International Journal of Electronics Communication and Computer Engineering
Volume 6, Issue 5, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Simulation of a Fault Tolerant Mobile Telecom Network

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Abstract **– The mobile telecom industry currently represent the fastest growing sector with emphasis on mobile data services. In general, the flexibility provided by mobility has satisfied users of current wireless networks, despite the extraordinary success of the cellular mobile telecommunications industry. However, the industry is still encountering various problems such as frequent call drops and lack of or inadequate service coverage areas. This paper discusses the simulation of a telecom network that is fault tolerant based on the failure scenarios examined. Two mobile networks were designed and simulated for fault tolerance. The first design is a mobile network connected directly to a SGSN (Serving GPRS Support Node) to serve as a non-fault tolerant mobile network. The second design adds a base station sub-system (BSS) into the network to form the fault tolerant design. Various parameters were used to measure the effectiveness of the designed networks including queuing delay, received power and the received throughput as the base station controller routes the packets from the mobile station to the SGSN and the packets from the SGSN to the receiving station. Our simulation results indicate that the addition of BSS increases the efficiency and the effectiveness of a mobile telecom network.**

Keywords **– Fault Tolerance, Mobile Network, GSM, OPNET, GPRS, Telecom.**

I. Introduction

Over the last few years, the cellular network industry has been struggling to cope with the increasing data demands of new devices like smart phones and tablets [1]. The majority of communications applications, from mobile telephone conversations to credit card transactions, assume the availability of a reliable network [2]. However, such applications have not been able to fully take advantage of the higher transmission rates available from the new radio interfaces and the rapid performance/cost improvements of the wireless transmission technologies that connect the rest of the cellular network beyond radio links [4]. Among the key reasons for this shortfall is the high latency caused by cellular networks' reliance on highly centralized custom routers and other packet processing devices. They run memory-intensive and computationally heavy protocols, ultimately leading to high latency and high cost. At this level, data are expected to traverse the network and to arrive intact at their destination [1].

The mobile telecom industry currently represents the fastest growing sector with emphasis on mobile data services. In general, the flexibility provided by mobility has satisfied users of current wireless networks, despite the lower quality and reduced service offerings as compared to wired networks [3]. Research is ongoing to extend the scope of services made available to mobile users to achieve the "anytime, anyplace, anyform" communications vision [4]. This vision is to provide voice, data, and multimedia services to users regardless of location, mobility pattern, or type of terminal used for access. As societal dependence on mobile terminals increases, users will demand the same system functionality, in terms of reliable service, that is characteristic of today's wireless-based telecommunications and data networks [4].

Despite the enormous success of the cellular mobile industry worldwide, the current architecture shows many signs of fundamental problems. For example, the difficulty and delay in producing a working specification for IPv6, particularly IPv4/v6 coexistence over a cellular network, is a striking example of the high complexity of the current network architecture [5] [6]. Similar difficulties are encountered when session continuity is desired between WCDMA (Wideband Collision-Domain Multiple Access)/HSPA (High Speed Packet Access') and LTE (Long-Term Evolution), cellular data networks, and between cellular and Wi-Fi networks [2]. Local traffic off-loading, desired for reducing traffic load in cellular core networks and accessing local network resources, is a relatively complicated update to specifications that touches many layers of both the network and the user device [6] .

In this paper, we compared two mobile telecom networks; a fault-tolerant network and a non fault-tolerant network. Section II discusses our related work while Section III explains the design of the telecom network with its simulation given in Section IV. Evaluation of the simulated network is discussed in Section V followed by our conclusion in Section VI.

II. Related Work

The effects of failures and survivability issues in Personal Computer System (PCS) networks have previously been investigated [4]. The authors laid emphasis on the unique difficulties presented by user mobility and the wireless channel environment. The

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impact of a failure in a wireless network depends on a variety of factors like the location and shape of the failed area, user mobility and user behavior. A simulation model to study a variety of failure scenarios on a PCS network was described, and the results showed that user mobility significantly worsens network performance after failures, as disconnected users move among adjacent cells and attempt to reconnect to the network. Thus, survivability strategies were designed to contend with spatial as well as temporal network behavior. A multilayer framework for the study of PCS network survivability was presented and metrics for quantifying network survivability were identified at each layer [4]. Possible survivability strategies and restoration techniques for each layer in the framework were also discussed.

Mobile IPv6 has also been proposed as an integral part of the next generation Internet protocol [3] as the importance of mobility on the Internet increases. Current specification of Mobile IPv6 does not provide proper support for reliability in the mobile network. Virtual Private Network (VPN) based Home Agent Reliability Protocol (VHAHA) was proposed as a complete system architecture and extension to Mobile IPv6 that supports reliability and offers solutions to the security problems that are found in Mobile IP registration. The key features of this protocol over other protocols are better survivability, transparent failure detection and recovery, reduced complexity of the system and workload, secure data transfer and improved overall performance [3].

The development and implementation of a Network Fault Tolerance (NFT) system that can detect and recover from failures of network interface cards, network cables, switches, and routers in much less than one second from the time of failure was developed [2] . The problem was divided into two parts: fault tolerance within a single local area network (LAN), and fault tolerance across many local area networks. The first part involves the network interface cards, network cables, and switches within a LAN, while the second part involves the routers that connect LANs into larger internetworks. Both parts of the NFT solution were implemented on Windows NT 4.0 PC's connected by a switched Fast Ethernet network. The NFT system was found to correct system failures within 300 milliseconds of the failure [2]

Efficient allocation of communication channels is critical for the performance of wireless mobile computing systems. A distributed dynamic channel allocation algorithm in which heavily loaded regions are assigned a large number of communication channels, while their lightly loaded neighbors are assigned fewer channels was developed [3]. As the spatial distribution of channel demand changes with time, the spatial distribution of allocated channels adjusts accordingly. The algorithm requires minimal involvement of the mobile nodes, thus conserving their limited energy supply. The algorithm was proved to be deadlock free, starvation free and fair. It prevents co-channel interference and can tolerate the failure of mobile as well as static nodes without any significant degradation in service [3].

III. NETWORK DESIGN

An architecture that divides the system into subsystem is needed to provide an overall understanding of the network elements and operation. Our presentation of the Mobile telecoms network is organized in three major segments shown in Figure 1.

A. Mobile Station

The mobile station (MS) communicates the information from the user and modifies it to the transmission protocols of the air-interface to communicate with the base station sub-system (BSS). The user information is communicated with the MS through a microphone and speaker for the speech while the keypad and display are used for short messaging [7]. The cable connection is used for other data terminals. The MS has two elements, the mobile equipment and the Subscriber Identity Module (SIM).

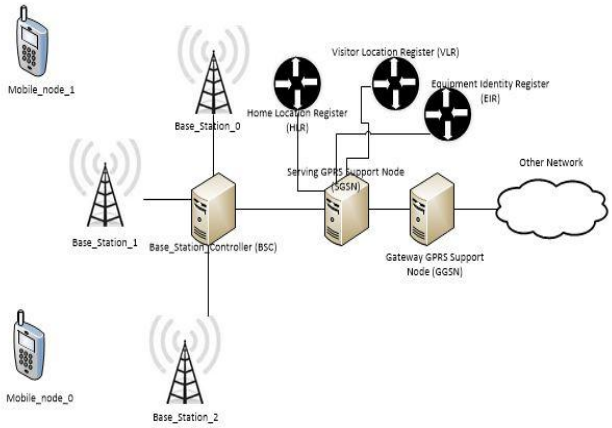

Fig.1. Architecture of a Mobile Telecom Network

B. Base Station Subsystem

The Base Station Subsystem (BSS) communicates with the user through the wireless air-interface and with the wired infrastructure through the wired protocol. In other words, it translates between the air-interface and fixed wired infrastructure protocols. The needs for the wireless and wired media are different but the wireless medium is unreliable, bandwidth limited, and needs to support mobility [7][8]. As a result, protocols used in the wireless and wired medium are different. The BSS provides for the translation among these protocols. It is made up of the Base Station Controller (BSC) and the Base Transceiver Station (BTS).

C. Network and Switching Subsystem

This is the heart of the Global System for Mobile Communication (GSM) System. It connects the wireless network to the standard wired network. It is responsible for the handoff of calls from one BSS to another and performs services such as charging, accounting, and roaming. Multiple base stations are connected to a central controller, which allocates radio channels, handles handoffs, and provides central control to all the base station elements.

D. Mobile Switching Centre

It acts like a standard exchange in a fixed network and additionally provides all the functionality needed to handle

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a mobile subscriber. The main functions are registration, authentication, location updating, handovers and call routing to a roaming subscriber. The signaling between functional entities (registers) in the network subsystem uses Signaling System7 (SS7) for trunk signaling in ISDN and widely used in current public network. If the mobile switching centre (MSC) also has a gateway function for communicating with other networks, it is called Gateway MSC (GMSC).

E. Home Location Register (HLR)

A database used for management of mobile subscribers. It stores the international mobile subscriber identity (IMSI), mobile station ISDN number (MSISDN) and current visitor location register (VLR) address. The main information stored in the register concerns the location of each mobile station in order to be able to route calls to the mobile subscribers managed by each HLR. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. The HLR also maintains the services associated with each mobile station and one HLR can serve several MSCs.

F. Visitor Location Register

The visitor location register (VLR) contains the current location of the mobile station and selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. A VLR is connected to one MSC and is normally integrated into the MSC's hardware [9]. Although each functional entity can be implemented as an independent unit, manufacturers of switching equipment implement the VLR together with the MSC, so that the geographical area controlled by the MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. MSC contains no information about particular mobile stations this information is stored in the location registers.

G. Equipment Identity Register (EIR)

This is a database that contains a list of all valid mobile equipment on the network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI). The EIR has several databases: white list for all known, good IMEIs, black list for bad or stolen handsets and grey list for handsets/IMEIs that are uncertain [10].

IV. Network Simulation

The mobile telecom network in this work was simulated using the OPNET tool. The fault tolerant and non-fault tolerant networks were simulated.

A. Non-fault Tolerant Mobile Telecom Network

Figure 2 shows the OPNET simulated non-fault tolerant telecom network. It consists of a mobile station, a SGSN (Serving GPRS Support Node), a GGSN (Gateway GPRS Support Node), an Internal HLR (Home Location Register), and a sink (Node for other network). A sink is used in place of an external packet data network because transmission of user data is only uni-directional in a telecom network.

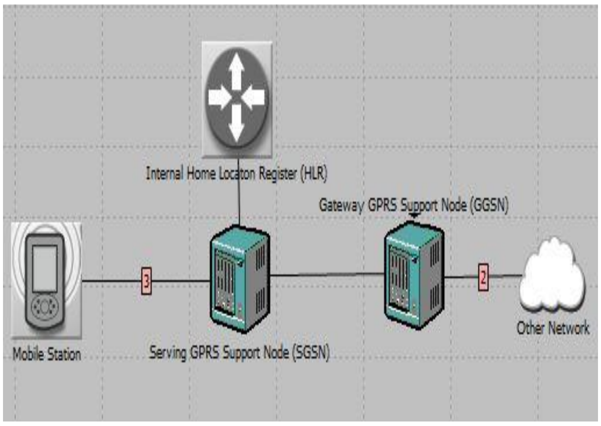

Fig.2. Non-fault tolerant Mobile Telecom Network

B. Fault Tolerant Mobile Telecom Network

The fault-tolerant mobile telecom network, shown in Figure 3 includes the implementations of the BSS. It also supports multiple mobile stations and wireless links between the mobile stations and BTSs. This enables simulation of the cell update scenario. A wireless link connects the mobile station and the BTS. The BSS consists of a Base Station Controller (BSC) and several BTSs. In our implementation, only six (6) BTSs are supported because the mobile station maintains an internal table of six highest signal power levels from various BTSs. The BSC routes the packets from the mobile stations to the SGSN and the packets from the SGSN to the receiving mobile station. The uplink frequency (from MS to BTS) is in the range 1850.2 MHz – 1909.8 MHz. The downlink frequency (from BTS to MS) is from 1930.2 MHz –1989.8 MHz. Uplink and downlink frequencies are allocated in pairs. The distance between uplink and downlink frequencies in PCS 1900 is 80 MHz.

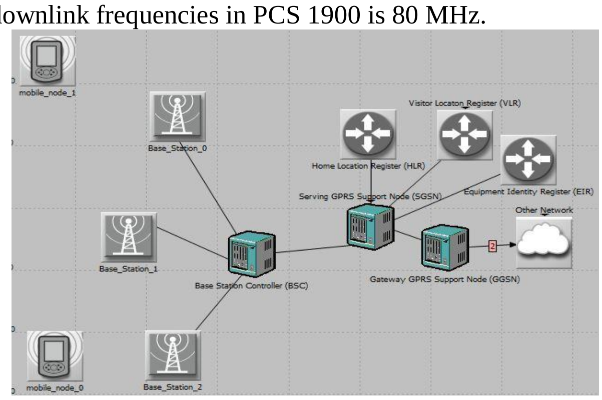

Fig.3. Fault tolerant Mobile Telecom Network

A BTS usually uses more than one frequency to support many users. On each frequency, Time Division Multiple Access (TDMA) frames with eight timeslots are sent. The frequency used by the BTS to send the broadcast control channel (BCCH) information is called the “BCCH frequency”. The BCCH is used by the mobile stations for channel measurements. In this model, a BTS can support up to 15 mobile stations. The BCCH source transmits a packet through the channel every five seconds. This allows power measurements in the mobile stations irrespective of whether the BTS is transmitting data or not.

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V. Evaluation of Simulated Network

Some scenarios are simulated in the designed mobile networks to study the effect of BSS on a mobile telecom network. The model is evaluated with parameters including queueing delay, received power and throughput. In this section, both non-fault tolerant and fault tolerant mobile telecom network results are compared in order to evaluate their efficiency with the same simulation parameters.

A. Queueing Delay

The packet queueing delay from the mobile station to the sink is measured to verify the implementation of the wireless connection and the base station controller (BSC). The queueing delays of the packets are shown in Figure 4. The queueing delay was obtained when the mobile station was connected to the SGSN through a BSC. This is because of the queueing imposed by the BSC in receiving, processing, and routing packets.

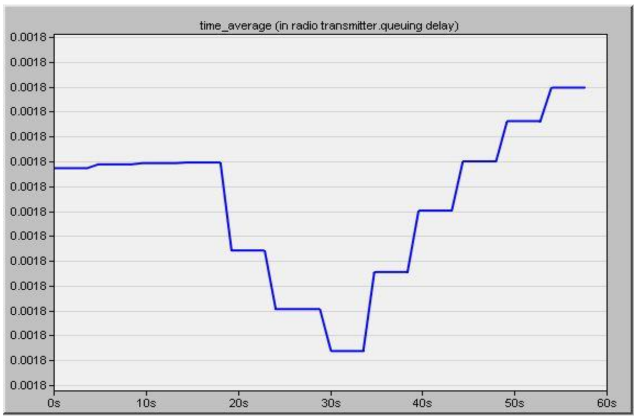


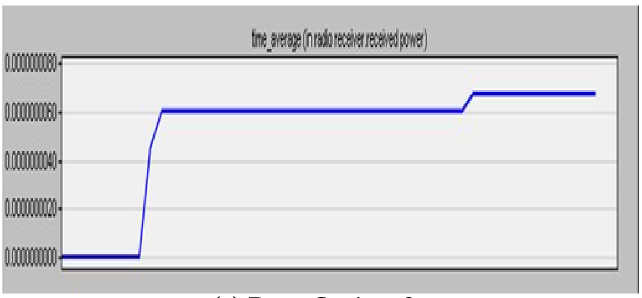
Fig.4. Queueing Delay when using base station controller

B. Received Power

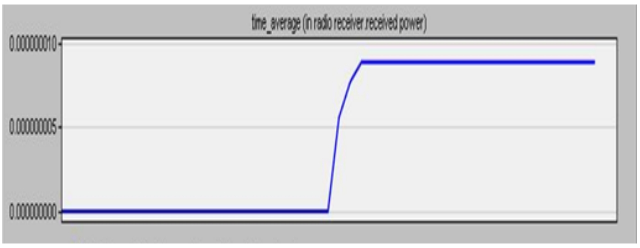
Power received by a mobile station (node 1) from the three base stations are shown on Figures 5 (a), (b) and (c), the power received from Base_Station_0 is the lowest of the three and, hence, the mobile does not transmit to Base_Station_0.

C. Throughput

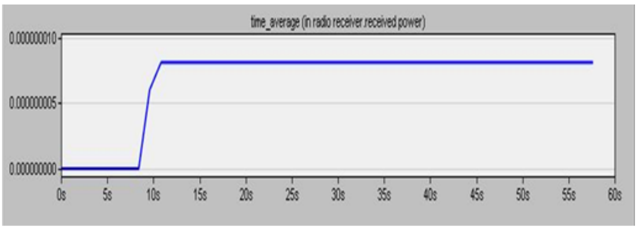
The transmitter throughput of the receiver channel of the BTSs and mobile station (node_1) are shown in Figures 6 (a), (b) and (c). This indicates that no packets are transmitted through channel 1 of Base_Station_2. It is evident that the packets from the mobile station are received by the Base_Station_1 and Base_Station_0



(a) Base_Station_0

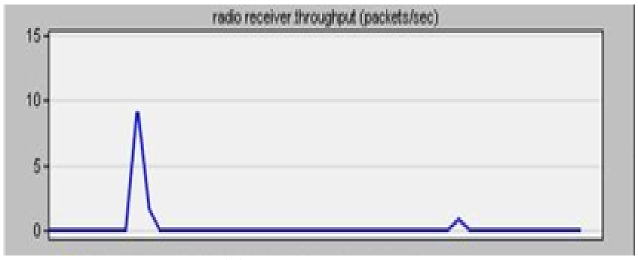


(b)Base_Station_1



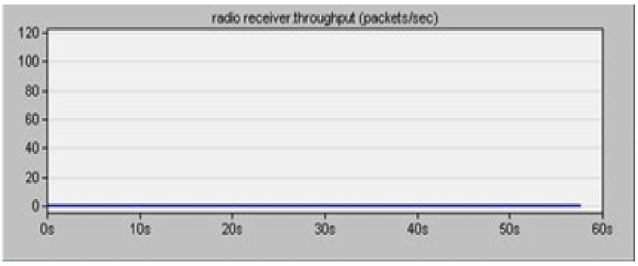
(c) Base_Station_2

Fig.5. Received power by Mobile Stations



(a)Base_Station_0

(b)Base_Station_1



(c) Base_Station_2

Fig.6. Receiver throughput from the Base stations.

VI. Conclusion

This paper has described the use of OPNET to model and simulate mobile telecom networks. The non-fault tolerant version of our mobile telecom model had network components including a mobile station, SGSN, GGSN, and HLR. The inclusion of Base Station Sub-system (Base Station and Base Station Controller) to this network makes it fault tolerant. Our evaluation revealed that the base station makes the network more efficient during processing of requests from mobile stations. Queueing delay was reduced with time when using a Base Station Controller. Received power of a mobile station is reduced when it is not transmitting with the Base station, and received throughput from the base station is zero when no packet is sent from the mobile station.

REFERENCES

[1] Byoung-Jo, K. and Paul, S. H. (2013). Directions for Future Cellular Mobile Network Architecture. AT&T Labs – Research.

[2] John, S. (2000). Network Fault Tolerance System. A Thesis submitted to the Department of Electrical and Computer Engineering for the Degree of Master of Science, Worcester Polytechnic Institute (May, 2000). http://www.informit.com/articles/article.aspx, Accessed 9th March, 2015.

[3] Rathi, S. and Thanuskodi, K. (2009). A Secure and Fault-tolerant framework for Mobile IPv6 based networks. (IJCSIS) International Journal of Computer Science and Information Security, Vol. 5, No. 1.

[4] David, T., Teresa, D., Hyundoo, S. and Charlermpol, C. (2002). Design of Reliable Communication Networks: Providing Fault Tolerance in Wireless Access Networks. IEEE Communications Magazine, Vol. 1 No 2 pp. 58-64.

[5] EFORT (2010). Telecommunications Network and Service Architectures Principles, Concepts and Architectures. Retrieved from http://www.efort.com, Accessed 11th March, 2015.

[6] Radio Access and Spectrum Cluster (2014). FP7 - Future Networks Cluster: 5G Radio Network Architecture. Retrieved from http://www.ict-ras.eu/, Accessed 9th August, 2014.

[7] Roger L.F. 1999, Fundamentals of Telecommunications. Published by john wiley & sons, inc.

[8] Koren .I, Krishna M.C. 2007, Fault Tolerant Systems, Morgan-Kaufman Publishers, San Francisco, CA.

[9] Nurul I.S, Halim S.A 2011, A Review of Simulation of Telecommunication Networks: Simulators, Classification, Comparison, Methodologies, and Recommendations, Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), March Edition, 2011.

[10] Victor. P.Nelson 1990,Fault Tolerant Computing, IEEE Computer society Press los Atlamitos. CA, USA.

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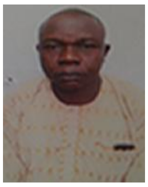

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