Optimization of Segment Size Assuring Application Perceived QoS in Healthcare

Vikram Jeet Singh, Megha Bhushan, Vikram Kumar and Kishori Lal Bansal

***Abstract*— Advances in the information and communication technology are significant for the improvement of healthcare services especially in rural areas of developing countries. This is also one of the United Nations Millennium Development Goals. In this work, we proposed a ubiquitous healthcare network and computed the optimum transmission segment size for applications needed to guarantee the perceived quality of service. This has been carried out through NS2 based simulation of a state wide area network infrastructure implemented in Himachal Pradesh, a state in the Western Himalayan region of India. The various types of healthcare applications and services have been classified into according to their QoS requirements as per guidelines in ITU report on network performance objectives. The infrastructure specific optimum values of segment size for these classes of applications running on TCP traffic are computed.**

***Index Terms*— FTP, healthcare, HIMSWAN, medical, NS2, QoS, simulation, TCP**

I. Introduction

IMPROVING health is central to the Millennium Development Goals. According to Chudi IP [25], there is problem of availability, accessibility, affordability, sustainability of services and weak referral systems. Even the World Health Report 2006 [26] reveals an estimated shortage of almost 4.3 million doctors, midwives, nurses and support workers worldwide. The shortage is most severe in the under-developed countries but many developed nations also report physician shortages, especially in rural areas [27]. One of the main reasons for this phenomenon could be that the physicians find better earning opportunities and working conditions in the urban localities. As a result, most of the quality healthcare centers are concentrated near the metro cities. The situation is not too different in our country as well, India ranks 67th in the list of 133 developing countries in the doctor-patient ratio as per Vedantam V [28].

Manuscript received Feb 04, 2015; revised April 01, 2015.

Vikram Jeet Singh is with the Department of Computer Science, Himachal Pradesh University, Shimla, India (vikramjeetsingh@live.in).

Megha Bhushan is with the Thapar University, Patiala, Punjab, India

Vikram Kumar was with the Himachal Pradesh University. He is now with the CSIRO, Queensland University, Australia

Kishori Lal Bansal is with the Department of Computer Science, Himachal Pradesh University, Shimla, India

The knowledge of quality of service (QoS) parameter values in network based healthcare applications can be useful while designing applications and services pertaining to the medical domain [3]. In order to optimize the QoS in network based healthcare applications and services, it is crucial to study the two aspects - the parameters of the transmitted biomedical information and the transmission behavior of the communication network [4], [5].

The relationship between network behavior and application parameters have already been studied by a number of research groups. Internet2 QoS Working Group has published a survey on QoS application needs [6]. TF-STREAM reported on best-practice guidelines for deploying real-time multimedia applications [7]. HEAnet reviewed several aspects of perceived quantitative quality of applications [8]. All these approaches are qualitative and are in general applications -we aim to create a quantitative representation of application perceived QoS, especially in the case of network based healthcare applications and services over a real state wide area network infrastructure.

In this paper, we studied the various QoS parameters (End to End Delay, Jitter, Throughput) and their relationship with segment size in order to meet the application perceived QoS of network based healthcare applications and services over Himachal State Wide Area Network (HIMSWAN) implemented as a part of the Indian National electronic Governance Plan [9]. This would allow improving the network based healthcare services [10], [11]. We, therefore, performed real network simulation on Network Simulator version 2 (NS2) and computed the optimum values for segment size for different kind of healthcare related applications and services over TCP.

The organization of this paper is as follows, section II presents a short note on basic terminology and the tools used in this work, and section III describes the methodology followed. Section IV presents the basic HIMSWAN network architecture under study along with the proposed tiered architecture for a ubiquitous healthcare network. Section V presents the details of our NS2 based simulation set up and its configurable parameters. Finally, in section VI, we present our results and findings followed by the conclusion in section VII.

II. Basic Terminology and Tools

A. *Quality of Service (QoS)*

QoS is an important consideration in networking [13], [14], but it also poses a significant challenge. QoS refers to the capability of a network to provide better services to the users by handling the network traffic over various technologies. QoS parameters are key factors in the roll-out of a new technology or service. These parameters increase in importance as networks become interconnected and more complex [15]. A short note on various QoS parameters is given next:

End to end delay or EED refers to the time taken for a data packet to be transmitted across a network from source to destination.

$T_{end\text{-}to\text{-}end}$ = (Total bits transmitted) / (Channel Capacity)

Throughput refers to the volume of data that can flow through a network in per unit of time. For heavy duty networks, this is likely to be the most accurate indicator of system performance.

Th_{link} = (Number of bits from source node to destination node) / (Observation Duration)

Data packets from a source will reach the destination with different inter-packet delays. A packet's delay varies with its position in the queues of the routers along the path between source and destination and this position can vary unpredictably [16]. This variation in delay is known as jitter and can seriously affect the quality of streaming audio and/or video and affect other applications.

B. Network Simulator (version 2)

NS2 is an open source discrete event driven network simulation tool [18], [19] for studying the dynamic nature of communication networks. It is implemented in C++ and OTCL programming languages. NS2 provides a highly modular platform for wired and wireless simulations supporting different network elements, protocols, traffic etc. In general, NS2 provides users with a way of specifying network parameters and simulating the corresponding behaviors. Result of the simulation is provided in a trace file with the extension .tr that contains detailed information about all the occurred events. The format of a trace string is as shown in Fig. 1:

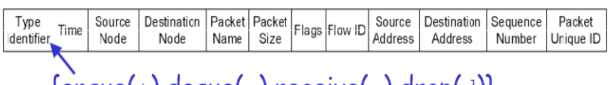


Fig. 1. Trace file format in NS2

C. Transmission Control Protocol (TCP)

TCP is one of the core protocols of the Internet protocol suite (IP) and is so common that the entire suite is often called TCP/IP. TCP provides reliable, ordered, error-checked delivery of a stream of octets between programs running on computers connected to a local area network, intranet or the public Internet [20].

D. File Transfer Protocol (FTP)

FTP is a standard network protocol used to transfer files from one host to another host over TCP-based network [22], such as the Internet. FTP is built on client-server architecture and uses separate control and data connections between the client and the server.

III. Methodology

The methodology for carrying out this work is divided into five phases. The first phase was an exhaustive bibliographical revision relating to the need, techniques and efforts being applied on the connectivity aspects of medical equipment and network based systems oriented towards remote health monitoring and treatment.

In the second phase, we identified the various types of network traffic and their pattern, relevant in the case of healthcare applications and services along with their classification as per the ITU Report [23].

The third phase was to design the ubiquitous healthcare network over HIMSWAN. This was achieved by modeling the HIMSWAN network in NS2.

In the fourth phase, the NS2 simulation was run on TCP transport protocol, FTP application, varying the packet sizes of data to be transferred.

In the last phase, we verified the results and thereafter presented the conclusion.

IV. Infrastructure Details

Vision of the Indian Government behind the implementation of state-wide area networks under the National e-Governance Plan played a key role in the success of e-governance in India. These SWAN projects are now the backbone of their respective states and of the country as a whole. E-governance has made it possible to implement a transparent and efficient governing system.

A. HIMSWAN

The major highlights of the Himachal State Wide Area Network (HIMSWAN) architecture are as given in [10] and presented below:

Star Topology has been implemented in HIMSWAN enabling complete and granted bandwidth availability.
HIMSWAN has a four-tiered architecture with following details, termed as HIMSWAN Point of Presence (POP):

1st Tier: SHQ (State Head Quarter) - 1

2nd Tier: DHQ (District Head Quarter) - 12

3rd Tier: THQ (Block Head Quarter) - 120

4th Tier: Local Level Departments

Horizontal and vertical connectivity has been implemented in HIMSWAN. DHQ to SHQ connectivity is termed as a Vertical connectivity and Connectivity of various District level organization and departments to the district head Quarter is termed as Horizontal connectivity.
Vertical connectivity has been done with the help of managed leased lines from Bharat Sanchar Nigam limited (BSNL), a leading internet service provider (ISP) in the country.Initially a bandwidth of 2 Mbps has been ensured for the vertical connectivity which can be at maximum extended upto 16 Mbps as per requirements.

ISBN: 978-988-19253-4-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

B. Ubiquitous Healthcare Network

The proposed ubiquitous healthcare network (Fig. 2) will have three-tier architecture with the 1st tier being the State Head Quarter (SHQ), consisting of major data servers and all the super specialty facilities. 2nd Tier, the existing HIMSWAN network, will act as a data transmission interface between tiers 1 and 3. The 3rd tier will consist of all the end level healthcare service providing agencies (hospitals, clinical laboratories, medical clinics etc).

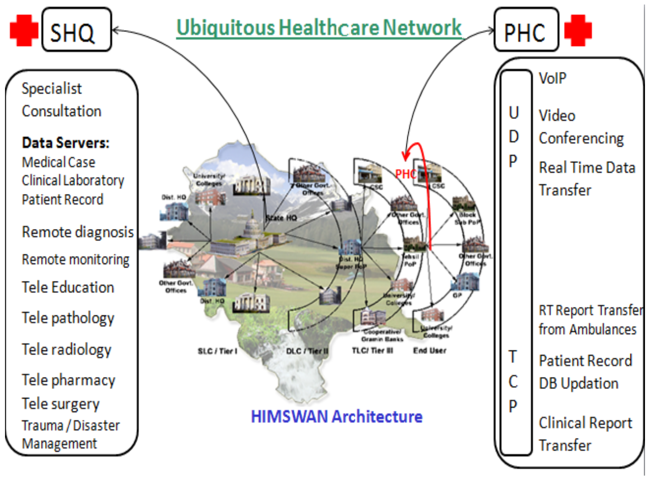


Fig. 2. Ubiquitous Healthcare Network

TABLE I: QoS CLASSIFICATION OF HEALTHCARE APPLICATIONS & SERVICES

QoS Class	Application	Example	Traffic
0	Real-time, jitter sensitive, high interaction	Trauma/ Emergency Case Remote Handling	TCP/UDP
		Remote Surgery through Robotic equipment such as NeuroArm, CyberKnife, da Vinci surgical system etc.	TCP/UDP
1	Real-time, jitter sensitive, interactive	Super-Speciality Audio/ Video Consultation	UDP
		Medical Case Referral	TCP/UDP
		Disaster Relief Operations	TCP/UDP
		Patient Counselling	UDP
2	Transaction data, highly interactive (Signalling)	Radiology Report Transfer (Ultrasound, CT, MR, X-ray, DICOM [PACS] format)	UDP
		Monitoring Vital Signs (BP, Heart rate, Pulse)	TCP
3	Transaction data, interactive	Real Time DB handling	TCP
		Clinical Document Transfer (PDF, PNG formats)	TCP
		Telepharmacy	TCP
4	Low loss only (short transactions, bulk data, video streaming)	Educational Purpose	TCP/UDP
5	Traditional Usage	Inventory Status	TCP
		Human Resource Status	TCP
		Daily Reports	TCP

The transfer of data from the third tier to the first tier involves the use of diverse technologies and applications. It can be characterized by the type of information sent (such as radiographs or clinical findings) and by the means used to transmit it. Many areas of medical practice have potential telemedicine applications [24].

In accordance with ITU report on Global Information Infrastructure, Internet Protocol Aspects and Next Generation Networks [23], we categorized the network based healthcare services into different QoS classes as represented in Table I.

V. SIMULATION AND EXPERIMENT

The proposed ubiquitous healthcare network was simulated over NS version 2.35. In this paper, simulation of only one segment consisting of all possible connectivity variation was considered. The detail of network segment considered for the simulation experiment is presented in Fig. 3. The simulation was carried out on a Dell PowerEdge 1800 Server machine with the configuration as 64 bit Intel Xeon processor 3.0GHz with Intel E7520 chipset, 1 GB RAM and Debian 6.0 OS.

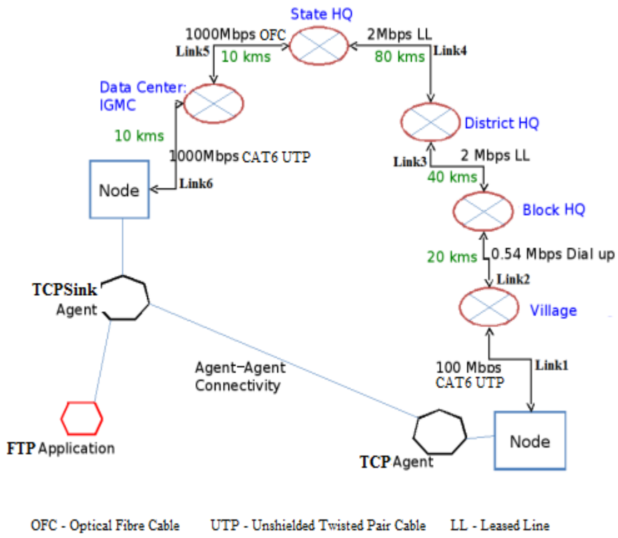


Fig. 3. Simulation Setup

Distance between the different nodes is as per the approximate real geographical distance. The queue size of all the routers is restricted to a maximum of 50 data packets (DropTail) considering this as minimum dedicated queue available for handling healthcare applications and services. The segment size range for variations in simulation setup is as per the suggested guidelines in the ITU report on network performance objectives [23]. The segments were generated for a period of one second in the simulation. The experiment has been performed a number of times to obtain stable and verifiable results.

VI. RESULTS AND DISCUSSION

The scenario presents optimal data packet value for network based healthcare applications and services involving transmission over TCP. The behavior of data packet size against QoS parameters [End to End Delay,

ISBN: 978-988-19253-4-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Jitter, and Throughput] was examined. The following observations are made out of the results obtained:

The minimum EED (0.060916 sec) remains constant irrespective of the data packet size; however, there is a lot of variation in maximum EED. Maximum EED is lowest (0.136329 sec) for data packet size 500 bytes, which keeps on increasing with increase in the data packet size and touches the highest point (0.616214 sec) for data packet size of 2500 bytes (Fig. 4).

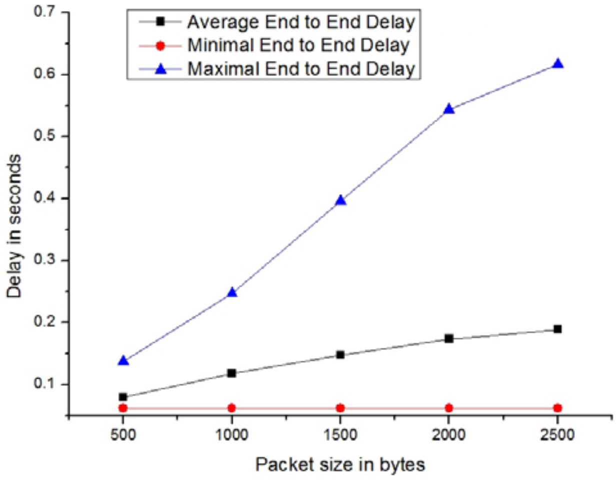
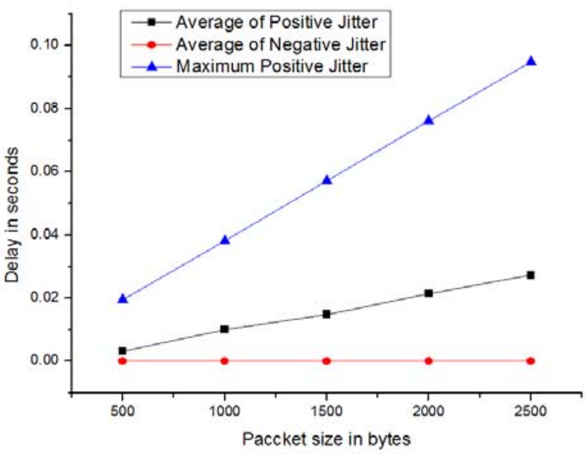


Fig. 4. Packet Size versus End to End Delay

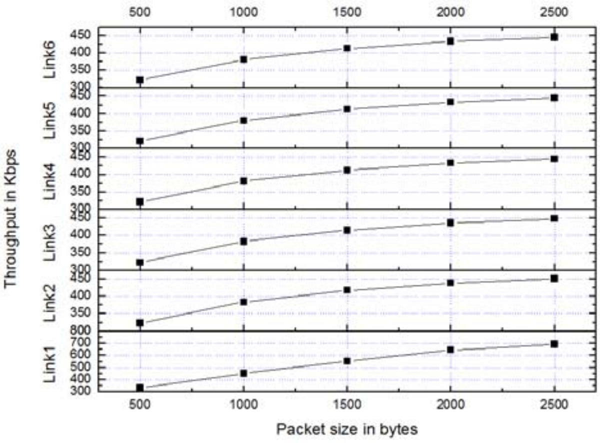
The general tendency of packet size versus jitter (Fig. 5) is same as that of EED. The minimum jitter value is same for all the data packet size variations considering the fact that the first event always tends to have zero jitter. Maximum value for positive jitter is 0.094906 sec for data packet size 2500 bytes and is minimum for data packet size 500 bytes. However, all the data packets of size 500 bytes received 100% positive jitter whereas, this value is 88.57% in case of 2500 bytes data packet size.



Packet Size in bytes	500	1000	1500	2000	2500
Total Events	156	110	90	80	70
Positive Jitter Events	156	99	87	73	62
Negative Jitter Events	0	11	3	7	8
Percentage of Positive Jitter	100	90	96.66666667	91.25	88.57142857
Average of Positive Jitter	0.003183	0.010132	0.014898	0.021383	0.027226
Percentage of Negative Jitter	0	10	3.333333333	8.75	11.42857143
Average of Negative Jitter	0	-0.000001	-0.000001	-0.000001	-0.000001
Maximum Positive Jitter	0.019456	0.038318	0.057181	0.076044	0.094906

Fig. 5. Packet Size versus Jitter

Finally, Fig. 6 shows the results obtained for packet size versus link throughput and Fig. 7 shows the relationship between packet size and overall system throughput. Considering the fact that system maximum throughput is bounded by the lowest link in the process, therefore, we consider the minimum link throughput as system throughput. In the case of TCP based transmission, Link6 comes out to be the bottleneck link in our system. System throughput increases with the increase in the data packet size. The maximum throughput of 444.979 Kbps is achievable with the data packet size of 2500 bytes.



Packet Size (in bytes)	Link Throughput in Kbps					
	Link1	Link2	Link3	Link4	Link5	Link6
500	334.192	323.126	322.5	321.877	321.876	321.874
1000	452.483	383.668	382.363	381.066	381.063	381.061
1500	554.373	416.999	415.085	413.188	413.183	413.18
2000	644.78	437.952	435.555	433.185	433.18	433.175
2500	692.424	450.796	447.875	444.991	444.985	444.979

Fig. 6. Packet Size versus Link Throughput

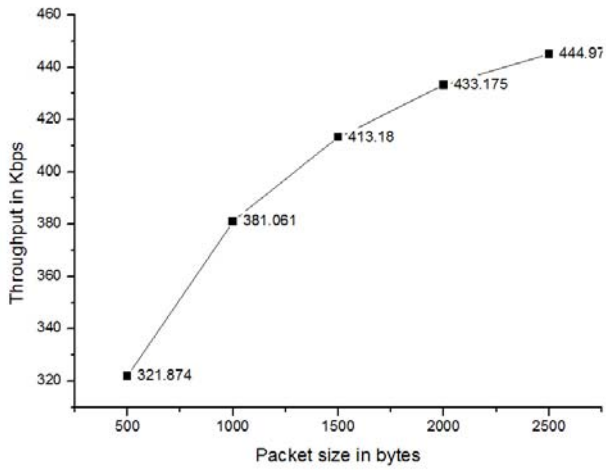


Fig. 7. Packet Size versus Network Throughput

Based upon the QoS parameter values obtained, we computed the estimated transmission times required for the node to node transfer of biomedical information in the form of reports and data files of standardized sizes through the proposed ubiquitous healthcare network [Table II].

To sum up, all these tendencies recommend the use of a low data packet size (500 bytes) for QoS classes 0-2 (jitter, delay sensitive) category of network based healthcare

ISBN: 978-988-19253-4-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

applications and services. On the other hand, data packet size of 2500 bytes was found suitable for jitter and delay insensitive category of applications (QoS classes 3-5).

TABLE II: TRANSMISSION TIMES FOR DIFFERENT MEDICAL REPORTS

Transmission Time in seconds = [Data in kb / Network Throughput in kbps]					
	Segment Size	Time		Segment Size	Time
	500	76.35		500	152.71
	1000	64.49		1000	128.99
Stress ECG = 3MB	1500	59.48	MRI = 6MB	1500	118.96
	2000	56.73		2000	113.47
	2500	55.23		2500	110.46
	Segment Size	Time		Segment Size	Time
	500	381.76		500	890.78
	1000	322.47		1000	752.43
X-ray = 15MB	1500	297.40	EEG = 35MB	1500	693.93
	2000	283.67		2000	661.90
	2500	276.15		2500	644.35
	Segment Size	Time		Segment Size	Time
	500	127.25		500	381.76
	1000	107.49		1000	322.47
CT Scan = 5MB	1500	99.13	Ultra Sound = 15MB	1500	297.40
	2000	94.56		2000	283.67
	2500	92.05		2500	276.15

VII. CONCLUSION

In this paper, data packet size as a critical application parameter for network based healthcare applications and services has been evaluated in order to meet the application perceived QoS over the proposed ubiquitous healthcare network. The results obtained show that the data packet size of 500 bytes is most optimal for QoS classes 0-2 applications over TCP, whereas, for applications belonging to QoS classes 3-5 in Table I, a data packet size of 2500 bytes is efficient.

These values have been selected according to the simulated network measurements and are thus recommended for further design of the network based healthcare services in order to guarantee the perceived QoS.

Our proposal presents an innovative solution making use of the existing network infrastructure that addresses the problem of integration of expert medical staff from one institution to monitor patients located at another. It also helps in releasing the support staff workload so that the time thus saved is better utilized to focus on providing even superior healthcare services to the patients. Finally, due to its pragmatic approach, it results in a cost-effective solution to address the requirements for modernization of health-care system in developing countries.

ACKNOWLEDGEMENTS

Vikram Jeet Singh is thankful to Dr. Dhirendra Sharma, Networking Incharge, Himachal Pradesh University, Shimla for his unconditional support and access to the resources for carrying out this work.

REFERENCES

[1] World Bank Data Report, URL: http://data.worldbank.org/topic/health (retrieved Oct 19, 2013)

[2] Vikram Jeet Singh, Dharam Pal Singh and KL Bansal, ‘Proposed Architecture: Cloud based Medical Information Retrieval Network’; International Journal of Computer Science and Engineering Technology (IJCSET), Vol. 04 No. 05 May 2013, ISSN: 2229-3345, Pages 485-496

[3] A Alfonzo, M K Huerta, S Wong, G Passariello, M Díaz, A La Cruz and J Cruz, “Design of a Methodology for Assessing an Electrocardiographic Telemonitoring System”, Proceedings, 29th Annual International Conference, IEEE EMBS Cité Internationale France, August 23-26, 2007

[4] Maheu M et al., "E-health, Telehealth and telemedicine: guide to start-up & success", Jossey-Bass 2001

[5] WC Hardey, "QoS Measurement and Evaluation of Telecommunications Quality of Service", Eds. John Wiley, Hardcover, 230 pages. [Book Review – R. Chodoreck, IEEE Communications Magazine, 40(2):30-32, 2002]

[6] D Miras, "A Survey on Network QoS Needs of Advanced Internet Applications", Working document, Internet2 QoS Working Group, December (2002)

[7] V Cavalli and E Verharen, "TF-STREAM Real Time Multimedia Applications", TERENA Technical Report, March 2002

[8] V Reijs, "Perceived Quantitative Quality of Applications"

[9] Official National e-Governance Plan (NeGP) website, URL: http://www.negp.gov.in (retrieved Oct 19, 2013)

[10] JF Huard, I Inoue, AA Lazar and H Yamanaka, "Meeting QoS guarantees by end-to end QoS monitoring and adaptation", V IEEE International Symposium on High Performance Distributed Computing, pp. 348-355, 1996.

[11] I Martínez, J Salvador, J Fernández and J García, "Traffic requirements evaluation for a Telemedicine network", International Congress on Computational Bioengineering ICCB'03, pp. 389-394, 2003

[12] Ashwani Chandel and Vikram Jeet Singh, ‘Research on the Design Architecture & Services over a State Wide Area Network: A case of Himachal Pradesh’, International Journal of Advanced Research in Computer Engineering Technology, Vol 4, Issue 2, 2015, pp 288-291

[13] AS Tanenbaum “Computer Networks”, Prentice Hall Publications, 4th ed., ISBN 0130661023

[14] BA Forouzan, “TCP/IP: Protocol Suite”, Tata McGraw-Hill Publishing Company Limited, 1st ed.

[15] National Research Council, “Networking Health: Prescriptions for the Internet”, The National Academies Press: Washington, DC (2000)

[16] RFC 3393, “IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)”, Internet Engineering Task Force (2002)

[17] “IOS IP SLAs UDP Jitter Operation Technical Analysis”, Cisco Documentation

[18] T Issariyakul and E Hossain , "Introduction to Network Simulator NS2," Springer, Oct. 2008, ISBN: 978-0-387-71759-3

[19] NS2 Tutorial by Marc Greis, URL: http://www.isi.edu/nsnam/ns/tutorial/ (retrieved Oct 19, 2013)

[20] Vincent G Cerf and Robert E Kahn, “A Protocol for Packet Network Intercommunication”, IEEE Transactions on Communications (May 1974) 22 (5): 637-648

[21] JF Kurose and KW Ross, “Computer Networking: A Top-Down Approach”, Pearson Education, Boston, 5th ed. (2010), ISBN 978-0-13-136548-3

[22] J Postel and J Reynolds, Internet Engineering Task Force, October 1985

[23] “Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next Generation Networks”, International Telecommunication Union: Y.1541

[24] Telecommunication Development Bureau ITU-D Study Group, "Telemedicine and Developing Countries", International Telecommunication Union - Sep 1997

[25] IP Chudi, “Healthcare problems in developing countries”, Medical Practice and Reviews, Vol. 1(1), pp. 9-11, April (2010)

[26] “The World Health Report 2006”, World Health Organization, URL: http://www.who.int/whr/2006/en/ (retrieved Oct 19, 2013)

[27] M Remirez, “Rural doctor shortage called ‘a crisis’ in Washington”, Seattle Times Newspaper, URL: http://seattletimes.com/html/health/2009078934_ruraldocs18m0.html (retrieved Oct 19, 2013)

[28] V Vedantam, “More doctors Ok; but we need more para-medical staff too”, Deccan Herald News, URL: http://www.deccanherald.com/content/189280/more-doctors-ok-we-need.html (retrieved Oct 19, 2013)