BANDWIDTH USAGE MAXIMIZATION FOR ENHANCEMENT OF DATA EXCHANGE EFFICIENCY IN TCP/IP-BASED NETWORKS

ANOPRIJENKO Alexander, ABABNEH Hasan

Donetsk National Technical University
Computer Science Department, Ukraine
anoprien@gmail.com

JOHN Samuel Ndueso

Covenant University
Electrical and Information Engineering Department, Ota, Nigeria
Johnsam8@hotmail.com

Abstract

Anoprijenko A., Ababneh H., John S.N. Bandwidth Usage Maximization for Enhancement of Data Exchange Efficiency in TCP/IP-based Networks. *Intensive development of modern computer networks and programmable device systems realized from them resulted in the sharp increase of load and complication of network infrastructure based on the stack of TCP/IP protocols. In turns, these stipulate the substantial increase of workload during exploitation of such networks. The indicating processes shows difficulties on the hardware part of a network, as well to the software tools. Thus, on a background of intensive expansion of the global infrastructure Internet both complication scales and work-load of corporate networks, grows substantially. Accordingly, providing the efficiency functioning of the networks, and also task creating on them based on high-performance of client-server and the distributed computer systems becomes more difficult. Thus, the important reservation toward increasing the efficiency and productivity of such networks lies on improving the effectiveness of data exchange within them.*

A various levels of throughput may be required for certain types of network traffic: data requires about 10Kbps; a voice-over-IP call, about 50K to 100Kbps; standard video, about 300K to 500Kbps [6]. But if we broadcast high-definition content, we're up to about 1.5M to 2Mbps of sustained utilization.

Households, for example, are doing a triple play of voice, video and data over televisions, computers and other devices, causing high demand on bandwidth requirements. Simultaneous use of advanced services, such as peer-

to-peer file sharing, IPTV and gaming, coupled with high-definition TV, could push bandwidth needs to 50Mbps per household.
Companies are seeing the bandwidth impact of using video in new ways and maximizing its efficiency stands to increase the throughput of a LAN or Wireless Area Network.

Another area seeing amazing growth in bandwidth consumption is healthcare. Advances in medical imaging that allows doctors view patient results from anywhere in real time are pushing the boundaries of today's bandwidth capabilities. In fact, some companies are generating and transmitting MRI scanner data that reaches 500MB per hour and 11TB per day.

This paper will discuss the use of protocols to meet the technological challenge toward improving the efficiency of data exchange in a modern computer network application and computing network environments in maximizing the use of bandwidth.

The number of host computers connected to the Internet continues to increase unceasingly rate and shows no sign of slowing down [1, 2]. This growth, illustrated in Figure 1 from Donetsk National Technical University network growth, has placed constrain on the network infrastructure that was built on what were, at the time ARPANET was created, experimental technologies.

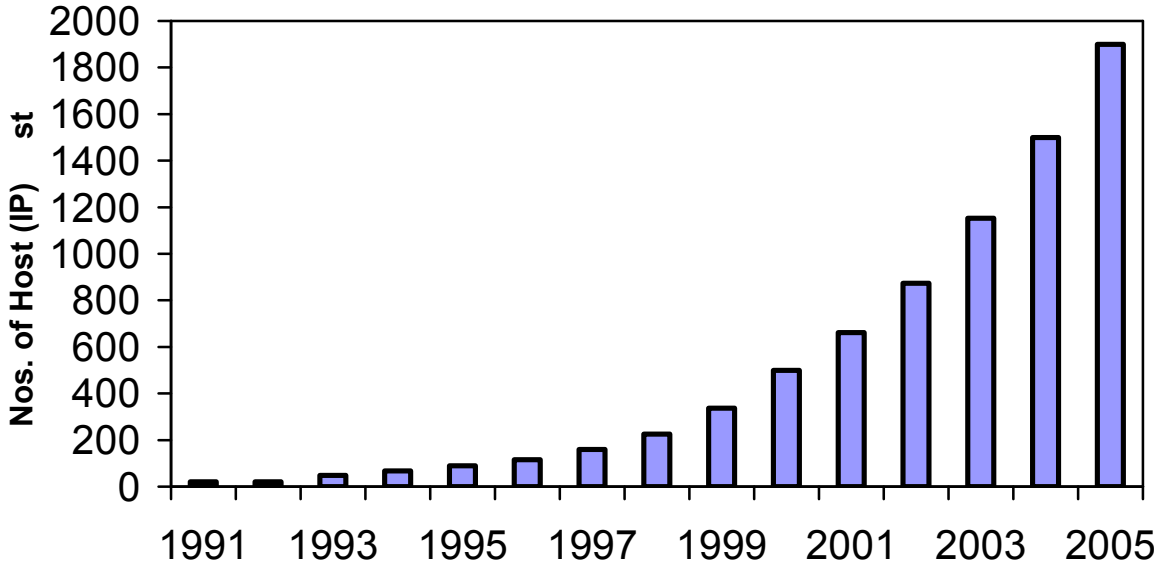

Fig. 1. Increasing number of computers in a typical sample of a corporate network (Donetsk National Technical University)

The other thing that's happening is that as communications merges with the IT infrastructure, it also gets intertwined with business processes and applications in a new way. The first step is moving to VoIP. From there, the longer term work of tying communications into businesses processes in totally

new ways begins. That's what's really exciting and the network problems become more difficult in maintaining compared to what it was before.

The first generation analog and second-generation digital systems were designed to support voice communication with limited data communication capabilities. Third generation systems are targeted to offer a wide variety of services such as *telephony, teleconference, voice mail, video conference, voice band data, message broadcast navigation, location etc.* Most of these services are wireless extension of Integrated Services Digital Network (ISDN), whereas services such as navigation and location information are mobile specific and demanded a high bandwidth.

Wireless network users expect a quality of service similar to that provided by the wire line networks such as ISDN. The third-generation network will concentrate on the service quality, system capacity and personal and terminal mobility issues. The system will be improved by using smaller cells and the reuse of frequency channels in a geographically ordered fashion.

With the above expectation of wireless communication, there is need to work on improving the technological advancement of the growing IT based on the efficiency of data exchange.

As earlier mention in one of my publications "Increasing the efficiency of data exchange in a computer networks based on the protocol of TCP/IP suite" [2]. The Fig. 2 shows basic components that can cause problems to a network leading to ineffectiveness on the network in terms of throughput which can negatively affect the network performance, both all the networks and individual network applications. A research carried out at Donetsk National Technical University shows how the factors below can really affect the efficiency of the throughput in wireless communication.

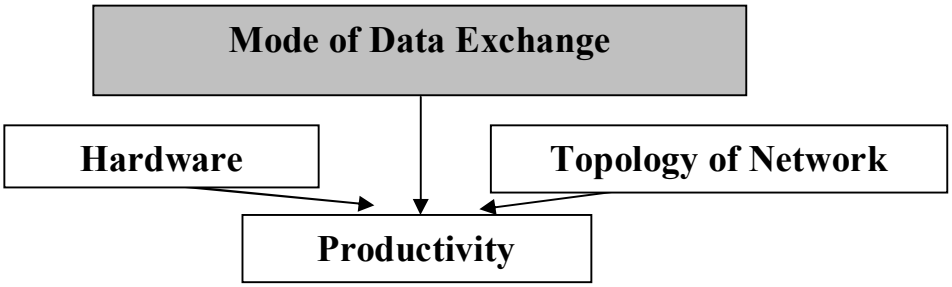

Fig. 2. Factors, determines the bandwidth of a network

The dynamic processes of data exchange in a distributed computer networks is so difficult, that to describe it in a linear or nonlinear analytic aggregation functions with sufficient accuracy is extremely difficult. Therefore, the functional performance of the network with influences on them these factors

(*Topology, Hardware, Software, Mode of data exchange, etc*) [2, 12] can be described only in a non-obvious kind with the use of algorithmic simulation methods.

In Fig. 2, of the many factors that affect the *throughput/bandwidth* of a computer network the most significant is the *mode of data exchange*. Thus, the main object of investigation becomes this factor *"mode of data exchange"* toward increasing the productivity in a wireless computer network. Going through the Fig. 3, the effective use of bandwidth plays a great role for efficient data exchange in wire or wireless networks. The coefficient of data loss (K_L) depends drastically on the workload of the system. The problem lies in finding the file size, data stream frequency of which in the process when a network is executing a command or transmitting a data, the loss rate will be minimized for a given desirer bandwidths (Q_T), Nominal bandwidth (Q_N), number of user (n_y) and known topology of the network.

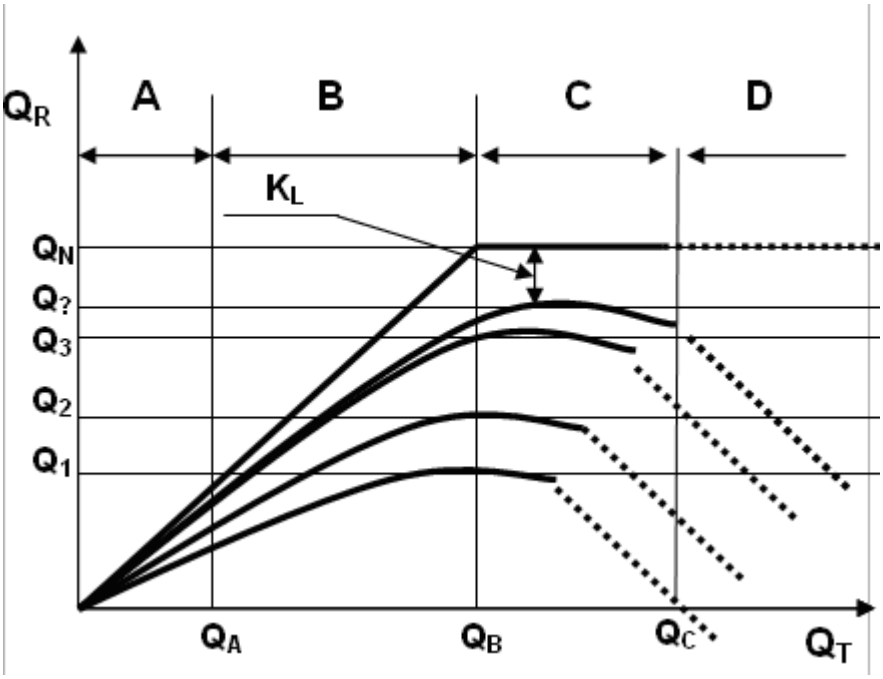

Fig. 3. The effectiveness of the real bandwidth in various modes

The Fig. 3, shows a summary results of research carried out toward the rate of data loss during data exchange in a LAN and the bandwidth efficiency of the network. In this case, a desirer bandwidth was propagated toward the data flow and real bandwidth was obtained from the data streamline of the experiment. The summary results of the research work, shows the area obtained in the graph. It is thus visible that dependence/desirer of bandwidth from work load Q_T has a variable close to ideal network (zone A), zone of decline to carrying network capacity (B), saturation zone (C) and a refusal area (zone D).

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 losses to network productivity due to more header been transmitted and retransmitted.

In connection with this, the basic method in researching the network efficiency is using a simulation means both with the use of the special tools, the universal systems “MATLAB” and “Netcracker Professional” to investigate the effectiveness of data transmission and how to maximize the bandwidth usage in order to increasing their productivity.

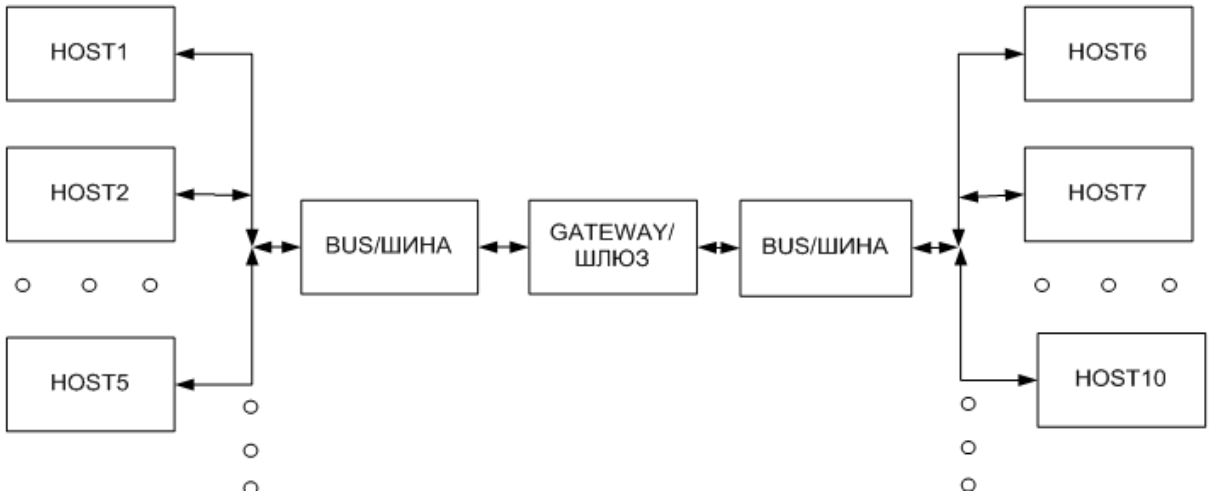

Fig. 4. Model structure of LAN connecting by gateway

The analysis shown in Fig. 4, model structure of network allows defining of the main functional elements:

Host – point of network serving the transport layer;

Bus – medium of transmission in the LAN;

Gateway – data transmission channel between two LAN.

The above shown schematic of network in Fig. 4, works with the outline functional elements.

The effectiveness functions of computer network were estimated based on the following indexes of work performance by the network:

Real bandwidth:

$$Q_R = \frac{1}{T}\sum_{i=1}^{n}\sum_{j=1}^{N} L_{ij},\ Mbit/\sec.$$

where, Q_R– real bandwidth;

L_{ij} – data block size;

T – simulation time;

N – quantity of data block successful send to i-nodes

Common bandwidth:

$$Q_{Total} = Q_N \frac{T_s}{T}$$

where Q_{Total} – Total bandwidth;
T_s – sending time;

Average delay time:

$$\Delta T = \frac{1}{N_y} \sum_{i=1}^{n} \sum_{j=1}^{N} \frac{\Delta T_{ij}}{N}$$

Where ΔT_{ij} – delay time during *j* data block generating in *i* node;

$$\Delta T_{ij} = T_{send} - (L_{ij} + N_{ij} \cdot S_E)/Q_N$$

where T_{send} – time between first and last sending data block;
S_E – length of frame header;
N_{ij} – number of frame in a packet

The modes of files exchange were analyzed by the following indexes:

1. time of data transmission (T_2);
2. require bandwidth capacity of a network (workload on a network) (Q_T):

$Q_T = \frac{I}{T}$, Kbyte/sec, where I – general information subjected to be transmitted, Kbytes
T – time of data exchange, sec
Time of data exchange was determined by the following formula:

$T_2 = (\Delta T + T_{transmission})\, n_f$, sec

where $n_f = I / L$ - quantity of the files passed by every networks, ΔT – time delay at data exchange due to collisions and other problems;
$T_{transmission}$ – spontaneous time of direct data exchange $T_{transmission} = I/Q$.
Then, the optimum condition of fast-action will be $\frac{T_2}{T} = Q_T \left[\frac{1}{Q_N} + \frac{\Delta T}{L} \right]$ ➔ min

The analysis of relation on general time needed in data transmission to time (real) (or effective) exchange allows the exposing of three main modes of operations:

First: the real rate of data exchange is below the rate that it is generated and the productivity of the distributed environment is limited by the bandwidth capacity of the network. It results into substantial under exploitation of computing possibilities of the distributed environment. But in this case, it is

possible to select the region of possible workload, when the general bandwidth capacity of the network remains maximal.

Second: actual rate of data exchange corresponds to the set workload, fulfilling the maximum burst performance of the distributed environment.

Third: actual rate of data exchange is more than the speed generated, but due to irrational file size mode of operations of the network is not optimum [2, 13].

In the number of other results of simulation confirmed from a well known fact, that workload more than 55% from a nominal data rate in a network distributed environment works in a mode of substantial loss of productivity data exchange. The achieved dependences allow the execution of concrete estimation of the loss which was shown in Fig.3.

In the whole analysis, this paper shows the role bandwidth usage for efficient data exchange in wireless network as correspond to the mode of data exchange in a corporate network affects the efficiency of its work; the basic indexes which is the Wireless Network performance and time delay of the file transmitting. Based on the exposed conformities, recommendations can be formulated on the increase of efficiency in data exchange [9, 10, 11].

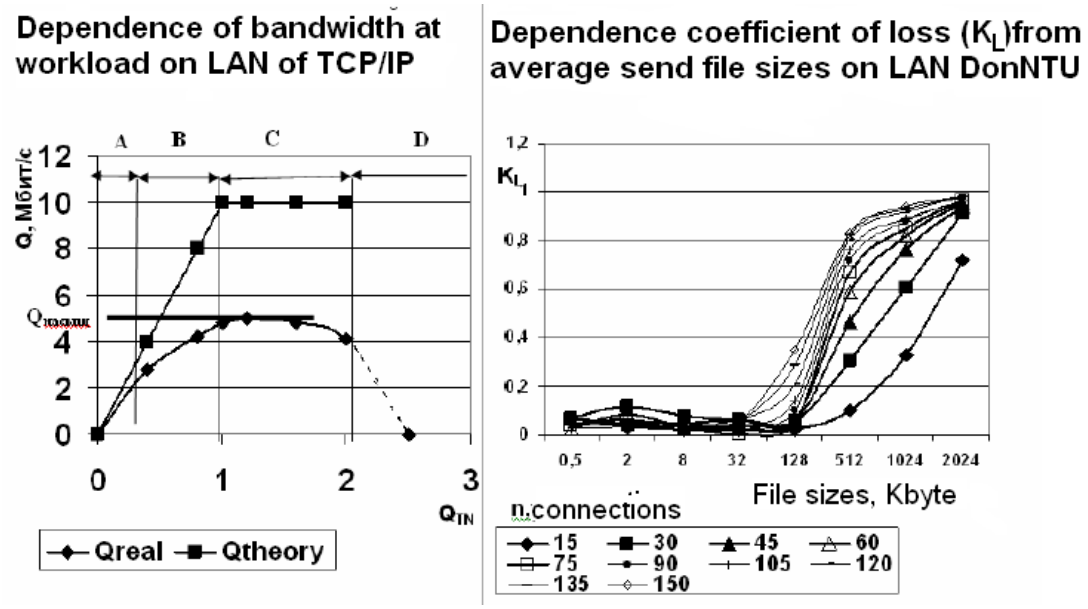

Fig. 5. The effectiveness of network data exchange in various conditions

The investigation results from the research on the dependence of bandwidth on LAN workload and dependence coefficient of loss (K_L) from average send file sizes is shown in Fig. 5. This shows how the zones influence of bandwidth and the coefficient of productivity loss as specially accepted which depends on the send file sizes and the node numbers of a wireless network.

In carried out a research on data exchange in a corporate intranet first, it is necessary to get the analytical dependences allowing approximately estimating

the workload on a channel of two-level corporate network. Extreme complexity of corporate intranet networks and the Internet make the development of analytic models very difficult and under such circumstances; simulation models are a viable alternative to understand the behavior of these networks.

The research work on the effect of data exchange of information on the efficiency of the bandwidth in used, allowed to obtained the following characteristic dependences of bandwidth capacity of a corporate network based on the stack of TCP/IP protocols. Thus, from the result, it is possible to select four zones as shown in Fig. 5:

A $Q_T << Q_N$, here $Q_R = Q_T$,

B $Q_T < Q_N$, here $Q_R < Q_T$,

C $Q_T \geq Q_N$, here $Q_R < Q_T$,

D $Q_T >> Q_N$, here $Q_R = 0$.

When the $Q_T \approx Q_N$, the network approaches saturated point, then $Q_R = Q_{saturated}$. As shown from the research carried out, increasing the efficiency in mode of data exchange allows bandwidth maximization in wired or wireless networks.

Recommended improve high-level method in designing and analyzing the efficiency functioning of computing networks based on combined use of different models and analytical dependences, that allows most adequately taking into account the influence in mode of data exchange towards functioning of corporate networks based on the protocols of TCP/IP.

The results of simulation (for example corporate network) using simulation system gives the maximum value parameters of workload for optimum file sizes, exceeding of which results in decline of bandwidth capacity usage in a computer network.

During the development and exploitation of computer networks and network applications allowed in most cases is the perfection on the modes of data exchange (send size of data blocks and other characteristic of data flow) by an average of 10-15% increment of their efficiency [2].

With a unified mode of data exchange framing across a network, dynamic bandwidth provisioning on a packet-by-packet basis, and hybrid data mixing capability, this maximizes bandwidth usage and yields major efficiency in wireless, equipment, and operation.

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