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Using IP Networks as a Deviceless Storage for Future Portable Computers

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***Abstract*—In this paper we propose a generic architecture for a small powerful mobile computer that relies on network and its servers for majority of its activities. Since the network is located in middle of this architecture, we discuss the feasibility and capacity of using the network as a temporary dynamic storage in the form of cache for limited and frequently used data/ control data. However the node delivery and file system design for the proposed network storage is not in the scope of this paper. We show how the routing loop can be utilized to convert the network delay and processing power of the routers to a virtual storage capacity in the network by keeping data in the network in form of floating IP packets. We call this approach Data Storage Technique on IP Networks (DSTN). In satellite and wireless communications this storage can be referred to as deviceless storage. We formulate the potential storage capacity and discuss the parameters that affect the capacity. We validate the technique by comparing the results obtained from the mathematical model with the results obtained from OpNet Modeler simulation tool. Since this paper is a preliminary part of this research, we address the future direction of the research in the last section.**

Keywords- Deviceless Storage; Floating IP; Hop Limit; Routing Loop Storage; Mobile Computer; TTL;

I. INTRODUCTION

The future Internet is expected to be fast and reliable. The concept of "Anytime, Anywhere" will drive the need for pervasive high speed, high capacity networks. Many experts expect major changes in information technology within the next few years in terms of using the Internet as part of a user's system [1]. They believe that the majority of user's needs would be re-shaped to the services on the Internet. Users can run their applications, access their programs and store their data on the provider's server instead of local computer as in "Cloud Computing" [1] and "Distributed Systems" [2]. Furthermore advances in microelectronics and nanotechnologies have led to a decrease in the size and weight of mobile systems like laptops, iPhones and PDAs. In the future, mobile computer devices are expected to be smaller, cheaper but more powerful. As an example for the perspective of future computers a conceptual pen-sized personal computer has been represented by the Tokyo-based NEC Company at the 2003 ITU Telecom World exhibition in Geneva where both keyboard and display were Virtual [3]. The device is a pen-shape computer that is connected to the Internet through the cellular phone network. The device-less [4] or virtual [3],[5],[6] User Interfaces (UIs) eliminate considerable size of the I/O. Device-less UI refers to the input/output systems in which images are being created on iris of the eye or on eyeglasses and input system involves user's voice, eye and body movement or brain pulses. Virtual UI usually includes small cameras and scanners [6] which create the keyboard or display by light on flat surfaces [3]. It consists of several infrared transceivers that create the input area (like keyboard) beside the device. The display also can be a touch-screen, roll-able [7] or flexible [8]. These displays are light weight and have very low power consumption. Roll-able display can be folded and unfolded. Flexible display easily bends and curves to some extent.

With these evolutions in microelectronics and IT world, it is an appropriate moment to look at the network from a new perspective. Network can be considered as a main part of small portable system having functionality of a powerful desktop PC and it can serve future mobile computers more than only a communication bed.

In our previous work [9] we conducted a pilot study to investigate the feasibility of keeping a single floating IP packet in the network over a desired time and proposed the preliminary design. In this paper, we focus on a model that utilizes the routing loop to convert the processing power of the routers and loop total delay to a virtual storage in the network and its capacity. We call this approach Data Storage Technique on IP Networks (DSTN). In satellite or wireless communications, the storage is constructed through the electromagnetic waves in the air space between antennas and therefore it can be referred to as deviceless storage. We emphasize that our focus in this paper is only on introducing the network dynamic capacity which is due to the delay that is not involved with intermediate routers' static memories. We do not tend to propose any data structure or file system for the content in this paper. Similarly node delivery is not the focus of this paper.

The organization of the paper is as follows: First, we present the proposed architecture and discuss the location of each computer system and associated network elements. Then we focus our paper on the use of network as a floating storage for the proposed architecture. We present the storage model and also formulate the storage capacity of the network. Furthermore we discuss the parameters that affect this capacity. In section V, we explain our simulation setup and scenario, and validate the model by comparing the results obtained from equations with the simulation results in section VI. Finally in the last section we discuss the results and address future direction of the research.

II. PROPOSED ARCHITECTURE

Fig 1 summarizes the proposed architecture that contains Host A as a portable computer device, the network that plays role as part of primary storage and the servers that serve the host. The portable device only includes a basic CPU, motherboard, user and network interface and power unit. It is possible to make the CPU architecture as simple as possible and distribute the complex processing over the network servers. From I/O part, only the network interface should be fully implemented in the device. User Interface can be device-less or virtual. These technologies eliminate considerable size of I/O. Motherboard and interconnections are integrated in any size applying nano-scale technologies. Power units should be fully implemented in the portable device including a battery and charging circuit. This unit has a considerable size and weight but by making the device operate with low voltage supply and consuming low power, power requirements can be decreased and as a result small power supply is adequate. The preconfigured servers on the network serve the portable device for both processing and storage. Technologies and protocols like Storage Area Networks (SANs) and iSCSI [10],[11] have been developed to use remote storages as a local one. Communication with peripherals like printer is through the network interface. From software point of view only core activities of the Operating System is located on the device itself.

Therefore if we make UI virtual and transfer the processing and storage responsibilities to the network servers, not much is left to pack into the small but powerful device. It is necessary to provide a limited primary storage in the implementation of the portable device, but the rest is located on the network and servers. For frequently used shared/control data the network is proposed to be used as a temporary storage as it is located in the middle of the architecture and it is the main communication bridge between the device and servers. Because of mobility characteristic of the proposed device and lack of adequate local resources, applying this approach in the proposed architecture is highly desired.

III. APPLYING DSTN IN THE PROPOSED ARCHITECTURE

In DSTN, we propose to keep data in the network in form of labeled packets in a closed routing loop between the routers [9]. This can be requested by either the mobile computer or the servers. Preconfigured routers -that will be called Control Routers (CR) in this paper, should forward the labeled packets to the next hop in the loop while other traffics are treated as default. Routers require a mechanism to frequently interact with the mobile computer and the servers to replace the packet –which is equal to read/write operations in traditional storages. Furthermore, at least one of the CRs must also prevent the packets from being dropped by frequently increasing the Hop Limit (HL) in IPv6 packet header or similarly Time to Live (TTL) in IPv4 [12],[13] to its maximum value. Fig 2 summarizes the steps highlighting responsibilities of the mobile node, servers and the routers.

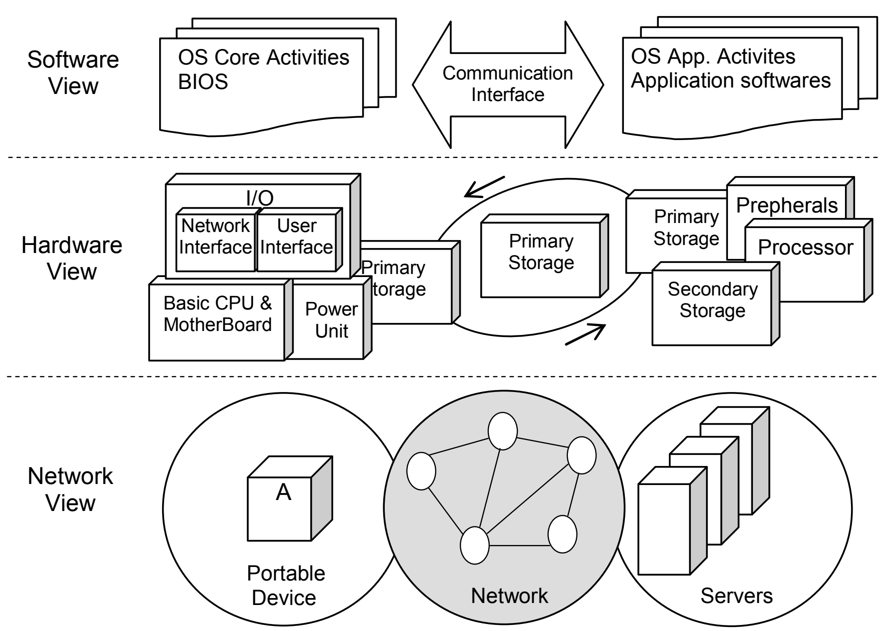

Figure 1. The architecture of the Proposed Mobile Computer.

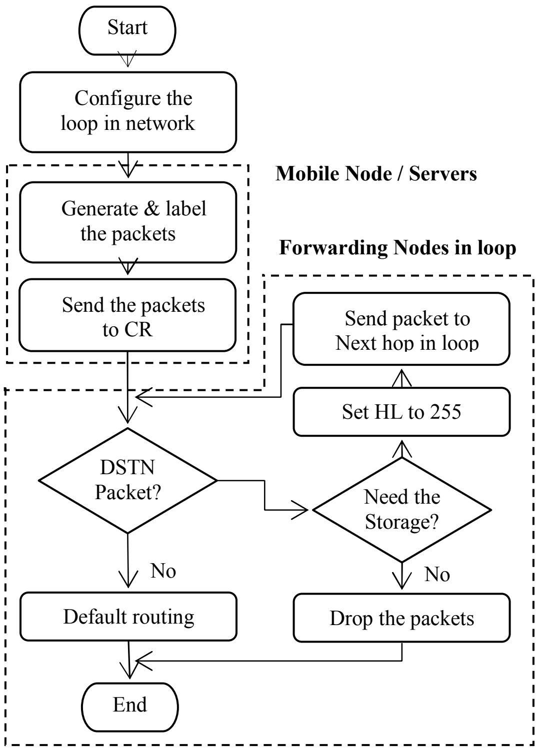

Figure 2. The implementation steps.

IV. THE STORAGE CAPACITY

The storage capacity depends on two parameters, first, the time that it takes for a single packet to traverse the Routing Loop (RL) and second, the routers' Forwarding Rate (FR) in term of number of packets. The time it takes for the packet to traverse the routing loop depends on the Total Delay (D_{Total}) as shown in (3). Routing Delay ($D_{Routing}$) is the aggregation of the delays occurring in the forwarding node and it includes Processing and Queuing Delays. Link Delay (D_{Link}) is the aggregation of delays occurring in the link and it includes Transmission and Propagation Delays [14]:

$$D_{Routing} = D_{Processing} + D_{Queuing} \quad (1)$$

$$D_{Link} = D_{Transmission} + D_{Propagation} \quad (2)$$

$$D_{Total} = D_{Routing} + D_{Link} \quad (3)$$

The RL time (t_{RL}) depends on the Total Delay and is calculated as follows where *m* is the number of hops:

$$t_{RL} = \sum_{i=1}^{m} D_{total\,i} = \sum_{i=1}^{m} (D_{Routing} + D_{Link})_i \quad (4)$$

As we excluded the routers' memories from the capacity we should assume that $D_{Queuing}$=0. Furthermore if we assume that all routers and links in the routing loop are identical, we have:

$$t_{RL} = m \times D_{total} \quad (5)$$

The Total Number of the Packets (TNP) that can be kept in the network is calculated as follows:

$$TNP = t_{RL} \times FR_{Max} \quad (6)$$

Note that if a single link appears twice in the loop it should be counted as two. The Capacity in term of Bytes depends on the packet size and is calculated as follows:

$$TD = TNP \times PacketSize - (IP, Transport\ \ Headers) \quad (7)$$

Access time (t_{Access}) is the time that it takes for one packet to pass through the same router again and it is equal to Routing Loop time. Because of the characteristic of the loop, the access is serial.

$$t_{Access} = t_{RL} \quad (8)$$

For example, the potential storage capacity between three routers with maximum FR of 50,000 packets per second (Pkts/s) and RL time of the 30ms, where packet sizes are 40Bytes (B), 1500B and 64KB respectively can be calculated as follows:

$$TNP = 0.03 \times 50{,}000 = 1500$$

$$TD \approx 1500 \times 40 \approx 58KB$$

$$TD \approx 1500 \times 1500 \approx 2.1MB$$

$$TD \approx 1500 \times 64k \approx 95MB$$

V. SIMULATION SETUP AND SCENARIO

We simulated our proposed model in OpNet Modeler [15] in order to provide adequate validation for our DSTN and investigate the effect of different parameters on the capacity. In all of the simulated scenarios there are six routers that are connected through full duplex links in a ring topology and they are configured to construct a routing loop for the traffic coming from the source node which is connected to only one of the routers. A simple workstation has been used to generate the traffic and a server has been used as the destination of the packets. Necessary changes have been made in source code of intermediate routers to prevent the packets from being dropped or reaching the destination. All routers and links are identical. In all scenarios, the router which is connected to the source node, receives the traffic and adds it to the loop until it starts queuing and then dropping the incoming traffic. In order to measure the storage capacity –i.e. number of the packets that is kept in the network, we calculate the number of generated packets for the period from beginning of the traffic generation until when queuing starts. We have repeated the experiment for different forwarding rates, different delays and different packet sizes to investigate the impact of each of these parameters on the capacity. Table I summarizes constant and variable simulation parameters.

As shown in the table, we have varied the total delay from 2.5s to 15s. We have also set two forwarding rates as 10Pkts/s and 20Pkts/s. Packet size has also been changed to

40B, 512B and 1024B respectively. However the default value for packet generation rate is 4Pkts/s, default maximum forwarding rate is 10pkts/s and default delay per link is 5s (Whenever they are not mentioned). The time that it takes for the packet to circulate the loop (t_{RL}) can be calculated by (1) where *m* is 6 in these scenarios. We multiplied the delay by 1000 and instead, removed three zeros from forwarding rates (in compared with real life situations) to be able to clearly observe the changes during simulation time.

TABLE I. SIMULATION PARAMETERS

Scenario	FR	D/link	Pkt Size
	Pkts/s	***S***	***Bytes***
Default Parameters	10	5	1024
Variable RL	10	V1	1024
Variable FR	V2	V1	1024
Variable Packet Size	10	V1	V3
V1=2.5,5,10,15 V2=10,20 V3=40,512,1024			

I. RESULTS AND DISCUSSION

Detailed results of the scenario with default parameters are illustrated in Fig 3. The figure compares the generated traffic from the source node (S) with forwarded and dropped traffic on one of the routers (traffics experienced by all of the routers in the loop are identical). As the packet generation starts at time t=57, the routers' traffic shows increasing steps of approximately 4 packets per second (Pkts/s) and reaches a steady plateau in first RL period (between t=59 and t=90). Increasing steps for each RL period continues until the traffic reaches the FR (t=90 to t=122) and the router which is connected to the source starts to queue the packets. Comparison between generated and forwarded traffic shows that the traffic that has been forwarded in each step is a coefficient of the traffic coming from S until the router reaches its maximum forwarding rate and starts queuing and then dropping the packets. Queue starts growing at t=122 when the incoming traffic –i.e. Sum of the DSTN traffic and the traffic coming from S, reaches the maximum forwarding rate of the router which is 10Pkts/s. And when the queue reaches its maximum at t=162 packet drop starts. However queues of all other routers are empty during the whole simulation time.

Fig 4 and Fig 5 show the effect of variation of delay, forwarding rate and packet size on the capacity in term of number of the packets, while Fig 6 shows the impact of these parameters on the data that can be kept in the network in term of Kilo Bytes (KBytes).

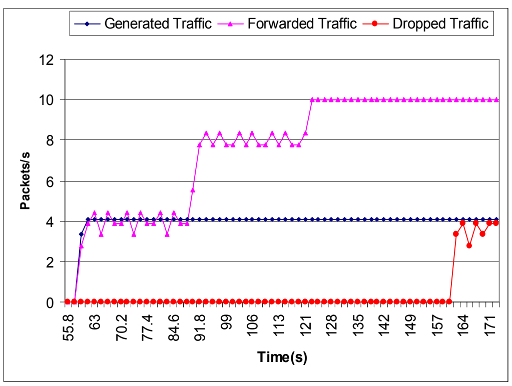

Figure 3. Comparison between generated, forwarded and dropped traffic.

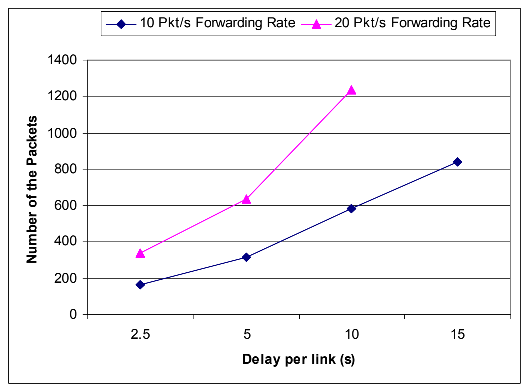

Figure 4. Number of the packets that is kept in the network with respect to forwarding rate and delay

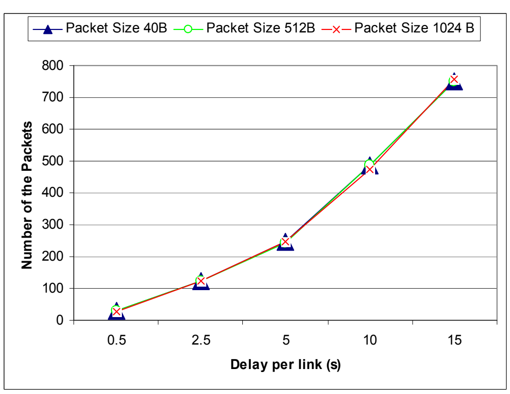

Figure 5. Number of the packets that is kept in the network with respect to different packet sizes.

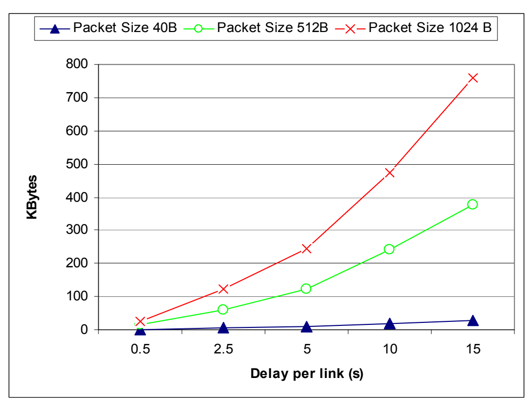

Figure 6. The data that is kept in the network with respect to different packet sizes.

Fig 4 shows the impact of changing delay and forwarding rate on the total number of packets that can be kept in the network. In figure 4 two series, represent 10Pkts/s and 20Pkts/s forwarding rates. In this graph Delay per link (D/Link) varies from 2.5s to 15s. For 10Pkts/s the total number of packets starts with 166 and increasing delay from 2.5 to 5, 10 and 15 increases the number to 316, 582 and 842 respectively (Also can be seen from Table II). It can be seen from Fig 4 that as hypothesized, the Total Number of Packets (TNP) increases with increasing the maximum forwarding rate and loop time which in turn increases the capacity.

Fig 5 depicts the simulation results for identical scenarios but with different packet sizes and delays. This figure shows that changing the packet size does not affect the total number of packets. This is due to the fact that in these scenarios the routers' maximum forwarding rates are packet-based. Therefore as transmission delays of the links are negligible compared with the large propagation delay, changing the packet size does not affect the total number of packets. In practice, the number of packets that can be forwarded in a fraction of time will decrease slightly by increasing the packet size; however as the routing loop time will also increase due to increasing transmission delay, it does not affect the total number of the packets (TNP). Although the results in Fig 5 shows that changing the packet size does not affect the TNP- with the assumption that the routers work packet-based, as shown in Fig 6 it has a considerable impact on size of the data that can be kept in the network and therefore increasing the packet size considerably increases the storage capacity.

TABLE II. COMPARISON BETWEEN THE TNP THAT HAS BEEN CALCULATED BASED ON THE MODEL AND SIMULATION'S TNP

Scen No	FR	Delay/ link	Packet Size	TNP Simulation	TNP Calculated
	Pkts/s	*S*	*Bytes*	*Packet*	*Packet*
1	20	2.5	1024	336	312
2	20	5	1024	636	612
3	20	10	1024	1236	1212
4	10	2.5	1024	166	162
5	10	5	1024	316	312
6	10	10	1024	582	612
7	10	15	1024	842	912
8	10	0.5	512	39	39
9	10	2.5	512	159	159
10	10	5	512	299	309
11	10	10	512	599	609
12	10	15	512	919	909
13	10	0.5	40	18	36
14	10	2.5	40	138	156
15	10	5	40	298	306
16	10	10	40	598	606
17	10	15	40	918	906

Table II compares the calculated TNP based on the equation (2) with the NTP obtained from the simulation (based on the same parameters). As can be seen from the table, for all of 17 different scenarios the values obtained from the simulation results are almost similar to the values calculated using the equations. For example for scenario 1 the TNP obtained from simulation is 366 packets and calculated TNP based on the model is 312. Similarly for Scenario number 17 the obtained TNP and the calculated are 918 am 906 respectively. This comparison validates the model and shows that DSTN storage capacity has a direct relation with Delay, Forwarding rate and packet size and as shown in figures 4 and 6, increasing any of these three parameters will considerably increase the capacity in terms of number of the packets and the data.

II. CONCLUSION AND FUTURE WORKS

In this paper, we proposed a generic architecture for a small mobile computer -that can be packed in scale of a pen, having functionality of a powerful desktop PC by utilizing the states-of-the-art in deviceless IOs, integrated circuits, distributed systems and IP networks. Based on this architecture we proposed our technique to use the network, which lies in the middle of the architecture as a part of primary storage for frequently-used data/ control data. As the mobile device has limited resources and can easily lose its coverage; the network itself maintains the content for the device in form of cache, based on a particular pattern or special service definition. This storage is serial and includes two parts: intermediate routers' static memory and the dynamic virtual storage which can be constructed based on the total delay in the network. Here we focused on the second part and presented the model and the capacity. The presented storage capacity is the network dynamic capacity and the routers' local memories are not included. We showed that forwarding rate of the routers, total delay and packet size are the parameters that impact the capacity. DSTN capacity can be referred as non-physical or deviceless storage in wireless and satellite communications.

However there are several issues that should be addressed in the future in order to implement the technique. The capacity of this technique significantly depends on the packet size and as the current Internet relies on very small IP packets, the pure DSTN storage size is not considerable - although adding routers' local memories makes it more feasible. In DSTN when failures occur the contents are lost and majority of today's networks are still error-prone and the packet loss is not negligible. Defining the service policy, QoS model, data structure, file system, control commands and resource management policy are some of the other future issues. Applying multicast for node delivery is another important issue which is under study as the next phase of the research. The drawback of the technique is that it increases the power consumption of the intermediate routers. The relation between the network traffic and the floated storage traffic also should be controlled in order to prevent the floating traffic from occupying the full capacity of the network.

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REFERENCES

[1] "Is cloud Computing Really Ready for Prime Time?" in *IEEE Computer Magazine*. vol. 42: IEEE Computer Society, January2009.

[2] A.S.Tanenbaum and M.Steen, *Distributed Systems: Principles and Paradigms* Upper Saddle River, NJ: Prentice-Hall, 2002.

[3] "Computers of the future", Available from: http://www.ssqq.com/ARCHIVE/vinlin25.htm (cited: 24/12/2008)

[4] H.SasakiI, T. Kuroda, P.Antonlac, Y.Manabe, and K.Chihara, "Hand-menu system: a deviceless virtual input interface for wearable computers", *Control Engnierrng and Applied Informatics,* vol. 8, pp. 44-53, 2006.

[5] "Virtual Keyboard Is Reality", Available from: http://www.extremetech.com/article2/0,3973,539778,00.asp (cited: 22/12/2008)

[6] J.Mantyjarvi, J.Koivumaki, and P.Vuori, "Keystroke recognition for virtual keyboard", in proceeding of *IEEE International Conference on Multimedia and Expo (ICME '02) Vol 2*, 2002, pp. 429 - 432

[7] "The first pocket eReader", Available from: http://www.polymervision.com/ (cited: 15/11/2008)

[8] Y.Chen, J.Au, P.Kazlas, A.Ritenour, H.Gates, and M.McCreary, "Electronic paper: flexible active-matrix electronic ink display", *Nature,* vol. 423, pp. 136-136, May 2003.

[9] S. R. Kamel, B. M. Ali, and S. Khatun, "Data Storage as a new perspective of future IP networks", in proceeding of *IEEE 9th Malaysia International Conference on Communications*, Kuala Lumpur, Malaysia, 15 -17 December 2009 pp. 539-542.

[10] J.Satran, K.Meth, C.Sapuntzakis, and E.Zeidner, "Internet small computer systems interface (iSCSI)", IETF RFC-3720, 2004.

[11] G.Orenstein, *IP Storage Networking: Straight to the Core*: Addison Wesley Professional, June 2003.

[12] R.Braden, "Requirements for Internet Hosts - Communication Layers", RFC-1122, October 1989.

[13] Y.Ohba, "Issues on Loop Prevention in MPLS Networks ", in *IEEE Communications*. vol. 1, December 1999.

[14] N.V.Mnisi, O.J.Oyedapo, and A.Kurien, "Active throughput estimation using RTT of differing ICMP packet sizes", in proceeding of *Third International Conference on Broadband Communications, Information Technology & Biomedical Applications*, Nov 2008 pp. 480 - 485

[15] "OpNet modeler", Available from: http://www.opnet.com. (Cited: 2008/06/10)