Strawman Amendment to Standard Air Interface for Fixed Broadband Wireless Access Systems in License Exempt Bands

Sponsor

LAN MAN Standards Committee of the IEEE Computer Society and the IEEE Microwave Theory and Techniques Society

Abstract: This standard specifies the air interface, including the medium access control layer (MAC) and a physical layer (PHY), of fixed point-to-multipoint broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layers optimized for the frequency bands of the application.The standard includes a particular physical layer implementation broadly applicable to systems operating between 10 and 66 GHz.

Keywords: WirelessMAN™ standards, metropolitan area network, fixed broadband wireless access networks, millimeter waves, microwaves, unlicensed, UNII

Strawman Amendment Standard Air Interface for Fixed Broadband Wireless Access Systems in License Exempt Bands

NOTE-The editing instructions contained in this amendment/corrigendum define how to merge the material contained herein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: ***change***, ***delete***, ***insert***, and ***replace***. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using strikethrough (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

1.1 Scope

Change the first paragraph of this subclause to the following:

This standard specifies the air interface, including the medium access control layer (MAC) and a physical layer (PHY), of fixed point-to-multipoint and mesh broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layers optimized for the frequency bands of the application.The standard includes a particular physical layer implementation broadly applicable to systems operating between 10 and 66 GHz.

Change the last paragraph of this subclause to the following:

For the purposes of this document, a “system” consists of an 802.16 MAC and PHY implementation with at least one subscriber station communicating with a base station via a point-to-multipoint (P-MP) or mesh radio air interface, along with the interfaces to external networks and services transported by the MAC and PHY protocol layers.

1.2 Purpose

1.3 IEEE 802 Architectural Conformance

1.4 Reference Model

1.4.1 Data/Control Plane

1.4.2 Management Plane

Please add the following new subclause

1.4.3 License Exempt Mesh Topology Option

The IEEE 802.16 TG4 system has an optional mesh topology. Unlike the basic point-to-multipoint mode, there are no clearly separate downlink and uplink subframes in the mesh mode. Each station (BS or SS) is able to create direct communication links to a number of other stations in the network instead of communicating only with the BS.

The stations with which a station has direct links with are called neighbors and shall form a neighborhood. A two-hop neighborhood contains, additionally, all the neighbors of the neighborhood. All the stations shall coordinate their transmissions in their two-hop neighborhood. A station may select any of the links it does have to its neighbors to forward traffic originated in the node itself or in some other node in the network. Coordinated transmissions ensure collision-free scheduling.

For transmission coordination, there is a specific control period in the beginning of each MAC frame in which each station shall periodically transmit its own schedule on a point-to-multipoint basis to all its neighbors. Within a given frequency channel, all neighbor stations receive the same schedule transmissions. All the stations in a network shall use this same channel to transmit schedule information in a format of specific resource requests and grants. A unique schedule transmission slot shall be determined with the aid of two-hop neighborhood addresses. (?)

In normally scheduled transmissions, all stations act like either a BS or an SS does for uplink bandwidth requests in the point-to-multipoint mode. In other words, a station that wishes to transmit must be granted the bandwidth it had requested earlier from a neighbor. Thus the transmitting station acts like a SS in uplink direction. Likewise, when a receiving station must have previously granted bandwidth in response to a request from its neighbor. Thus a receiving station acts like a BS in the uplink direction.

2. Normative references

3. Definitions

4. Abbreviations and acronyms

5. Service Specific Convergence Sublayer

6. MAC Sublayer - Common Part

Change the first paragraph of this clause to the following:

In a network that utilizes a shared medium, there must be a mechanism to provide an efficient way to share the medium. ~~A t~~Two-way point-to-multipoint and mesh topology wireless networks ~~is a~~are good examples of ~~a~~ shared mediums: here the mediums ~~is~~are the space through which the radio waves propagate.

The downlink, from the base station to the user operates on a point-to-multipoint basis. The 802.16 wireless link operates with a central base station and a sectorized antenna which is capable of handling multiple independent sectors simultaneously. Within a given frequency channel and antenna sector, all stations receive the same transmission. The base station is the only transmitter operating in this direction, hence it can transmit without having to coordinate with other stations, except for the overall time-division duplexing that divides time into uplink and downlink transmission periods. It broadcasts to all stations in the sector (and frequency); stations check the address in the received messages and retain only those addressed to them.

However, the user stations share the uplink period on a demand basis. Depending on the class of service utilized, the SS may be issued continuing rights to transmit, or the right to transmit may be granted by the base station after receipt of a request from the user.

6.1 MAC Service Definitions

6.2 Data/Control Plane

6.2.1 Addressing and Connections

6.2.2 Message Formats

6.2.2.2.4 Uplink MAP (UL-MAP) Message

Please replace the Figure 29 graphic with the following:

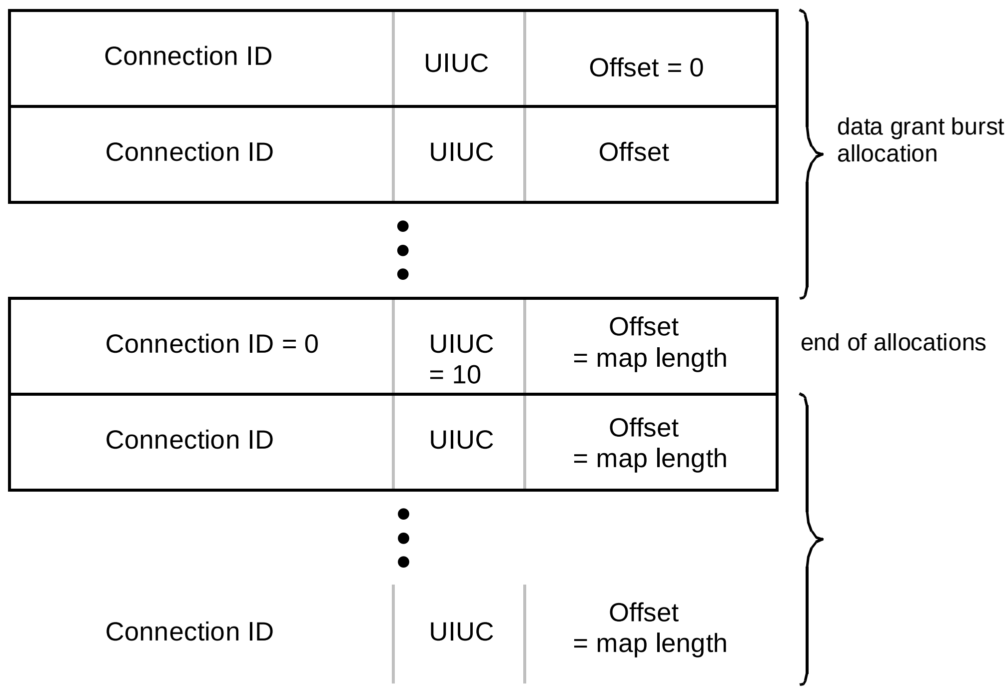

Figure 29—UL-MAP Information Element Ordering

— **MAP Information Elements**

Each Information Element (IE) consists of three fields:

1) Connection Identifier
2) Uplink Interval Usage Code
3) Offset

—

— **Power Control Information Element**

Each Information Element (IE) consists of three fields:

1) Connection Identifier
2) Additional Set
3) Power Control

Information elements define uplink bandwidth allocations and power control changes. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements are strictly ordered within the UL-MAP, as shown in Figure 29.

Please insert the following new subclause:

6.2.2.2.4.1 License Exempt Bands - Power Control Information Element

When a power change for a connection (CID) is required, use the Expansion IE (UIUC Code=15) as follows:

1) Connection Identifier (16-bit)- This is the CID.
2) Additional Set - (4-bits)
3) Power Control - (4-bits)

This IE shall be sent only when is needed.

For example, to adjust the power control for a specific CID, the BS must create a UL-MAP message with two different IEs applied to the same SS (in case of GPT mode), a standard IE providing the active Burst Type (Dynamic Set) with offset, and a second Expanded IE (UIUC=15). This IE contains both the Power Control adjustments and an additional set of parameters.

Please insert the following new subclause and figures

6.2.2.2.28 License Exempt Mesh Option Messages

6.2.2.2.28.1 Mesh Schedule (MSH-SCH) Message

A Mesh Schedule message shall be transmitted by all the stations in a mesh mode at a periodic interval to inform all the neighbors the schedule of the transmitting station. Each station shall determine its own unique Mesh Schedule message transmission time using the two-hop neighborhood information.

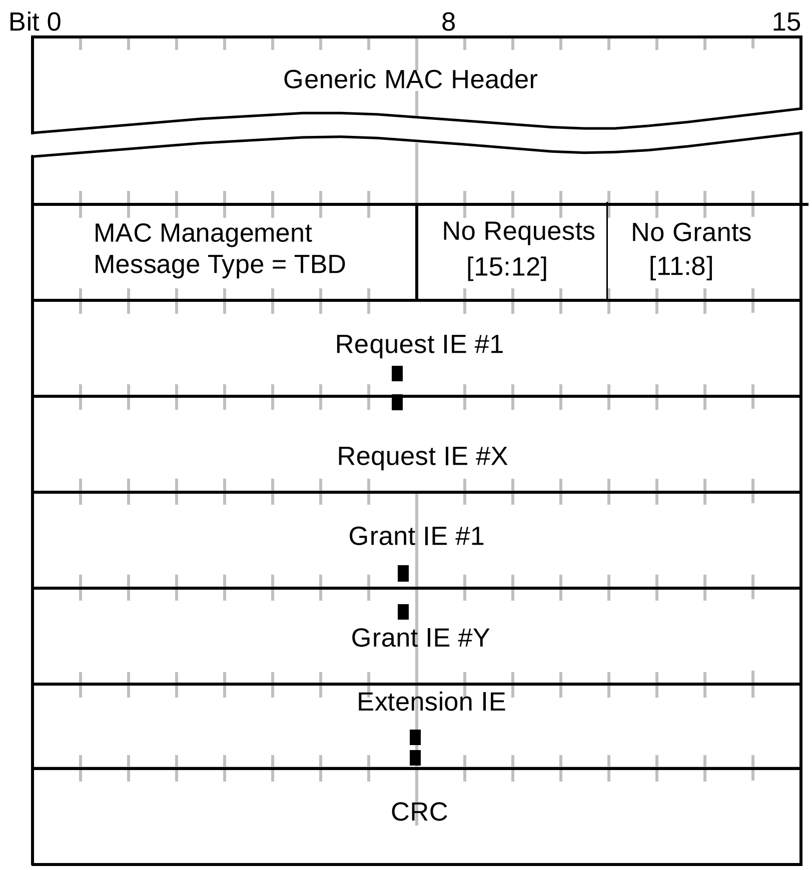

Figure 1—MSH-SCH Message Format (SS to SS)

The transfer syntax of each of the information elements of the MSH-SCH message is illustrated in Figure tbd through Figure tbd+3. Various fields are respectively described in Table n through Table n+3.

6.2.2.2.28.2 Mesh Mode Bandwidth Request IE

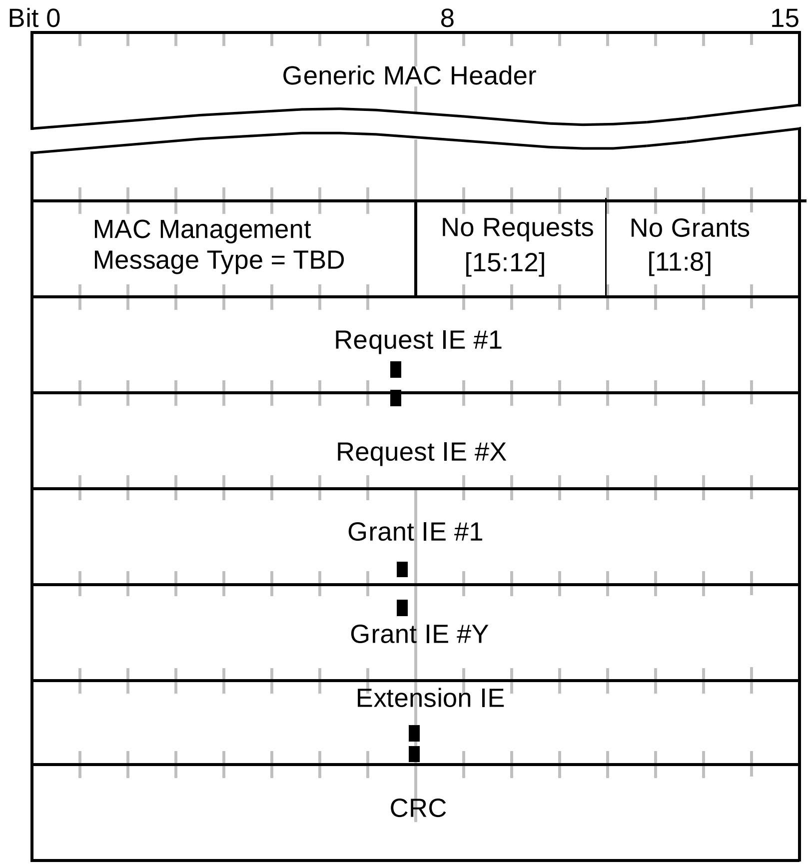

Figure 2—MSH-REQ Format (SS to SS)

6.2.3 Transmission of MAC PDUs

6.2.4 Uplink Service

6.2.5 Bandwidth Allocation and Request Mechanisms

6.2.6 MAC support of PHY layers

6.2.6.7.2 License Exempt Dynamic Frequency Selection

DFS is the process that is used primarily to assign one of several possible channels to the SS. Additionally, especially in a mesh mode, DFS may be also used to assign a most feasible channel to each link (unicast/multicast/broadcast). The process requires monitoring by the SS and assignment of channels by the upper processing layers of the BS.(Comment: in both Mesh and Directional Antenna Systems the DFS will assign the most feasible channels)

6.2.6.7.2.1 RSSI and CCI measurement of a Downlink Channel:

Within the mesh and directive antenna system architectures, each SS, prior to registration, will monitor the available channel spectrum. Typically, the SS will go to each assigned channel (which can be a few as 4 or as many as 9….depending on the channel bandwidth TBD) and monitor each channel and compile a list of readable channels. Each channel will be characterized in terms of its RSSI, which will be determined by the PMD measurement of the preamble bits of the OFDM bursts (in a TBD manner), and a similar reading will be made of the Co-Channel Interference (CCI), also to be determined by the PMD measurement of a designated OFDM "quiet time" (TBD).

6.2.6.7.2.2 Valid Channels

Valid channels will be considered to be only those channels which have a high enough S/N allowing successful synchronization and demodulation of the MAC Management Messages

6.2.6.7.2.3 Assignment of Downlink Channel ID's to RSSI and CCI Measurements.

Valid channels will allow the MAC layer to read the Downlink Channel Descriptor (DCD) and Downlink Access Definition (DL-MAP) messages. These messages are transmitted periodically (see Table 67 in Ref 1) on the channel being monitored.

The DCD will provide the SS with a Downlink Channel ID (1 Byte) and the channel EIRP, which is encoded at a TLV tuple in the DCD (specifically as a Type 2 byte; 1 byte message described as a Downlink Physical Channel Attribute. See 11.1.2.1, DCD Channel Encodings)

The DL-MAP will provide the 64 bit Base Station ID.

The Base Station ID; Downlink Channel ID, channel EIRP, RSSI reading and CCI reading will be sent to higher processing layers.

The higher processing layers, not detailed herein, will make a choice concerning the most acceptable downlink channel to monitor. The higher processing layers will then tune the PMD to the most acceptable channel, and re-synchronize to this channel.

6.2.6.7.2.4 Registration Procedure

The SS will obtain all necessary downlink and uplink parameters as described in Sections 6.2.7.2 and 6.2.7.3. This being done, a link will be established with the BS and ranging will be undertaken to finalize any corrections to timing and synchronization; as per Section 6.2.7.5 and 6.2.7.6.

This procedure being completed the SS would then normally proceed with the establishment of IP connectivity, as per Section 6.2.7.8.1. However; in the IEEE 802.16.4 MAC it is proposed that this step be delayed; and that a new message, a Dynamic Frequency Selection Request Message (DFS-REQ) be transmitted to the BS.

The DFS-REQ would be in the standard MAC Management Message Format (6.2.2). The DFS-REQ can be sent by the SS or the BS. Base Station originated DFS-REQ messages would be soliciting best-channel information from the particular SS (identified by the Vendor ID in the configuration file). SS originated DFS-REQ messages would be carrying candidate channel information to the BS.

Additionally, there is a new MAC management message called DFS-RSP. This message is a BS originated message sent in response to the DFS-REQ message from the SS.

The DFS-REQ would carry TLV encoded information. The TLV tuples will have configuration files having the settings described below.

6.2.6.7.2.5 TLV Configurations for SS Transmitted DFS-REQ Messages

All uplink DFS-REQ messages sent by the SS to the BS must contain the following TLV settings:

1) Vendor ID of SS
2) Base Station ID (current)
3) Downlink Channel Configuration Setting (current)
4) Uplink Channel Configuration Setting (current)
5) Downlink ID
6) Channel EIRP
7) Mean RSSI
8) Mean CCI
9) CCI variance
10) RSSI variance
11) RSSI Fading rate (optional) (current channel)

Base Station ID, Downlink ID, Channel EIRP, mean RSSI, mean CCI,CCI variance, RSSI Variance, RSSI Fading rate (optional) (First Alternative channel)

………..

Base Station ID, Downlink ID, Channel EIRP, mean RSSI, mean CCI,CCI variance, RSSI Variance, RSSI Fading rate (optional) (Last Alternative channel)

6.2.6.7.2.6 TLV Configurations for BS Transmitted DFS-REQ Messages

All downlink DFS-REQ messages are sent by the BS to the SS after the SS has successfully registered with the BS. This message is sent in order to interrogate the SS on the quality of all the possible received channels. This message is generated by the upper processing layers beyond the scope of this specification (such layers would be unique to either the Mesh or Directive Antenna systems). The SS would respond to this message by sending the DFS MAC management message described earlier.

The TLV for this message would contain:

1) Vendor ID of SS
2) Base Station ID
3) Downlink ID (1st channel to measure)
4) Base Station ID
5) Downlink ID (Nth channel to measure)

6.2.6.7.2.7 TLV Configuration Settings for BS Transmitted DFS-RSP Messages

All downlink DFS-RSP messages sent by the BS to the SS shall contain the following TLV configuration settings:

1) Vendor ID of SS
2) Base Station ID (assigned)
3) Downlink ID (assigned)
4) Downlink Channel Configuration Setting (assigned)
5) Uplink Channel Configuration Setting (assigned)
6) Uplink EIRP setting (assigned)

6.2.6.7.3 Co-Existence

The DRFM forms the basis on co-existence, it is needed so that other terminals, operating on different systems will at least be able to learn something about the potential interference.

6.2.6.7.3.1 Downlink Radio Frequency Management (DRFM) Message

This message is sent out on an occasional basis (once every 30 seconds to once every minute) on the downstream channel of a base station, which can have multiple antennas. Its purpose is to send its RF configuration information to adjacent Base Stations. This message will provide the adjacent base stations with information that is useful for the choice of frequencies, radiation patterns, and EIRP's that the adjacent base stations can use in such a way that potential CCI is mitigated.

6.2.6.7.3.2 Hierarchical Assumptions for Interference Mitigation and Co-Existence: First Come/First Claim

In the License-Exempt environment of the IEEE 802.16.4 specification, it is proposed that for fixed point to multipoint access systems complying to the specification, that the first FWA systems' occupation of a space/frequency zone be respected and protected against co-channel interference from any FWA system installed thereafter. Control would be exercised by an adaptive algorithm that would operate within the BS and set up its RF transmission characteristics in compliance to this general co-existence rule. Such algorithms work best with configurations of oblong microcells arranged in rosette configurations. However, they can work with omnidirectional radiating systems as well.

6.2.6.7.3.3 Downlink Radio Frequency Management (DRFM) Message

A Radio Frequency Management Message shall be transmitted by the BS at a periodic interval (30 sec. TBD) (Table XX TBD).The DRFM is a MAC Management Message of Type 28 (TBD). It begins with a Generic Downlink MAC header and its format is shown in Figure (XX TBD)

This message will characterize the Radio Frequency Emission properties of the BS, and other co-located emitters which can be other base stations or channels controlled by the single base station. The purpose of this message is to inform nearby and potentially interfering BS and SS of the radiation of the originating BS

Each emission from the BS is characterized by giving its channel frequency, EIRP, direction, and beamwidth, The following parameters will be included in a DRFM:

1) Base Station ID - The Base Station ID is a 64 bit long field identifying the BS. The Base Station ID may be programmable or derived from the configuration file used to set up Base Station parameters on installation and activation.
2) GPS Locator - GPS Location of the BS which can have up to 64 co-located radio emitters which can be either other base stations or a multiple of channels from a single base station. The GPS coordinates are loaded into the configuration file used to set up the Base Station parameters on installation and activation. The resolution of the GPS inputs are to 0.01 minute, and consist of signed latitude and longitudes. The GPS locator field is 7 bytes long and contains reserved bit fields.
3) Height of BS - The height of a BS in meters above ground level. This is a 10 bit long field allowing the indication of a maximum height of 1024 Meters.
4) Base Station Emitter Number - The number of distinct channel emissions that are emanating from the BS and its co-located base stations (having the same GPS locator). This is a 6 Bit long field that also defines the number of TLV Downlink Channel Emission (DCE) frames to be read.
5) Downlink Channel Emission (DCE) Frame - This is a TLV encoded frame that contains information on each emission's radiation characteristics. Up to N=64 emissions can be specified as

originating from the location of single BS. Each frame shall contain the frequency of the emission (4 bytes in multiples of Kilohertz); EIRP per emission (in signed units of Power Spectral Density dBm/MHz) 1 Byte; direction of emission with respect to Magnetic North in increments of 2 degrees covering 0-360 degrees azimuth (1 Byte); Beamwidth of emitting antenna in increments of 2 degrees covering 0-360 degrees beamwidth (1 Bytes); and 1 Byte reserved for future use. The DCE frames N={1 to X} will correspond to the emissions from the BS whose ID is given. Emissions from other co-located but independent base stations will be given in N={(X+1) to 64}.

Please insert the following new figure:

Bit 0								8							Bit 15

EC	**EKS**	**Rsvd**	**Length**					
Connection Identifier								
HT=0	**CSI**	**FC**	**FSN**	**CI**	**PDE**	**CPT**	**PSP**	**Rsvd**
HCS	**MAC Management Message Type = 28 (TBD)**							
Base Station ID Byte 1	**Base Station ID Byte 2**							
Base Station ID Byte 3	**Base Station ID Byte 4**							
Base Station ID Byte 5	**Base Station ID Byte 6**							
Base Station ID Byte 7	**Base Station ID Byte 8**							
LAT 0=N 1=S	**Latitude Reading Degrees (0-90)**	**Latitude Reading Minutes (0-60)**	**Reserved**					
Latitude Reading 1/100 Minute (0-100)	**Reserved**							
LNG 0=W 1=E	**Longitude Reading Degrees (0-90)**	**Longitude Reading Minutes (0-60)**	**Reserved**					
Longitude Reading 1/100 Minutes (1-100)	**Height of BS in 1 meter Increments (0-1024) Bits 10-15**							
Height of BSCont.Bits 0-3	**Number of Base Station Emitters (N=1-64)**	**Reserved**						
DCE Byte 1 Frequency of Emitter N=1	**DCE Byte 2 Frequencyof Emitter N=1**							
DCE Byte 3 Frequency of Emitter N=1	**DCE Byte 4 Frequency of Emitter N=1**							
Eirp 0= - 1= +	**EIRP in dBm/MHz for Emitter N=1**	**Direction of Emitter N=1 in 2 degree steps 0-360 degrees with Magnetic North Ref={00000000}**						
Beamwidth of Emitter N=1 in 2 degree steps 0-360 degrees	**Reserved**							
1.0	•							
1	•							
•	•							
DCE Byte 1 Frequency of Emitter N=64	**DCE Byte 2 Frequencyof Emitter N=64**							
DCE Byte 3 Frequency of Emitter N=64	**DCE Byte 4 Frequency of Emitter N=64**							
Eirp 0= - 1= +	**EIRP in dBm/MHz for Emitter N=64**	**Direction of Emitter N=64 in 2 degree steps 0-360 degrees with Magnetic North Ref={00000000}**						
Beamwidth of Emitter N=64 in 2 degree steps 0-360 degrees	**Reserved**							

Figure XX TBD Downlink Radio Frequency Management Message Format

6.2.6.7.3.4 Reception of the HBS-RFMM

The HBS-DRFM is solely for use by the upper management layers of the BS. It will require the BS to either direct an independent receiver to monitor this message, or it may direct one of its link receivers to undertake monitoring. The BS would have to scan its environment for each adjacent BS and embark on a Scanning and Synchronization procedure as outlined in Section 2.11.2. Once synchronization is achieved and DL-MAP MAC management messages are received the receiver will have to wait for the HBS-DRFM. This being done, the BS receiver, under control of the upper management layers, will scan another sector until all possible adjacent BS have be identified and characterized through their HBS-DRFM messages.

6.2.6.8 License Exempt Mesh Mode Option

Only TDD is supported. On contrary to the basic point-to-multipoint mode, there are no clearly separate downlink and uplink subframes in the mesh mode. Otherwise the frame is similar:

1) It is divided into an integer number of physical slots.
2) TDD framing is adaptive (though a fixed framing is favored to ease MSCH scheduling).

Downlink-MAP and uplink-MAP messages are not used. Instead, mesh option specific MAC Management messages (MSCH) are used to define the usage of the rest of the TDD frame. First TBD Pass in the beginning of the frame shall be reserved solely for MSCH transmission.

6.2.7 Quality of Service

Insert the following subclause after 6.2.9

6.2.8 ARQ

While there are several well-known ARQ algorithms, two are more commonly used; go-back-N and selective-repeat. Both of these algorithms require the sender to assign a monotonically increasing integer values to each transmitted packet. The difference lies in the method by which they handle lost packets. These methods are outlined below to assist in determining suitability.

The go-back-N algorithm receiver detects a loss when a packet arrives with a sequence number that is higher than expected. The receiver then sends a negative acknowledgement (NACK) to it peer to request a retransmission of the missing packet. The receiver then throws away any packets received whose sequence number is higher than that of the missing packet. The sending peer now begins retransmitting the missing packet and the following packets even though they were received by the receiver.

The selective-repeat algorithm likewise notifies the peer of a lost packet by issuing a NACK. However, it buffers any other received packets with higher sequence numbers and sends out an ACK for each. The sending peer receives the NACK and retransmits the missing packet. Following this retransmission, the sending peer continues sending packets again. However, it begins where it left off prior to the retransmission. There is no retransmission of segments which were correctly received by the receiver peer prior to the lost packet.

There is a variation of selective-repeat that improves performance and link utilization. This variation involves the use of a cumulative acknowledgment (CACK). For example, if the receiving peer receives a set of contiguously sequenced number packets, it can send a CACK with the last sequence number received. This informs the sending peer that all packets up to and including the packet whose sequence number is included in the CACK have been correctly received. This permits the sending peer to advance its transmission window upon receipt and the reduces the amount of bandwidth required to transmit ACKs for each packet.

It is of use to note that if a window size of one is chosen, perhaps due to a lack of receiver buffer, then all three algorithms are reduced to a form of ARQ known as stop-and-go.

6.2.8.1 ARQ Parameters Selection

ARQ algorithms can be tuned to fit an application. The following parameters can be negotiated between session endpoints for this purpose.

6.2.8.1.1 ARQ Algorithm Parameter

The ARQ Algorithm TLV indicates the ARQ protocol to be used. The DSA/DSC-RSP message will contain:

1) An acknowledgement of this parameter, signified by the parameter's exclusion from an SFES (if one is included).
2) A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3) A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the algorithm at any time using the DSC mechanism and this TLV parameter. The DSA/DSC-REQ message includes the following QoS parameter

Name	Type (1 octet)	Length (1 octet)	Value (variable length)
ARQ Algorithm	1	4	Unsigned 16-bit value 1 - selective-repeat w/ CACK - default 2 - selective-repeat 3 - go-back-n All other values are illegal, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default.

6.2.8.1.2 ARQ Window Size Parameter

The Window Size TLV indicates the maximum number of outstanding packets, which may be sent without receiving a NACK. Note that the receiving peer of the reliable packet stream is responsible for buffering higher sequence numbered acknowledged packets and thus has final say for the window size. The DSA/DSC-RSP message will contain:

1) An acknowledgement of this parameter, signified by the parameter's exclusion from an SFES (if one is included).
2) A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3) A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the window size at any time using the DSC mechanism and this TLV parameter. The DSA/DSC-REQ message includes the following QoS parameter

Name	Type (1 octet)	Length (1 octet)	Value (variable length)
ARQ Window Size	1	4	Unsigned 16-bit value Range: 1 - 255 Default: 8 0 or 255+ are illegal values, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default

6.2.8.1.3 Retries Count Parameter

The Retries Count TLV indicates the maximum number of attempts that will be made to retransmit any packet. Note that the receiving peer of the reliable packet stream is responsible for buffering higher sequence numbered acknowledged packets and thus has final say for the window size. The DSA/DSC-RSP message will contain:

1) An acknowledgement of this parameter, signified by the parameter's exclusion from an SFES (if one is included).
2) A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3) A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the retries count at any time using the DSC mechanism and this TLV parameter. The DSA/DSC-REQ message includes the following QoS parameter

Name	Type (1 octet)	Length (1 octet)	Value (variable length)
ARQ Retries Count	1	4	Unsigned 16-bit value Range: 1 - 15 Default: 2 0 or 15+ are illegal values, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default

6.2.8.1.4 ARQ Timeout Parameter

The ARQ Timeout TLV indicates the maximum number of frame times that may elapse before the receiving ARQ peer should consider the retransmission retries to have expired. This value will depend upon many factors including the flow's priority and bandwidth as well as the number of active stations. Therefore, there is no default value. The DSA/DSC-RSP message will contain:

1) An acknowledgement of this parameter, signified by the parameter's exclusion from an SFES (if one is included).
2) A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3) A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the timeout period at any time using the DSC mechanism and this TLV parameter. The DSA/DSC-REQ message includes the following QoS parameter

Name	Type (1 octet)	Length (1 octet)	Value (variable length)
ARQ Timeout	1	4	Unsigned 16-bit value Range: 1 - 64k Default: N/A 0 is an illegal value, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default

6.2.8.1.5 ARQ Element Type Parameter

The ARQ Element Type TLV indicates the type of element that will be transmitted and acknowledged within the ARQ mechanism. The DSA/DSC-RSP message will contain:

1) An acknowledgement of this parameter, signified by the parameter's exclusion from an SFES (if one is included).
2) A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3) A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the element type at any time using the DSC mechanism and this TLV parameter. A dynamic change for this ARQ element will require that all outstanding elements of the previously employed element type be acknowledged prior to sender's change request (TLV) and subsequent use of the new element type. The receiver should interpret all elements received following the receipt of the TLV to be of the new element type.

The DSA/DSC-REQ message includes the following QoS parameter

Name	Type (1 octet)	Length (1 octet)	Value (variable length)
ARQ Element Type	1	4	Unsigned 16-bit value 1 - MPDU 2 - MSDU 3 - Byte Count Default: MPDU All other values are illegal, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default

There are currently two algorithms being defined for ARQ; Go-Back-N and Selective-Repeat.

6.2.8.2 ARQ Algorithm: Go-Back-N

6.2.8.2.1 GBN General

Objectives of the GBN ARQ protocol:

It should be possible to support different levels of ARQ on a per flow basis, for example:

1) No ARQ for voice traffic
2) Limited ARQ for TCP traffic - limited number of re-transmissions, such that the number of re-transmissions can be changed.

3) The ARQ protocol should not un-necessarily constrain the peak BW for the flow (by limiting the number of MPDUs per frame, for example).
4) The ARQ protocol should avoid the use of timers to control re-transmissions.
5) The ARQ protocol should enable the link layer parameters and/or size of the MPDU to change between re-transmissions.
6) The ARQ protocol should be robust and recover from various error events, such as loss of ACK packets etc.
7) The ARQ protocol should be simple to implement, and should be able to scale up to hundreds of connections per point to multipoint link
8) Since upstream BW is at premium, the ARQ protocol have the following properties:
9) It should not consume an excessive amount of upstream BW for ACK slots.
10) It should minimize the amount of extra upstream contention request traffic created due to upstream re-transmissions.

6.2.8.2.2 GBN - Downstream Algorithm

1) The BS maintains the reqWinOff, scWinOff, curWinOff and the ackWinOff counters for each flow, at the transmitting end. The reqWinOff counter is incremented when a new CS-PDU arrives, the scWinOff counter is incremented when bytes from the transmit buffer are scheduled, the curWinOff counter is incremented when the bytes actually get transmitted and the ackWinOff counter is incremented when an ACK is received from the receiver. When an CS-PDUs gets scheduled for transmission, the BS creates the MPDU and inserts the curWinOff field into the MPDU header.
2) The SS maintains an ackWinOff counter, on a per flow basis. The value of this counter is set to the sequence number of the next byte that the SS expects to receive. If a MPDU is received correctly, then this counter is incremented by the number of bytes contained in the MPDU. If the MPDU is lost or received in error, then the counter is not incremented.
3) As long as there are bytes in the flow transmit queue that have not been acked, the BS schedules a special ACK packet in the upstream (on a per flow basis). The SS returns the ackWinOff value in the ACK packet. The SS also indicates in the ACK packet whether the last MPDU in the downstream frame was received correctly or in error.
4) If an MPDU is lost, then the SS drops all subsequent MPDUs on that flow, until it receives the one with the expected sequence number. When the BS receives a NACK, it re-transmits all the bytes in the queue with sequence numbers of ackWinOff and greater.
5) If one or more MPDUs are not able to get across after N re-transmissions, then the BS drops the first CS-PDU in its transmit queue. It then continues by sending the next HL- PDU, with the same Sequence Number (curWinOff) as the on that the SS is expecting. When the SS starts receiving a new CS-PDU, it drops the incomplete CS-PDUs that it was trying to re-assemble.

6.2.8.2.3 GBN - Upstream Algorithm

1) The upstream ARQ protocol that is described in this section has the desirable property that all re-transmissions are controlled directly by the BS. This facilitates the operation of the ARQ protocol, since the BS can allocate upstream BW for re-transmissions, without having to be prompted to do so by the SS.
2) The BS updates its own copy of the reqWinOff field by examining the MAC header of REQ and data packets coming from the SSs. It gives upstream data slot allocations in the MAP packet, and updates the scWinOff counter with every grant allocation, by the number of bytes in the payload portion of the grant.

3) On receiving an allocation, the SS creates and transmits the MPDUs, and increments its own copy of the curWinOff counter by the number of bytes in the transmission payload. On receiving an CS-PDU, it increments its copy of the reqWinOff counter by the size of the HL_PDU. It puts the curWinOff and reqWinOff counters in the appropriate fields in the MPDU header.
4) If an MPDU is lost, then the BS detects this and sends a NACK back to the SS. It also allocates BW for re-transmission of the lost MPDUs. When the SS receives a NACK, it rolls back its curWinOff counter and sets it equal to the ackWinOff counter value received from the BS, and re-transmits the data.
5) If an MPDU is not able to get across after N re-transmissions, then the BS sets the flush flag in the ACK. When the SS gets the flush, it drops the CS-PDU at the head of its transmit queue. If there are additional packets in the transmit queue, then it requests BW for them by using the REQ slots.

6.2.8.3 Selective Repeat - General

In the following ARQ discussions in this section, the term PDU (Protocol Data Unit) refers to a unit of retransmission. Since the issue of retransmission unit is a separate from the algorithm itself, we use this generic term in this discussion. The next section specifically talks about retransmission units.

ARQ algorithms can be broadly classified into three types, one with window size of one and two algorithms that support window size greater than one. The ARQ algorithm with window size of one is called Stop-and-Wait (SW). SW significantly reduces the effective throughput of a connection, even under ideal conditions. Therefore, it is important to implement an ARQ algorithm that supports window sizes of greater than one in TG4 systems. Two well-known algorithms, namely Go-back-N (GBN) and Selective Repeat (SR) support windows sizes of greater than one. Both GBN and SR require that the PDUs be numbered and the receiver negatively acknowledges (NACK) lost or corrupted PDUs. Both algorithms can also make use of Cumulative Acknowledgements (CACK) as positive acknowledgements for correctly received PDUs.

In GBN, once the receiver detects a lost or corrupted PDU, it sends a NACK to the sender and discards all subsequent PDUs that are correctly received, until the lost packet is retransmitted or the ARQ mechanism gives up retransmission based on time-outs and/or number of retransmission attempts. Once the sender is notified about a lost PDU, the sender resends all PDUs starting from the lost PDU. Unlike GBN, the SR ARQ algorithm selectively retransmits only the lost PDUs. There are many variations of SR. However, in this submission we consider a variation of SR that uses CACK and bitmap-based ACK. A bitmap-based ACK combines the benefits of a cumulative ACK and a set of positive and negative ACKs into one message. In terms of CACK traffic, the SR algorithm has the same overhead of GBN.

The advantage of SR over GBN is its optimal use of over-the-air bandwidth. SR only retransmits the lost PDUs, whereas GBN retransmits all PDUs starting from the lost PDU, including those correctly received by the receiver. It is possible for a correctly received PDU to be retransmitted multiple times with GBN. Note that in both schemes, the sender has to buffer PDUs until the number of retries is exhausted. In SR, the receiver has to buffer all correctly received PDUs and deliver the PDUs in order to the upper layer. While this increases the amount of memory required in the receiver, the performance improvements justify the increased memory requirements at the receiver. Since the bandwidth-delay product of the TG4 systems will be very small, large window sizes are not needed and small window sizes would not require significant memory in SS and BS. In general, the performance of GBN is closer to SR only in very low error environments, whereas SR performs better than GBN in all environments. Therefore, we suggest that the SR ARQ be specified as a default ARQ algorithm or one of the optional ARQ algorithms for TG4 systems.Retransmission Units and Changing Link Conditions

In this section we discuss retransmission units to be used with Selective Repeat ARQ described in the previous section. Note that the algorithm described in the previous section is independent of a particular retransmission unit and can work with different retransmission units. While it is important to design an ARQ protocol that is robust and adapts to link conditions, the complexity of the implementation must also be kept in mind. Due to changing link conditions, the amount of data that can be sent varies from frame to frame. This along with the adaptive modulation makes the BWA scheduler to deal with a varying capacity channel. It is important not to unnecessarily complicate the amount of work needed by scheduler when ARQ is enabled. Also, the choice of retransmission unit should not assume any particular type of PHY or optional features that may or may not be implemented by all systems.

We do not consider retransmission at the Convergence Sub-layer PDU (CS-PDU) level. Since the ARQ is implemented at the link-layer, the retransmission unit should be specified at the MAC PDU (MPDU) level. Moreover, with large CS-PDU sizes, CS-PDU-level retransmission could cause significant problems and severely affect the effective goodput of the system. In summary, the specification of a retransmission unit must meet the following requirements:

1) Should not increase the overhead of a connection that has ARQ disabled.
2) Should not unnecessarily complicate the scheduler implementation on BS.
3) Should not assume any 802.16 MAC optional features being available with ARQ. For example, it should work with or without optional features such as fragmentation and packing.
4) Should support varying MPDU sizes between retransmissions. But this should not increase the overhead of systems that do not change MPDU sizes between retransmissions.

6.2.8.3.1 MPDU Sequence Number based Retransmission and its Advantages

Since the ARQ is implemented at the MPDU level, the natural choice for the retransmission unit is the MPDU. The MPDUs are given a sequence number when they are created [1]. MPDUs are retransmitted when the sender is notified about lost MPDUs. Note that this MPDU-Sequence Number (MPDU-SN) approach does not add complexity to the scheduling mechanism. This also makes no assumption about the optional features of 802.16 MAC. This would work with or without packing and/or fragmentation. In addition, with fragmentation, the MPDU sequence number along with Fragmentation Control (FC) bits can be used to re-assemble CS-PDUs reliably, even if ARQ is disabled (FSN is not needed). This does not increase the overhead, when ARQ is disabled. The number of bytes to be added for the FC and MPDU-SN fields can be a variable (one or two bytes), depending on the desired maximum window size and whether ARQ and/or Fragmentation are enabled. The TYPE field in 802.16 Generic MAC Header can be used to control the number of additional bytes present. If packing is enabled, the MSDU-SN based scheme can be used without any modifications. In this case, a single MPDU may have one or more fragments of a CS-PDU. The MPDU-SN based retransmission does not require that the fragmentation state be changed between retransmissions. Moreover, if encryption is enabled for this connection, an MPDU-SN based retransmission scheme does not require the retransmitted unit be re-encrypted.

6.2.8.3.2 Changing Link Conditions and Adaptive Modulation

When link conditions change and with adaptive modulation, there may be certain circumstances where the MPDU cannot be resent with the same size. In these scenarios, it may be desirable to support ARQ where the size of the retransmitted unit be allowed to change (i.e., reduce in size) between retransmissions. With SR ARQ and no packing, allowing the retransmission unit to reduce the size between retransmissions may result in wastage of bandwidth, as the retransmitted units will be fragmented across multiple MPDUs. However, if packing is enabled, changing retransmission unit can be implemented with some additional overhead. Even with adaptive modulation, it is possible to keep the MPDU size the same, by varying the number of PHY slots required to transmit the same amount of data between modulation changes. Such implementations can use the MPDU-SN based scheme described in the previous subsection.

One possible approach to deal with change in MPDU size is to implement a numbering scheme similar to the one proposed in [2]. This would use two sequence numbers, one based on the CS-PDU and another based on the CS-PDU fragment. This approach does assume fragmentation and packing being enabled for ARQ enabled connections. If this approach is followed, the pair {CS-PDU-SN, FSN} identifies a fragment, where FSN (Fragmentation Sequence Number) is the sequence number of the fragment within a CS-PDU. This scheme allows the fragments be retransmitted independently. While this scheme provides some flexibility in retransmission when link conditions change, this does come with a cost. The disadvantages include, increased scheduling complexity, re-encryption of the MPDU (if encryption is used), and overhead associated with having two sequence numbers. Especially when the CS-PDU sizes are small and if multiple CS-PDUs are typically sent in a single MPDU, the overhead associated with additional sequence numbers can be high.

6.2.8.3.3 Conclusion

We have presented our arguments for Selective Repeat ARQ to improve the performance of TG4 systems. We have presented our arguments in support of a MPDU-SN based scheme that uses MPDUs as retransmission units. The {CS-PDU-SN, FSN} scheme can be supported as an optional sequence numbering method for TG4 SR ARQ.

6.2.8.3.4 References

[1] A Proposal for the Enhancement of the 802.16.1 MAC to Provide a per-Service Flow Reliable Connection Service, 802.16.4c-01/10, by Jacob Jorgenson, Ken Peirce and Subbu Ponnuswamy, Malibu Networks, Inc.

[2] Data Integrity in 802.16.4 MAC, 802.16.4c-01/06, by Naftali Chayat, Vladimir Yanover, and Inbar Anson, BreezeCOM Ltd.

6.3 MAC Sublayer - Common Part - Management Plane

6.3.1 MAC Sublayer - Common Part - Service Interface Specification

6.3.2 MAC Sublayer - Common Part - MIB Definitions

Insert the new subclause after 6.3.2

6.4 Dynamic Frequency Selection

Insert the new subclause after 6.4

6.5 Coexistence with other 802.16b Systems

8.PHY Layer

8.2.7.3 Power Control

Please modify this subclause as shown:

<u>The requirements for power control varies with the bands being used.</u>

<u>8.2.7.3.1 Frequency Bands 10 - 66GHz</u>

As with frequency control, a power control algorithm should be supported for the uplink channel with both an initial calibration and periodic adjustment procedure without loss of data. The base station should be able to provide accurate power measurements of the received burst signal. This value can then be compared against a reference level, and the resulting error can be fed back to the subscriber station in a calibration message coming from the MAC layer. The power control algorithm should be designed to support power attenuation due to distance loss or power fluctuations at rates of at most 10 dB/second with depths of at least 40 dB.

8.2.7.3.2 License Exempt Bands

The use of a Power Control IE is required to provide a faster Power Control mechanism than that provided by periodic Ranging protocol. This is a requirement of the license exempt environment.

8.2.7.3.2.1 Power Control Steps

The anticipated power control on a link at 5.25-5.35 and 5.725-5.825 GHz will span a dynamic range of 51 dB. This gain variation is what can be expected between a BS antenna and a SS that is located anywhere from 50 to 2000 meters from the BS (radiating at either 23 dBm/MHz or 17 dBm/MHz).

Note that both the BS and the SS must have a dynamic power range of 51 dB.

Step size of power control range will be 3 dB and the power levels shall provide monotonic transmission power.

For operation in the 5725-5825 MHz band the power control will be set in the following steps in terms of EIRP spectral density (dBm/MHz):

23 20 17 14 11 8 5 2 -1 -4 -7 -10 -13 -16 -19 -22 -25 -28

For operation in the 5250-5350 MHz band the power control will be set in the following steps in terms of EIRP spectral density (dBm/MHz):

17 14 11 8 5 2 -1 -4 -7 -10 -13 -16 -19 -22 -25 -28 -31 -34

8.2.7.3.2.2 Downlink Power Control

The permissible EIRP values are provided in the previous section. The downlink EIRP will be provided in a MAC management message detailed in section 6.2.2.2.

8.2.7.3.2.3 Uplink Power Control

The uplink channel EIRP will be calculated by the SS using the RSSI information, Downlink EIRP characteristics obtained from the DCD message, and other information such as modulation to be used, etc. The uplink channel EIRP will be set on a packet-by-packet basis by the SS. Same applies to all mesh mode transmissions with the exception of the Mesh Scheduling Message transmission (see 2.1). The calculation of this EIRP will be undertaken by control layers operating above the IEEE 802.16.4 MAC and PHY layers. These upper layers will also control the setting of the EIRP in the SS PMD system. EIRP will be set in steps as described above. There will be no other MAC messages giving indication of the EIRP setting of the uplink channel EIRP by the SS. TBD are the uplink EIRP margin settings so as to ensure a specified PER or BER for the modulation that is chosen by the SS.

8.2.7.3.2.4 Uplink Power Control in the Ranging Request (RNG-REQ) Message

The current IEEE 802.16.1 MAC allows the SS, upon initialization and thereafter, to periodically request that the BS determine network delay and request transmit power settings for the SS. This request is undertaken using a Ranging Request Message (RNG-REQ Sec 6.2.2.2.5) . In response to this request, the BS transmits a Ranging Response (RNG-RSP) message (Sec. 6.2.2.2.6) which carries TLV encoded information that specifies the relative change in the transmission power level (EIRP) that the SS is to make in order to insure that transmissions arrive at the BS at the desired power level. The amount of power correction is sent as a Type 2 message with a length of 1 byte. The value it carries is a TX power offset adjustment, represented as a signed 8 byte and having 0.25 dB resolution. It should be noted that the RNG-RSP message can be sent at anytime and the SS must be prepared to receive and act on it accordingly.

The SS power control messages as embodied within the RNG-REQ and RNG-RSP messaging will be maintained. The power control information will be used by the upper control layers to determine the EIRP that the SS transmits (and can theoretically adjust) on a packet-by-packet basis. This power control information is useful to the SS since it will tell the SS whether it is calculating the correct EIRP for its packet transmissions. The response from the BS will indicate the effect of factors (such as co-channel interference not measured by the SS) that degrade the reception of its signals at the BS.

9. Configuration File

10. Parameters and Constants

11. TLV Encodings

12. Bibliography

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