MBWA Design Issues

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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.

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 at most each DL frame (typically less frequently)
  - **Sending this each DL frame (and UL feedback) will incur excessive control overhead and reduce number of active users per DL frame**
- 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 per DL Frame)	802.16a OFDMA (bytes per DL Frame)
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 users in DL frame

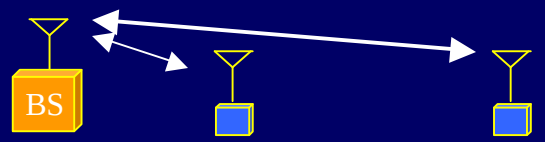
MAC frame ACKs

- 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
  - MAC frame ACK is 14B. If MAC frame/ACK is corrupted, sender needs to contend to retransmit
  - **Excessive overhead; potential TCP back-off due to time-out**

UL Data Requests

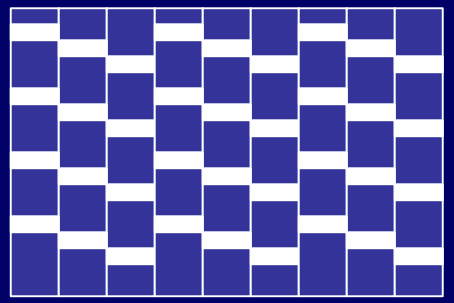
- MBWA requirement
  - *Contention-free resource per user after BS grants access*
  - *Fast, deterministic request time*
  - *Very low bit rate overhead*
- 802.16a
  - Several modes: UGS, rt-polling, nrt-polling, Best effort (BE)
  - **BE mode for TCP/IP traffic is contention based, may require active 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



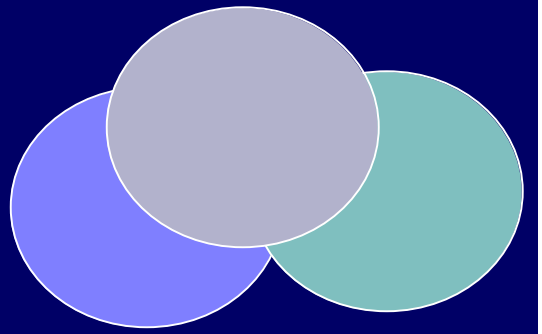
- MBWA requirement
  - *Closed-loop power control for DL and UL*
  - *Low bit rate, dedicated resource per active user*
  - *Rate of update matched to channel coherence time (millisecond time-scale)*
  - Improper power control has severe consequences in cellular environment (increased inter-cell interference, 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-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



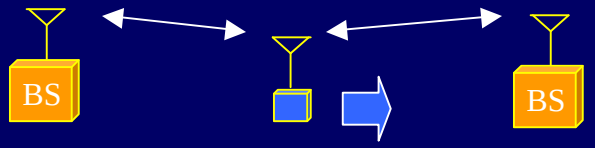
- MBWA requirement
  - *Share across all users for efficiency and eliminate pilot overhead for data and control frames*
  - *Must be temporally "continuous" (e.g. mobiles must see pilots every symbol time) to accommodate high-Doppler environments*
  - *Must cover entire transmission bandwidth*
- 802.16a
  - (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



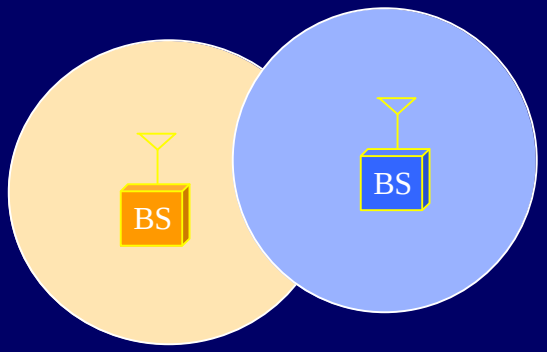
- MBWA requirement
  - *Minimum or no intra-cell Interference on DL and UL*
  - *Link budget designed for averaged (not bursty) inter-cell interference*
  - *All logical channels sweep entire band to avoid frequency selective fading*
- 802.16a
  - No intra-cell interference
  - **(OFDM) TDM/TDMA will 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**

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
  - Frequency planning complicates fast handoff
  - **Not presently designed for handoffs**

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**

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
Fast Handoffs	Y	N	N	N
No Frequency planning	Y	Y	N	N

Summary of PHY/MAC Issues

- Message-based MAC for critical control channels imposes fundamental limitations on air-link efficiency
- Contention 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