Comparing the ns3 Propagation Models

(Authors: Mirko Stoffers, George Riley)

Project Report

Georgia Institute of Technology
ECE 6110 Computer Networks
Spring 2016

Submitted by
Abhinav Murali (GT ID: 902924251)
Mrunmayi Paranjape (GT ID: 90311020)
Prapurna Jayakrishna Duvvuri (GT ID: 903091962)
Uday Kiran Ravuri (GT ID: 903145978)

Overview:

In this experiment, we aim to recreate the experiments performed by authors in [1] and reproduce the results observed in the paper. The experiment is designed to compare the propagation loss models in ns3 and compare the performance of different routing protocols in wireless ad-hoc networks. Wireless ad-hoc networks are decentralized networks with no pre-established links. Such networks are characterized as having a random node deployment with nodes having little or no information about the topology and node mobility. It is important to investigate the behaviour of these networks under various network conditions, including path loss, interference and traffic intensity. To simplify the analysis, we restrict our focus to two major objectives listed below:

- Compare the performance of propagation loss models implemented in ns3 for wireless ad-hoc networks in terms of network efficiency and computational complexity
- Observe the difference in behavior for different categories of routing protocols.

Note that we make some assumptions about the network conditions in order to isolate the effects of propagation loss models for various routing protocols:

- The traffic intensity is set to a low value to ensure that the number of collisions is minimized in the network during channel access and data transfer.

Propagation loss

The transmitted signal experiences a combination of channel effects that affect the received signal strength at the receiver. These effects include factors such as attenuation, fading, shadowing, interference, etc as shown in Fig 1. The results are captured using sophisticated statistical channel models that model the behaviour of a signal in different channel types. Since the wireless channel is vastly different at different locations and time, it not possible to model the behavior using a universal loss model. As a result, there are several propagation loss models that have been documented in literature.

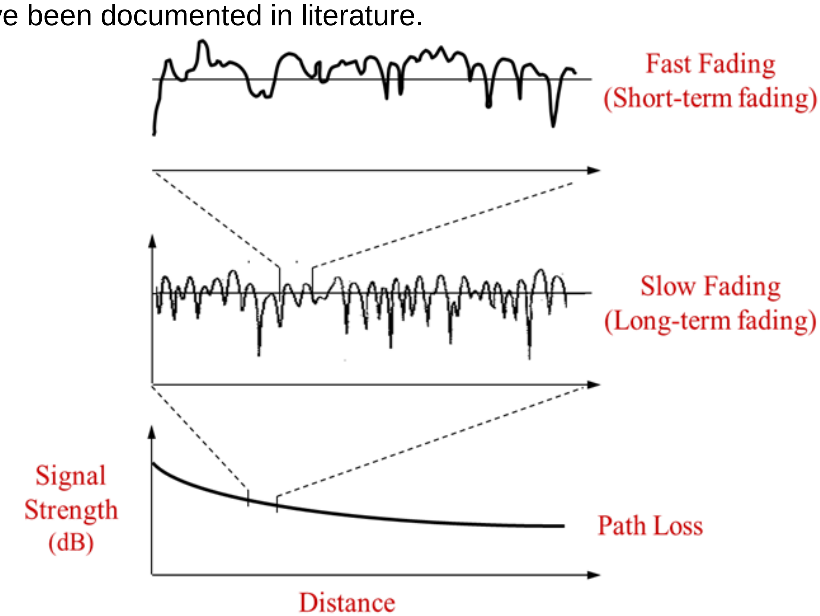

Fig 1. Channel effects

In this experiment, we consider a small subset of these loss models and observe the difference in performance by varying the channel assumptions. We aim to show that choosing a loss model is not a trivial task and that the performance of the network is highly dependent on these assumptions. In particular, we show that the assumptions about the loss models will greatly affect the efficiency that can be extracted from the network for different routing protocols. Loss Models are classified into three groups:

- Abstract Propagation Loss Models
- Deterministic Path Loss Models
- Stochastic Fading Models

Loss Model	Default Parameters	Modifications
Fixed RSS	RSS : -150dBm	RSS : -50dBm
Matrix	Loss : 1.8 x 10^{308}	Loss : 50
Range	Max. Range : 250m	
Random	Loss : Constant (1dB)	Loss : N(50dB,25dB)
COST Hata	F = 2.3 GHz, BS Ant. Ht = 50m, MS Ant. Ht = 3m, Min. Dist = 0.5m	
Friis	Wavelength = 58.25mm, System Loss : 1, Min. Dist = 0.5m	
Log Distance	Exponent = 3, Ref. Dist. = 1m, Ref. Loss = 46.67dB	
Three Log Distance	Dist. = 1m, 200m, 500m; Exponents = 1.9, 3.8,3.8; Ref. Loss (1m) = 46.67dB	
Two Ray Ground	Wavelength = 58.25m, System Loss : 1, Min. Dist = 0.5m, Ht. above Z = 0m	Ht. above Z = 1m
Jakes	Rays per path = 1; Oscillators per ray = 4; Doppler freq = 0Hz, Distribution = Const (1)	
Nakagami	Dist. = 80m, 200m; Exponents = 1.5,0.75,0.75	

Table 1: Propagation loss models considered for the experiment

Experiment Setup

We consider a set of 50 IEEE 802.11a wireless ad-hoc nodes distributed across a 1km x 1km area. Further, we chose a subset of 20 nodes, each of which is paired with a random peer in the network. This is shown in the figure below:

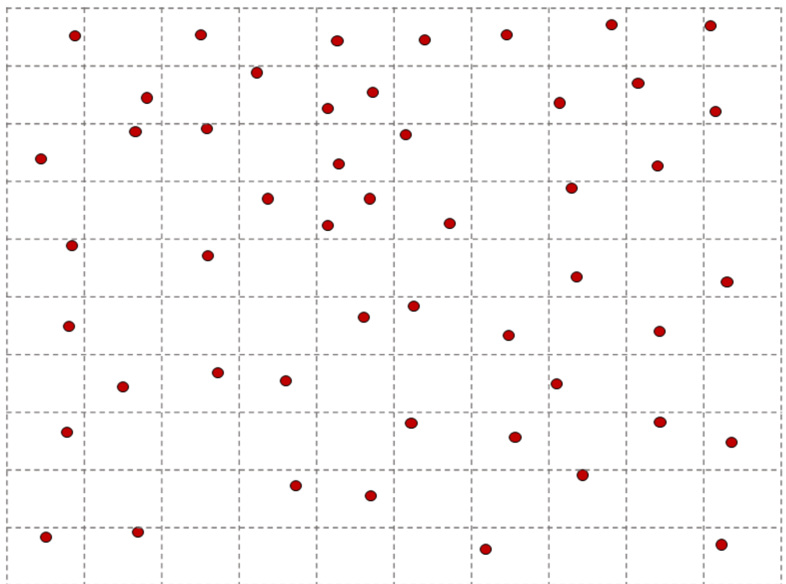

Fig 2. Network topology

Simulation Parameters:

Parameter	Authors in [1]	Experimental setup
Traffic Intensity	2%	2%
UDP Traffic	500 kbps	500 kbps
Traffic source	OnOffApplication (constant bit rate traffic)	OnOffApplication (constant bit rate traffic)
Transmit power	[1mW, 10mW, 100mW, 1000mW]	[1mW, 10mW, 100mW, 1000mW]
Routing protocols	[AODV, OLSR, DSDV]	[AODV, OLSR, DSDV]
Simulation platform	ns-3.12.1	ns-3.12.1
Timing information	RDTSC register	RDTSC register
System Information	2.8 GHz quad-core Xeon CPU 6 GB RAM, Ubuntu 11.10, ns–3.12.1	2.6 GHz, Core-i7 6700 HQ, 8 GB RAM, Ubuntu 12.04, ns–3.12.1

Results:

We shall now present the simulation results for the given experiment. We compare our results with those obtained in the paper.

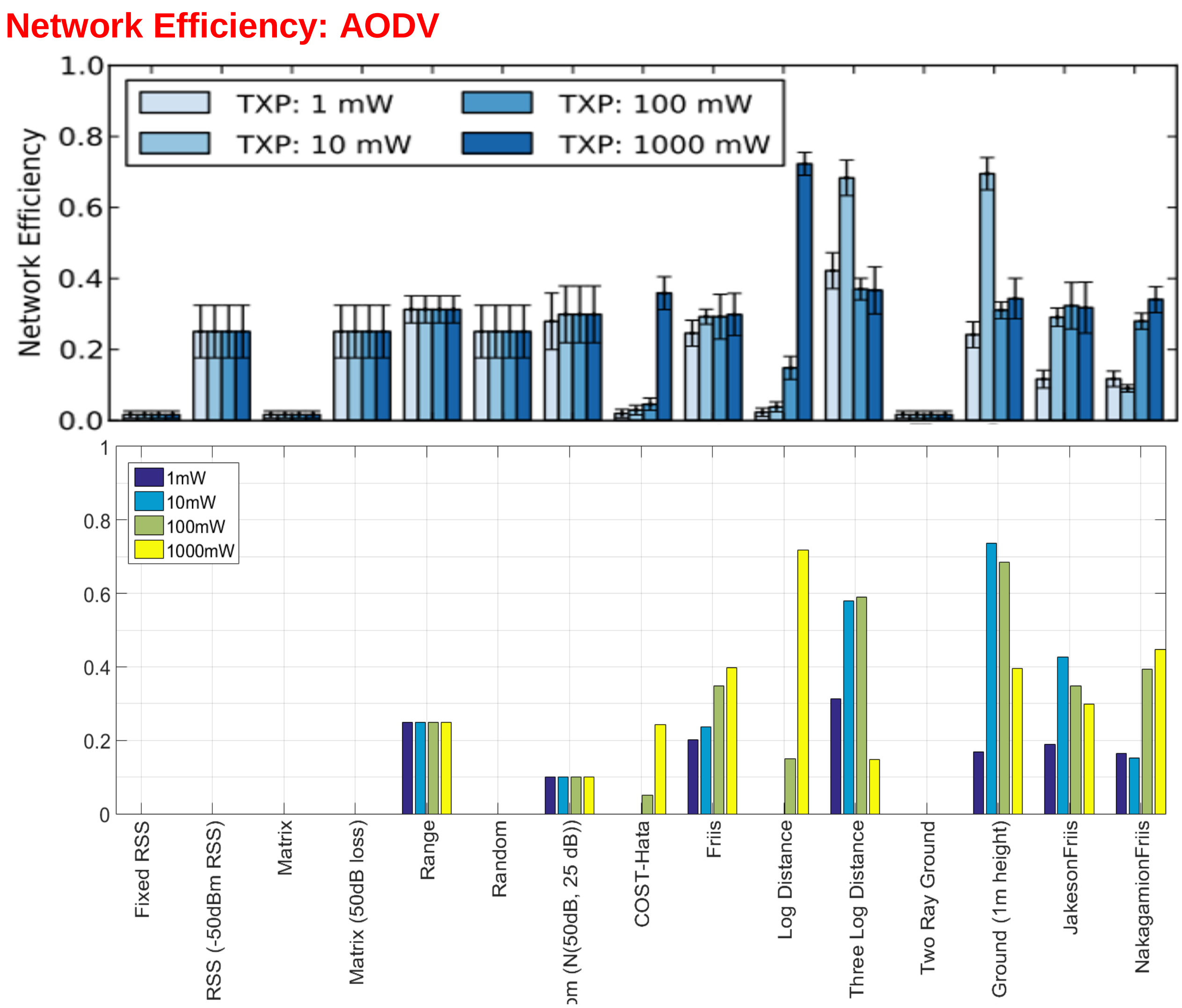

Fig. 3 Network Efficiency: AODV, Results reported in [1] on top and results from our simulations at the bottom.

Performance similarities

We observe major similarities in the results discussed in the paper and our experiments. In particular, we were able to verify the following trends:

- We observe a slight increase in throughput when the Random propagation loss model is fed with random numbers, instead of a constant loss.
- For COST-Hata and Log Distance Models, increasing transmission power increases the network efficiency - this is explained as environment conditions are assumed to be urban areas, hence, require higher transmission power to reach higher number of nodes.
- When the Friis model is applied, the network achieves considerable efficiency for low transmission rates which is however not improved by increasing transmission power.
- For the combination of Friis and Jakes/Nakagami fading model, we observe minor decrease/increase in the network efficiency, albeit with a low throughput at low Tx powers.

Performance differences

We also observe some anomalies in results which are discussed below:

- Although the authors in [1] report non-zero throughput (approx 20-30%) for abstract loss models, our simulations produce zero throughput (0%). Furthermore, we did not observe any change in throughput by randomizing the start time or the transmit power of all the nodes in the network. We expected the throughput to increase for a sufficiently high transmit power and/or random start times of the UDP applications at the nodes, but that was not observed. We therefore attribute this <u>anomalous behaviour to a bug in ns-3.12.1 implementation</u> used in the experiments.

****

Network Efficiency: OLSR

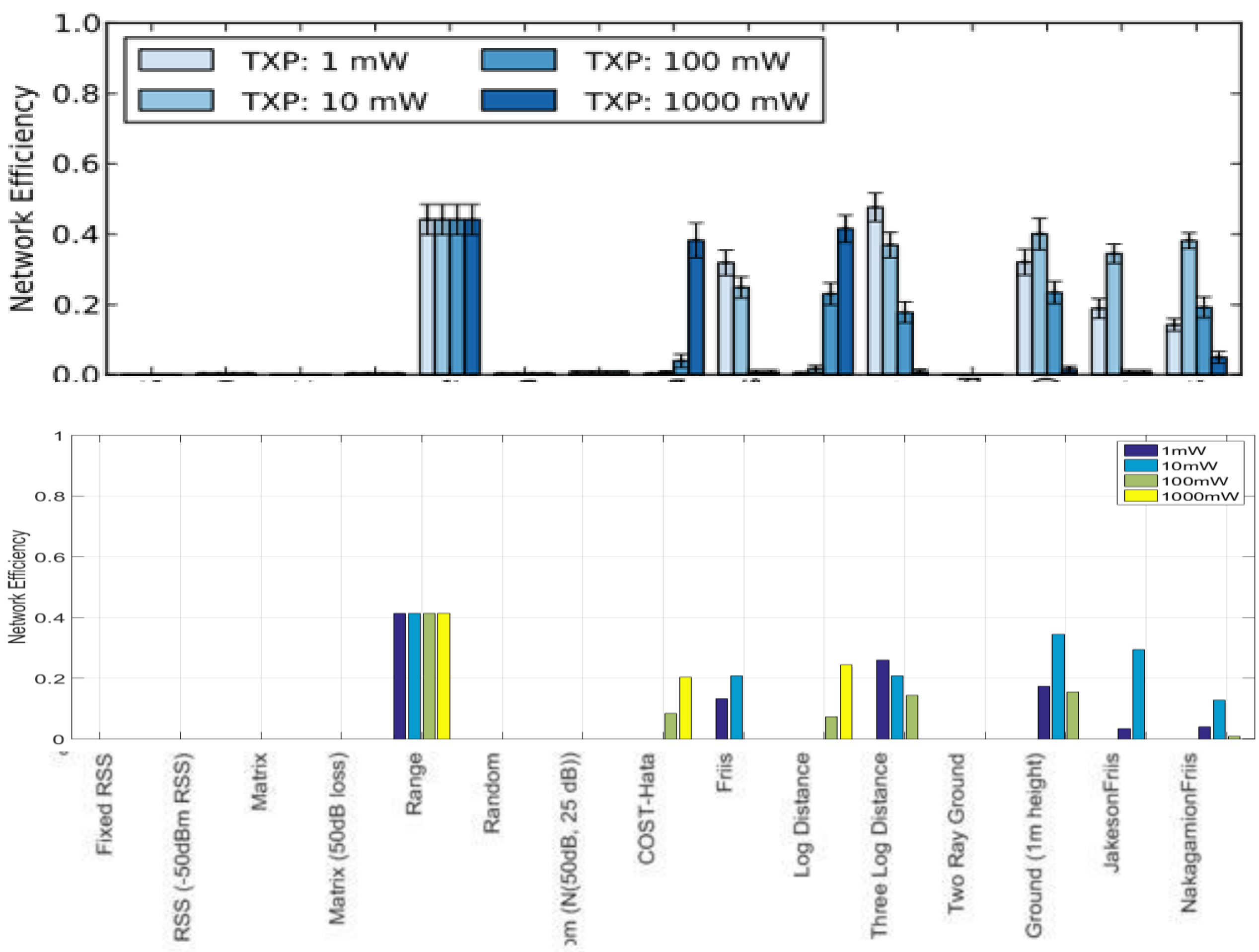

Fig. 4 Network Efficiency:OLSR, Results reported in [1] on top and results from our simulations at the bottom.

Network Efficiency: DSDV

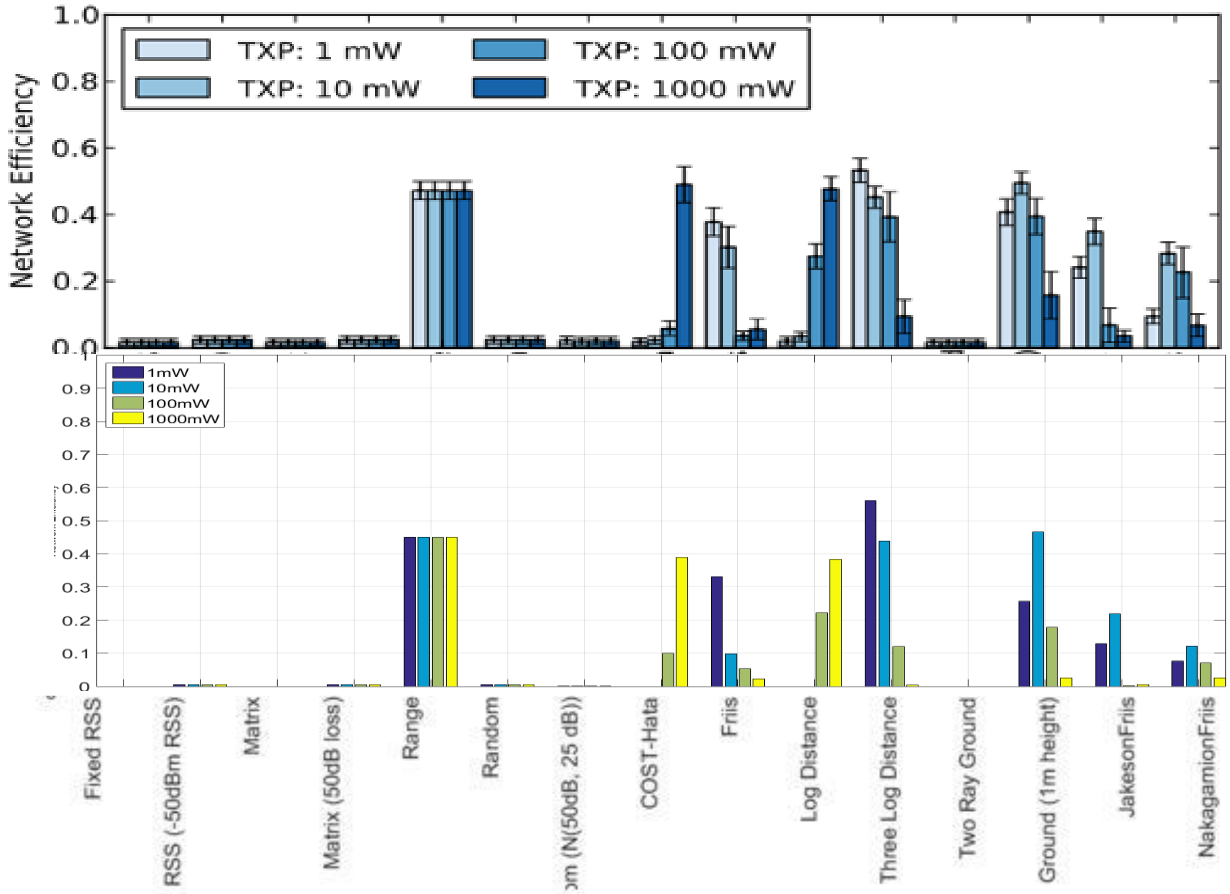

Fig. 4 Network Efficiency: DSDV, Results reported in [1] on top and results from our simulations at the bottom.

Because OLSR and DSDV fall in the same category of routing protocols, i.e proactive routing protocols, we discuss the results for these protocols together. This behavior is confirmed by the trends observed in the paper and our experiments. We observe that OLSR and DSDV have similar results which is remarkably different from AODV results.

This difference can be explained by the mechanism of these protocols. AODV is On-demand routing protocol. It requests route packets whenever data is to be transferred and from responses, selects path into packet header. Each intermediate route just looks at the header and routes the packet. Hence, nodes can also cache routes. Thus every time a packet is to be transmitted, route is established in AODV. DSDV and OLSR are Proactive Routing Protocols. It is table driven routing which is based on global topology information. It also involves periodic exchange of control messages for route maintenance and updates. Hence, it has low link setup to data transfer delay.

Thus in DSDV and OLSR, nodes have routing tables on which they rely for packet transfer. Hence, in this protocols, there might be incomplete routing table if links are not discovered initially, and packet can be lost due to missed routes.

Performance similarities

We observe major similarities in the results discussed in the paper and our experiments. In particular, we were able to verify the following trends:

- With the Random model applied DSDV and OLSR cannot gain any considerable throughput due to the random nature of the links.
- DSDV and OLSR feature quite high efficiency when the Maximal Range model is used.
- For COST-Hata and Log Distance Models, increasing transmission power increases the network efficiency - this is explained as environment conditions are assumed to be urban areas, hence, require higher transmission power to reach higher number of nodes.
- The fading models again appear to decrease the signal quality on average.

Performance differences:

We did not observe any anomalous behavior in the results from our experiments for proactive routing protocols: OLSR and DSDV

****

Computation Time per packet: AODV

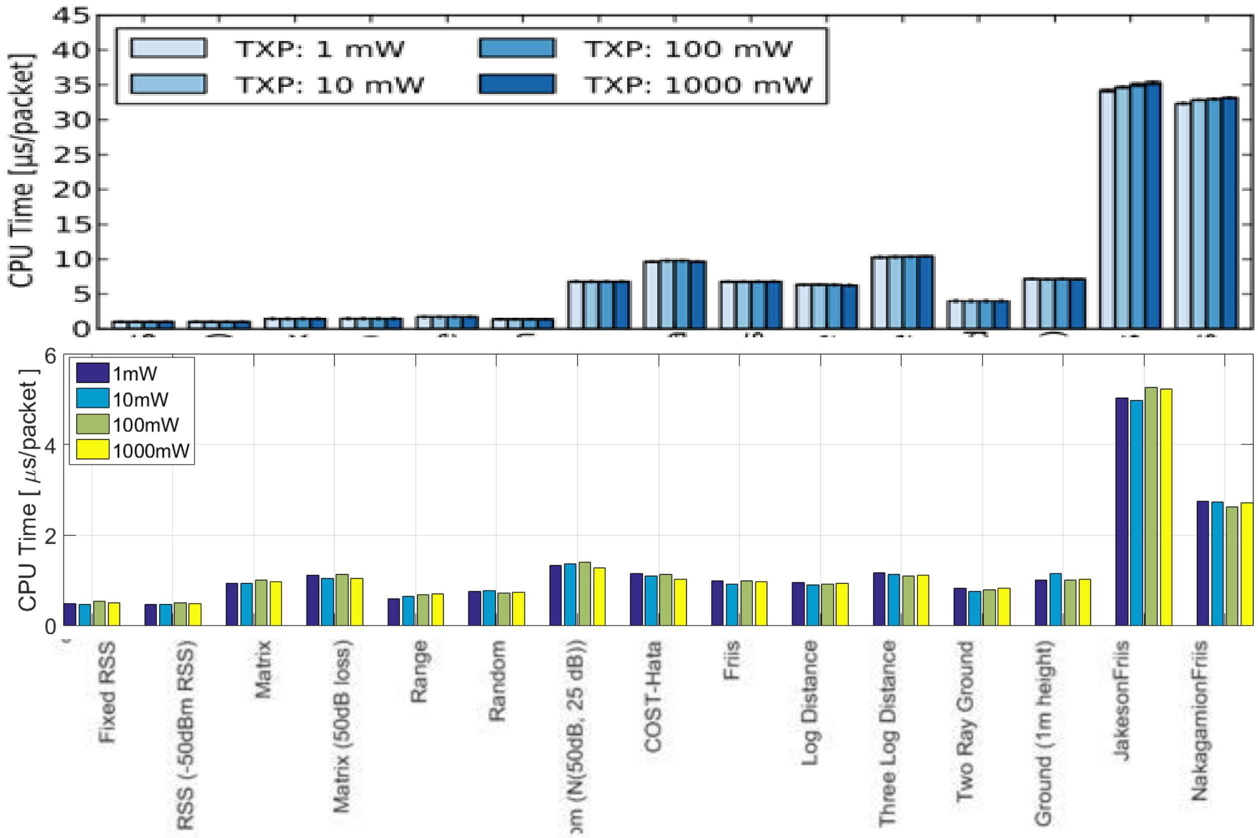

Fig. 5 Computation time per packet: AODV, Results reported in [1] on top and results from our simulations at the bottom.

Computation Time per packet: OLSR

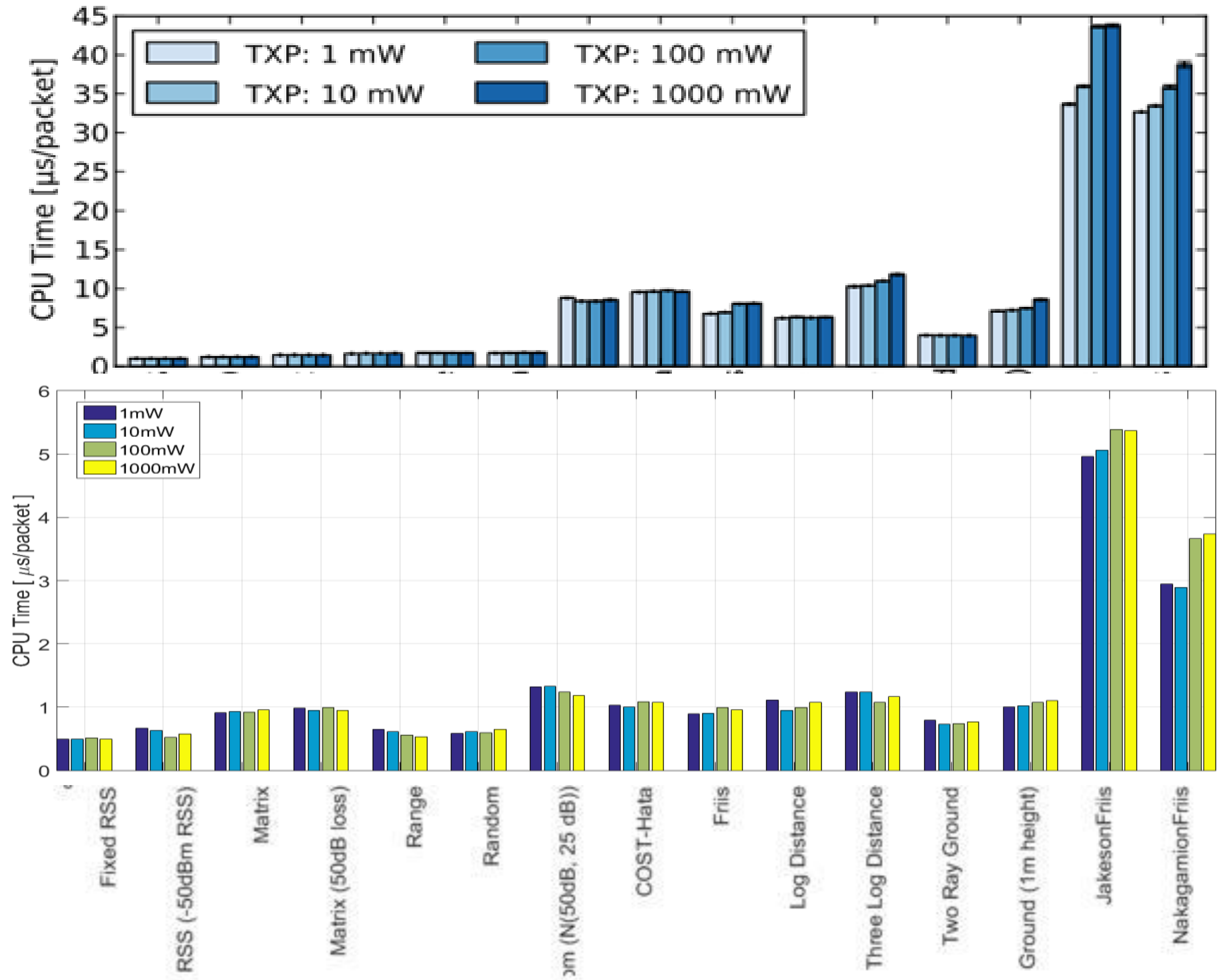

Fig. 6 Computation time per packet: OLSR, Results reported in [1] on top and results from our simulations at the bottom

Computation Time per packet: DSDV

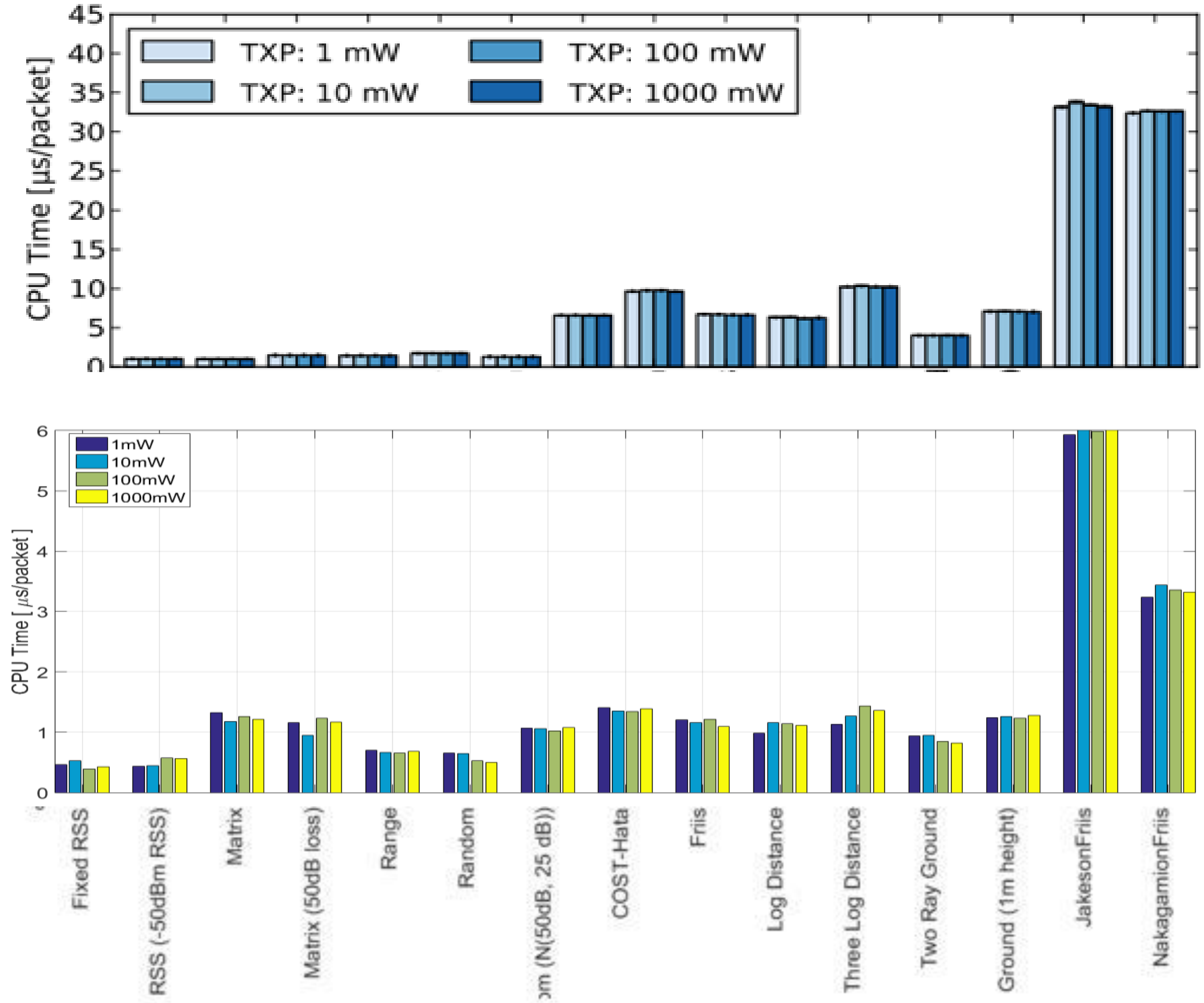

Fig. 7 Computation time per packet: DSDV, Results reported in [1] on top and results from our simulations at the bottom

We group the discussion of computation times for all three routing protocols since they exhibit a similar behavior, due to the fact that computation of time is independent of the routing protocols used.

Performance similarities:

We observe major similarities in the results discussed in the paper and our experiments. In particular, we were able to verify the following trends:

- The composite fading and loss models (Jakes + Friis and/or Nakagami + Friis) are computationally more intensive compared to other loss models considered in this experiment. This is because of the complexity of the mathematical model used for modelling the behavior of the fading models. As a result, the fading models on average are likely to take 2 - 3 times the average computation time required for the abstract and deterministic models.

- In all of complexity trends, we observe that the transmit power does not have much impact on the calculated CPU time per packet.
- We observe a slight dependency of CPU time on transmit power in case of OLSR protocol with the Jakes and Nakagami models.

Performance differences:
We also observe some anomalies in results which are discussed below:
- The CPU time per packet observed in our experiments, is significantly lower than the results observed in the paper for all models. We attribute this anomalous behavior to the hardware used in the experiment. In particular, we believe that a combination of high CPU frequency, modern powerful processor and more processing capacity (RAM) may have helped reduce the computation time.

Conclusions
- The trends we obtained from our simulations correlate with those reported in [1] by and large. Some of the differences in the magnitude of values in between the two simulations stem up because of the difference in the processor clock speed used in the two simulations.
- We also suspect that some of the differences could be because of the fact that we used a Linux virtual Operating System within a Windows box and this could have resulted in differences in memory access times. However, to determine the reasons of the finer differences in the magnitudes, a larger simulation set with multiple varying parameters needs to done.
- We can further experiment with various parameters to calculate which loss model can be efficient to use for various routing protocols.
- Fading models aim at increasing accuracy of the calculated propagation loss by taking into account the frequent changes to the communication environment where fading channels are required.
- All in all there is no one-fits-all solution with respect to the proper choice of a propagation loss model.

References

1. Stoffers, Mirko, and George Riley. "Comparing the ns-3 propagation models."*Modeling, Analysis & Simulation of Computer and Telecommunication Systems (MASCOTS), 2012 IEEE 20th International Symposium on*. IEEE, 2012.