Maximizing the Allowable Coverage Area of a Broadband Wireless Communication System that Utilizes an Occupied Frequency Band

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Presentation Outline

- Motivation
  - Explanation of the general problem and the approach taken in presenting the results

- Theoretical Formulas Used
  - Interference bound
  - Propagation model
  - Antenna gains and patterns
  - Transmit power level of the user antenna
Presentation Outline Cont.

- **Algorithm For Computing the Forbidden Zone**
- **Results**
  - Forbidden Area Ratio
  - Adjusting the azimuthal pointing of the AP Antenna
  - Adjusting the ground direction of the AP antenna
Presentation Outline Cont.

– Effects of adjusting the AP antenna height
– Effects of adjusting the AP antenna distance
– Effects of using power control
– Effects of increasing the gain of the user antenna
– Interference from the AP antenna
Presentation Outline Cont.

- Summary
  - Conclusions
  - Future Work
- Questions
Motivation
Interference Bound

\[ P_{\text{received}} \quad ? \quad N(10^{M/10} \quad ? \quad 1) \]

- M is the Margin
- N is the noise power
Propagation Model

Transmitter (IS antenna)

line-of-site wave

reflected wave

Receiver (IWS antenna)

\[ h_t \]

\[ h_r \]

\[ d \]
Propagation Model

\[ P_{\text{received}} \quad ? \quad \frac{P_{\text{transmitter}} \ g_{IS - IWS} \ g_{IWS - IS} \ g_m}{? \ 4? \ ?^2} \quad \frac{? \ ? \ ?}{? \ ? \ ?} \ ((h_r ? h_t)^2 \ ? \ d^2) \]
Antenna Gains and Patterns
Antenna Gains and Patterns (AP antenna)

\[ g(\theta, \phi) \equiv \frac{ab}{\theta^2} \left(1 - \cos \theta \right)^2 \left( \sin \frac{a}{\theta} \sin \phi \cos \theta \right) \sin \left( \frac{b}{\theta} \sin \phi \sin \theta \right) \]
Antenna Gains and Patterns
(IS antenna)
Antenna Gains and Patterns (IWS antenna)

\[
g(\phi) = \frac{(1 \cos \phi)^2}{\frac{2?a^2}{a^2} \sin^2 \phi} \left[ \frac{2?a J_1 \left( \frac{2?a}{a} \sin \phi \right)}{\sin \phi} \right]^2 \frac{2?a_1 J_1 \left( \frac{2?a_1}{a_1} \sin \phi \right)}{\sin \phi}
\]
Transmit Level of the User Antenna

\[ P_{IS\_antenna} (dBm) ? P_{received} (dBm) ? G_{IS} (dBi) ? G_{AP} (dBi) ? PathLoss (dB) ? AddiLoss (dB) \]

\[ PathLoss (db) ? 40 \log d \ ? 20 \log h_{transmitter} \ ? 20 \log h_{receiver} \]

\[ P_{IS\_antenna} (dBm) ? 81 ? G_{IS} (dBi) ? 18 ? 106 ? 20 ? 9 \]
Algorithm for Computing the Forbidden Zone

\[
\begin{align*}
P_{\text{received}} & = \frac{P_{\text{IS antenna}} g_{\text{IS IWS}} (\gamma_{\text{IS IWS}}, \gamma_{\text{IS IWS}}) g_{\text{IWS IS}} (\gamma_{\text{IWS IS}}) g_m}{(h_{\text{IS antenna}} h_{\text{IWS antenna}})^2 d^2} \\
& = f_1(d, h_{\text{IS antenna}}, h_{\text{IWS antenna}}, h_{\text{AP antenna}}, \gamma_{\text{AP}}, \gamma_{\text{IS}}, d_a) \\
& = f_2(d, h_{\text{IS antenna}}, h_{\text{IWS antenna}}, h_{\text{AP antenna}}, \gamma_{\text{AP}}, \gamma_{\text{IS}}, d_a) \\
& = f_3(d, h_{\text{IS antenna}}, h_{\text{IWS antenna}}, h_{\text{AP antenna}}, \gamma_{\text{AP}}, \gamma_{\text{IS}}, d_a)
\end{align*}
\]
Algorithm for Computing the Forbidden zone
Algorithm for Computing the Forbidden Zone

\[ G(d) \overset{?}{=} \frac{P_{IS\_antenna} F(d)}{4 \left( (h_{IS\_antenna} - h_{IWS\_antenna})^2 - d^2 \right)} \overset{?}{=} N \left( 10^{10} \right) \]

The graph shows the function \( G(d) \) with non-interference area, \( G(d) < 0 \), and interference area, \( G(d) > 0 \), with the last zero at \( d = d_1 \).
Algorithm for Computing the Forbidden Zone

$G(d)$

Interval of interest

Last zero in the interval $[0, d_{\text{max}}]$
Azimuthal Pointing Adjustment

Distance from the IWS antenna in the x-direction, \(d\) [meters]
Azimuthal Pointing Adjustment

\[ d \text{[meters]} \]

Distance from the IWS antenna in the x-direction, d[meters]
Forbidden Area Ratio, FAR [%]

Absolute Value of the Azimuth Angle of the AP antenna, \(|\text{azimuth}_{\text{AP}}[^\circ]|\)

Distance form the IWS antenna in the x-direction, \(d[\text{meters}]\)
Adjusting the Ground Direction of the AP Antenna

![Chart showing Forbidden Area Ratio (FAR) as a function of ground direction.]
Adjusting the Ground Direction of the AP Antenna

Forbidden Area Ratio, FAR[%]

Ground direction of the AP antenna, $\theta_{AP}$
Effects of the AP Antenna Height

![Graph showing the relationship between AP antenna height and Forbidden Area Ratio (FAR)]
Coverage Dependence on the AP Antenna Distance

Forbidden Area Ratio [%]

Distance between AP antenna and the IWS antenna, da [m]

- 180
- 90
- 0
Distance from the IWS antenna in the x-direction, \(d\) [meters]

Distance from the IWS antenna in the y-direction, \(d\) [meters]

Area = 29.89%
Effects of Power Control

- **FAR [%]**
  - $AP=0$ / no pc
  - $AP=0$ / pc

- **Distance between IWS and AP antennas, $d_a$ [m]**

- **Graph 1:**
  - FAR [%] vs. $d_a$ [m]
  - Different markers for $AP=0$ / no pc and $AP=0$ / pc

- **Graph 2:**
  - FAR [%] vs. $d_a$ [m]
  - Different markers for $AP=180$ / no pc and $AP=180$ / pc
Effects of Power Control

![Graph 1: FAR vs. Distance between IWS and AP antennas](image1)

- **AP:** 0
  - Far: no pc
- **AP:** 180
  - Far: pc

- **AP:** 180
  - No power control

![Graph 2: Improvement vs. Distance between IWS and AP antennas](image2)

- **AP:** 0
  - Improvement: 120
- **AP:** 90
  - Improvement: 80
- **AP:** 180
  - Improvement: 60
Effects of Power Control

![Graph showing the effects of power control on FAR (False Accept Rate) with distance between IWS and AP antenna.](image)

- FAR [%] vs. Distance between IWS and AP antenna, $d_a [m]$
- Two lines representing $h_{AP}=30$ and $h_{AP}=70$

The graph illustrates the relationship between the distance between the IWS and AP antenna and the FAR percentage, highlighting how power control affects the FAR at different distances.
Effects of the Antenna Gain Increase

Ground direction of the AP antenna, $\theta_{AP} [\degree]$
Effects of the Antenna Gain Increase
Distance between IWS and AP antennas, $d_a$ [m]

FAR [%]

AP = 0°

AP = 90°

AP = 180°

Improvement [no dim]
Effects of the Antenna Gain Increase and Power Control

Distance between the IWS and AP antennas, $d_a$ [m]
AP Antenna Interference
Summary

- Maximizing the area coverage
  - Select a direction for the AP antenna
  - Maximize the distance between the AP and the IWS antenna
  - Adjust the AP antenna height
  - Determine whether power control is necessary
- Repeat the steps if necessary
- Determine which step applies for specific implementation
Future Work

- A case with two or more antenna in the sector
- Using different antenna patterns
- Use different frequency
- Confirm the finding with measurements from real-life case scenario
Questions