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| Purpose | This document will be the focus of a call for comments. |
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# Strawman Text for the TG4 MAC Standard

# 1 Introduction

This strawman document is a simple compilation of text submitted by small teams within the TG4 MAC team. These teams were formed at Session 11.5 of volunteers. The TG4 MAC team discussed the solutions to a list of topics generated at Session 11. Small teams were then formed and charged with putting into text those MAC elements on which the group had formed consensus. In cases where consensus could not fully be reached, alternatives are included in this document. This document is to be the target of a call for comments. The purpose will be to further refine the preliminary solutions addressed in this group-generated strawman. Only formatting and grammar changes have been made to increase readibility. Section headers and line numbers have been added to assist in identifying elements for discussions.

# 2 Ranging and Frame Synchronization

1. At initialization an Initial Ranging is done in two steps:
   - Coarse ranging in an Initial Maintenance contention window.
   - Fine ranging in an individual Station Maintenance window.

   Initial Maintenance window shall be maximum round trip propagation delay (desired cell radius) plus maximum allowable implementation delay.
   We should not worry about a priori specification of maximum round trip propagation delay because Initial Maintenance region size shall be specified in UL-MAP message. Then this should be up to the Service Provider function of BS/SS capabilities and desired cell radius .

2. A Periodic Ranging shall be done for parameters adjustment including power control. In Table 67 are provided T2, T3, and T4 timers for Ranging.
   The timeout values could be modified in response to TG4 needs if necessary.

For the case where tighter power control is needed, there are two alternatives:

- Increase the number of unicast ranging opportunities for each SS in order to do a more dynamic power control. That implies modification of T4 counter but increase the overhead and implicitly decrease bandwidth.
- Or use the IE on the UL-MAP message to transmit when necessary a power adjustment parameter. When BS wants to tell any SS to adjust the power it could be done through an extended IE (UIUC=15).
  This gives you the choice to adjust SS transmitted power as much as you need as UL-MAP is sent every frame.

### 2.1 Conclusions

There doesn t appear to be any reason to make basic changes in the Ranging mechanism from the TG1 Draft. However Table 64 shall be modified as a function of TG4 requirements in which case we should not worry about timers modification.

With this issue comes again the problem of Burst Type and IE definitions. Given the fact that TG4 is at the beginning of its work and PHY parameters and framing concept will be different from TG1, we propose moving Tables 4 and 5 to section 10.
This change will give us the liberty to do changes and to define our IE and Burst Types.

## 3 MAP Flexibility in Burst Type definition

### 3.1 References

[1] IEEE 802.16/D2 - 2001, Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems

### 3.2 Abbreviations and Acronyms

| | |
|---|---|
| DCD | Downlink Channel Descriptor |
| UCD | Uplink Channel Descriptor |
| IE | Information Element |
| DIUC | Downstream Interval Usage Code |
| UIUC | Upstream Interval Usage Code |

### 3.3 Problems

Following the discussions from Session #11 and Session #11.5, we realized that the definition of Burst Types (Table 4,5) and Uplink Map Information Elements might not be appropriate for TG4 PHY layer.

Reasons:

- There are three possible modes of FFT size defined: 64,256,1024
- Guard interval size: 1/32,1/16,1/8,1/4
- Modulation: BPSK, QPSK, 16QAM, 64QAM
- Coding: Convolutional 1/2,2/3,3/4, Reed-Solomon (?), turbo-coders (?)
- Preamble: none/shortened (midamble)/full preamble.

Even if we take 802.11a as a baseline, 8 possible burst types with/without preamble requires a larger list of Burst Types and Information Elements. Given the channel conditions for UNII bands we will need a robust adaptive modulation mechanism, power control and greater freedom to change the modulation or/and the FEC parameters.

Even if we presume that we shall constantly use just one set of (FFT size, GI size) we have to be able to dynamically specify changes in coding and modulation as well as the presence/absence of preamble symbols.

### 3.3.1 DIUC.

The above observations suggest that 16 values of DIUC type (table 4) may not be enough.
However the odds of using more than 12 Burst Types per frame is very small and the DCD message lets us change Burst Type parameters if required. The point is that we will need the change more often than TG1 specifies and it may be better to study the possibility to have a larger table at the expense of an additional overhead in DL-MAP message.

### 3.3.2 UIUC.

Same problem but more important is the IE type definition (table 5) as well as the size of IE in UL MAP message. Because of the channel characteristics on the uplink transmission it is very likely that we will have to use more than 6 Data Grant Burst Types and change them in a dynamic manner. Only existing choice right now is the Expansion IE (value 15) which gives a number (?) of additional 32-bit words in the IE. That will give us a constant overhead of 4 bits (expanded UIUC) and an increased complexity of UL-MAP interpreter.

Keeping the same tables will result an additional table on what the expanded IE means and keep the value of UIUC =15. That will make the document more complicated perhaps, than necessary, aside from implementation-related complications.
However these definitions are very tight linked to PHY parameters.

## *3.4 Proposed Changes*

Given the fact that using only the Expansion IE will lead to a constant overhead and a new definition table of expanded IE s we propose the following changes in the Draft Document, one of them based on minimal changes and the second based on more changes but giving us a large freedom on how to handle these issues.

### 3.4.1 Minimal Necessary Changes

- Move Table 4 Mapping of Burst Type to Downlink Interval Usage Code in Section 10 Parameters and Constants , eventually in 10.1.1 PHY-Specific Values .
- Move Table 5 Uplink Map Information Elements in Section 10 Parameters and Constants , eventually in 10.1.1 PHY-Specific Values .

### 3.4.2 Additional Desirable Changes.

- Modify Figure 28 — Uplink MAP Message Format (?) To avoid explicit specification of IE size and length of UIUC and Offset.
- Modify Figure 27 — Downlink MAP Message Format (?) to avoid explicit specification of DIUC and Start PS length.
- Modify Figure 24 — Top-Level Encoding for a Burst Descriptor to avoid explicit specification of UIUC length.
- Modify Figure 26 — Top-Level Encoding for a Downlink Burst Descriptor to avoid explicit specification of DIUC length.
- Page 57, line 50: a UIUC instead of a four bit UIUC
- Page 66, line 35: A Uplink Interval Usage Code (UIUC) instead of A four-bit Uplink Interval Usage Code (UIUC)
- Page 60, line 47: a DIUC instead of a four bit DIUC

## *3.5 Conclusions.*

In summary, we propose the following set of modifications:

**Move Tables 4 & 5 from section 6 to section 10.**
This kind of modification will address part of the problem but will need some specific explanations, because in some paragraphs and figures are implicitly specified the size of discussed parameters.

# 4 Power Control

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 CPE that is located anywhere from 50 to 2000 meters from the BS (radiating at either 23 dBm/MHz or 17 dBm/MHz).

Both the BS and CPE will 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

### 4.1 MAC Encoding Requirements and EIRP Setting On the Downlink Channel.

The downlink of the BS is shall operate at an EIRP given above. The duration over which it remains fixed will be dependent on the type of system that is operating. In a directive antenna type system, the fixed EIRP may be maintained for very long periods and may be changed only occasionally over the lifetime of the link. In a mesh system, the downlink EIRP rules shall apply to Mesh Scheduling Message transmission which does specify the range of the transmitting node. In this respect, each node of a mesh system shall act as a BS at a time of Mesh Scheduling Message transmission. In both instances the EIRP will be determined by control layers operating above the IEEE 802.16.4 MAC and PHY layers, and as such, are not relevant to this description. These upper layers will control the setting of the EIRP in the BS PMD system and will provide the information to the MAC for message formatting.

The downlink EIRP shall be sent out as a MAC Management Message, detailed in Section 6.2.2.2 of

Ref 1. The downlink EIRP will be contained in the Downlink Channel Descriptor Message (DCD) as a TLV tuple, as described in 11.1.2.1-DCD Channel Encodings. The TLV message is Type 2 with a 1 Byte Length. The units shall be signed EIRP Power values given the above ranges. The downlink transmit power will also be included in a new optional RFMM (Radio Frequency Management Message) that will form another type of management message.

### 4.2 Uplink Channel 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 in Paragraphs 1.4 and 1.5 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.

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

The current IEEE 802.16 MAC allows the SS to on initialization and thereafter, periodically request the BS to 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 of Ref 1) . In response to this the BS transmits a Ranging Response (RNG-RSP) message (Sec 6.2.2.2.6 of Ref 1) which carries TLV encoded information that specifies the relative change in the transmission power level (EIRP) that the SS is to make in order that transmissions arrive at the BS at the desired power. The amount of power correction is sent as Type2 message of length 1 Byte, the value of which is a TX power offset adjustment as a signed 8 bit byte having _ dB resolution. It should be noted that the RNG-RSP message can be sent 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.

# 5 Mesh Mode

The IEEE 802.16 TG4 system shall have an optional mesh mode. On contrary to the basic point-to-multipoint mode (section 6 in TG1 MAC), there are no clearly separate downlink and uplink in the mesh mode. Each station (BS or SS) shall be able to create direct communication links to a number of other stations in the network instead of communicating always directly with the BS.

The stations which a station have 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 shall ensure collision-free scheduling.

For the transmission coordination there is a specific control period in the beginning of each MAC frame in which each station shall transmit periodically its own schedule (5.1) on a point-to-multipoint basis to all its neighbors. Within a given frequency channell, all neighbor stations receive the same transmission, i.e. the Mesh Schedule messages. All the stations in a network shall use this same given channel to transmit schedule information in a format of specific resource requests and grants. An unique schedule transmission slot shall be dettermined with the aid of two-hop neighborhood addresses.

In normal scheduled transmissions stations shall act like either a BS or a SS in uplink in a point-to-multipoint mode. When transmitting, the station has been granted some bandwidth it has earlier requested from a neighbor, and the station acts like a SS in uplink direction. When receiving, the station has granted some bandwidth earlier requested by its neighbor, and the station acts like a BS in uplink direction.

## 5.1 New MAC Management Message: Mesh Schedule (MSCH)

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.

A node shall generate MSCHs in the format shown in Table 1.

| 6 Packet section | Length |
|---|---|
| Generic Header | 6 bytes |
| Nr requests | 4 bits |
| Nr grants | 4 bits |
| List of request IEs | Nr req * 4 byte |
| List of grant IEs | Nr grnt * 4 byte |
| Extension IE | Variable |
| CRC-32 | 4 bytes |

Table 1. Contents of the MSCH message.

The transfer syntax of each of the information elements of the MSCH message are illustrated in Figure 1 through Figure 3. Various fields are respectively described in Table 2 throughTable 4.

| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| Octet 1 | Start frame offset | | | Posi… | | | | |
| Octet 2 | tion | | Node ID | | | | | |
| Octet 3 | Duration | | | | Channel | | | |
| Octet 4 | Pers/Pri | | | | PHY mode | | | |

Figure 1. Transfer syntax of the request IE.

| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| Octet 1 | Start frame offset | | | Posi… | | | | |
| Octet 2 | tion | | Node ID | | | | | |
| Octet 3 | Duration | | | | Channel | | | |
| Octet 4 | Pers/Pri | | | | Mode | Rsvd | | |

Figure 2. Transfer syntax of the grant IE.

| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Octet 1 | Extension Identifier |
| Octet 2 | |
| Octet .. | |
| Octet M | |

Figure 3. Transfer syntax of the extension IE.

| Name | Length | Purpose |
|---|---|---|
| Start frame offset | 3 bit | Start frame identifier as frame offset: 0=current, 1=next, etc. |
| Position | 7 bit | The start position of the reservation in 4-tick blocks |
| Node ID | 6 bit | Identifies the destination node |
| Duration | 4 bit | The number of PSs reserved |
| Channel | 4 bit | Logical frequency channel number |
| Pers/Pri | 4 bit | Persistency/Priority field |
| PHY mode | 4 bit | Indicates the PHY mode used in the requested channel |

Table 2. Contents of the request IE.

| Name | Length | Purpose |
|---|---|---|
| Start frame offset | 3 bit | Start frame identifier as frame offset: 0=current, 1=next, etc. |
| Position | 8 bit | The start position of the reservation |
| Connection ID | 6 bit | Identifies the connection |
| Duration | 6 bit | The number of PSs reserved |
| Channel | 4 bit | Logical frequency channel number |
| Pers/Pri | 4 bit | Persistency/Priority field |
| PHY mode | 1 bit | 0= as requested, 1= reduce mode |
| Rsvd | 3 bit | For future use |

Table 3. Contents of the grant IE.

| Name | Length | Purpose |
|---|---|---|
| Identifier | 8 bit | Identifies the extension field (defines also the length of the field) |
| Extension data field | 8*(M-1) bit | The actual content of the extension element |

Table 4. Contents of the extension IE.

### *6.1 MAC support of PHY layers (6.2.6 in [1])*

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:

- divided into an integer number of physical slots
- 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 specific MAC Management messages (MSCH) are used to define the usage of the rest of the TDD frame. First TBD PSs in the beginning of the frame shall be reserved solely for MSCH transmission.

# 7 ARQ Solution Options (2)

## *7.1 Go-Back-N*

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.

- The ARQ protocol should not un-necessarily constrain the peak BW for the flow (by limiting the number of MPDUs per frame, for example).
- The ARQ protocol should avoid the use of timers to control re-transmissions.
- The ARQ protocol should enable the link layer parameters and/or size of the MPDU to change between re-transmissions.
- The ARQ protocol should be robust and recover from various error events, such as loss of ACK packets etc.
- The ARQ protocol should be simple to implement, and should be able to scale up to hundreds of connections per point to multipoint link
- Since upstream BW is at premium, the ARQ protocol have the following properties:

1. It should not consume an excessive amount of upstream BW for ACK slots.
2. It should minimize the amount of extra upstream contention request traffic created due to upstream re-transmissions.

### 7.1.1 Downstream ARQ Protocol

- 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.

- 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.
- 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.
- 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.
- 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.

### 7.1.2 Upstream ARQ Protocol

- 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.
- 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.
- 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.
- 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.
- 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.

## 7.2 Selective Repeat Algorithm and its Advantages

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 timeouts 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:

- Should not increase the overhead of a connection that has ARQ disabled.
- Should not unnecessarily complicate the scheduler implementation on BS.
- 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.
- Should support varying MPDU sizes between retransmissions. But this should not increase the overhead of systems that do not change MPDU sizes between retransmissions.

### 7.2.1 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.

### 7.2.2 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.

### 7.2.3 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.

### 7.2.4 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.

# 8 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)

## *8.1 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).

### 8.1.1 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

## *8.2 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, Ref 1)

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.

## 8.3 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 of Ref. 1. 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 of Ref. 1.

This procedure being completed the SS would then normally proceed with the establishment of IP connectivity, as per Section 6.2.7.8.1 of Ref 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 Ref 1). 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 following settings:

## 8.4 TLV Configurations for SS Transmitted DFS-REQ Messages

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

Vendor ID of SS
Base Station ID (current)
Downlink Channel Configuration Setting(current)
Uplink Channel Configuration Setting (current)
Downlink ID, Channel EIRP, mean RSSI, mean CCI, CCI variance, RSSI variance, 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)

### 8.5 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 uniques to either the Mesh or Directive Antenna systems). The SS would respond to this message by sending the MAC management message described in Section 1.6.
The TLV configuration of this message would be :

Vendor ID of SS
Base Station ID, Downlink ID (1st channel to measure)
Base Station ID, Downlink ID (Nth channel to measure)

### 8.6 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:

Vendor ID of SS
Base Station ID (assigned )
Downlink ID (assigned)
Downlink Channel Configuration Setting (assigned)
Uplink Channel Configuration Setting (assigned)
Uplink EIRP setting (assigned)

## 9 Co-Existance

The RFMM 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.

### 9.1 Radio Frequency Management 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

## *9.2 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.

## *9.3 Contents of RFMM*

The RFMM must contain enough information so that adjacent base stations will be able to calculate the level of co-channel interference they could introduce by their own activity and how much they could also sustain caused by the activity of other adjacent base stations.

CCI can be predicted if there is some knowledge of the radiation and frequency characteristics of the adjacent bases stations. The following parameters are important to the calculation of CCI:

EIRP of the adjacent base station
Frequency of the EIRP
Direction of the EIRP
Spread of the EIRP ( antenna directivity)
Geographical Location of the EIRP
Height of EIRP Radiator
Range of between BS (EIRP radiator) and SS.

The geographical location of the BS can be provided as a GPS derived coordinate, which can be programmed into the BS on its deployment. Other parameters such as the height of the BS antenna, the direction of its antenna with respect to an easily derived reference such as Magnetic North, the beamwidth and of the antenna beam would also be programmed into the BS by the user on deployment. The EIRP and Frequency would be radiation factors derived autonomously by the BS. The range between the BS and the SS would be determined by the BS; each SS range from the BS would be included in the parameter list as the SS registered with the BS.

## *9.4 Proposed HBS-RFMM Message*

It is proposed that the RFMM be configured as a MAC management message with the CID value set to {OXFFFF}. Furthermore it is proposed that the Management Message Type Field be set to a new value (currently reserved in the Ref 1) of 25, to indicate a message that will be called a HBS-RFMM (for hub/base station RF Management Message). The TLV encoded information will follow which will include:

Base Station ID
Downlink ID
Base Station Height (Optional)
Base Station GPS coordinate
.
.
.
Beamwidth of Antenna (1) in degrees
EIRP of Antenna(1)
Magnetic Bearing of Antenna(1) in degrees (optional)
Channel Frequency of Antenna (1)
SS (1) Range, EIRP(optional)
.
.
SS (n) Range, EIRP(otptional)
.
.
.
.
Beamwidth of Antenna (N) in degrees
EIRP of Antenna(N
Magnetic Bearing of Antenna(N) in degrees(optional)
Channel Frequency of Antenna (N
SS (1) Range, EIRP(optional)
.
.
SS (n) Range, EIRP(optional)

*Note: A base station can have (1 N) antennas co-located at the same GPS coordinate and height*
*An antenna can have (1 .n) SS stations in operation .*

## *9.5 Reception of the HBS-RFMM*

The HBS-RFMM 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 of Ref 1. Once synchronization is achieved and DL-MAP MAC management messages are received the receiver will have to wait for the HBS-RFMM. 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-RFMM messages.

## *9.6 References*

REF 1: IEEE 802.16/D2-2001, February 2001 *Draft* Standard Air Interface for Fixed Broadband Wireless Access Systems