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802.16s Air Interface Considerations

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**Objectives:**

1. Establish long haul Point to Multipoint (PtMP) mission critical private network. This is motivated by:
   * Remote areas are not well covered by the public communication provider networks.
   * The network is mission critical and as such, it cannot be shared with non-mission critical lower priority consumer market applications.
   * As a mission critical system, the network needs to survive disasters. In a case of failure, the mean time/maximal time to repair is under the control of the network owner.
   * Given the criticality of the system, it should meet strong federal CIP security requirements.
   * Traffic characteristics uncommon or not supported by consumer market networks, e.g., reverse asymmetrical traffic and non-routable protocols.
2. Affordable acquisition of frequency license for private network operation requires the 802.16s standard to support a wide range of bands and channel size. It is proposed to support a channel sizes between 100 KHz and 1.25 MHz.
3. Support fixed and mobile broadband services in a unified network. Applications include:
   * Distributed Generation control (an emerging application driven by residential solar panel deployment).
   * SCADA
   * AMI Backhaul
   * Distribution Automation
   * Mobile Workforce Management
   * Video surveillance

1. Support a Base Station service area up to a radius of 40 miles. This is motivated by:
   * Low cost infrastructure deployment with a low density of endpoints.
   * The ability to deploy a network based on the available PLMR tower footprint. Additional towers are expensive, may take a long time to deploy and in some cases may not be permissible.
2. Non-line-of-sight. This is motivated by:
   * Deployment flexibility and cost
   * Low antenna applications (e.g., antenna installed at residences in the case of the distributed generation application).

1. Flexible Bandwidth Allocation. This is motivated by:
   * Service territories containing a mixture of high- and low-density sectors.
   * Different networks will have different traffic patterns (symmetrical, asymmetrical and reverse asymmetrical)
2. Total throughput per sector up to 6 Mb/s. This is motivated by:
   * Certain endpoints require continuous or momentary high speed (e.g., video surveillance)
   * Traffic aggregation to/from a very large number of end points.
   * Deployment of new Intelligent Endpoint Devices (IEDs), many now incorporating web server functionality.
3. Latency requirements: One way latency as low as 10 ms for small packets. This is motivated by certain applications which require very fast response time. E.g. Distribution Automation (DA) and distributed generation.

**Considerations:**

1. OFDM/OFDMA is the preferred PHY layer technology due to its superior multipath performance and the sub-channel structure which enables flexible multi-sector and multi-cell deployments. PAPR can be addressed by using low FFT schemes, e.g., 128 FFT. This will further help maintain a healthy subcarrier spacing as the channel size is reduced.
2. Traffic patterns (symmetrical, asymmetrical and reverse asymmetrical) will vary between networks. This implies the air interface should have flexibility in configuring the number of OFDMA symbols in the downlink subframe and in the uplink subframe (referred to as the DL: UL ratio). It is suggested that ratios should be variable between to 10:1 and 1:10.
3. As a consequence of the variable traffic characteristics, Time Division Duplex (TDD) operation is considered to offer significant throughput advantages over Frequency Division Duplex (FDD). The throughput in the one direction can be dramatically increased if the requirement in the other direction is negligible.
4. Tower installations may use 1 omnidirectional antenna, or 2, 3 or 4 sector antennas. Depending on the type of deployment, it is desirable to support operation of a sector using any subset of downlink and uplink sub-channels. For example, if a re-use plan of (1,3,3) is required 6 sub-channels may be deployed using 2 downlink and 2 uplink sub-channels in each sector.
5. A consumer market WiMAX system leverages the relatively large number of sub-channels and the asymmetrical traffic characteristics (i.e., much higher throughput required in downlink than in uplink direction) to balance the link budget. I.e., the Base Station transmits at high power over the full channel while the Remote Stations transmit at a relatively low power over few sub-channels only. To support symmetrical or reverse asymmetrical traffic characteristics, the required number of sub-channels used by a Remote Station to transmit in the uplink direction, depending on the application, may be similar or even higher than the number of sub-channels required for downlink communication. A balanced system requires therefore the Remote Stations to be able to transmit at a similar power level as the Base Stations.
6. Support of 40 miles radius translates into a round trip delay of 430 µs. In order not to exceed the minimum necessary TDD timing gaps overhead, the actual gaps should be configurable according to the longest distance in the network. The configuration should support however a maximal value of BS TTG = 430 µs plus the minimum required receive to transmit switching time.
7. The relatively narrow channel sizes in scope do not offer much benefit in frequency diversity. Continuous subcarriers per sub-channel offer greater flexibility to reduce interference in both transmit and receive directions.
8. Significant reduction in subcarrier spacing relative to the 10.94 KHz of the WiMAX standard is not recommended because it introduces Inter-Carrier Interference due to poor orthogonality.
9. The channel sizes in scope are relatively narrow and therefore a large number of pilots to measure the frequency response of the channel is not required. This consideration, and the need to reduce overhead as much as possible, suggests that AMC permutation is better suited for this system than PUSC in both the downlink and uplink directions. For example, a downlink PUSC system employs 4 pilots per sub-channel vs 2 pilots per sub-channel in AMC 2x3.
10. Efficient use of a relatively narrow channel requires alignment of all phases of communication into the same band, i.e., the downlink subframe, the uplink subframe, the preamble and the CDMA code should all employ the same set of subcarriers.
11. Frame Duration: Some applications require very low latency and therefore a frame duration of 5 ms should be supported. On the other hand, delay tolerant applications may require high throughput which becomes more efficient with an increase in frame duration due to the reduction in the per frame overhead and reduced fragmentation. It is suggested that frame durations up to 50 ms should be supported.
12. The use of multiple zones in downlink and uplink sub-frames offers the opportunity to create groups of Remote Stations in the sector and optimize certain parameters for each of the groups. The downside however is the related inefficiency. It is suggested to support a single AMC zone in the downlink and in uplink directions.

1. Support of the FCC Spectrum emission mask applicable to various target frequency bands requires high attenuation at the edge of the channel. For example, FCC Part 27 (applicable to the upper 700 MHz A block) requires attenuation at the edge of the channel exceeding 43 + 10 log (P) in dB where P is the transmit power in watts. Thus, if the transmit power of the radio is 10 Watts, the attenuation at the edge of the channel should exceed 53 dB. The guard band required from the edge of the channel depends on the transmit power level required, the type of Power Amplifier used, the power back off and the performance of the Digital Pre-Distortion (DPD) mechanism. Price constraints may dictate the guard band size and therefore, it is suggested to use one of the following flexible solutions:
   * Allow for a configurable sampling clock which can be adjusted as needed to support the FCC requirement
   * Use AMC 1x6 permutation (12 sub-channels with 9 consecutive subcarriers per sub-channel including one pilot) and remove sub-channels on the edge to create the guard band needed
2. Maximization of throughput is accomplished by:
   * Maximizing FEC code in both the downlink and uplink.
   * Reducing per frame overhead by support of longer frame duration if the applications can sustain the latency.
   * Reducing 802.16 protocol overhead
   * Dynamic Packet Header Suppression (PHS)