DOI:https://doi.org/10.15276/aait.02.2019.1

UDC 004.9

METHOD OF DYNAMIC FORMATION OF CONTENT IN CONDITIONS OF LIMITED RESOURCES

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ABSTRACT

This paper presents a method of dynamic formation of content in conditions of limited resources to improve the quality of the process of receiving and transmitting information. The developed method is based on the model of the receiving part of the information receiving and receiving system, the basic content model and the model of the information receiving and transmitting system. To develop the method, the heterogeneity of the system for receiving and transmitting information and the types of information transmitted to the user was investigated. The method of dynamic formation of content (type, format) takes into account the characteristics of all components of the system for receiving and transmitting information and provides the definition of the necessary content for real-time transmission over the Internet. The method includes determining the speed of receiving and transmitting information, determining the characteristics of the device and the browser based on the model of the receiving part of the system of receiving and transmitting information, choosing the type of content (multimedia, video, text, etc.), on the basis of the developed decision rules, depending on the characteristics defined in the model of the receiving part of the system for receiving and transmitting information, show of the selected type of content on the user's screen, taking into account the operating system, browser, browser window, using the content model and the model of the receiving part of the system for receiving and transmitting information, and checking the need to change the type of content. Checking the need to change the type of content occurs in two cases: if a new user connects during a session and if no users connect within a specified time slice. Thanks to the developed method, when connected to a site, the user will receive information in the form that his device can play. To assess the quality of the developed method, an experiment was conducted with the participation of students. As a result of the experiment, it was proved that the quality of the process of receiving and transmitting information increased by 1.55 times due to the use of the developed method of dynamic content formation.

Keywords: Distance Learning; Mobile Learning; Content; Content Formation; Receive Data; Transmit Data; Method of Dynamic Content Formation; Limited Resources

***For citation*: Victor A. Krisilov, Katherine A. Pysarenko, Vu Ngoc Huy Method of Dynamic Formation of Content in Conditions of Limited Resources. *Applied Aspects of Information Technology*. 2019; Vol.2 No.2:89–104. DOI:https://doi.org/10.15276/aait.02.2019.1**

INTRODUCTION. FORMULATION OF THE PROBLEM

At present, due to the rapidly growing characteristics of the systems of reception and transmission, storage, processing and display of information, work on the Internet has become a common task.

But the quality of the process of receiving and transmitting information (RTI) significantly depends on the characteristics of software and hardware.

Thus, users with devices that have low performance, or due to poor communication channels, mustn't receive the information of interest [1, 2], [3, 4], [5]. As a result, users leave the site they are interested in because of the low characteristics of the software and hardware. So, organizations that provide users with heavy, seemingly high-quality content may lose potential customers because the latter have no opportunity to view it [5, 6].

Research, development and application of methods and means of adapting content to the characteristics of software and hardware of a specific system of receiving and transmitting information (SRTI) are aimed at creating new methods for compressing in-formation [7, 8], [9, 10], [11, 12], new protocols RTI [13, 14], [15, 16], [17, 18], [19], intelligent tools for analyzing and dynamically adjusting the processes of the [20, 21] processes or using more powerful hardware of all components of the SRTI. However, such solutions are not suitable for most organiza-tions because of their high cost and complexity of development. Most often, this problem is faced by organizations that provide distance learning services, regardless of which intermediary they use. [22, 23], [24, 25].

The quality of the process of receiving and transmitting information depends on the amount of useful transmitted / received content, the out-of-sync audio and video, the reproduction of all types of

content [26]. It is proposed to evaluate the quality of the PPI process as a percentage of users who do not leave the site due to the delay of the RTI and the quality of information reproduction.

The solution may be to provide the user with such content, which he will be able to view using his software and hardware.

Thus, a study aimed at developing methods for the dynamic formation of content in conditions of limited resources is relevant.

The purpose of this work is improving the quality of the process of RTI in conditions of limited resources by developing a method for dynamic content generation.

According to the goal, it is necessary to solve the following tasks:

– analyze the models used for the dynamic formation of content on the Internet;

– explore the heterogeneity of the SRTI: the software-hardware configurations of the SRTI that are currently in use, on the basis of this, generalize (unify and typify) their description, and the most common configurations form;

– investigate the types of information transmitted to the user: dependencies that describe the types and formats of the transmitted content, and the corresponding characteristics of the SRTI;

– develop a method of dynamic formation of content (type, format), taking into account the characteristics of all components of the SRTI and ensuring the determination of the necessary content for real-time transmission over the Internet;

– perform testing of the proposed method in real time on the Internet.

ANALYSIS OF THE DEVELOPED MODELS FOR THE DYNAMIC FORMATION OF CONTENT

The presented method takes into account previous developments. For example, in [4, 5], [26, 27] goals of the educational process were introduced and the types of content were described, [5] proposed the formation of a learning style based on the student's behavior to determine content adaptability, [27] presented a method for adapting content according to the amount of information transmitted, [28] proposed to present material to the user, based on a special course model and base knowledge.

In [7, 8], [9, 10], [11, 12], [13, 14], [15,16], [17,18], [19,20], [21], the tools that are currently used to improve the quality of RTI are considered. In contrast to the proposed method, the funds are expensive and difficult to develop.

In [30], RESS (Responsive Design + Server-side) technology was considered. When using Server Side components, only the page template that is relevant for the access device is loaded. When resizing the window on the client side changes do not occur, to load the new template when you resize the browser window requires a reboot. In contrast to the proposed model, the technology checks only use the PC / mobile device and browser. So even if the user can get “heavy” content using his smart device, he will receive only the version of the site for mobile devices.

Today, most content adaptation methods, for example [31, 32], are based on content formation depending on the individual abilities of a particular student, so some students get a lighter material, while others get more complicated. But both of them get it in the same form, which does not solve the problem of reproducing some types of content on devices with weak characteristics.

The developed method is based on the model of the receiving part of the system for receiving and transmitting information, the basic content model and the SRTI model. Consider them in more detail.

[28] Represents the model of the receiving part of the system of transmission and reception of information:

$$RD=< tc, tg, os, srd, p, ms, b, ssb, v_{pp} >,$$

where: *tc* – the type of connection available to the user; *tg* – the type of device with which the user gets access to the information; *os* – the user's operating system; *srd* – the resolution of the user's device screen; *p* – the user's device processor*; ms* – user device memory; *b* – browser; *ssb* – browser window size; *vpp* – RTI speed.

Each of these characteristics is used by method of dynamic formation of content.

[28] Also represents the basic content model:

$$I=< tp, d, C>,$$

where: *tp* – the type of content that will be used, depending on the user's characteristics; *d* – section availability to a specific user; *C* – content.

Content *C* consists of many sections of the site, each of which can have a number of elements:

$$C = \bigcup_{i=1}^{n} R_i \text{ , where } R_i = \bigcup_{j=1}^{m} r_{ij} ,$$

where: *R* – many sections of the site that provides information resource; $r \in R$ – an element of the section R; *i* – the index that indicates the minimum number of sections; *n* – the index that indicates the maximum number of partitions; *j* – the index that indicates the minimum number of elements in a particular section; *m* – the index that indicates the maximum number of elements in a particular section.

The element of the section *r* in the general case can be represented as follows:

$$r=<tct, v_r, pr, sct, ct>,$$

ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)

where $tct \in T$ – the content type of the item;
T – type of content (video, graphics, text, etc.);
v_r – the recommended RTI speed; pr – the priority of using this element with other elements with an equal size of sct; sct – the size of the content element of the transmitted information in bytes; ct – the content part of the element.

The SRTI model [4,5], [6], [29] contains a description of the user, an information resource and their interaction based on the model of the CSPP receiving part and the basic content model (Fig. 1).

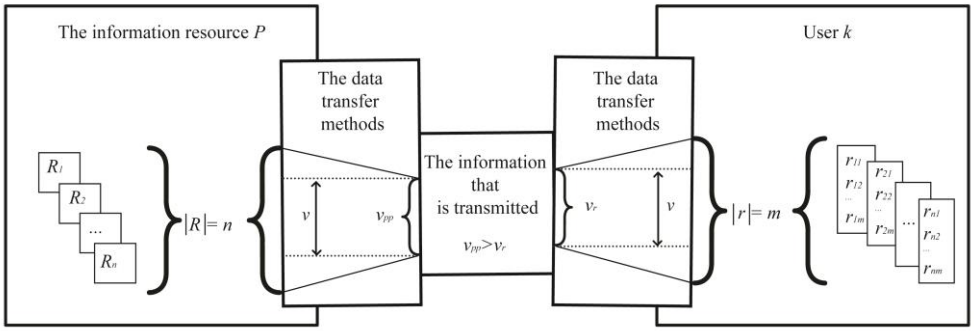
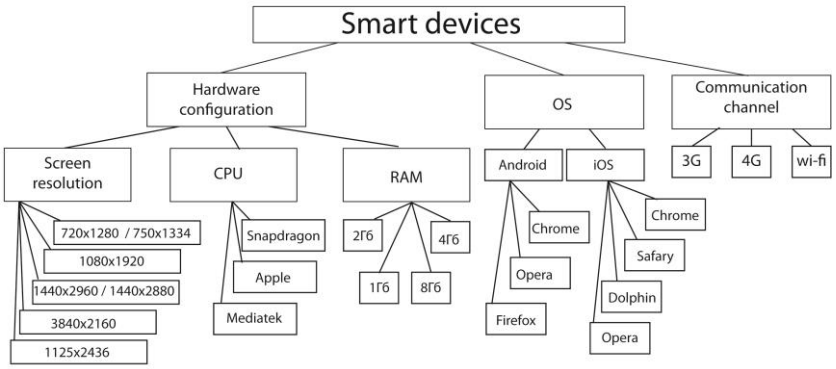


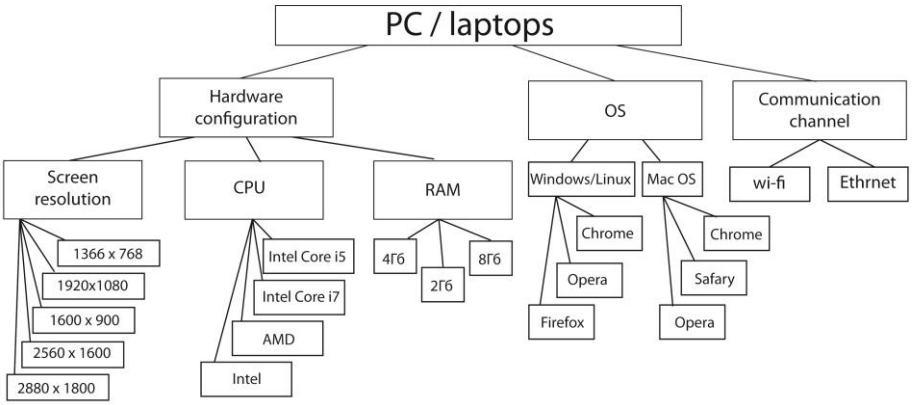
Fig. 1. **The SRTI model**
Source: **compiled by the authors**

1. HETEROGENEITY OF SRTI

The solution of the problems of RTI is considerably complicated by the heterogeneity of the information media used in the SRTI. At the same time very different hardware, the characteristics of which (processor, memory, network equipment) lie in a wide range, are used. Software (operating systems, browsers, information compression tools, network protocols of different levels) is also very different.



a



b

Fig. 2. **Characteristics of user software and hardware when using: a – smart devices; b – PCs and laptops**
Source: **compiled by the authors**

ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)

All this can vary in different sessions even for one user, therefore there is a problem of compatibility of all components of the SRTI, and this, in turn, affects the quality of the RTI process.

SRTI heterogeneity can be divided into two blocks: SRTI heterogeneity for smart devices and for PCs/laptops, because software and hardware for these blocks are very different from each other and the decision rules that are developed for the method of dynamic content generation take into account both blocks. It was decided to present the heterogeneity of the SRTI in the form of Fig. 2 for clarity of the differences in software and hardware used when working on PCs/laptops or smart devices.

Fig. 2a shows the most common software and hardware of Ukrainian users who use smart devices to access an information resource.

Fig. 2b shows the most frequently encountered software and hardware by Ukrainian users who use PCs and laptops to access information resources.

The above figures show the specifics of using tools and networks by Ukrainian users, which will continue to be a limitation for the method of dynamic formation of content.

2. TYPES OF INFORMATION TRANSMITTED TO THE USER

To highlight the types of information transmitted to the user, consider the classes that can be conducted for users who take a distance course. Types of classes are divided into: lecture, practical, laboratory and control classes. Each type of activity must be represented using a certain type of content. The types of content will include: multimedia, audio/video, presentations, text.

The best option is the online broadcast of classes, but not for all such classes are possible because of the exact time of their conduct. Another option is to view recorded online class broadcasts. However, these cases require quite powerful hardware of users' devices and high-speed Internet. In conditions when it is necessary to study course materials, with the help of devices that have small technical characteristics, it is possible to provide lesson materials in a simpler form.

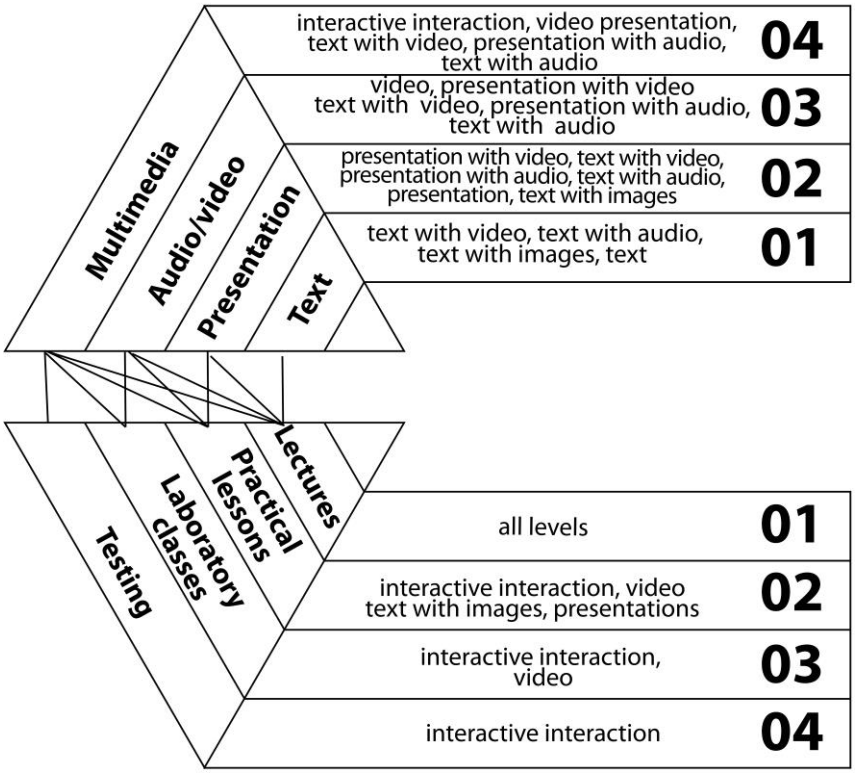


Fig. 3. **Attitude of content types to types of interaction between students and teachers**
Source: **compiled by the authors**

Fig. 3 shows the relationship of content types to student interactions. Information that a user can rceive is presented in four basic levels, where each level has fuzzy boundaries and can intersect with the previous and next levels. For each level of content types, information types are indicated in order of increasing complexity of transmitting and receiving this

information. For each level of interaction types, possible types of information presentation are indicated.

Information that a user can receive is based on the types of content and is presented in the form of four basic levels, where each level has fuzzy boundaries and can intersect with previous and subsequent levels: multimedia, audio / video, presentations, text.

The types of information that a user can receive:

– at the sight of the "multimedia" content - interactive interaction, presentation with video, text with video, presentation with audio, text with audio;

– at the sight of the "audio / video" content - video, presentation with video, text with video, audio, presentation with audio, text with audio;

– at the sight of the "presentation" content - presentation with video, text with video, presentation with audio, text with audio;

– at the sight of the "text" content - text from video, text from audio, text.

At the same time, the text has the lowest complexity of reception and transmission, while multimedia has the highest.

Kinds of activities can use a certain type of information, which the user can receive. Testing is related to multimedia, because Interactive interaction of the student is necessary for a qualitative assessment of his knowledge. To pass the laboratory work can be used by media or audio-video. For the delivery of practical work can be used multimedia, audio-video, presentations. For the presentation of lectures can be used any of these types of information that can be received by the user.

3. CORRESPONDENCE BETWEEN RTI SPEED AND CONTENT TYPE

The method of dynamic formation of content is based on the idea that the user will receive such a kind of content that will be able to reproduce his device taking into account its characteristics and quality of the communication channel.

Therefore, consider the possible types of content and the conditions in which they can be transferred to the user.

The type of content is selected in accordance with the speed RTI. Experiments have been conducted to assess the required RTI speed when viewing content of various types.

Standard characteristics of the Internet speed recommended when viewing a video are shown in Table 1.

Table 1. **Recommended video bitrate**

Type of translation	Standard frame rate (24, 25, 30)	High frame rate (48, 50, 60)
2160p (4k)	35-45 Mbps	53-68 Mbps
1440p (2k)	16 Mbps	24 Mbps
1080p	8 Mbps	12 Mbps
720p	5 Mbps	7,5 Mbps
480p	2,5 Mbps	4 Mbps
360p	1 Mbps	1,5 Mbps

Source: **compiled by the authors**

Experiments were made, the audience of which consisted of students. Experiments have shown that with the standard frame rate (24, 25, 30), provided that the communication channel at the time of viewing will be used only for viewing, and other programs will not download any files, for viewing video of average quality (480p) the optimum Internet speed is at least 2-3 Mbps, for HD video (720p) – at least 8 Mbps, for movies in FullHD (1080p) format - at least 12 Mbps.

For the method of dynamic formation of content, based on the above, a correspondence was established between the speed of the RTI and the type of content, which is presented in Table 2.

Table 2. **Type of content that is provided to the user at a certain speed RTI when using PC**

Type of content	Speed
Multimedia	>18 Mbps
FullHD video	12-18 Mbps
HD video	8-11 Mbps
Text + high quality images + audio	6-7 Mbps
SD video	3-4 Mbps
Text + audio	3-4 Mbps
Text	< 3 Mbps

Source: **compiled by the authors**

When watching videos in good quality, you need to take into account not only the RTI speed, but also the capabilities of the device on which the video will be viewed. For example, on a laptop with a dual-core processor, performance may not be enough to play video in FullHD format, and the video will go jerky, although the Internet speed may be enough. Therefore, decision rules were formulated for the provision of a certain type of content, using the method of dynamic formation of content, depending on the characteristics of user devices and the speed of RTI.

4. TYPICAL CONFIGURATIONS OF USER DEVICE CHARACTERISTICS

To represent the decision rules, let us present typical configurations of user device characteristics, where the configuration number corresponds to the characteristic index in the formulas (Tables 3; 4; 5 and 6).

ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)

Table 3. **Typical configurations characteristics user devices: connection type, the screen resolution of the user device**

No.	*tc*	*srd*	*ms*
1	*wifi*	≥(1080x1920)	≥4GB
2	4G	≥(1366 x 768)	≥8GB
3	3G∧4G	≥(720x1280)	≥2GB
4	–	–	3>ms≥2GB

Source: **compiled by the authors**

Table 4. **Typical configurations of user device characteristics: device type, memory size of the user device**

No.	*tg*	*ms*
1	PC ∧ laptop	≥4GB
2	tablet ∧ smartphone	≥8GB
3	–	≥2GB
4	–	3>ms≥2GB

Source: **compiled by the authors**

Table 5. **Typical configurations of user device characteristics: operating system, processor**

No.	*os*	*p*	*op*
1	Windows ∧ Linux ∧ MacOS	Intel ∧ AMD	os1 ∧ p1
2	Android ∧ iOS	Snapdragon ∧ Apple	os2 ∧ p2

Source: **compiled by the authors**

Table 6. **Typical RTI speed configurations**

No.	***v***
1	≥ 18 Mbps
2	≥ 8.5 Mbps
3	$12 \le v < 18$ Mbps
4	$8 \le v \le 11$ Mbps
5	$6 \le v \le 7$ Mbps
6	≥ 5 Mbps
7	≥ 4 Mbps
8	≥ 3 Mbps
9	$3 \le v \le 4$ Mbps
10	≥ 2 Mbps
11	$1.5 \le v < 2$ Mbps
12	< 3 Mbps
13	< 1.5 Mbps

Source: **compiled by the authors**

DECISION RULES FOR PROVIDING USERS WITH CERTAIN TYPES OF CONTENT

Seven decision rules were developed to provide users with a specific type of content.

The first decisive rule is to provide the user to a type of content – multimedia, be it lectures, laboratory or practical exercises, testing:

$$T = \text{Multimedia}, x$$
$$(tg_1 \vee tc_1 \vee v_1 \vee ms_1 \vee srd_1 \vee op1) \vee (tg_2 \vee ms_2 \vee srd_1 \vee op_2) \vee ((tc_1 \vee v1) \vee (tc_2 \vee v2))), \quad (1)$$

where: *tg1*, *tg2* – types of devices with which the user gets access to information (Table 4): *tg1* - PC or laptop, *tg2* - tablet or smartphone; *tc1*, *tc2* – type of connection that is available to the user (Table 3): *tc1* - wi-fi, *ec2* - 4G; *v* – RTI speed (Table 6): *v1*≥ 18 Mbps, *v2*≥ 8.5 Mbps; *ms* – memory of the user device (Table 4): ms1≥4Гб, ms2≥8Гб; *srd* – screen resolution of the user device (Table 3): *srd1* ≥(1080x1920);

op – layout of characteristics (Table 3): *op1*=Windows or Linux or MacOS or Intel or AMD, op2=Android or iOS Snapdragon or Apple.

Type of content "multimedia" is provided to the user in one of two cases:

1) Each of the following characteristics takes the first configuration: *tg* is the type of device through which the user gets access to information, *tc* is the type of connection available to the user, *v* is the RTI speed, *ms* is the memory size of the user's device, *srd* is the screen resolution of the user's device and *op* is the composition of the characteristics: *os* is the user's operating system and *p* is the user's device processor. That is, in order to get the type of content "multimedia" the user must use a PC or laptop, wifi, the user must have a PPI speed of more or corresponding to 18 Mbps, the memory size is greater or corresponding to 4 GB, the screen resolution is larger or the corresponding (1080x1920), the user must have an Intel or AMD processor and use one of the following OS: Windows, Linux or MacOS.

2) The user must use a tablet or smartphone, the memory size is more or corresponding to 8 GB, the screen resolution is larger, or the corresponding (1080x1920), the user must have a Snapdragon or Apple processor and use one of the following OSs: Android or iOS, in addition, the user must use 4G and have a RTI speed of at least or corresponding to 18Mbps or 3G-4G and the user must have a PPI speed of at least or the corresponding 8 , 5 Mbps.

The second decisive rule is to provide the user with a type of content – FullHD video, whether it be lectures, laboratory or practical classes, testing:

$$T = \text{FUllHD video}, x$$
$$(tg_1 \vee tc_1 \vee v_3 \vee ms_1 \vee srd_1 \vee op1) \vee ((tg_2 \vee ms_2 \vee srd_1 \vee op_2) \vee ((tc_1 \vee v_3) \vee (tc_2 \vee v_2))). \quad (2)$$

Type of content "FullHD video" is provided to the user in one of two cases:

1) The user must use a PC or laptop, wi-fi. The user's device must have a PPI speed of not more than 18 Mbps and no less than or corresponding to 12 Mbps, more memory or 4 GB correspondingly, more screen resolution, or appropriate (1080x1920), have an Intel or AMD processor. The user must use to use one of the following OS: Windows, Linux or MacOS.

ISSN 2617-4316 (Print)
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2) The user must use a tablet or smartphone. The user's device must have more memory or the corresponding 8 GB, the screen resolution is greater, or the corresponding (1080x1920), have a Snapdragon processor or Apple. The user must use the Android OS or iOS, 4G and have a RTI speed of not more than 18 Mbps and no less than or corresponding to 12 Mbps, or 3G-4G and have a RTI speed of not less than or corresponding to 8.5 Mbps

The third decisive rule concerns the provision of a user with a type of content - HD video, whether it is lectures, laboratory or practical exercises, testing:

$$T= \text{HD video, } x$$
$$(tg_1 \vee tc_1 \vee v_4 \vee ms_1 \vee srd_2 \vee op1) \wedge ((tg_2 \vee ms_1 \vee srd_3\ op_2) \vee ((tc_1 \vee v_4) \vee (tc_2 \vee v_7))). \quad (3)$$

Type of content “HD video” is provided to the user in one of two cases:

1) The user must use a PC or laptop, wi-fi. The user's device must have a RTI speed of no more than or corresponding to 11Mbps and no less than or corresponding to 8Mbps, memory size is greater or corresponding to 4 GB, screen resolution is larger, or appropriate (1366x768), has an Intel or AMD processor and the user must use one of the following operating systems: Windows, Linux or MacOS.

2) The user must use a tablet or smartphone. The user's device must have more memory or the corresponding 4 GB, the screen resolution is greater, or the corresponding (720x1280), has a Snapdragon processor or Apple. The user must use the Android OS or iOS, 4G and his device must have a RTI speed of no more than or corresponding to 11 Mbps and no less or of the corresponding 8 Mbps, or the user must use the Android OS or iOS, 3G ∧ 4G and his device must have speed RTI is greater or corresponding to 4 Mbps.

The fourth decisive rule is to provide the user with a type of content, which may consist of audio, high-quality images and text, whether it be lectures, laboratory or practical classes, testing:

$$T=(\text{Text + high quality images + audio}),\ x$$
$$(tg_1 \vee tc_1 \vee v_5 \vee ms_3 \vee srd_2 \vee op_1) \wedge ((tg_2 \vee ms_3 \vee srd_3 \vee op_2) \vee ((tc_1 \vee v_6) \wedge (tc_3 \vee v_8))). \quad (4)$$

Type of content “text with high quality images and audio” is provided to the user in one of two cases:

1) The user must use a PC or laptop and wi-fi. The user must have RTI speed of no more than or corresponding to 11 Mb / s and no less or corresponding to 7 Mb / s, more memory or corresponding to 6 GB, a larger screen resolution, or appropriate (720x1280). The user must have an Intel or AMD processor and use one of the following operating systems: Windows, Linux or MacOS.

2) The user must use a tablet or smartphone. The user's device must have more memory or the corresponding 2 GB, the screen resolution is larger, or the corresponding (720x1280), has a Snapdragon processor or Apple. The user must use the Android OS or iOS. In addition, the user must use wifi and his device must have a RTI speed greater than or corresponding to 5 Mbps, or the user must use 3G∨4G and his device must have a RTI speed greater or corresponding to 3 Mbps.

The fifth decisive rule concerns the provision of the user with the type of content – SD video, whether it is lectures, laboratory or practical classes, testing:

$$T= (\text{SD video}),\ x$$
$$(tg_1 \vee v_9) \wedge (tg_2 \vee ms_4 \vee v_{10}). \quad (5)$$

Type of content “SD video” is provided to the user in one of two cases:

1) The user must use a PC or laptop and have a PPI speed of no more than or corresponding to 4 Mbps and no less or an appropriate 3 Mbps.

2) The user must use a tablet or smartphone, the memory capacity is more or corresponding to 2 GB and less than 3 GB, and have a RTI speed of more or the corresponding 2 Mbps.

The sixth decisive rule is to provide the user with a tyoe of content in the form of text with audio, whether it is lectures, laboratory or practical exercises, testing:

$$T= (\text{Text + audio}),\ x$$
$$(tg_1 \vee v_9) \wedge (tg_2 \vee ms_3 \vee v_{11}). \quad (6)$$

Type of content “text with audio” is provided to the user in one of two cases:

1) The user must use a PC or laptop and have a PPI speed of no more than or corresponding to 4 Mbps and no less or corresponding to 3 Mbps.

2) The user must use a tablet or smartphone, the memory capacity is more or corresponding to 2 GB and have a RTI speed of less than 2 Mbps but more than 1.5 Mbps.

The seventh decisive rule concerns the provision of a user with a type of content in the form of text, whether it is lectures, laboratory or practical exercises, testing:

$$T= \text{Text } x\ (tg_1 \vee v_{12}) \wedge (tg_2 \vee v_{13}). \quad (7)$$

Type of content “text” is provided to the user in one of two cases:

ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)

1) The user must use a PC or laptop and have RTI speed of less than 3 Mbps.

2) The user must use a tablet or smartphone and have RTI speed of less than 1.5 Mbps.

6. METHOD OF DYNAMIC FORMATION OF CONTENT

The method of dynamic formation of content is based on the obligatory preliminary (at the beginning of each session), also during the entire session (with a given periodicity), determining the characteristics of the SRTI, takes into account both the basic variants of the transmitting part and the characteristics of the receiving part, and based on a system of developed decision rules, which, based on the analysis of the current characteristics of the SRTI, determine the appropriate type of content, which ensures an improvement in the quality of the RTI.

The method of dynamic formation of content consists of the following steps:

1. Start a session.

2. Starting the time counter (by default – 30 minutes).

3. Determination of the RTI speed – v_{pp} for the model of the receiving part of the system of transmission and reception of information – *RD*.

The determination of the PPI speed between the server and the user device is based on the test transmission of a fixed-size packet (3 MB). The RTI speed is calculated as a ratio of the size of the packet that was sent to the user, to the time during which this packet reached the user. Time is defined as the difference between a timestamp before sending a packet to a timestamp upon receiving a packet.

When a new user is connected, a request is sent to the server to select the type of content for the new user, its RTI speed is calculated, and the speed of other users is recalculated. If necessary, users are informed about the desirability of changing the type of content.

On the client side is enabled counter. If within the time period specified by the administrator (30 minutes by default) new users were not connected, a request is sent to the server for checking the content type. After that, the RTI speed for all connected users is recalculated, and if necessary, it is proposed to change the type of content.

4. Determining device and browser characteristics based on model of the receiving part of the system of transmission and reception of information – *RD*: operating system – *os*, screen resolution – *srd*, browser – *b*, browser window size – *ssb*.

Characterization of the device and the browser is distributed between the client and server parts of the system. In the client part, using the window object, we obtain information about the resolution of the user's screen in pixels and data on the size of the browser window in pixels. Using navigator.platform, we obtain information about the operating system used on the user's device. The received data is automatically transmitted to the server upon user authorization. On the server, using the built-in PHP function, the browser used by the user is determined.

5. The choice of content type (multimedia, video, text, etc.), based on the developed decision rules, depending on the characteristics defined in the *RD* model RTI speed – v_{pp} and the recommended RTI speed – v_r

The recommended RTI speed is defined in model of content *C*: the content consists of many sections of the site, and each section – of the section element. For each element of the section, it indicates the content type of this element (video, graphics, text, etc.), the recommended RTI speed is vr, the priority of using this element with other elements, etc, when describing it. Examples of recommended speeds are shown in Tables 2 and 3.

Each section element can be represented by several types of content (video, graphics, text, etc.). The recommended RTI speed for a required section element may vary depending on its type of content.

The required section is selected and the RTI speed – v_{pp} and the recommended RTI speed – v_r of the element of the section are compared. The section element is selected for which the recommended RTI speed will be less than the RTI speed. The selected element of the section checks the content view.

It is checked whether the selected content type meets the decision rules (1-7). If it doesn't comply, then the content is checked, which has less complexity of transmission (Fig. 4). This will occur until one of the types of content complies with one of the decision rules (1-7). In the simplest case, this is text.

6. Reproduction of the selected type of content on the user's screen, taking into account the operating system, browser, browser window, using content models and model of the receiving part of the system of transmission and reception of information.

7. Checking the need to change the type of content occurs in two cases:

– if during a session, a new user is connected;

– if within a specified time has not connected any users.

Because the bandwidth of the communication channel may vary, while students may be asked to change the type of content during the distance course. So that the user does not search for the necessary part of the course, after changing the type of content, it was decided to divide all the content into specific parts (subsections of the course) and put labels so that the user immediately gets to the necessary part of the course. For example, when the text

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changes to video, whether it is vice versa. The best way is when all kinds of content are attached to text data. In this case, even students with low device characteristics and a slow communication channel will be able to view the necessary materials from a distance course.

7.1 Implementation of points 1-5.

7.2. If the selected content has changed, then sending a message to the user about the advisability of changing the type of content.

A message is formed in the form of a feedback form in a modal window, in which the user must choose whether he is ready to change the type of content or not.

7.3. If the user agrees to change the type of content, then the display of a new type of content.

8. USE OF DISTANCE LEARNING SYSTEM

Five experiments were delivered for students.

The first experiment was aimed at assessing the quality of the course reproduction by software and hardware during a videoconference. It was attended by 2 groups of 25 students.

The second experiment was aimed at identifying user preferences regarding software and hardware.

The third experiment was aimed at identifying problems with receiving and transmitting information when using smartphones.

The fourth experiment was aimed at identifying problems with receiving and transmitting information when using PCs and laptops.

The fifth experiment was aimed at assessing the quality of reception and transmission of information using the developed method of dynamic formation of content.

The 2-5 experimentation involved 46 first-year students, 52 third-year students, 34 fourth-year student.

Experiment 1. Video conferencing

To assess the quality of reproduction of the training course by software and hardware used for receiving and / or transmitting data, an experiment was conducted in the form of videoconfaration based on BigBlueButton and Moodle on a server with the characteristics: Ubuntu 14.04.5 LTS 64 bit, 4Гб RAM, 64KiB L1 cache, 4MiB L2 cache, processor Intel (R) Core (TM) i5 CPU 650 @ 3.20GHz, open ports 80, 1935, 9123.

Two Groups of 25 students each were connected with PCs, laptops and mobile phones (headphones, microphone and webcam) with different characteristics of the devices they used. During the class, the quality of audio and video was assessed. With such a relatively small number of distance learning users, 80 % of the participants experienced problems with each of the evaluated components: slowing down the output of the image during the broadcast, lagging the image from the sound, distortion of the sound. At the same time, 12 % of users could not connect to the online lecture in real time due to the insufficient characteristics of the software and hardware used by them.

In addition, it is necessary to take into account that the state of technical means when transmitting or receiving information may vary from session to session. Based on the data obtained using the developed tools for the automated determination of the characteristics of software and hardware in the current session for educational institutions and each student participant, and the specification of the course components transmitted in a particular session, the characteristics of providing information are improved: the image lag is eliminated from sound and slow image output.

Experiment 2. Using of software and hardware that students prefer

Students had to make five connections to a distance course and try to view different types of content from the device they most often work with. At the same time, if a student cannot receive information from the current device, then he should try to change it to a more powerful one, if there is one.

According to the research, 47 % of the entire audience of students begin to take a distance course on the chosen subject with the help of smartphones or tablets. From this it follows that half of the students prefer to master the proposed material using smartphones, but due to the insufficient characteristics of software and hardware and / or poor communication channel they cannot obtain the necessary information on the subject and are forced to change the device with which they work. But it is not always convenient when a student tries to absorb the material, not being at home or at the university. This entails a significant loss of the audience of students who could not see the necessary material, which is confirmed by the following experiment.

Experiment 3. Using smartphones

Since almost half of the students prefer to take a distance course using smartphones (experiment 2), it was decided to evaluate the software and hardware of students to build method of dynamic formation of content to improve the quality of RTI.

Students had to make five connections to a distance course and try to view different types of content from smartphones. In this case, if they believe that they receive insufficient quality information,

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they should switch to using PCs or laptops and try to view the content using new devices. During the experiment, it was recorded that 80 % of students who worked with smartphones, on average after 3-5 connections, switched to using PCs or laptops.

During the first connection to the distance course, all students were given the task to perform a test task, in the form of "multimedia", using smart phones.

Only ~5 % of the entire student audience could work with multimedia:
– 2 students of first year (~4 % of first-year students);
– 2 students of third-year (~4 % of third -year students);
– 3 students of fourth-year (~9 % of fourth-year students).

During the second connection to the distance course, all students were given the task to view a lecture downloaded as a type of video content using smartphones.

Could not watch the video lecture 25 % of the entire audience of students:
– 18 students of first year (~26 % of first-year students);
– 11 students of third-year (~11,5 % of third -year students);
– 4 students of fourth-year (~9 % of fourth-year students).

There were problems with slow loading and video playback in ~31 % of the entire audience of students:
– 22 students of first year (~48 % of first-year students);
– 14 students of third-year (~27 % of third -year students);
– 5 students of fourth-year (~18 % of fourth-year students).

During the third connection to the distance course, all students were given the task to view a lecture loaded as content type "Text + high quality images + audio" using smartphones.

There were problems with viewing images in ~13 % of the entire audience of students:
– 8 students of first year (~17 % of first-year students);
– 5 students of third-year (~10 % of third -year students);
– 4 students of fourth-year (~12 % of fourth-year students).

During the fourth connection to the distance course, all students were given the task of viewing a lecture loaded as content type "text (with low quality images) + audio" using smart phones.

There were problems with viewing images in ~3 % of the entire audience of students:
– 2 students of first year (~4 % of first-year students);
– 1 student of third-year (~2 % of third -year students);
– 1 student of fourth-year (~3 % of fourth-year students).

During the fifth connection to the distance course, all students were given the task to view a lecture downloaded as a "text" type of content using smartphones: all students were able to view text information.

After passing the experiments, a survey was conducted among students who had problems with viewing information. Students had to answer three questions in a test form.

Table 7. **Survey of students participating in the experiment**

Year of study	1	3	4
The number of students who would not try to work with a distance course after finding problems (try to get a lecture later or switch to PC)	6 students (~13 % students of first year)	22 students (~42 % students of third-year)	26 students (~76,5 % students of fourth-year)
The number of students who would try to use other ways of working with the material (but not more than 2 times): try to get a lecture later or or go to the use of PC	40 students (~87 % students of first year)	23 students (~44 % students of third-year)	5 students (~15 % students of fourth-year)
The number of students who would try to use other ways of working with the material (more than 2 times): try to get a lecture later or switch or go to the use of PC	35 students (~76 % students of first year)	7 students (~13,5 % students of third-year)	3 students (~9 % students of fourth-year)

Source: **compiled by the authors**

When connected to a distance course:
– all students were able to see text information;
– only 3 % of students could not see content with images;

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– there were problems with watching videos for 56 % of students;
– only 5 % of students were able to work with multimedia.

At the same time ~ 41 % of students do not want to change the software and hardware used to work with educational material, which entails a decrease in the quality of education.

The results of the experiment confirm the need to use the method of dynamic formation of the content presented in this work.

Experiment 4. Using laptops and PCs

Students had to make five remote course connections and try to view different types of content using a PC or laptop. At the same time, students had to fix all the problems that they have with viewing content.

During the first connection to the distance course, all students were given the task to perform a test task, in the form of "multimedia", using PCs or laptops.

Only ~7,5 % of the total student audience could not work with multimedia:
– 5 students of first year (~11 % of first-year students);
– 3 students of third-year (~6 % of third -year students);
– 2 students of fourth-year (~6% of fourth-year students).

During the second connection to the distance course, all students were given the task to view a lecture downloaded as a type of video content using PCs or laptops.

There were problems with slow loading and video playback in ~5 % of the entire audience of students:
– 4 students of first year (~9 % of first-year students);
– 2 students of third-year (~4 % of third -year students);
– 1 student of fourth-year (~3 % of fourth-year students).

During the third connection to the distance course, all students were given the task to view a lecture loaded as content type "Text + high quality images + audio" using PCs or laptops:

There were problems with viewing images in ~3 % of the entire student audience:
– 2 students of first year (~9 % of first-year students);
– 2 students of third-year (~4 % of third -year students);
– all students of fourth-year were able to view content

During the fourth connection to the distance course, all students were given the task of viewing a lecture loaded as content type "text (with low quality images) + audio" using PCs or laptops: all students were able to view information.

During the fifth connection to the distance course, all students were given the task to view a lecture downloaded as a "text" type of content using PCs or laptops: all students were able to view text information.

Thus, we can conclude that even when using PCs and laptops, a number of students experience problems with reproducing content due to insufficient device characteristics or a poor-quality communication channel.

Experiment 5. Using of the developed method

In this experiment, the distance course was built on the basis of the proposed models, and content was provided using the dynamic content generation method. Thus, the section of the site that was tested was divided into section elements, each of which had a specific type of content and recommended RTI speed. When connecting students to the course, using the method of dynamic formation of content, the rate of RTI was checked, determined the element of the section that can be viewed by each individual student, based on the RTI speed, the recommended RTI speed of each element of the section and the developed decision rules. So, after using the method of dynamic formation of content, all students were able to obtain the necessary information on the course the first time. Only 3 % of student transfers from mobile devices to PCs were registered. At the same time, any student hadn't problems with content reproduction.

In general, the quality of the RTI process can be estimated as the percentage of users who do not leave the course due to the delay of RTI and the quality of playback. Before using the developed method, the quality of the RTI corresponded to 20 %, after its use the quality of the RTI corresponds to 97 %. Thus, the quality of the process RTI increased 4,85 times.

Fig. 4 shows a graph that shows how many students have problems when working with different types of content when using smartphones (*experiment 3*). The Figure shows that in most cases, students who use smartphones have problems playing content.

Fig. 5 shows a graph that shows how many students have problems working with different types of content when using PCs / laptops (*experiment 4*). When using PCs and laptops, students very rarely have problems reproducing content. However, they are still present when playing high-quality images,

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video and multimedia. However, it is impossible to transfer all students to the use of PCs and laptops, if problems arise, because most students are not willing to "end lessly" try to obtain the necessary material (*experiment 3*, Table 7, Fig. 6).

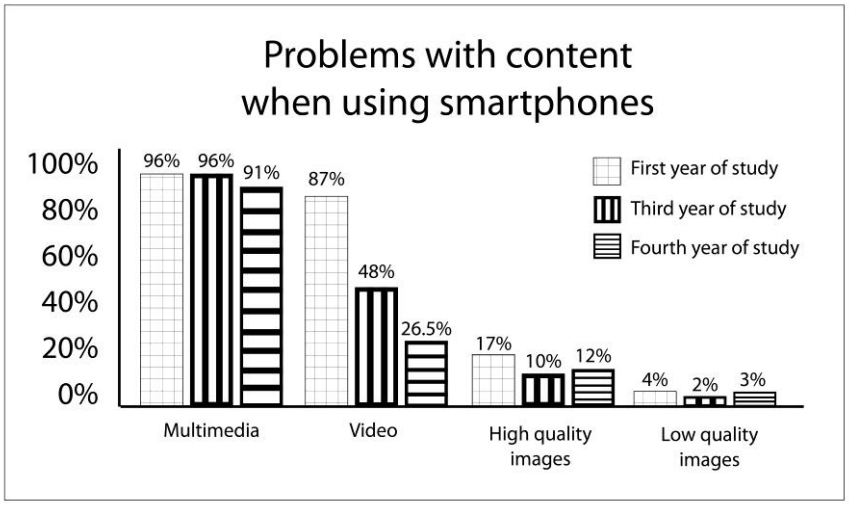

Fig. 4. **Problems with content when using smartphones**
Source: **compiled by the authors**

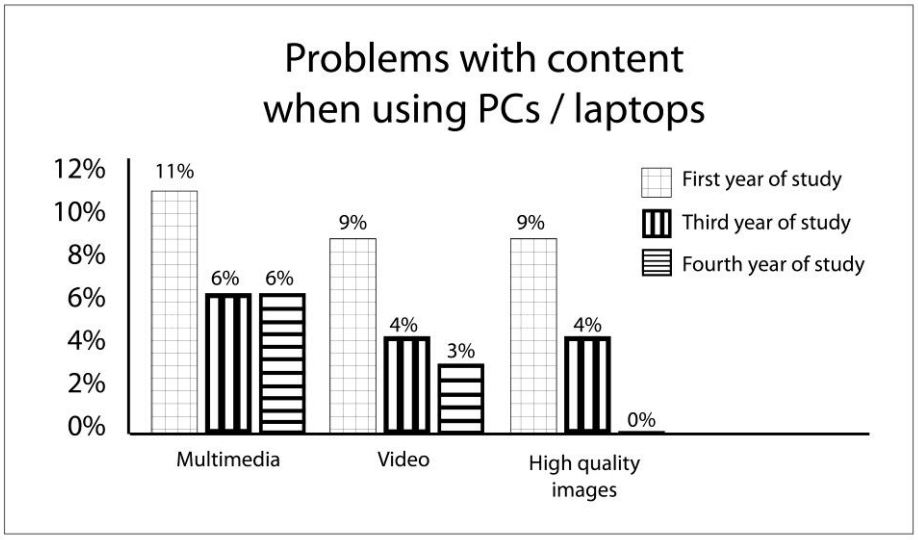

Fig. 5. **Problems with content when using PCs / laptops**
Source: **compiled by the authors**

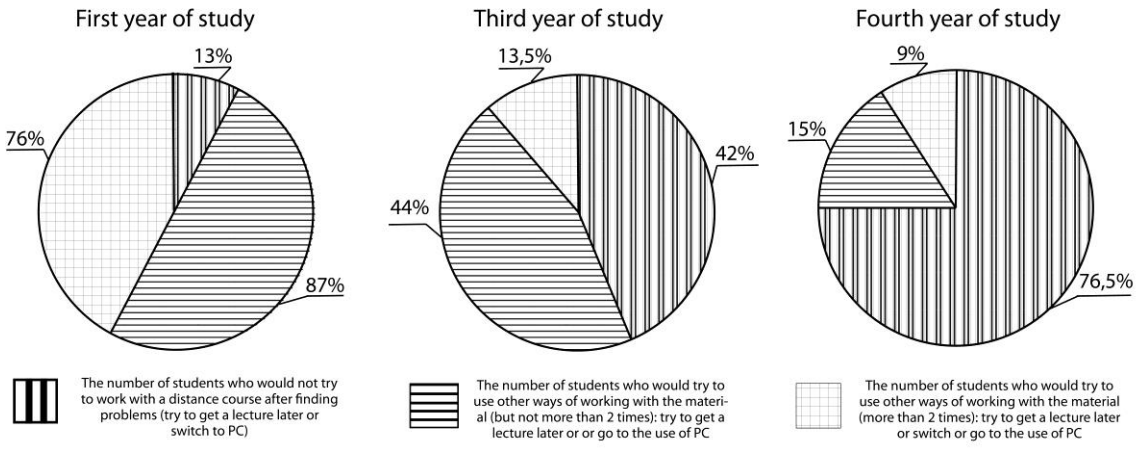

Fig. 6. **The readiness of students to work with the material even in terms of**

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problems with distance courses

Source: **compiled by the authors**

Based on the above, we can conclude that there is a need to use the method presented in this paper.

CONCLUSION

Developed a method of dynamic formation of content, which is based on a system of developed decision rules. The method of dynamic formation of content was used in the information system of dynamic content formation, which was written using php, javaScript, jQuery.

The developed method allows you to present information in such a way that a user who tries to access the site from a device with low characteristics and / or a poor communication channel will still are able to view the necessary content, which will take on a form that the user's device can play.

To assess the quality of the developed method, an experiment was conducted among students of the system software department. 47 % of the entire audience of students involved in the experiment began to take a distance course on a selected subject using smartphones or tablets. After several attempts to connect to the course using mobile devices, 80% of students who worked using mobile devices switched to using PCs or laptops due to poor communication channels or insufficient device characteristics.

THE DISADVANTAGES OF THE METHOD INCLUDE

1. Each section element is desirable to present in several forms: “multimedia”, “FullHD video”, “HD video”, “text + high quality images + audio”, “SD video”, “text + audio”, “text”. At the same time, in addition to the species chosen by the author, the section of the element must necessarily have a representation in the form of textual information. Each element of the section is formed manually by the authors of the course, which increases the complexity of creating content.

2. The method of dynamic formation of content is limited to the use of tools and networks, which are shown in Fig. 2 but, the listed tools and networks, cover a large number of devices and are easily expandable.

Despite the complexity of creating content and a limited amount of software and hardware, after using the developed method, all students (regardless of the devices used) were able to obtain the necessary information on the course from the first time, which differed only in the type of content (text, video, etc.), only 3 % of students moving from mobile devices to PC were registered.

It is proposed to evaluate the quality of the RTI process as a percentage of users who do not leave the course due to the delay of the RTI and the quality of reproduction. The quality of the RTI process when using method of the dynamic formation of content corresponds to 97 %. Due to the use of the developed method, the quality of the RTI process has increased 1,55 times. So, the developed method provides RTI quality improvement process in resource restrictions.

Thus, the method of dynamic content formation will allow potential customers to be saved to organizations that cannot afford expensive technical solutions for their SRTI.

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Conflicts of Interest: the authors declare no conflict of interest

Received 25.01.2019
Received after revision 17.04.2019
Accepted 23.04.2019

DOI: https://doi.org/10.15276/aait.02.2019.1
УДК 004.9

МЕТОД ДИНАМІЧНОГО ФОРМУВАННЯ КОНТЕНТУ В УМОВАХ ОБМЕЖЕНИХ РЕСУРСІВ

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АНОТАЦІЯ

У даній роботі представлений метод динамічного формування контенту в умовах обмежених ресурсів для підвищення якості процесу прийому-передачі інформації. Розроблений метод заснований на моделі приймаючої частини системи прийому-передачі інформації, базової моделі контенту і моделі системи прийому-передачі інформації. Для розробки методу було досліджено гетерогенність системи прийому-передачі інформації та види інформації, що передається користувачеві. Метод динамічного формування контенту (тип, формат) враховує характеристики всіх компонентів системи прийому-передачі інформації та забезпечує визначення необхідного контенту для передачі в реальному часі в мережі Інтернет. Метод включає в себе визначення швидкості прийому-передачі інформації, визначення характеристик пристрою і браузера на основі моделі приймаючої частини системи прийому-передачі інформації, вибір виду контенту (мультимедіа, відео, текст тощо), на основі розроблених вирішальних правил, в залежності від характеристик, визначених у моделі приймаючої частини системи прийому-передачі інформації, відтворення обраного виду контенту на екрані користувача з урахуванням операційної системи, браузера, вікна браузера, за допомогою моделі контенту і моделі приймаючої частини системи прийому-передачі інформації, і перевірки необхідності зміни виду контенту. Перевірка необхідності зміни виду контенту відбувається в двох випадках: якщо під час сеансу роботи підключається новий користувач і якщо протягом заданого кванта часу не підключилося жодного користувача. Завдяки розробленому методу, при підключенні до сайту користувач буде отримувати інформацію в тому вигляді, який зможе відтворити його пристрій. Для оцінки якості розробленого методу був проведений експеримент за участю студентів. В результаті експерименту, доведено, що якість процесу прийому-передачі інформації збільшилася в 1,55 разів за рахунок використання розробленого методу динамічного формування контенту.

Ключові слова: дистанційне навчання; мобільне навчання; контент; формування контенту; прийом даних; передача даних; метод динамічного формування контенту; обмежені ресурси

DOI:https://doi.org/10.15276/aait.02.2019.1
УДК 004.9

ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)

МЕТОД ДИНАМИЧЕСКОГО ФОРМИРОВАНИЯ КОНТЕНТА В УСЛОВИЯХ ОГРАНИЧЕННЫХ РЕСУРСОВ

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АННОТАЦИЯ

В данной работе представлен метод динамического формирования контента в условиях ограниченных ресурсов для повышения качества процесса приемо-передачи информации. Разработанный метод основан на модели принимающей части системы приемо-передачи информации, базовой модели контента и модели системы приемо-передачи информации. Для разработки метода была исследована гетерогенность системы приемо-передачи информации и виды информации, передаваемой пользователю. Метод динамического формирования контента (тип, формат) учитывает характеристики всех компонентов системы приемо-передачи информации и обеспечивает определение необходимого контента для передачи в реальном времени в сети Интернет. Метод включает в себя определение скорости приемо-передачи информации, определение характеристик устройства и браузера на основе модели принимающей части системы приемо-передачи информации, выбор вида контента (мультимедиа, видео, текст и т.д.), на основе разработанных решающих правил, в зависимости от характеристик, определенных в модели принимающей части системы приемо-передачи информации, воспроизведение выбранного вида контента на экране пользователя с учетом операционной системы, браузера, окна браузера, с помощью модели контента и модели принимающей части системы приемо-передачи информации, и проверки необходимости изменения вида контента. Проверка необходимости изменения вида контента происходит в двух случаях: если во время сеанса работы, подключается новый пользователь и если в течении заданного кванта времени не подключилось ни одного пользователя. Благодаря разработанному методу, при подключении к сайту пользователь будет получать информацию в том виде, который сможет воспроизвести его устройство. Для оценки качества разработанного метода был проведен эксперимент с участием студентов. В результате эксперимента, доказано, что качество процесса приемо-передачи информации увеличилось в 1,55 раз за счет использования разработанного метода динамического формирования контента.

Ключевые слова: дистанционное обучение; мобильное обучение; контент; формирование контента; прием даннях; передача даннях; метод динамического формирования контента; ограниченные ресурсы

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ISSN 2617-4316 (Print)
ISSN 2663-7723 (Online)