

MBWA Design Issues

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Samir Kapoor, Ph.D.
Flarion Technologies
135 Route 202/206 South
Bedminster, NJ 07921

Voice: 908-947-7062
Fax: 908-947-7090
E-mail: s.kapoor@flarion.com

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Purpose:

To provide information on design issues related to mobile broadband wireless access and make comparisons with 802.11a and 802.16a PHY and MAC.

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Mobile Broadband Wireless Access Systems

Design Issues

May 20, 2002

Key MBWA PHY/MAC Design Issues

- MAC Control Channels
 - Traffic Assignments
 - Channel Descriptors
 - MAC frame ACKs
 - UL Data Requests
 - Power Control
- Pilots
- Inter-cell Interference
- Handoff
- Frequency Planning

Air Interfaces considered for MBWA suitability

- Wireless LAN
 - 802.11a-1999 PHY + MAC
- WirelessMAN
 - PHY - 802.16a/D2-2002 OFDM, TDM/TDMA
 - PHY - 802.16a/D2-2002 OFDMA
 - MAC – 802.16, ARQ
 - FDD, 2-11 GHz Licensed

Traffic Assignments and Channel Descriptors



- MBWA requirement
 - *PHY coding and modulation options per user must be modifiable by Base Station on a millisecond time-scale, e.g., for 100 mph/160kmph at 3 GHz carrier, Doppler = ~445 Hz, coherence time ~2.2ms*
 - *Must incur very low control overhead for efficiency*
- 802.16a
 - DL-MAP/UL-MAP sent every DL frame. DCD/UCD sent less often
 - RNG-REQ/RSP or DBPC-REQ/RSP MAC msgs to change burst profiles
 - **Too slow presently. Excessive overhead for fast updates**
- 802.11a
 - All info carried in each individual burst. 13 symbol PLCP overhead
 - **PCF mode for real-time traffic is inflexible, suffers throughput and latency performance loss under heavy priority traffic load**
 - **Inefficient air-link resource use across users**

Traffic Assignments and Channel Descriptors Overhead

MAC Mgmt Message	802.16a OFDM (bytes)	802.16a OFDMA (bytes)
DL-MAP	$15 + 2n$	$15 + 5n$
UL-MAP	$7 + 4n$	$7 + 6.5n$
DCD	$17 + 12n$	$17 + 12n$
UCD	$27 + 9n$	$36 + 9n$
Total		
n = 1	93	107.5
n = 16	498	595

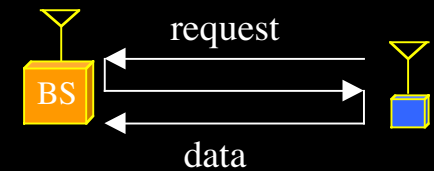
The parameter **n** is the number of bursts/burst profiles

MAC frame ACKs



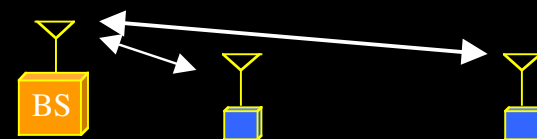
- MBWA requirement
 - *Contention-free resource per user*
 - *Fast, deterministic ACK/NAK response times*
 - *Very low bit rate overhead*
 - *RTT delay/variation in MAC frame ACKs (with ARQ retransmissions) should minimally impact end-to-end TCP RTT mean and variance estimates*
- 802.16a
 - MAC frame ACKs are standalone or piggybacked MAC msgs indicating selective and/or cumulative ACKs
 - **Excessive overhead when not piggybacked or when selective. Single DL frame ACK could cost one UL burst**
 - **Can experience contention with both data and control traffic**
- 802.11a
 - **Excessive overhead: MAC frame ACK is 14B.**
 - **Potential TCP back-off due to time-out: If MAC frame/ACK is corrupted, sender needs to contend to retransmit**

UL Data Requests



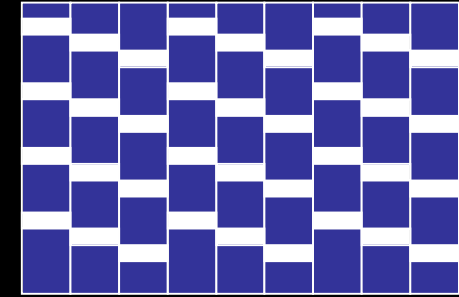
- MBWA requirement
 - *Contention-free resource per user after BS grants access*
 - *Fast, deterministic request time*
 - *Very low bit rate overhead*
- 802.16a
 - Several modes: UGS, rt-polling, nrt-polling, Best effort (BE)
 - **BE mode for TCP/IP traffic is contention based, may require active and substantial maintenance level**
 - **For each UL bandwidth request, a BE TCP/IP connection has to send distinct 6B MAC msg or piggyback using 2B grant mgmt sub-header**
 - **Piggybacking not guaranteed. Could cost one UL burst**
- 802.11a
 - RTS/CTS exchange (20B/14B) before sending packet
 - **Contention-based non-deterministic latency, not low overhead**

Power Control



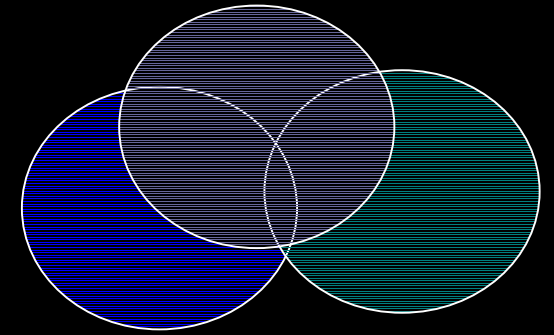
- MBWA requirement
 - *Closed-loop power control for DL and UL*
 - *Low bit rate, dedicated resource per active user*
 - *Rate of update matched to channel coherence time (millisecond time-scale)*
 - Improper power control has severe consequences in cellular environment (increased inter-cell interference, conservative coding and modulation options, reduced cell coverage, increased mobile power consumption)
- 802.16a
 - Power control on startup/periodically via dedicated 4B MAC msgs or RNG-REQ/RSP MAC msgs
 - **Too slow presently. Can be done at most once per DL frame per user**
 - **Not contention-free resource. Too much overhead for fast updates**
- 802.11a
 - **None**

DL/UL Pilots



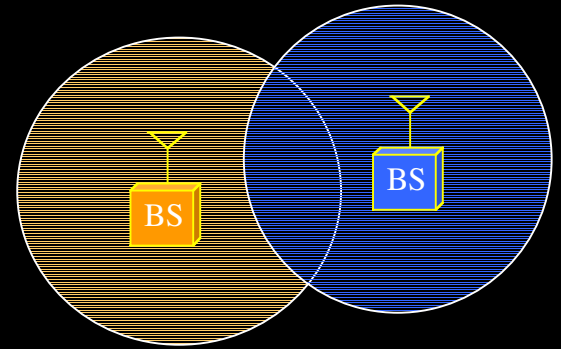
- MBWA requirement
 - *Share across all users for efficiency and eliminate pilot overhead for data and control frames*
 - *Must be temporally “continuous” (e.g. mobiles must see pilots every symbol time) to accommodate high-Doppler environments*
 - *Must cover entire transmission bandwidth*
- 802.16a
 - (OFDM) Shared pilots via preamble at beginning of each DL burst. Each UL burst carries own pilots
 - (OFDMA) 1 fixed pilot and 4 variable pilots per sub-channel
- 802.11a
 - **Not shared. Each user burst has 13 symbol PLCP preamble for sync and 4 pilots tones per payload OFDM symbol**
 - **Excessive overhead; inefficient for all but large packets**

Interference



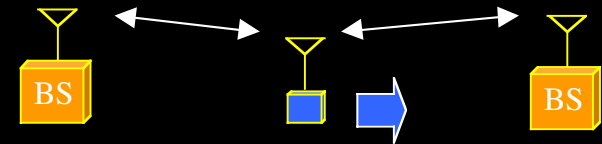
- MBWA requirement
 - *Minimum or no intra-cell Interference on DL and UL*
 - *Link budget designed for averaged (not bursty) inter-cell interference*
 - *Logical channels should utilize entire band, e.g., through frequency-hopping*
- 802.16a
 - No intra-cell interference
 - **(OFDM) TDM/TDMA will cause strong, bursty inter-cell interference**
 - (OFDMA) Obtains time and frequency diversity via scrambling and raster pattern permutations for sub-channels
- 802.11a
 - **CSMA/CA in-cell; inefficient in loaded cells/harsh RF environment**
 - **Inter-cell interference is bursty, not averaged**

Frequency Planning



- MBWA requirement
 - *Allows efficient use of expensive licensed cellular spectrum*
 - *PHY/MAC should be designed to allow for universal frequency reuse*
 - *No frequency planning allows higher network capacity and ease of deployment through reduced network engineering*
- 802.16a
 - **(OFDM) Frequency planning likely required**
 - (OFDMA) Universal frequency reuse possible
- 802.11a
 - **Frequency planning likely required**

Hand-offs



- MBWA requirement
 - *Must be fundamentally designed/optimized for fast hand-offs under vehicular mobility across multiple layers (PHY, MAC, Security, Network)*
 - *Minimize/eliminate packet loss/re-ordering (Key for VoIP, gaming, etc.)*
 - *Mobile driven handoffs (avoid the need for “handoff boxes” in network)*
- 802.16a and 802.11a
 - Difficult to minimize/eliminate packet loss at vehicular speed handoffs due to latency/contention in MAC control
 - (802.16a) : Long/slow initialization sequence (scan for pilots, decode DL-MAP, decode UCD, perform ranging, negotiate basic capabilities, authorize, key exchange, registration, IP connectivity, transfer operational parameters, setup connection)
 - Frequency planning complicates fast handoff
 - **Not presently designed for handoffs**

Comparison at a Glance

Feature	MBWA	802.16a OFDMA	802.16a OFDM	802.11a OFDM
Fast DL/UL Traffic Assignments and Link Adaptation	Y	N	N	N/A
Contention-free, fast, low bit rate MAC frame ACKs	Y	N	N	N
Contention-free, fast, low bit-rate UL data requests	Y	N	N	N
Fast Power Control	Y	N	N	N
Shared, Continuous DL pilots	Y	Y	Y	N
Inter-cell interference averaging	Y	Y	N	N
No Frequency planning	Y	Y	N	N
Fast Handoffs	Y	N	N	N

Summary of PHY/MAC Issues

- Message-based MAC for critical control channels imposes fundamental limitations on air-link efficiency
- Contention/competition amongst control and data messages leads to latency
- Large or non-deterministic latency cannot support the short coherence time of mobile channels
- Lack of “thin” control channels leads to lower coverage and user capacity
- *Significant performance advantages can be realized through an integrated PHY/MAC MBWA design*

Summary and Conclusions

- 802.11a/802.16a MAC/PHYs are well adapted for WLAN and fixed wireless but do not meet MBWA requirements in their present form
- Fundamental, extensive structural changes are essential for adaptation to MBWA
- Resulting MAC/PHY will be substantially different from existing 802.16a and 802.11a
- More efficient to draft a fresh MAC/PHY specification to meet all MBWA objectives for a **focused**, optimized, best-in-class, competitive solution
- Flarion recommends a new 802 Working Group to address MBWA