Performance Evaluation of LR-WPAN for different Path-Loss Models

Neeraj Choudhary
Department of Computer Science and Engineering,
National Institute of Technology,
Jalandhar, Punjab, India

Ajay K Sharma
Department of Computer Science and Engineering,
National Institute of Technology,
Jalandhar, Punjab, India

ABSTRACT
LR-WPAN is Low-Rate wireless personal area network standard IEEE 802.15.4. This paper is to establish path loss models for predicting wireless data transmission performance for IEEE 802.15.4 protocol standard. We use two different path-loss models to check the performance of network. Applying the channel models in our OMNeT++ simulation Mobility Framework environment for IEEE 802.15.4 systems, we find that the simulated performance of these models gives different results for both models. We show that these solutions increase the network performance and decreases energy consumption significantly.

Keywords
IEEE 802.15.4, LR-WPAN, Mobility Framework, OMNeT++.

1. INTRODUCTION
This paper studies the effect of changing Path Loss Model on wireless sensor networks. Path loss is the reduction in power density of an electromagnetic wave as it propagates through space. In current network simulators different models are used that describe the effects on the wireless channel. This can be done in different levels of detail, what clearly influences the accuracy of the results being generated by a simulation. Many simulators leave choice to select one of several given models, and to parameterize them according to the user's needs. The Mobility Framework [1-2] model (MF) IEEE 802.15.4 incorporates three models by defaults, which are Free Space, Two Ray Ground and Log Normal Shadowing. We introduce three models of Path Loss that account for the attenuation of signal based on distance: Free-Space, Two-Ray and Log-normal Shadowing. Path loss ***(PL)*** is a measure of the average RF attenuation suffered by a transmitted signal when it arrives at the receiver, after traversing a path of several wavelengths. It is defined in [3-4].

1.1 Free Space Model
This model is used to predict the signal strength when the transmitter and the receiver have a clear, unobstructed line-of-sight (LOS) path between them. It predicts that the received power decays as a function of Transmitter-Receiver distance raised to some power – typically to the second power [5]. The Free Space model [7], also known as Friis propagation model, calculates the average radio signal attenuation over distance d. When assuming isotropic propagation of waves this relates to a quadratic loss of signal power over distance given in [6]. Although the parameters can be adjusted the model behaves completely deterministic and neglects physical effects like reflection, scattering or fast fading. Consequently, in a scenario with a single transmitter and several receivers, the area containing successful receivers is a fixed circle. As such, this model is highly idealistic and unrealistic. It basically represents the communication range as a circle around the transmitter. If receiver is within the circle, it receives all the packets. Otherwise, it loses all the packets.

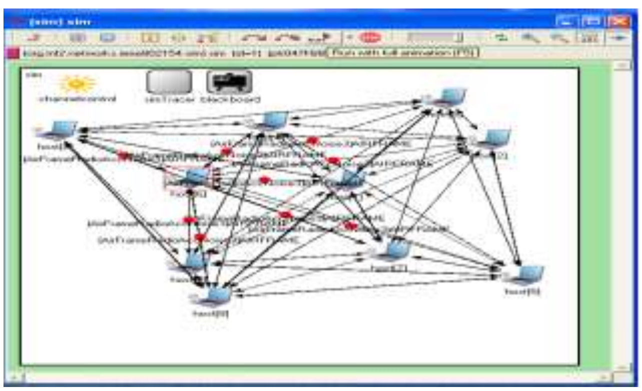
1.2 Two-Ray Model
This model, which is a more realistic model than the Free-Space model, addresses the case when we consider a ground reflected propagation path between transmitter and receiver, in addition to the direct LOS path. This model is especially useful for predicting the received power at large distances from the transmitter and when the transmitter is installed relatively high above the ground. It is interesting to note that at far distances, the received power becomes independent of the frequency. Also, the received power attenuates much more rapidly with distance, compared to the Free-Space model, i.e., attenuates to the fourth power of the distance [5]. The Two Ray Ground model [7] takes into account an additional reflection on the ground in the path-loss calculation. Although the conceived reception powers match reality better, this model still is deterministic and has a circular-shape reception area.

1.3 Log-Normal Shadowing Model
The empirical approach for deriving radio propagation models is based on fitting curves or analytical expressions that recreate a set of measured data. Adopting this approach has the advantage of taking into account all the known and unknown phenomena in channel modeling. A widely-used model in this category is Log-normal Shadowing. In this model, power decreases logarithmically with distance. The average loss for a given distance is expressed using a Path Loss Exponent. For taking into account the fact that surrounding environmental clutter can be very different at various locations having the same transmitter-receiver distance, another parameter is incorporated in the calculation of path loss. According to measurement results, this parameter, called shadowing hereafter, is a zero-mean Gaussian distributed random variable (in dB) with a standard deviation, also expressed in dB. Shadowing accounts for the fact that measured data are sometimes significantly different from the average power at a given distance from the transmitter. For calculating the received power based on this model, we first calculate the received power at a reference distance using the Friis formula. Then, we incorporate the effect of path loss exponent and shadowing parameters [5]. Theoretical and experimental propagation models have shown that the transmitted signals decrease logarithmically with distance.

2. SYSTEM DESCRIPTION
The model presents the implementation of the CSMA mode of IEEE 802.15.4 standard. It is developed in OMNET++ Mobility

Framework developed by CSEM. Thus, the radio never enters sleep mode, which makes it a bad candidate for ultra low power wireless sensor networks, but can be useful for comparison purpose. There are four main modules: snrEvalRadioAccNoise3,DeciderRadioAccnoise3, WiseRoute, SensorApplLayer each of which is an independent module implemented in Mobility Framework OMNeT++. The modules are connected with each other via gates and communicate via messages [1].

The Fig. 1 demonstrates the IEEE 802.15.4 wireless sensor network in the field simulated TKENV is a plane area defined in playground X-Y coordinates [2-3]. The feature provided by the Mobility Framework allows having mobility on sensor nodes. Therefore the connections between the sensor nodes are generated dynamically. The area of simulation in the FIG. 3.1 is delimited by black border around white area. The Fig. illustrates channelcontrol, simTracer, blackboard and host (various sensor nodes). The channelcontrol handles all the connections and responsible for establishing communication channels between host module that are within communication distance.



The simTracer provides a general interface for collecting statistical data of a simulation and has minimal impact on the performance of the simulation and leaves full flexibility for different analysis methods. It maintains parameters that need to be accessed by more than one module within a node [6]. Blackboard is used to evaluate the performance of protocol. It allows to exchange information between layers, without passing pointers to modules [6]. The various nodes revealed here host 1 to host 9 are sensor nodes, host 0 act as a sink node.

To perform the simulation in OMNeT++ the important parameter are presented in omnetpp.ini file are presented in Table 1. The simulations are run for 10 sensor nodes, with 5000 seconds of total simulation time, in an area of 500m X 500m. The mobility of each node is also defined in the omnet.ini file with mobility speed and update interval in every 0.5s. All the parameters that are used in realistic simulations are set according to the parameter listed.

Table 1

SIMULATION PARAMETERS

Parameters	**Value**
Sim-time-limit	5000 s
Carrier frequency	868 E + 6
Max Tx Power	110.11 mW
Signal Attenuation Threshold	-120 dBm
Alpha	2
Application Header length	10 byte
RSSI Threshold	-90, -70, -50, -30 dBm
No. of nodes	10
Mobility Speed	1
Playground X, Y	500 m, 500 m

As previously discussed, the IEEE 802.15.4 standard is particularly relevant to WSNs. In this system we have used two different path loss models for IEEE 802.15.4 at 2.4GHz, both of which are based upon the log-distance path loss model.

2.1 Path Loss Model 1

The IEEE 802.15.4 use the path loss model as explained in detail in section 2.3 for communication. The equation used for calculating the path loss model is given in [5]. This equation is used to calculate the path-loss for this model.

2.2 Path Loss Model 2

The IEEE 802.15.4 specification specifies a path loss model for communication at 2.4GHz. The lower bound of 0.5m is added from the IEEE 802.15.2 specification (upon which the model is derived). Through inspection this model can be seen to specify free space LOS propagation for the first eight meters (using Friis free-space propagation), and the log-distance path loss model with $d_0 = 8$m and $\eta = 3.3$ (with no lognormal shadowing) for distances greater than this as the equation given in [8].

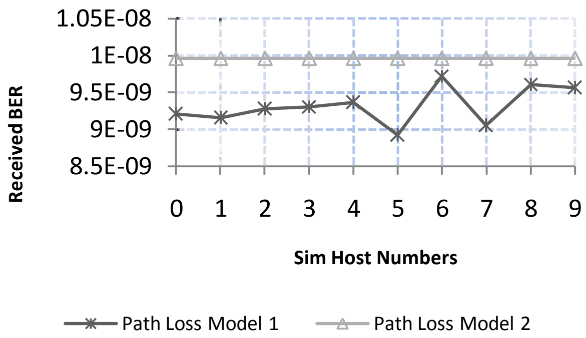
By inspecting both the models we obtain the results as given this section.

3. RESULTS AND DISCUSSIONS

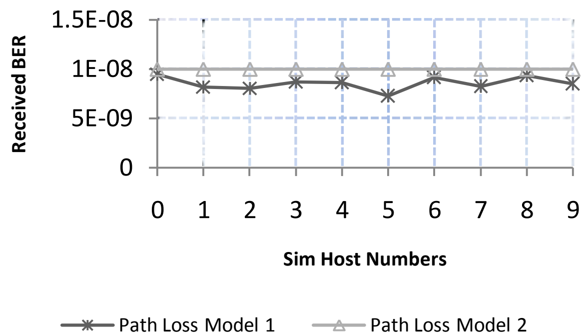
In the simulation, a small wireless sensor network nine sensor nodes is organized in a regular playground of 500m X 500m with a single sink node at the upper left of the network that is destination for all packets snapshot of the network is shown in the chapter 3. The simulation run for path-loss model 1 and path-loss model 2 and the results gathered from simulation are compared for these path-loss models discussed in this section.

3.1 Case 1: BER

The bit error rate (BER) gives the probability of a single bit begins incorrectly transmitted across a communication channel. We obtain the results BER versus number of nodes transfer packet. The fig 1 (a) shows the result for path-loss models using chipset CC1100 whereas fig. 2 (b) shows the results for path-loss model using chipset CC2420. In this we optimized result for each sim host on the path-loss models. The fig 1(a) presents that the BER is almost same in case all sim hosts for Path-Loss Model 1. But for Path-Loss Model2 it varies for all sim hosts. The BER obtained for path-loss model 1shows that it degrades the performance of the network load. This happens may be due to more number of packets present in network and cross talk may increase. The path-loss model performs better than the path-loss model 2 as shown in fig. (a) that the BER is less than in path-loss model1.



(a)



(b)

Fig 1: BER in different Path Loss Models for different Sim Host Numbers using chipsets (a) CC1100 (b) CC2420

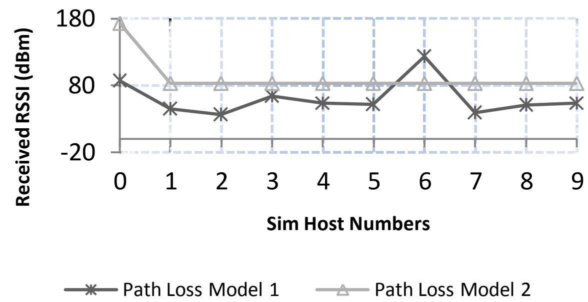
The fig. 1(b) shows the results for the chipset CC2420 and also compares the both path-loss models. It is clearly indicate that the result of path-loss model 1 is same for both chipset if we compare these results with fig. 1 (a). But in case of path-loss model 2 the results are very different. The graph represents the high BER in this case and may be due to noise increases in the network. The Path-loss model 2 in below given graph presents that there less error while transfer packets as compare to the path-loss model 1.

If the results of both fig. 1 (a) and (b) than it has been observed that the models using on the chipset CC1100 performs better than chipset CC2420. For chipset CC1100 the path-loss model performance is improved. Use of path-loss model 2 reduce the deflection will deteriorate BER substantially.

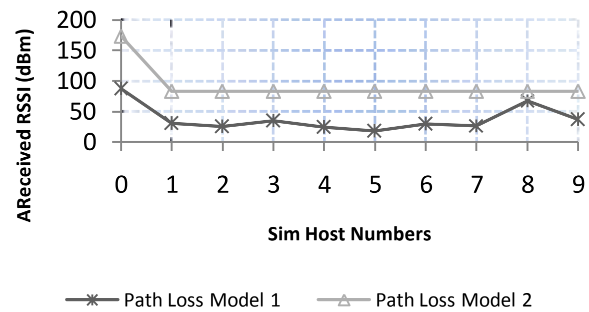
3.2 Case 2: RSSI

In this case we present the results for measuring RSSI for sim hosts. RSSI can easily reflect on walls and other obstacles present in the area. The fig. 2 (a) shows the reading of received signal strength. There are variations for RSSI for sim host in case of path-loss model1. Whereas in the path-loss model 2 the RSSI is same for all sensor node apart from sink node. It has observer very high signal strength for sink node for path-loss model 1.So, the path-loss model 2 gives high-quality signal strength in comparison with path-loss model 1.

In the fig. 2 (b) shows the results for different path-loss model on chipset CC2420. The results shown in the fig. (b) that there is variability in the RSSI for path-loss model 1. There is no temporal pattern in the RSSI unevenness. We observed that for path-loss model 2 RSSI shows consistency from sim host 1 to 9, while it is very elevated in case of sink node.It is marked from graph that path-loss model 2 gives better result than path-loss model 1. The chipset CC1100 gives improved results for RSSI even for path-loss model 2. Thus, it has been concluded from above discussion that the efficiency of path-loss model 2 is much more than path-loss model 1 for RSSI.



(a)

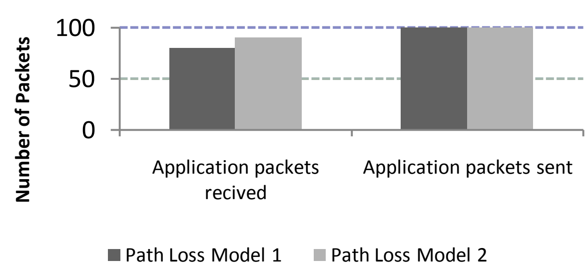


(b)

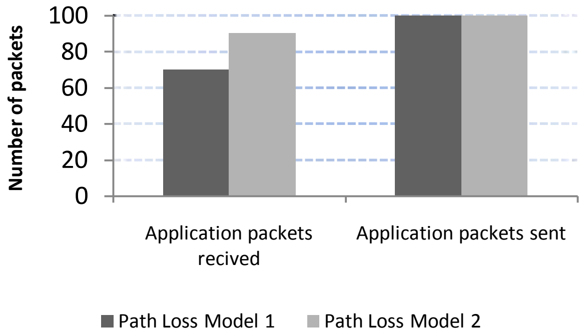
Fig. 2: RSSI in different Path Loss Models for different Sim Host Numbers using chipset (a) CC1100 (b) CC2420

3.3 Case 3: Tx and Rx Packet

We observe transmit (TX) and receive (RX) packets in the network. The observations are traced by the sim tracer that how many numbers of packets transmit and receive in this network. The fig. 3 (a) shows the result for path-loss model 1 and path-loss model 2 on chipset CC1100. We find the 90 number of packets transferred in case of path-loss model 1while, only 80 number of packets received for path-loss model 1. The number of packets transmit is same for both 100.



(a)



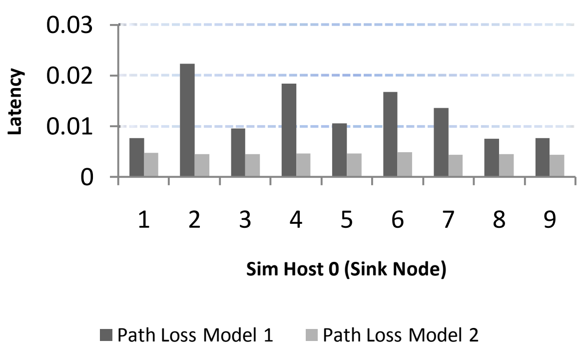
(b)

Fig. 3: TX and RX packets for different Path-Loss models on chipsets (a) CC1100 (b) CC2420

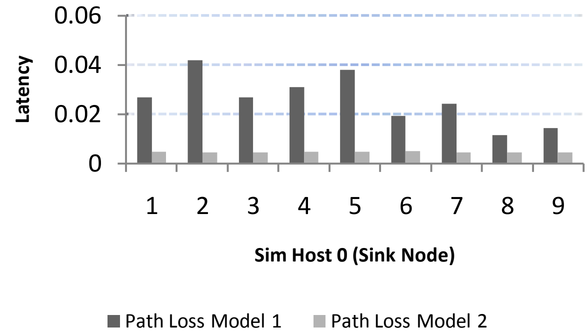
The above shown histogram presents result for the chipset CC2420. It is observed from above histogram that only 70 numbers of packets are transfer for path-loss model 1 whereas 90 for path-loss model 2. The number of packets transmit is 100. The performance of network for TX and RX packet is not good for path-loss model 1 in both chipset. It is very deprived on chipset CC2420 for path-loss model 1. But it is fine for path-loss model 2 as shown in fig. 3 (b).

3.4 Case 4: Latency

We observe here the different latency (delay) time for different path-loss models for different chipset. The latency time is monitor at the sink node (sim host [0]). Latency has great impact on the network. If the more delay in transfer of frames or packet noted this means the latency time increases and the network performance degrades. In the fig. 4 (a) and (b) sows the latency for different path-models in different chipsets. The fig. 4 (a) histogram presents the more delay in transfer packets for path-loss model 1 than path-loss model 2. The value of latency is almost similar for each sim host.



(a)



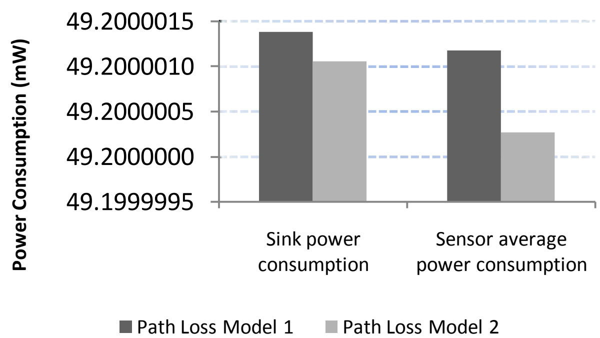
(b)

Fig. 4: Latency in different Path Loss Models for Sim Host 0 (Sink node) using different chipsets (a) CC1100 (b) CC2420

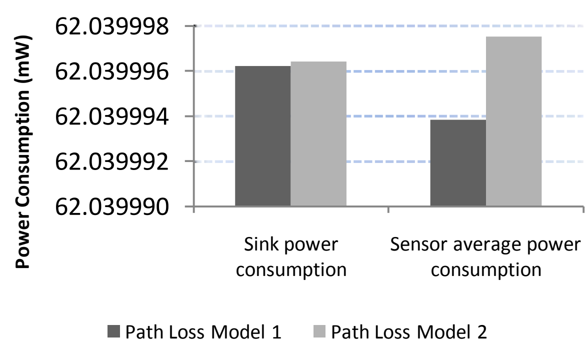
In fig. 4 (b) highlights the latency of path-loss model 1 as in this case also the latency for path-loss model 1 is noted high in comparison with path-loss model 2 on chipset CC2420. If the results of fig. 4 (a) and (b) are compared then it has seen clearly that chipset CC1100 gives better result for path-loss model 2.

3.5 Case 5: Power Consumption

The fig. 5 (a) and (b) shows the power consumption of the network observed by the sim tracer. The power consumption for the path-loss model 1 is much more than path-loss model 2 for chipset CC1100. The sink power consumption is less for path-loss model 2 as shown in the histogram fig. 5 (a).



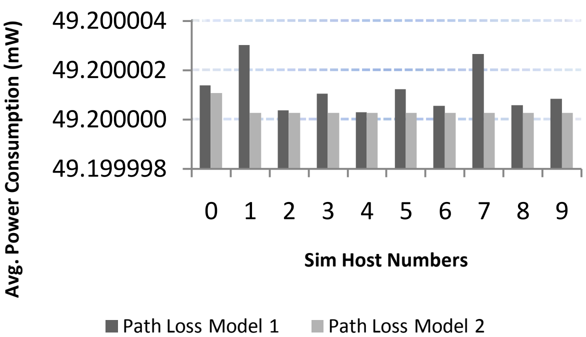
(a)



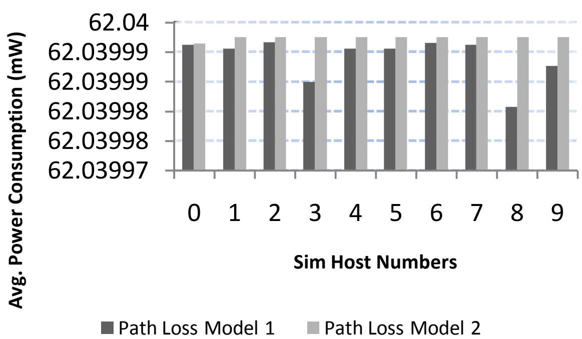
(b)

Fig. 5: Power Consumption for different Path-Loss models on chipsets (a) CC1100 (b) CC2420

We find that for chipset CC2420 the power consumption is more in case of path-loss model 2 than path-loss model 1. So, in this case the path-loss model 1 performs better. But if we compare the results of figure (a) and (b) then the chipset CC1100 performs better for path-loss model 2. Power consumption is a problem that has been extensively addressed in the research of wireless sensor networks. Since the radio is main cause of power consumption in a sensor node, transmission-reception of data should limited as much as possible. The power consumption of an active node is equal to the sum of the power consumption in all working modes.



(a)



(b)

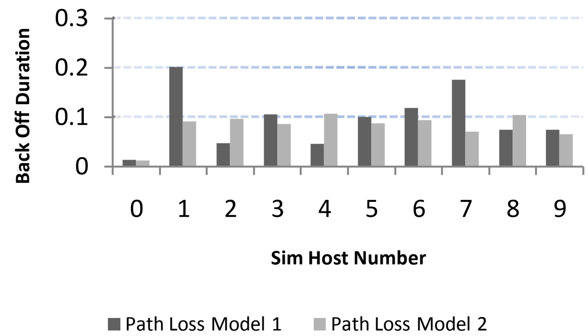
Fig. 6: Power Consumption in different Path Loss Models for different Sim Host using chipsets (a) CC1100 (b) CC2420

The sleeping power consumption is orders of magnitude lower than active power consumption. The fig. 6 (a) and (b) presents the power consumed by each sensor node for different path-loss model in different chipsets. It has been observed from below shown figures that power consumption for path-loss model 2 is less as compare to the path-loss model 1for chipset CC11000.

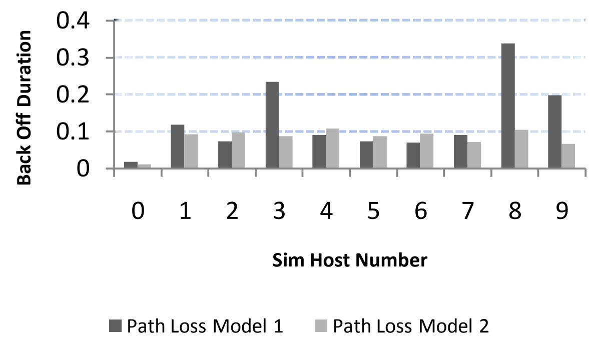
But for chipset CC2420 the histogram shows that power consumption by path-loss model 1 is less than path-loss model 2. If we compare the fig. 6 (a) and (b), it is evident that chipset CC1100 performs better for this network for path-loss model1.

3.6 Case 6: Back-Off

In this case we present the back-off period for each sim host in different path-loss models using different chipsets. When any sensor node wishes to transmit data packet it waits for random number of back-off periods before sensing channels. If the channel is busy, the node increases the number of attempts by one and checks if maximum number of attempts exceed, it generates error and report to upper layer. So, the maximum back-off period observed in our network for each sensor node is shown in figures below. The fig. 7 (a) presents the maximum back-off period for sim host 1, 6, 7 more than 1s in case of path-loss model 1.



(a)



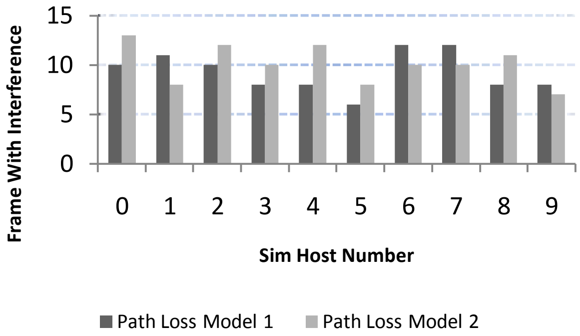
(b)

Fig. 7 : Back-Off Duration in different Path Loss Models for different Sim Host using chipsets(a) CC1100 (b) CC2420

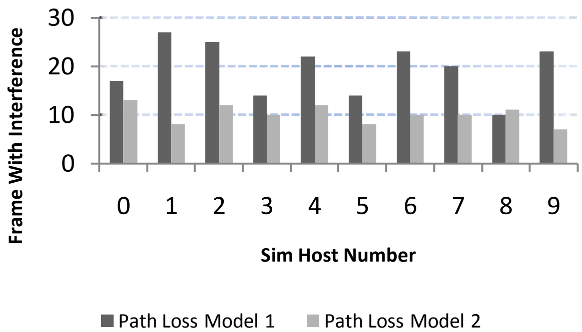
The back-off period in case of path-loss model 2 for these nodes is less than path-loss model 1. Back-off duration is more than 1s for sim host 4, 8 for path-loss model 2; other sim host has less than 1s of back-off duration period.

3.7 Case 7: Frames with or without Interference

This case shows the number of frames received with interference for path-loss models in different chipsets. The fig. 8 (a) shows that the frames received in both path-loss models has more or less at different sim host numbers. The sim host numbers 0, 2, 3, 4, 5, 8 receives more number of frames with interference for path-loss model2.



(a)

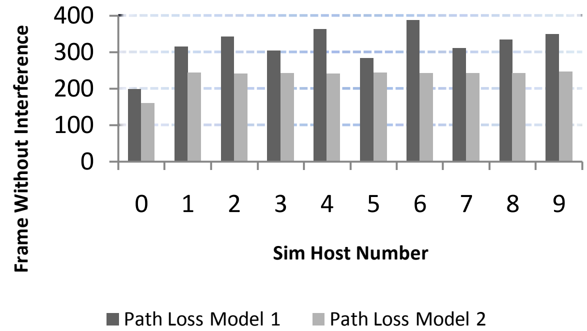


(b)

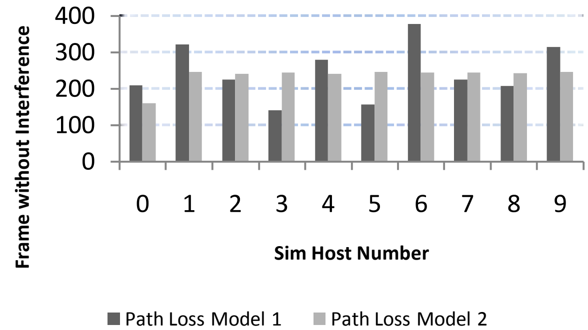
Fig 8: Frame-with-interference in different Path Loss Models for different Sim Host using chipsets (a) CC1100 (b) CC2420

While sim host numbers 1, 6, 7, 9 have more number of frames with interference for path-loss model 1. The below given histogram shows the result for chipset CC2420, it has been observed that more number of frames received with interference in case of path-loss model1. Whereas the frames receive in case of path-loss model 2 with interference are less in numbers.

The figure presents the number of frames received without any noise or interference for different path-loss model for different chipsets. We find that the frames received without interference is in path-loss model 1 are more than path-loss model 2 for different chipsets. Thus in case of sim host number 6 the maximum value observed for the frames received shown in figures 9 (a) and (b). It is recorded lowest for sim host number 3 for chipset CC2420 in path-loss model 1. The values for path-loss model 2 almost identical for both chipsets; only the difference is very small.



(a)

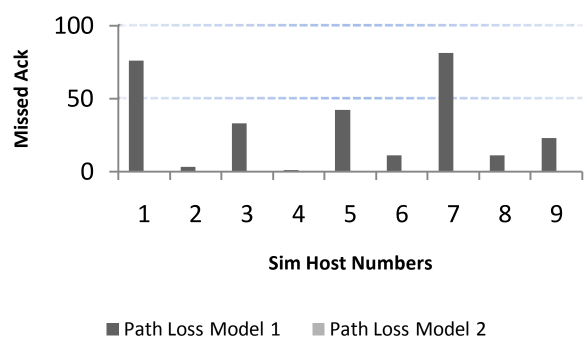


(b)

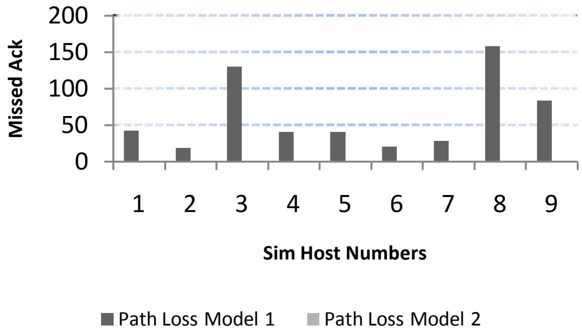
Fig. 9: Frame-without-interference in different Path Loss Models for different Sim Host using chipsets (a) CC1100 (b) CC2420

3.8 Case 8: Ack

This part shows the information about the acknowledgement (ack) missed and receives during simulation. We observe that the missed acknowledgement for path-loss model 1 is more than 30 for sim host number 1, 3, 5, 7. On the other hand the missed ack for path-loss model 2 is nil as shown in fig. 10 (a) for chipset CC1100.For chipset CC2420 the missed ack are also nil for path-loss model 2. Whereas it is recorded maximum on sim host 3, 8 and 9 for path loss model 1 as present in the fig. 10 (b).



(a)

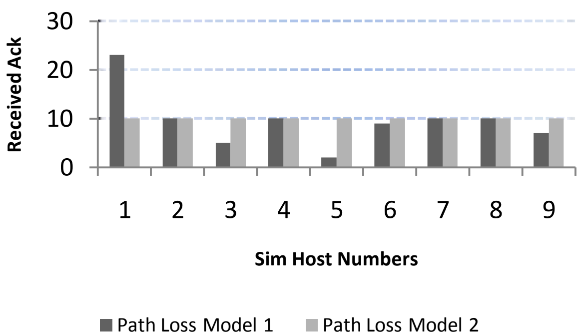


(b)

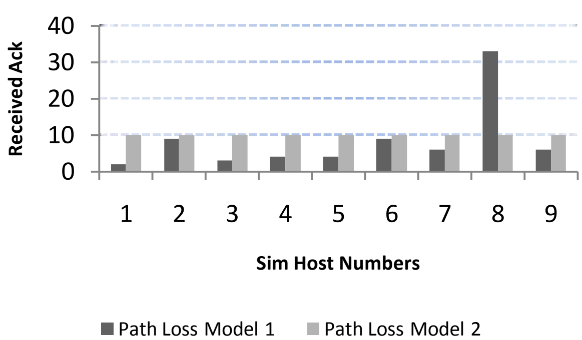
Fig. 10: Missed Ack in different Path Loss Models for different Sim Host using chipsets(a) CC1100 (b) CC2420

It is clearly seen that the performance of path-loss model 1 is better in this case if we compare the results of these path-loss models for different chipsets.

We observed from fig. 11 number of ack received during simulation. Fig. 11 (a) shows the results for chipset CC1100. The numbers of ack received in case of path-loss model 2 are 10 for each host. While it is more than 10 for sim host and less than 10 for sim host 3, 5, 6, 9 in case of path-loss model1. The next histogram in figure (b) shows results for chipset CC2420.



(a)



(b)

Fig. 11: Received Ack in different Path Loss Models for different Sim Host using chipsets (a) CC1100 (b) CC2420

The above histogram in fig. 11 (b) present that the values for path-loss model 2 is 10 same as for chipset CC1100. But for path-loss model 1 more number of ack received for sim host 8.While it less for other sim host 1-7, 9. So, the performance of path-loss model 2 is same for both chipsets whereas it is different for path-loss model 1.

4. CONCLUSION

In this paper we present the different path-loss models for LR-WPAN (IEEE 802.15.4). We have discussed simulation results for the comparative investigation of the performance for different wireless Path-Loss Models in a simulated environment for different chipsets.

The path-loss model 1 performance is observed better for chipset CC1100. Use of path-loss model 2 reduces the deflection deteriorate BER substantially. The signal strength received for path loss model 2 is high and constant for sim host 1 to 9 for both chipsets. But in case of chipset CC1100 it is recorded very high 120 dBm at sim host 6 for path-loss model 1.The simulation results indicated that the power consumption decreases and efficiency of sensor networks increase when path-loss model 2 is used instead of the path-loss model 1. The different latency time is recorded for different chipset at sink node. As latency has great impact on network. The time recorded for path-loss model 2 is very less than path-loss model 2.

It is evident from the discussions that each of the path-loss models studied performs well in some cases yet has certain drawbacks in others for different chipsets. Our simulation results show that the path-loss model 2 performed significantly better than path-loss model 1.

5. REFERENCES

[1] http://sourceforge.net/projects/mobility-fw/

[2] “Mobility Framework”,http://mobility-fw.sourceforge.net/

[3] H. L. Bertoni, “*Radio Propagation for Modern Wireless Systems”,* Upper Saddle River, NJ, Prentice Hall PTR, 2000, pp. 90-92.

[4] Tapan K. Sarkar et. al. “A Survey of Various Propagation Models for Mobile Communication”, June-2003

[5] Masood Khosroshahy, Thierry Turletti, Katia Obraczka, “Snapshot of MAC, PHY and Propagation Models for IEEE 802.11 in Open-Source Network Simulators” Sept-2007.

[6] Kuntz et. al. “Introducing Probabilistic Radio Propagation Models in OMNeT++ Mobility Framework and Cross Validation Check with NS-2”, March-2008.

[7] T. S. Rappaport. Wireless Communications: Principles & Practise. Prentice Hall Communications Engineering and Emerging Technologies Series. Prentice Hall PTR, Upper Saddle River, NJ 07458, 1996.

[8] Geoff V. Merett, “Energy- and Information-Managed Wireless Sensor Networks: Modelling and Simulation” Oct-2008.