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ANALYSIS OF THE DATA TRANSMISSION IN COMMUNICATION CHANNELS WITH NOISE

Annotation: In data networks struggle with errors it is integral to the integrity of the data. One way to reduce errors in the transmission channel are methods of data transmission, such as a Idle RQ (Repeat reQuest), Go back N and a SR (Selective Repeat). The above methods of data enable evaluation of the data link layer protocols developed under the influence of interference of various nature on data channels. Taken into account the effect of interference in the retransmission of the channel, and the channel length dependence of the size of the frame on the likelihood of errors in the frame as well as the number of attempts before a successful transmission of a frame. Existing methodology for assessing the performance of data-link protocols developed in assuming the absence of interference on the data channels. The mathematical expectation of the number of attempts until the first successful delivery of the frame, the dependence of the real performance of the protocols under conditions of noise for different access technologies in mono.
Keywords: data channel, error-handling, performance, the actual speed of the channel interference, Idle RQ, Go back N, SR, computer networks

INTRODUCTION

Development of communication networks in the world today are not only wired but also wireless channels. Currently, there are a number of wireless solutions, such as radio equipment, radio relay stations, and atmospheric optical link.

The current stage of development of networks characterized by explosive acceleration of the process of mutual convergence, which held in each of the previously mentioned specialized infrastructures. Borders, recently seemed unshakable, eroded, and replaced by the same specialized networks with limited functions comes a new hybrid multi-service infrastructure with a much broader range of services provided.

In the development of conventional and high-speed converged networks, it is important to realize the impact of the methods of flow control and error control performance. These methods implemented on the data link layer in some network-layer protocols, such as X.25, at the transport level and in some application protocols.

Simulation of performance management flow and error control - an extremely difficult task. The simplest case is to use a control channel protocol running between the two devices connected to the two-point connection. Here we are interested only constant propagation delay of data between two devices, a constant bit rate, frame error probability and statistical characteristics of the traffic. When designing items flow control mechanisms and error control protocols such as TCP, it is important to be able to affect the performance of the flow control and error control at levels above the level of data transfer.

Connecting between two workstations can be as simple as connecting any device with the Internet, the device can be in any size/configuration and operates on any operating system, but the main physical connections are through:

1) Optical fiber: is a method of transmitting information from one place to another by sending pulses of light, the main protocols that are used for this operation are SONET (Synchronous Optical Networking) & SDH (Synchronous Digital Hierarchy), they are standardized protocols that transfer multiple synchronized digital bit streams using lasers or LEDs. The two protocols are basicly the same, SONET is widely used in North America and SDH is using in the rest of the world. Due to the nature of these protocols and there transport-oriented features, they were the obvious choice for transporting the fixed length Asynchronous Transfer Mode (ATM) frames also known as cells. Optical Transport Network (OTN) is standardize by International Telecommunication Union (ITU) as G709, it revised in 2009 so that it had considerable features and functions, among them is that G709 supports Forward Error Correction (FEC). These enhancements resulted from the need for greater packet client related features at various gigabits/s rates.
2) Copper via on the Ethernet: Ethernet introduced in 1980 and standardized in 1985, since then it has evolve to be the most widely used transport protocol for LANs, data center networks and carrier networks. Since then Ethernet speeds evolved from 10Mbps to 100 Gbps. Ethernet is a link layer protocol in the TCP/IP stack, describing how networked devices can format data for transmission to other network devices on the same network segment, and how to put that data out on the network connection. It touches both Layer 1 (the physical layer) and Layer 2 (the data link layer) on the OSI network protocol model. The major reason for the success of Ethernet in industry was the adoption of the Ethernet standard (IEEE 802.3), allowing for interoperability between different vendor's products (Carrier Sense Multiple Access with Collision Detection CSMA/CD, Access Method and Physical Layer Specifications) [2]. This specification allowed many different vendors to produce network interfaces and media that supported Ethernet.
3) Wireless connection: A Wireless network is a wirefree connection between two or more devices that swap data via radio waves. It used to connect devices such as laptops, tablets and phones to the Internet, the business network and applications. Mobility is considered the primary benefit of wireless network, mobile-based data communication is increasingly climbing in demand and has a rising share of overall network traffic. On the standardization side, 3GPP release and beyond have been approve by the ITU as ITU-Radio. The next generations will certainly have more enhancements and further increase in access data rates that will further enhance the usability of cloud access

through mobile devices. The major technologies for mobile data access today are WiMAX, Bluetooth, ZigBee, LTE and Wi-Fi. As for Wi-Fi Connections, they use the protocol 802.11 a,b,g,n and ac, these versions differ by bandwidth, frequency, stream data rate (speed) and distances that they cover [1]. However, there still are many obstacles that stand on the way that make wireless connection not so efficient, mainly among them are noise and buildings, which make the BER high, compared with other types of network connections.

1. ARQ (Automatic Repeat-reQuest) SCHEME

Methods of error control used to recover from the loss or damage of protocol data units as they pass from sender to recipient. Typically, the error control comprises detection error based on a frame check sequence (Frame Check Sequence, FCS) and retransmission of the protocol data unit. Error control and flow control are implementing together in a single mechanism that regulates the flow of protocol data units, and determines when to retransmit one or more protocol data units. Thus, error control, as well as flow control is a function realized on different protocol levels.

The mechanisms of control channel

For flow control and error checking at the data, usually used three methods: Idle RQ, Go Back N steps and a SR. The last two methods are special cases of a sliding window technique. We consider all of these methods in this section.

Imagine two end systems connected directly to the communication channel. The transmission system is going to send a message or block of data to the sender. The data is sending not a single block, and are breaking down into a sequence of frames. This procedure is perform on one or several of the following reasons:

– The final size of the receive buffer.
– The longer the transmission time, the higher the probability of error, which resulted in the need to re-transmission of a frame. With a smaller frame size errors are detected faster and less data has to be retransmitted. [1]

Idle RQ

The simplest scheme flow control is flow control idle RQ, operates as follows. The sender sends the frame to accepted it, the recipient reports its desire to take another shot, sending back a confirmation of receipt of the frame. Before sending the next frame, the sender must wait for confirmation. Thus, the receiver can stop the flow of data, a "hold" for confirmation.

ARQ scheme Go Back N

The most frequently used form of error control based on flow control using sliding window, called automatic repeat request to Go Back N. In this method, the station may send a series of frames consecutively numbered modulo any maximum value. The number of unacknowledged frames window size determined by the method of sliding window flow control. If no errors recipient will confirm the received frames as usual (RR or confirmation messages "on free" data modules). If the receiving station detects an error in the frame, it can send a negative acknowledgment REJ (REJect- failure) to the frame. The receiving station will discard that frame and all subsequent incoming frames until it receives the correct copy of the erroneous frame. Thus, the broadcasting station received the message REJ, must retransmit erroneous frame and all subsequent frames, which she has managed to convey.

ARQ scheme with SR

In the scheme of automatic repeat request with selective refusal retransmitted only those frames for which the sender receives a negative acknowledgment (NAK), called in this case SREJ (Selective REJect- selective rejection), as well as frames, while waiting for the confirmation of which has expired.

The algorithm of selective denial seems to be more effective than the return on the scheme with N steps, because it minimizes the number of retransmitted frames. On the other hand, the receiver has to manage a buffer large enough to store all the frames received after sending commands to them SREJ, up until the erroneous frame is retransmitted. Also, the recipient must himself arrange received frames in the correct order. The sender must also have a more complex logic, allowing the transfer of frames out of order. Due to the greater complexity of the algorithm of selective rejection was significantly less common than the circuit return to the N steps.

2. FORMULATION OF THE PROBLEM

This article examines the performance of networks in the data link layer model ISO/OSI. Despite the increasing use of networks, to date, there is no method of testing channels of this type. This situation often leads to difficulties in their commissioning. The reason - the lack of criteria for evaluating the quality of the channel, even in the simplest configuration of a point-to-point.

When you select a channel the question of choice of data transmission protocol, such as a protocol with the expectation protocol is data loss with acknowledgments and a sliding window protocol. This article examines the performance of ARQ scheme and return to the N steps in the sliding window protocol.

Minutes from the loss of data confirmation, the fact of receiving the transmitted frame must be confirm by a special message (ACK – acknowledgment, NAK) [1]. If as a result of noise on the physical layer frame is lost, then any attempts to recover it at the link layer will not be performed. This class of service is use where the physical layer provides such high reliability in transmission, frame loss that are rare and recovery from the loss of frames can be shifted to the upper levels. This type of service is also used for data transmission in real time where better lose some data than to increase a delay in their sending. For example, voice, video images.

Minutes of the sliding window. The sender has a certain constant n - the number of frames that the sender can send without waiting for confirmation of each. Upon receipt of confirmation sent frames will be dropped from the send buffer and the buffer will be replenished with new ones.

The window may include N packets, and there may be delays in obtaining evidence for the window. For example, if an error occurs during transmission, the sender receives a negative acknowledgment on the package with the number K, need retransmission, and it starts with the package K.

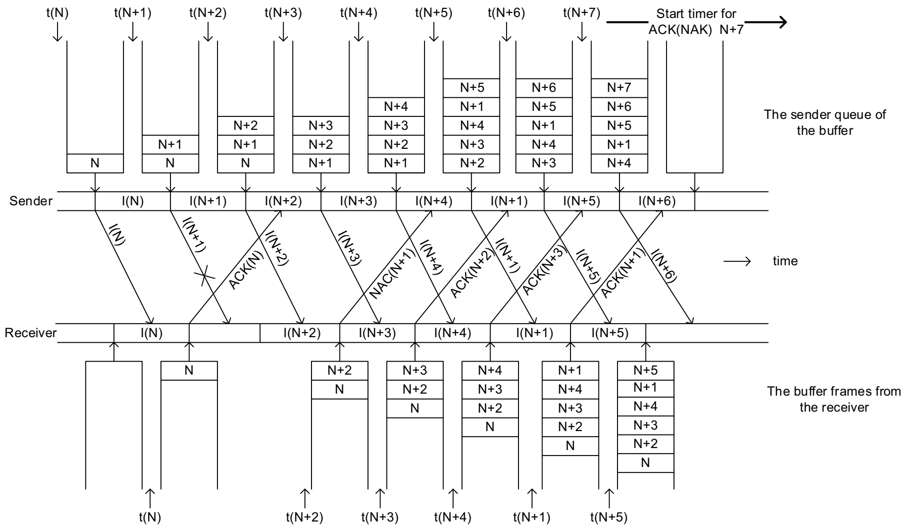

Figure 1. Sliding window protocol

The time frame of delivery confirmation and delivery time may in some cases be large [1]. It can lead to serious waste of bandwidth. Here's an example - the satellite channel of 50 Kbps with a total delay of 500 ms. Suppose we want to use protocol 4 to the frame size of 1000 bits. At the time of 0 ms sender sends the first frame. The 20 ms frame is completely sent in 270 ms and it is accepted in 520 ms sender received confirmation. These figures suggest that the sender was blocked during 500/520, ie 96% of the time. And this - the loss of bandwidth.

This problem is a consequence of the rules by which the sender waits for an acknowledgment before sending the next frame. This requirement can be relaxed - allow the sender to send to n frames without waiting for their confirmation. The proper choice of the values *N* of n (window size), the sender can fill all of the time needed for sending a frame and receiving confirmation. In the above example, n must be equal to at least 26. This is exactly the number of frames that the sender will have time to send over 520 ms, before you will receive a confirmation to frame 0. So are unconfirmed 25 of 26 shots, a window will be on the sender 26 frames.

This technique is known as the conveyor. Its use in the event of unreliable channel faces a number of problems. The first of them - what to do if in the middle of the stream disappears or gets corrupted frame? The recipient has already received a large number of frames to the point when the sender detects that something has happened. When the recipient receives the damaged frame, he must discard it; what to do with the subsequent frames? The link layer is required to transmit packets to the network layer in the order in which they sent to the sender.

3. MODEL SELECTIVE REPEAT

With the increase in the window size error probability in the window is increased. We consider the probability of occurrence of an error in the i-th frame in the size of m frames. From the theory of probability is known [4] probability distribution between the possible values of a random variable - the number of occurrence of an event at m experiments

$$P_{k,m} = C_m^k * p^m * q^{m-k} ,$$

where p – error probability in the frame,
$q = 1 - (1 - e)^N$,
C_m^k — the number of ways in which of the m experiments can select k.

The probability of a successful transmission of a frame in the i-th attempt

$$q_i = (1 - q)(1 + q + q^2 + q^3 + \cdots + q^i)$$
$$q_i = 1 - q^i$$

q – probability of distortion of one frame.
$q = 1 - (1 - BER)^n$,
n – size of frame,
k – number of frames in window,
$q_k = 1 - (1 - (1 - BER)^n)^k$,
BER –Bit Error Rate - the probability of bit errors.

Define the number of attempts to retransmit the frame, which achieved given the likelihood of a successful transfer:

$$P_{set} = 1 - q^i,$$

then,

$$m = \frac{\lg(1 - P_{set})}{\lg q_k}$$

The expected number of attempts until the first successful delivery of all the frames in a window (Figure 1):

$$M(i) = \sum_{i=1}^{\infty} p_i * i ,$$

where i - number of attempts,
p_i – the probability of delivery of undistorted frame on the i-th attempt,
p_k - the probability of delivery of undistorted k frames in the window, $p_k = 1 - q_k$

$$M(i) = \frac{p_k}{(1 - q_k)^2} = \frac{1}{p_k} \quad (1),$$

which determines the rigid dependence protocol performance, the level of noise in the channel.

Figure 2 for Pspec = 0.97 and BER = 10^{-3} with an increase in the frame size dramatically increases the number of repetitions. When BER <10^{-3} the number of repetitions of the frame does not exceed two. If the calculations to take BER=10^{-2}, the number of repetitions will increase dramatically, since the size of 500 bytes.

To simplify the calculations we take the ideal data link. Ideally, the data channel BER is equal to 0, in other words, in the data transmission channel frames are not damaged. From Figure 1 we see that the channel data do not expect a receipt. With it we can eliminate waiting time to obtain a receipt. As sending personnel receive positive

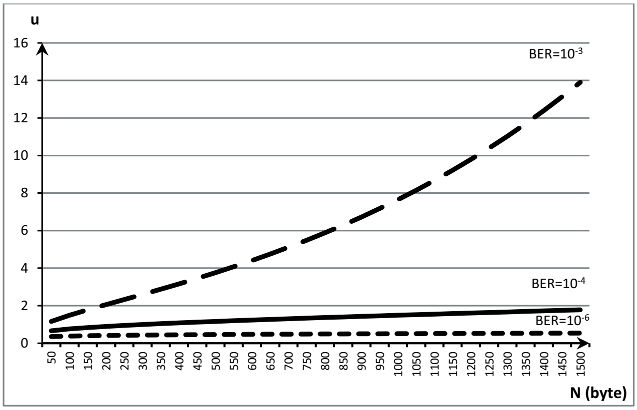

Figure 2. The dependence of the number of transmissions required of successful transmission of the frame at different values of BER depending on the frame size

In addition to delays associated with the transmission time information and frame overhead, it is also necessary to take into account real propagation delay in the transmission media (electric cables, optical, etc.).

The conditions for channel noise estimates transmission times of the N bit data frame introduce real data rate - V.

$$V = \frac{(N_{frame} - C) * k}{T_k} * p_k \quad (1),$$

where N – the length of the frame,
C – number of check bits in the frame,

T time frame transmission

$$T = \frac{N}{R} + \frac{N * S}{R_{sig.pr}} = \frac{N * R_{sig.pr} + R * N * S}{R_{sig.pr} * R} \quad (2)$$

$$T_k = \frac{N * k}{R} + \frac{k * N * S}{R_{sig.pr}} + T_{gap} * k = \frac{k * (N * R_{sig.pr} + R * N * S)}{R_{sig.pr} * R} \quad (3)$$

where T_{gap} – the interval between two frames,
S – the length of the data link,

R – rated speed channel,

$R_{sig.pr}$ – the propagation velocity of the signal in the transmission medium:

$$R_{sig.pr} = c * \mu,$$

where c - the speed of signal propagation in vacuum
μ - relative velocity of propagation of the signal in the data channel.

For the most common cabling fair value for actual speed signal propagation in a vacuum
Coaxial cable - relative velocity of propagation: 0.66 (%) [1]
Twisted pair cable cat3- - relative velocity of propagation: 0.65-0,71 (%) [2]
Fiber-optic cable - the relative velocity of propagation: 0.66-0,78 (%) [3]
Also for Ethernet technology, make calculations for the expression (1) in Figure 3. which shows the actual speed of the channel in view of the length of the channel. Input parameters are defined as follows:

C = 24 bytes, NACK = 72 bytes [4], R = 10 Mb/s, BER = 10^{-5}, $R_{sig.pr} = 1.98 * 10^8$ meter/s

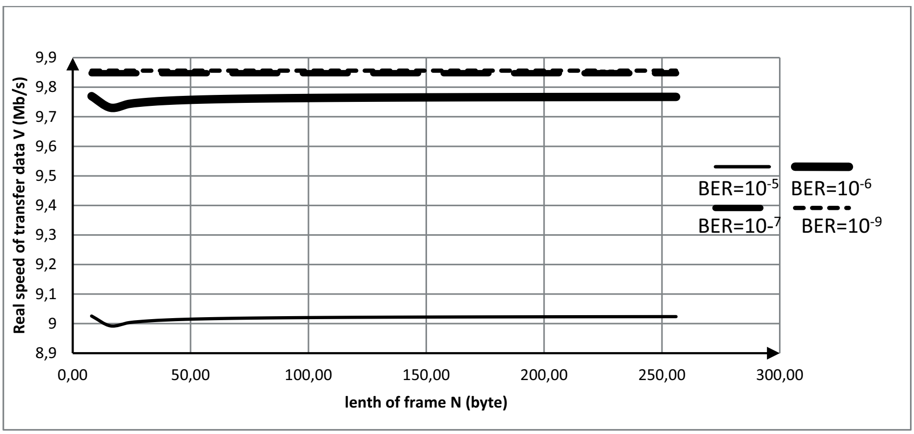

Figure 3. The actual speed of the communication channel (Ethernet)

4. SIMULATION MODEL

A. Formal model of experimental research

Using software Matlab Simulink library (communication tools) has developed a simulation model that implements selective repeat transmission mode.

Block "real speed protocol link layer", depending on the number of frames of repetitions determines the real speed to send the message using the formula:

$$V_{real} = \frac{m*N}{time} \tag{7}$$

where, V_{real} - the actual transfer rate from simulation model, time - time spent on transmitting the message, taken in the simulation.

The simulation model (Figure 4) data for the method of "selective repeat" consists of the following units:

- Formation of the message. In this unit, set the window size and frame size. Formed stream of frames with titles and numbers in the data queue.
- Formation of the transmission window. In this block, the frames are sent depending on the receipt, if received an ACK, is sent to the next frame in the queue, the current frame is sent again if adopted NAK.
- Transfer frames at a nominal rate. Unit transmits frames to the communication channel delays to achieve a given nominal speed.
- Channel without error, to check the transmitted data. The unit checks if the frames in blocks of "acceptance window" and "the formation of a window for the transmission": if the frames are the same, the ACK is sent, otherwise - NAK.

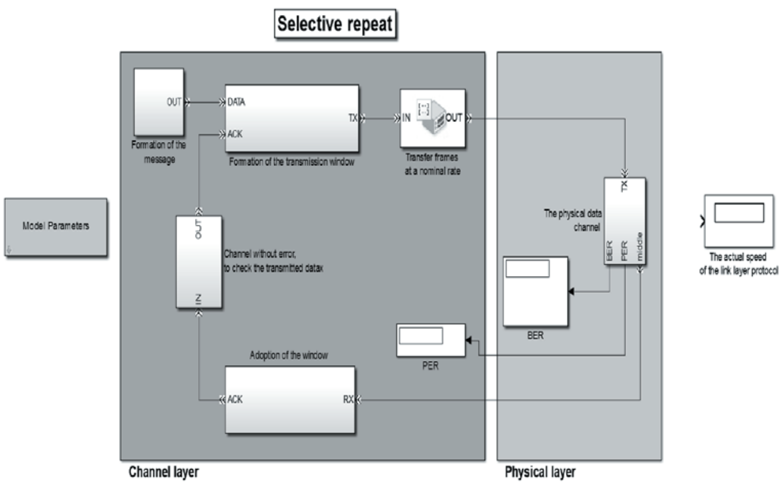

Figure 4. The circuit model of "selective repeat"

Adoption of the window - the received frames in the window.

Model Parameters. In this block, set parameters to determine data transmission method.

PER (package error rate) - the probability of packet errors.

BER - bit error probability in the communication channel.

The physical data channel - channel interference, a given level of probability BER.

The actual speed of the link layer protocol.

4.1. FORMATION OF ERROR FRAMES IN THE TRANSMITTED STREAM

Frame size was chosen 1120 bytes, window size is varied for different values of BER.

C. Interpretation of the measurement results

Simulation models for the three transmission modes have been designed based on real data link layer protocols. For the model of selective repeat the basis was taken HDLC protocol.

Output unit "real speed link protocol" (Figure 5) collected in a file for comparison with the results of analytical modeling. The simulation model noise in communication channels were manually entered data to generate error frames in the stream are listed in section 4.

B. The maximum number of retries on error equal to five has been found in the frames. For example, the first time the source of messages sent to the frame, the recipient of the message, an error is detected in the frame, sends a NAK message to the source, in turn, the source sends the frame again - can maximally be five such repetitions.

Figure 5 shows a comparison of the results of analytical and simulation models at the level of BER = 10-5 for the selective repeat. At the same time it dispatched 3,000 personnel, including both the correct and incorrect frames. Window size ranging from 46 to 1500 with the increased pitch of the frame 2.

Because of the selective repeat the simulation results (Figure 5), we see the results of most of the matches, but also there is a difference in speed. The difference in speed is associated with repeat - it is in these areas was less than the number of repetitions. Due to the high probability of errors the number of repeats ranged from 3 to 5 times.

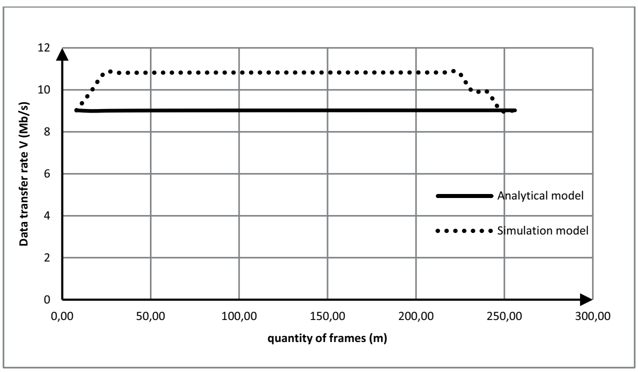

Figure 5. Comparison of the results of mathematical and simulation models at the level of BER = 10^{-5}

Revealed the difference in the rates for the selective repeat, change the speed connected with errors. The difference in the actual speed of the two models is negligible, ranging from 0.1 to 1.2 Mb/s.

5. CONCLUSIONS

In this paper gives the conditions for optimization of real data transmission speed in the standard data link layer protocols, depending on the frame size and level of noise in the communication channels. Recommendations for achieving the highest performance link-layer protocols for method of selective repeat.

Based on the comparisons made by the simulation and analytical models, we can conclude that the results of these methods are similar, although the methods of introducing errors into the communication channels in the two methods were different. The analytical model based on probabilistic interference estimates were evenly distributed, and in the simulation model error types (single, multiple, packet) to be entered manually, i.e. controlled by the user model. Having examined the influence in the simulations of different error types (single, multiple, burst errors) in the link layer protocols performance for the different methods of transmission have been identified as types of errors will affect the performance of data-link protocols.

Comparison of results simulation and analytical modeling, shows that their deviation does not exceed the boundaries of 11%, which confirms the consistency of the experiments.

Best results are achieved when using the selective repetition, thus it is necessary to take into account the buffer size and processing power. The method of calculating the real rate for the methods "Idle RQ", "Go Back N," "SR", based on consideration of the size of frames in windowed mode, the number of frames in the window and the level of interference in the communication channels. Recommendations on the choice of the timer for different methods of communication.

The conditions for optimization of real data transmission rate in the standard data link layer protocols, depending on the frame size and level of interference in the communication channels. Recommendations for achieving the highest performance data link layer protocols.

Bibliography

1. F.I. Kushnazarov, V.V. Yakovlev, “Assessing the impact of noise on the performance of data-link protocols”, Proceedings of the St. Petersburg University of Transport., vo1 1 (42) Dec. - 2015. - pp. 133-138.
2. Standart ISO/IEC 11801 Edition 2.0, IEC 61156-5, IEC 60794-2, IEC 60794-2-20, EN 50173-1, TIA 568C.3
3. N.A. Bashtannik Performance evaluation computer system information measurement and control system for special purposes PhD work. Sciences .:Astrakhan in 2010. 176. Bibliography .: p. 134-145.
4. F. Halsall, Data Communications, Computer Networks and Open Systems. Addison-Wesley, 1996.-907pp.