CS6120: Wireless Communication and Networks

Assignment 3: Path Loss and Propagation Loss Models in Cellular Networks

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Extension: 15 % penalty for each day, and maximum two days will be allowed to submit after the due date

1 Introduction

In this assignment, the task is to check and analyze the effects of path loss and propagation loss in cellular networks using a network simulator tool called ns-3. For this assignment, the LTE model in ns-3 is considered as a cellular network. To relate with what we discussed in the cellular networks module in class, Mobile Station (MS) in GSM is referred to as User Equipment (UE) in LTE and similarly Base Transceiver Station (BTS) in GSM is referred to as evolved Node Base station (eNB) in LTE.

2 Instructions to Install ns-3

2.1 Installing ns-3 in Virtual Machine Using VirtualBox

Step 1 : Download and install VirtualBox in your PC.
(Link for VirtualBox - Download VirtualBox from here by selecting Ubuntu 22.04)
Step 2 : Create a new VM in VirtualBox and use Ubuntu 22.04.1 LTS desktop version as OS
(Link for Ubuntu 22.04.1 LTS Download Ubuntu 22.04.1 from here)
Step 3: In Ubuntu OS based VM, install ns-3
(Link for installing ns-3 - Follow the instructions given in this link to install and run ns-3)

Note: ns-3 can also be installed directly onto a linux system.

2.2 Installing ns-3 in Windows

To install ns-3 tools in windows, first you need to install virtual machine.
Step 1 : Download and install VMWare in your PC.

(Link for VMWare - Download VMWare from here)
Step 2 : Install ns-3 tools
Step 2.1 : Go to link : https://www.nsnam.org/releases/
Step 2.2 : Download the latest release of ns-3 (ns 3.36.1)
Step 2.3: Go inside ns-allinone-3.36.1 using following command :

```
cd ns-allinone-3.36.1
```

Step 2.4 : Enter the following command

```
./ns3 configure --enable-examples --enable-tests

./ns3 build

./test.py
```

Step 2.5: Run the following command to ensure that ns-3 is correctly installed and running

```
./ns3 run hello-simulator

./ns3 run first

./ns3 run test-runner
```

3 Assignment Problem

Consider an LTE cellular network which consists of a UE (MS in GSM) and an eNB (BTS in GSM). The transmitted signal is propagated through the wireless medium or channel and it is received at the receiver end. One of the important aspects of the cellular network system design is to model the performance of a wireless network channel. Because the radio channels are random and the transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and foliage. The variation in received signal power over distance is due to path loss and shadowing. Path loss is caused by dissipation of the power radiated by the transmitter as well as effects of the propagation channel. Shadowing is caused by obstacles between the transmitter and receiver that attenuate signal power through absorption, reflection, scattering, and diffraction. This assignment focuses on modeling the signal propagation aspects in wireless medium using ns-3.

3.1 Free Space Propagation Model

It is assumed that the propagated signal follows the free space propagation model (i.e., there is a clear line-of-sight path between the transmitter and the receiver or there is no obstacles in the path between them). The free space propagation model can be expressed mathematically using the Friis power transmission formula in free space:

$$P_r = P_t \times \frac{G_t G_r \lambda^2}{(4\pi d)^2 L}, \tag{1}$$

where P_r denotes the received power, P_t denotes the transmitted power, G_t denotes the transmitter antenna gain, G_r denotes the receiver antenna gain, λ denotes the wavelength of the signal, d denotes the separation distance between the transmitter and the receiver, and L denotes the system loss (losses due to transmission line attenuation, filter loss, and antenna loss).

- Assume the antennas used at the both end are isotropic (i.e., non-directional) antennas with $G_t = 1$, $G_r = 1$, and L = 1, the transmitted power P_t is 50 W, and the UE and the eNB are static.
  - Fix the separation distance as 1 kilometer and calculate the received power by varying the signal frequency from 100 MHz to 900 MHz with the step size 100 MHz. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the Friis model theoretical results with the simulated results, and write your inferences.
  - Fix the signal frequency as 900 MHz and calculate the received power by varying the separation distance from 100 meters to 1000 meters with the step size of 200 meters. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the Friis model theoretical results with the simulated results, and write your inferences.
- Assume the antennas used at the both end are parabolic directional antennas (i.e., $G_t = G_r = L > 1$) and the average gain of the dish parabolic reflector antenna, $\frac{G_t G_r}{L}$, is $(10 \times \log_{10}(0.6 \times (\pi \times 3/\lambda)^2))$. It is also assumed that the transmitted power P_t is 50 W, set a beamwidth as 60 or 120 degrees and an orientation as 0 degree, and the UE and the eNB are static.
  - Fix the separation distance as 1 kilometer and calculate the received power by varying the signal frequency from 100 MHz to 900 MHz with the step size 100 MHz. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the Friis model theoretical results and the simulated results obtained using isotropic antenna, and write your inferences.
  - Fix the signal frequency as 900 MHz and calculate the received power by varying the separation distance from 200 meter to 2000 meter with the step size of 200 meters. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the Friis model theoretical results and the simulated results obtained using isotropic antenna, and write your inferences.

3.2 Two Ray Propagation Model

In a mobile radio channel, a single line-of-sight path between the transmitter and the receiver without obstacles is rare, specially in urban areas. As shown in Figure 1, the two ray ground reflection model illustrates signal propagation in which there is one direct path between the

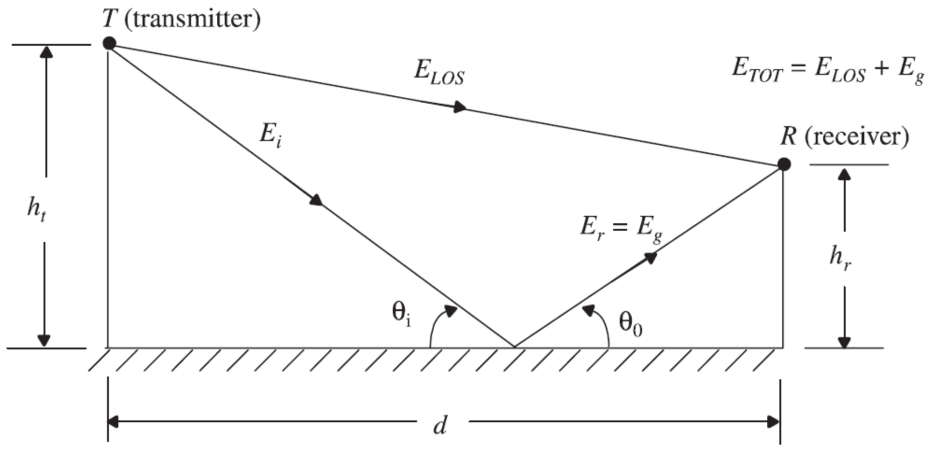

Figure 1: Two-ray ground reflection model [1]

transmitter and the receiver and one reflected path [1]. The two ray propagation model can be expressed mathematically as

$$P_r = P_t G_t G_r \times \frac{h_t^2 h_r^2}{d^4 L}, \tag{2}$$

where h_t and h_r represent height of the transmitter and height of the receiver, respectively.

- Assume the antennas used at the both end are isotropic antennas with $G_t = 1$, $G_r = 1$, and L = 1, the transmitted power P_t is 50 W, the frequency of operation is 900 MHz, and the UE and the eNB are static.
  - Fix the separation distance as 1 kilometer and calculate the received power by varying the height of the transmitter h_t from 10 to 50 meters with the step size of 10 meters and height of the receiver h_r from 1 to 5 meters with the step size of 1 meter. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the two ray model theoretical results, and write your inferences.
  - Fix the height of the transmitter $h_t = 50$ meters and the height of the receiver $h_r =$ 2 meters and calculate the received power by varying the separation distance from 100 meters to 1000 meters with the step size of 200 meters. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the two ray model theoretical results, and write your inferences.
- Assume the antennas used at the both end are parabolic directional antennas (i.e., $G_t = G_r = L > 1$) and the average gain of the dish parabolic reflector antenna, $\frac{G_t G_r}{L}$, is $(10 \times \log_{10}(0.6 \times (\pi \times 3/\lambda)^2))$. It is also assumed that the transmitted power P_t is 50 W, set a beamwidth as 60 or 120 degrees and an orientation as 0 degree, and the UE and the eNB are static.

- Fix the separation distance as 1 kilometer and calculate the received power by varying the height of the transmitter h_t from 10 to 50 meters with the step size of 10 meters and height of the receiver h_r from 1 to 5 meters with the step size of 1 meter. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the two ray model theoretical results and the simulated results obtained using isotropic antenna, and write your inferences.
- Fix the height of the transmitter $h_t = 50$ meters and the height of the receiver $h_r = 2$ meters and calculate the received power by varying the separation distance from 100 meters to 1000 meters with the step size of 200 meters. Simulate the same using ns-3 network simulator. Then, generate a graph to compare the simulated results using parabolic antenna with the two ray model theoretical results and the simulated results obtained using isotropic antenna, and write your inferences.

3.3 Generic Propagation Model

In this model, it is assumed that the UE is a non-static (i.e., mobile) device and the eNB is static. Obstacles (e.g., buildings, floors, walls) between the transmitter and the receiver are considered with shadowing effects for the following scenarios:

- both the UE and eNB are in outdoors,
- the UE is in indoors and the eNB is in outdoors,
- two kinds of antennas (isotropic and parabolic) can be used, and
- hybrid propagation models (i.e., deterministic (Friis and two-ray) and empirical (Hata and Okumara)) can be considered based on the combination of indoor and outdoor scenarios.

Model these scenarios using ns-3, generate graphs to compare results by varying different parameters, and write your inferences.

4 ns-3 Modules Required for Implementing the Assignment

- Antenna Module
- Buildings Module
- LTE Module
- Mobility
- Propagation

5 Submission Format

Create a separate folder for each part of the assignment (i.e., 3.1, 3.2, and 3.3) inside a main folder named "$A3\_ < your\_name > \_ < your\_roll\_no. >$". Then create a single tarball of the main folder with all of its subfolders and submit it in the CS6120 course moodle page. Also, the same should be shared via email to prabhut@cse.iitm.ac.in.

References

[1] T. S. Rappaport, "Wireless Communications: Principles and Practice," 2nd Edition, Prentice Hall, 2002.