Design Principles for Fixed Wireless Access Solutions
Session 2902
Design Principles for Wireless
Cisco’s Broadband Fixed Wireless
System Components
System Configuration
Selection of sites
Site survey
Path profiling
Path analysis
Equipment selection to achieve the required fade margin

Establishment of frequency plan, considering legal restraints
Installation of equipment
Performance monitoring
Site Selection

- A basic consideration is the physical location of the sites at each end of the link.
- Ideally, there should be a clear line-of-sight between antennas.
- If not possible, then modern radio technology may allow reflected signals to be used.

Line-of-Sight

- Microwave signals travel in a straight line but they spread as they travel.
- The required beam clearance is called Fresnel Zone.
- The Fresnel Zone is an imaginary ellipsoid which surrounds the straight line path between the antennas.
The antennas must be high enough to allow the first Fresnel zone to clear the hills, earth bulge, buildings or trees.
Because the earth is not flat, earth curvature must be taken into account when planning for paths longer than approximately seven miles.

Additional required antenna height is calculated using the formula:

\[
\text{Added Height} = \frac{D^2}{8}
\]

Where \(D\) is the Path Distance in Miles and Added Height is in Feet.
Fresnel Zone and Earth Bulge

\[ H1 = 43.3 \sqrt{\frac{D}{4F}} \]

\[ H2 = \frac{D^2}{8} \]

Where

- \( D \) is the Path Length in miles
- \( F \) is the frequency in GHz

Site Survey

- Things to look for when doing a site survey are:
  - Topography of the path
  - Possible obstructions
  - Proximity of site to airports
  - Building or tower heights
  - General Site layout
  - Site access
  - Antenna location and mounting
Site Survey (Cont.)

- Antenna height
- Lightning grounding
- Cable path to equipment
- Distance between antenna and indoor equipment
- Equipment room layout
- Power availability
- GPS co-ordinates of the sites

Path Profiling

- Plot the co-ordinates on a topo map or enter it in a path profiling software with terrain database for the region
- Check for any possible obstruction in the path
• Calculate the distance between the sites
• Might have to ride along the path to look for obstructions
• Get the co-ordinates of the obstruction

Path Study

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A1: NRD</td>
<td>Frequency (MHz) = 5775.0</td>
<td>K = 1.33</td>
<td>%F1 = 60.00</td>
</tr>
<tr>
<td>Latitude</td>
<td>34 45 26.0 N</td>
<td>Longitude</td>
<td>092 23 24.0 W</td>
</tr>
<tr>
<td>Longitude</td>
<td>092 23 24.0 W</td>
<td>Azimuth</td>
<td>69.55°</td>
</tr>
<tr>
<td>Elevation</td>
<td>410 ft ASL</td>
<td>Antenna CL</td>
<td>100.0 ft AGL</td>
</tr>
<tr>
<td>A3: THA</td>
<td>Latitude</td>
<td>34 45 38.0 N</td>
<td>Longitude</td>
</tr>
<tr>
<td>Longitude</td>
<td>092 22 45.0 W</td>
<td>Azimuth</td>
<td>249.56°</td>
</tr>
<tr>
<td>Elevation</td>
<td>410 ft ASL</td>
<td>Antenna CL</td>
<td>80.0 ft AGL</td>
</tr>
</tbody>
</table>

USPS: Little Rock, AR
Apr 18 00  RAD
A1: NRD - A3: THA
Path Analysis

- Determine the theoretical system performance along the proposed path
- Consider wind, rain, fog and atmospheric absorption
- Select proper antenna and coaxial cable for required fade margin and availability

Fade Margin

- Fade margin is the “extra” signal power added to a given radio link to ensure that the link will continue working if it suffers anomalous signal propagation effects (such as fading)
The fade margin is the result of the path equation

\[
\text{Fade margin} = \text{system gain} + \text{antenna gain (Tx + Rx)} \\
+ \text{Free space path loss} \\
+ \text{Cable/connector loss for each end}
\]

System Gain

It is simply the arithmetic difference between the transmitter’s output power and the receiver’s sensitivity threshold

\[
(\text{System gain}) = (\text{transmit power}) - (\text{Receiver sensitivity})
\]
Receiver Sensitivity

- Sensitivity—Receiver sensitivity is an indication of the ability of the microwave receiver to detect the proper signal
- Expressed as a negative dBm value for a particular Bit Error Rate (BER)

Antenna Gain

- The antenna manufacturer provides the information
- Expressed in dBi
### Antenna Gain (Cont.)

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Size (ft.)</th>
<th>Approx. Gain (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>1</td>
<td>14.5</td>
</tr>
<tr>
<td>2.5</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>2.5</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>5.8</td>
<td>1</td>
<td>22.5</td>
</tr>
<tr>
<td>5.8</td>
<td>2</td>
<td>28.5</td>
</tr>
<tr>
<td>5.8</td>
<td>4</td>
<td>34.5</td>
</tr>
</tbody>
</table>

### Cable Loss

- RF energy is carried between the antenna and the radio equipment through a coaxial cable.
- Always results in loss.
- The amount of loss is directly proportional to the length of the cable, and is inversely proportional to the diameter of the cable.
- Also proportional to frequency.
Cable Loss

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>400 MHz Loss (dB/100 ft.)</th>
<th>2.5 GHz Loss (dB/100 ft.)</th>
<th>5.8 GHz Loss (dB/100 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMR400</td>
<td>2.6</td>
<td>6.8</td>
<td>10.8</td>
</tr>
<tr>
<td>LMR600</td>
<td>1.62</td>
<td>4.45</td>
<td>7.25</td>
</tr>
<tr>
<td>1/2&quot; Heliax</td>
<td>2.25</td>
<td>5.7</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Free Space Path Loss

- It is the signal energy lost in traversing a path in free space only, with no other obstructions

\[
\text{Attenuation in dB} = 96.6 + 20 \log_{10} D + 20 \log_{10} F
\]

Where \( D \) is the Path Length in miles and \( F \) is the frequency in GHz
Path Calculation

Example: Calculate the Fade Margin for a 9 mile path at 2.5 GHz using 4 ft. dish antennas (27 dBi gain) at each end. Assume cable and connector losses of 5 dB for each end. Radio Tx Power 25 dBm and Rx Sensitivity -80 dBm

Fade Margin = System Gain + Antenna Gain—FSPL—
Cable/Connector Losses

System Gain = Tx Power—Rx Sensitivity
= 25 -(-80) = 105 dBm

Therefore, Fade Margin = 105 + (27 + 27) - 124 - (5 + 5) = 25 dBm

Path Availability

Availability% = \(1 - 2.5 \cdot abD^3 \cdot (10^{-F/10}) \cdot (10^{-6})\) \times 100

where:
- \(D\) = Path length in miles
- \(f\) = frequency in GHz
- \(F\) = Fade margin in dB
- \(a\) = terrain factor
  - 4 for very smooth terrain over water, flat desert
  - 1 for average terrain with some roughness
  - 0.25 for mountains, very rough or very dry terrain
- \(b\) = Climatic factor
  - 0.5 for hot, humid coastal areas
  - 0.25 for normal, interior temperature or subarctic areas
  - 0.125 for mountainous or very dry but non-reflective areas
**Path Availability (Cont.)**

**Example:** Given a 25 mile path with average terrain but some roughness in an inland temperature climate, operating at 5.8 GHz with a desired availability of 99.95%. What fade margin should be assigned to the link?

\[
\text{Availability}\% = \left\{1 - 2.5 \cdot abD^3 \cdot (10^{-F/10}) \cdot (10^{-6})\right\} \times 100
\]

\[
0.9995 - 1 = -2.5 \cdot (1)(0.25)(5.8)(25^3)(10^{-F/10}) \cdot (10^{-6})
\]

Fade Margin = 20.55 dB

---

**System Availability vs. Outage Time**

<table>
<thead>
<tr>
<th>Availability %</th>
<th>Outage Time %</th>
<th>Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>8760 hours</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>4380 hours</td>
</tr>
<tr>
<td>80</td>
<td>20</td>
<td>1752 hours</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>876 hours</td>
</tr>
<tr>
<td>95</td>
<td>5</td>
<td>438 hours</td>
</tr>
<tr>
<td>98</td>
<td>2</td>
<td>175 hours</td>
</tr>
<tr>
<td>99</td>
<td>1</td>
<td>88 hours</td>
</tr>
<tr>
<td>99.9</td>
<td>0.1</td>
<td>8.8 hours</td>
</tr>
<tr>
<td>99.99</td>
<td>0.01</td>
<td>53 minutes</td>
</tr>
<tr>
<td>99.999</td>
<td>0.001</td>
<td>5.3 minutes</td>
</tr>
<tr>
<td>99.9999</td>
<td>0.0001</td>
<td>32 seconds</td>
</tr>
</tbody>
</table>
Path Measurements

• Highly recommended, specially for partial LOS and non-LOS links
• Usually requires at least 2 people
• A test transmitter with antenna
• A receive antenna with portable spectrum analyzer
• And access to the roof

Align the antennas at both sites to get maximum signal strength and measure:
  - Average path loss in a 1-hour period
  - Depth of deepest fade in a 1-hour period
  - Height of largest up-fade in a 1-hour period

• Compare the results with the calculated values
• Select the equipment accordingly
Frequency Planning

- Frequency for use
- License status (licensed or unlicensed, do they have an operating license from the governing body, can they acquire one?—do they need one?)

Desired Signal
Unwanted Signal
Frequency Reuse

- Effective use of limited frequency spectrum
- Available frequencies are distributed among a group of cells
- Frequencies are not reused in the nearby cells
- A certain level of carrier to interference has to be maintained

No. of Channel Sets N=7
3—Sectors per Cell
Installation Process

1. Site Survey
   - Site Approved
     - Integration Partner Can Be Used
     - Path Analysis And Measurement
       - Path Approved (w/without Diversity)
         - Site Rejected
         - Integration Partner Can Be Used
           - Site Approved
             - Integration Partner Can Be Used
               - 3. Site Preparation and Equipment Ordering
                 - Integration Partner Can Be Used
                   - 4. Install Equipment
                     - Link Established
                       - Debug
                         - 5. Establish Link
                           - Link Established
                             - Yes
                             - No
                               - 6. Monitor Link for 1 day
                                 - Pass
                                 - No
                                   - 7. Monitor Link for 7 days
                                     - Pass
                                     - No
                                       - 8. Start Collecting Ongoing statistics
                                         - Turnover to Customer

Agenda

- Design Principles for Wireless
- Cisco’s Broadband Fixed Wireless
- System Components
- System Configuration
Cisco’s Broadband Fixed Wireless

- High-speed, point-to-point, broadband fixed wireless

Features

- IP Packet-based solution
- Up to 44.4 Mbps full-duplex throughput between fixed sites
- Interface to the uBR 7246 and uBR 7223
- Supports 6 and 12 MHz channel bandwidths
- Supports MMDS (2.50–2.69 GHz) and U-NII (5.725–5.825 GHz) frequency bands
- Encryption support: 56 bit DES with RSA key management
OFDM

• The carriers for each channel are made orthogonal to one another, allowing them to be spaced very close together, without individual carrier guard band overhead as in FDM.

Orthogonal Frequency Division Multiplexing

• The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period.

Base Frequency = 1/T
Where T = Symbol Period
All other signals are zero at the center frequency of each of the other carriers in the system.

Conventional OFDM utilizes single transmit and receive antenna.

Cisco solution combines OFDM with spatial processing—VOFDM (Vector Orthogonal Frequency Division Multiplexing).

Greatest benefit comes from exploiting both frequency and spatial diversity.
Spatial Diversity

- Spatial diversity results when the receiver of the microwave radio accepts signals from two or more antennas vertically or horizontally separated apart.

VOFDM

- The two received signals will not be simultaneously affected to the same extent by the presence of multipath fading, because of the different path lengths.

Two Antenna Diversity provides 1–14 dB of Gain.
Agenda

- Design Principles for Wireless
- Cisco’s Broadband Fixed Wireless
- System Components
- System Configuration

P2P Product Components

- Universal broadband router Cisco 7223 or 7246
- Wireless line card
- Wireless transverter
- Power feed panel
Universal Broadband Router

- uBR7246
  Four modem card slots with two port adapter slots
- uBR7223
  Two modem card slots with one port adapter slot

Wireless Modem Line Card

- Enable wireless non-line-of-sight connectivity
- Delivers up to 44 Mbps full-duplex throughput
- Each line card supports two antennae for spatial diversity
Power Feed Panel

- Combine -48V DC power input with the RF signal into a single cable
- Support single or dual antennae

RF Head (ODU)

- Integrated, environmentally sealed unit
- Modular duplexer simplifies channel plan changes
- Multiple mounting options
Complete System

P2MP Product Components

- Headend
  
  Universal broadband router 7223 or 7246
  Wireless line card goes into uBR7246/7223
  Wireless transverter
  Power feed panel

- Subscriber side
  
  Cisco 26XX/36XX SMB router
  Wireless NM module
  Wireless transverter
P2MP Product Components

- Headend
- Subscriber Site

Product Availability

- P2P U-NII and MMDS is available today
- P2MP MMDS, FY Q4
- P2MP U-NII, end of the year
P2P Configuration

- These are the basic parameters needed to configure a P2P broadband fixed wireless system:
  - Radio master
  - Radio operating-band
  - Radio channel-setup
  - Radio transmit-power
  - Radio receive-antennas
  - Radio cable-loss
Configuration Commands

- Radio master—to configure the wireless modem card to operate as the master radio
  
  Radio master
  No radio master

- Radio operating-band—to specify the radio operating band and transmit/receive frequencies within that band

  ```
  radio operating-band Tx transmitFrequency Rx receiveFrequency
  
  transmitFrequency Positive number in the range 2500 to 2690 (MMDS)
  or 5725 to 5825 (UNII)
  receiveFrequency Positive number in the range 2500 to 2690 (MMDS)
  or 5725 to 5825 (UNII)
  ```

  `Wireless Router1(config-if)# radio operating-band MMDS Tx 2503 Rx 2605`
Configuration Commands

• Radio channel-setup—to adjust bandwidth and throughput to increase the reliability of the link

radio channel-setup bandwidth \{6 | 12\}
throughput\{high | medium | low\}

<table>
<thead>
<tr>
<th>12 MHz Channel</th>
<th>Payload Rate</th>
<th>6 MHz Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High (44.4 Mbps)</td>
<td>Medium (39.1 Mbps)</td>
</tr>
<tr>
<td>Payload Rate</td>
<td>High (22.2 Mbps)</td>
<td>Medium (19.6 Mbps)</td>
</tr>
<tr>
<td>SNR @ BER 10^{-11} (Single Antenna)</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>SNR @ BER 10^{-11} (Dual Antenna)</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

Configuration Commands

• Radio transmit-power—to configure the transverter to transmit a specific amount of power

radio transmit-power \textit{power}

\texttt{Wireless Router1(config-if)# radio transmit-power 25}
\textit{transmit-power =Positive number representing power stated in dBm}
Tx Power range For MMDS = 15 - 35 dBm
Tx Power range for UNII = 5 - 25 dBm
• Radio receive-antennas—to configure the number of receive antennas in use

   radio receive-antennas \{1 | 2\}
   no radio receive-antennas

   Wireless Router1(config-if)# radio receive-antennas 1

• Radio cable-loss

Use this command in interface configuration mode to enter the effective cable loss (measured in dB at 400 MHz) of the cable between the wireless modem card and the specified wireless transverter, including the power feed panel, connectors and lightning protection

The cable loss parameter cannot be set to a value greater than 12 dB.

   Wireless Router1(config-if)# radio cable-loss
   antenna number positive number (1-12)

   Wireless Router1(config-if)# radio cable-loss 1 5
Summary

- Design Principles for Wireless
- Cisco’s Broadband Fixed Wireless
- System Components
- System Configuration

Design Principles for Fixed Wireless Access Solutions

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