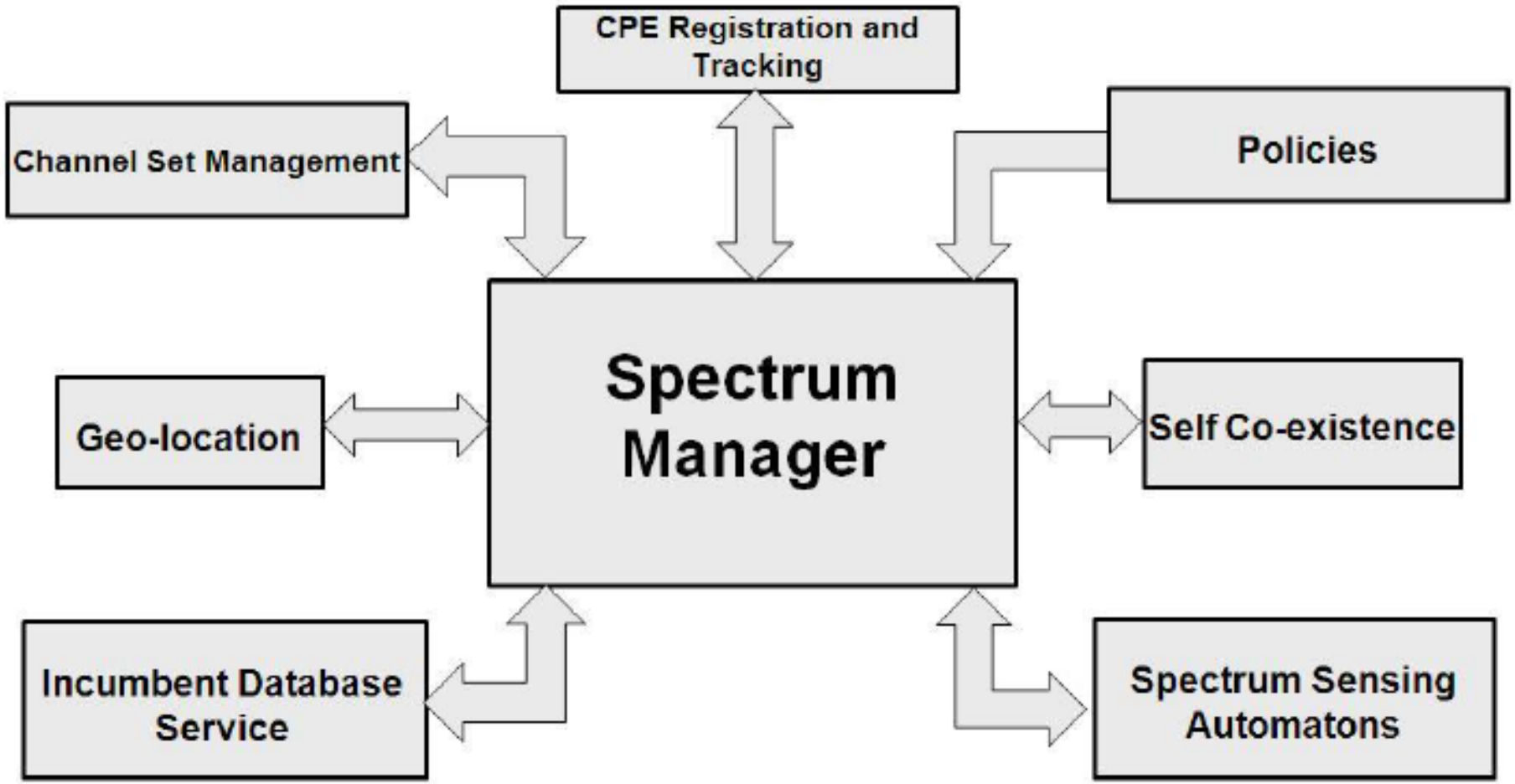
Channel Bandwidth	6, 7, 8 MHz
Data Rate	4.54 to 22.69 Mb/s
Spectrum Efficiency	0.76 to 3.78 ((bit/s)/Hz)
Modulation	QPSK, 16-QAM, 64-QAM
EIRP	Local reg. dependent, typ. 4 W
Media ACCES	OFDMA
Cyclic Prefix	1/4, 1/8, 1/16, 1/32
Duplexing Technique	TDD (Time Division Duplex)
Number of CPE supported by BS	512

With 12 simultaneous users the minimum data rate per CPE would be 1.5 Mb/s downlink and 384 kb/s uplink

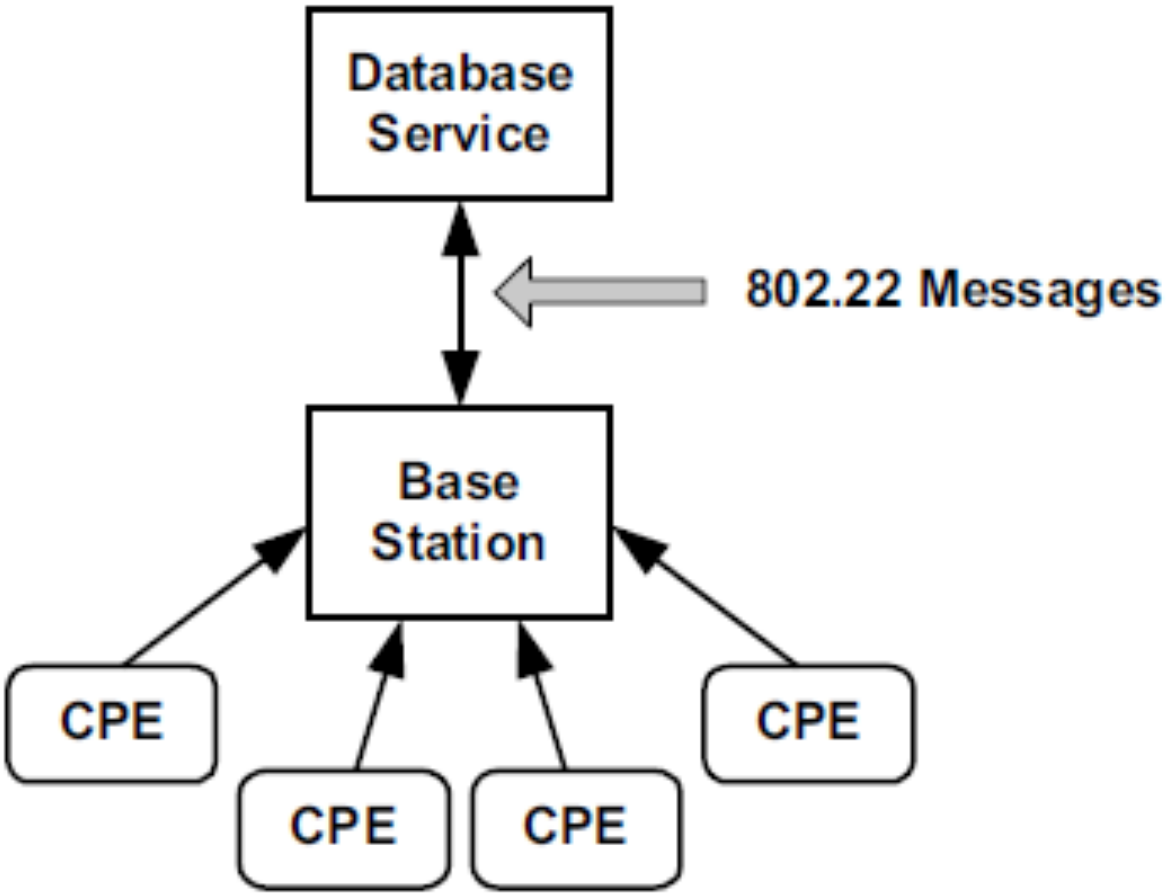
Physical Layer (PHY)

- OFDMA
- WRAN typical propagation time from 25 μs to 50 μs
- 40 μs cyclic prefix preamble
- Flexible modulation and coding schemes (QPSK, 16QAM and 64QAM)
- 48 subchannels

Spectrum Management

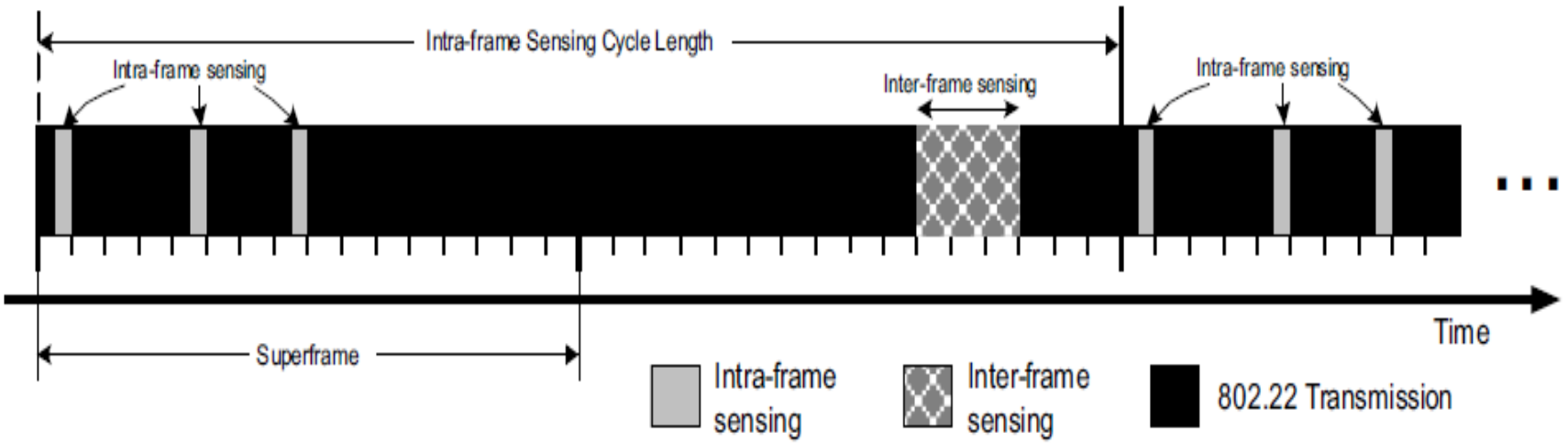


Database Service



Structure of the IEEE 802.22 WRAN access to the database service

Channel Sensing



Notice that there are several quiet periods devoted to sensing the channel to prevent collisions.
The sensing is divided into two processes, one coarse and fast and another more accurate that can take up to a 158 ms for superframes.
Sensing is done both at the CPE and the Base Station and results are consolidated at the BS.

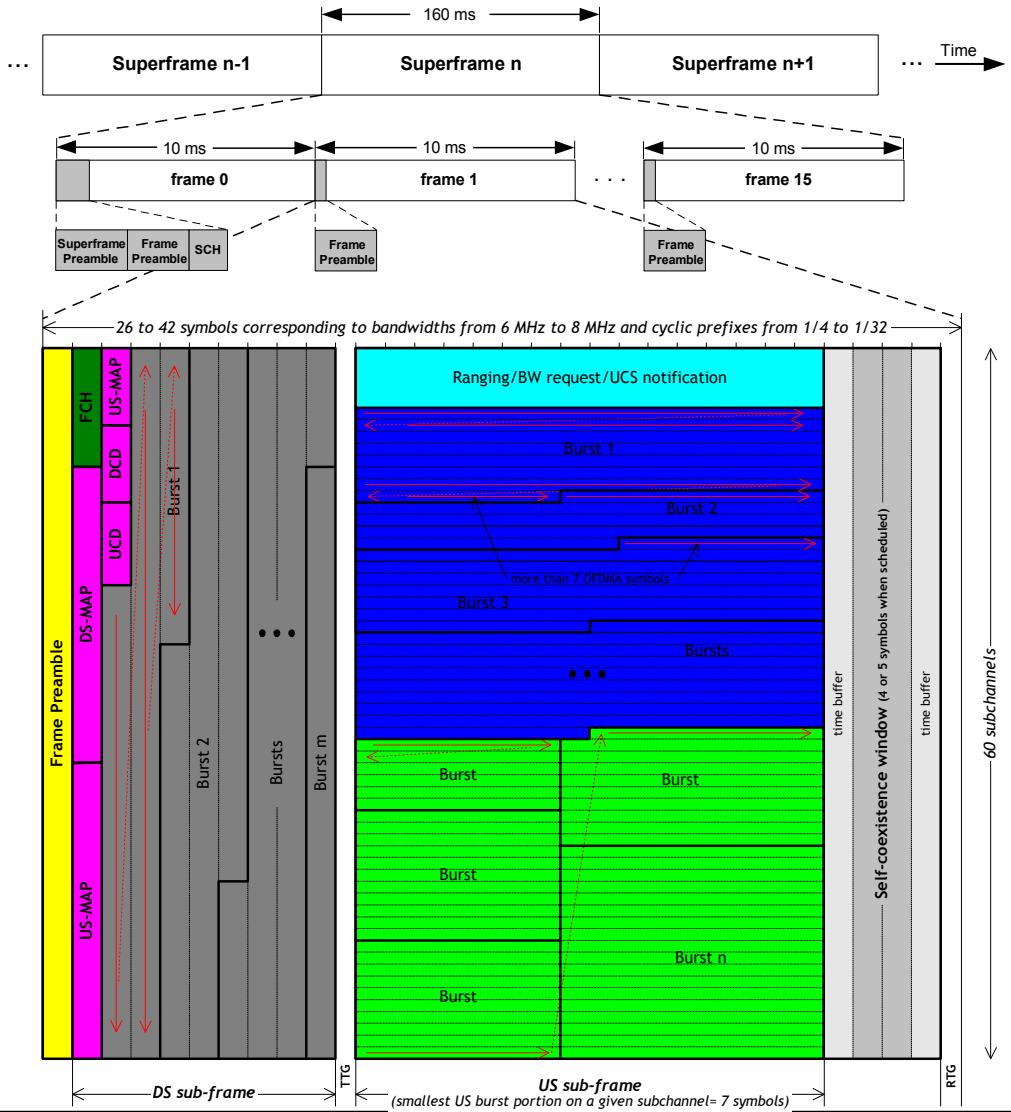
Frame Structure

802.22 Frame Structure

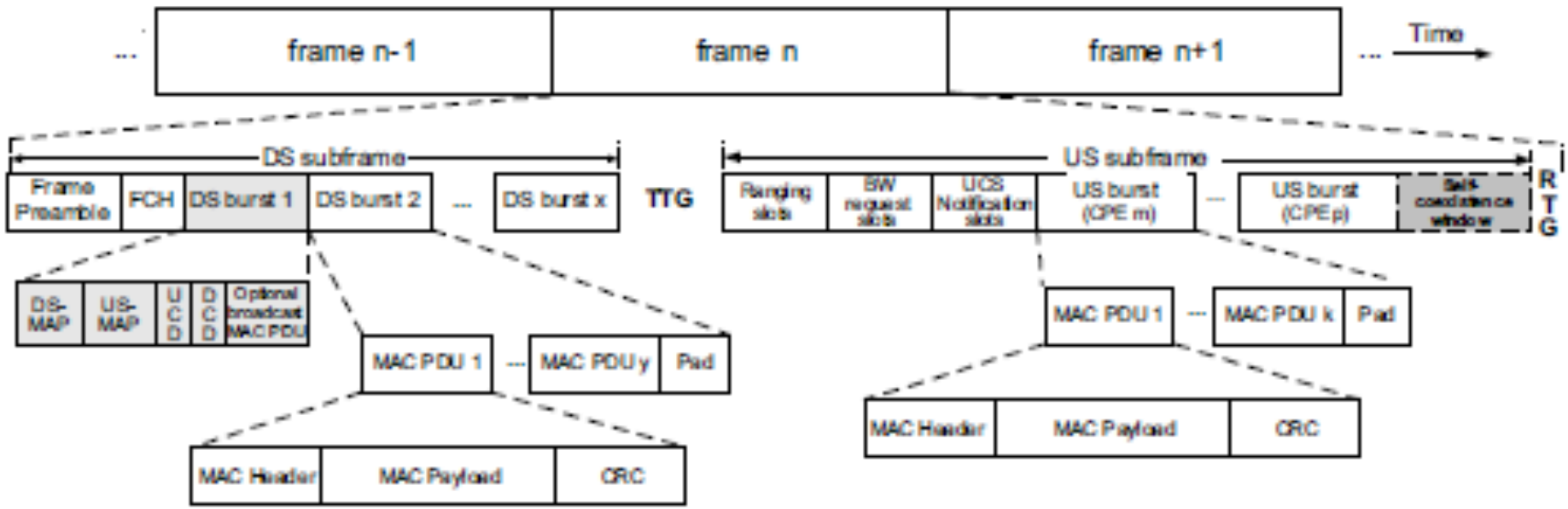
Superframe = 160 ms

Frame = 10 ms

Superframe =16 frames



Frame



MAC Frame structure

Antennas

- Each CPE needs two antennas: one omni and one directional
- Omni used for spectrum sensing and measurement
- Directional used for actual data communication.
- There might be need for a third antenna to perform database consultation, say through a cellular system

802.22 in the UK

- The Communications Regulator, Ofcom UK, has announced that it is officially moving forward with plans for the introduction of licence exempt **White Space** wireless broadband technology in the UK. This uses the radio spectrum that exists between digital terrestrial TV channels to deliver internet access over a **Wireless Regional Area Network** (WRAN).
- In principal such a technology would have many advantages. Related services typically exist between the lower **470MHz** and **790MHz** frequencies, which travel further and more easily through walls. Each TV channel is given a slice of this spectrum and a small gap (the white space) is then left between the channels to limit the potential for interference.

802.22 in the UK

- A number of trials are currently underway in the UK and are already showing some promising results. However the technology, which appears to work like Wi-Fi, is still very complicated to get right.
- The primary problem is that White Space routers (connectivity hardware) would first need to consult a **frequency database hosted online**.
- Digital TV channels often swap frequencies and failing to use the correct ones could result in interference, thus it's necessary to keep an up-to-date and locally aware database.
- Ofcom has decided to allow multiple third-party providers to develop databases, which it believes will create a competitive marketplace and incentivise operators to provide the best database service to consumers.

802.22 in the UK

- Download speeds of up to **22Mbps** per channel could be possible by using this technology, although that would be shared (contended) with other users. Never the less it could prove to be a lifesaver for isolate towns and villages.
- The regulator now expects to consult on a **Draft Statutory Instrument** for making white space devices licence exempt. The technology itself could be **launched in the UK during 2013**.

802.22 in South Africa

- TV white spaces can open up low-cost high-speed internet across Africa: All we need is the regulatory go-ahead.
- “We have the skills, the entrepreneurs, a spectrum model we can replicate, the standards, the technology and clearly we have the demand,” said South African Henk Kleynhans in the wake of a TV white spaces workshop in Johannesburg. “All we need is a regulatory go-ahead.”
- Unused TV white spaces could be the way to get highspeed wireless internet to millions in Africa including who have been enforcedly “offline” till now because they live outside major cities.

Example of commercial device specs

Frequency Bands	UHF 470-786 MHz (US and ETSI)
Channel Spacing	6 MHz (US), 8 MHz (ETSI)
Bandwidth	100 kHz (M2M) to 4.5 MHz (Rural BB)
Modulation	QPSK, 16QAM
Data Rates	4, 6, 8, 12, and 16 Mb/s
Data Rate Control	Dynamic or fixed
Receive Interface	Proprietary to reduce co-channel interference
RX Sensitivity (6 or 8 MHz)	-89 dBm for 10-6 BER using QPSK 1/2 -86 dBm for 10-6 BER using 16QAM 1/2
RX Blocking Resistance	-50dBm TV transmission on chan N+2 -20 dBm cellular station transmissions
RX Max Signal	-16dBm with full linearity
Operating Mode	TDD (Time Division Duplexing) or optionally FDD for point-to-point use
User Ports	Mini-B USB or 10/100 baseT Ethernet

Example of commercial device specs

NETWORK SPECIFICATIONS

Multipoint Client Capacity	4096
Typical Client Loading	60 clients with 3Mb/1Mb residential SLA
Management	Web-based browser using https interface
End-to-End Latency	30-100 ms typ.
REGULATORY SPECIFICATIONS	
ACP and Spectrum Mask	Meets FCC and Ofcom specifications -55 dBr +/- 3 MHz relative to 12.2 dBm

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	-40° to 55° C
Operating Humidity	Up to 95%, non-condensing
Shock and Vibration	MIL-STD-810
Security Mechanism	WPA2/AES-128 bit shared secret key

Example of commercial device specs

BASE STATION	
RF Transmit Power	+30dBm level across band within +/- 1dB
Antenna System	4.8 dBi Omni, MIMO Space Diversity option
Antenna Connector	“F” type female 75 Ohms, 1.3:1 VSWR
Unit Dimensions	19.6” x 6” x 1.75”
Weight	5 lbs
Mounting	19 inch EIA 1 unit rack
CPE	
RF Transmit Power	+27dBm level across band within +/- 1dB
Antenna System	12 dBi, 15° Beamwidth, 1.5:1 VSWR
Antenna Connector	“F” type female 75 Ohms
Unit Dimensions	9.20” x 7” x 1.6”
Enclosure Material	Anodized aluminum
Weight	3 lbs 12 oz
Mounting	Outdoor on Mast
Voltage	100-240 VAC, 50-60 Hz or 12 VDC
Power Consumption	Tx: 12W, Rx: 5W, Idle: 3W

Questions?