MOBILE WIRELESS COMMUNICATIONS - INTRODUCTION

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## 2G Wireless Systems

<table>
<thead>
<tr>
<th>Generation</th>
<th>Standard</th>
<th>Rate</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>2G</td>
<td>GSM (Global System for Mobile Communications)</td>
<td>10 Kbps</td>
<td>Voice calls</td>
</tr>
<tr>
<td>2G</td>
<td>CDMA (Code Division for Multiple Access)</td>
<td>10 Kbps</td>
<td>Voice calls</td>
</tr>
<tr>
<td>2.5G</td>
<td>GPRS (General Packet Radio Service)</td>
<td>50 Kbps</td>
<td>Internet/ e-mail access</td>
</tr>
<tr>
<td>2.5G</td>
<td>EDGE (Enhanced Data Rates for GSM Evolution)</td>
<td>200 Kbps</td>
<td>Internet/e-mail access</td>
</tr>
</tbody>
</table>
## 3G Wireless Systems

<table>
<thead>
<tr>
<th>Generation</th>
<th>Standard</th>
<th>Rate</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>3G</td>
<td>WCDMA (Wideband CDMA)/UMTS (Universal Mobile Telecommunication System)</td>
<td>384 Kbps</td>
<td>Video Telephony, video streaming</td>
</tr>
<tr>
<td>3G</td>
<td>CDMA 2000</td>
<td>384 Kbps</td>
<td>Video Telephony, video streaming</td>
</tr>
<tr>
<td>3.5G</td>
<td>HSDPA (High Speed Downlink Packet Access)/HSUPA (High Speed Uplink Packet Access)</td>
<td>5-30 Mbps</td>
<td>Online Gaming, HD Streaming</td>
</tr>
</tbody>
</table>
## 4G Wireless Systems

<table>
<thead>
<tr>
<th>Generation</th>
<th>Standard</th>
<th>Rate</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>LTE (Long Term Evolution)</td>
<td>100-200 Mbps</td>
<td>Mobile TV, Multiplayer Gaming</td>
</tr>
<tr>
<td>4G</td>
<td>WiMAX (Worldwide Interoperability for Microwave Access)</td>
<td>100 Mbps</td>
<td>Mobile TV, Multiplayer Gaming</td>
</tr>
</tbody>
</table>
Basics of Wireless Communications
Wireless Signal Propagation
Wireless Channel Fading

• The wireless signal can reach the receiver via direct and *multiple* scattered paths.
  – Multipath Propagation
  – As a result, the receiver sees the *superposition* of multiple copies of the transmitted signal.

• These signal copies experience different
  – Attenuations
  – Delays
Wireless Channel Fading

• Results in *interference*, amplifying or attenuating the signal power seen at the Rx.
  – This phenomenon is termed as **fading**.
• Strong destructive interference is referred to as a *deep fade*.
Wireless Channel Fading

Fading Channel Magnitude vs Time

Deep fade
Wireless Signal and Channel Modeling
Multipath Delay Characterization

- Each replica of the wireless signal $s(t)$ is delayed, attenuated, phase shifted.

\[ T \]

\[ T_d \]
Multipath Delay Characterization

• $T$ is the symbol duration.
• $T_d$ is the \textit{delay spread}.
Multipath Delay Characterization

- If $T_d > T$, i.e. delay spread is larger than symbol time, there is ISI (Intersymbol Interference).
WSSUS Channel Variables - Delay

- Typical wireless channel delay spreads are of the order of $1\text{km}/3 \times 10^5 \text{kms}^{-1} \sim 3 \mu s$. 

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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,

$$R_{\text{max}} = \frac{1}{3 \times 10^{-6}} = 333 \text{ Kbps}$$
Let $H(f)$ denote the FT of the wireless channel impulse response $h(t)$.

The *bandwidth* of the channel response is termed the *coherence bandwidth* $B_c$. 
As the delay spread $T_d$ increases, coherence bandwidth $B_c$ decreases. $B_c \sim 1/T_d$
Implication of Coherence Bandwidth

- If $B_c$ is greater than the wireless signal bandwidth $B_s$, there is NO distortion.

- Such a wireless channel is also known as a Flat Fading channel.
Implication of Coherence Bandwidth

- If $B_c$ is smaller than the wireless signal bandwidth $B_s$, there is distortion.

- Such a wireless channel is also known as a Frequency Selective channel.
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,

\[ B_c \approx \frac{1}{3 \times 10^{-6}} = 333 \ \text{KHz} \]
Back to Time Domain

• If the coherence bandwidth is **lesser** than the wireless signal bandwidth

\[
B_c \leq B_s
\]

\[
\Rightarrow \frac{1}{T_d} \leq \frac{1}{T}
\]

\[
\Rightarrow T \leq T_d
\]

• Hence, ISI in time domain is equivalent to Frequency Selective distortion in frequency domain.

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Doppler Effect in Wireless Channels

- Relative motion between transmitter (Base station) and receiver (mobile) causes a **shift** in the frequency of the received signal.
  - This change in frequency is known as the *Doppler shift* $f_d$. 
Doppler Effect in Wireless Channels

- The bandwidth corresponding to the maximum Doppler shift is known as the *Doppler spread* $B_d$. 
Doppler Effect in Wireless Channels

• The Doppler shift $f_d$ for a path is given by the expression below.

$$f_d = \left( \frac{v}{c} \cos \theta \right) f_c$$
Doppler Effect in Wireless Channels

- $f_c$ is the carrier frequency.
- $v$ is the relative velocity of motion between transmitter and mobile receiver.
- $\theta$ is the angle between the incident wave and the direction of observer motion.
- At 60 Km/Hr, 2 GHz and $\theta = 0$, $f_d \sim 55$ Hz.

$$f_d = \left(60 \times \frac{5}{18}\right) \times \frac{1}{3 \times 10^8} \times 2 \times 10^9 = 55 \text{ Hz}$$