Performance Analysis of TCP over UMTS Network

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ABSTRACT

TCP (Transmission Control Protocol) is the most commonly used protocol for internet communication due to its features. Internet applications, such as the FTP (File Transfer Protocol), HTTP (Hyper Text Transfer Protocol) and e-mail, primarily depend on TCP. Originally designed for a wired network, TCP exhibits degraded performance when used in a wireless network environment due a number of reasons. With the newer advances in the communication networks, it is necessary to discover possible ways to enhance TCP's performance in a wireless network. This paper evaluates and analyses TCP's performance in a UMTS (Universal Mobile Telecommunication System) network. A resource optimization strategy has also been proposed for the same. By focusing on a number of parameters concerned with TCP's performance including the TTI (Transmission Time Interval), RTO (Retransmission Time Out) and transmission power, etc., various simulation models have been designed to optimize the performance in UMTS network. Nevertheless, these parameters are further evaluated, analyzed and optimized to maximize TCP's efficiency in UMTS during a hard handover process.

Key Words: **TCP, UMTS, Performance Optimization, Mobile Network.**

1. INTRODUCTION

UMTS is a third-generation cellular network is rapidly emerging as the leading global standard. UMTS provides efficient data rates for indoor or short-range outdoor environments [1]. Moreover, UMTS also uses packet switched mode which allows seamless access of internet to mobile users. FTP, HTTP, e-mail, etc are globally the most popular and widely used internet applications that mainly rely on TCP and IP (Internet Protocol) for reliable data transport over heterogeneous networks [2]. While TCP is responsible for providing a reliable data transfer, IP on the other manages routing this data between the source and the destination via a number of links [3].

Design and implementation of TCP was originally aimed at wired technology hence its performance and efficiency degrades in a wireless network due to a number of reasons such as environmental effects; interference, fading, shadowing etc. Reliability and end-to-end data delivery are key features of TCP due to which TCP has become more popular and is preferably used with 3G technologies e.g. UMTS. Though, researchers have proposed a number of solutions for improving TCP's efficiency over the wireless technology, this area still need attention due to increasing demands of the users. The main objective of this research is performance evaluation of TCP during communication in a UMTS. This network has been chosen due to lack of usage of such system in Pakistan.

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Globally, a number of schemes have been proposed. The available literature, however, focuses primarily on WLAN (Wireless Local Area Networks). UMTS incorporates sophisticated and reliable radio link layers compared to WLANs. Therefore, an investigation TCP's performance over UMTS network may help outlining key features that play important role in performance optimization. Rest of the paper has been organized as follows. Section 2 outlines globally proposed solutions for optimization of TCP performances over other types of networks. We provide an insight into the TCP'S strengths and weaknesses in Section 3. Section 4 is dedicated to UMTS network description. Features of UMTS have been outlined to provide a brief understanding of the network to the users. We present our results in Section 5 along with the discussion on performance analysis of TCP. Finally, we conclude our findings and outline our future research objectives in Section 6.

2. RELATED WORK

There has been a focus on optimization of TCP's performance globally and a number of schemes have been globally proposed. The literature claims to have analyzed TCP's performance and optimization of the same has been carried out. But there has been a lack of constructive focus on the issues to be addressed. Comparison of the results becomes complex and difficult as the performance evaluation depends greatly on parameters and protocols. One of the solutions has been proposed by [4] where the authors differentiate packet loss in a wireless network with that of wired network congestion. Similarly, [5] proposed a strategy involving threshold to choose a dedicated session channel to be used during communication.

Although, a number of researchers have focused the issue of optimization of TCP performance [2-3,6-8] over various types of communication systems, there is still lack of clear delineation of the goals to be achieved. This paper employs a simulation based approach to analyze the performance of TCP over UMTS network using FTP and HTTP protocols. A number of issues have been focused to optimize TCP's parameters to:

- Maintain the performance in a wireless environment similar to that in a wires network.
- Maintain efficiency during handoff, maintain power consumption, optimize variations in the TTI and RTO, maximize data rate and its enhancements, overcome disconnections, etc.

In a wireless link, with a high BER (Bit Error Rate), TCP does not perform efficiently. A broad investigation has been carried out to focus on such issues and how to fight these destructive environmental effects. Some of the solutions include proxy-base, link-layer and end-to-end solutions [7]. Bottomless fading effects on wireless links may result in rupture errors if the effects last for a significant amount of time [8]. Network congestion and BER can be thought of as packet losses that gradually makes TCP inefficient when used for wireless communication networks [9]. TCP's performance further degrades during a hard handover phase. Our main aim is to evaluate performance of TCP for data transfer over UMTS and optimize it to provide a step by step guidelines for implementation of a next generation network in Pakistan. To understand the importance of the proposed work, it is basic familiarity with TCP is necessary. We discuss the momentous, existing and upcoming architecture of the Internet protocols in the next section.

3. TCP AND IP

This section provides a brief overview of TCP and its general features. A large number of applications use TCP over internet especially due to guaranteeing secure delivery of data packets [10]. It also provides P2P (Point-to-Point) and end-to-end connections over internet. In a P2P session, a TCP connection is established between only one sender and a single receiver. End-to-end on the other hand, refers to transporting the data packets from source to destination and the parameters involved during the session [2]. We chose TCP due to following features [11]:

- Connection-Oriented
- Bidirectional
- Endpoint-Identified and Multiply-Connected
- Reliable
- Acknowledges each transmission
- Stream-Oriented transmission of data
- Data-Unstructured
- Data-Flow Managed

The communication between any two nodes carried out with the help o the TCP/IP protocols stack. Fig. 1 illustrates the stacks.

5th and 6th layers of the OSI (Open Systems Interconnection) model have been combined to form a single layer; application layer. The network access layer consists of the 1st and 2nd layers of the OSI model. There are fewer layers in TCP/IP representation that makes troubleshooting simpler as compared to the OSI model. This model has gained trustworthiness due to its protocols. However, reliable and safe data transfer is required by global net applications where TCP is commonly treated,

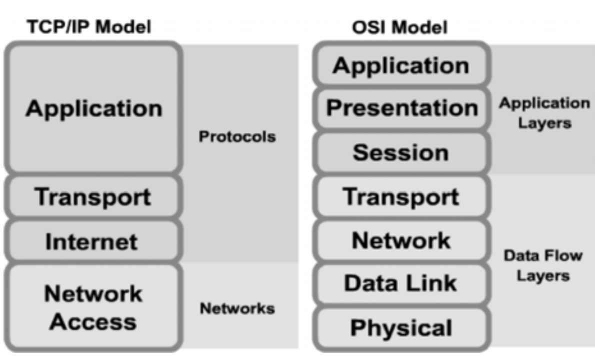

FIG. 1. COMPARISON OF TCP AND OSI MODEL [9]

keeping the TCP/IP protocol stack and the network element structure unchanged plays vital role. Nevertheless, this condition should be maintained even if the wireless connection requires mobility. Hence, TCP needs to be modified to meet the expectations in a wireless environment as most of future applications, making use of mobile internet access, directly or indirectly, depends upon TCP's performance [9]. In this paper we consider TCP v4 for implementation, evaluation and optimization. Performance evaluation of TCP on different types of wireless networks will help in designing an optimized solution to improving TCP's performance. Section 4 briefly outlines the UMTS network features.

4. UMTS NETWORK

3G technology promises high speed and high bandwidth wireless services. It supports a wide variety of advanced applications especially used in mobile personal communication [7]. UMTS [12] is one of the major wireless technologies of 3G. We discuss some main features of UMTS in this section.

GSM (Global System for Mobile Communication) provided the base for the development of UMTS and its services [11]. UMTS have been implemented in many European countries although a number of specification implementations are still under observation [6]. UMTS basic architecture is shown in Fig. 2. UMTS architecture has been classified into the three functional blocks; UE (User Equipment), CN (Core Network) and UTRAN (Universal Terrestrial Radio Access Network).

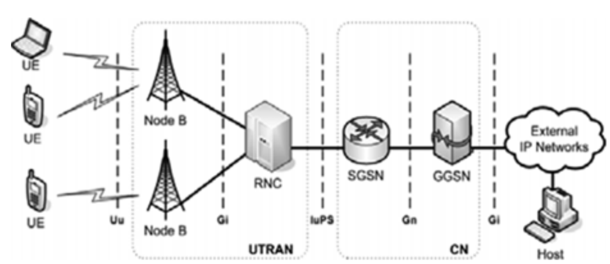

FIG. 2. UMTS BASIC ARCHITECTURE [13]

UEs are user equipments or mobile nodes. UTRAN connects UE with the CN. UTRAN consists of one or more RNC (Radio Network Controller) and base stations (Node Bs). RBS (Radio Base Stations) send and receive data and can directly communicate with the UEs. RNC manages a number of activities including power management, handover, channel allocation, etc. whereas, CN is responsible for routing the user traffic [12]. Handover or handoff is a process in which a user switches channel without disruption of services [4]. The UMTS supports Vertical Handoff, horizontal handoff, Intra-system handoff, soft handoff and hard handoff.

In this paper we focus on performance optimization of TCP during the hard handoff. During a hard handoff, the user can use services of a single station at a time. Hence, previous connection needs to be terminated prior to establishing a new one. This is often referred to as "BREAK BEFORE MAKE" [12]. Optimization components values of both of the TCP and UMTS may result in proficient use of network resources. We present the experimental results and thorough analysis of the findings in the next section.

5. EXPERIMENTAL RESULTS & ANALYSIS

OPNET MODELER was used to simulate the network scenario and to analyze and optimize performance of TCP over UMTS network. FTP and HTTP applications were used for data transfer to achieve the desired objectives. A number of performance parameters including TTI, RTO and Tx power, were considered and the values were varied for performance optimization of TCP under various condition. Fig. 3 show the simulation model using HTTP server (without handover) whereas Fig. 4 illustrates handover scenario using HTTP Server. The network model based on the UMTS architecture includes an Node Bs, http server, RNC, GGSN, node-1, UEs and SGSNs. HTTP and FTP traffic was configured independently using this model. UE and SGSN communicate data (send and receive), whereas, the RNC controls all base stations within its region, including Node_B_0 and Node_B_1. The dark blue circle indicates that the UE_0 is controlled by the Node_B_0. Node_B_1, on the other hand, is responsible for communication with the UE_1, as it is present in the light blue circle which marks the region of Node_B_1 base station. RNC controls both base stations. Simulations have been repeated using FTP server for FTP traffic analysis.

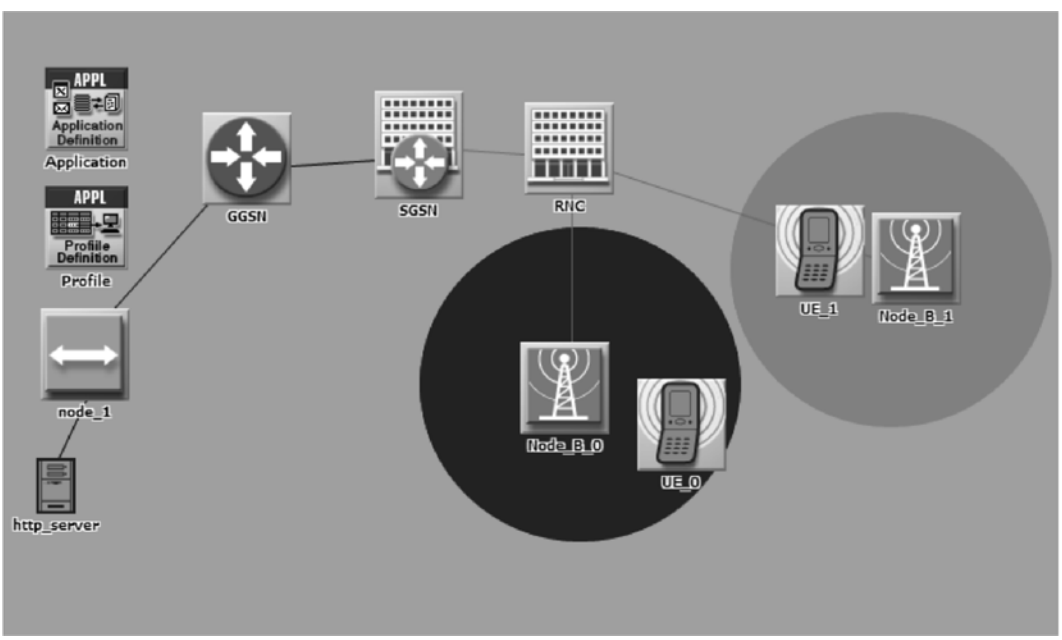

FIG. 3. HTTP SERVER SCENARIO (WITHOUT HANDOVER)

5.1 Parameters and Settings

By evaluating TCP parameters, optimization may be achieved. Values of the network components were set as shown in Figs. 5-6, necessary to design scenarios discusses above.

The performance was evaluated using two different scenarios; with handover and without handover. Mobile nodes were used in the second scenario where handover was simulated. A number of tests were carried out with the help of simulations with varying certain parameters to boost the performance characteristics. The output was compared with previous scenarios. Only the parameters listed in the value have been changed. We use acknowledge mode for RLC layer as it has been described as a standard mode of operation. Unacknowledged and transparent modes do not provide up to the mark performance. Table 1 lists the RNC parameters and the TCP parameters have been outlined in Table 2.

In this paper we have focused some specific performance parameters including the RTO, RTT (Round Trip Time) and the TTI. We assume that for secure communication DES-1 (Data Encryption Standard) Protocol has been used by the system by default. The HTTP's page response time is the actual time taken to complete an http transaction. This includes the total time taken to send a request to the server and to receive its reply. It has been analyzed with the help of Fig. 7, that if RTO increases and the link is

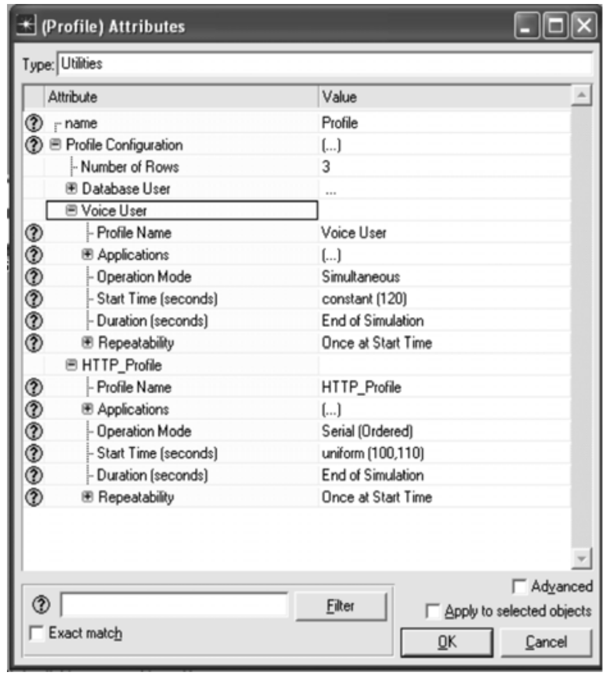

FIG. 5. PROFILE SETTING

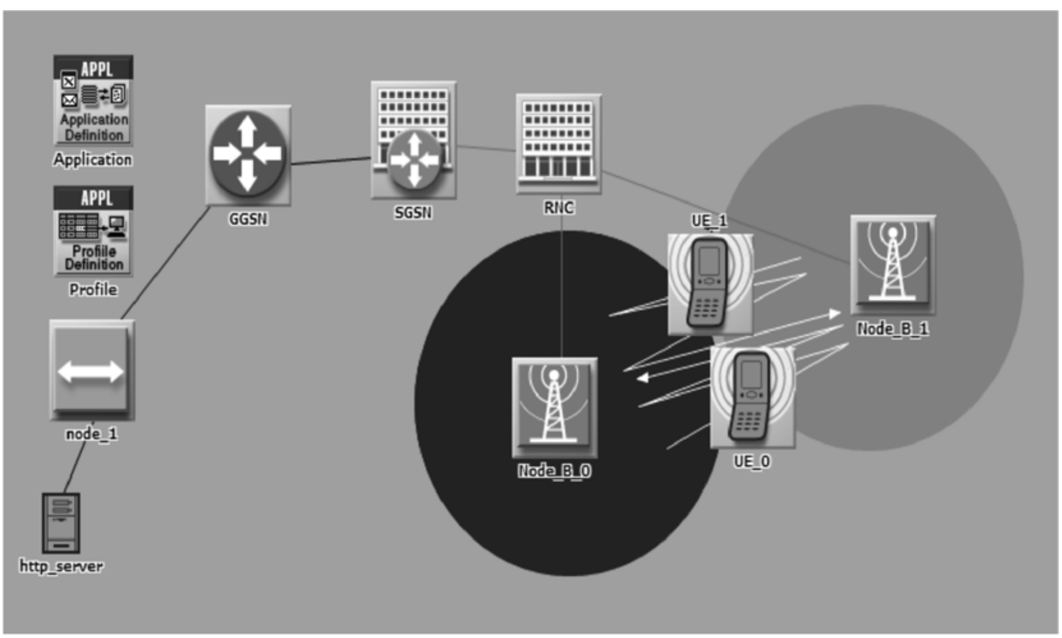

FIG. 4. HTTP SERVER SCENARIO WITH HANDOVER

noisy, the performance degrades with time. Nevertheless, decreasing RTO on a noisy link still degrades the performance. Hence optimizing the RTO value helps in maximizing TCP's performance.

Considering the delay graphs shown in Figs. 8-9 respectively, and in the graphs of upload and download response time as shown Figs. 10-11, decrease in the size of TTI increases the overhead bits in the TTI PDU header. Nevertheless, processing and encapsulation time increases with smaller PDUs. In contrast, stuffing dummy bits may be necessary for large TTI if the radio bearer's handover data is smaller than the TTI frame. Hence, optimizing TTI's frame size may help in maximizing TCP's performance.

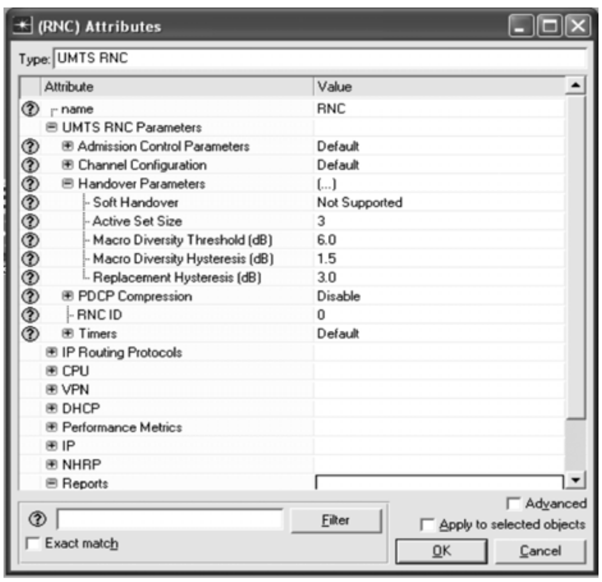

FIG. 6. RNC SETTING

TABLE 1. RNC UMTS PARAMETERS

Window Size (Transmitter)	32
Window Size (Receiver)	32
Discard Mode (SDU)	Timer Based No Explicit
MRW Timer	140ms
Timer Discard	1500ms
MRW (max)	6
DAT (max)	4
In-Sequence Delivery	No
UL RLC Mode	AM
DL RLC Mode	AM

TABLE 2. TCP PARAMETERS

TTI	10ms	Physical Layer
Bit Rate (Channel)	Constant [44,128,256] kbps	
Power Control (Closed Loop)	Ideal (IndependentErasures Block)	
Mode of Operation	Acknowledged Mode	RCL Layer
PDU (Delivery)	In Sequence	
PDU (Size)	320 bits	
RLC_Tx	1024 PDUs	
RLC_Rx	1024 PDUs	
RTO (init)	3 sec	TCP Layer
RTO (max)	60 sec	
RTO (min)	1 sec	
Duplicated ACKs for Fast Retransmit	3	
FTP	50,100,200 kbs	Application Layer
HTTP Page Per Session	Geometric	

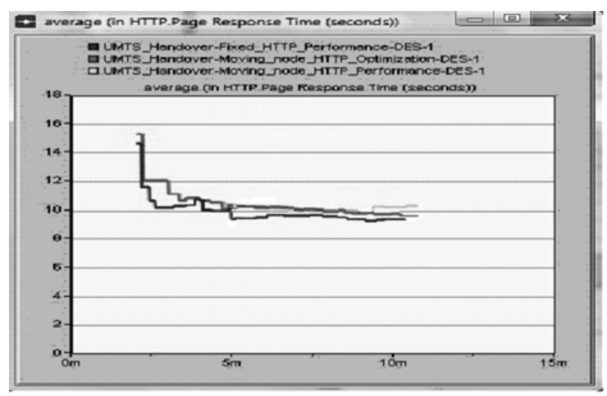

FIG. 7. HTTP PAGE RESPONSE TIME

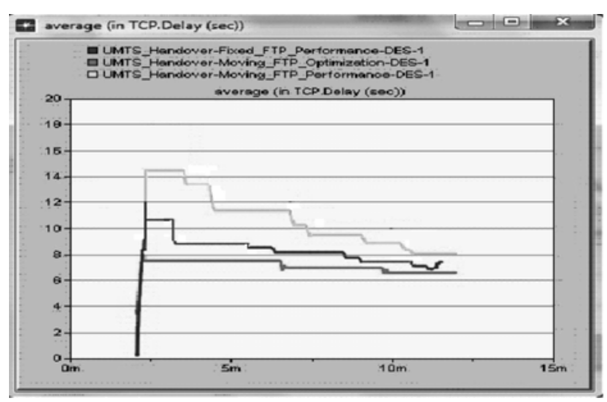

FIG. 8. TCP DELAY - FTP

Fig. 12, illustrating transmission power and Retransmission count. Here, our approach is by adopting dynamic power allocation, increase the efficiency at a minimum power level. If the retransmission count increases, the power is increased based on a feed back received in a closed loop power control. Moreover, if the power level further increases resulting in an increase in the background noise floor, the power is decreased. As shown in Fig. 12, retransmission power is high at the beginning hence the mobile station power has been increased from 0-6m. Nevertheless, as the retransmission count decreases, the power decreases successfully.

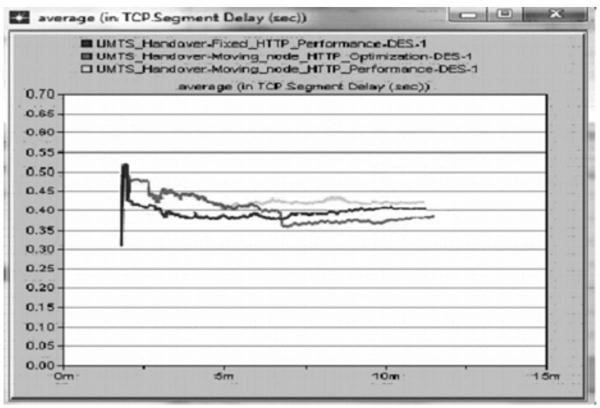

FIG. 9. TCP SEGMENT DELAY - HTTP

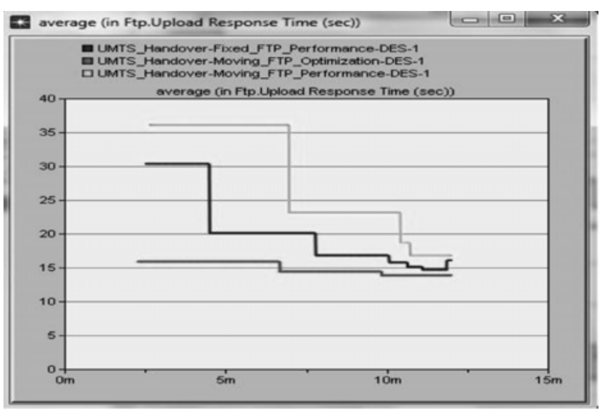

FIG. 10. FTP RESPONSE TIME (UPLOAD)

The experiments were repeated for analyzing reliability of the system. The standard deviation was also calculated as shown in Table 3. The experiments are repeated with varying number of handoffs to evaluate the delay associated with frequent handoffs. The R1-R4 represent the execution or the number of runs of the simulation.

6. CONCLUSION

In this paper we focused the performance of TCP during the hard handover process in UMTS system. FTP and

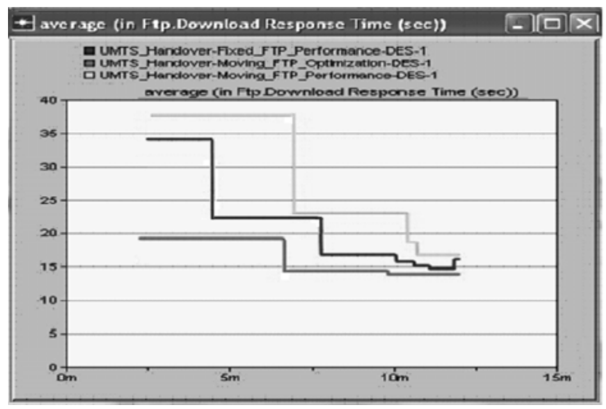

FIG. 11. FTP RESPONSE TIME (DOWNLOAD)

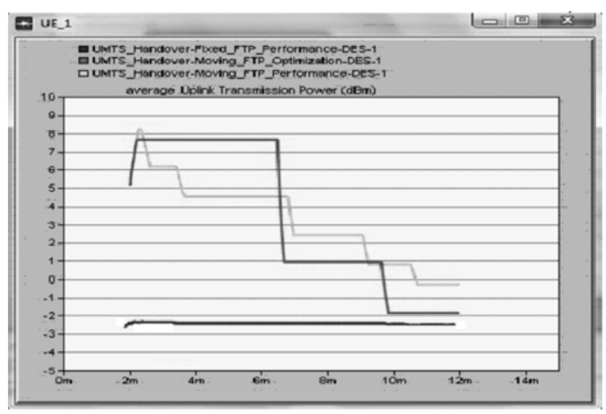

FIG. 12. FTP TX POWER

TABLE 3. DELAY IN TCP HANDOVER PHASE

No. of HOs	Delay in R1 (ms)	Delay in R2 (ms)	Delay in R3 (ms)	Delay in R4 (ms)	Average Delay	Standard Deviation Error
1.	212.345565	244.345665	313.345244	299.334543	267.342750	47.234380
5.	1022.983432	1076.983244	1103.343289	1056.989343	1065.07483	33.878930
10.	2765.873298	2344.978732	2509.938232	2989.938439	2652.68218	283.79057

HTTP applications were used for TCP performance analysis. The output was improved with the help of optimization of key parameters associated with TCP during handover process in the UMTS network. It was observed the optimized values including RTO, TTI and power, improved TCP's performance over a wireless network. However, more focus is needed on the QoS (Quality of Service) of the system. It is equally important to the characteristics of the channels to evaluate the effects on the capacity of the system. Nevertheless, design of power schemes, for better distribution of power, especially for WCDMA is also vital with respect to identification of the problems associated with the conventional schemes available. Power optimization and control schemes are needed to boost network performance parameters.

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