ERSLab

F. Nunziata

Microcells

Electromagnetics
and
Remote Sensing Lab
(ERSLab)

Università degli Studi di Napoli Parthenope
Dipartimento di Ingegneria
Centro Direzionale, isola C4 - 80143 - Napoli, Italy

ferdinando.nunziata@uniparthenope.it

Outline

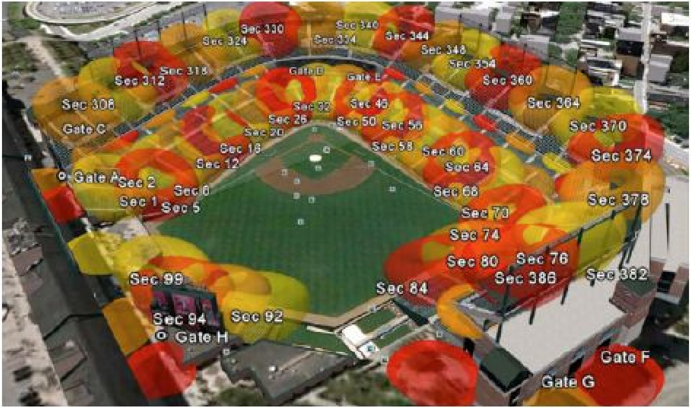
Introduction

The need to increase wireless coverage and capacity within an increasingly crowded ecosystem has led to a variety of alternative solutions and new challenges for the owners and operators of today's mobile networks

Small cells

Introduction

Introduction



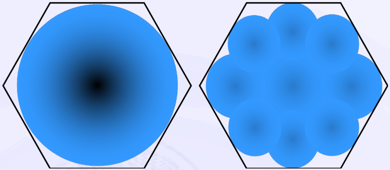
Aruba WLANs deliver stadium-wide Wi-Fi coverage.

604 access points installed to provide free WiFi to all fans on a carrier-neutral basis.

Small cells

- Femtocell is characterized as a very low-range, low-power base station, able to be deployed in a home, home office or very small business. The coverage range is usually less than 30 meters and the output power is around 20 dBm.
- Picocells operate on the same principles as femtocells. A dedicated BTS (Base station) feeds the remote radio heads and antennas, creating a network of very small individual cells.
- Microcells are among the largest of the small cell solutions, operating at an approximate power output of about 30 dBm and providing a coverage radius of up to 500 meters.

Microcells

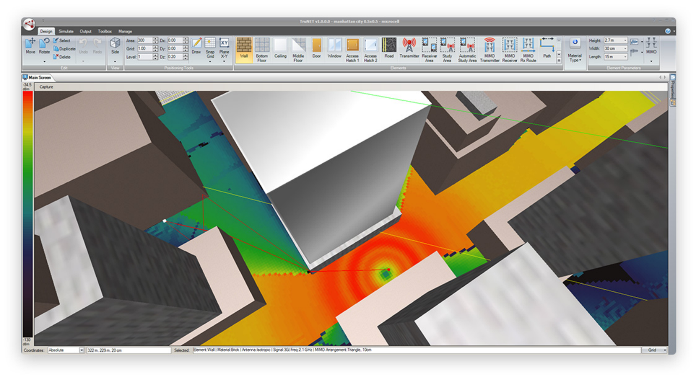


Smaller cells

The deployment of microcells is motivated by a desire to reduce cell sizes in areas where large numbers of users require access to the system. Serving these users with limited radio spectrum requires frequencies to be reused over very short distances, with each cell containing only a reduced number of users.

Microcells

- TX antenna is typically at about the same height as lampposts in a street. Often is mounted at a similar height on the side of a building.
- The coverage is up to hundreds of meters and the shape (mostly influenced by surrounding buildings) is far from being circular.
- The coverage area and hence the interference between sites is mostly controlled through the environment surrounding the TX station.



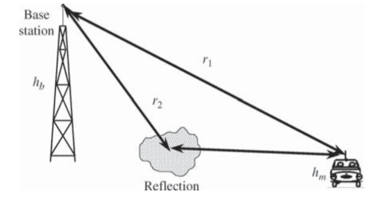
The dominant propagation mechanisms are free space propagation plus multiple reflection and scattering within the cell's desired coverage area, together with diffraction around the corners of buildings and over rooftops.

Path loss

- Physical models.
- Empirical models.

Outline

Two rays model



- In a line-of-sight situation, at least one direct ray and one reflected ray will usually exist.
- The approach is similar to the derivation of the plane earth loss. The key differences are: 1) the direct and reflected path lengths can be very different; 2) the magnitude of the reflection coefficient can be different from unity.

Two rays model

$$\frac{1}{L} = \left(\frac{\lambda}{4\pi}\right)^2 \left| \frac{e^{-jkr_1}}{r_1} + R\frac{e^{-jkr_2}}{r_2} \right|^2 \quad (1)$$

- R is the Fresnel reflection coefficient.

The behavior of (1) must be analyzed wrt distance.

- At large distances, $R \approx -1$ and the path loss exponent tends to the plane earth one, i.e.; 4.
- At short distances, the two waves interfere resulting in fluctuations around the mean value that is the free space one. Hence, the path loss exponent is close to 2.

Two rays model

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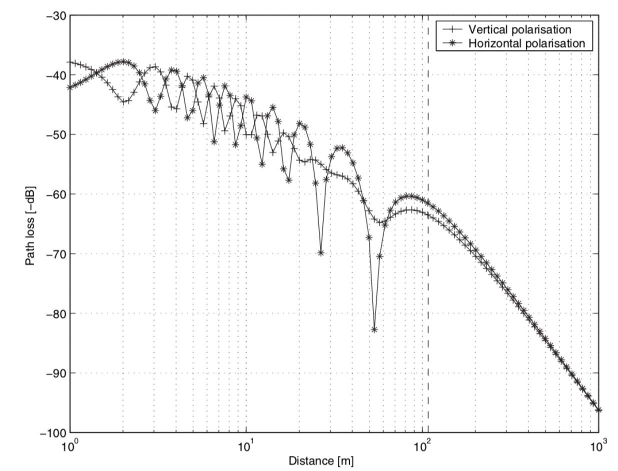
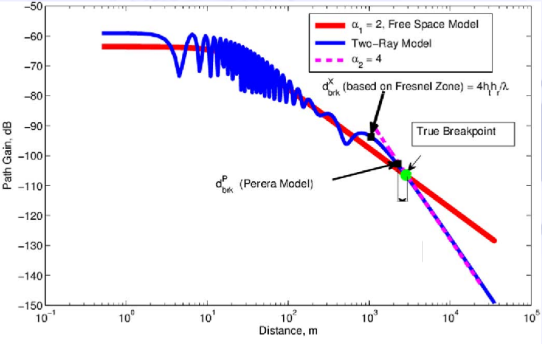


The two-ray model produces two regimes of propagation

Two rays model

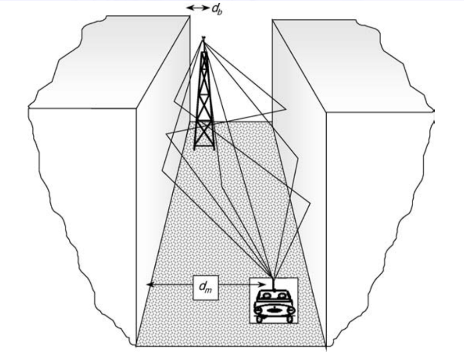
- The breakpoint distance between the two propagation regimes is given by the distance at which the first Fresnel zone touches the ground:

$$r_b = \frac{4h_b h_m}{\lambda} \tag{2}$$

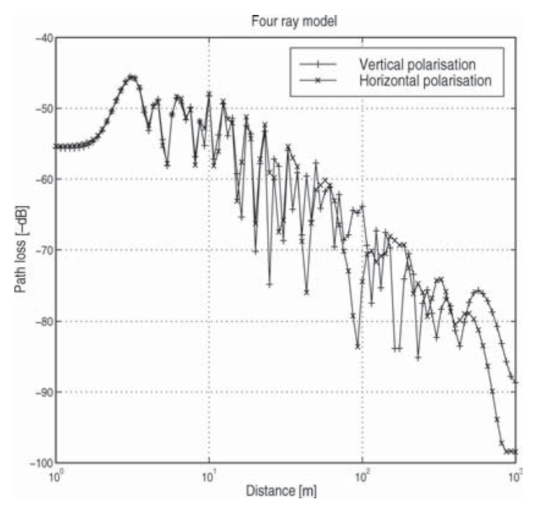


Street canyon model

- The buildings around the mobile can all interact with the transmitted signal to modify the simple two-ray regime.
- A street canyon model is more appropriate. It assumes that TX and mobile are located in a long street lined on both side by buildings with plane walls.



Street canyon model



Street canyon model

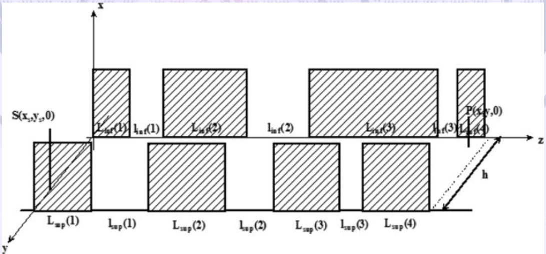
- It calls for large fluctuations that depend on the interaction of signals reflected by both ground and vertical walls. Typically, single reflections are accounted for.
- It results in a limited difference between vertically and horizontally polarized signals.
- The path loss exponent is close to the free space one (i.e.; 2) over a broad range of distance.
- At longer distance the path loss exponent tend to 4.

Random waveguide model

Random waveguide model

The path loss exponent suggested by the street canyon model for longer distances is not supported by experimental evidence. In fact, actual measurements indicate that the exponent may reach up to 7.

Gaps between buildings must be included !



Outline

1. Introduction
2. Physical models
   - LOS
   - NLOS
3. Empirical models
   - Dual-slope
4. Other impairments

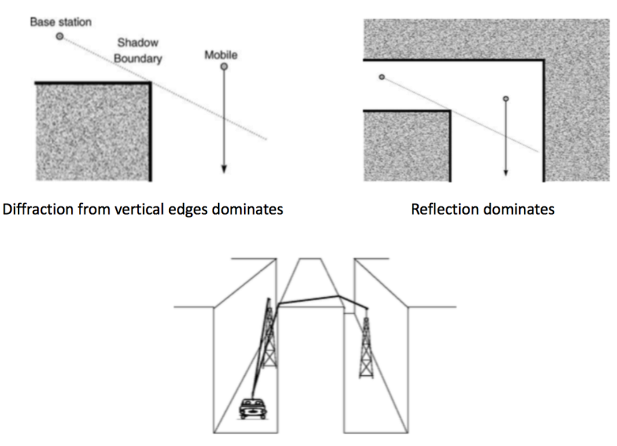
NLOS mechanisms

When the line-of-sight path in a microcell is blocked, signal energy can propagate from the base to the mobile via several alternative mechanisms:

Propagation mechanisms in the NLOS case

- Diffraction over building rooftops.
- Diffraction around vertical building edges.
- Reflection and scattering from walls and the ground.

NLOS mechanisms



Diffraction from vertical edges dominates

Reflection dominates

Rooftop diffraction dominates

NLOS mechanisms

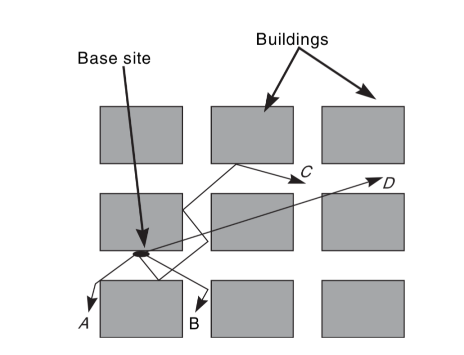
At shorter distances

The propagation is dominated by : a)diffraction by the vertical edges; b) reflection/scattering from the vertical walls and the ground. The geometry and the characteristics of the environment make a specific mechanisms dominating against the others.

At larger distances

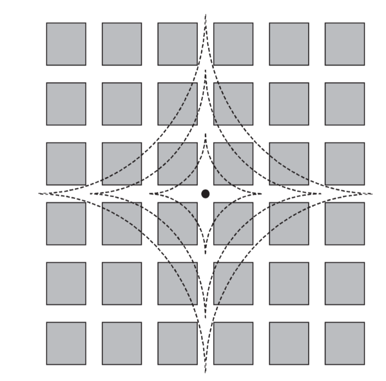
The rooftop diffraction is the main mechanism since a larger number of reflection/scattering/diffraction is needed over larger distances.

Path loss variation with distance



The short paths A and B involve only a single reflection or diffraction and are likely to be dominant sources of signal energy. The long path C is likely to be very weak as four individual reflection losses are involved, and the rooftop-diffracted path D is then likely to dominate.

Coverage area



System range is greatest along the street containing the base site. When the mobile turns a corner into a side street, the signal drops rapidly. The resultant coverage area is therefore broadly diamond-shaped

Lesson learned

Scattering mechanisms

The mechanisms that dominate the scattering in the microcells environment are reflection, scattering, diffraction from the vertical edges and rooftop diffraction. Their strength is distance-dependent.

The variation in propagation mechanism with distance is expected to call for a path loss behavior with distance characterized by two slopes.

Outline

Dual-slope model

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The physical understanding of path loss in macrocell environments and actual field measurements suggest that a dual-slope model must be adopted.

- Two separate path loss exponents are used to characterize propagation together with a breakpoint distance that dictates the change from one regime to the other.

$$L = \begin{cases} 10 n_1 log\left(\frac{r}{r_b}\right) + L_b & r \leq r_b \\ 10 n_2 log\left(\frac{r}{r_b}\right) + L_b & r > r_b \end{cases} \quad (3)$$

- where r_b is the breakpoint distance and L_b is the reference path loss at $r = r_b$.

Dual-slope model

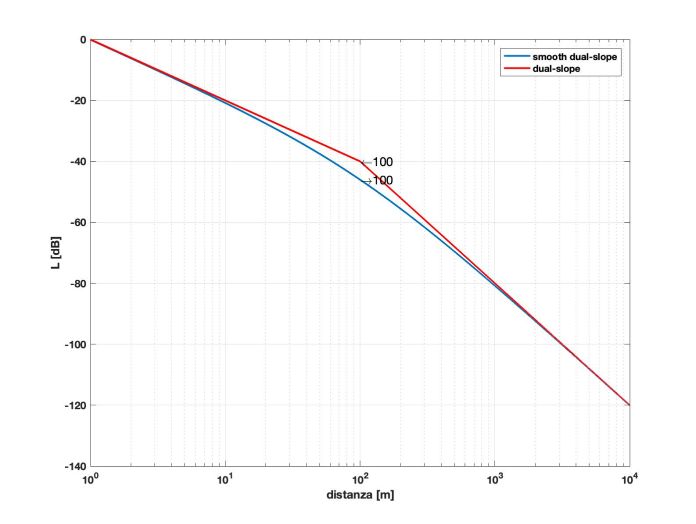
- To avoid the sharp transition between the two propagation regimes, a low-pass function is used that results in the following path loss model:

Smooth dual-slope path loss model

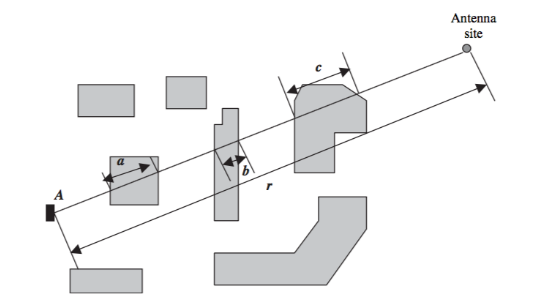
$$L = L_b + 10n_1 log\left(\frac{r}{r_b}\right) + 10(n_2 - n_1)log\left(1 + \frac{r}{r_b}\right) \quad (4)$$

- The breakpoint distance is generally considered as the point at which the first Fresnel zone touches the ground.

Dual slope model



Lee microcell model



It consists of a dual slope LOS model plus a term that accounts for blockage due to buildings.

Other impairments

- Shadowing: The log-normal distribution still applies and a typical location variability is in the range $6 - 10$dB.
- Narrowband fading: Although typically a LOS component is in place, the large number of multipath components that call for a power comparable (or even larger) than the LOS, result in a Rician statistics whose k factor is quite low.
- Wideband fading: The key idea that underpins microcells is reducing cell's size to have a significant lower delay spread that allows high data rate. Typical τ_{RMS} are below $0.5\mu s$