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OSI-INTERLAYER CONSISTENCY PROBLEM

The article introduces the OSI-interlayer consistency problem, gives the possible solution through the use of developed theoretical foundations the OSI-interlayer protocol consistency. It is known that the formation and organization of data transfer subject to TCP/IP protocol stack, which is the most popular and common in today's networks. In fact, TCP/IP – a systematic set of protocols, is divided into four levels, which are correlated to the OSI reference model. Analysis of the existing scientific approaches to solve the network management problems led to the conclusion about need of their further development and identify contradictory situation, which became the basis of new actual problem. Namely, there are contradictions between the requirements for ICS:between the requirement to improve the effectiveness of ICS, which requires additional costs and the requirement of reducing the cost of the ICS building&between the requirement to improve the effectiveness of ICS, which requires protocols development, and requirement to reduce the protocols cost. The basic hypothesis is advanced that the effective maintenance of interlayer coordination is possible through the use of the proposed technology of permanent horizontal communication in the OSI model layer.

Keywords: *OSI, TCP/IP, network protocol, Internet-technology, OSI-interlayer consistency, TCP-session.*

Introduction

In modern conditions there is widespread use of Internet technologies in various fields of people activity and life – the scientific, medical, industrial, military, business areas and the field of leisure and recreation. It is obvious growing number of users, amount of data, the number of available Internet services, increased demands on the quality of these services. It is known that the formation and organization of data transfer subject to TCP/IP protocol stack, which is the most popular and common in today's networks. In fact, TCP/IP – a systematic set of protocols, is divided into four levels, which are correlated to the OSI reference model.

The main idea of the OSI model is a decomposition of the overall problem (all functions) for the data formation and transmission on the seven levels in the relevant hierarchy. On the one hand, it simplifies the tasks of individual protocols that perform clearly limited to their level of function and enables them to be designed and developed without affecting on other levels protocols. But, on the other hand, with the improvement and the increasing complexity of protocols and technologies all the more acute protocols interactions problem arises, because the question of the protocols consistency at different levels problem solving has been overlooked in the development of the OSI model and the TCP/IP stack (which, in fact, completely subject to all the principles of the OSI organization).

Thus, it is actual scientific and applied problem of interlayer consistency, the solution of which is possible through the use of developed theoretical foundations the OSI-interlayer protocol consistency, which is devoted to this work. The hypothesis is advanced that the effective maintenance of interlayer coordination is possible through the use of the proposed technology of permanent horizontal communication in the OSI model layer.

Analysis of latest research and publications.

Currently, the Global Information Infrastructure (GII) is regarded as the future infrastructure of the information society, serving its information (science, education, mass media, advertising, etc.) and other structures. It is developed the basic system standards of this concept, regulated in the GII International Standards, which are represented in the form of ITU-T Y-series Recommendations [1,2].

In accordance with the standards of the GII is a framework that provides development, implementation and interoperability of existing and future services in the field of telecommunications and information technology applications. This should allow free access to the resources of its users in any place and at any time to ensure the necessary level of security and privacy in a reasonable cost and quality.

Among the goals of the main GII are: providing of communication services variety; support for multiple open applications; to cover all forms of media (audio, text, data, image, video, etc.), its use and handling; minimization the use of the necessary resources for the functioning of the GII; support for mobility, maximizing performance and characteristics such as, for example, transaction processing speed, speed image regenerating etc.; ensuring the necessary level of quality, which expects to receive the service user; software defined indicators of reliability [1,2].

Experience shows that ensuring the QoS (Quality of Service) guarantee in the info-communication systems (ICS) is directly dependent on the performance objectives of each level of the TCP/IP protocol stack. In fact, TCP/IP – a systematic set of protocols, divided into four layers, which are correlated to the OSI reference model [3,4]. The main idea OSI model decomposition is a predetermined function of forming and transmitting data through the links on the seven layers in the respective hierarchies.

On the one hand, this details the individual protocols tasks that perform clearly functions limited their layer, and enables them to design and development, without affecting on other layers protocols. But, on the other hand, with the improvement and the increasing complexity of protocols and technologies all the more acute protocols interactions problem arises, because the question of the protocols consistency at different levels problem solving has been overlooked in the development of the OSI model and the TCP/IP stack (which, in fact, completely subject to all the principles of the OSI organization). Fig. 1 shows a comparison of the layers of the reference models OSI and TCP/IP protocols stack from the point of view of layers compliance, the examples of TCP/IP stack protocols, as well as protocol data units (PDU) of each layer.

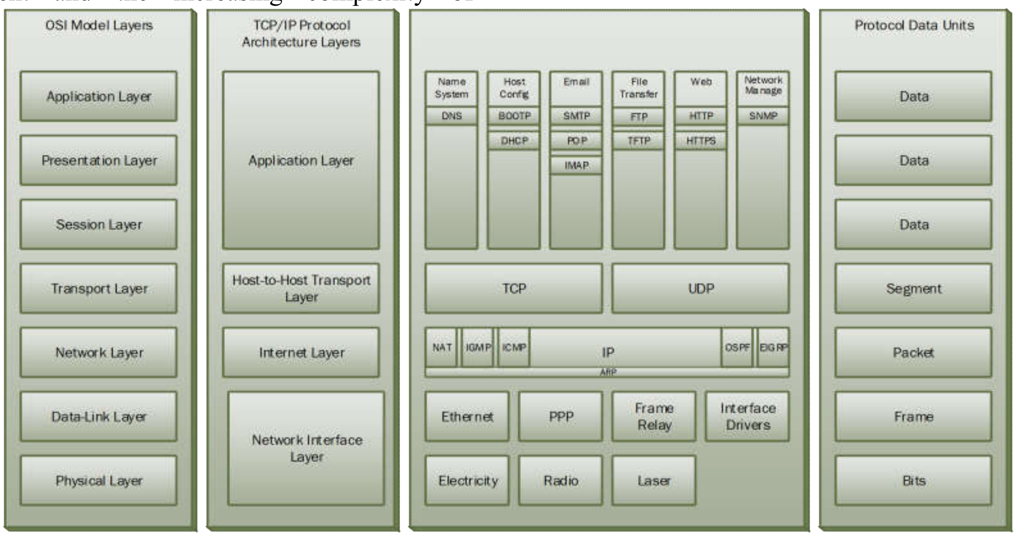

Fig. 1. Comparison of the layers of the OSI reference model and TCP/IP protocols stack

As shown by the analysis traffic control means applying often determines the quality worth noting that to date for the solution of network management tasks developed a number of mechanisms, algorithms and protocols that are in varying degrees of efficiency solve set tasks. The main tasks of traffic management parameters include the management of user traffic (intensity, packet size), traffic distribution process management (routing) and the buffer resource management (service and restriction of queues on the routers, explicit congestion notification).

Consider the general problem of lack of coordination solutions network management tasks on the example of the most common tools – routing. Usually, routing is implemented on the basis of dynamic routing protocols. Currently, the most common protocols used are: EIGRP (Enhanced Interior Gateway Routing Protocol), OSPF (Open Shortest Path First), IS-IS (Intermediate System to Intermediate System), BGP (Border Gateway Protocol) in IP networks [5] and PNNI (Private Network to Network Interface), IISP (Interim Inter-Switch Protocol) in ATM [6]. Advantages of routing protocols are their dynamism that is periodic recalculation of the routes based on information on the network.

However, the most common routing protocols have a number of disadvantages, which include:

the use of the calculating the shortest path algorithm;

route selection based on the network topology, without taking into account information on its current load;

lack of consideration of ICS multiflow and multiprotocol;

lack of consideration of the conditions of congestion avoidance, as well as consistency of decision-making mechanisms intended for this purpose;

presence of only an indirect relationship routing tastes solving with providing a guaranteed quality of service by supporting multiple metrics.

In practice, these disadvantages often lead to overloading of individual routes or networks in general and unjustified loss of data packets, and fluctuations in traffic intensity, which manifests in unstable operation of ICS. In terms of efficient use of network resources, these factors become the reason for the decline in network performance, which is especially noticeable at the level of the individual sessions that are critical to the quality of service indicators.

Thus, the actual problem is formation of primarily theoretical bases OSI-interlayer consistency protocol interactions (or rather the functions performed by separate protocols), and creating an interface, via which it is possible to provide coordinated control of the individual parameters or entire protocol decisions according to current the situation in the network (Fig. 2).

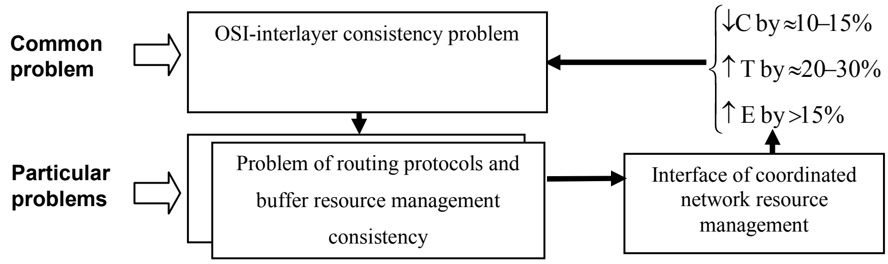

Fig. 2. Communication of general and particular problems

Analysis of the existing scientific approaches to solve the network management problems led to the conclusion about need of their further development and identify contradictory situation, which became the basis of new actual problem. Namely, there are contradictions between the requirements for ICS:

between the requirement to improve the effectiveness of ICS, which requires additional costs and the requirement of reducing the cost of the ICS building;

between the requirement to improve the effectiveness of ICS, which requires protocols development, and requirement to reduce the protocols cost.

This contradictory situation is the basis of relevant, new scientific and applied problem of interlayer consistency or in other words the problem of ensuring consistency the operating parameters of the network protocols in the real ICS.

The relationship of contradictions and problem is shown in Fig. 3.

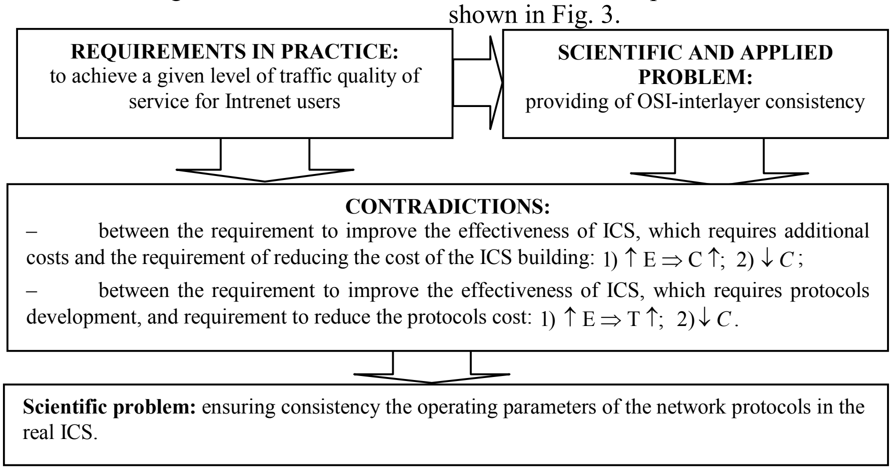

Fig. 3. Contradictions scientific and applied problems relationship

The aim of the article is to give the solution to the scientific problem by the application of the developed theoretical foundations to ensure the OSI-interlayer consistency. At the moment, the existing network protocols are little related to each other through interaction interfaces of OSI model layers, thus solving their tasks autonomously and just providing services for the upstream and downstream layers.

Providing technology of permanent horizontal communication within the OSI model layers as a basis of the consistency ensure hypothesis is proposed on the basis of a strategy that consistently implements the following steps: a) the choice of a system of OSI model indicators; b) the development of mathematical models with horizontal connections; c) development of the optimization criteria; d) multi-criteria optimization.

Presentation of the main research material

It should be noted that, in general, to date for the mathematical description of the ICS, there are many approaches, which are based on the use of the capabilities of different mathematical apparatus [7-9]. Among them are the game-theoretic models, optimal decision making models, control machines models, probabilistic and aggregative models of complex systems. Each of the mathematical apparatus determines its approach to the formalization of the tasks associated with the routing process, the management of network parameters and the process of information exchange, which ultimately formulated as optimization problems.

Besides these mathematical approaches, it deserves attention apparatus of differential equations of the network state, which corresponds quite accurately the requirements. Within the framework of the state set model requarements of processes dynamics (including TCP-session), taking place in the ICS, change network settings (structural and functional), as well as the integration of the simultaneous existence of several flows in the network are satisfied.

As an example, consider the process of information exchange in the IP-network, wherein the establish and support the TCP-session in order to prevent possible overloading on intermediate nodes and the subsequent communication packet loss, additional algorithms are used [10]. In order to prevent buffer overflows, packets are begin to drop in advance for notify transmit nodes, seeing rejection, to reduce their rate. TCP applications reduce the transmission rate when them detects packet drop. For preventive restrictions queues used algorithms such as RED (Random Early Detection) and WRED (Weighted Random Early Detection) [11-15].

In order mathematical description of simultaneous TCP-sessions based on classes of service in accordance with the version of TCP Tahoe [16,17] the dynamics of multiflow data exchange based AQM-algorithms (Active Queue Management) is displayed as a system of equations:

$$\frac{d\lambda_i^k(t)}{dt}=\begin{cases}\text{slow start}:\\ \left(1-P^k(t)\right)\cdot\dfrac{MSS}{RTT^k}\cdot\lambda_i^k(t)-P^k(t)\cdot\left(\lambda_i^k(t)\right)^2+P^k(t)\cdot MSS\cdot\lambda_i^k(t);\\ \text{congestion avoidance}:\\ \left(1-P^k(t)\right)\cdot\left(\dfrac{MSS}{8\cdot RTT^k}\cdot\lambda_i^k(t)+\dfrac{MSS\cdot MSS}{\left(RTT^k\right)^2}\right)-\\ -P^k(t)\cdot\left(\lambda_i^k(t)\right)^2+P^k(t)\cdot MSS\cdot\lambda_i^k(t),\end{cases} \quad (1)$$

where λ_i^k - traffic intensity i-th of TCP-session in flow with k-th class of service ($i=\overline{1,M^k}$), M^k - the number of TCP-sessions k-th flow, $k=\overline{1,K}$, K - the number of classes of service; RTT^k - round trip time of k-th stream; P^k - the probability of dropping (block) packages of k-th class of service.

The probability of packet drop can be formalized in accordance with the AQM-algorithms that implement the preventive limitation of the queue before it actually overflows. Moreover, for each class of service is generally planned to organize a separate queue with different models of packet drop.

So the RED algorithm [11-14], which was developed to take into account classes of service WRED, the calculation of the probability of packets dropping with k-th service class is made in accordance with the expression:

$$P^k(t)=\frac{1}{m^k}\cdot\frac{N^k(t)-N^k_{min}}{N^k_{max}-N^k_{min}}, \quad (2)$$

where m^k - mark probability denominator; N^k_{min}, N^k_{max} - the minimum and maximum size of the queue, respectively; $N^k(t)$ - the average queue size at the network node.

For further research as a model dropping packets used the expression (2), and the average size of the queue $N^k(t)$ calculated based on the Little formula:

$$N^k(t)=\frac{\sum_{i=1}^{M^k}\lambda_i^k(t)}{B^k-\sum_{i=1}^{M^k}\lambda_i^k(t)}, \quad (3)$$

where B^k - connection bandwidth allocated to k-th TCP flow.

In order to confirm compliance of the proposed model (1)-(2) to data transmission process in TCP-session real conditions research of one TCP session was conducted, during which intensity $\lambda(t)$ was the calculated. Initial data: the value of the available bandwidth B=100 Mb/s; congestion window at the receiving node equal to 64 KB; data segment size MSS = 1460 bytes. Graphically, the solutions of equations (1)-(2) for different values of RTT are shown in Fig. 4.

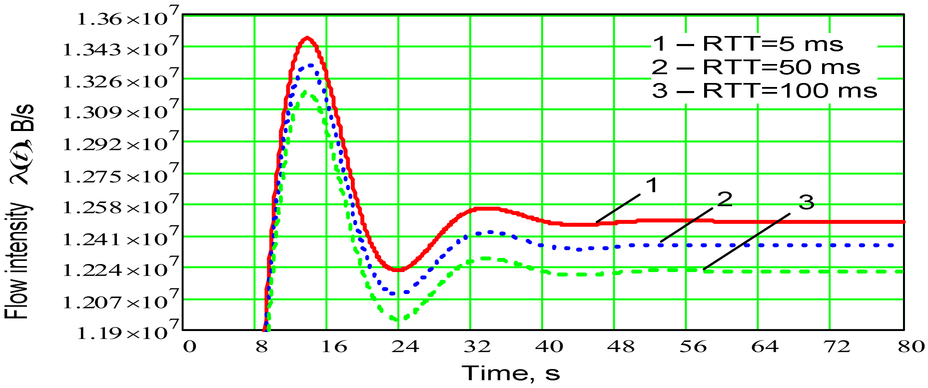

Fig. 4. Changing the flow intensity in a TCP-session for different values of RTT

Fig. 4 shows that, firstly, the change of intencity $\lambda(t)$ is oscillatory and at some point of time is set at a certain value, which corresponds to the actual process of data exchange with the TCP protocol. Secondly, with a decrease in the segment round trip time RTT (which means, for example, of improving the channel or free channel and buffer resources), the intensity, which reaches a TCP flow at steady state, increases and tend to the value of connection bandwidth.

The resulting model (1)-(2) has a pronounced non-linear character that from a mathematical point of view means presence of nonunique solutions of equations that lead to qualitative changes in the system behavior in certain conditions. In practice, the analysis showed a loss of stability causes oscillation of both external and internal parameters and operating conditions. The internal parameters include the TCP protocol, AQM-algorithms (in the framework of the proposed RED algorithm models) and modes of transmission in accordance with the version of TCP. The external parameters leading to a TCP session instabilities include changes in the network structure (the failure or addition of network links and nodes, which causes a change in the available bandwidth), an abrupt change in the intensity of transmitted traffic, increasing propagation delays, as well as presence of other types of traffics (considering transit flows and short-lived connections).

Investigation of the TCP-session reaction to fluctuations or administrative changes of these parameters and the further behavior is performed by making changes to the original set of equations (1)-(2). The changes concern parameters included in the system of equations (1)-(2) or of the structure and type of the initial differential equations. Fig. 5 shows the cases of stability loss, by which is meant the deviation of the TCP-session from the stationary state. In this case, the steady state is the mode when the intensity of the TCP flow with time is set to a value close to the real connections bandwidth.

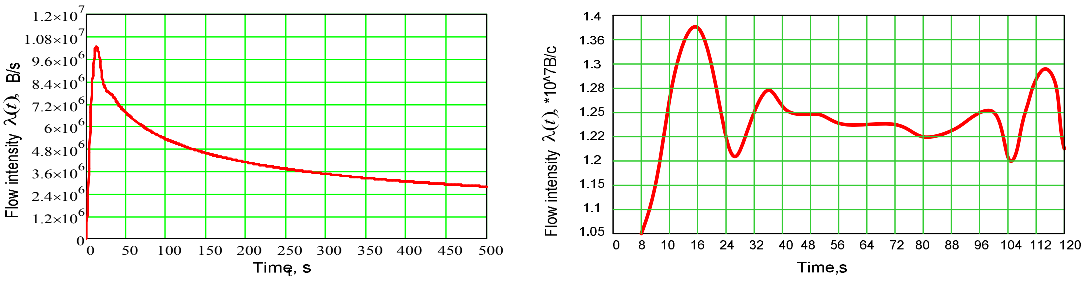

Fig. 5. Changing the flow intensity under the unstable TCP-session

Conclusions and perspective for future research

Thus, it is worth emphasizing the need to address such problem as the detection and analysis of the causes and consequences of the unstable operation of TCP-sessions [16-18]. Most of the traffic management tools are inadequate to ensure QoS and they often cause the loss of ICS effectiveness. It was found that this is due to shortcomings of mathematical models and heuristic schemes that formed the basis of these algorithms.

These studies will provide an additional stage of the mathematical description of ICS, which would then be the basis for advanced network protocols and technologies, as well as help to consistently manage settings specific protocols at various layers to ensure the exchange of data in the TCP-sessions. For the end user this will mean a decrease sessions disconnections, delays, network devices and channels congestion, packet loss and, consequently, improve quality of service.

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ПРОБЛЕМА OSI-МЕЖУРОВНЕВОЙ СОГЛАСОВАННОСТИ

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В статье уделено внимание научной проблеме OSI-межуровневой согласованности. Решение данной научной проблемы возможно путем использования разработанных авторами теоретических основ OSI-межуровневой согласованности протоколов, чему и посвящена данная работа. Известно, что формирование данных и организация их передачи подчиняются протоколам стека TCP/IP, который является наиболее популярным и распространенным в современных сетях. Фактически TCP/IP – это систематизированный набор протоколов, делится на четыре уровня, которые коррелируются с эталонной моделью OSI. Главной идеей модели OSI является декомпозиция общей задачи (всех функций) по формированию и передачи данных по каналам связи на семь уровней в соответствующей иерархии. Это, с одной стороны, упрощает задачи отдельных протоколов, которые выполняют четко ограниченные своим уровнем функции и дает возможность их разработки и развития, не мешая протоколам других уровней. Но, с другой стороны, с совершенствованием и усложнением протоколов и технологий все более остро встает задача их взаимодействия, потому что вопросу согласованности решения задач протоколов разных уровней не уделялось достаточное внимание при разработке модели OSI и стека TCP/IP (который, собственно говоря, полностью подчиняется всем принципам организации OSI). Таким образом, актуальной является научно-прикладная проблема обеспечения межуровневой согласованности, разрешение которой возможно путем использования разработанных авторами теоретических основ OSI-межуровневой согласованности протоколов, чему и посвящена данная работа. Выдвигается гипотеза о том, что эффективное обеспечение межуровневой согласованности возможно путем применения предложенной технологии постоянных горизонтальных связей в моделях уровней OSI.

***Ключевые слова:** OSI, TCP/IP, сетевой протокол, Интернет технологии, OSI-межуровневая согласованность.*

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