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Scenario of Interaction of the Mobile Technical Objects in the Process of Transmission of Data Streams in Conditions of Impacting the Powerful Electromagnetic Field

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***Abstract* — This paper analyzes the current state of the problem of obtaining and processing big data streams by a group of mobile technical objects (drones) under the influence of powerful electromagnetic field. Recommendations regarding to the design of mobile systems characterized by increased survivability are given.**

***Keywords* — data stream, mobile system, drone, electromagnetic field, microwave pulse, survivability.**

I. Actuality

The paradigm of the development of modern information systems is their progressive and ever-increasing integration into various spheres of activity (public administration, industry, energy, communications, etc.) and the simultaneous complication of the functions they perform. Successful tests of algorithms for organizing and functioning of complex mobile systems for registering and transmitting data streams (swarm algorithms) have given rise to a new direction in the design of information systems [1, 4]. Such systems are characterized by sophisticated architecture, heterogeneity, structural diversity, multifunctionality, and so on. In terms of composition, such systems can be divided into a number of subsystems that are distributed in space; they are mobile and functioning asynchronously among themselves for the performance of a single goal. The considered technical objects are designed to solve the tasks of information registration, temporary buffering and real-time processing of data streams. Under the task of information registration, one should understand photo and video recording, monitoring of the state of electromagnetic and radiation environment, etc. Temporary buffering allows you to preserve the integrity of data when being processed and transmitted. The set of problems being solved by such systems allows the performing of both current and new classes of tasks [4].

The unifying factor in the design of such systems is the assured transmission of data streams using wireless technologies. In this case, the factor of external influence on the functioning of a complex mobile system is of particular interest. The external influence should be understood here as meteorological (natural) effects (for example, lightning) and artificial (for example, a powerful electromagnetic field). With external electromagnetic effects on a complex mobile system, an important role is played by the problem of increasing survivability [8]. For example, the work [1] presents a complex mobile system consisting of a number of drones, united in a single network. The communication channels are organized on the base of IEEE 802.11 standard family to communicate with each other. The successful achievement of the stated objectives depends on the characteristics of the network organization and the external effect of natural and / or artificial origin. The presented system is characterized by low noise immunity under the conditions of a powerful electromagnetic field. That reduces the data transfer rate and provides the integrity of the data streams transferred.

There are the solutions on the use of drones as unmanned retransmission nodes to support a wireless telecommunication link between two nodes [2]. When the propagation range of a radio signal from stationary nodes does not justify itself, and the power increase mode of transmitters does not guarantee their stealthiness (makes them radio beacons), the mobile relay nodes are used then to amplify wireless communication channels, acting as a "the last mile". The solutions have been analyzed where the mobile objects can act as communication repeaters: ground transport vehicles, helicopters or geostationary satellites. However, these facilities have certain limitations in performance under unfavorable conditions: inaccessible areas (mountains, caves, ice roads) and high operating costs. The authors propose and justify the strategy of using drones as mobile relay communication nodes to overcome these limitations [2]. The essential shortcoming is the lack of

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organizational arrangements for the deployment of such systems and the security of the data transmitted by them.

The work [3] presents the method of data collection from stationary objects provided by drones. Its essence lies in the preliminary estimation of the amount of data received from each node and, accordingly, in the choice of appropriate data transmission technology in order to minimize the total data acquisition time from all stationary nodes. The disadvantage of this solution is the technical aspect: the use of narrow-band antennas while using high-speed data transfer standards. The task of adjusting with stationary nodes may take longer than the use of lower-speed standards and omni-directional antennas. The work [6] deals with the problem of transferring large data streams in mobile engineering systems in which the drone and the sensor network are regarded as the objects. The modern systems of collecting data by sensor networks from geographically distributed points have been analyzed. The efficiency has been shown of using drones for data collection from sensor networks. Several approaches have been proposed to solve the problem of data transmission using the Big Data technology. The work [6] describes the ideal conditions under which the system functions, and the data rate indicators correspond to the maximum possible within the chosen data transmission standard, and which requires the addition of a mathematical apparatus for describing the scenarios of the drone behavior under impact conditions. In many cases, the abovementioned systems that operate in the conditions of the destructive external environment are subjected to additional requirements for reliability and survivability. This is done to ensure the safety and integrity of the accumulated data as a result of the functional task of the drone for their further transfer to the processing center. For example, the swarm of drones can be considered as an information and communication system for providing access to the Internet in remote locations under natural conditions, and in the case of using ultra-broadband communication technology, the system can be characterized as possessing the property of survivability in the event of an external destructive effect on blocking out the signals of control and data transmission [5]. The downside is the unsolved problems of finding the compromise in the power-producing aspect that ensures the operation of the drone and the use of energy-intensive technology for the assured data transmission. Taking into account the absence of a universal approach to solving the problem of ensuring the electromagnetic stability of a group of mobile technical objects (drones) in the conditions of the assigned task to provide the guaranteed high-speed data transmission in the studies [1-3, 6], this line of the research is topical today. The objective of this work is to develop the scenarios for the interaction of a group of mobile technical objects while providing the assured data transmission under the conditions of external electromagnetic influence.

II. Description of the System

A group of mobile technical objects (drones) will be considered as a data system. Each of the drones can simultaneously perform the following functions: information recording, primary processing, transmission, reception, storage, and data destruction. Let us also notice that the additional conditions for the operation of the drone are reception, acknowledgment, transmission of control commands and broadcast messaging. According to the functions, the drone can be described by a set of the group parameters:

- the parameters relating to the subsystem of reception and transmission of service information (for example, control commands);
- the parameters relating to the subsystem of information registration, its primary processing, temporary data storage, data reception and transmission.

This study does not consider the features of controlling a group of drones (parameters relating to the subsystem of reception and transmission of service information). It is assumed that the control with the account of the external impact is based on already known algorithms with weak a priori and weak a posteriori info ware for solving group control problems under the conditions of organized counteraction in dynamic, nondeterministic environments [4]:

- if the task is to control a single object, then the "drone-environment" system is continuous, and its functionality is described by a system of differential equations as following:

$$\dot{S} = \tilde{f}(A(t), S(t), g(t), t) \tag{1}$$

where $\dot{S} = \frac{dS(t)}{dt}$ – is the derivative of the steady-state vector-function of the "Drone-Environment" system; $A(t) = [a_1(t), a_2(t), ..., a_m(t)]^T$ – is the vector-function describing the set of actions of the drone; $S(t) = f_S(A(t))$ – is the function of actions of the drone; $g(t)$ – is the external influence;

- if the task is to control a group of objects in a destructive external environment, then the functional specifying the objective of the functioning of a group of objects can be represented in the form of:

$$\begin{aligned} Y_c &= \int_{t_0}^{t_f} [F(\Re(t), E(t), A_c(t)) - G(A_c(t), g(t))] dt = \\ &= \int_{t_0}^{t_f} F(\Re(t), E(t), A_c(t)) - \int_{t_0}^{t_f} G(A_c(t), g(t)) dt \to \max \end{aligned} \tag{2}$$

where $\Re(t)$ – are the states of the drones in the group; $E(t)$ – is the state of an external environment; $A_c(t)$ – the actions of the drones; $G(A_c(t), g(t))dt$ – the function of the external negative influence.

At present, it is of interest to develop the scenario for the interaction of drones within the solution of the assured data transmission resulting from the registration of the target information. For this purpose, let us consider the following subsystems of the drones: information registration subsystem, primary processing subsystem, temporary storage subsystem, data receiving and transmission subsystem and the subsystem of recording the intensity of electromagnetic interference (sensor) (Fig. 1).

The hardware-software subsystem of data reception and transmission is characterized by the following: the standard of transmitted data depending on the selected frequency, the speed of data reception and transmission, the sustainability and integrity of the data received. For example, such a subsystem may be presented by a set of radio modules

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operating within the standards of the IEEE 802.11 family, and the sustainability and integrity of the received data at the level of data transfer protocols.

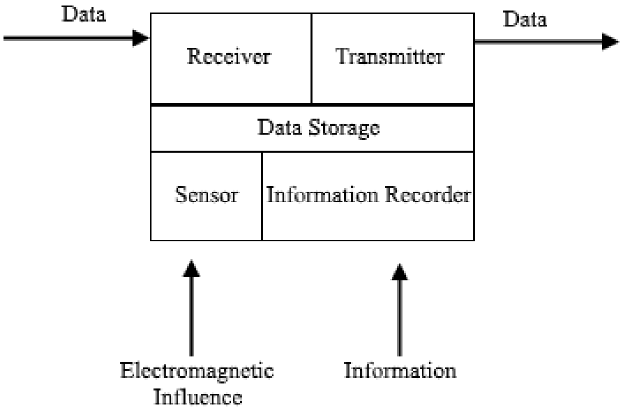

Fig. 1. The Subsystems of the Drone

The subsystem of temporary data storage is characterized by the capacity, the load monitoring function, and the function of verifying the integrity of stored data.

The sensor carries out the function of recording the intensity of external electromagnetic effect in a wide range of frequencies, for the drone to choose the optimal standard for the data transferring among other drones and for the generating the service messages about the location of the electromagnetic impact zone. It is important that the information received from the sensor is the influential factor when choosing the data exchange standards for the subsystem of data transmission and reception. In fact, the information recorder performs the information registration with its subsequent conversion into the data storage format in the temporary storage subsystem. A photo and video camera or a microphone can take on the role of the recorder.

III. Scenarios of Interaction

Let us consider the scenarios of a group interaction of drones when solving the task of assured data transmission under the conditions of external electromagnetic influence.

The pulses of electromagnetic radiation, like any radio signal, are characterized by the propagation distance and the attenuation in space. However, the impact of electromagnetic radiation pulses has a different effect on the information system as they are approaching their source. While regarding a group of drones as the information system, it is possible to distinguish conditionally three zones of electromagnetic radiation influence (Fig. 2).

In the zero area there is no evidence of electromagnetic effect registered by the sensor, or the effect occurs to be below the noise level. The drone operates in the routine mode. Depending on the task assigned, the drone performs data reception and transmission using the most high-speed standards, for example, IEEE 802.11ac (5 GHz frequency, 433 Mbps data rate, 150 m transmission range in the open space), in the real time mode.

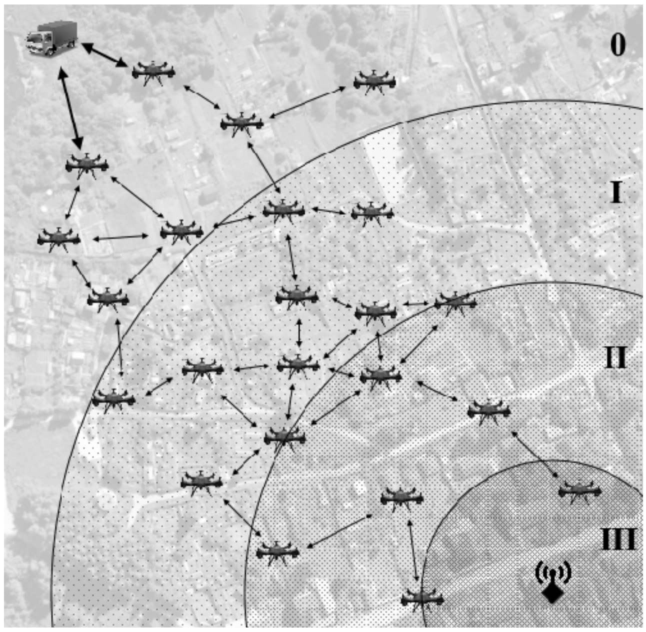

Fig. 2. The zones of electromagnetic radiation impact on the group of drones

The data warehouse is not enabled when rebroadcasting and is involved in the process of converting data from the information recorder into the required format for the further data transmission to the data center. In the first zone, the sensor registers the electromagnetic effect, but its impact does not provide any tangible losses in the process of exchanging the data among the drones. The drone selects the optimal data transmission standard in accordance with its speed characteristics. The most high-speed frequency standard at which the effect is minimal is selected depending on the intensity and frequency of the electromagnetic effect. For example, if the electromagnetic interference covers the range from 2 up to 6 GHz, then it is advisable to go to the IEEE 802.11ad standard, which operates in the 60 GHz range. The disadvantage of this standard is the condition of forming a beam that provides reliable communication within less than 15 meters, which poses the problem of increasing the density of drones in space for high-speed data exchange.

In the second zone, the sensor registers a rapidly growing level of electromagnetic effect, the narrow-band interference appears, aimed to suppress the specific ranges in which data is exchanged; the data flow rate is dropping significantly due to the increase in the noise threshold when approaching the source region of electromagnetic pulses. The optimal solution to maintain the assured data transmission is to use the ultra-wideband communication technology at close ranges when low energy consumptions, using ultra-wideband signals with extremely low power spectral density as a carrier [11]. The use of an ultra-wide frequency band (at least 500 MHz) at distances up to 20 m makes it possible to achieve a data transfer rate of up to 50 Mbps [11]. In the third zone, a destructive effect of the electromagnetic field on the semiconductor component base of the drone occurs. This leads to the appearance and development of degradation processes in its microstructural elements and to the consequent malfunctions of normal operation of objects. The stored information is either distorted or destroyed completely [1]. The drone operates in an emergency mode. At the same

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time, it is supposed to manage to solve the task of broadcast announce message about the critically powerful effect of an electromagnetic field in a given location. If possible, the data in the storage are destroyed.

IV. Conclusions

The task of the paper is to develop a scenario for the interaction of a group of mobile objects (drones) under the conditions of powerful electromagnetic influence. The definitions of the concepts of mobile objects and the consequences of the influence of powerful electromagnetic effects on them have been given. The analysis has been carried out of the problem of providing guaranteed delivery of large amounts of data under the said conditions. The scenario has been proposed for the interaction of a group of drones within a framework of the common task they perform. The variants have been considered of increasing the survivability of mobile objects under the conditions of powerful electromagnetic effect.

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