Monitoring of moving objects in the absence of a GSM signal

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Abstract. Many modern transport processes require constant on-line monitoring and management. However, the main difficulty lies in the lack of a stable GSM connection. One of the possible solutions to this issue is the use of MESH networks. These represent the possibility of wireless communication between multiple entities, which are nodes on a distributed network. The article presents the results of the development of original local radio modules and a base station to ensure uninterrupted transmission of digital data from the monitoring object, in conditions of insufficient GSM coverage. The complex provides the following operating modes: simple interaction via a GSM channel, data transmission via a self-organizing network, as well as sensory interaction between objects. In the absence of GSM communication, the repeater provides on-line data transmission from the monitoring object, at a distance of up to 860 m, at a distance from the base station - at least 500 m. The use of the new complex makes it possible to promptly respond to changes in operating factors and prevent emergency situations during the operation of vehicles.

An important element of digitalization and informatization of a modern motor transport complex is positioning systems and data transmission from objects of control and monitoring to a thematic user.

Technologies for receiving and transmitting digital information are used for remote positioning of mobile objects, monitoring vehicle parameters and the condition of drivers, monitoring and analyzing logistics services, and managing them [1, 2, 3, 4, 5, 6].

It is very important that most of the digital information needs to be broadcast in real time. The following transport processes requiring on-line monitoring and control can be: transportation of valuable, dangerous and special cargo [7, 8]; loading and unloading operations control [9, 10], application of technical vision systems for traffic management [11, 12], drivers condition monitoring [13, 14, 15], mobile equipment dynamic data transfer and interactive diagnostics [16, 17], control and management of technological operations that are performed in automatic mode (drones) [18, 19]; use of intelligent transport systems in public transport [20, 21] and much more.

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In most cases, for on-line monitoring of the state of the monitored object, excluding satellite navigation systems, a GSM signal is used, which is provided by a certain cellular operator. However, the main difficulty in the formation of a GSM communication channel is the lack of a guarantee of the continuity of the GSM / GPRS broadcast. [22, 23]. Interference in the radio channel and the lack of a GSM connection may occur due to the large distance of cell towers; absorption of a radio signal in the atmosphere due to the phenomenon of molecular resonance, which is obtained by the presence of water and oxygen molecules; radio waves shielding when passing through solid particles (metal, wood, concrete, etc.); diffraction phenomena, when a signal meets objects comparable to the wavelength and of the terrain top; scattering of the signal when it encounters a cluster of objects that repeatedly reflect it (for example, swaying foliage of trees), etc. [24].

Obviously, these reasons the high degree of urgency of the problem of the lack of a stable GSM connection predetermine, for mobile agricultural equipment including. The importance of solving the problems of on-line transmission of digital data, when a significant distance from objects of developed infrastructure, rugged terrain and a network of protective forest belts many authors note [25, 26 etc.]. Thus, the following we have to state. Despite the high level of development of information technologies, now GSM-operators continuous communication via the GPRS channel cannot guarantee.

The purpose of the research has been determined, based on the foregoing. Stable on-line communication with the monitored object, in the absence of a GSM connection ensuring.

The main tasks of the work are determined:
- development of local radio modules and a base station to ensure uninterrupted transmission of digital data from the monitoring object, in conditions of insufficient GSM coverage;
- organization and testing of a new system of on-line monitoring and control of objects.

The technology of MESH networks - is based on the proposed principle of wireless transmission of digital data in real time, in the absence of GSM communication.

MECH data transmission technology is a mesh network that a distributed data transmission system represents. It consists of many network nodes interconnected by a wireless data transmission channel. This technology is becoming more and more widespread in transport systems, both in Russia and abroad. [27, 28]. MESH reliability and stability of radio communication in difficult field conditions, with insufficient coverage of GSM connection provides. When one of the nodes of the MESH network stops functioning, other nodes continue to work, connecting with each other directly or through other intermediate nodes.

Testing of the developed equipment out in conditions of limited GSM signal coverage was carried. These are agricultural fields, with difficult terrain, near protective forest belts. The vehicle tracks were recorded and saved in the Wialon monitoring system, at the time of the movement of the monitored objects [29].

The proposed hardware and software complex is designed to transmit data from a vehicle, with a view to monitor its operating modes, control parameters and control the possibility of actuators. The complex (Fig. 1) includes an onboard navigation terminal, as well as a proprietary radio module [30] for organizing a sensor data transmission network, based on the TI 13XX microcontroller.

The original radio module for transmitting information from a vehicle has the ability to broadcast digital data in conditions of insufficient GSM / GPRS signal coverage. The module automatically selects a data transmission channel using a telecom operator with a higher and more stable signal. The essence of the proposed development by the diagram in Fig. 2 is illustrated.

The device contains: a 32-bit ARM Cortex M4F microcontroller with an operating frequency of 80 MHz (1), a GSM / GPRS modem with two SIM cards with a choice of
operator (2), a GPS receiver with an internal antenna (3), a radio transceiver with a range 434 MHz and 868 MHz with external antenna (4), Bluetooth module (5), storage device based on SD card with a capacity of at least 2 GB (6), analog input with operating voltage from 0 to 36 volts (7), digital input from 0 to 36 volts (8), frequency input 0-1000 Hz (9), pulse input with operating voltage in the range from 0 to 36 volts (10), RS485 interfaces (11), RS485 interfaces (12), CAN interface (13).

Fig. 1. A set of a prototype system for on-line monitoring and control of objects, in conditions of insufficient GSM coverage: onboard navigation terminals with original radio modules (a, b, c); original base transceiver station (d)

The use of the proposed module reduces the time for obtaining digital information from control devices of technical vehicles. This allows you to respond in a timely manner to changes in controlled information, which prevents abnormal situations when monitoring vehicles. Thus, the reliability and efficiency of systems for transmitting controlled information is increased.

Fig. 2. Block diagram of the module for uninterrupted transmission of digital data from control and monitoring devices of a vehicle in conditions of insufficient GSM cellular coverage
The following main modes of operation the complex provides.

*Simple interaction mode via GSM channel*, which is similar to the work of a classic on-board terminal. If there is a possibility of data transmission via the GSM / GPRS network, then the accumulated information is reset to the specified server.

*In the mode of data transmission through a self-organizing network*, radio modules on board the Complex form a dynamic sensor data transmission network. When any of the Complexes within this network has the ability to access the Internet (either through GSM / GPRS or through the Ethernet port), then it is automatically assigned as a gateway. Through one information is transmitted about the state of the vehicle and / or its control.

*In the sensor interaction mode*, the radio network allows on-line interaction between vehicles and infrastructure elements. This makes it possible, without direct interaction with the conditional server, to solve tasks related, for example, to obtaining the approximate coordinates of a vehicle even in the absence of a GPS / GLONASS signal, optimizing the movement of these vehicles or sending warnings about an emergency or potentially dangerous situation.

Was as follows the methodology for a series of experiments. 2 test objects were brought into the field: № 2 (Tractor Terrion ATM 7360) and № 3 (combine harvester John Deere 1175). Object № 2 was a repeater for object № 3. Object № 1 is a base station (all-terrain vehicle UAZ-3741) (Fig. 3).

![Fig. 3. Demonstration of tracks and broadcasting messages in the interface of the Wialon monitoring system of a field series of experiments](image-url)

During the experiment, the distance of object № 3 from the base station was 1490 m. The distance between object № 2 and the base station (object № 1) was 220 m. The distance between objects №№ 2, 3 was 1280 m. At the same time, there was no communication between the base station and object № 3. Also, object № 3, located in the zone of no GSM signal, did not have access to the services of a cellular operator (MTS). The on-line connection of facility № 2 with the base station was stable. When objects №№ 2, 3 come closer to a distance of 860 m, the repeater (object № 2), without losing its own on-line connection with the base station, resumed on-line data transmission from object № 3 to the base station. The distance between object № 2 and the base station was 500 m. The location of object № 3 has not changed. Confident updating of messages (on-line signal transmission)
from it to the base station was lost only when object № 2 was removed at a distance of more than 750 m.

Thus, the possibility of using the proposed technology and the developed technical means for on-line monitoring of objects located in the zone of absence of a GSM signal was experimentally confirmed.

**Conclusions**

1. The inaccessibility of on-line broadcasting of information when there is no GSM signal is one of the acute problems of digital data transmission in innovative transport technologies. Currently, GSM operators cannot guarantee continuous communication via GPRS.
2. A set of a prototype system for on-line monitoring and control of objects has been developed and manufactured in conditions of insufficient GSM coverage. It consists of 3 units of on-board navigation terminals with original radio modules and an original base transceiver station.
3. Field tests have established that the repeater provides on-line data transmission from the monitoring object, at a distance of up to 860 m, at a distance from the base station - at least 500 m.
4. The proposed digital data transmission technology and the device for its provision allow data transmission with an insufficient level of GSM / GPRS signal. Its application reduces the time for obtaining digital information from mobile objects control devices. This allows you to respond in a timely manner to changes in current conditions and prevent abnormal situations during the operation of vehicles.

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