A Simulation Model for Determining Data Exchange Mode Analysis Network Influence

Samuel N. John and Aderemi A. Atayero, *Member IEEE*

Abstract — **Emergence of large scale specialized networks with a large number of computers marked a new stage in network infrastructure development. Increase in bandwidth is followed by a commensurate increase in the amount of traffic sent over the Internet. Optimizing the use and allocation of bandwidth continues to be an ongoing problem. We present a simulation model to resolve the technological challenges of increasing the efficiency of data exchange in computer networks.**

Keywords — **Bandwidth, computer network, efficiency, Data exchange mode, Protocols, Simulation model..**

I. Introduction

Computer networks play an important and ever increasing role in the modern world. The development of the Internet, the corporate intranet, and mobile telephones have extended the reach of network connectivity to places that some years ago would have been unthinkable. This intensive development of modern computer networks and the sophistication of software-hardware systems results in a sharp growth of workload and complexity of computer networks based on the TCP/IP protocols, which models many protocols as finite state machines.

Despite the increase in link bandwidth on network backbones, optimizing the use and allocation of bandwidth continues to be an ongoing problem. This problem affects the effectiveness of protocols thus playing an important role in data transmission over a network environment.

One of the major aspects in solving this problem and increasing effectiveness of computer networks was a research carried out in designing and developing simulation models for analyzing computer [1]. The features in realizing the protocols and their influence on increasing efficiency of data exchange was considered since the process affects both the hardware and software of a network. A thing of value in this case is providing efficient organization of data exchange on a network, which significantly affects the productivity of network applications.

The use of mathematical models in designing networks is most preferable, since a mathematical model is an aggregate of formulas and/or logical conditions determining the change in the process state of a system epending on their parameters, initial conditions and time. One of the classes of mathematical models is simulation models. These models are computer programs with step-wise reproduction of real-time in-system events. Modern requirements dictate the necessity for a wider application of multi-service networks, which are able to pass heterogeneous traffic effectively; including digital data, graphics, audio- and video-information. Presently, there exist few solutions that allow for effective combination of *free size* heterogeneous data communication within the framework of one network. This implies that heterogeneous traffic possesses a strong temporal correlation across various time scales and is thus *bursty* in nature [2], [3].

Data link protocols used in local area networks is a method of accessing network resources and are based on time-sharing of the nodes. In this case, as well as in all cases of division of resources, the situation of random streamline query seems likely and may lead to queuing. In describing this process the models of theory of mass service are employed [4].

In developing the distributed computing and modeling based on the Internet infrastructure, it is important to consider the increased network effectiveness at all levels of the TCP/IP stack, beginning with their speed of signal distribution at physical layer level and onward to the application layer [4].

A selected mode of data exchange typically allows for a low network workload, thereby increasing the real bandwidth capacity, which subsequently results in an increased overall network functional efficiency. A method of increasing the efficiency in a computer network was offered by means of perfecting the modes of data exchange in them, which allows for an increase in computer network usage efficiency without additional expenses on infrastructure of the network [5].

The rest of the paper is organized as follows: In section II we present a scenario based on literature review of factors affecting the efficiency of data exchange in computer networks based on the TCP/IP protocols stack and the basic problems in this area were analyzed. Section III gives a detailed presentation of the simulation models. Section IV shows the research result using the developed simulation models. The model of TCP is represented in section V with some details on the methodology for increasing the effectiveness of data exchange.

II. Factors Affecting the Efficiency of Data Exchange in Computer Networks

The mode of data exchange was examined as the main objective of this research, since its perfection often engenders a considerable improvement in network and network application performance without substantial additional expenditure.

The main task of analysis and modeling of the modes of data exchange in modern computer networks based on the protocols of TCP/IP is increasing the performance efficiency of work on the network and network application, and above all, increasing their productivity.

The objective mathematical representation of the task can be expressed as a functional objective:

• S.N. John (phone:+234.806.299.4678; e-mail: johnsam8@hotmail.com)and A.A. Atayero (phone: +234.805.256.7491; e-mail: atayero@ieee.org) are with the Department of Electrical and Information Engineering, Covenant University, Nigeria.

To find such parameters of a data stream block, at which the real bandwidth capacity of network (Q) is maximum.

$$Q = f(Q_N, L, \lambda, n_y)$$

where

Q_N – nominal bandwidth capacity of the network

L – size of the sent data blocks

λ – parameter of data blocks stream (for every nodes)

n_y – numbers of active nodes in the networks.

Thus, the main object of investigation becomes *mode of data exchange* towards increasing the productivity in either wired or wireless computer networks. As seen from Fig. 1, the effective use of bandwidth plays a great role in efficient data exchange of networks. The coefficient of data loss (K_L) depends on the workload of the system. The problem lies in finding the file size and data processing frequency. The loss rate will be minimal for a desired bandwidth (Q_T), nominal bandwidth (Q_N), and number of user (n_y). Q_R the real bandwidth of the network.

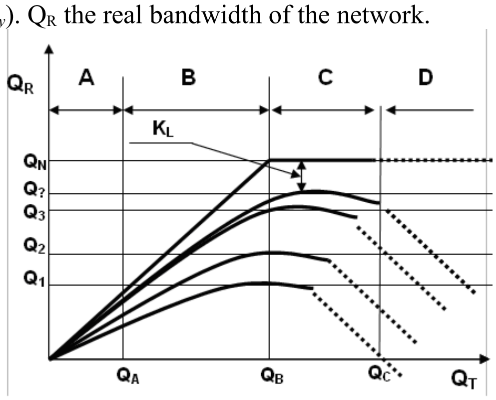

Fig. 1. The effective usage of Computer Network

Fig.1 shows a summary of research results carried out towards determining the rate of data loss during data exchange in a LAN and the bandwidth efficiency of the network. Data was sent over a desired bandwidth and the real bandwidth value was obtained from the data streamline experiment. It is thus obvious that the dependence of bandwidth on workload Q_T has a variable close to ideal network (zone A). Zone B represents decline in network carriage capacity, C – saturation zone, and D - refusal [5]. That the mode of data exchange affects the mode in which computer networks operate and the effectiveness of the real bandwidth (a.k.a. throughput) is obvious from these results.

The performance of network with small file sizes may result in substantial losses in network productivity due to more header retransmission. These processes are best investigated by employing a simulation model for analyzing their influence

III. Simulation Models

The dynamics of data exchange in a distributed computer network is complex and difficult to describe in a linear (or nonlinear) analytic aggregation function with sufficient accuracy. Therefore, the performance of a network with influences on it by Topology, Hardware, Software, Mode of data exchange, etc [4, 6], can be described only with aid of algorithmic simulations. In the reported context, the simulation model was developed using special software tools (e.g. *MATLAB* ™, *Network Simulator*™ and *Netcracker Professional*™) to investigate the effectiveness of data transmission and how to maximize bandwidth usage with a view to increasing their productivity.

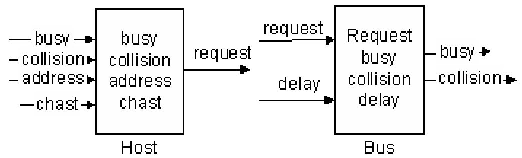

Fig. 2. Structure of physical layer models

In developing distributed computing systems based on internet infrastructure, it is important to consider all the TCP/IP stack layers beginning from the physical layer, through network layer, transport layer and ending with the applications layer. These layers exhibit a difficult character of bandwidth capacity dependence on chosen modes of data exchange, hence the need to develop multilevel simulation for these layers. The developed model of link layer exposes the most critical areas of a network in different working modes. *Simulink*™ block model was used in creating two types of the object models: «nodes» or (Host) and «Channel» or (Bus) (Fig. 2).

On the transport and network interface layers, a *Simulink*™ model was developed and realized in block models of three object types: Host, Bus and Gateway, to handle model of data channel between local area networks with possible exit to the global network [7]. *Simulink*™ S-function tool was used in creating a special block of models and control programs. In the simulation model of object Host, three of its main states were considered: *delaying, receive frame* and *send frame*. In every state, the algorithmic state of object Host has a different function represented by a system of differential equation as shown below:

$$\begin{cases} \overline{x}_{i+1} = \overline{G}(\overline{u}_i, \overline{x}_i, t_i); \\ \overline{y}_{i+1} = \overline{g}(\overline{u}_i, \overline{x}_i, t_i); \\ t_{i+1} = t_i + \Delta t. \end{cases}$$

where

$\overline{x}_{i+1}, \overline{x}_i$ – i^th^ values of variable state vector of Host;

$\overline{y}_{i+1}$ – i^th^ values of variable output vector of Host;

$\overline{u}_i$ – i^th^ values of variable input vector of Host;

$\overline{G}, \overline{g}$ – vector-function;

t_{i+1}, t_i – $_{(i+1)}$ – i^th^ values of model time;

Δt – step of simulation.

Within the S-functions usage framework mechanism, the vector-functions $\overline{G}(\ )$ *and* $\overline{g}(\ )$ were realized in functions *mdlUpdate* and *mdlOutput.* These functions allowed imitation of function nodes of Ethernet networks under the TCP/IP protocols.

Host Object Modeling

The S-functions realized Host Model has the following vectors: x – vector of the state, y – output vector and u – input vector. For realization the model in the form of S-function, it was necessary to develop the structure of the vectors *x, u, y* and functions of mdlInit, mdlOutput, and mdlUpdate. These allowed for imitating function nodes of the Ethernet network under the TCP/IP protocols.

The model sends and receives frames as part of packets generated by data blocks for transmission. The structures of frame in the generated data block are shown below:

1	2	3	4	5	6		
To whom	N - frame 0 - ack.	From whom	N package	Nos. of Frames	1'	...	1

Components of vector *u*: **Input: *u*** 1) Signal from the bus; 2) Collision [2]. Components of vector *y*:**Output: *y*** 1) Signal from the bus; 2) Amount of sent and acknowledged information; 3) Delay time (it is determined at the end of package transmission). **Components of vector *x:*** The vector state of x contains buffers and variables of the state. The condition at which buffer changes are given as followings:

TCP: - every step, generated data blocks; - receiving of acknowledgement on packets; - exceeding waiting time of acknowledgements.

PackOut: - new data in the TCP buffer (placed in PackOut); - exceeding waiting time of acknowledgement (deleting of packets from the buffer); - receipt of acknowledgement (deleting of packets from the buffer).

FrameOut: - in the buffer all frames of packet N erased; From PackOut timer = 0, in this case all frame of the packet and address are deleted from the nodes.

An adaptive method was used for the choice of considering acknowledgement (*Ack*) delay time. *Acks* of packets was sent not considering queuing and it was initiated in the beginning of buffer. Time in the *PackOut* started counting as soon as the packet was placed in the buffer. We considered that the connections were sent between all nodes of the network in the moment the packets start to enter into the buffer. Also, we assume the connection starts between all the nodes of the network at the moment the simulation begins. If the waiting time for the packets lapses, then the current and subsequent packets in this connection are deleted, the value of the sent packet is reset, the number of the last sent packet is considered equal to the number of the last acknowledged packet. An *ack* is sent only to the packet of number more than number of the last received packet.

The *frameln* Buffer must of a necessity clear the frames, which were earlier received but which could not be arranged into a packet. During simulation of the model *HOST,* three main objects were selected based on their transition states: *Delay time; Receive of frame and Sending of frame.* Actions were executed in the process of transition from one state to another state.

The processing of these data takes into account all basic features of the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) scheme [4], [8], [9]. Fig. 3 shows the flow chart of state algorithm of the object *Host.*

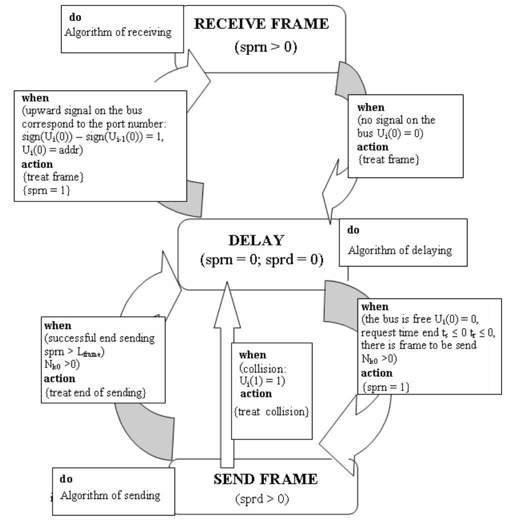

Fig. 3. State algorithm chart of object Host

The elements of Host were realized based on the TCP/IP protocol and Ethernet [5], [6]. Data from the bus goes into the Host generated by the Poisson principle of data flow. Below is a stepwise model of the Host taken from the flowchart of Fig. 3: a) treatment of collision if the nodes participates in it, b) transmission of frame, c) begin and end of frame transmission, d) receiving of frame, e) treatment of acknowledgement and f) waiting time (delay).

MODELING TCP

Approaches to flow and congestion control are central to any network transport protocol. These algorithms control how quickly data packets are injected into networks. Open-loop protocols inject packets into the network regardless of the network or receiver; closed-loop protocols react to signals from the network or the receiver concerning congestions or buffer allocations. Closed-loop protocols employing end-to-end congestion control (such as TCP) which are critical to the success of the Internet because they adapt to congestion [6], [9].

Thus, the achieved result offers a special method for increasing the efficiency of data exchange in a distributed computer network. The essence of the developed method consists in exploiting the interdependence of the analytical and empirical methods. It also helps in developing complex simulation models for deciding the most effective mode of data exchange during a given condition on exploitation of computer networks and applications.

Increasing the efficiency of data exchange in computer networks based on the TCP/IP protocol requires solving complex problems which are related to the following: choice and optimization of network topology, optimizing the bandwidth capacity of the channel, choice of routes, choice of methods of data flow streams and verifying the parameters in control, analyzing the buffer sizes of switches and routers, and choosing strategy for congestion control.

IV. SIMULATION RESULTS

The result of the simulation from the developed models were obtained considering the size of data block (L_{min}, L_{max}

= constant) and the generated frequency of the data block. Fig. 5 shows the dependence of the real bandwidth capacity to a network workload over a computer network for (L_{max} and L_{min} = const). Analysis of the graph shows that as Q_T increases to 10 Mbps, the real traffic also increases. Reduction of real bandwidth capacity takes place after exceeding the standard speed of Ethernet transmission (10 Mbps).

Exchange of data blocks with small size, as seen from the Fig.5 results in the substantial decline of the maximum possible real traffic. In particular, during data transmission blocks with an average size of 100 byte have the value Q_R = 2,5 Mbps practically independent of Q_T. The Q_R increase begins from an average file size of 0,4 Kb, therefore most acceptably, it is necessary to acknowledge the average file sizes not less than 0,4 Kb. As Q_T increases from 12 to 20 Mbps, we observe a tendency of decline in Q_R.

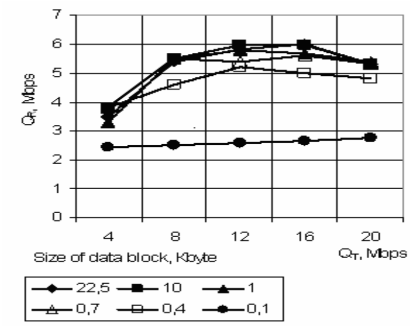

Fig. 4. The real bandwidth capacity for Lmax и Lmin = const.

Fig. 5 shows dependence relation of the real bandwidth traffic Q_R to the required bandwidth traffic Q_T. The Q_{RT} correlation from the Fig. 5 shows that as L > 0.4 Kb the coefficient of traffic falls regardless of the size of data block. At Q_T of about 4 Mbps $Q_{RT} \approx 0,9$, this implies a total satisfaction of network requirement. When Q_T rises to 20 Mbps, Q_{RT} becomes less than 0,3 making the degradation of the network (zone of decline to carrying network capacity) as shown in section II above.

In all it can be seen that the mode of data exchange affect the mode in which computer network operate, and also on the effectiveness of the real bandwidth which is the throughput of a network. The performance of network with 'send small file' sizes may results in substantial loss of network performance due to more headers being transmitted and re-transmitted.

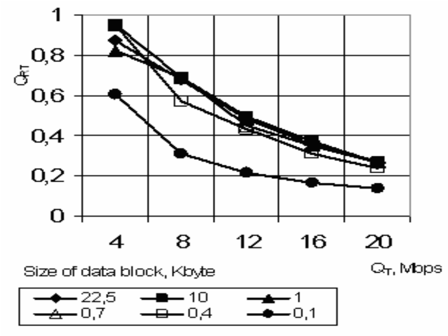

Fig. 5. Dynamics of change of real to required bandwidth traffic at different average sizes of data blocks

The analysis of Q_{RT} dependence at different values of parameter of data flow leads to a valid conclusion that this dependence has the same features as the one shown in Figure 4.

V. Conclusion and Recommendation

A model for generating realistic workload distributions for networks and the Internet using the Matlab™ and Simulink™ was presented. The developed model captures both the temporal and spatial interactions between sources and the network and the interconnections between them. Improved high-level method in designing and analyzing the efficiency of computer networks based on a hybrid of different models and analytical dependences is recommended. This takes into account the influence of the mode of data exchange on the functionality of corporate networks based on the TCP/IP protocols. It further allows for a unified mode of data exchange framing across a network, dynamic bandwidth provisioning on a packet-by-packet basis, and hybrid data mixing capability, which maximizes bandwidth usage and yields increased efficiency of wireless equipment and operation.

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