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EXPLORING NS-3 VS. ALTERNATIVES: LTE HANDOVER OPTIMIZATION IN NETWORK SIMULATIONS

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Abstract: The advent of LTE, marking the fourth generation in cellular network technology, has revolutionized the telecommunications landscape, bringing forth substantial enhancements in efficiency, data rates, latency, cost-effectiveness, capacity, and coverage. As a successor to the third-generation (G3) networks, LTE, or Long-Term Evolution, has become the cornerstone of modern telecommunications infrastructure in many countries. This study delves into the critical aspect of handovers or handoffs in cellular communication, specifically addressing the seamless transfer of data packets between channels within the same network.

Categorizing Base Transceiver Station (BTS) antennas and managing handovers at border points stand as pivotal challenges within GSM groups and LTE networks. In certain indoor environments like offices and residential areas, handovers may be deemed unnecessary in regions with stronger signals than the source station. However, at points like exit doors, where signal strength diminishes, handovers become imperative. The identification and mitigation of unnecessary handovers pose a significant question for network experts. Determining whether it is feasible to recognize and manage these unessential handovers optimally, considering the geographic location of the node and signal strength, has been a longstanding inquiry.

Addressing the complexity of implementing large-scale networks in real-time scenarios, this research highlights the invaluable role of simulators. Simulators serve as instrumental tools for network developers to comprehend the intricacies of network structures and ascertain their real-time deployability and economic feasibility. Evaluating various network simulation languages such as NS-2, NS-3, OMNET++, PeerSim, JiST, and OPNET, this study aims to guide network simulator developers in selecting the most suitable tool for their specific needs. The focus shifts to NS-3 as a powerful and promising tool for simulating LTE network structures and diverse handover scenarios. In light of Sinclair et al.'s work in 2013, we explore the capabilities of NS-3 in implementing LTE networks and simulating intricate handover scenarios. The study provides insights into the potential of NS-3 as a comprehensive solution for network developers, offering a platform to assess and optimize LTE networks while addressing the critical issue of handovers.

Keywords: LTE, 4G, handover, NS-3, network simulation, cellular networks

1. Introduction

Today, most operators in modern country are using the LTE network. LTE's fourth- technological generation is a major improvement in efficiency, higher data rates, lower time lag, cost savings, capacity, and coverage. While the new LTE is officially called the fourth generation of the G4 cellular network (4G stands for 4th Generation, meaning the fourth generation), it has several improvements toward the current G3. In cellular telecommunication, the term "hand off" or "handover" refers to the transferring process or data packet from a channel to another channel which is connected to the same network. In cellular networks, how to categorize BTS antennas and Handover handoffs along the border points are main issues in GSM groups and LTE networks. In indoor spaces such as office and residential areas, some parts such as windows, that receive the stronger signal than the source station, Handover is unessential, but in other places such as the exit doors, handover occurs. Having a geographic location of the node by the base station and the signal strength, could be recognized that the requested Handover is required. This question that is it possible to identify and eliminate or manage unessential Handovoers in an optimal condition, has occupied the experts' minds for a long time. In this research, creating the network, especially large networks, would be difficult in a real-time scenario, so the implementation in the real world won't be easily feasible and inexpencive. Therefore, simulators help to networks' developers to dominate the network that is able to be developed in real-time deployment or no. In this case, we examine the LTE network structure and various Handovers' structure, tools features and network simulation languages such as (NS-2, NS-3, OMNET ++, PeerSim, JiST, OPNET),we are submitted the best choice for network simulator developers by comparing them. Then, we introduce the ns3 as a powerful tool and examine the possibility of LTE implementing and Handover scenarios in it (Sinclair et al., 2013).

2. LTE Network

LTE is contraction of "long-term evolution." LTE, fourth- technological generation is a major improvement in efficiency, higher data rates, lower time lag, cost savings, capacity, and coverage. The upper layers of LTE are TCP / IP-based, all-IP network are similar to the current wired connection status. LTE is kind of a 4 G wireless broadband technology which is developed by the industrial business group: the Third Generation Partnership (3GPP). 3G technologies are based on GSM, LTE significantly provides the maximum peak data packets with 100 Mbps potential to download and 50 Mbps to upload, time delay, resilient bandwidth capacity, and the synchronization with GSM and UMTS technology. LTE supports a variety of data types: text, voice, video, and message LTE transfer. LTE networks are implemented in both FDD and TDD. FDD is similar to the Full Duplex method used in networks' cables. In the TDD method, scheduling is used to send and receive on the network. The TDD is contraction of "Time Division Duplexing" , it acts as a downloader at a specific point in time and it is very similar to the Half-Duplex method that used in network cables. LTE uses two different radio stations to send and receive information from the telecommunication tower of client, to receive information from the Orthogonal Frequency Division (OFDM), which requires Multiple Input Multiple Output (MIMO). It means different inputs, with this feature that the user can use two or more antennas to reduce the delay in sending and receiving information and increasing communication speed with using the specified channel. In standard LTE, 4x4 ports can be configured. (The first number is the number of transmitting antennas and the second number is the number of receiving antennas.) To send information (from cellphone to telecommunication tower), LTE uses a single-carrier frequency division multiple access signal (SC-FDMA). Most LTE gatget do not have a strong signal to send data, so because of high power SC-FDMA is more appropriate than OFDMA to send data because of its high power.

Table 1. Mobile data standard

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Mobile Data Standards

	WCDMA	HSPA HSDPA/HSUPA	HSPA+	LTE	LTE Advanced
Max DL rate	384 Kbps	14 Mbps	28 Mbps	100 Mbps	> 1 Gbps
Max UL rate	128 Kbps	5.7 Mbps	11 Mbps	50 Mbps	> 500 Mbps
Round trip latency	150 mS	100 mS	50 mS	10 mS	5 mS
3GPP Release	Rel 99/4	Rel 5/6	Rel 7	Rel 8	Rel 10
Deployment	2003	2005 – 2007	2008	2009	~ 2014
Radio Access Technology	CDMA	CDMA	CDMA	OFDMA/SC-FDMA	OFDMA/SC-FDMA
ITU Generation	3G	3.5G	3.5G	3.9G	4G

2.1 Benefits of LTE

From the consumer's point of view, a considerable advantage of LTE is the data transfer Speed. Theoretically, 100Mbps information is received and 50Mbps data is sent. The amount of information exchanged requires various factors such as bandwidth, frequency oscillation, MIMO settings and the quality of the wireless path. Currently, most of LTE networks have a normal speed about 5Mbps to 25Mbps, but with the further expansion of this network and the use of LTE-Advanced, data transfer rate can be even more quickly than the speed of Internet service providers (DSLs). From a telecommunications aspect, LTE architecture has been simplified over previous networks. LTE uses Internet protocols (IP). But in the end, the cost of building and running this new telecom network will be reduced by using equipment such as Plug and Play, auto-settings and auto-optimization.

3. Handover

In cellular telecommunication, the term "hand off" or "handover" refers to the evocation of transferring procedure, call or data packet from one channel to another channel that is connected to the same network. Position management maintains the current BS server's status for the mobile station. When a MN of the old BS server is moved to the new BS server, Handover Management enables the old server to retrieve users information to the new BS. Communicating during the movement is considered in this chapter. One of the most important features of wireless networks is "mobility." In order to be accessible in a certain geographic environment (cell), a movable terminal has to remain near the main station. When the portable terminal moves from one cell to another, the terminal has to connect to the main station that masks the cell. This is an event that the MS enters from one BTS to another BTS. In the other words, if one of the following conditions occurs, handover could be happened: The received signal power levelof the MS from BTS is lower than normal range of Rx level

The quality of the received MS signal from BTS is less than its permissible RX Quality The distance between the MS and the BTS is increased (Taiming Advance)

The Handover mechanism defines the steps that will be taken to transfer all data pockets and assigned resources to the terminal, which enables the terminal tobe connected to the network infrastructure. The most basic form of

Handover is when the telephone call is going out of the last cell to the new cell, the channel that used in cell is oriented and connected to a new channel.

3.1. Types of Handover

3.1.1. The first category

- intracellular: The aim is to call transfer that comes out of cell area to another cell which is covered.
- Extracellular: The aim is to change the channel that may interfere or fade by a fading channel.

3.1.2. The second category

There are four types of handover that carry communicational in the following formats:

1. Between channels (time slots) in a cell.
2. Inter-cells (BTSs) are controlled by a BSC.
3. The cells that dominat by different BSCs are all sub-sets of a MSC.
4. Interactions between cells are controlled by MSCs.

3.2.3. Third category

Handover on UMTS is based on the definition of different types.

For the type of function, Handover is categorized into the following items:

Intra-mode Handover: Between two FDD or TDD carriers with similar or different frequencies.

Inter-mode Handover: between FDD and TDD modes.

Inter-system Handover: Between distinct 3G or 3G-2G systems.

3.3. Comparing Handovers

A Hard-Handover Advantage is each conversation that use only one channel at the moment. Hard-Handover is probably very short and is not usually acceptable by the user. In the old analogue systems, it's heard as a sound click in digital systems that are not impressive. Another advantage of HardHandover is that the phone hardware does not need to receive two or more parallel channels that make it cheaper or easier. One of the most disadvantages is that if the Handover are floped, the conversation will flaw or abnormal. One of the advantages of Soft-Handover is that the source cell connection breaks when an authentic interface is created with the target cell, thus these are the chances that the cell would be end abnormally due to the unsuccessful Handover. fading and interference are irrelevant to different channels, so there is less likelihood to happened at the same moments in channels, so when the conversation is in a Hard-Handover, the reliability of this interface is higher, because in a cellular network, the maximum handover occurs in status where the coverage is weak. When the channel has interruption or fading, calls are unreliable. Soft-Handover does not enter the crisis by fading in a channel. This advantage causes more hardware cost per phone that should be able to process multichannels in a communication. Another part thatisused for - Soft Handover is multiple channels in the network to support a communication. It reduces the number of free channel holder and network capacity. By setting the duration of the soft handover and the size of the arenas that occur, network engineers balance the trustworthiness of the conversation. In spite of the price ,the capacity will reduce (Jansen et al., 2010).

4. Tools and network simulation languages

An important part of the system development is the evaluation of its performance with regard to transition and delays in real scenarios. In many cases, performance evaluation and functionality of the network is achieved through simulation experiments, which also requires a suitable environment and simulation tools. To make this principle issues , software application have been created a variety of computer network simulations with magnificent features that have their own weaknesses and strengths.

One of these vital simulation tools NS, 3NS, OPNET ++, PeerSim, JIST and OPNET. Accustoming with the performance is the main step towards developing an overall methodology for generating network simulators. Therefore, we will continue to study the characteristics of the simulators (Azadi Marand et al., 2013).

4.1. NS-2 simulator

The NS-2 development was supported by the DARPA VINT project from 1997 to 2000 and was supported by SAMANDARPA and NSF CONSER from 2000 to 2004. Nowadays, the NS-2 is considered as a useful tool in open source network simulator. The NS-2 is accomplished by the capabilities of the C ++ and the OTCL, that is kind of handwritten language with the TCL structure and Object-oriented capabilities that is added to TCL at MIT have been designed and implemented.

4.2. NS-3 Simulator

The NS-3 project was officially launched in mid-2006, Butthe first fixed version was released in June 2008. It is created as a library version that connects dynamically or statically to a main C ++ application. These libraries define the NS-3 simulator and the simulation topology. Because of the NS-3 simulator architecture, hardware simulation works with each protocol. It requires somecode in the simulation model to set up the protocol as a real-world implementation. Because of the NS-3 simulator architecture, hardware simulator works with protocols based on the NS-2 image, which only works with selected protocols for hardware support. Many codes need to be implement by the simulation model as a real-world implementation.

4.3. OMNET ++ simulator

OMNET ++ is a discrete, multi-purpose, open source simulation tool although it is free for academic and non-commercial applications. The componentbased architecture and the object-oriented structure of OMNET ++ are able to simulate systems that are appropriate for a discrete event method. Although the principle aim is the telecommunication networks simulation, but itcould be successful implementation in other field such as the IT system Simulation, segmentation networks, hardware architectures and business processes. Since OMNET ++ is a multi-purpose simulator (Azadi Marand et al., 2013).

4.4. OPNET simulator

The OPNET tool provides the ability to design and study telecommunication networks, case networks, and networks' protocol. The main programming language in this C simulator is C ++ and also supports the new versions of C ++. . In addition, OPNET performs many tasks automatically, without any programming requirementthe small things. Another advantage of OPNET is the high speed of execution. Just a few in seconds. It also has the ability to communicate with MATLAB and use it to modeling at the lowest level.

4.5. JiST simulator

The key goal of JiST is the creation a simulation system that can simulate discrete-events both efficiently and transparently in the run-time range with a standard language. To achieve this goal, just one standard language is used at runtime. These three features (efficiency, transparency, and standard language) show an important distinction between JiST and previous simulation systems,JiSt method uses a well-coordinated system with a cluster of nodes that provides a dynamic network and computational simulation state (Azadi Marand et al., 2013).

4.6. Comparing and evaluating tools and languages for network simulation

The results of comparing the simulators in Tables 1 show the following items. These are obtained by examining simulators of different sources and using them simulators on medium sized sample. The results show the performance of the ns3 simulator.

5. NS3

The ns-3 simulator is a discrete network simulator that main purposeis the research and training. The ns-3 project is an open source developing project that began in 2006. The aim of this chapter is introduced the ns-3 to the client. First,we talk about a few key points: ns-3 project is open source and trying to maintain an open environment for researchers to assist software sharing ns-3 is provided to open source network simulation platforms tostudy more and network training.

In summary, the ns-3 delivers the network's data packetwork model and also provides a simulation engine for clients to perform simulation experiments. Some reasons to use the ns-3 contains studies that are tough in real systems, conducting a controlled study of the behavior of the system re-generation of the work environment, and learning about how the network works. Users should notice to the model collection at ns-3 is focused on how to model Internet and network protocols, but ns-3 has not any limitation to connect the Internet. manyclients use ns-3 based on non-Internet-based models. There are several simulation tools for network simulation (Dahmani et al., 2019). A number of the distinctive features of ns-3 arecompared to other tools:

The ns-3 is designed as libraries that can be combined with each another or with other external software libraries. While some simulation platforms the integratedgraphical user interface (GUI), in which all tasks areexecuted, the ns-3 has more modularity in the field. Several external simulators can be used with data analysis and visualization tools with ns-3. Users should expect to work on the command line in the C ++ tool or Python development software (Gabli et al., 2019).

Ns-3 In ns-3, the simulator is fully written in C ++ with the Pythons' optional structure. As a result, the simulation script can be written in C ++ or in Python.

It makes the possibility of real implementationcode by the simulator. To Compared with ns-2, ns-3 has more accurate models in popular research areas (including LTE and sophisticated WiFi models).

5.1. Mercurial

Sophisticated software systems require a plenty of solutions to manage the organization and to change code and basic documentation. There are many methods to do this, you might even know some of the systems that are used to do it. The synchronous version system (CVS) is probably the most wellknown of the above. The ns-3 project uses Mercurial for the source code management system (Lin, 2020).

5.2.Code Source Management System

Version Control or Source Control in English: (Revision control) is a system for controlling and checking changes in information unit involved in creating a software program. The information unit can contain source files, directories, MAC files, software objects, etc. Controls are especially substantial where several developers want to work on shared resources. In this case, concepts such as comparison, compilation, interference, and so forth come that the source control should be able to provide the right solution for each one. Today, software is usually used to do this. Thereare still companies that use old methods like having a text file in folder, sharing,copy and so on.

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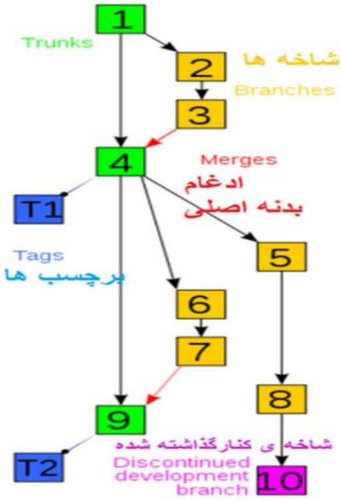

Figure 1. An example of the tree of the source version project (Azadi Marand et al., 2013)

5.2.1. SCM types

Code management software is divided into two distributed and centeralized categories:

Centeralized: such as CVS / Subversion (svn), that includes server software and a number of clients. All changes are stored on the server and users (developers) apply / receive new changes using the client have done them.

Distributed: such as GIT / Bazaar has been removed of this server category, each client can be a server and would be a full history. In this category, changes can be made without having the connection (Dahmani et al., 2019).

5.2.2. Normal operation in SCMs

Since SCMs do the equivalent job, also the main sections are similar,we can expect to do a single operation.

Init: make a new cache to save changes in it.

checkout / pull / fetch: getting information from the cache and make a working tree. switch branch: Switch between various developmental branches. add / delete / rename: Make changes to the files that SCM tracks them.

Save: a handful of changes that may occur in different files.

Status: View the status of project files.

Diff: present changes.

Log: show history of changes.

The above commands are usually the same in these software applications. For example, both the Apache Subversion and Gate software have the log command and are used as svn log and git log.

5.2.3. Comparison of control systems such as SVN, Git, Mercurial and CVS

Using version controllers in huge projects does not let to the project to be out of control, and programmers (druthers, or project controllers) would be done each part of the project without causing problems or damage to each other which are impossible to return to the project. Which version controller is suitable for your project? We will look at the comparison of these systems and we will compare them about the speed, user-to-user or server-based, features and learning, and will ultimately help you choose the right system (Lin, 2020).

5.2.3.1. Concurrent Versions System (CVS)

This system was introduced under the GNU Licensing License, which has the initial operation of receiving and sending the "check out", "check in" files. The system has implemented the intersection of files in an elementary method, which only allows you to make changes to the latest version, this system was the first system that the user had to make the changes publicly immediately in order to make sure that the user does not make any changes, the lack of feature called automatic operation which prevents the file form being corrupted in thiscondition. Currently, CVS also supports splitting. CVS server works on Linux servers and its users can use it on all operating systems.

5.2.3.2. Apache Subversion (SVN)

SVN uses a concept that called automatic operation. So that all changes are either fully applied on the original file. Many developers have switched from CVS to using SVN due to new technology of enhancement of CVS capabilities. While spliting up in CVS is considered to be a heavy operation, SVN is suitable for this and is suitable for thisand also to hugewith a large number of folders.

The main critique about the SVN system is the low speed to comparedwith the new systems and the lack of a large and distributed system to control the version of the distributed version of the user-to-user modell, instead of the central server. In global projects, user systems work better for the user, but may not be appropriate for other scenarios. The negative point about central servers was the down time of these servers, which at this time users did not have access to the code.

5.2.3.3. Git

This system is developed by Linus Torvalds, the GIT is radically different to CVS and SVN. The main point about GIT is faster and more controlled version distribution, which is contrary to the principles of CVS. Its basic system is designed for Linux and will have the highest speed on it. It also works on other Linux-like systems, as well as a version for Windows. Git is not moderated for non-single-player projects or projects with low-end users. It also has the ability to navigate through the history of changes, so that each of the examples created has a history. The overall system changes, which helps the user to use this history without having an Internet connection.

5.2.3.4. Mercurial

This system is a major difference with other similar systems, the system is written in Python instead of C, so many Python developers prefer to use this system. Mercurial has similar capabilities to the SVN system, so , learning would be easy for users who have worked with SVN is easy. One of the issues with Mercurial is that it does not allow merging of two parents, and, unlike Git, a script is used as a separate system. This may be useful for some users, but many will not change Git's capabilities with anything else.

5.3. What system do I use?

Many of those who are already working with this system prefer to use CVS, these people have found ways to adapt themselves to the bugs of this system, but if you are looking for a similar but flawless system, use SVN . If your project is an open source project, Git will be the best choice for you. If you want to have a single cache and your developers are low (less than 100 people), SVN is the right choice for your system. If you want something between the two systems, Mercurial is the perfect choice. The first decision you must take is that your choice system will respond to all the needs of the project and your team (Gabli et al., 2019).

5.3.1. WAF

When you download the source code to your local system, you need to compile that source in order to create a usable program. The Waf build system is used on the ns-3 project.

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5.3.2. Developmental environment

As mentioned above, coding is done in ns-3 on C ++ or Python. Many applications are ns-3 in Python, but both models are written in C ++.

5.4. How to run the program in ns-3?

Copy the program file with the .cc extension to the Scratch folder inside the ns3.22 directory and type the following command in the Linux command line. ./Waf -run Scratch / Program file name

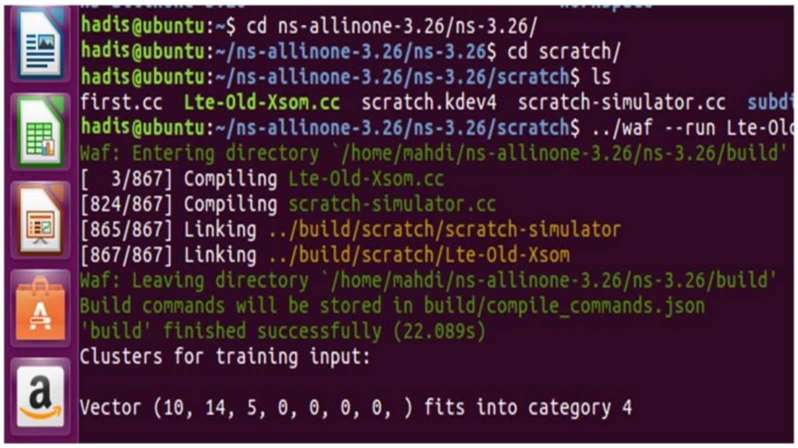

Figure 2. Run the program in the NS-3 environment

5.4.1. How to run the program in the NetAnim environment?

In the installation path, we type the following command.

./NetAnim

In the open source, select the file created after running the program with the ./Waf command with the extension (.xml).

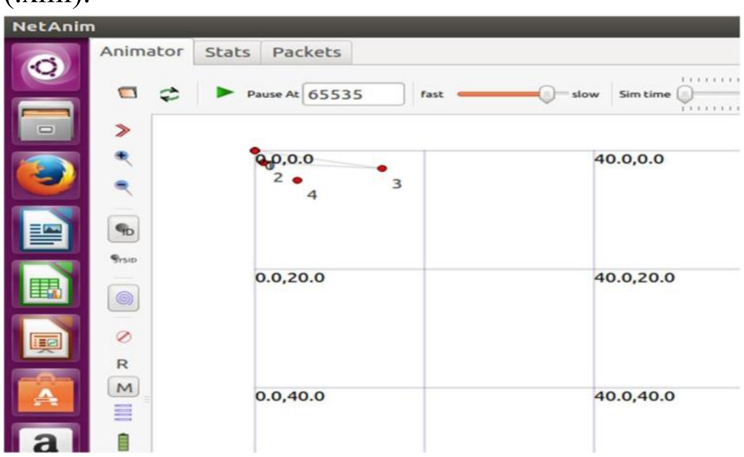

Figure 3. Sample program output in NetAnim environment

6. Conclusion

LTE network of 4th generation technology is a major improvement in spectral efficiency, higher data rates, lower time lag, cost savings, capacity, and coverage. How to arrange BTS antennas and handover at the border points are substantial issues in these networks. Indoor spaces allow us to create unessential handover. Our surveys' results show that several scenarios such as the use of the SOM (Sinclair et al., 2013), the neural network such as

Xmeans clustering algorithm, the ICA colonial competition algorithm (Atash paz gorgi, 2008) and other innovative and meta-innovative algorithms are for predicting and eliminating unwanted handover. Implementing, testing and evaluating these algorithms in the ns3 simulation environment is well suited to its features and capabilities. It is also estimated from the research findings that it is possible to simulate the actual implementation code in the simulator environment. It is suggested that, for future research, SOM, ICA, X-means and other AI techniques in the environment should be tested. The ns3 is designed to optimize the LTE network for different scenarios.

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