V_HAND: Simulator for Behavior Modeling of Mobile Nodes between Heterogeneous Networks

Victor Chi†, Francisco González††, Lizzie Narváez†

†UADY, Unidad Tizimín, ††ITESM Campus Cuernavaca, México

Summary
The goal of the work described in this paper is to show the procedure for the development of a graphical tool, in this case, a simulator for a context-aware algorithm for the correct and timely decision-making in the heterogeneous handoff process in wireless overlay networks. This paper describes the related concepts with the handoff process in overlay heterogeneous networks; the algorithm of decision-making of handoff is included and finally, the analysis and design process of the simulator is described.

Key words:
Vertical handoff, heterogeneous networks, mobile node, simulators.

1. Introduction

The network performance is associated to the time that the packages take from the source to its final destination. This network latency has a direct impact at response time of the applications, and finally, in the user's satisfaction.
Mobility at wireless networks increases of several ways the latency of the network. For this reason, it's important to know more about mobility and the way in which affects the performance of the network.
In the last years, wireless networks have been occupied a significant position in the market of the local area networks (LAN's). Over and over, organizations find that wireless networks are an indispensable complement to the traditional wired networks in order to satisfy the requirements of mobility, re-localization, ad hoc interconnection, and coverage in difficult to wire places. One of the major benefits of wireless networks is the mobility, where the main subject is that user can be connected to the network at any place in which he/she is and while he/she moves.
Related to heterogeneous mobile environments, the challenge now is to allow user's access at any time and place to the services that these offers, independently of the networks and devices that are used and the involved Wireless Internet Service Provider. At the moment at which the mobile devices change of network technology, the users do not have to notice this situation, as it happens in the homogenous mobile environments, nevertheless, is advisable that users can define their preferences as cost, bandwidth, etc.
The challenge in heterogeneous environments is to implant the same concept of transparent mobility of homogenous environments, through different kinds of network technologies and administrative domains. The problem of transparent vertical mobility is to get that transitions between heterogeneous technologies of the same or different administrative domain are imperceptible or cause less distraction as possible to the user. A major part of the solution to this problem is in an adequate administration of heterogeneous handoff, which depends in a great extent on the handoff decision algorithm which executes the transition at the opportune time and to the best network available [1].
As previously mentioned, in several current works of investigation [1,2] is proposed the development and validation of a distributed algorithm that makes and provides correct and timely decisions to the vertical handoff process. The algorithm will self-adapt to the operating conditions of the media involved, to the quality requirements of applications in execution, to the mobility and geographic context of the mobile station, and to the connectivity user's preferences. Similarly, this algorithm should not be tied into the features of particular mobile terminals or radio networks.
But once we have the decision algorithm, another problem arises: how to validate an algorithm of heterogeneous handoff, which must be making decisions with the context information?. One of the ways for the validation of the algorithm is the simulation.
It is decided to use simulation because this one allow us design a model of a real system and to experiment with this model, in order to understand the behavior of the system and/or evaluate several strategies for the operation of the system.
On the other hand, the simulation offers several advantages [3]. Some of them are:

- A detailed observation of the system that is being simulated can lead to a better understanding of the system and consequently to suggest strategies that improve the operation and efficiency of the system

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- The simulation of complex systems can help to better understanding of the operation system, to detect the most important variables that interact in the system and to understand the interrelations between them

Therefore, a simulation model will be developed to evaluate the handoff algorithm in generic test handoff scenarios in an overlay system. The simulation will compare the proposed decision algorithm with conventional decision algorithms.

2. Networks simulators analysis

The goal of this paper is to show the development of a simulator for modeling heterogeneous networks transitions for the correct and timely decision-making in the vertical handoff process. In this section will be described the most important simulators used at the network area.

NS-2 is one of the most powerful tools for simulation of wired, wireless and mobile networks protocols. Is considered the most extended for research as well as educational proposes, and is based in two languages: a simulator written in C++, and an extension of TCL (object oriented) which is used for execute the scripts. A link exists between the scripts and simulator, which creates a relationship with the OTCL and the C++ objects. The users create new simulation objects through the interpreter, which are instanced inside the interpreter. NS-2 has an extensive networks and protocols library, and is considered a standard for simulation of communication networks.NS-2 does not have a simulation environment, animation capabilities (real time), and statistical analysis [4].

GloMoSim is a simulation environment for wired and wireless network systems. Has an open source version for academic institutes with research propose and a commercial version well-know as QualNet. Nevertheless, GloMoSim works in homogeneous networks. In the future GloMoSim will be able to work with hybrid networks that support wired and wireless capabilities [4].

OPNET is a connection-oriented simulation language. Particularly, uses an OPNET modeler well-know as “modeler simulator”, which is a development environment that allows the design and study of communication networks, devices, protocols and applications. It’s a powerful tool for graphic simulation of communication systems which allows the development of complex network models. Its object-oriented hierarchy structure permit to model a whole GSM network, with its fixed part (mobile stations, switching centers and data bases) and mobile stations. OPNET simulates the generation, reception and ending of cell phone calls. Mobility is also contemplated through localization and handoff procedures. Nevertheless, OPNET is a commercial simulator [5].

In conclusion, the reason for which we decided to develop a simulator for the context-aware algorithm is that NS-2 and GloMoSIM works with homogeneous networks. On the other hand, OPNET in spite of work with heterogeneous networks, it’s commercial, not open source and expensive. An open source simulator will help the research community in this area to test its protocols.

3. Handoff description

One of the most important features of a mobile network is the ability for a user to move from one cell to another. There are two aspects of mobility in a personal communications services (PCS) networks: the handover and the roaming [6].

Handoff: When a mobile user is engaged in conversation, the mobile station (MS) is connected to a base station (BS) via a radio link. If the mobile user moves to the coverage area of another BS, the radio link to the old BS is eventually disconnected, and a radio link to the new BS should be established to continue the conversation. This process is variously referred to as automatic link transfer, handover or handoff.

Roaming: When a mobile user moves from one PCS systems (e.g., the system in Morelos City) to another (e.g., the system in Yucatan City), the system should be informed of the current location of the user. Otherwise, it would be impossible to deliver the services to the mobile user.

In summary, handoff is a mechanism that quickly switching the connection of a subscriber of a cell to another neighboring cell while the user moves from one place to another. To perform a handoff, this can take several seconds, so if users move too fast, their calls will be dropped [7].

3.1. Handoff process.

It’s important to define when, where and how perform the handoff. The vertical handoff process has four phases:

At the beginning phase a handoff planning is done, that is, to establish the criteria for which the handoff is necessary. An obligatory reason for handoff making is due to the actual link degradation, which generates a quality lose at that link. Another reason, considered as optional for handoff making, is the existence of a new network better than the actual one.

At the preparation phase, all network connections are monitored, that is, a networks discovering is made with the purpose of selecting the best one until the moment of network change. This phase is the most important because affects the normal working of communication. Generally, we could say that in the preparation phase the best disposable network is chosen based on criteria and the best transition moment based on policies.
At the execution phase the method for transition making is defined, and could be soft or hard handoff. The execution phase establishes the connection with a new network and executes events of association, re-association or disassociation.
During the evaluation phase, the decision of network change is evaluated as well as the applications quality. This phase is considered as a reflective model in which the handoff process evaluates itself, that means that it has the capability of improve itself.
Figure 1 shows the vertical handoff process phases.
Several classifications of handoff exist according to the reference author. One of them given in [8] is to classify them like horizontal handoff and vertical handoff.

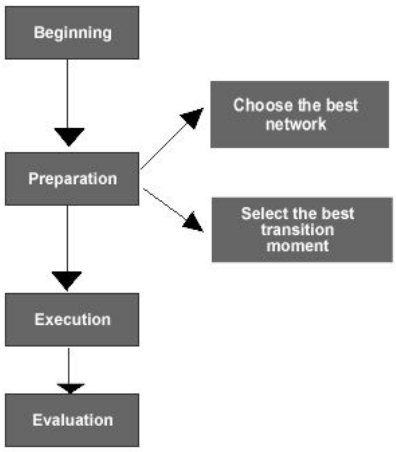

Fig 1. Phases of vertical handoff process.

3.2 Horizontal handoff

A *horizontal handoff* is defined as a handoff between base stations that are using the same type of wireless network interface. This is the traditional definition of handoff for homogeneous cellular systems such as cellular telephony systems, wide-area data systems, and wireless local area networks [8]. One feature of a horizontal handoff is that the handoff decision take place based on received signal strength.
Figure 2 shows the horizontal handoff process. In this figure, each hexagon represents the cell of the access point (AP), and all of them belong to the same wireless network technology. At the moment that a mobile device moves from one cell to another, the horizontal handoff process is happening.

3.3 Vertical handoff

The next generation wireless networks will be integrated by a plethora of heterogeneous wireless overlay technologies and multi-mode mobile terminals running a common network layer protocol (IP). A new kind of handovers is required to support seamless mobility over heterogeneous technologies [1]. These handovers are knows like *vertical handoff* (VHO's).
The vertical handoff happens between base stations that are using different wireless network technologies [8]. The terms horizontal and vertical follow from the overlay network structure that has networks with increasing cell sizes at higher levels in the hierarchy (figure 3).
The VHO is embedded in the system and its characteristic is that the mobile station always switches to the smallest coverage area. On the other hand, a VHO also can be defined as the process that changes the point of attachment of a mobile station, from one base station in a wireless technology to another base station in another wireless technology.

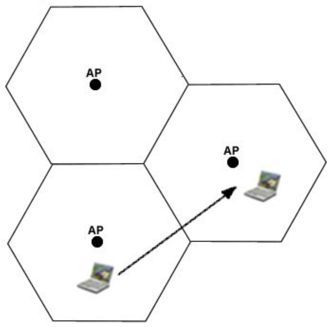

Fig 2. Horizontal handoff.

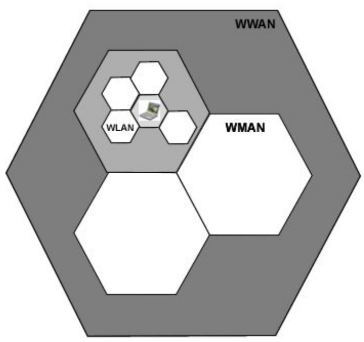

Fig 3. Vertical handoff.

4. Description of the algorithm for the correct and timely decisión-making

In this section we will describe the control handoff algorithm. This algorithm response how, where and when perform the handoff process. Two algorithms are required: the execution algorithm and the decision algorithm. Figure 4 shows the control algorithm.
The selection of the best network determines to what network we are due to connect. This selection will be based on certain parameters known like handoff criteria, which are used to select the best network. These criteria can be: metric of handoff, measured of performance and parameters of mobility.
In order to detect the best network we will calculated a cost function. For this, the cost of association to each one of the networks available and which the user can access according to its location is calculated. The best network will be the one with the lower cost.

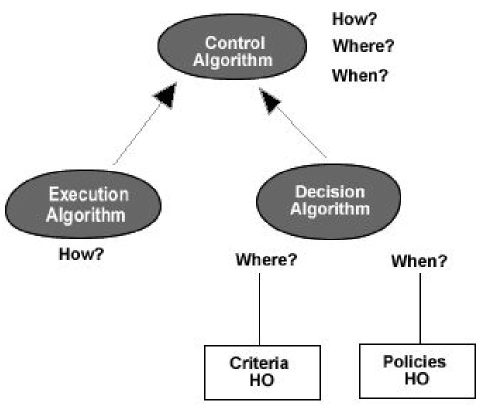

Fig 4. Control algorithm for the vertical handoff process.

The cost of using a network *n* at a certain time is a function *f* of several parameters such as the bandwidth it can offer (*Bn*), the power consumption of using the network access device (*Pn*) and the cost (*Cn*) of the network. The function is represented as:

$$Cost\ (n) = f(Bn, Pn, Cn)$$

In this case, the bandwidth is calculated periodically because it depends on the number of users who are connected to the network in a given time (the available bandwidth is inversely proportional to the number of users); the power consumption and cost of the network are fixed parameters.
The policies of handoff are used to determine the necessity of handoff and the opportune moment for their execution. In order to detect the best time we will calculate a benefit function for the time t and compare it with the benefit function for the time *t+1* and *t+2*. If the benefit for the time t is greater than the benefit for *t+1* and *t+2*, then, time *t* is the best time to trigger a handoff.

5. Simulator's architecture from a design sight

In this section is described in detail the architecture in which the simulator operation is based, identifying its modules and their interaction. The simulator will be integrated of three modules (graphic user interface, decision algorithm and network monitoring) and data bases. Figure 5 shows the simulator elements.

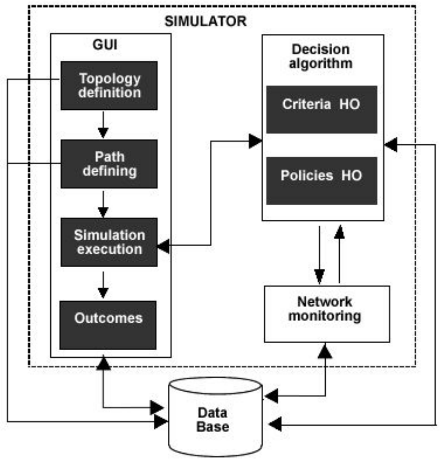

Fig 5. Simulator architecture.

Topology definition: this module contains the network topology, that is to say, here will be created the scenario which will be used through the simulation. The scenario will be integrated by macrocells, microcells and picocells and the technologies that will be represented are *UMTS*, *CDMA2000* and *WIMAX* for macrocells. *802.11* standards *a, b* y *g* for microcells and *Bluetooth* for the picocells.
Path defining: in this module will be defined the path followed by the mobile node during the simulation. The path will be represented by straight line segments and for each segment a speed of movement will be given for the mobile node and the type of application that will execute, which could be a data application o sensitive to relay (voice, image).
Simulation execution: the main objective of this module is to begin the simulation once the topology network and the mobile node path was defined. For execution is required the interaction with the decision algorithm.
Outcomes: this module will provide the information for each moment in which a handoff was executed during the whole path of the mobile node.
Decision algorithm: contains the vertical handoff algorithm for best network selection and timely moment

for the handoff execution. For this purpose a policies and criteria of handoff are required.

Network monitoring: the main objective of this module is to detect for each time unit the networks that provide coverage to the mobile node.

Data base: is required for information storage and will contain dynamic and static data. For data dynamism simulation, each time the data base is acceded, the data will change by random. The data base will have three kinds of data: handoff metrics, performance measures and mobility parameters described at section 6.2.

6. Simulator implementation

The graphic user interface will be developed in Macromedia Flash 8.0 and the module programming will be use the ActionScript 2.0 language. For the data base will be used MySQL. In the next paragraphs each module will be described.

The reason for the use of Macromedia Flash instead of Java for the simulator development is that Macromedia Flash provides a friendly graphic user interface (GUI) and contains predefined visual objects that can be used with the object oriented paradigm. Macromedia Flash is compatible with dynamic pages languages like PHP, Coldfusion and ASP, in contrast, Java only is compatible with JSP.

6.1 Graphic interface description

The graphic interface of the simulator is similar to the figure 6. The development of the simulator consists of three phases.

First phase consists of two steps. In the first step the user will construct the topology with which the simulation will work. For this, the user may select a macrocell, microcell or picocell from the toolbar. The macrocells that will be considered are: UMTS, CDMA2000 and WIMAX. The microcells considered are the standard a, b and g of the 802.11 and within picocells will only consider Bluetooth. Once selected the cell, this will be drawn in the work area. Finally, the user will provide the necessary information according to the selected cell, as technology of the cell, power and number of users. With base to the proportionate power the coverage of each cell will calculate. Figure 7 shows the first step of the first phase. The second step consists of defining the path that will follow the mobile node. This path will be defined by straight line segments. For each segment of straight line, the preferences of the mobile node will be defined. The preferences are classified in data application and data or sensible realy.

The second phase, consist of the execution of the vertical handoff algorithm. In this phase, it is considered the beginning, preparation and execution of the handoff algorithm. The user will see the execution of the simulation and a window will display the timely moment of the handoff and the best network.

The third phase will show only the outcomes where handoff happened. These outcomes are very important because a statistical analysis can be made and that will be very useful for the evaluation phase.

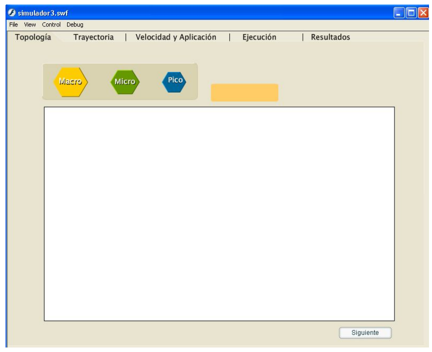

Fig 6. Simulator graphic interface.

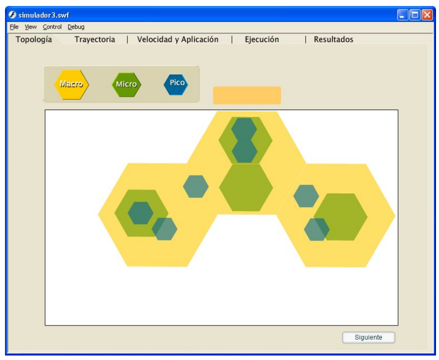

Fig 7. Topology construction.

6.2 Data base description

The data base will contain static and dynamic data. For dynamism data simulation, each time the data base is accessed, the data will change randomly. The data base will have the next information:

Handoff metrics: power consumption (battery level and power of transmission) and monetary costs of connectivity.

Performance measures: of network: (bandwidth consumed, disposable bandwidth and latency) and the handoff.

Mobility parameters: position, distance and speed of the mobile user.

7. Results

As a result from this paper, we can mention that the context-aware algorithm for the correct and timely decision-making proposed in [1] is being used to test the simulator. Nevertheless, due to the modular architecture in which the simulator was designed, other algorithms can be used.
On the other hand, the simulator's architecture offers a flexible mechanism which allows the addition of future handoff criteria using the same simulator.
Finally, the simulator has the advantage of not being only limited to a MySQL database, because we had used XML as intermediate layer.

8. Conclusions

Although the simulator is not yet developed to the 100%, it is convenient to say that with this simulator will be possible the more detailed analysis of mobility of the nodes in an heterogeneous networks, than the laboratory tests, because with these tests only we could work with Bluetooth and 802.11. However, the proposed simulator we will be able to test the previously mentioned technologies and UMTS, CDMA2000 and WIMAX.
The contribution of this work is the collaboration of the simulator in activities of modeling and simulation of heterogeneous networks of international scientific community.
On the other hand, with the results that the simulator in its last phase will throw, these will be able to be used as input data, to make the phase of evaluation of the handoff process.

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Victor Manuel Chi-Pech [vmcpech@uady.mx] obtained his degree in Computer Science from the Autonomous University of Yucatan (UADY) in 1996 and his M. Sc. degree in Wireless Network from Monterrey Technological Institute (ITESM), Campus Cuernavaca, in 2007.
Victor Chi works since 2000 in the Autonomous University of Yucatan, as a full time professor. He has participated in development projects of software engineering. Currently is giving courses on wireless networks and software engineering in the professional programs in the UADY.

Francisco Alejandro González Horta [fglez@itesm.mx] obtained his B.Sc. degree in Electronics and Communications Engineering from the American University of Cholula, Puebla in 1985 and his M. Sc. Degree in Software Engineering from Monterrey Technological Institute (ITESM), Campus Cuernavaca, in 1992.
Since 1998, he works in the Division of Engineering and Sciences of ITESM, Campus Cuernavaca as a professor of plant, which seeks to engage in teaching and research. His topics of interest include: Formal Languages Theory, Design Protocol Communications, Wireless Networks and Mobile Digital Telephony and Videoconferencing Systems.

Lizzie Edmea Narváez-Díaz [lendiaz@uady.mx] received the degree in Computer Science from the the Autonomous University of Yucatán (UADY) in 1997. She received the Master of Computer Science degree from Monterrey Technological Institute (ITESM), Campus Cuernavaca, in 2007.
Currently, she is a full time teacher at the Autonomous University of Yucatán since 2000 at the Network department in Tizimín México. She has participated in development projects of software engineering. Currently is giving courses on wireless networks in the professional programs in the UADY.