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SIMULATION INVESTIGATION OF ETHERNET NETWORK PERFORMANCE

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***Abstract**. The paper discusses the basic principles of the Ethernet technology. The most popular Ethernet standards are examined. The necessity for using of simulation approaches for a network analysis and design is considered. The publication presents a simulation study that considers how the main network parameters (packet size, network load, and number of network nodes) affect the Ethernet performance. The simulation results will help administrators make well-informed decisions on how to manage an Ethernet networks and fine-tune the network parameters.*

1. INTRODUCTION

Ethernet is the most popular networking technology used in the contemporary networks. Because Ethernet networks are cheap, easy to set up, and very fast, their use is quickly becoming popular for industrial and utility application. As the enterprise network infrastructure expands to support different types of traffic and software applications, traffic management becomes critical. Complete visibility into an Ethernet network's behavior becomes more important and more challenging.

Rapidly developing software technologies require an improvement of Ethernet network performance. It creates a general need for new algorithms for network traffic control and proper setting of the Ethernet parameters and configurations [1]. Analytical approaches study the network performance based on over-simplified assumptions. This means the final results to be biased towards network performance under ideal conditions. The inaccuracy of analytical models focuses the expert attention on computer simulation to obtain correct results. The simulation is the better approach to investigate the network operation, Ethernet performance, and communication protocols [3, 4]. The simulation can reply of the questions that often go unanswered - what is happening network throughout taking into account the application performance, bandwidth utilization, network congestion and appropriate prioritization of user and application traffic.

The main purpose of the paper is to present the work of the Ethernet networks and to analyze the network performance through a network simulator. For the purpose of the investigation the main parameters that affect the network performance are defined – packet size, number of network nodes, and network load. Different simulation scenarios are built to study the effect of these parameters on the Ethernet network performance and the guidelines for setting their values is developed.

2. ETHERNET TECHNOLOGY

Ethernet is the dominant local area network (LAN) technology implemented worldwide defined by international standards, specifically IEEE 802.3. Ethernet was originally developed by Xerox, DEC, and Intel in early 1970s. Basically, Ethernet includes a shared transmission medium such as a twisted pair cable or coaxial cable and a multi-port hub [7]. All devices on the network use the same share media for communication. The network nodes are connected to each other through the hub using the cables in a star-like or a bus-like topology [6]. It enables the connection of up to 1024 nodes.

Ethernet uses a broadcast access method called Carrier Sense Multiple Access/Collision Detection (CSMA/CD) in which all computers see all messages. Each computer can access the network and can send message anytime it likes without having to wait for network permission. The message travels to every computer on the network. Each network station listens to the network and examines the received data to determine whether it is a destination. The computer can recognize the message because the message contains its MAC address. The sent data also contains the address of the sending computer so the message can be acknowledged.

Collision occurs when two computer send messages at the same moment. In this case, both transmissions are damaged and each of the colliding computers waits a random amount of time before resending the message.

The first generation of Ethernet networks (10BASE5) use “thick” coax cable with N-type connectors for a backbone. The maximum segment length is 500 meters and the maximum total length is 2500 meters. This type of network provides the transmission speed up to 10 Mbps. The present generation of Ethernet standards uses twisted-pair wiring or fiber-optic cables in a star network topology. A star network topology employs a central node (hub or switch) to connect the network segments. It results in the network performance and such networks can provide transmission speed up to 100 Mbps or even Gigabit Ethernet 1000 Mbps.

3. NETWORK SIMULATION APPROACH

In the last decade the simulation became a powerful approach for analyzing and design of complex network systems. According to simple definition the simulation is the imitation of the real process or system over the time. The behavior of a network system is studied by developing a simulation model. The one is a physical, mathematical, or logical representation of network processes and systems [3, 4]. A simulation model presents a set of assumptions about the network behavior. Engineers use models to test different hypotheses by investigation of many “What-If” questions concerning the real system. Generally, there are two forms of network simulation: analytical modeling and computer simulation [5]. The first one uses mathematical analysis to predict the effect of changes to the existing systems or to investigate the performance of the new systems under different circumstances. The main disadvantage of this approach is that many real network systems are so sophisticated and they cannot be presented by a set of equations. In edition to this, the analytical modeling is inappropriate to simulate the dynamic nature of a network. In this instance, the investigation of the system behavior over time always requires a computer simulation. With computer simulation approaches to performance evaluation, network systems can be modeled with almost any level of detail desired and the design space can be explored more finely than is possible with analytical-based approaches or measurements. Computer simulation can combine mathematical and empirical models easily, and incorporate measured characteristics of network devices and actual signals into analysis and design [2].

The network simulators are one of the most complex software tools that provide comprehensive development environment for simulation and performance analysis of communication networks. The main advantages of the simulators can be summarized in the following points [4]:

- Simulators enable the study of complex network systems;
- The effects of information and environmental changes on the model's behavior can be analyzed;
- Simulators can be used to verify analytical models;
- Simulators are appropriate tools for test interoperability between network nodes;
- Network Simulators can be used with pedagogical purposes for training new operators, administrators, and users that can experiment in a simulated environment knowing that their mistakes couldn't cause any problems.

The main disadvantage of network simulator is that the building of simulation model requires special skills. The other problem is that a simulation modeling can be time-consuming.

The above considerations show that network simulators are appropriated tools to obtain adequate information on functionality and performance of communication networks and protocols.

4. SIMULATION INVESTIGATION OF NETWORK PERFORMANCE

The chapter presents a simulation study that considers how the main network parameters (packet size, network load, and number of network nodes) affect the Ethernet performance. The network performance is defined as a relation between the successful received packets and the sent traffic. The simulation network presents Ethernet office network (10BASE5) with a scale - 100x200m. It can support transmission speed up to 10 Mbps. In the example network 32 stations are connected together using a shared coaxial bus (Fig. 1).

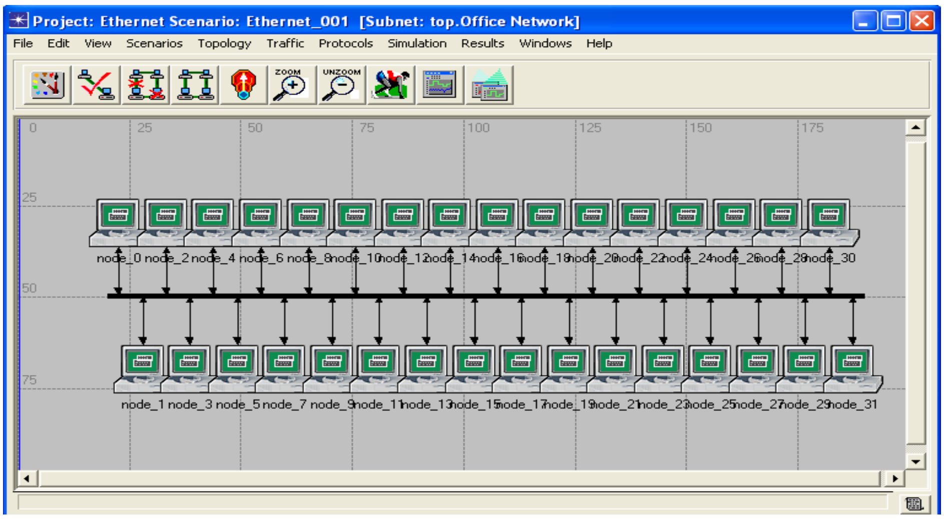

Fig. 1. Simulation network

The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol is used to determine which node may transmit at any given time and to resolve collisions if two or more nodes transmit at the same time. Different scenarios are considered in respect to the generation parameters of the stations. These devices generate Ethernet packets at configurable rates. The traffic patterns for the Ethernet stations are set up for four cases. Each station will generate traffic at an average rate of one 1024 byte packet every 250, 100, 50, and 20 milliseconds. The average traffic that each node will generate from the interarrival time and the packet size can be calculated:

$$1024 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.25 \text{ sec} = 32 \text{ Kbps} \quad (1)$$

$$1024 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.1 \text{ sec} = 80 \text{ Kbps} \quad (2)$$

$$1024 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.05 \text{ sec} = 160 \text{ Kbps} \quad (3)$$

$$1024 \text{ bytes/packet} * 8 \text{ bits/byte} * 1 \text{ packet}/0.02 \text{ sec} = 400 \text{ Kbps} \quad (4)$$

Fig. 2 compares the performance of the Ethernet LAN under different conditions – the scenarios are characterized with different station generation rate.

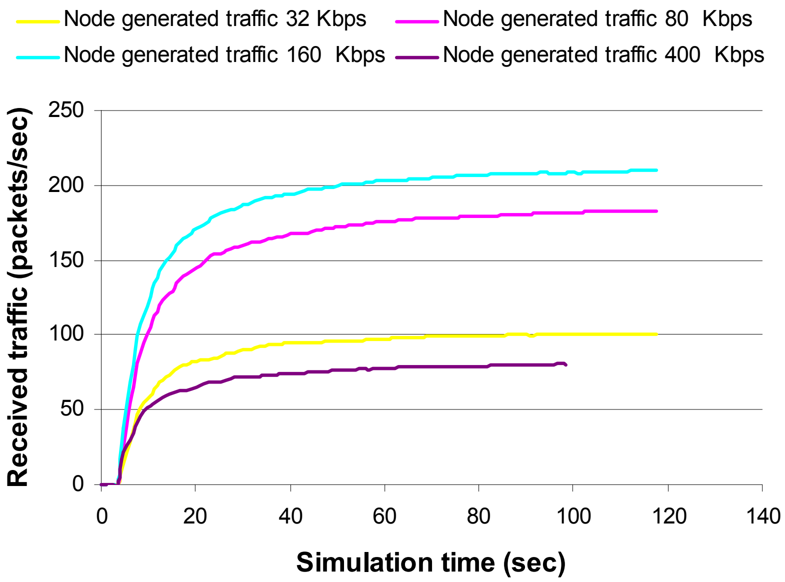

Fig. 2. Received traffic

The above graph shows that with increasing generated traffic the performance increases till a certain maximum throughput is reached. This shows a band of acceptable packet generation rate in which the throughput has maximum.

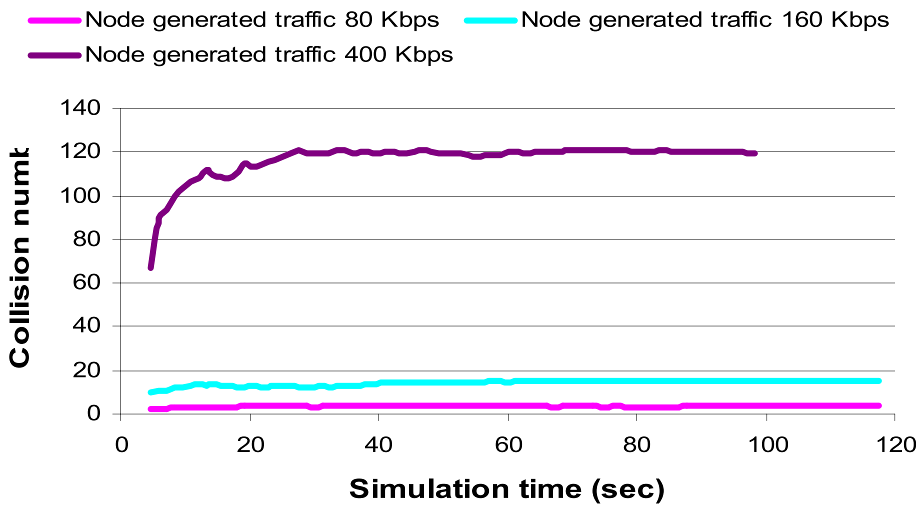

Fig. 3. Collision number

The simulation values approximately match the calculations made earlier using the configuration parameters excluding the scenario in which every station generates traffic 400 Kbps. This is the worst case in respect to network performance although the stations generate highest traffic. The discrepancy between the send and receive packet rate can be accounted for by inspecting the Collision statistic (Fig. 3).

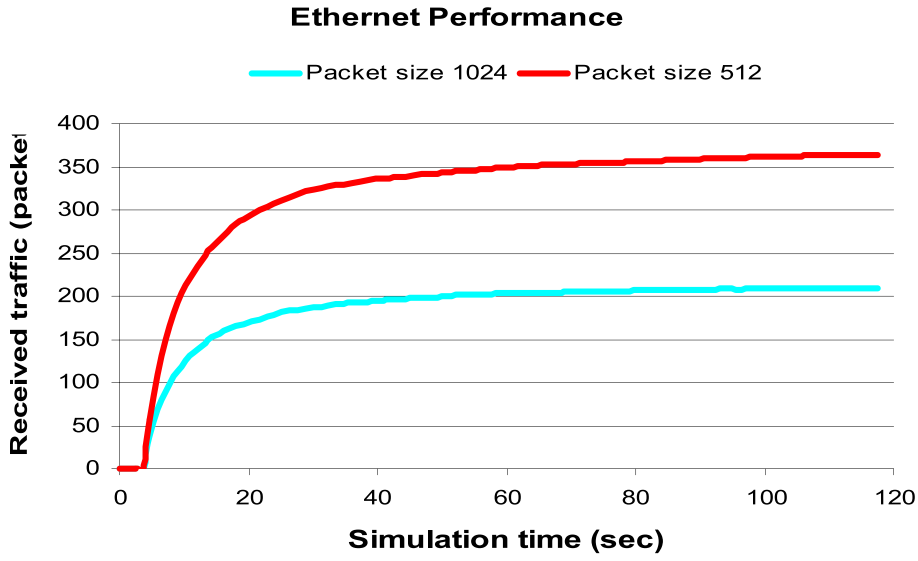

Fig. 4. Ethernet performance for different packet size

The results for collision number show that some of sent packets have been collided and required retransmissions, reducing the performance. This is true for all scenarios, but the most overburden scenario experienced far more collisions. The average number of collisions indicates that generation rate is within a given limit the number of collisions is not too much, but once the critical threshold is reached the number of collisions increases dramatically. This fact explains the reason for the worst performance of the scenario in which station generation rate is highest (400Mbps).

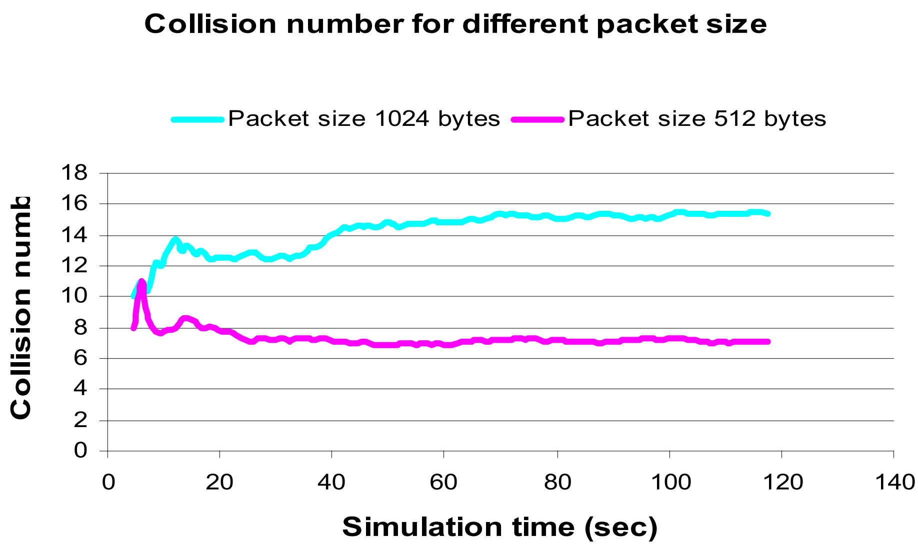

Fig. 5. Collision number for different packet size

In the simulation a packet size is 1024 bytes. To study the effect of the packet size on the performance is created the new scenario in which a packet size 512 bytes is used. The next experiment reveals how the packet size affects the Ethernet network performance for the scenario with traffic generation rate 160 Mbps (Fig. 4).

The simulation results show that performance for the 512 byte packet size is greater than that for the 1024 byte packet. This can be explained with the fact that the average number of collisions for 1024 byte packet is higher (Fig. 5).

The next experiment is dedicated to the impact of the station number on the number of the collisions. For this purpose the number of network stations is reduced to 16. Figure 6 presents a comparative study of two scenarios with 16 and 32 network stations. The results show that if the number of nodes in the network increases the number of collisions increases. Therefore, this fact affects the network performance.

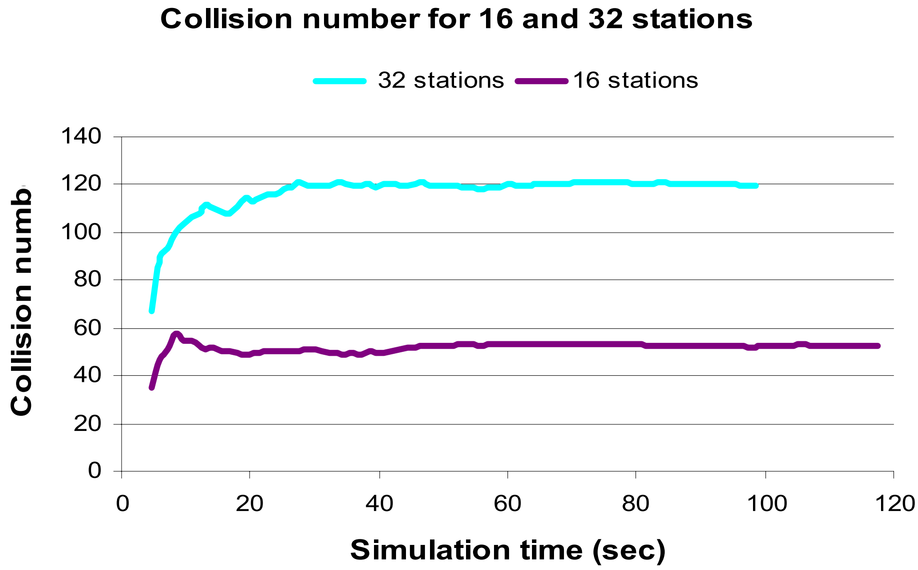

Fig. 6. Collisions for different network number

5. CONCLUSIONS

The paper demonstrates the principles of the Ethernet networks. It presents a simulation study on the impact of the main parameters that affect the Ethernet network performance – packet size, network load, and number of network nodes. The experiments show that the maximum network performance depends on the band of the packet generation rate. The study reveals that the smaller packet size and station number lead to better performance.

The simulation results will help administrators make well-informed decisions on how to manage an Ethernet network and fine-tune the network parameters.

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