

# Performances Analysis of mobile ad hoc routing protocols under realistic mobility and power models

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## Abstract

Taking into account realistic mobility patterns on a real 3D environment can drastically improve the end-to-end performances. Moreover networks characteristics such as throughput, delay and control traffic can be accurately analyzed when doing simulation with realistic mobility and power models. This paper addresses the need for simulation and analysis of existing routing protocols for military tactical scenarios under more accurate wireless radio pipeline models. The presented work aims to investigate the impact of radio propagation models on different routing protocol parameters.

We have defined different mobility models suitable for the military domain. These mobility models have been generated using a Matlab scenario generator (SMGEN). SMGEN allows linking automatically the generated scenario (with its specific mobility model) to OPNET Modeler through API EMA and C-MEX function. We have also modified the received power pipeline and the others related pipelines in order to integrate a new algorithm, which considers the real characteristics of the propagation channel (namely Path-Loss and Multipath). The modified structure and its process are presented.

We have measured routing performances parameters (Delay, Throughput and Route Error) for AODV in moving military environments. Our framework aims to evaluate the effect of a modified power strength on obtained results and to demonstrate that suitable results can be obtained from realistic power models.

## I. Introduction

In wireless mobile ad hoc networks (MANET), systems characteristics are strongly affected by the variability of the wireless channel. This variability is due to phenomenon such as fading, multipath, Doppler Effect, obstacles and atmospheric effects. To better understand and analysis the performances of mobile networks protocols, simulation tools are preferred to real word tests. The advantage of simulator over real word tests is the possibility to isolate different parameter and deeply analyze performances metrics. It also helps developer in changing their models and perform test using identical scenario. Since MANET is still in its early stage, most of the protocols been developed are tested using simulation software. All indications are that simulation will remain the first choice for analyzing network protocols performances.

Mobility models represent one of the important modeling and analysis tools in a MANET simulator. For the protocols performances evaluation to be done efficiently, mobility models

proposed in simulator should depict real environment situation. A variety of models have been proposed for mobile ad hoc networks. The most commonly used mobility model is the random waypoint. In this model, node randomly selects destination and speed from a specific distribution. It then moves toward this destination with the selected speed. Upon reaching the destination, the node pauses for a random time and then chooses randomly a new destination with a new speed. These steps are repeated until the end of the simulation.

One concern regarding proposed simulators e.g. Opnet is the lack of real word mobility pattern in the mobile nodes movement. In this research work, we focus on creating a mobility model generator with realistic mobility scenarios. It seems that directly developing mobility models in Opnet is very complex and time consuming and can explain the fact that most people used the random waypoint model. Acknowledging this fact, we've developed an easy to use mobility models generator which can be passed to Opnet for protocols performances analysis and help users quickly create more realistic mobile ad hoc scenarios. Another concern is the limited number of mobility models specially when simulating scenarios where Manet is used for conferences, tactical environment, etc. Opnet doesn't offer a large variety of mobility model. Since Manet is a mobile network which is deployed dynamically in tactical, rescue and conferences environment, we need scenario models that can effectively describe these different situations.

We also investigated the effects of wireless physical layer modeling in mobile ad hoc networks. OPNET like others simulators e.g. ns simulator, GloMoSim focus on higher layer processes development and proposed simple channels models which inadequately describe the wireless environment channels. Unlike other networks, physical layer represent a important part of wireless networks and should be better considered when testing protocols performances with any simulator. Wireless channel characteristic e.g. path loss, fading, Doppler effects must be accurately modeled and their effects on network protocols performances better understood. In this paper, we addressed these issues and developed a new model for radio propagation channel. The model which is implemented in OPNET considered two important physical layers factors namely path loss and fading.

In addition, this paper presented the impact of physical layer factors on routing protocols performances through the analysis

of different parameters such as number of Route Errors Sent, Throughput and Packet Delay. Our contributions are the following:

- A creation of a mobility model generator that generate different realistic network models which are passed directly to Opnet for simulation.
- A development of adequate propagation models for wireless physical layer. These models give a better representation of physical layer status in terms of path loss and Doppler effects.
- A deeply analysis for routing protocols performances when submitted to different physical layer factors and traffic load.

The paper is organized as follows. First we present the methodology used to develop the scenarios and mobility models generator and how the models are passed to Opnet Modeler. Second we present how we modeled the radio propagation pipeline in order to integrate propagation models for path loss and Doppler effects. Finally the Opnet simulation results and performances analysis of routing protocols under the proposed propagation models are presented for different mobility scenarios.

## II. Methodology for the Mobility model generator

This section presents an overview of the three parts of our simulator but it will be focused on the scenarios and mobility modeling. The models described here depict tactical environment scenarios.

### II.1. Scenarios specification methodology [1]

In order to facilitate fast and automatic generation of scenarios, a graphic user interface (GUI) allows various inputs setting and options choice before running the simulation. The preliminary stages are:

- Choice of a predefined scenario or creation of personalized cases.
- Choice of one of the four implemented mobility models, 2D-Random Walk (2D-RWM), GMM and two extensions of the RVGM. All these models are differently implemented to meet some specific requirement of our main application which is military. If groups' mobility models are chosen, then some additional parameters (in scenarios definition such as number of groups, min and max number per group) are activated and must be set.
- Setting of global parameters of the simulation including the duration or observation time, the incremental interval of time, the viewing option (creation of movie file), the option for nodes' activation or extinction and finally the results saving files.

The simulation process includes three phases:

**Phase 1:** The initial distribution of the nodes on the simulation area.

For individual models (2D-RWM and GMM), the distribution of nodes is random.

In RVGM models, groups locations are either determine randomly or by the user who has also the possibility to fix the inter-nodes distances inside a group.

**Phase 2:** The research of the trajectory of each node according to the chosen mobility model by determining its position, speed and orientation at every moment.

**Phase 3:** The results are depicted on graphs or visualised as movie clip of the network topology evolution.

The extinction option allows in a random way to extinguish certain nodes (i.e. temporary disappearing from the network topology). Then, they can be reactivated or not after a random time.

Figures 1 and 2 are respectively examples of GMM and RVGM for tactical scenarios with definition of battlefronts directions.

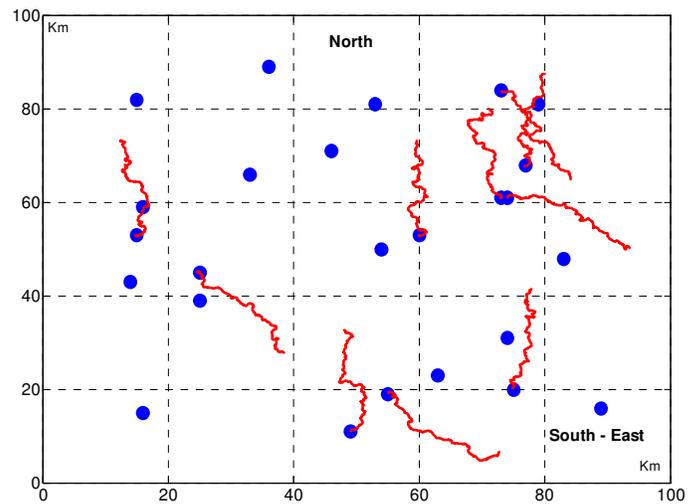


Figure 1: Example of GMM model with 2 fronts directions for tactical scenarios

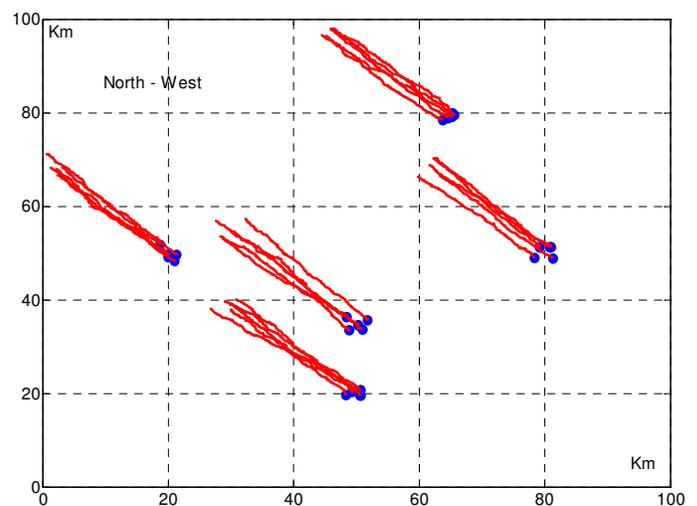


Figure 2: Example of RVGM model with 1 front direction for tactical scenarios

## II.2 Power models and link with Opnet Modeler

The power models implemented includes Large-scale and small-scale fading. Large-scale model allows path-loss calculation as function of distance and environmental parameters (terrain, building and vegetation). Small-scale fading takes into account multipath and Doppler effects due to the nodes' velocities. Large-scale and small-scale fading constitute respectively the second and the third part of our simulator. More details on path-loss calculation are given in section III. Some main outputs computed using our simulator are transmitted to Opnet modeler.

For this purpose, Opnet source code for radio transceiver pipeline is modified especially stages 4 to 7. The coupling of the two tools is made using Matlab C-MEX function and Opnet EMA (External Model Access) API. The link process is summarized on figure 3.

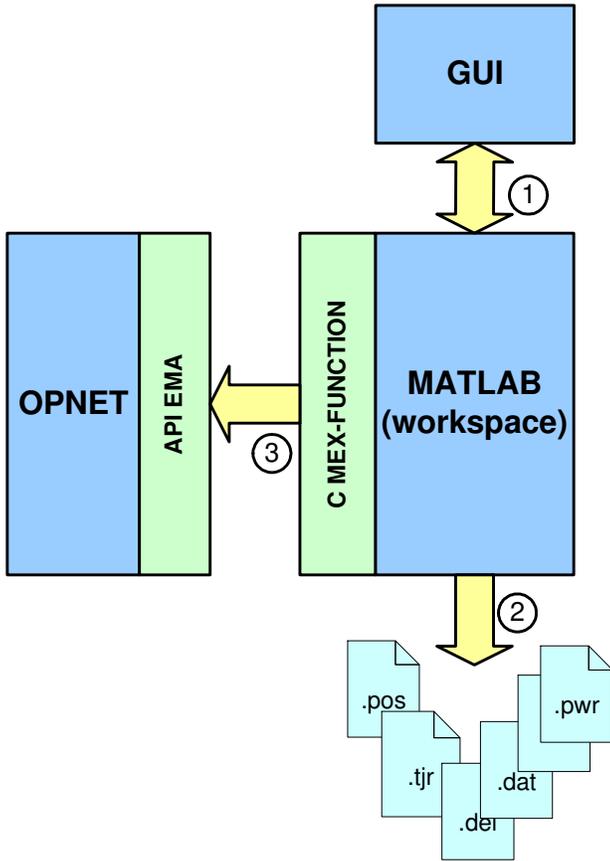


Figure 3: Link between Matlab simulator and Opnet modeller

## III. Proposed propagation models

The Opnet users have two options: First, use the terrain modeling. In this case the value for propagation loss is calculated. Otherwise, the free space propagation loss is computed as a function of wavelength and propagation distance with the relation

$$L_{dB} = 20 \log_{10} \left( \frac{\lambda}{4\pi d} \right) \quad (eq. 1)$$

$\lambda$  is wave-length and  $d$  is distance between transmitter and receiver in meter.

This relation is not accurate when working on real physical environment. For this reason, a semi deterministic large-scale propagation (Walfish-Ikegami model) is implemented using Matlab. It also takes into account various parameters buildings, roads and other obstacles characteristics which are important for a relevant prediction especially in urban areas. According to visibility conditions, two cases are distinguished in path loss calculation: line-of-sight (LOS) and non line-of-sight (NLOS) [2].

LOS:

$$L_{dB} = 42.6 + 26 \log_{10} d_{Km} + 20 \log_{10} f_{MHz} \quad (eq. 2)$$

NLOS:

$$L_{dB} = \begin{cases} l_0 + l_{rts} + l_{msd} & l_{rts} + l_{msd} > 0 \\ l_0 & l_{rts} + l_{msd} \leq 0 \end{cases} \quad (eq. 3)$$

Where,  $l_0$  is free space loss,  $l_{rts}$  is roof top to street diffraction and  $l_{msd}$  is multi-screen diffraction loss.

Our implementation is made using Matlab software package. Environmental characteristics are extracted from a Geographic Information System (GIS) databases containing Digital Terrain Model, vegetation, Buildings and roads layers data. The accuracy of GIS data is not so important in this case because we are interested by only average values.

Knowing the maximum radio range for each node, we construct adjacent matrix for the whole network based on graph theory. Many appropriate algorithms allow defining all possible routes between two given nodes. We can then, evaluate each route in term of path losses and in regard of received power threshold. Many other conditions such as maximum number of hops along the end-to-end transmission can be taking into account. Multipath fading is also computed with Doppler spread [3]. Figures 4 and 5 are typical results of path-loss calculation and multipath computation.

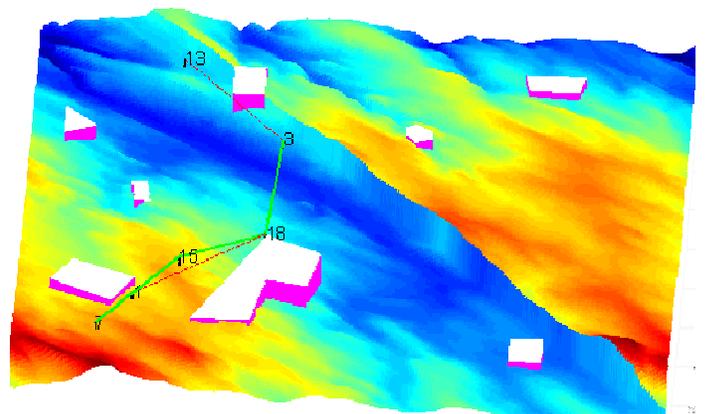


Figure 4: Typical example of path loss computation on 3D environment

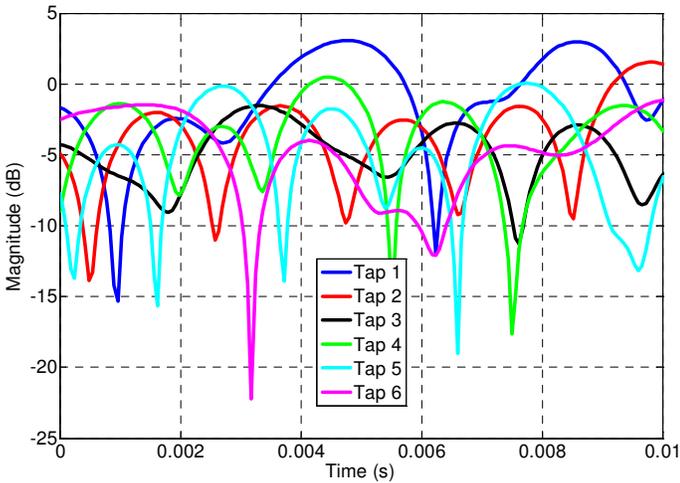


Figure 5: Typical example of multipath computation

#### IV. Opet simulation and Results

Two studies were conducted using the Opet simulator. The purpose of the first study is to evaluate how the data load affects the routing protocol performances in the two physical layers environments. For this simulation, all the nodes can randomly sent a different size of data to any destination within the network. The number of nodes is 50 with the same speed and set of protocols. The nodes movement are from Gauss Markov mobility model and are generated using our mobility model generator. 80 per cent of the nodes are in movement. The rest are fixed. The nodes speed is between 20 and 40 km/h. In the first scenario the default parameters for the physical layers settings are used. The radio transmission range is set to 400m in order to avoid the networks partition. The scenario doesn't consider any terrain configuration. As specified in Opet model documentation the received power in the radio transmission pipeline is based on free space model. The second scenario has the same number of nodes and mobility models. In this scenario, the default physical parameters are replaced by our proposed propagation models as described in section 3. In both scenarios, Ad hoc On-Demand Distance Vector (AODV) is used as the routing protocol with default settings. All protocols used in the two simulations e.g. MAC, IEEE 802.11 are the same.

We analyze AODV routing parameters such as AODV Error Sent, AODV Routing traffic and Manet delays vs. data load. The results are presented on Figure 6,7 and 8. In all scenarios, the results obtained from the two power models are very different. It appears to us that the chosen routing protocol is able to choose more reliable route with the proposed propagation model. This can explain why the number of route errors sent in this case is much smaller than in the case of free space power model. Regarding the AODV routing Traffic vs. load, we expected its value to increase with the load in the network. Figure 7 presents the average value and AODV performances is more realistic when considering a power model with Walfish-Ikegami model. For the average Manet delay, we observed a great difference in the two scenarios when the network load increase.

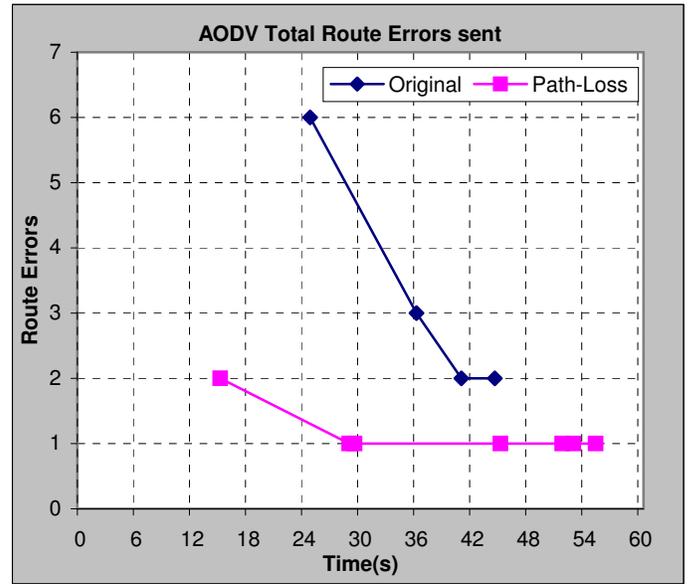


Figure 6: AODV Total Route Errors Sent

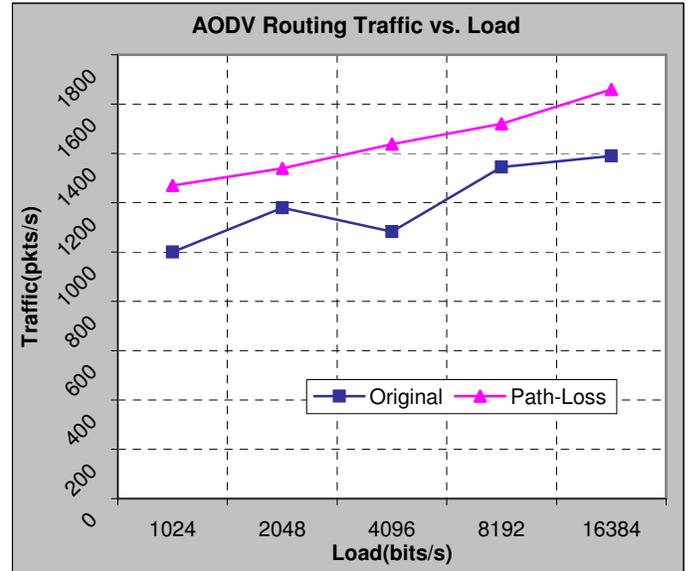


Figure 7: AODV Routing Traffic vs. Load

The purpose of the second study is to compare the default and Walfish-Ikegami models by using simple network scenarios. The two created scenarios for this comparison have the following characteristics: 25 nodes network nodes, nodes speed from Gauss Markov Mobility model, 80% of the nodes are mobile nodes and transmission range is set to 400m.

In both scenarios, a fixed mobile transmitter sent a 512 bytes data packets to a specific mobile node each second. Ad hoc On-Demand Distance Vector (AODV) is used as the routing protocol with default setting. All protocols used in the two simulations e.g. MAC, IEEE 802.11 are the same. Figure 9 and Figure 10 show the Wireless Lan Traffic and Manet Received Traffic in the two simulations. The red one is for the Opet

original Power Model and the black one depict our power model with Path-Loss. After 30 s of simulation, as the node move away from each other, the number of hops between the transmitter and the receiver increase during 16 s. In this period the Manet received traffic obtained from models with Path-Loss and fading differs from the default Opnet model. The reason is that in the first case, the power model more accurately described the real state of the environment which affects the values of the received nodes signal. Consequently real performances of AODV can be more efficiently analyzed. After 46 s of simulation, Opnet default models doesn't consider multipath effects on the received signals, which can allow routing protocols to better perform since a route to receiver can be found.

## V. Conclusion and further works

Conducted by the need of interaction between physical layers models developers and network simulator developers (which focus on high layer models development), we have proposed a new mobility model generator and a more realistic radio propagation models for use in Opnet simulator.

After carefully analyzing the effects of the proposed power models on different routing protocol parameters, this paper confirms the necessity of changing the free space model used in Opnet. Since big difference appeared in both scenarios with default model and Walfish-Ikegami model, more tests with others routing protocols need to be done. In addition, we need to develop other statistics in order to better evaluate the impact of others physical layer factor on routing protocol performances.

## References

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- [4] OPNET Technologies Inc. <http://www.Opnet.com/>

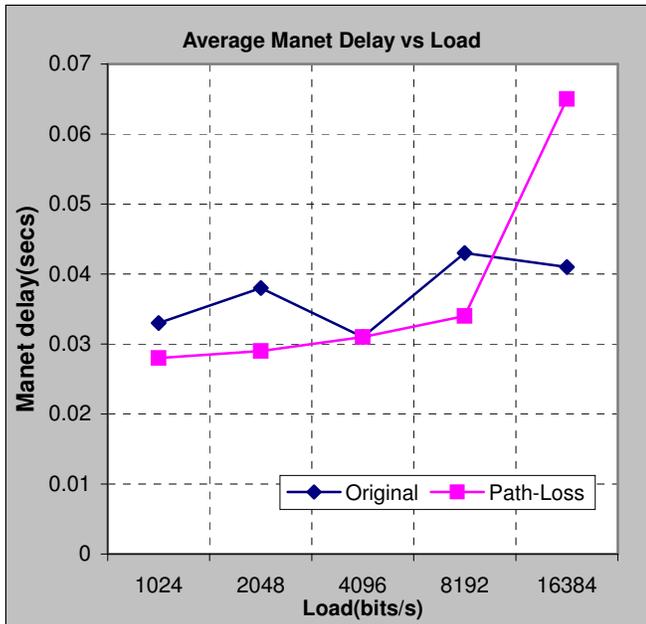


Figure 8: Typical example of multipath computation

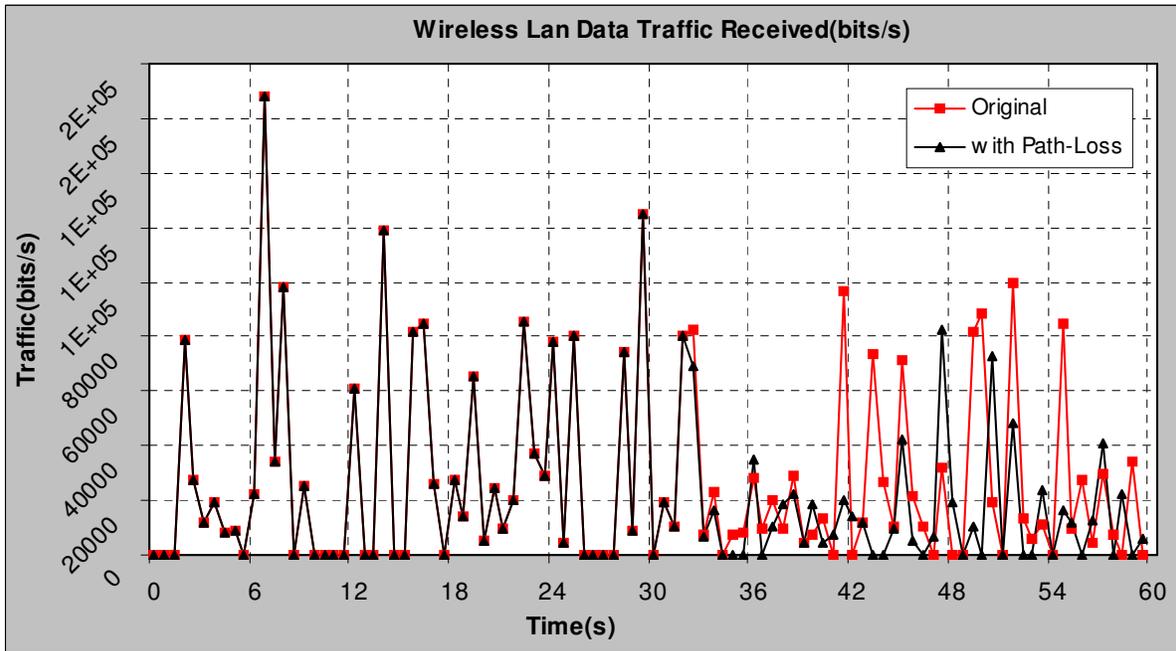


Figure 9: Typical example of multipath computation

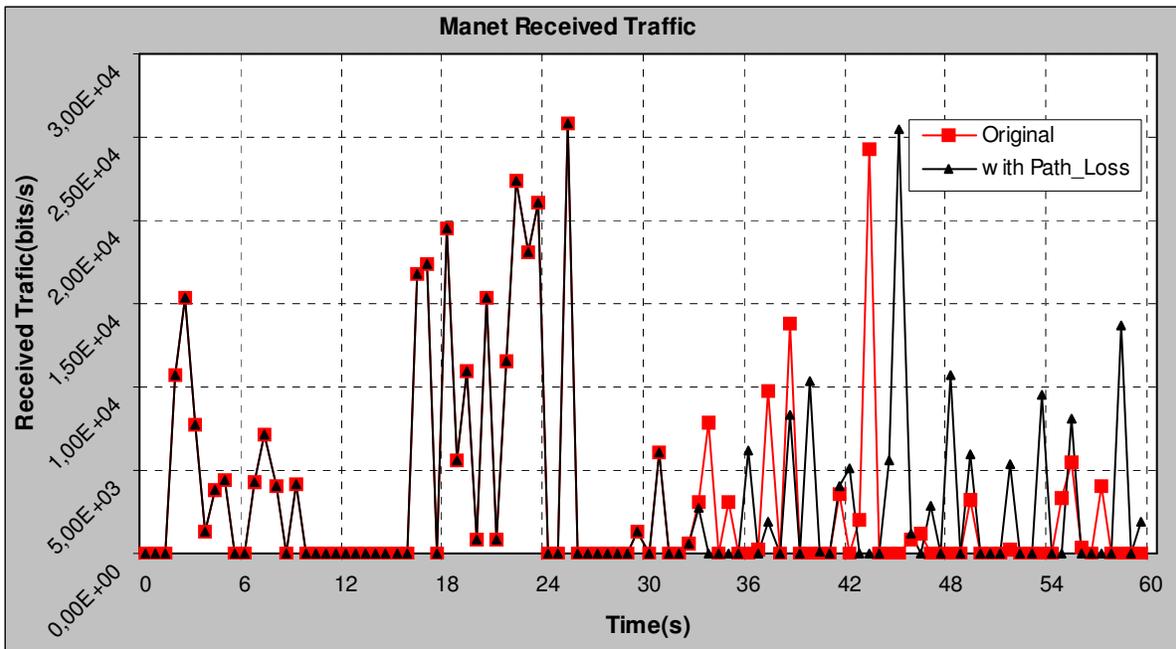


Figure 10: Simulated Manet Received traffic