

## Network Simulator: A Learning Tool for Wireless Technologies

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Communication protocols are a crucial area in the telecommunication engineering curricula. Learning the basis of this field requires the study of multiple and heterogeneous concepts that, in most cases, are explained by the translation and summarization of the published specifications. By this method, pupils memorize certain theoretical issues without understanding the correlation among them. As computers are available in a wide variety of scenarios, the simulation tools can be of great help for a better understanding of this communication area. Among the multiple network simulators that are accessible nowadays, we consider the Network simulator or ns-2 as one of the best option for future engineers who might be asked to work with a simulation tool in their professional tasks. The aim of the utilization of ns2 in laboratories is to show the packets exchange between two hosts and how some factors (Propagation model, MAC interface, MAC configuration, communication protocol, etc) have a significant contribution on the performance of wireless networks. In order to facilitate the learning of the fundamental concepts associated to wireless technologies, the teacher should consider which exercises will be proposed. As illustrative examples, in this paper we describe some works developed by students of the University of Malaga in their Master Thesis.

**Keywords** Communication Protocols, Wireless Technologies, Network Simulator

### 1. Introduction

Nowadays, there is a great interest in the area of ubiquitous and mobile computing. The appropriate work in this field requires the learning of quite heterogeneous concepts. For example, the students may be asked to understand the signal codification, the OSI protocol stack, the MAC behaviour or some routing algorithms. Specifically, the teaching of routing protocols is often based on the presentation of the specifications related to the most significant protocols and the structure of the messages that they employ. By applying this methodology, this task becomes tough and the students do not even understand the utility of these protocols and their characteristics.

In order to ease the learning of protocols, the utilization of illustrative examples is strongly recommended. As these days the access to computers is widely available, the simulators become an appropriate learning tool in this area. As a first step, the teacher should select the simulation tool. At the present time, there are several network simulators: Opnet [1], Omnet++ [2], Network Simulator [3], Glomosim [4], etc. However, the Network Simulator is considered as de facto standard due to its high utilization and it is also employed in professional activities. Probably, the success of this tool is due to its GPL (GNU General Public License) licence that has made the development of recent protocols possible. Therefore, we encourage the utilization of the Network Simulator.

Although its popularity is on the rise, the employ of the Network Simulator presents some initial problems as the utilization of the already included protocols is easy but their modifications or the inclusion of new ones may become hard tasks. In this paper, we explain how the Network Simulator can be used and the main phases that are required for the inclusion of new protocols in ns-2. As illustrative examples, we briefly describe our experience with several Master Thesis. They were mainly focused on the performance of mobile ad hoc networks. This field includes the management of wireless concepts as well as the understanding of conventional and specific ad hoc routing protocols.

The rest of the paper is structured as follows. In Section 2, the main characteristics of the Network Simulator are presented. Section 3 shows some works that have been performed by Master Students at the University of Málaga. Finally, Section 4 draws the main conclusions.

## 2. The Network Simulator

NS-2 or Network Simulator is a discrete-event simulator whose implementation was started by 1989 with the development of the Real Network Simulator. Initially, NS-2 was focused on the simulation of wired technologies but the Monarch group from the Department of Computer Science at the University of Rice developed the necessary extensions [5] in order to include the software for wireless and mobile hosts. This contribution is widely accepted and it is commonly included in the recent version of ns-2 that can be downloaded from the official site (see [3]).

As a first approximation, the ns-2 could seem a bit difficult to work with. In order to ease its utilization, its structure is explained next. The ns-2 employs two languages. Firstly, the main characteristics of the scenario to simulate are described by OTcl [6]. Secondly, the kernel of ns-2 is specified by C++. It is organized in different folders, each one corresponds to an specific protocol. For example, there is a folder called AODV where all the files that are necessary for the implementation of this protocol are stored. If a user wants to utilize the already developed software that is included in the ns-2 release, he/she will have to know how to specify the scenario by OTcl. However, if some new protocols want to be tested or studied, the inclusion requires the modification of C++ files. In our experience, the modifications are not too troublesome but finding where to modify is usually quite hard.

Once the simulations have been run, the results are presented in a text version. One example of the traces is as follows:

```
r 1.35 3 2 ack 40 ----- 1 3.0 0.0 15 201
+ 1.351 1 0 ack 40 ----- 1 3.0 0.0 15 201
- 1.352 2 0 ack 40 ----- 1.39 0.0 15 201
```

Each line of the trace file is associated to a packet event. The ns-2 includes the Network Animator or NAM. This tool enables the visualization of the packets exchange. Although the animation of the network behaviour seems to be very attractive for the students, it is quite difficult to extract some statistics about the network performance from the trace file. Therefore, the simulation is followed by a post-processing phase that is usually based on the execution of any scripts normally coded in PERL or AWK [7].

The Figure 1 shows the relationship between the different programs involved in the ns-2 utilization. As it is shown, the simulation scenario could be completed by a program for traffic generation (*cbrgen*) and a mobility generator (*setdest*). This mobility generator helps researchers to easily construct mobility traces that follow the Random WayPoint [8]. This mobility pattern is commonly utilized for the ad hoc studies.

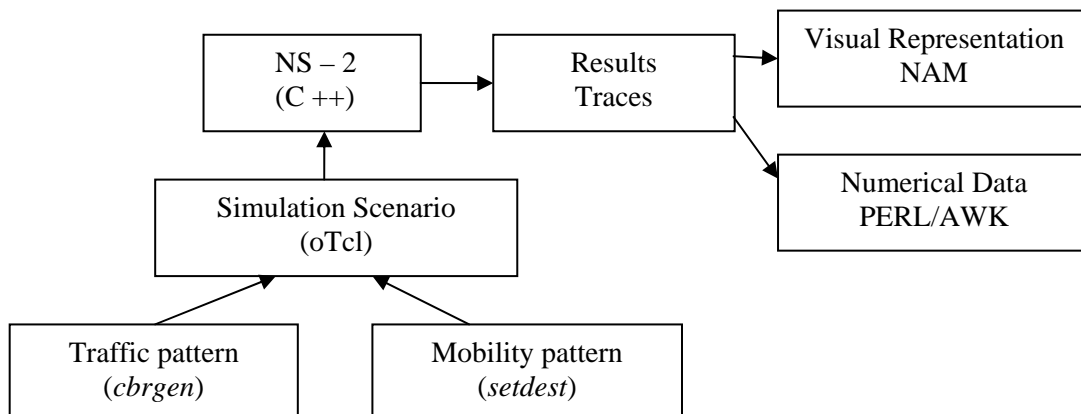


Figure 1. Structure of the execution of ns-2 simulations.

### 3. Examples of Utilization

The ns-2 includes a great variety of implemented protocols. However, sometimes it is necessary to modify them or include new ones. As these activities require a high effort, we have performed them as Master Thesis. Next, we present the description of some of the Master Thesis that we have done. They are all based on mobile ad hoc networks. The MANETs (Mobile Ad Hoc NETWORKs) are composed by the union of wireless devices that intercommunicate among them without the existence of any pre-installed infrastructure. The MANET nodes should behave as hosts as well as routers in order to forward the packet from distant devices.

In order to configure the MANET nodes, in the tcl script, the following specification should be included:

```

$ns_ node-config -addressingType      flat or hierarchical or expanded
                 -adhocRouting       DSDV or DSR or TORA or AODV
                 -llType              LL
                 -macType             Mac/802_11
                 -propType            "Propagation/TwoRayGround"
                 -ifqType             "Queue/DropTail/PriQueue"
                 -ifqLen              50
                 -phyType             "Phy/WirelessPhy"
                 -antType             "Antenna/OmniAntenna"
                 -channelType         "Channel/WirelessChannel"
                 -energyModel         "EnergyModel"
                 -initialEnergy       (in Joules)
                 -rxPower             (in W)
                 -txPower             (in W)
                 -agentTrace          ON or OFF
                 -routerTrace         ON or OFF
                 -macTrace            ON or OFF
                 -movementTrace       ON or OFF

```

With these lines, the ad hoc routing protocol is easily specified as well as the wireless channel or the MAC interface. Additionally, the script configures the level of traces that are presented in the trace file.

Some of the Master Thesis that we have guided are:

- A DSR policy based on the Path Stability

In isolated ad hoc networks, it is interesting to analyze the criterion for selecting the best path among all the paths that can be constructed in the network. Usually, the utilized criterion corresponds to the minimum number of hops. However, in this Master Thesis the student analyzed some new criteria based on the path stability, that is, the criterion should select the path that is expected to have the longest lifetime. (In ad hoc network the path lifetimes are finite as the mobile devices are moving).

The Path Lifetime is strongly dependent on the Link Lifetime. In order to estimate the link lifetimes, the student employed the Signal Strength. Therefore, a cross-layer philosophy was utilized. Additionally, the student understood how the channel propagation influences the signal strength.

The work was based on the DSR (Dynamic Source Routing) protocol [9]. With this routing protocol, the student was familiarized to the employ of caches for the storage of learnt paths.

As future works, the students could analyze which the appropriate timeout is for the entries in the caches based on the signal strength.

- Integration of ad hoc network into wired Networks

In the field of ad hoc networks, a quite hot topic is the integration of this type of networks into the Internet. The integration requires the utilization of several technologies as the Mobile IP or the Address Autoconfiguration. There are all dependent on the Gateway Discovery. Thanks to the work elaborated by Ali Hamidian [10], a Master Thesis student analysed which gateway discovery is more appropriate (proactive, reactive, hybrid) for a seamless integration of MANETs and the Internet.

As a Master Thesis work, the students could study the influence that the interval of the Modified Router Advertisements has on the network performance. Hybrid Gateway Discovery could also be adapted to the network density or to the mobility of the devices.

The Figure 2 shows the scenario that could be considered for these studies. This image has been extracted from the NAM tool.

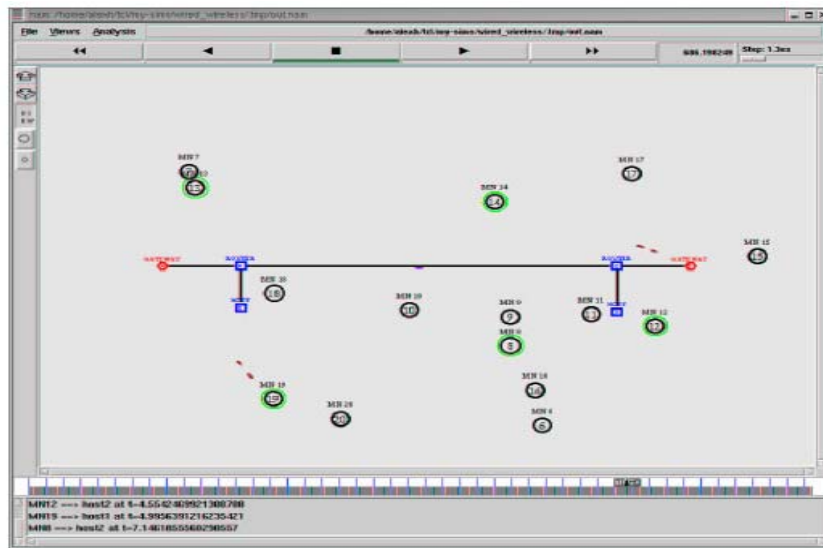


Figure 2. Scenario for wireless/wired network extracted from NAM.

- Analysis of DAD techniques in ad hoc networks

When mobile devices are integrated into external networks, they should be provided with a global IPv6 address [11]. In infrastructureless networks, the method for obtaining this address could be in an autonomous way. In a stateless configuration, the IPv6 address is generated by the concatenation of the prefix information to a theoretical unique number. Although the constructed number is expected to be unique, under some circumstances, this condition does not hold. Therefore, the generation of the IPv6 address is followed by a technique by which the self-generated IPv6 address is confirmed as unique. This operation is called as Duplicate Address Detection or DAD.

The conventional DAD operation is often referenced as the try-and-wait operation. By this method, the node that has constructed the IPv6 address asks for a route to a hypothetical node which possesses the same IPv6 address. It waits for one second for a possible response and if no response is received, the node assumes its IPv6 address is unique.

The main disadvantage of this operation is related to the waiting time. In order to overcome it, several proposals have been published. The students could compare them and conclude which one outperforms.

The Figure 3 shows the transmission process in a MANET.

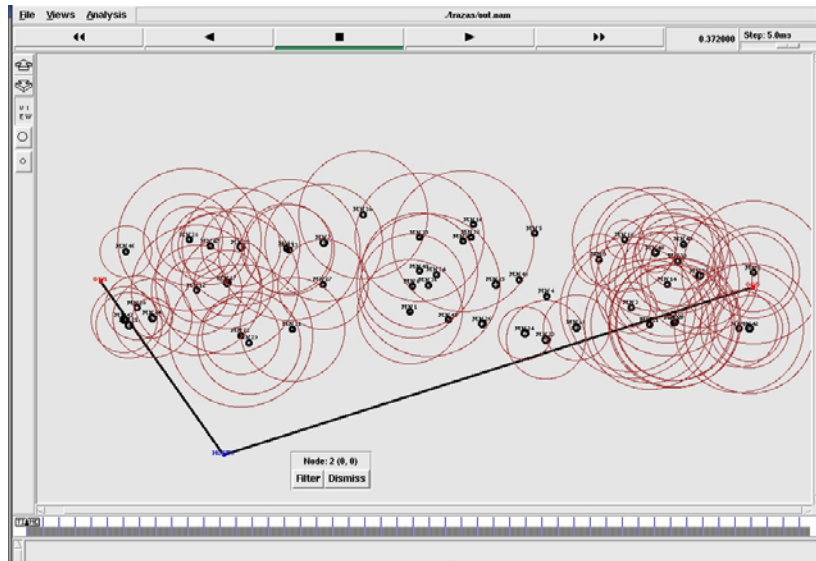


Figure 3. Transmission of Packets in a hybrid MANET extracted from NAM

#### 4. Conclusions

In this paper, the utilization of the ns-2 has been explained. As a guideline, the methodology that we recommend for the inclusion of new protocols in ns-2 have been shown. As illustrative examples, some works related to Master Thesis have been presented and proposed.

#### Acknowledgements

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#### References

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