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Re:	IEEE 802.20 Session#1 Call for Contributions
Abstract	This contribution discusses desired characteristics and gives numerical guidelines for an MBWA Air Interface
Purpose	For informational use only
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Desired Characteristics for a Mobile Broadband Wireless Access Air Interface

1 Introduction

The purpose of this document is to discuss desired parameters for an air interface for Mobile Broadband Wireless Access (MBWA) system. These parameters are motivated by the desire to create an MBWA Air Interface (AI) that is optimized for providing high-speed IP-based data transport over a wireless link to data-oriented devices. This system is targeted at existing and future licensed frequency bands, deployable in configurations typical of wireless cellular networks.

The wireless modem for accessing the cellular network using the MBWA AI may be either directly integrated into data devices or be connected to data devices via a communication interface (e.g., PCMCIA, USB, ethernet). These data devices include handheld and portable devices such as laptop computers, Personal Digital Assistants (PDAs), digital cameras, mobile phones (as a data complement to voice-oriented wireless networks) and mobile gaming devices. In addition, the wireless modem can be embedded in larger platforms such as automobiles or desktop computers. The IP-based applications include, but are not limited to, data and real-time applications such as full Internet web browsing, e-mail, file upload and download without size limitations (e.g., FTP), video and audio streaming, VPN connections, Voice over IP (VoIP), instant messaging (IM) and on-line multi-player gaming.

Some desired characteristics were presented for the MBWA Air Interface in a document on "Initial Views on Desired Characteristics" (802m_ecsg-02/08). Parameters from this document were incorporated into the PAR for the 802.20 Working Group (802.20-02-01), and are summarized in the following table:

Table 1: Parameters given in PAR for IEEE 802.20

Characteristic	**Value for** 1.25MHz paired FDD 2.5MHz unpaired TDD
Spectrum	< 3.5 GHz
Peak user data rate (DL)	> 1 Mbps
Peak user data rate (UL)	> 300 Kbps
Peak aggregate data rate per cell (DL)	> 4 Mbps
Peak aggregate data rate per cell (UL)	> 800 Kbps
Mobility	Up to 250 km/hr
Spectral efficiency (sustained)	> 1 b/s/Hz/cell
Airlink MAC frame RTT	<10 ms

Here are some comments regarding the characteristics in this table:

- **Spectrum:** The AI should be designed for deployment within existing and future licensed spectrum below 3.5 GHz, since this range covers the typical practical range for cellular wireless deployments for mobile services.
- **Channelization:** The MBWA system frequency plan should include both paired and unpaired channel plans, and allow channel bandwidths (e.g., 1.25 MHz) suitable for deployment in existing licensed frequencies and co-deployment with existing or planned cellular systems.
- **Peak Data Rates:** This table gives peak user data rates and peak aggregate data rates for the case of 1.25 MHz (or equivalently 2.5 MHz of unpaired TDD spectrum). These numbers would scale for other channel bandwidths. Note that the peak data rates are a function of the coding rate and the modulation constellation, and not of operating conditions.
- **Mobility:** The vehicular mobility classes defined in ITU–R M.1034-1 include speeds up to 250 km/h.
- **Spectral Efficiency:** The "sustained" spectral efficiency serves as a target for the downlink in a typical loaded cell under typical operating conditions. It should be noted that this target (> 1 bit/s/Hz/cell) is significantly higher than the sustained spectral efficiency achieved by existing cellular systems (ref. slide 15 in the presentation 802m_ecsg-02-17).
- **Latency**: The round-trip time (RTT) over the airlink for a MAC data frame is defined here to be the duration from when a data frame is received by the physical layer of the transmitter to the time when an acknowledgment for that frame is received by the transmitter. This can also be called the "ARQ loop delay," and should be less than 10 ms. Fast acknowledgment of data frames allows for retransmissions to occur quickly, reducing the adverse impact of retransmissions on IP packet throughput.

In the next two sections, the desired characteristics for the PHY and MAC-related Air Interface are discussed, with the understanding that the PHY and MAC are closely related and should be dealt with in a unified fashion for optimal performance.

2 PHY-related Air Interface Characteristics

In this section, additional desired properties and numerical guidelines for the physical layer of the AI are given.

- **Cell sizes**: Metropolitan area cells with sizes typical of macrocellular wireless networks should be supported. Smaller cells should also be supported to accommodate operational, deployment and capacity considerations.
- **Channel bandwidth:** For full performance evaluation of an FDD implementation of MBWA, the channel bandwidth should be paired spectrum consisting of two 1.25 MHz bands.
- **Carrier Frequency:** For full performance evaluation, a carrier frequency of 1.9 GHz should be used. For informational evaluation, other carrier frequencies such as 800MHz may be considered.

- **Multi-Sector Operation:** The system should have the ability to support 6 or more sectors per cell. In addition, the MBWA system should be well-suited for a typical configuration of 3 sectors per cell.
- **Doppler Tolerance**: To support vehicular mobility, the AI should support full operation in the presence of a Doppler spread of more than 400 Hz, with graceful degradation in data rate and performance for higher Doppler. (Note that at the proposed evaluation carrier frequency of 1.9 GHz, Doppler of 400 Hz corresponds to 228 km/h.)
- **Delay spread tolerance**: Based on the channel models, the system should tolerate 10 microseconds of delay spread, and the performance should degrade gracefully in the presence of longer multipath components.
- **Advanced coding:** In order to improve robustness, the forward error correction (FEC) should be chosen to give high coding gain in accordance with the state-of-the-art in error-correcting codes. For a rate ½ code, the SNR required for achieving 10^{-2} frame error rate on a binary-input AWGN channel should be less than 1.5 dB from capacity. In terms of $Eb/N0=1/(2R\sigma^2)$, where σ^2 is the noise variance, the information-theoretic capacity limit for rate R=1/2 is Eb/N0=0.2 dB. The FEC should thus achieve the target FER of 10^{-2} at an SNR of less than Eb/N0=1.7 dB. This performance can be achieved through the use of Turbo Codes or Low-Density Parity-Check (LDPC) Codes.
- **Frequency reuse:** As described in the document 802m_ecsg-02/08, the frequency reuse factor should be less than or equal to 1, meaning the same frequencies can be reused in all cells and sectors. In addition, through the use of directed adaptive antennas and other techniques, it may be possible to use the same frequency band more than once in the same cell or sector.

These PHY-related numerical targets are summarized in the following table.

Table 2: Additional PHY Parameters

Parameter	**Proposed value**
Channel Bandwidth (for FDD)	1.25 MHz
Carrier Frequency	2.0 GHz for full evaluation; 800 MHz for informational evaluation
Sectorized Operation	Can support 6 or more sectors per cell (typical 3 sectors)
Doppler Tolerance	> 400 Hz
Delay Spread Tolerance	> 10 microseconds
FEC Gap from Capacity for Rate ½ Code at 10^{-2} FER	< 1.5 dB
Frequency reuse factor	1 or less

3 MAC-related Air Interface Characteristics

In this section, desired characteristics for the MAC are discussed.

- **MAC States:** The AI should support multiple MAC protocol states with fast transitions among them. These should include an "On" state where a user is actively using system resources to transmit and receive data. In order to conserve air-link resource usage when users are temporarily not using the system, there should be a "Hold" state that requires fewer system resources (e.g., control messages) to maintain. Both the Hold state and the On state are considered "active" states. Finally, there should be a "Sleep" state in which the mobile is inactive.
- **Number of users:** The AI should support more than 100 active (On or Hold state) users per sector/cell. The number of inactive (Sleep state) users may be large and essentially unlimited.
- **Fast state transitions:** By making the transitions between the states fast and dynamic, the system capacity may be improved while maintaining the user experience (e.g., maintaining good end-to-end TCP/IP performance). The transition from the On state to the Hold state should take place in less than 100 ms, while the transition from Hold to On should take place in less than 50 ms. The transition from the active Hold state to the inactive Sleep state should be less than 100 ms, while the access time to go from Sleep to On should be less than 200 ms. All of these times are for typical scenarios under moderately loaded conditions.
- **Paging**: For users that are in the inactive Sleep state, there should be a paging mechanism to wake these users up from Sleep state and bring them into an active On state. This allows the mobile terminals to conserve energy when not in active use, while at the same time supporting real-time applications such as voice and instant messaging where there may be incoming packets sent to inactive mobile terminals. The MBWA air interface should support the ability for the base station to send paging signals as often as once every 100 ms. Frequent paging reduces the delay in waking a user up, enabling services such as "push-to-talk" (PTT). The frequency of monitoring these paging signals may be dependent on the application and on the requirements for the mobile terminal device. In addition, the paging signals should last no longer than 1 ms, so that it is possible for a mobile in Sleep state to wake up for a very brief duration to listen to the paging signals and then go back to an inactive state again. The shortness of the paging signal helps reduce the amount of energy expended by a battery-powered mobile terminal during Sleep state, increasing the device's standby time.
- **Resource allocation**: The AI should support fast resource assignment and release procedures on the uplink and downlink for maximum utilization, especially for IP applications with bursty traffic patterns. In addition, it should provide efficient support of IP Quality of Service (QoS) requirements. Both the uplink and downlink should be fully scheduled allowing differentiation of service amongst users and applications. The AI should support automatic selection of optimized user data rates that are consistent with the RF environment constraints. In particular, the AI should allow the FEC coding rates and modulation constellation to be changed on a codeword-by-codeword basis. To allow for fine scheduling granularity, the minimum user scheduling interval should be less than 2 ms. A request from the mobile terminal

for UL resource allocation should take less than 10 ms, assuming no additional delays from contention.

- **Handoff**: The AI should provide mechanisms that support inter-sector and inter-cell handoff at vehicular speeds that minimize packet loss and latency for robust and seamless (i.e., without service interruption) IP packet transmission. The AI should enable handoff to take place in less than 200 ms, comparable to the state transition time.
- **Multicast**: The AI should provide mechanisms that support multicast delivery service.

The MAC-related numerical targets are summarized in the following table:

Table 3: Additional MAC Parameters

Parameter	**Proposed value**
Number of Active Users per Sector/Cell	> 100
Transition from Active On to Active Hold State	< 100 ms
Transition Time from Active Hold State to Active On State	< 50 ms
Transition Time from Active Hold State to Inactive Sleep state	< 100 ms
Access Time from Inactive Sleep State to Active On State	< 200 ms
Paging Signal Periodicity	< 100 ms
Paging Signal Duration	< 1 ms
Minimum Scheduling Interval	< 2 ms
UL Request Time	< 10 ms
Inter-Sector/Cell Handoff Time	< 200 ms