Technical Note

Wireless Channel 802.11 in NS-3

Lesly Maygua-Marcillo[1], Luis Urquiza-Aguiar[1], Martha Paredes-Paredes[1]

[1]   Departamento de Electrónica, Telecomunicaciones y Redes de Información, Facultad de Eléctrica y Electrónica, Escuela Politécnica Nacional (EPN), C. Ladrón de Guevara E11-253, Quito PO.Box 17-01-2759, Ecuador; lesly.maygua@epn.edu.ec, cecilia.paredes@epn.edu.ec.

*   Correspondence: luis.urquiza@epn.edu.ec; Tel.: +593-2-2976300 ext 2311

Abstract: Network Simulators (NS) is typically used to study services and applications in complex scenarios due to the infeasibility of deploying real testbeds. This is the case of Mobile Ad hoc Networks (MANETs) which can be extensively used in emergency situations or to gather information without infraestructure. An important factor to get realiable results in the MANETs' simulations is the wireless channel module of NSs. In this report, we explain how thw wireless channel is implemented in NS-3 and it can be configured.

Keywords: NS-3, simulation, wireless channel, propagation model.

1.   Introduction

A wireless communication allows sending a signal or a certain amount of data from one point to another (transmitter and receiver) without the need for a guided medium.A wireless channel uses a specific frequency band to transmit information. The wireless channel of IEEE 802.11, one of the enabled technologies for MANETs, employs the 2.4 GHz or 5.9 GHz band. The Wireless Channel 802.11 in NS-3 tries to model the real functionality of the standard.

2.   Overview

Wireless Channel 802.11 in NS-3 is modeled by the class `YansWifiChannel` which works together with `WifiPhy` class. `WifiChannel` includes the helper class `YansWifiChannelHelper`. By means of the latter, we can configure predefined channels with propagation and delay models [1].

Each channel use two models for its configuration. These are:

– PropagationLossModel
– PropagationDelayModel

In NS-3, the default 802.11 channel considers the following models: A delay propagation model equal to a constant and a propagation loss model based on log normal distribution. More specifically, they are named: ConstantSpeedPropagationDelayModel and LogDistancePropagationLossModel [1]. Now, we analyze the propagation and delay models in NS-3.

PropagationLossModel

These models calculate the reception power considering the transmission power and position of transmitting and receiving antennas.

- **Cost231PropagationLossModel:** This model extends to the range of 1500 MHz to 2000 MHz. It is designed for suburban area.

- **FixedRssLossModel:** It establishes a constant reception power level (configurable) independent of the transmission power. If we consider several loss models, this should be the first model to avoid excluding the losses calculated by the other included models.

To configure this model in a NS-3 simulation need only an attribute. This attribute is **Rss** and we can use the following command line:

```
wifiChannel.AddPropagationLoss("ns3::FixedRssLossModel","Rss",DoubleValue
(-80));
```

- **FriisPropagationLossModel:** It implements the Friis' propagation loss model. It allows to predict the power level that will be received considering some distance in ideal conditions. That is, without obstacles of any nature near the link that may affect the electromagnetic propagation [2]. The original formula considering the case of an isotropic antenna without heat loss was described as:

$$\frac{P_r}{P_t} = \frac{\lambda^2}{(4\pi * d)^2} \qquad (1)$$

Update we have:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi * d)^2} L \qquad (2)$$

Where: P_t:Transmission power(w)
P_r:Reception power (w)
G_t:Transmission gain (dimensionless)
G_r:Reception gain (dimensionless)
λ: Wavelength (m)
d: Distance (m)
L: System loss (dimensionless)

Implementing, $f = c/\lambda$, where C is the speed of light in vacuum, and f is the frequency in Hz. This model is valid only for propagation in free space. This model is used for small to medium distances.

The attributes used for this model in NS-3 are:

- Frequency: The carrier frequency at which propagation occurs (Hz).
- MinLoss: The minimum value of the total loss (dB). Initial value: 0. - SystemLoss: Set the system loss used by the Friis propagation model. Initial value: 1.

To configure the FriisPropagationLossModel function in a simulation scenario, it is necessary to add the following line:

```
wifiChannel.AddPropagationLoss("ns3::FriisPropagationLossModel","Frequency",DoubleValue
(5.15e9),"SystemLoss",DoubleValue (1),"MinLoss",DoubleValue (0));
```

- **TwoRayGroundPropagationLossModel:** It implements a loss propagation model with a diredt ray in line of sight and a second one reflected to earth. This model uses the following equation:

$$P_r = \frac{P_t G_t G_r (H_t^2 * H_r^2)}{d^4 * L} \qquad (3)$$

This model does not give good results for short distances due to the oscillations caused by the constructive and destructive combination of the two rays.

To use this model in ns-3 in necessary to consider the following attributes:

- Frequency: The carrier frequency at which propagation occurs (Hz).
- HeightAbove: The height of the antenna (m).
- MinDistance: At this distance the propagation model refuses to give results (m).
- SystemLoss: Set the system loss used by the Two Ray Ground propagation model.Initial value: 1.

The command line that allow us configure this model is:

```
wifiChannel.AddPropagationLoss("ns3::TwoRayGroundPropagationLossModel",
"Frequency",DoubleValue (), "HeightAboveZ", DoubleValue
(1.5),"MinDistance",DoubleValue ());
```

- **LogDistancePropagationLossModel:** The reception power is calculated with the logarithmic distance model.

$$L = L_0 + 10nlog(\frac{d}{d_0}) \qquad (4)$$

where: n:Path loss distance exponent
d_0:Reference distance (m)
L_0:Path loss at reference distance (dB)
d:Distance (m)
L:Path loss (dB)

To set the model in NS-3 is necessary consider the following attributes:
- Exponent: Exponent of the Path Loss propagation model. NS-3 value:3.
- ReferenceDistance: Distance at which the reference loss is calculated (m).
- ReferenceLoss: Reference loss at reference distance (dB).Default is Friis at 1m with 5.15 GHz.

- **ThreeLogDistancePropagationLossModel:** It's the same model as LogDistance but considering three distances (close, in the middle and far) with different exponents.

When the path loss is requested at a distance less than the reference distance d_0, the transsmission power is returned (without path loss). The reference distance is set by default to 1 m and the reference loss is predetermined in FriisPropagationLossModel with 5.15 GHz and, therefore, $L_0 = 46.67$ dB.

- **ItuR1411LosPropagationLossModel:** Model is designed for systems without line of sight, short range outdoor on rooftops at frequencies from 300 MHz to 100 GHz. The model depends of several parameters, such as: street width, orientation, etc. The model expresses its loss based on the sum of: loss of free space, the diffraction loss of the roof to the street and the reduction due to the multiple diffraction screens of buildings.

- **JakesPropagationLossModel:** It is a deterministic model. It is used in cellular mobile communications. It sses the Clark's method. NS-3 uses two parameters for this model: DopplerFrequencyHz, NumberOfOscillators [3].

- Kun2600MhzPropagationLossModel: For urban areas at a frequency of 2600 MHz.

- **MatrixPropagationLossModel:** The propagation loss is fixed for each pair of nodes and does not depend on their actual positions. Useful for synthetic tests. By default it is assumed that the propagation loss is symmetric.

- **NakagamiPropagationLossModel:** It implements the fast fading Nakagami model which explains the variations in signal strength due to multipath fading. The model does not account

for the path loss due to the distance traveled by the signal. In a simulation, it is recommended to using it in combination with other models that take into account the path loss [4].

The Nakagami distribution applied to the power level is implemented with GammaRandomVariable or ErlangRandomVariable. [5].

Rayleigh model [6] is a special case of Nakagami model. In fact, Nakagami model describes different fading equations. Nakagami-m only gives us the fast fading effect which simply vary the reception power according to a Nakagami distribution.

This model include several parameters to its configuration in ns-3 which are described below:

- Distance 1: Begin the second distance field. Initial value: 80m by default.
- Distance 2: Begin the third distance field. Initial value: 200m by default.
- m_0: Used for distances smaller than Distance 1. Initial value: 1.5 by default.
- m_1: For distances smaller than Distance 2. Default is 0.75.
- m_2: For distances greater than Distance 2. Initial value: 0.75 by default.
- ErlangRv: Access to the underlying `ErlangRandomVariable`.
- GammaRv: Access to the underlying `GammaRandomVariable`.

As already mentioned above, in order to have also the effect of distance, you can add any other model you want. In this case we show Log Distance model on top of the Nakagami. The following command lines are necessary to set theses models.

```
YansWifiChannelHelper wifiChannel;
wifiChannel.AddPropagationLoss("ns3::LogDistancePropagationLossModel");
wifiChannel.AddPropagationLoss("ns3::NakagamiPropagationLossModel","m0",
DoubleValue(1),"m1", DoubleValue(1),"m2", DoubleValue(1));
```

You can also add any other parameters/attributes to each of the models [7].

- **OkumuraHataPropagationLossModel:** It is used for trajectory losses in open area and long distances ($> 1km$). The original Okumura Hata model is designed for frequencies of 150 MHz to 1500 MHz [8]. Almost all models are designed for urban areas. Therefore, the model can not cover all scenarios in all frequencies.

- **RandomPropagationLossModel:** It considers a loss of random propagation; It changes every time the model is called. As a consequence, all packages (even those that are sent between two fixed nodes) experience a random propagation loss.

- **Shadowing Model:** It is modeled according to a log-normal distribution with variable standard deviation as function of the relative position (indoor or outdoor). One random value is drawn for each pair of MobilityModels, and stays constant for that pair during the whole simulation. Thus,it is appropriate for static nodes only. This model considers that the mean of the shadowing loss in dB is always 0. For the variance, there are three possibilities of standard deviation,

- outdoor (m_shadowingSigmaOutdoor, defaul value of 7 dB) $\rightarrow X_\mathrm{O} \sim N(\mu_\mathrm{O}, \sigma_\mathrm{O}^2)$.
- indoor (m_shadowingSigmaIndoor, defaul value of 10 dB $\rightarrow X_\mathrm{I} \sim N(\mu_\mathrm{I}, \sigma_\mathrm{I}^2)$.
- external walls penetration (m_shadowingSigmaExtWalls, default value 5 dB) $\rightarrow X_\mathrm{W} \sim N(\mu_\mathrm{W}, \sigma_\mathrm{W}^2)$

- **RangePropagationLossModel:** The loss depends only on the distance in meters (range) between the transmitter and the receiver. The only MaxRange attribute determines the path loss. The receivers in or inside the MaxRange meters receive the transmission at the transmission power level; those beyond MaxRange receive a power at -1000 dBm.

In Table 1, we show a summary of default parameters to configure propagation models [9].

Table 1. My caption

Configuration of Propagation Loss Model	
Propagation model	**Default Parameters**
Fixed RSS	Rx signal strength: -150 dBm
Friis	Minimum Distance: 0.5m Wave Length: 58.25mm System Loss: 1
Log Distance	Reference Distance: 1m Reference Loss: 46.67 dB Exponent: 3
Three Log Distance	Distances: 1 m, 200 m, 500m Reference Loss at 1 m: 46.67 dB Exponents: 1.9, 3.8, 3.8
Two Ray Ground	Minimum Distance: 0.5m Wave Length: 58.25mm Height above Z: 0m System Loss: 1
Jakes	Rays per Path: 1 Oscillators per Ray: 4 Doppler Frequency: 0 Hz Distribution: Constant(1)
Nakagami	Distances: 80 m, 200m Exponents: 1.5, 0.75, 0.75
COST-Hata	Minimum Distance: 0.5m Center Frequency: 2.3 GHz Base Station Antenna Height: 50m Mobile Station Antenna Height: 3m

PropagationDelayModels

For this case NS-3 can implement the following two models:

- **RandomPropagationDelayModel:** The propagation delay is completely random, and changes every time the model is called. All packages, even those that are sent between two fixed nodes, experience a random delay. As a consequence, the order of the transmitted packets is not maintained.

- **ConstantSpeedPropagationDelayModel:** In this model, the signal travels with constant speed, equal to the speed of light. The delay is calculated according to the positions of the transmitter and the receiver. The Euclidean distance between the antennas Tx and Rx is used. This model considers that the Earth is flat. To obtain the channel configuration by default, the following lines of code are used:

```
YansWifiChannelHelper wifiChannel = YansWifiChannelHelper::Default ();
wifiPhy.SetChannel (wifiChannel.Create ());
```

3. Configuration and Results

In this section we show the configuration of channels and the simulations carried out.

To create a network device in ns-3 we must consider the different layers. First, create the nodes. Next, the MAC and PHY layers must be added. In this point, it is necessary to configure the channel

and finally add the different stacks and applications. Fig. 1 shows the structure that the script must have. The green box indicates the class that is used to configure the wireless channel.
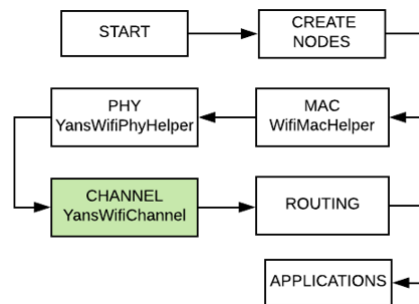
Figure 1. Results of first simulation

In general, to configure a propagation loss or delay model in ns-3 is necessary the following command line:

```
wifiChannel.AddPropagationLoss("ns3::PropagationLossModel","Parameter
1",DoubleValue(),"Parameter 2",DoubleValue(), "Parameter 3",DoubleValue());
```

This command will be modified based on the selected model and parameters.

To configure a default wireless channel in NS-3 we can use the following lines:

```
YansWifiChannelHelper channel=YansWifiChannelHelper::Default()
```

The tables 2 and 3 show the propagation and delay model used for each channel simulation.

Table 2. Models used in simulation of channel 1

CHANNEL 1	
Propagation model	LogDistancePropagationLossModel
Delay model	ConstantSpeedPropagationDelayModel

Table 3. Models used in simulation of channel 2

CHANNEL 2	
Propagation model	Fixed Rss Loss Model
Delay model	ConstantSpeedPropagationDelayModel

The results of the transmission are shown in Fig.2 and Fig.3. Using channel N°1 there is a loss of 60% of packets, while using channel N°2 there is a packet loss of 0%. This difference is due to the fact that channel 2 implements a propagation loss model that allows to directly configure the reception power without relating to the transmission power.

In order that the configuration can be analyzed by our readers at the end of the tutorial, we add the scripts as. This concludes our tutorial.

4. Conclusions

In this note, we have reviewed how to configure a wireless channel in NS-3. We provide a review of wireless channel available in NS-3 and provide a useful example of their configuration in a 802.11

Figure 2. Results of first simulation

Figure 3. Results of second simulation

MANET simulations. Our toy example shows that the configuration of this parameters can change the results of the simulations drastically.

Supplementary Materials: The following are available with this note: the simulation file for simulating wireless channel in a MANET example in NS-3.

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