4G MOBILE WIRELESS WiMAX

Aditya K. Jagannatham
Indian Institute of Technology Kanpur
Commonwealth of Learning Vancouver
WSSUS Channel Variables - Delay

- Typical wireless channel delay spreads are of the order of 3 $\mu$s.
WSSUS Channel Variables - Delay

• Therefore, to avoid ISI, $T > T_d = 3 \, \mu s$.
• It is immediately clear the maximum symbol rate in outdoor channels is,

$$R_{\text{max}} = \frac{1}{3 \times 10^{-6}} = 333 \, \text{Kbps}$$
Coherence bandwidth

• Coherence bandwidth of the channel is defined in terms of delay spread as,

\[ B_c \approx \frac{1}{T_d} \]

• For outdoor channels, \( T_d \sim 3 \, \mu s \) as seen earlier.
  – Hence, the coherence bandwidth \( B_c \) is given as,

\[ B_c \approx \frac{1}{3 \times 10^{-6}} = 333 \, \text{KHz} \]
Single Carrier Schematic

\[ B = 10 - 20 \, \text{MHz} \]
Single Carrier Vs. Multi Carrier

• Consider instead a multi-carrier modulation (MCM) with $N$ sub-bands of bandwidth $B/N$.

• Each band of bandwidth $B/N$ has a subcarrier.
Multi Carrier Schematic

\[ B = 10 \text{ MHz}, \quad N = 1000, \quad B/N = 10 \text{ KHz} \]
Multi-Carrier Communication

• The $N$ subcarriers are at frequencies

$$\left(-\left(\frac{N}{2}-1\right)\frac{B}{N}, -\left(\frac{N}{2}-2\right)\frac{B}{N}, \ldots, -\frac{B}{N}, 0, \frac{B}{N}, \ldots, \left(\frac{N}{2}\right)\frac{B}{N}\right)$$

• The $i^{th}$ SC is at $if_o$, where $f_o = B/N$ is the fundamental frequency of the multi-carrier system.

$$f_i = if_o = i\frac{B}{N}, \quad -\left(\frac{N}{2}-1\right) \leq i \leq \left(\frac{N}{2}\right)$$
MCM – Overall Rate

• In an MCM system, one is transmitting $N$ parallel symbols over time $N/B$.  

Symbol Time = $N/B$
Orthogonal Frequency Division Multiplexing (OFDM)

• By converting a wideband channel into multiple orthogonal narrowband channels, one can tremendously simplify the receive processing.

  – If the subcarrier bandwidth is less than the coherent bandwidth, then each narrowband carrier experiences flat-fading.

• It can be processed with much lower complexity compared to frequency-selective fading.
Orthogonal subcarriers in a WiMAX system with a carrier spacing of 15.625 KHz.

- Observer, there is NO guard band
  - Hence, efficient use of spectrum
Orthogonal Frequency Division Multiplexing

- An OFDM schematic employing a bank of modulators (BoM) is given below.

![Diagram of OFDM schematic](image-url)
WiMAX

WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS
WiMAX Timeline - Beginnings

• IEEE 802.16 group was formed in 1998
  – To develop an air-interface standard for wireless broadband.

• Initially focused at development of an LOS-based point-to-multipoint WBS.
  – Slated for operation in the 10GHz–66GHz millimeter wave band.
WiMAX Timeline - Beginnings

• The resulting standard—the original 802.16 was completed in December 2001.
• Salient features of this standard included
  – Single-carrier physical (PHY) layer.
  – Burst time division multiplexed (TDM) MAC layer.
WiMAX Timeline - Precursor

• The IEEE 802.16 group subsequently produced 802.16a, an amendment to the 802.16 standard.
  
  – Included NLOS applications in the 2GHz–11GHz band (Multipath Propagation).
  
  – Employed an Orthogonal Frequency Division Multiplexing (OFDM) based physical layer.
  
  – Additions to the MAC (Medium Access Control) layer, such as support for Orthogonal Frequency Division Multiple Access (OFDMA), were also included.
WiMAX Timeline - Precursor

• Further revisions resulted in a new standard in 2004, called IEEE 802.16-2004.
  – This formed the basis for the first WiMAX solution.
WiMAX Timeline - Inception

• Early solutions based on the IEEE 802.16-2004 targeted fixed applications.
  – Referred to as fixed WiMAX.

• In December 2005, the IEEE 802.16 group completed and approved IEEE 802.16e-2005.
  – Amended the earlier fixed WiMAX IEEE 802.16-2004 standard to add mobility support.
  – This forms the basis for the WiMAX solution for mobile applications.
  – Often referred to as mobile WiMAX.
PHY (Physical) Layer

• PHY is responsible for transmission and reception of radio signals

• The WiMAX physical layer (PHY) is based on Orthogonal Frequency Division Multiplexing.
  – This offers simplified reception in multipath and allows WiMAX to operate in NLOS conditions.
  – OFDM is now widely recognized as the PHY of choice for mitigating multipath in Broadband Wireless Access (BWA) – WLAN, LTE, Bluetooth
## WiMAX OFDM Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed WiMAX</th>
<th>Mobile WiMAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subcarriers</td>
<td>256 128</td>
<td>512 1024 2048</td>
</tr>
<tr>
<td>Used data subcarriers</td>
<td>192 72</td>
<td>360 720 1440</td>
</tr>
<tr>
<td>Pilot subcarriers</td>
<td>8 12</td>
<td>60 120 240</td>
</tr>
<tr>
<td>Number of null/guardband subcarriers</td>
<td>56 44</td>
<td>92 184 368</td>
</tr>
<tr>
<td>Cyclic Prefix</td>
<td></td>
<td>1/32, 1/16, 1/8, 1/4</td>
</tr>
<tr>
<td>Oversampling Rate (Fs/BW)</td>
<td>Depends on BW. 7/6 for 256 OFDM, 8/7 for multiples of 1.75 MHz and 28/25 for multiples of 1.25 MHz, 1.5 MHz, 2 MHz or 2.75 MHz.</td>
<td></td>
</tr>
<tr>
<td>Channel BW (MHz)</td>
<td>3.5 1.25</td>
<td>5 10 20</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>15.625</td>
<td>10.94</td>
</tr>
</tbody>
</table>

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WiMAX Features

• WiMAX Supports Several Advanced Features
  – Scalable Data rate and number of subcarriers (128 – 2048)
  – Adaptive Modulation and Coding (Number of bits per symbol and Error Control)
  – High Peak Data Rates ~ 75-100 Mbps
  – Advanced Antenna Techniques
WiMAX Features

- Alamouti Space-Time Code
- Beamforming Directional Transmission
- Spatial Multiplexing Transmission of Multiple Streams
WiMAX Features

• Support for TDD and FDD
  – Fixed-WiMAX and mobile-WiMAX support both TDD and FDD.
  – This allows for a low-cost system implementation.
Flexible & Dynamic Resource Alloc.

• Both UL and DL resource allocation are controlled by a scheduler in the BS.
• Capacity is shared among multiple users on a demand basis, using a burst TDM scheme.
• Further, using the OFDMA-PHY mode, multiplexing is additionally done in the frequency dimension.
  – By allocating different subsets of OFDM subcarriers to different users.
• Resources may be allocated in the spatial domain employing Advanced Antenna Systems (AAS).
OFDMA Resource Allocation

Frequency

Time

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25
WiMAX Scheduling Services

• MAC uses a *scheduling service to deliver and handle services* with different QoS reqs.
• Determines the mechanism the network uses to allocate UL and DL resources for the services.
## WiMAX Scheduling Services

<table>
<thead>
<tr>
<th>Scheduler type</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsolicited grant services (UGS):</td>
<td>Support for fixed-size data packets at a constant bit rate (CBR). - Voice</td>
</tr>
<tr>
<td>Real-time polling services (rtPS):</td>
<td>Designed to support real-time service flows, such as MPEG video, that generate variable-size data packets on a periodic basis. - Video</td>
</tr>
<tr>
<td>Non-real-time polling service (nrtPS):</td>
<td>Designed to support delay-tolerant data streams, such as an FTP, that require variable-size data grants at a minimum guaranteed rate.</td>
</tr>
<tr>
<td>Best-effort (BE) service:</td>
<td>Supports data streams, such as Web browsing, that do not require a minimum service-level guarantee. – Internet, e-mail</td>
</tr>
<tr>
<td>Extended real-time variable rate (ERT-VR) service</td>
<td>For real-time applications, such as VoIP with silence suppression, that have variable data rates but require guaranteed data rate and delay.</td>
</tr>
</tbody>
</table>
## Mobility Support

- WiMAX supports the following types of mobility

<table>
<thead>
<tr>
<th>Type</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomadic.</td>
<td>The user is allowed to take a fixed subscriber station and reconnect from a different point of attachment.</td>
</tr>
<tr>
<td>Portable.</td>
<td>Nomadic access is provided to a portable device, such as a PC card, with expectation of a best-effort handover.</td>
</tr>
<tr>
<td>Simple mobility.</td>
<td>The subscriber may move at speeds up to 60 kmph with brief interruptions (less than 1 sec) during handoff.</td>
</tr>
<tr>
<td>Full mobility:</td>
<td>Up to 120 kmph mobility and seamless handoff (less than 50 ms latency and &lt;1% packet loss) is supported.</td>
</tr>
</tbody>
</table>
Network Architecture
Reference Network Architecture

<table>
<thead>
<tr>
<th>AAA</th>
<th>Authentication, Authorization, Accounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASN-GW</td>
<td>Access Service Network Gateway</td>
</tr>
<tr>
<td>ASP</td>
<td>Application Service Provider</td>
</tr>
<tr>
<td>MIP-HA</td>
<td>Mobile IP Home Agent</td>
</tr>
<tr>
<td>MS</td>
<td>Mobile Station</td>
</tr>
<tr>
<td>OSS</td>
<td>Operational Support Systems</td>
</tr>
<tr>
<td>BSS</td>
<td>Business Support Systems</td>
</tr>
</tbody>
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