Design and Implementation of a Simulation Environment for the Evaluation of Authentication Protocols in IEEE 802.11s Networks

Ikbel Daly, Faouzi Zarai, and Lotfi Kamoun

LETI Laboratory, University of Sfax
Sfax, Tunisia
{ikbel.daly,faouzi.zarai,lotfi.kamoun}@isecs.rnu.tn

Abstract. Mesh technology presents a great deviation in the field of wireless networks thanks to its assets brought in the level of mobility, the quality of services and distribution of radios resources. Due to its importance, a working group was formed in IEEE organization in order to work out a standard for the Mesh networks under the reference IEEE 802.11s. Consequently, a whole of tasks remain in the course of research such as security. That allows the appearance of several solutions and protocols suggested by the researchers' community in the literature. However, the existing simulators do not contain yet complete modules which allow studying this network. To remedy these problems, we thought of developing an environment of simulation for the evaluation of the authentication protocols for the IEEE 802.11s networks. This tool allows the easy development and the integration of new modules and thereafter its performances evaluation by providing appropriate measurements.

Keywords: IEEE 802.11s, Mesh network, simulator, authentication protocols, handoff.

1 Introduction

After the success of the Wireless Local Area Networks (WLANs), the world of wireless saw the birth of new technologies such as the Ad hoc networks and the Wireless Mesh Networks (WMNs) which propose a facility and a flexibility of deployment.

The Mesh network also called multi-hops network constitutes a flexible architecture ensuring the effective circulation of data between the wireless equipments by elimination of the problem of corrupted ways. This characteristic is consolidated by the automatic installation and configuration as well as the co-existence with existing networks. This technology is all the more reliable since it is dense and is by definition multi-services voice, data and video.

Moreover, WMN is characterized by its capacity to extend its coverage area. Consequently, its architecture is able to change dynamically to allow the fluent mobility of its users. This freedom during clients' movement imposes several challenges that we quote mainly the problem of security. Indeed, we must ensure the access only to authorized users by avoiding all risks of attack or intrusion. This

J. Del Ser et al. (Eds.): MOBILIGHT 2011, LNICST 81, pp. 206–218, 2012.
© Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2012

problem becomes increasingly serious and vulnerable with the opening of network medium towards the outside and in the case of routers movement.

A simulator network presents a fast, economic and effective solution for the networks tests. Indeed, the installation of a real network introduces a heavy operation from sides of material, time and cost. Then, it is essential to have a solution which makes it possible to solve these problems by guaranteeing the application of the various mechanisms and protocols which are necessary for the engineering of such a network. This solution reveals by the use of a network simulator which allows moreover the study of the behavior and the capacities of complex networks. Besides, it provides the possibility of developing new protocols and furthermore testing its performances and effectiveness.

In the field of networking, there are several types of network simulator. NS2 is one of the most known simulators in the researchers' community [1]. Indeed, it is open-source, fast and contains a big diversity of models. On the one hand, the complexity of the language programming used with NS2 causes a great difficulty for the development of new protocols. On the other hand, NS2 is characterized by the management of wireless networks as well as new technologies such as the Ad-hoc network and the study of some aspects in particular the mobility management, the access security and the control of congestion, etc. These aspects are treated by other simulator; we quote as an example Glomosim, Qualnet and Opnet.

Mesh technology states a subject of topicality since its standardization is under development. It is not adjusted yet in the majority of existing network simulators. In contrast, a novice version of this type of network was implemented in the new simulator NS3 [2]. This version just provides the backbone which is the first level of the WMN and is made up of the Mesh nodes bound by the routing protocol HWMP [3]. This implementation adopts the proposal IEEE 802.11s draft standard version 3.0.

Because of our need to test the performances of the new suggested solutions and protocols in the field of Mesh networks, the idea to develop an adequate simulator to this type of network is triggered. The new simulator is modular; it integrates several modules which allow the management, the control and the administration of network. We quote as an example the following modules:

- Channel Modeling
- Area modeling
- Management of the arrivals
- Deployment of the radios resources
- Radios resources management (CAC, Scheduling...)
- Neighbors discovery
- Mobility management (handoff)
- Security management
- Management of the observations.

The remainder of this paper is organized as follows. In Section 2, we give an overview about the Mesh technology. In Section 3, we explain through a class diagram the design our environment of simulation. Then, the implementation phase is illustrated in Section 4. And an example of manipulation of this new tool is described in section 5. Finally, we conclude the paper in Section 6.

2 Overview of WMN

The revolution of wireless, started by the success of the standard IEEE 802.11, pushed the community of researchers in the design, the analysis, the development, and the deployment of new wireless solutions. In particular, the Wireless Mesh Networks (WMN), have captured the interest of university research and industry, because of their capacity to meet at the same time the requirements of the suppliers of wireless access to Internet and the users.

Mesh topology is a network topology qualifying the networks (wired or not) in which all the hosts are connected gradually without central hierarchy, thus forming a structure in form of net. That makes it possible to avoid having critical points, which in the case of breakdown, cut the connection of part of the network. Indeed, if a host is out of service, its neighbors will pass by another path. The implementation of such a topology is called network Mesh [4].

Thus, Mesh network consists of nodes which communicate directly with their neighbors by removing the interconnected network between the access points. Moreover, this type of network forms an emergent class of wireless networks, which is able to be dynamically organized and configured. It takes the principle of a wireless network that is based on the multi-hop transmission. A typical example of a Mesh is presented in Figure 1. Mesh architecture of two levels concentrates the routing on the wireless part (the first level - backbone), made up of Wireless Mesh Routers (WMRs) and of the access points which offer a connectivity to mobile stations (the second level) [5].

Considering the importance of this type of networks and the various advantages brought by this technology, a working group was created within the IEEE (Institute of Electrical and Electronics Engineers) with an aim of arranging a new standard under the reference 802.11s [6], [7].

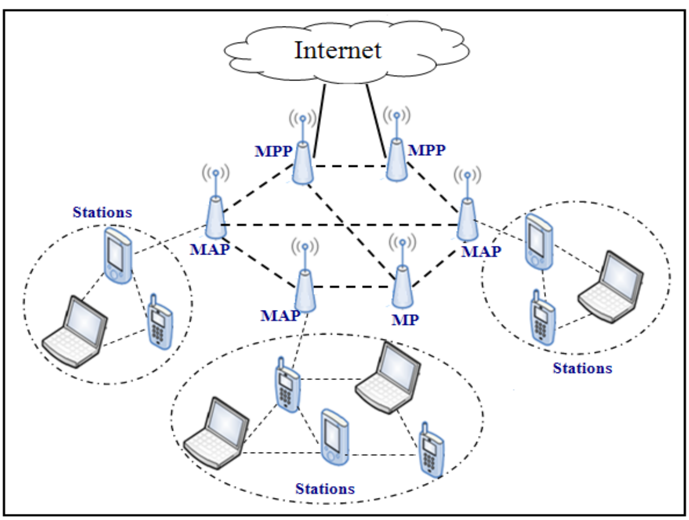


Fig. 1. Overview of wireless Mesh network

This emergent standard defines a whole of terminologies schematized in Figure 1. First of all, any node that supports Mesh services such as control, management, and the operation of the Mesh is a Mesh Point (MP). If the node supports in more the access to stations (STAs) or with the nodes which do not have the Mesh services, it is called a Mesh Access Point (MAP). Moreover, a Mesh Portal Point, noted MPP, is a Mesh point which has a non-802.11 connection with Internet and the external networks.

Although there are the significant advantages of the successful deployment of the wireless Mesh networks in the whole world, some technical limitations and problems will remain to be solved and will probably require more advanced research for the deployment of such a network [8] Moreover, the upcoming standardization of Mesh network will clarify some concepts and will put an end to some problems. We quote mainly the quality of service, the security, the mobility and the interference problem.

While these networks continue to develop, several efforts and works are provided to be ensured of the smooth running of the services offered by Mesh network. Indeed, we cannot be certain of granting the access to network only for the authorized users or the continuity of connectivity following the mobility of the various network equipments or the conservation of an acceptable quality of services even with real time applications only if we propose a set of protocols that manage all these aspects and others in order to provide a reliable Mesh network.

With the aim of solving these problems, the community of researchers suggests several solutions and protocols. And concerning the phase of validation, they were obliged to adapt their proposals to an ad hoc environment due to the absence of a Mesh network implementation in the majority of network simulators. Following this need, the existence of a simulator adapted to this type of network becomes a need which makes it possible to test the suggested protocols and to evaluate its performances.

3 Simulation Design

In this section, we start on the design of an environment of simulation for the evaluation of authentication protocols for the IEEE 802.11s networks. First of all, this developed tool is supposed to create the wireless Mesh network architecture with its various levels and nodes. Then, it handles and manages the Mesh services and nodes by the management of traffic, the management of the mobility and the mechanism of neighbors discovery, etc. Then, the simulator allows the addition of a set of control mechanism through the implementation of new protocols and in particular those of security and re-authentication.

In order to carry out all these modules in such a simulator, we start with the construction of a conceptual model for this tool in the form of a class diagram. In fact, this schema is a net of classes and associations which models the structure of an object, its role within the system in addition to its relations with the other objects.

Figure 2 presents the various modules which will be implemented in our simulator. The principal class of this diagram is the model of the WMN creation. It includes all the essential methods for the generation of such a type of network as well as the other additional methods for services control and the administration of the various network equipments.

First, we have to prepare our environment of study which is composed of the set of nodes mentioned in Figure 1. This task appears in the diagram by the reservation of classes for the creation of the different network components; the stations, the nodes MAPs and MPPs. Indeed, the MP class is formed by the whole of specific parameters to MAPs in Mesh network. Moreover, we find multiple methods to operate the various services of an access point as an intermediate point with the external networks (MPPs).

For the second network level, a station class was developed. It comprises the required information to identify a WMN user as well as the various actions which are likely to be carrying out by a simple station such as the emission and the reception of data.

After the formation of the Mesh, we have recourse to regulate the several functionalities ensured by any wireless network and those specific to IEEE 802.11s networks. Indeed, we also require specifying the type of studied architecture and the

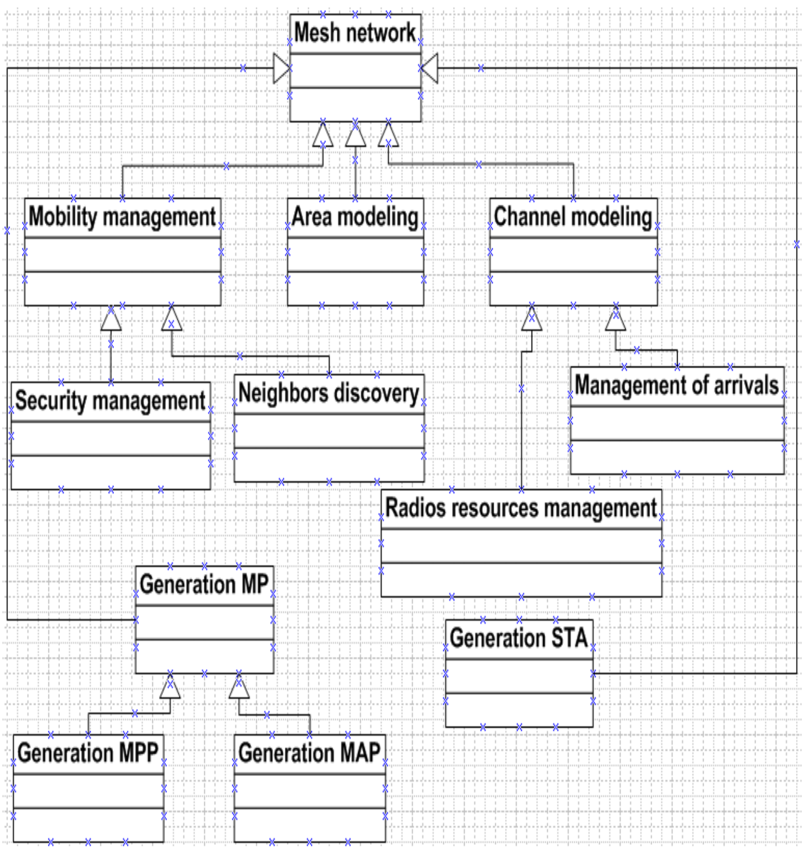


Fig. 2. Simulator class diagram

distribution of the different components (such as central, distributed or hierarchical network architecture) create by using the module "Area modeling". With an aim of ensuring and managing the communication between MPs and their users, we have recourse to a whole of models which are used to adjust the transmission of packets between the various Mesh network entities.

Indeed, to ensure the connectivity and the establishment of communications, we must manage the different channels (Channel modeling) by reserving the required radios resources (Deployment of the radios resources) and organizing the exchanged flows and packets (Management of the arrivals). Consequently, the characteristics of the services and the applications managed in a network from traffic point of view make it possible to know and control the load of a specified network. Moreover, the study of behavior and the analysis of performances of such a network require the knowledge of the characteristics and statistical measurements for the various types of applications which are active during the transmission.

Among the assets brought by an IEEE 802.11s network, we quote the effective mobility management with an aim of providing a freedom in moving for the customers who seek to communicate during their movements without any constraint of connectivity, and where the change point of attachment is completely transparent. For these reasons, the study of mobility notion is raised by the module "Mobility management". In order to establish the scan phase, the network nodes carry out the procedure of the "neighbors discovery" to browse the vicinity of every MP and STA to facilitate the connectivity between these entities.

The reliability, the adaptability and the scalability are the most significant attributes of this type of network. However, security in a Mesh network is not yet well defined which requires the adoption of powerful mechanisms to be protected from several attacks. This problem of the insecurity becomes increasingly vulnerable and critical especially during handoff phase (i.e. following the change of channel during communication). That requires the application of an effective and well defined policy of security.

Moreover, securing the transmitted information is a task whose complexity gradually grows, parallel to the increase in the number of applications and with the degree of medium opening towards the outside. Consequently, the authentication of users becomes necessary. It is significant as well on the level of ensuring security as of the facility and the safety of employment for the user. Indeed, the authentication process is one of significant measurements to confront against attacks in Mesh networks, by allowing only authorized users to obtain connections and preventing the intruders from being integrated in the network and disturbing its operation.

In our simulator, we have integrated the security aspect of the dynamic stations during channel changes, in order to evaluate the performances of such an implemented authentication protocol.

4 Simulation Implementation

A flexible and easy handling remains always among the most decisive criteria for the success of such a development project. This is why the choice of a programming language must be well studied.

The software of development on the subject of simulation is diversified and can be presented in the form of a structured programming language like the language C++ and object oriented programming language for example Java. The choice of a specific language depends on the category of the tasks which will be carried out, the requirements to satisfy and its performance compared to the other languages.

In our case, it was necessary to choose Java, an object oriented language which proves to be most adequate thanks to its rich and fertile libraries, the portability of its programs, its flexibility, its facility of use and its robustness [9].

Through the development of this environment of simulation we endeavor to:

- set up a wireless Mesh network architecture with the required entities and components,
- implement the mobility aspect in order to study the station handoff,
- implement the security aspect of the dynamic stations during their changes of channel,
- evaluate the impact of these concepts on the behavior of network.

Consequently, this tool makes it possible to specify the various parameters of this type of network and to simulate its behavior with an aim to study the performances and the effect of implemented aspects such as the protocols of mobility and security. To guarantee the correct functioning of our network generated by the simulator as well as the studied models. A model is an essential element to understand the behavior of such a phenomenon or such an object. In our case, we implemented some models which are mainly:

- Traffic model: it can be mathematical or analytical. The model of network traffic is represented by the statistical models, namely Poisson model , Exponential model or Geometrical model,
- Mobility model: it define the manner of nodes movement in the coverage area of the network,
- Propagation model: it contains the implementation of the wireless propagation environment, namely the attenuation model.

4.1 Models

4.1.1 Traffic Model

In our study, we will consider two traffic models; voice and Internet flow (Web).

- **Voice Model**

The voice transmission is a real time service. The constraint of time constitutes a priority that must be respected for the generation of this type of application [10].

For this type of application, we have adopted the traditional model. In this case, the arrival of the phone calls follows the "Poisson process", which is characterized by the value λ as an average rate of call and the duration of a call follows an "Exponential process" with μ average.

- **Web Model**

This model is characterized by a whole of the parameters based on the consultation of HTML pages. In Internet flow, the access to the Web sites can be split in several sessions. Each session is defined by specific characteristics such as periods of datagrams loading, periods of datagrams inter-arrived and the periods of reading (periods of silence).

The statistical characteristics of this model are [10]:

➢ The appearance of the sessions follows a "Poisson process",

➢ On the session level:

- the number of HTML pages call follows a Géométrical distribution of typical average $\mu = 5$ calls/session,
- the reading time of HTML pages follows an Exponential distribution of average *μlec,* with $1 / \mu lec$ between 4 and 12 s,
- the number of datagrams per call follows a Géométrical distribution of average $\mu dgm = 10$ *dgm*/call,
- the duration of datagrams inter-arrival is an Exponential distribution depending on the network rate of transmission.

4.1.2 Mobility Model

The mobility model is based on a non uniform and random distribution of stations movements in the coverage area of the network. The movement of a node follows a Random Waypoint model, which is expressed by [11]:

➢ Mean speed of the movement noted v such as $v \in [0, 20\, m/s]$,

➢ Movement direction represented by the angle noted θ, such as $\theta \in [0, 360^\circ]$.

The movement of nodes is generated in a periodic way and with a random way during simulation.

4.1.3 Propagation Model

The simulated propagation model supposes that the signals transmitted between the various network components undergo attenuation on a small scale. Indeed, if a node i sends a message with a power of emission Pe the station j receives it with a power of reception Pr (eq1) such as:

$$P_r^j = P_e^i - 10 \log \left(\frac{d}{T_r}\right)^4 \quad (1)$$

With:

P_e^i: Power of emission of the signal of i expressed in dB,

P_r^j: Received power of the signal of J expressed in dB,

d : Distance between the nodes expressed in meters,

T_r: Zone of vicinity expressed in meters.

4.2 Parameters and Results of Simulation

After having implemented the various models of a wireless Mesh network, the following stage consists in studying the performances of our simulator. The stage of evaluation is based on the influence of the increase in the mobile stations number and their mobilities on a set of criteria. As a preliminary phase, we must fix a list of parameters in order to carry out the various scenarios on the simulator as well as to extract precise values reflecting the state of network.

4.2.1 Parameters of Simulation

An example of Mesh network architecture is defined by its geographical coverage (Size with X and Y coordinates) and its population (MPs and STAs). The simulated network is characterized by a cover which is spread out over hundreds of meters, comprises a preset number of MPs nodes and a variable number of stations that varies according to the scenarios of simulation.

Each MP node is defined by:

- Its position in the network: defined by the node coordinates following the axes X and Y,
- Its channel number: allotted in order to avoid the problem of interference,
- Its range of transmission: defined by the coverage of its signal which decreases while moving away from the site of the concerned MP,
- A unique identifier.

Each station is defined by:

- Its position in the network: defined by the node coordinates following the axes X and Y. In order to adjust our simulation with reality, it is necessary that nodes have different positions and carry out random movements in the network,
- The mobility model: the speed $v \in [0, 20\, m/s]$ and the movement direction follows the angle $\theta \in [0, 360^{\circ}]$,
- A unique identifier,
- The traffic model:
  - ➢ The arrival of a packet follows the "Poisson process" with average λ = 0,2 call/hour ,
  - ➢ The duration of the communication follows the "Exponential process" with average μ=10 minutes.

4.2.2 Scenarios of Simulation

After the configuration of the network parameters and nodes and the implementation of the various models, it is essential to simulate the behavior of this simulated network to evaluate its performances.

We will consider two types of exchanged traffic between the nodes:

- Voice communication,
- Web communication

While basing on these types of communications as well as the parameters of simulation, we evaluate the performance of implemented protocols by extracting the simulation results according to three criteria:

- Handoff latency: the time passed between the change of point of attachment request and the association with the new MAP,
- Blocking rate: represents the number of blocked stations at handoff for the total number of stations which requests handoff,
- Loss rate: represents the number of lost packets for the total number of the emitted packets.

5 Example of Use

Due to its importance and many the assets brought by this technology, wireless Mesh networks capture the attention of the industrialists and the researchers that allows the appearance of a variety of products and protocols. Indeed, several interesting works were undertaken on this type of networks of which some propose solutions to manage users' mobility, others study the problem of security, and a third category which are interested in the re-authentication after a change of location in the wireless Mesh network.

The endeavor in [12] is to introduce a secure re-authentication mechanism named SWMM (Secure Wireless Mobility Management), which is carried out during the cross of mobile stations by different nodes to allow users fulfilling an effective and reliable handoff as well as a secure access to services offered in Mesh network. In this study, the authors have improved previous methods which deal with the problem of mobility as well as security. Indeed, they have applied the Wireless Mobility Management (WMM) mechanism [13] to support an environment which manages handoff in effective way. In addition, they have also slightly modified this previous method and the EAP-TTLS scheme [14] to provide the network's security.

In order to prove that the proposed protocol SWMM outperforms other existing method, this solution and another suggested in literature, EAP Independent Handover Authentication method (EAP-IHA) [15], have been implemented in our simulator.

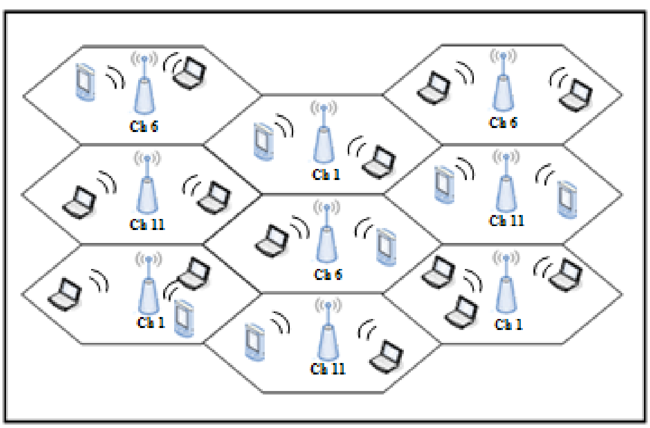
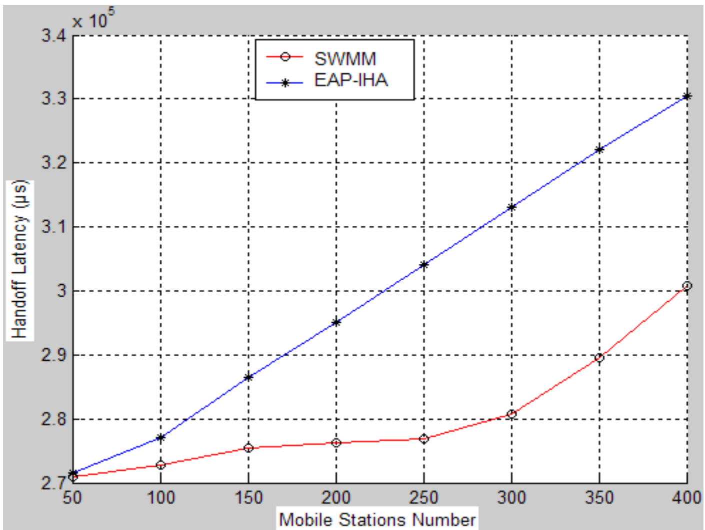


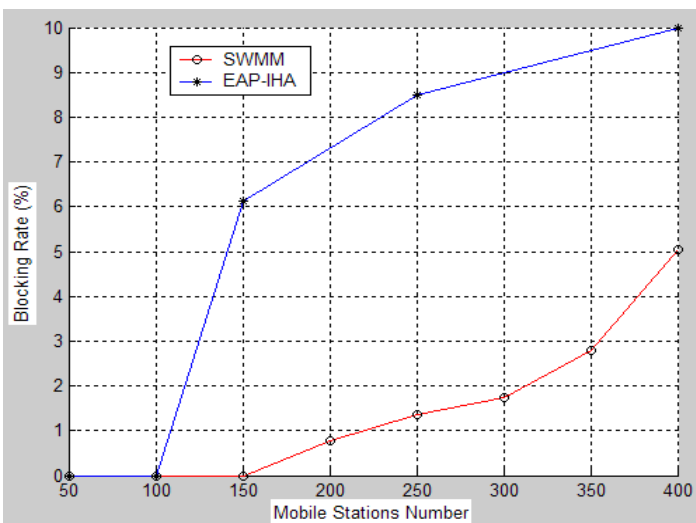
Fig. 3. WMR architecture generated by the simulator for SWMM and EAP-IHA

Figure 3 shows the Mesh network architecture generated by the simulator for the evaluation of the authentication protocols. It is made up of 9 MPs and a variable number of stations. Each MP is characterized by its coverage area and its number of channel. This last parameter is granted to different MPs by the network in order to eliminate the problem of interference.

The obtained results by the simulator following the implementation of these two protocols make it possible to plot the curves of Figure 4.

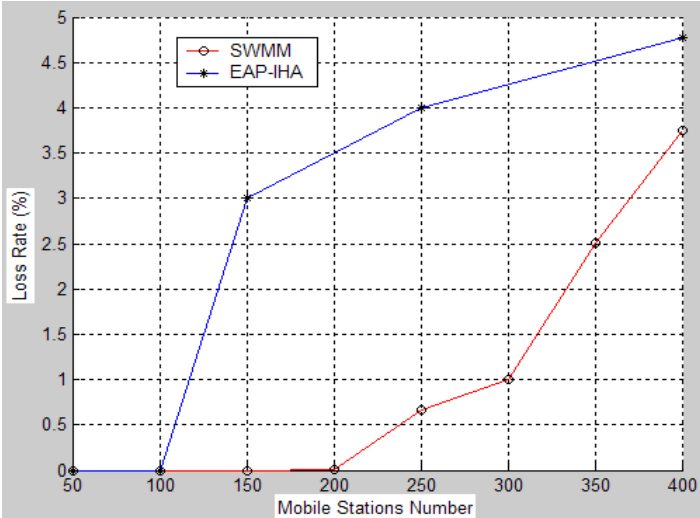


(a) Handoff Latency vs. Mobile stations number



(b) Blocking Rate vs. Mobile stations number

Fig. 4. Simulation results with SWMM and EAP-IHA protocols



(c) Loss Rate vs. Mobile stations number

Fig. 4. (*Continued*)

The interpretation of these curves makes it possible to evaluate the influence of the increase of network population on the value of handoff latency (a), blocking rate (b) and loss rate (c) on SWMM and EAP-IHA.

6 Conclusion

In this paper, we have presented our Java network simulator which is dedicated to the IEEE 802.11s networks. This tool is classified among the first simulators which treat this type of network since wireless Mesh network is still in the course of standardization by the IEEE organization. Among the advantages of this environment of simulation, we first of all quote the simplicity of the handling of various offered functionalities. Moreover, this simulator allows the easy development and the integration of new modules and protocols. Thereafter, it provides the required measurements to evaluate the performances of these modifications with more reduced time compared to the other existing simulators. Our current simulator presents the first stage towards the implementation of a more advanced tool which allows the treatment of Mesh networks. Indeed, we aim to add a set of supplementary modules which ensure a better handling of network. As future work, we claim to integrate a graphic interface to facilitate the use of the supported modules and the implementation and the validity test of the added protocols.

References

[1] NS-2, The Network Simulator, `http://www.isi.edu/nsnam/ns`
[2] The ns-3 network simulator, `http://www.nsnam.org/`

[3] Andreev, K., Boyko, P.: IEEE 802.11s Mesh Networking NS-3 Model
[4] Catoio, G., Cibot, L., Laloux, M.: Etendre dynamiquement la couverture d'un réseau Mesh (2006/2007)
[5] Faccin, S.M., Wijting, C., Kneckt, J., Damle, A.: Mesh wlan networks: concept and system design. IEEE Wireless Communications (April 2006)
[6] Camp, J.D., Knightly, E.W.: The IEEE 802.11s Extended Service Set Mesh Networking Standard
[7] IEEE P802.11s/D0.01 Draft Amendment to Standard for Information Technology-Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements-Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications: Amendment: ESS Mesh Networking (March 2008)
[8] Qiu, L., Bahl, P., Rao, A., Zhou, L.: Troubleshooting Wireless Mesh Networks
[9] Holzner, S.: Total Java, Editions Eyrolles (2001)
[10] Ajib, W.: Gestion de transmission d'un flux temporaire de donnés dans un réseau radio mobile d'accès TDMA. Thesis, ENST Paris (2000)
[11] Wai, F.H., Ye, Y.N., James, N.H.: Intrusion Detection in wireless Ad Hoc networks. Introduction to wmobile Computing Technical Report CS4274
[12] Daly, I., Zarai, F., Kamoun, L.: Secure Wireless Mobility Management. In: IEEE 17th International Conference on Telecommunications, ICT 2010 (2010)
[13] Huang, D., Lin, P., Gan, C., Jeng, J.: A Mobility Management Mechanism using Location Cache for Wireless Mesh Network. In: QShine 2006, Waterloo, Ontario, Canada, August 1979. ACM (2006)
[14] Khan, K., Akbar, M.: Authentication in Multi-Hop Wireless Mesh Networks. Proceedings of World Academy of Science, Engineering and Technology 16 (November 2006) ISSN 1307-6884
[15] Izquierdo, A., Golmie, N., Hoeper, K., Chen, L.: Using the EAP Framework for Fast Media Independent Handover Authentication. National Institute of Standards and Technology, USA (2008)