Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Summary of 802.22 Features Relevant to 802.15.4m
Date Submitted: 11 May, 2012
Source: Kunal Shah, Cristina Seibert
Company: Silver Spring Networks
Address []
E-Mail: [kshah @ silverspringnet.com]
[cseibert @ silverspringnet.com]

Re: []

Abstract: [This contribution is prepared to identify recommendations to TG4m.]

Purpose:

Table of Content

- 802.22 Reference architecture
- Components of the reference architecture
- Spectrum sensing services
- General super-frame structure
- General MAC frame structure
- Geo-location and ranging process
  - BS-to-CPE
  - CPE-to-CPE
- Geo-location calculation
- Synchronization mechanisms
- Proposed TG4m architecture
- Recommendations to TG4m

Reference architecture for BS

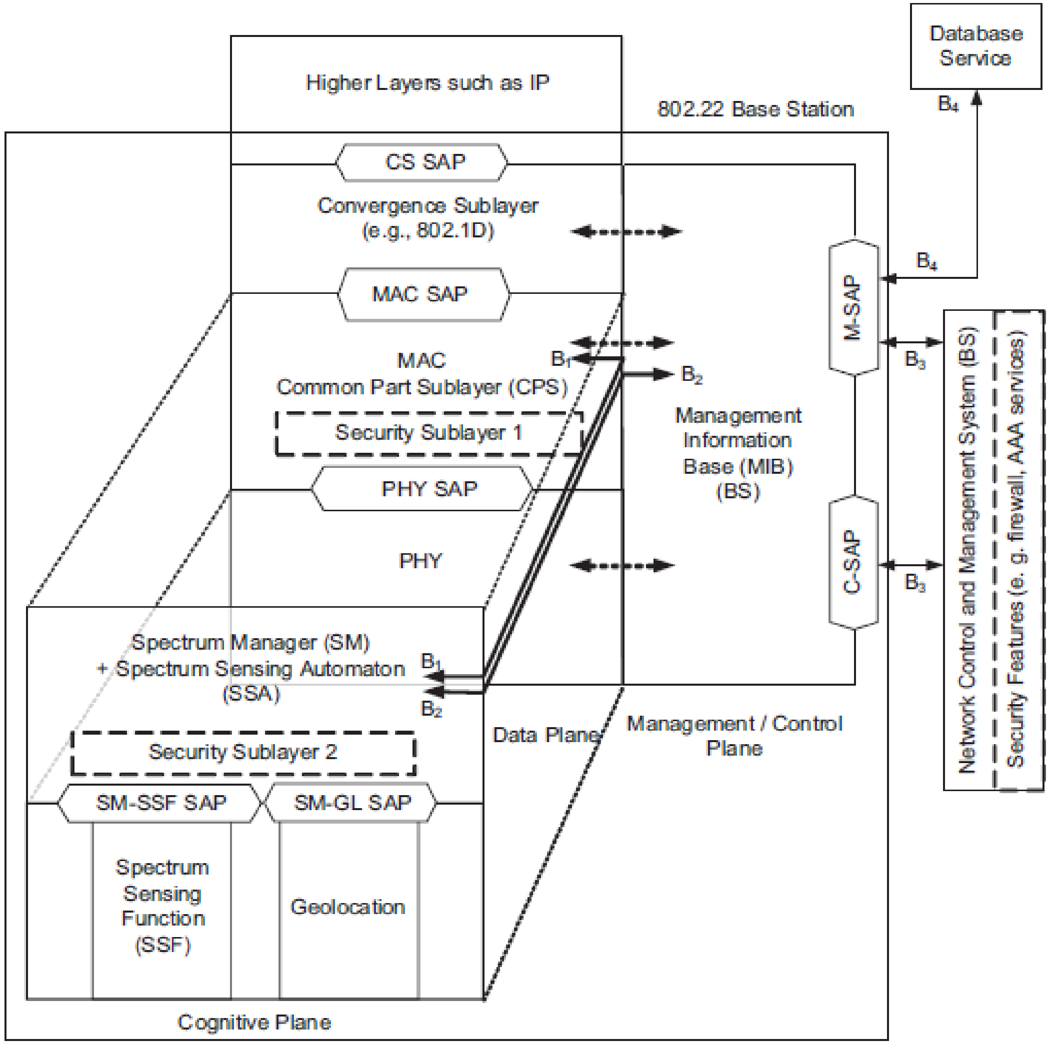


Figure 3 — Protocol Reference Model (PRM) of the IEEE 802.22 BS

SAP – Service Access Point
C-SAP – Control SAP
M-SAP – Management SAP

Reference architecture for CPE

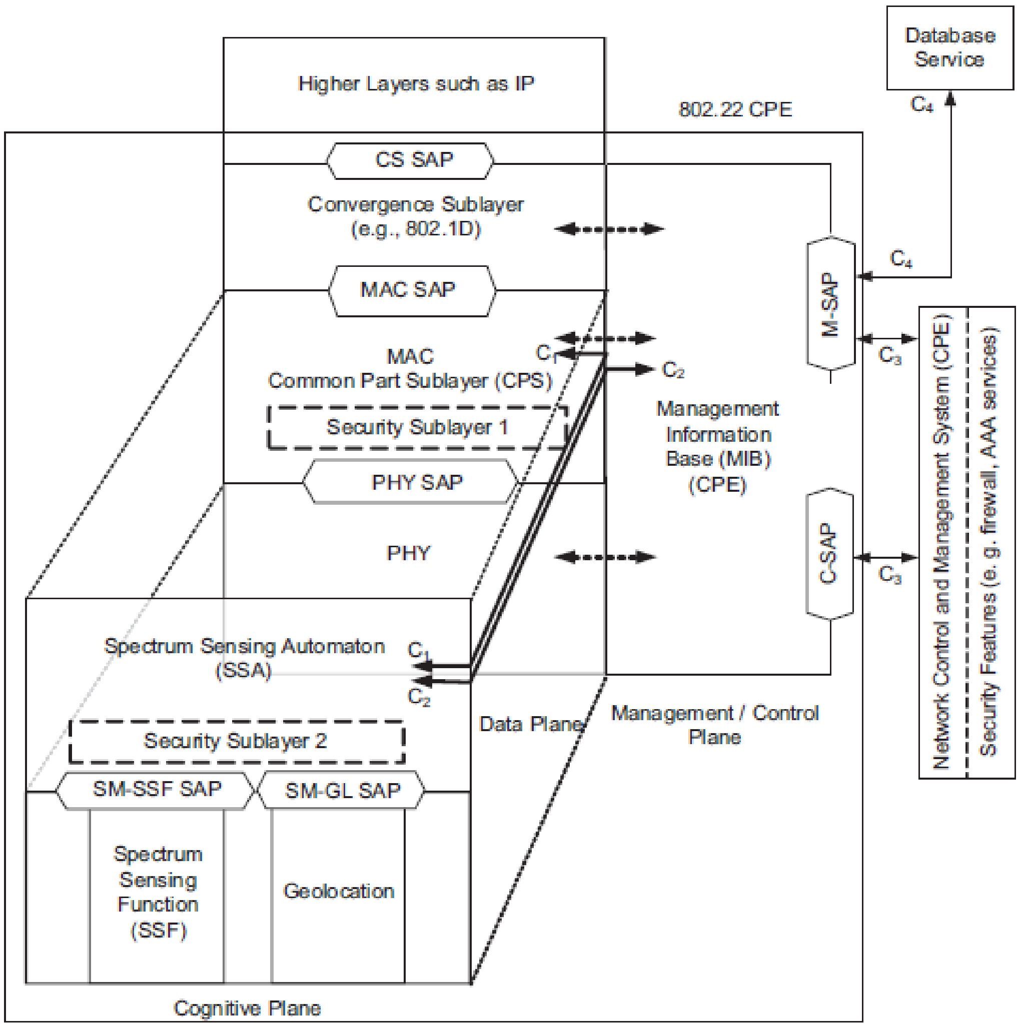


Figure 4 — Protocol Reference Model (PRM) of the IEEE 802.22 CPE

Components of the reference architecture (1/3)

- Data plane
  - PHY layer
  - MAC layer
  - Convergence sub-layer (CS)
- Data and control/ management plane
  - Service specific CS
    - Transformation and mapping of external network data
  - MAC Common Part Sub-layer
    - MAC functionality of system access, connection establishment and connection maintenance
  - Security sub-layer
    - Authentication, secure key exchange and encryption
  - Management Information Base (MIB)
    - SNMP is used to communicate with the database

Components of the reference architecture (2/3)

- Spectrum Manager (SM)
  - Spectrum availability information, channel lists, quite period scheduling
  - Takes appropriate action to resolve interference issue
    - Provides quite period to perform in-band sensing
  - Gather information from devices (sensing and geo-location information)

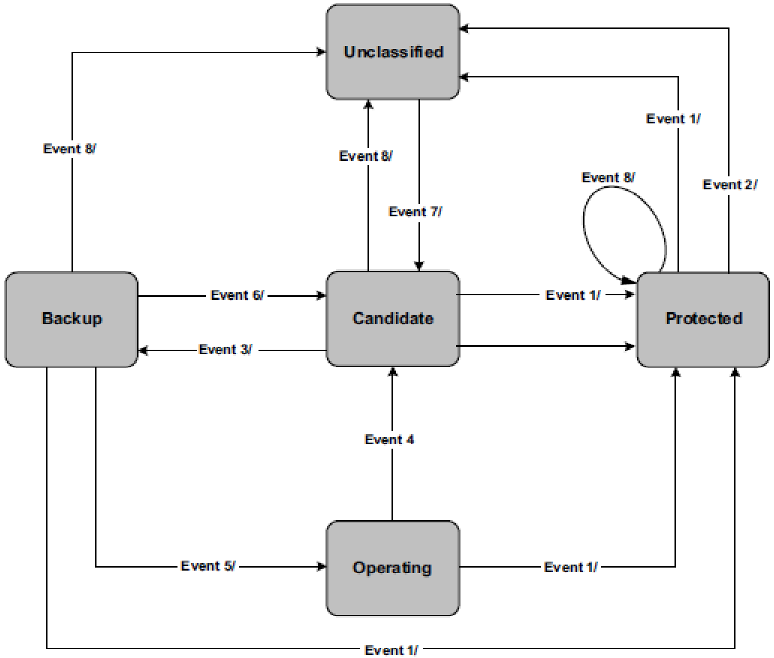
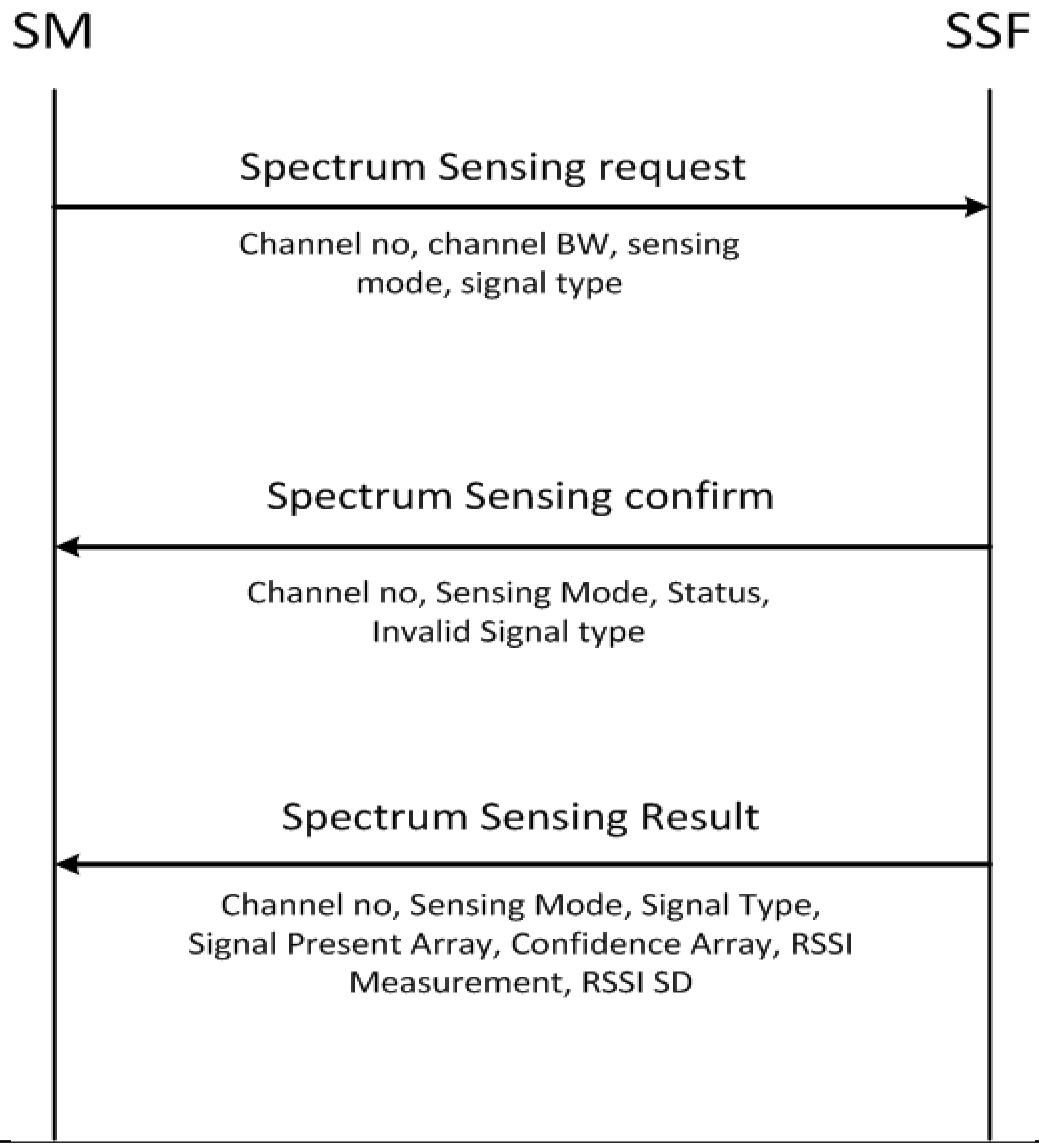


Figure 162 — Channel set transition diagram

Components of the reference architecture (3/3)

- Sensing requirements:
  - Operating channel shall be sensed at least every 2 sec
  - Back up channel shall be sensed once every 6 sec
  - Candidate and protected channel must be sensed every 6 sec for 30 sec (before it is elevated to a backup list)
- Spectrum sensing Automation (SSA)
  - Implements specific procedures for sensing the RF environment
    - At the intimal turn-on of the BS and CPE (before association is established with BS)
    - Quite period defined by the SM
    - Out-of band sensing at the BS
    - Ideal time at the CPE
    - CPE loses contact with its BS

Spectrum Sensing Services



Spectrum Sensing Input

Table 236 —Spectrum Sensing Function input signals

Input name	Input description	Length (bits)	Values
RF	Radio Frequency signal from the sensing antenna	N/A	N/A
ISO 3166 Country Code	Regulatory domain of operation	24	ASCII Characters—e.g., USA represents United States of America
Channel Number	The channel number that is to be sensed by the SSF	8	0–255
Channel Bandwidth	The bandwidth of the channel to be sensed by the SSF	4	0000 = 6 MHz 0001 = 7 MHz 0010 = 8 MHz 0011–111 = *Reserved*
Signal Type Array	An array indicating the signal types for which the SSF is to sense	32	Described in Table 237
Sensing Window Specification Array	An array of sensing window specifications. Each SFS specifies the details of the sensing window for a given signal type being sensed	N×32, where N is the number of signal types enumerated in Signal Type Array. The 24 bits cover the NumSensingPeriods, SensingPeriodDuration & SensingPeriodInterval.	Ranges for values given in Table 238:Bits 0–7: NumSensingPeriodsBits 8–17: SensingPeriodDurationBits 18–31: SensingPeriodInterval
Sensing Mode	The sensing mode specifies which SSF outputs are valid and in some cases it specifies the behavior of the SSF	2 bits	Sensing modes specified in Table 239
Maximum Probability of False Alarm)	In sensing modes 0 and 1 this value specifies the maximum probability of false alarm for each sensing mode decision in the signal present array	8 bits	Maximum Probability of False Alarm—0x00 indicates '0' and 0x01 indicates '0.001', and 0xFF = 0.255

Table 237 — Signal type array indices

STA Index	Signal type
0	Undetermined
1	IEEE 802.22 WRAN
2	ATSC
3	DVB-T
4	ISDB-T
5	NTSC
6	PAL
7	SECAM
8	Wireless Microphone
9	IEEE 802.22.1 Sync Burst
10	IEEE 802.22.1 PPDU MFS1
11	IEEE 802.22.1 PPDU MSF2
12	IEEE 802.22.1 PPDU MSF3
13–32	*Reserved*

Table 239 — Summary of the sensing modes

Sensing mode	Valid SSF outputs	Description
0	Signal Present Array	For each signal type the SSF generates a binary decision as to whether the signal is present in the television channel
1	Signal Present Array Confidence Array	Same as sensing mode 0 with the addition of a confidence metric for binary decision
2	Mean and standard deviation of the measured RSSI	For each signal type the SSF generates an estimate of the mean and standard deviation for up to 255 instantaneous RSSI measurements on a specified channel (see 0)

Spectrum Sensing Output

Table 241 — Range of a confidence metric

Limit	Value	Description
Minimum confidence metric	0x00	No confidence in signal present decision
Maximum confidence metric	10xFF	Total confidence in signal present decision

Table 242 — RSSI measurements

Limit	Length (bits)	Value	Units	Description
RSSI	M × 8	Signed Integer	dBm	Up to M RSSI measurements. M can be as large as 255. These RSSI shall be measured in dBm and shall be normalized for a 0 dBi antenna gain and 0 dB coupling and cable loss. Signed in units of dBm in 0.5 dB steps ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.

Table 243 — Range of the mean and standard deviation of a field strength estimate error

Parameter	Length (bits)	Value	Units	Description
RSSI	8	Signed Integer	dBm	Mean of the M RSSI measurements. Signed in units of dBm in 0.5 dB steps ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.
Standard Deviation	8	Integer	dB	Standard Deviation of the M RSSI measurements. Expressed in units of dB in 0.1 dB steps ranging from 0.0 dB (encoded 0x00) to +25.5 dB (encoded 0xFF). Values beyond +25.5 dB shall be encoded as 0xFF.

General Super-frame Structure

Two operational modes:

- Normal Mode
  - Cell occupies one channel and operates on all the frames in a super-frame
- Self-coexistence mode
  - Multiple cell share the same channel and each coexistence cell operates on one or several different frames

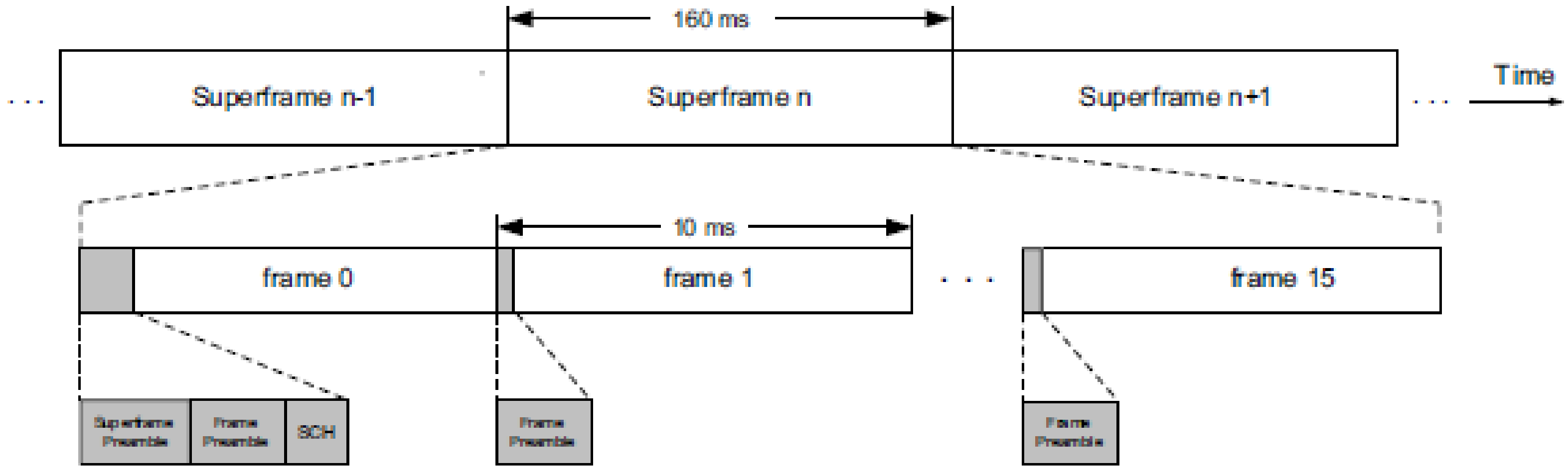
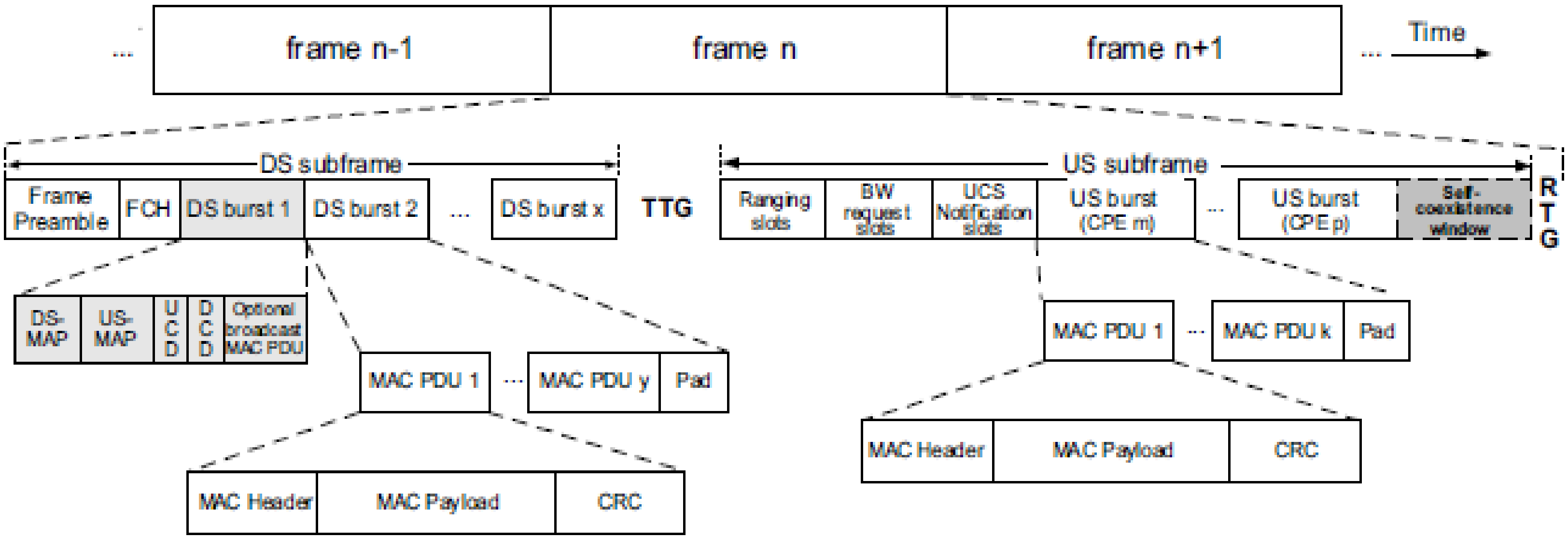


Figure 10 — General superframe structure

General 802.22 MAC frame structure



Geo-location

- Two modes of geo-location used with 802.22
  - Satellite-based (mandatory)
  - Terrestrial-based
- Satellite-based geo-location
  - The BS and CPE (customer premise equipment) determine the latitude and longitude of its transmitting antenna
    - within a radius of 50 m

Terrestrial-based geo-location

- Ranging process
  - Coarse ranging
    - BS keeps an indication of absolute timing to compensate signal propagation delay (as part of the RNG_CMD IE)
    - Zero value when CPE is co-located with BS and increases as distance increases
  - Fine ranging
    - Amount of residual delay in CPEs (measured by manufacturer)
    - CPE provide the residual delay during the registration through REG_REQ MAC message
  - BS-to-CPE and CPE-to-CPE ranging process
    - The location of BS and minimum two reference CPEs has been determined (surveying, satellite-based initial geo-location)

BS-to-CPE ranging process (1/2)

- BS transmits RNG_CMD MAC message to specific CPE and starts its counter T52 (at the start of the frame preamble)
- BS notes the size of transmit/receive transition gap (TTG) for given channel BW and cyclic prefix

Table 203 — WRAN frame parameters

Cyclic Prefix	Number of symbols per frame [1]			Transmit-receive turnaround gap [2] (TTG)			Receive-transmit turnaround gap [3] (RTG)		
BW	6 MHz	7 MHz	8 MHz	6 MHz	7 MHz	8 MHz	6 MHz	7 MHz	8 MHz
1/4	24	28	32	1439 TU	1680 TU	1918 TU	561 TU	1520 TU	2402 TU
1/8	26	31	36	1439 TU	1680 TU	1918 TU	2097 TU	1776 TU	1378 TU
1/16	28	33	38	1439 TU	1680 TU	1918 TU	1073 TU	1392 TU	1634 TU
1/32	29	34	39	1439 TU	1680 TU	1918 TU	753 TU	1392 TU	1954 TU

- CPE acquires values of the amplitude and phase rotation of the received subcarriers
  - Removes STS encoding and keeps the resulting info as vector '**vertiner1**'

BS-to-CPE ranging process (2/2)

- BS determines the time of arrival of the key multipath relative to the synchronization time at CPE (recovered by preamble correlator)
- CPE responds to the RNG_CMD message by sending RNG_REQ CDMA message
  - In time slot allocated in the US_MAP
- BS stops **T52** timer at the time of arrival of the CDMA ranging burst
- BS acquires the values of amplitude and phase rotation from the output of FFT and removes CDMA signature
  - Corrected value, '**vernier2**', stored at BS and sent to geo-locator

CPE-to-CPE ranging process (1/2)

- BS starts by signaling in US-MAP for the CPE (UIUC field in the US-MAP set to 0 for active mode)
- BS indicates timing advance for CPE to use for its burst, so that it received within the cyclic prefix at the nearby reference CPE
- BS signals the presence of passive mode for reference CPEs (UIUC = 1)
- CPEs are to use synchronization mode = 0 (US-MAP IE)
  - CBP burst capture synchronous to the BS

CPE-to-CPE ranging process (2/2)

- BS uses same frame for CPE-to-CPE ranging process as that used for BS-to-CPE
- CPE in active mode transmits its CBP burst relative to the start of the fourth symbol and specified EIRP level (US-MAP IE)
  - It contains CBP identification IE to confirm the burst comes from the right CPE
- Reference CPE captures the CBP burst and acquires the amplitude and phase rotation (I&Q values) – 'vernier3'
- BS queries the values from each reference CPE
  - arrange this data to be process by terrestrial geo-location proses

Geo-location calculations

- Propagation time and distance

BS-to-CPE Roundtrip **(**Propagation) time = T52 – (Range_map + TTG) – CPE residual delay + vernier1 + vernier2

BS-to-CPE Propagation distance = c * propagation time/ 2

CPE1-to-CPE2 Roundtrip (Propagation) time = Local transmit timing reference at CPE1 + TACBP – Local receive timing reference at CPE2 + Vernier3

CPE1-to-CPE2 Roundtrip (Propagation) time = –PT1 + TACBP + (PT2 – CPE2 residual delay) + Vernier3

CPE1-to-CPE2 Propagation distance = c * propagation time/ 2

Where, PT1: propagation time between the BS and CPE1
PT2: propagation time between the BS and CPE2
TACBP: Timing Advance of the CBP burst

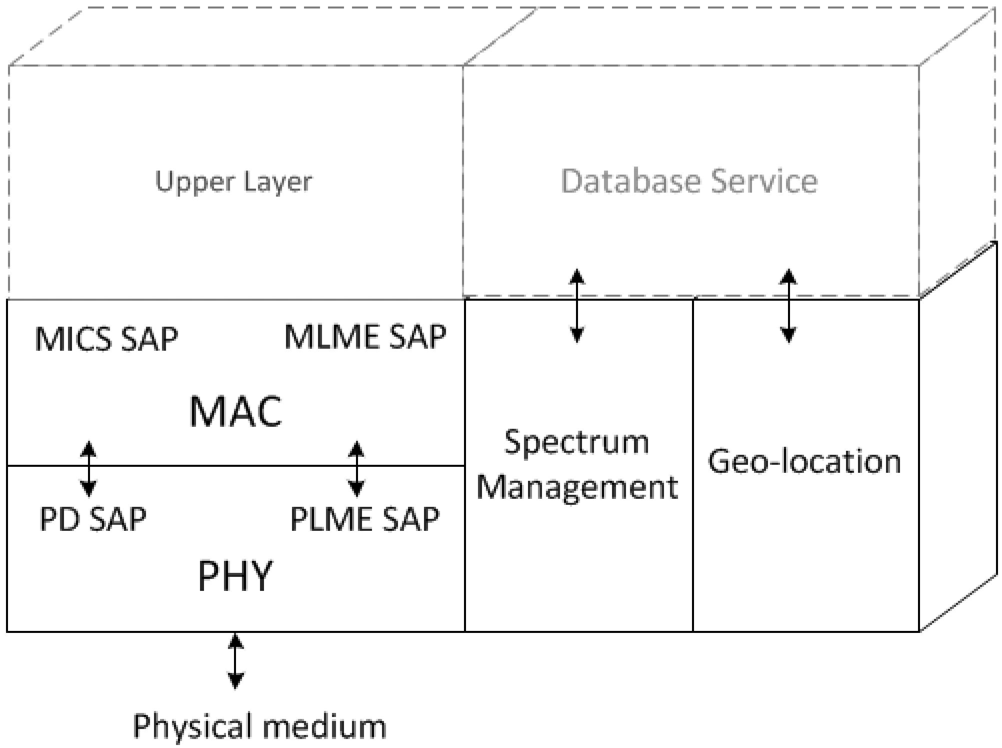
Synchronization mechanisms

- Downstream synchronization
  - Performed by each CPE
  - Synchronize the CPE's local clock to the reference clock at the BS
  - Downstream info includes the timing of the next upstream transmission opportunities for CPE
- Upstream synchronization
  - Initial ranging and periodic ranging process

Upstream Synchronization

- Initial ranging
  - Used by all CPEs to synchronize to the system
  - Used for detecting and adjusting time offset and adjusting the transmission EIRP level
  - Occupy first 5 OFDM symbols of the upstream frame
    - Performed using 3 consecutive symbol (indicated in the US-MAP for CPE)
    - 2 more buffer symbols at the BS to avoid spilling onto the other signals
- Periodic ranging
  - CDMA Periodic ranging (for system periodic ranging)
  - BW request (upstream allocation for BS) and
  - UCS notification transmission (reporting detection of an incumbent

Proposed TG4m Architecture



Recommendations to TG4m

- Adopt reference architecture proposed in previous slide
- A number of 802.22 mechanisms and processes are also relevant
  - Spectrum management
    - Sensing as dictated by regulatory requirements, e.g. for Mode I devices under FCC
  - Ranging
    - Synchronization mechanisms
    - Distance calculation
    - Messages carrying ranging-specific content
      - recommend use of information elements for this purpose
    - Beacons extensions for periodic ranging, also via IE