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DEVELOPMENT OF AN INTERACTIVE INFORMATION SYSTEM USING AUGMENTED REALITY MEANS

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ABSTRACT

This paper describes the technology of formation of the augmented reality, a comparative overview of the proposed development tools, as well as an analysis of existing types of software for handheld devices. The work is a continuation of a series of articles [1-5].

The study developed an information system that in conjunction with a web server provides interactive visualization effect. Currently, one of the important directions of development of Ad Hoc networks is VANET. However, in recent years, VANETs and their applications are increasingly being considered to work in complex application with other new telecommunication technologies. Thus, the use of unmanned aerial vehicles (UAV) (Unmanned Aerial Vehicle) can often significantly improve the functioning of the VANET and / or expand the functionality of this network. Using augmented reality applications also provides for VANET new opportunities, particularly in connection with the use of UAV. At the same time, in most VANET applications, including the use of UAVs and AR, the VANET architecture is based on software-defined networks (SDN). In the proposed structure, the UAV performs the functions of a SDN controller, which peripheral modules are located in the vehicles of the priority cluster. The image from the UAV is received on augmented reality glasses by the driver's assistant, which allows him to know the speed and other parameters of the movement of ambulances and other similar vehicles. A model of timely traffic light control is proposed. The VANET technology was chosen as the base for the implementation of control functions. To better manage the scalability and flexibility of the VANET, it is complemented by SDN technology, where the UAV acts as a controller. For visual assessment of the situation and control, the model uses augmented reality technology. The video stream received from the UAV can be supplemented with the necessary current information, for example, the speed and intensity of vehicle traffic on crossing streets, vehicle dimensions, etc.

Keywords: *Augmented reality, information support, UAVs, the SDN for VANET applications.*

1 INTRODUCTION

1. The use of augmented reality, drones and SDN applications for VANET.

VANET (Vehicular Ad Hoc Network) worked well in the implementation of the exchange of traffic between road users. However, the capabilities of VANET are not always enough to solve modern problems. SDN technology, which is based on the separation of traffic management tasks and data transmission tasks, favorably complements the VANET. This section proposes a model for controlling traffic lights along the entire route of special transport (ambulances, fire brigades ...), in which an unmanned aerial vehicle acts as an SDN controller. The model also takes into account the possibility of using augmented reality technology in traffic lights control in order to reduce the inconvenience of other road users associated with the need to pass special vehicles [8, 9].

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functioning of the VANET and / or expand the functionality of this network. Using augmented reality applications also provides for VANET new opportunities, particularly in connection with the use of UAV. At the same time, in most VANET applications, including the use of UAVs and AR, the VANET architecture is based on software-defined networks (SDN). Many authors use clustering techniques to select a rational architecture for the VANET.

Next, we consider the traffic light control model in VANET with priority service. The control of traffic lights in the VANET, in comparison with existing systems for switching traffic lights at intersections, makes it possible not only to reduce vehicle delays [9], but also to reduce CO2 emissions in urban environments [7]. The article [6] notes that the use of a traffic light control system can increase the traffic capacity of intersections by 42%.

1.1. Priority Service VANET Model.

This section discusses the traffic light management model with priority service. Priority service means that there is a cluster of cars that moves at a constant speed and for which, along the route of its movement, it should be ensured that traffic lights at intersections are in a state of unhindered passage of this cluster of cars, as shown in Figure 1.

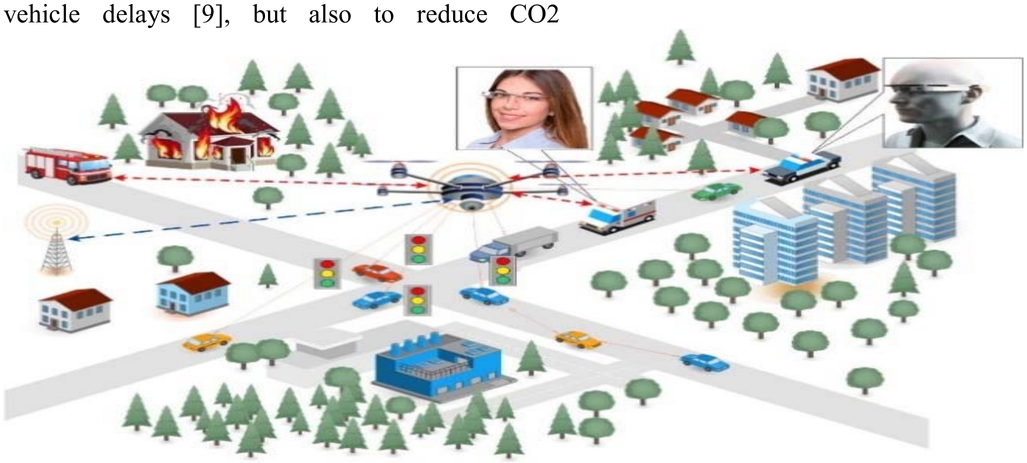

Figure 1 - Network elements interaction architecture.

The simplest implementation of such a priority passage of cars consists in early switching of all traffic lights on the way to the green state for this cluster. However, with a sufficiently long route, this leads to unjustified delays for other vehicles at this intersection, as well as to the impossibility of timely passage of the intersection, for example, by ambulances. To reduce the waiting time for cars of conventional clusters, as well as to ensure timely passage of intersections by ambulances, the following model is proposed, based on the use of the VANET, augmented reality and the architecture of software-defined networks, shown in Figure 2.

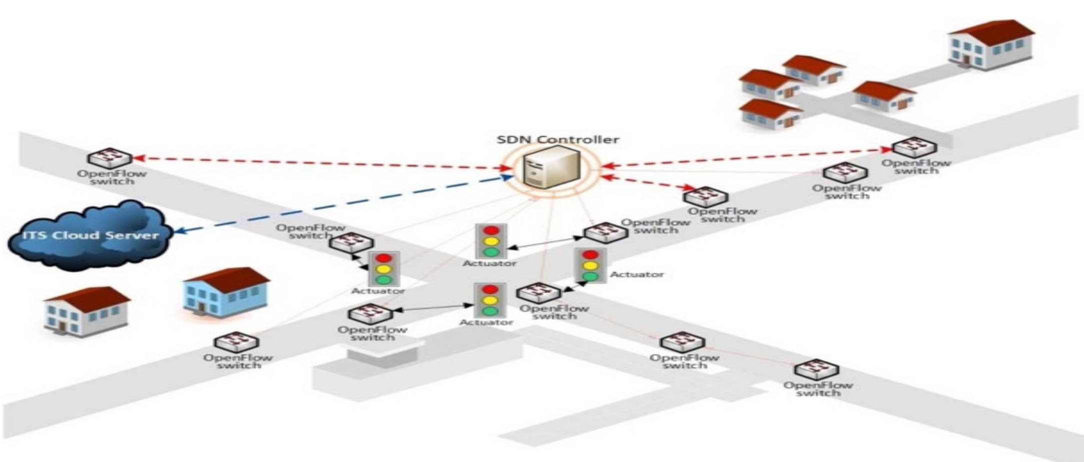

Figure 2 – SDN architecture.

In the proposed structure, the UAV performs the functions of a SDN controller, which peripheral modules are located in the vehicles of the priority cluster. The image from the UAV is received on augmented reality glasses by the driver's assistant, which allows him to know the speed and other parameters of the movement of ambulances and other similar vehicles.

1.2 Traffic Control Algorithm.

Assume that the travel time of vehicles of the considered cluster along the route T is determinedas the sum of the travel time of individual elements of the route T_{ik}.

$$T = \sum_{i=1}^{k} T_i \quad (1)$$

where i = 1 ... k number of the segment, k - the quantity of route segments.

The control task is to ensure a minimum delay in the arrival of a given vehicle through the road network using automatic traffic control devices, when interacting with them via a wireless network of the IEEE 802.11p standard (VANET). The task can be described as the problem of choosing the shortest route, i.e. reaching $min(T)$ by choosing the optimal route P among the set of possible routes {P}.

For a formal description of the model, we represent the road network in the form of a graph *G*, the vertices of which are the intersections - *v*, and the arcs of the road - *e*. In the general case, there is a directed graph. It should be noted that this graph can include only those vertices and arcs (intersections and roads) that can be used in the route. Each arc of the graph is assigned a number that characterizes the distance between intersections or the time it takes to travel this distance c_j. The solution to the problem consists in a dynamic (interactive) search for the shortest (in terms of distance or time) path by points of the beginning and end of the route. The peculiarity of solving this problem is that it is necessary: firstly, to determine the coefficients that take into account the time of passage of the route element, taking into account the possibility of control, secondly, to determine the time for giving control signals (schedule or control plan) and thirdly, to be able to rebuild route at any current position of the vehicle m.

We assume that the beginning of the route is at the vertex s, and the end of the route is at the vertex t.

Proposed algorithm:

1. The current position is equal to the beginning of the route m = s.
2. Finding the shortest path between the current position and the end of the route $P_{min} = \{v_1, v_2, \dots, v_k\}$
3. Formation of the list of times of switching on the permitting signal of traffic lights in the direction of the vehicle (control schedule) $L = \{\tau_1, \tau_2, \dots, \tau_k\}$
4. Transmission of control signals (enabling signal activation) for the next i-th section of the route.
5. Waiting for a signal of readiness (unavailability) of the i-th element of the route during the travel time on sections up to the i-1 section of the route, inclusive.
6. If ready, following to element i of the route, $i = i + 1, m = i$. After passing the i-th element of the route, the control action is canceled (transfer to the normal operating mode).

Otherwise, go to n. 2.

7. If the destination point is reached (m = t), then stop, Otherwise, go to step 4.

At the beginning of the algorithm, the initial position of the vehicle is set (item 1), then the search for the shortest path between the current position and the destination is performed. For this purpose, any of the known algorithms for finding the shortest path in a graph can be used. In this case, preference should be given to heuristic algorithms, which can significantly reduce the search time. In addition, templates (variants) of routes obtained in advance can be used. After finding (choosing) the path, the sequence and time of transmission of control signals (turning on the enabling traffic signal) on the route elements are formed. This sequence is built in chronological order of the selected moments of transmission of control signals. The time (moment) of transmission of the control signal is selected based on the time required for the vehicle to arrive at a given route element and the time required to clear the intersection from passing vehicles.

$$t_i = \max\left(t_i^{(arr)}, \tau_i\right) \quad (2)$$

where, $t_i^{(arr)}$ is the time of arrival of the vehicle to the i-th element of the route;

τ_i is the time required to free the route element from associated vehicles (or increase its throughput). In the general case, $\tau_i = f(a, r)$ where **a** is the intensity of car traffic, **r** are the parameters of the route element (intersection, road). The description of this functional dependence is a separate task that requires certain research and field experiments. In our case, we will assume that a known function $f_i(a)$ is assigned to each of the vertices of the graph. Such a function can be specified, for example, by a table obtained experimentally. Traffic intensity **a** can be determined by various methods: statistically (according to schedule), using monitoring tools (stationary cameras, video cameras/cameras placed on the UAV, messages from other means of monitoring real traffic).

The effectiveness of the application of control actions is quite easy to evaluate by simplifying the route model to a multiphase QS, with the number of phases equal to the number of route elements, and vehicles as a flow of applications at its input. For example, with an exponential distribution of the service time (passage of the section) and the simplest flow at the entrance, the route passage time can be described as

$$T = \sum_{i=1}^{k}\left(\frac{p_i \bar{t}_i}{1-p_i} + \bar{t}_i\right)$$
(3)

Where $p_i = \lambda_i t_i$ is the load on the i-th phase,
λ_i is the flow rate at the i-th phase,
t_i– time of service (travel) of the i-th section,
k - the number of sections in the route.

When applying a control action on the i-th element, the value of t_i changes, namely, it leads to a decrease in this value. As a consequence, there is a decrease in the value of T. This can be seen from the expression above. Thus, the travel time along the route is significantly reduced, the degree of this decrease can be determined when scheduling control actions. This is achieved by a timely increase in the throughput of the route elements, up to the complete release of the route elements from associated transport. The main advantage of this method is that the control action (allowing traffic signal) is produced within the minimum required time, which minimizes the impact on car traffic.

This section discusses the provision of priority passage of vehicles with special signals. Often this creates inconvenience to other road users, because they have to wait for a long time until the motorcade passes. This is due to the fact that traffic lights switch long before the approach of cars with special signals.

A model of timely traffic light control is proposed. The VANET technology was chosen as the base for the implementation of control functions. To better manage the scalability and flexibility of the VANET, it is complemented by SDN technology, where the UAV acts as a controller.

For visual assessment of the situation and control, the model uses augmented reality technology. The video stream received from the UAV can be supplemented with the necessary current information, for example, the speed and intensity of vehicle traffic on crossing streets, vehicle dimensions, etc.

Within the framework of the proposed model, an algorithm has been developed for choosing the optimal route of movement by minimizing the time of arrival at a given point.

2. INVESTIGATION OF THE INTERACTION OF AUGMENTED REALITY APPLICATIONS AND UAV CONTROL METHODS.

In this section, we study the interaction of augmented reality applications and control methods for unmanned aerial vehicles. To conduct the study, an experimental stand was developed and during the experiment, the UAV was controlled by means of augmented reality technology. At the same time, the quality of service of the transmitted traffic was assessed and a subjective assessment of the quality of perception by observers was carried out. The study determined the characteristics of the network connection required for a given perceptual quality when controlling the UAV through augmented reality application [5].

Controlling unmanned aerial vehicles in urban areas is a difficult task, since unforeseen obstacles can arise on the route of the UAV, which must be quickly detected and avoided. For the widespread introduction of UAV systems, it is necessary to solve the problem of ensuring reliable and timely control of the vehicle. In flying sensor networks, UAVs are actively used as a flying segment that collects data from ground sensors and delivers them to a server for further processing. Flying sensor networks turned out to be popular in the field of agriculture, when it is necessary to control a large area, in industry, when it is necessary to monitor hard-to-reach and remote objects, for example, gas pipelines, and have also proven themselves as routers that are used to quickly deploy a network in crowded areas.

It is customary to distinguish between three types of UAV control: manual, automated and automatic.In the first case of manual control, the UAV pilot is based on information received in the video image format from the UAV camera. With

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this control, augmented reality technology and tactile Internet applications can be applied to facilitate control tasks. Augmented reality allows you to add virtual data to objects of the surrounding physical world using specially designed display devices, in particular, augmented reality glasses. The tasks of tactile internet include delivery of information on the impact of the network on an object at a remote distance, and sending a response back. Obviously, with such an exchange of data, the delivery delay should be as low as possible.

When controlling the UAV, the pilot changes the position of the UAV in space by turning or tilting his head through the augmented reality application, based on the video that comes from the camera installed on the UAV to the AR display device.

To ensure stable control of UAVs using augmented reality applications, it is necessary to ensure the solution of the following tasks:

• transfer data on changes in the position of the pilot's head from the AR device to the UAV;

• to carry out continuous transmission of video images from the UAV camera to the AR device;

• ensure the fulfillment of the specified characteristics of the network;

• assess the quality of perception in the implementation of the UAV control process using the AR application.

2.1 Features of data transmission when controlling UAVs.

As mentioned earlier, the pilot controls the movements of the UAV and the video camera installed on it by tilting and turning the head, i.e. changes in its position in space. During the experiment, the camera was placed on the UAV so that only rotation along the vertical axis was ensured; therefore, to ensure the maximum viewing radius, it was necessary to rotate the UAV itself in the required direction. AR goggles are worn by the pilot and they display the video stream from the UAV camera. Thus, the pilot sees the objects surrounding the UAV and can change the location of the UAV, thereby moving the camera in the desired direction. For normal operation of the pilot, it is necessary to ensure not only a high-quality display of the video stream on the AR device, but also transmit a timely response to changes in the position of the controller's head to the UAV and the camera.

Thus, the response of the UAV must correspond to the commands of action; for example, when the head is tilted down, the camera must change its position and also turn down as quickly as possible, so that the video stream is comfortable for the pilot to perceive. To accomplish this task, a gyroscope and an accelerometer installed on the AR device are used. Data from the accelerometer and gyroscope about the change in the angle of inclination or rotation of the pilot's head are transmitted to the UAV, which, in turn, understands this command as a control command and transfers it further, depending on the destination. Figure 3 shows the model of interaction between the AR device and the UAV.

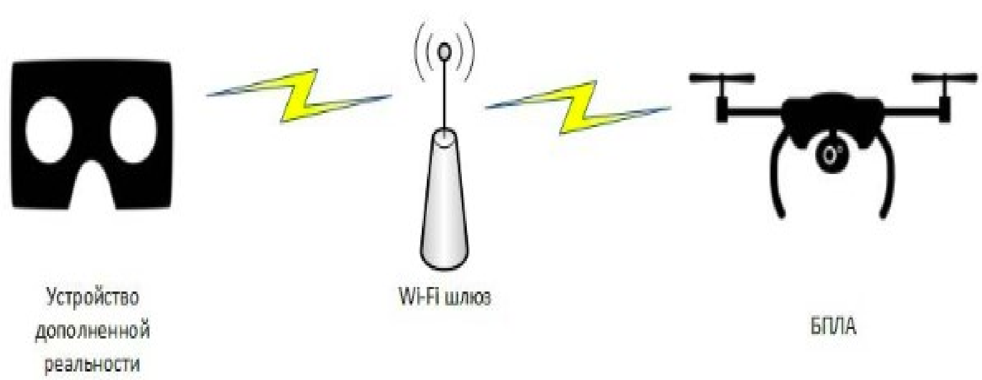

Figure 3 - Model of interaction between the AR device and the UAV.

However, video is a large volume of traffic and requires adequate bandwidth. In this experiment, you may encounter interference in the communication channel. Also, the quality of video information transmission is affected by such indicators of the quality of service as the level of loss and delivery delays. The deterioration of the values of these indicators leads to failures in the control of the UAV and greatly affects the quality of perception of the pilot and the control decisions made by him, since they are carried out on the basis of video data received from the UAV camera. Based on the above, for the study, a model of interaction (Figure 3) of an augmented reality device and a UAV was developed, in which Wi-Fi technology of the IEEE 802.11n standard was selected as a wireless data transmission technology. Within the framework of this standard, it is possible to transfer large amounts of data with a bandwidth of up to 150 Mbit / s, which is more than enough to solve research problems.

The following is a study of the influence of the network service quality indicators on the quality of the pilot's perception in the AR system when controlling the UAV.

2.2 Conducting an experiment to control a UAV using an augmented reality application and analyzing the results.

The expert is wearing augmented reality glasses, which display the video stream coming from the camera located on the UAV. The expert turns his head in different directions, including up and down, thereby changing the direction of the camera position. Thus, the viewing angle changes and other video information is displayed. The task of the expert is to subjectively assess the response of the UAV and the quality of the modified video image in the AR glasses when applying the control action. Three scenarios of the experiment were implemented, in each of which the influence of changes in network characteristics, such as latency, loss and decrease in bandwidth, on the quality of perception was investigated. For each scenario, 20 experiments were performed. To obtain adequate estimates, the experts were shown a reference case in which no degrading effects on the network were introduced, i.e. as close as possible to ideal data transmission conditions.

For the reference case, the Hurst parameter was also calculated and its value turned out to be 0.61, which indicates a self-similar structure of the transmitted traffic. To simplify the analysis of the results of the experiment, when transmitting the reference sequence, a subjective assessment of the quality of perception was set equal to 5 points on a five-point scale. In the first scenario, the effect of increasing delay on the quality of perception was investigated. The results are shown in Table 1.

Table 1 - Experimental Results With Increasing Delay.

Delay, ms.	Subjective assessment on a five-point scale	Hurst parameter values
No delay	5,0	0,61
10-30	4,4	0,60
50-150	3,8	0,59
150-250	2,7	0,56
250-350	2,1	0,52

Table 1 shows that with delivery delays not exceeding 100 ms, the quality of video stream perception by an expert remains at an acceptable level, however, when controlling a UAV with such a delay value, a number of difficulties arise. Due to the data lag, the pilot (in our case, the expert) does not understand at what moment exactly it is necessary to change the movement or stop, thus, the control is carried out at random without visual control, the commands are transmitted with a delay, and, therefore, the response is returned with a delay. In this example, the Hurst parameter correctly establishes the relationship between the values of service quality indicators and subjective assessments of the quality of perception in the AR systems. Obviously, with delays above 150 ms, UAV control by means of an augmented reality application is not possible.

The second scenario involved adding losses to the communication channel between the UAV and the augmented reality device. Table 2 shows the results of this experiment.

Table 2 - Experimental results with an increase in the level of losses.

Bandwidth, Kbps	Subjective assessment on a five-point scale	Hurst parameter values
With no restrictions	5,0	0,61
Up to 1700	4,9	0,61
Up to 1500	3,6	0,56
Up to 1000	2,7	0,55
Up to 500	1,7	0,49

According to the assessments of the quality of perception and the value of the Hurst parameter presented in Table 3, it can be seen that a critical decrease in bandwidth affects the quality of user perception in augmented reality systems. As well as in the two previous cases, there are difficulties in controlling the UAV, because the expert (pilot) ceases to possess up-to-date information about the movement of the UAV and the objects surrounding

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it. All data transmitted with long delays, some of them are lost, and an expert wearing augmented reality glasses starts to feel dizzy.

The study found that augmented reality applications can be used to control unmanned aerial vehicles. However, it should be borne in mind that control takes place in real time, therefore, it is necessary to fulfill certain requirements for the characteristics of the network to ensure timely and comfortable control of the UAV based on current video information. In this section, we investigated the influence of network performance indicators on the quality of user perception in an augmented reality system when transmitting video images for control tasks from a UAV camera. Based on the results obtained, it was found that in a network with minimum delays of up to 100 ms, control of a UAV using an augmented reality application is possible without losing the quality of perception and control accuracy.

3. A TYPICAL MODEL FOR MANAGING INTERNET OF THINGS BASED ON AUGMENTED REALITY TECHNOLOGY.

This section describes the framework for using augmented reality technology as an interface for interacting with the IoT for monitoring and control. It presents the main functional elements, interaction protocols and approaches to implementing the interaction of IoT devices using AR technologies over the network.

Augmented reality technology allows virtual 2D / 3D graphics to be displayed in additional layers of information about real-life objects, which expands the possibilities of interaction with the virtual world and data. As a result of the intensive development of the concept of the Internet of Things (devices, systems, infrastructure, applications, etc.) and its widespread implementation in various areas of human activity (industry, healthcare, education, agriculture, entertainment, etc.) in order to increase information content and process automation, it is of interest to use augmented reality technologies as a new type of interface for monitoring and controlling IoT.

To solve this issue, it is necessary to determine the general structure of the augmented reality application in relation to the tasks of controlling and monitoring devices and the IoT system. Monitoring the operation of IoT devices and systems using augmented reality means observing data created in the virtual world and displayed in real life when looking at a physical object (thing). Controlling the operation of devices and systems of the Internet of Things using augmented reality consists in transmitting control commands that are generated from the AR terminal.

There are two ways to transmit control actions to the AR-terminal:

• If the AR-terminal is a device such as a smartphone or tablet with a touch screen, then control requests are generated when interacting with virtual objects by pressing on the touch screen.

• If the AR terminal is a device without a touch screen, for example, the AR glasses, the control is carried out through the interface of the voice assistant.

After transmitting the control request, the AR-terminal generates a request to the AR-server, and then AR-server interacts with the IoT-server and transmits the necessary information. Figure 4 shows a general diagram of the implementation of augmented reality applications for managing and monitoring devices and systems of the Internet of Things.

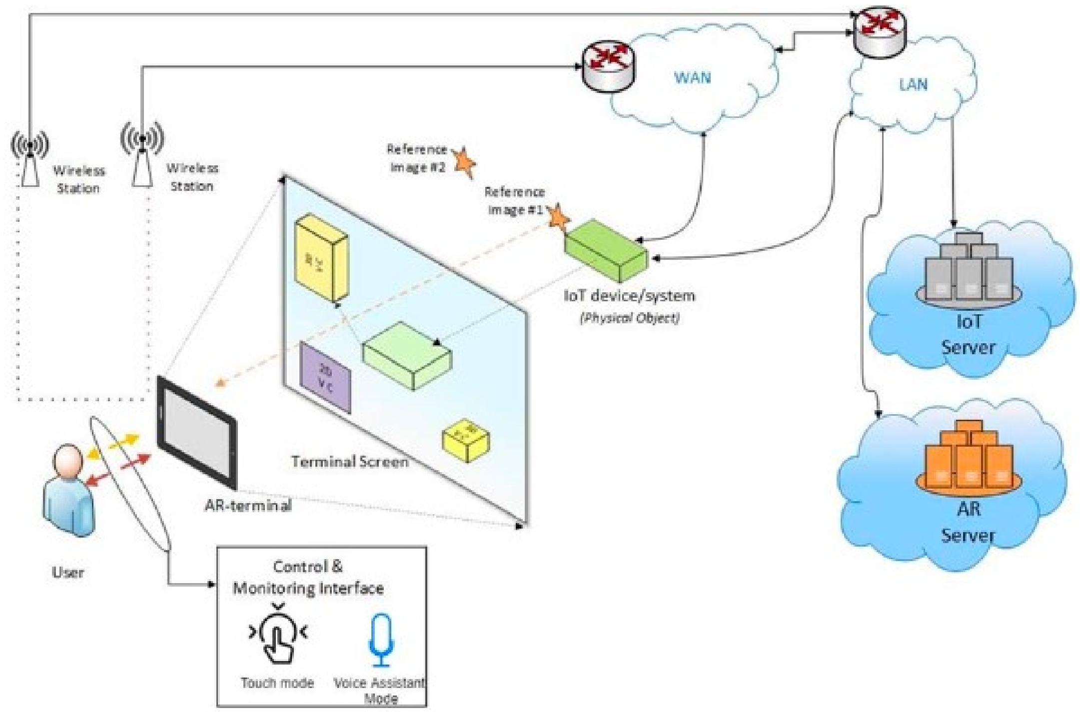

Figure 4 - General scheme of implementation of AR applications for managing and monitoring IoT devices and systems.

3.1 Classification of IoT applications for AR technology.

We define a set of IoT applications for which the AR technology can be used to implement the control and management functions. IoT applications can be divided into groups based on the classification of functions that a given application or service implements. Services can be implemented both on the basis of one or several applications. The functions that an IoT application performs can be divided depending on the areas of human and society life in which the application is applied.

1) Classification of IoT applications for integration with AR technology based on the scope:

a. Medicine and healthcare

b. Ecology
c. Agriculture
d. Commerce and retail
e. Education
f. Fire safety
g. Safety
h. Environment
i. Automobile transport
j. Smart city
k. Appliances

2) Classification of IoT applications for integration with AR technology based on the hazard level of objects:

a. high-risk facilities (nuclear power plants, hospitals, etc.)

b. safe facilities (shops, games, etc.)

The use of augmented reality to control and monitor IoT systems and devices at high-risk facilities requires special attention to ensuring security.

3) Classification of IoT applications for integration with AR technology based on the way of interaction with the IoT device:

a. Management through AR
b. Monitoring through AR
c. Control and monitoring through AR

3.2 Classification of IoT devices for the implementation of object identification systems.

We will define the classification of reference images that can be used to identify or recognize a physical object (IoT devices and / or systems) and formulate general recommendations for the use of various methods for recognizing IoT objects in different areas of human activity. The reference image performs the function of identifying the observed object. Since there are many solutions for identification at the moment, the following classification is proposed.

The classification is determined by the following recognition methods:

a. Based on reference image.

b. Based on the coordinates of the location of devices and systems of the Internet of Things and the AR-terminal.

c. Based on the reference image and coordinates of IoT devices and systems, as well as the AR terminal.

The first approach allows you to uniquely identify the object of the physical world (device or IoT system) to which the reference image is attached. In order to obtain augmented reality data without delays and distortions, factors such as the size of the device's camera, the complexity of the reference image, etc. must be taken into account. A QR code can be used as an example of a reference image for quick identification.

In the second case, identification is carried out based on data from the sensors of the AR-terminal: accelerometer, gyroscope, magnetometer, GPS receiver, etc. This approach shows a high percentage of errors in recognition and is not recommended for use on high-risk facilities. Also, this approach is not recommended for use in enclosed spaces, as well as with a high density of IoT devices.

In the third case, it is proposed to use a combined approach to improve the identification accuracy, as well as to minimize the risk of replacing the reference image. Thus, the identification of an IoT device or system is based on the reference image and coordinates of the IoT device, as well as the position of the AR terminal.

3. CONCLUSION

The concept of the Internet of Things has opened up many opportunities in terms of creating new services. Today, a large number of applications have been developed that can make everyday life easier. There are also a number of well-proven solutions for various spheres of human activity, for example, in the housing and utilities sector, medicine, and the oil and gas industry. With the advent of augmented reality technology, these possibilities have expanded. Augmented reality allows you create additional virtual layers for the real world. Anything can be presented to the augmented reality user in different ways, depending on the degree of access to information, the information content that the user wants to receive, the type of added data, etc. Since, according to forecasts, the number of IoT devices will be about 3000-5000 per person, the issues of allocating network resources, unloading traffic from the network and identifying IoT objects using cloud services are in great demand.

1. It has been established that the main indicator of the quality of service provision is the response time, i.e. the time from the moment the user's environment changes until the required message is presented to the user. This time depends on the distribution of functions for the provision of services by executive elements.
2. In order to minimize the response time to changes in the user's environment, a hierarchical structure of resource allocation is proposed when providing augmented reality services. The hierarchical model makes it possible to localize a significant proportion of data and traffic, which saves resources on the bandwidth of the communication network.
3. A new four-level structure of an augmented reality service delivery system has been developed based on a modified multilevel edge computing system (MM-MEC) using the device-to-device interaction technology, D2D.
4. A method has been developed for offloading traffic for a network providing augmented reality services, based on a multi-level system of edge computing with four levels of traffic offloading, which allows not only to meet the requirements for a 5ms delay, but also to reduce losses several times compared to existing methods for all major augmented reality services: circular video streams, multiplayer games and augmented reality web applications.
5. A model has been developed for the timely control of traffic lights based on VANET, supplemented with SDN technology, where a UAV is used as a controller, and augmented reality is used for a faster and more accurate assessment of the traffic situation.
6. A study of the interaction of augmented reality applications and UAV control methods was carried out; an experiment was carried out to assess the quality of the perception of the video stream by the pilot and the effectiveness of the control of the UAV by the pilot wearing AR glasses.
7. A structure for monitoring and controlling IoT devices and systems using AR technology is described. A number of examples of integration of augmented reality technology and the concept of the Internet of Things for the provision of services in various spheres of human activity are considered.
8. The possibility of introducing the latest AR and IoT technologies has been explored to

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increase the information accessibility and interactivity of art objects, which, in turn, helps to attract younger visitors and, at the same time, preserve cultural heritage objects for future generations.

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