Monitoring of moving objects in the absence of a GSM signal

Sergey Rodimtsev[1*], *Alexander* Psaryov[2] and *Andrey* Chuykin[3]

[1]Oryol State University named after I.S. Turgenev, Department of Service and Repair of Machines, 302030, Oryol, Russia
[2]Oryol State Agrarian University named after N.V. Parakhin, Department of Power Supply, 302019, Oryol, Russia
[3]LLC «Farvater CAN Technologies», 143403, Krasnogorsk, Russia

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.

* Corresponding author: rodimcew@yandex.ru

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).

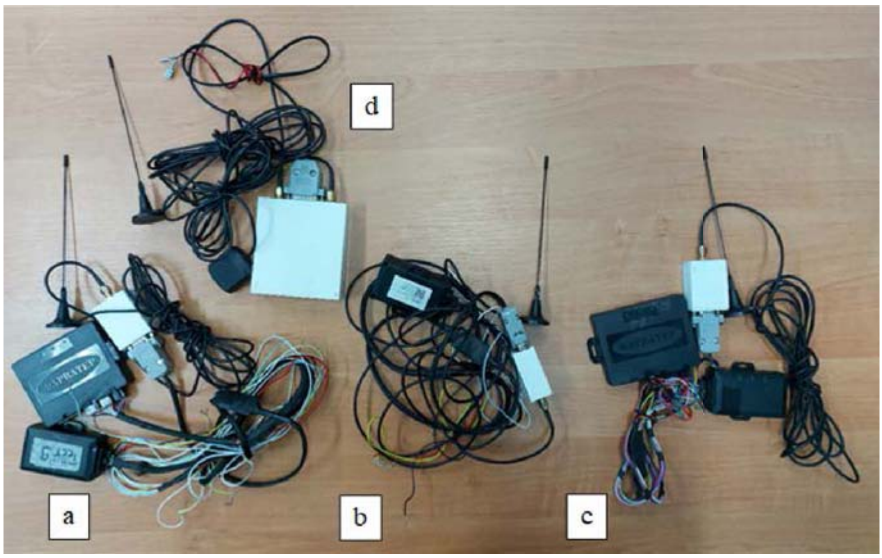

Fig. 1. A set of a prototype system for on-line monitoring and control of objects, in conditions of insufficient GSM coverage: onboard navigation terminals with original radio modules (a, b, c); original base transceiver station (d)

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.

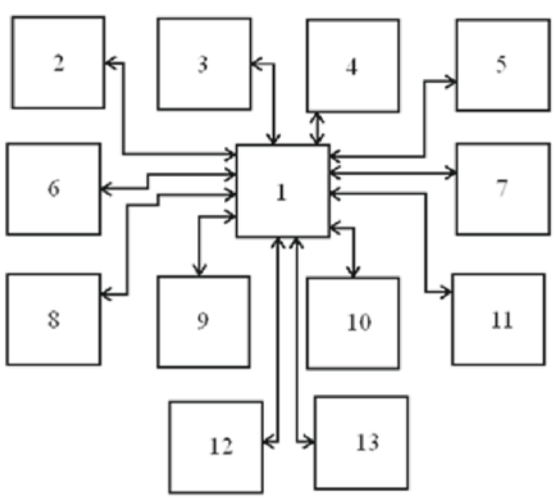

Fig. 2. Block diagram of the module for uninterrupted transmission of digital data from control and monitoring devices of a vehicle in conditions of insufficient GSM cellular coverage

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).

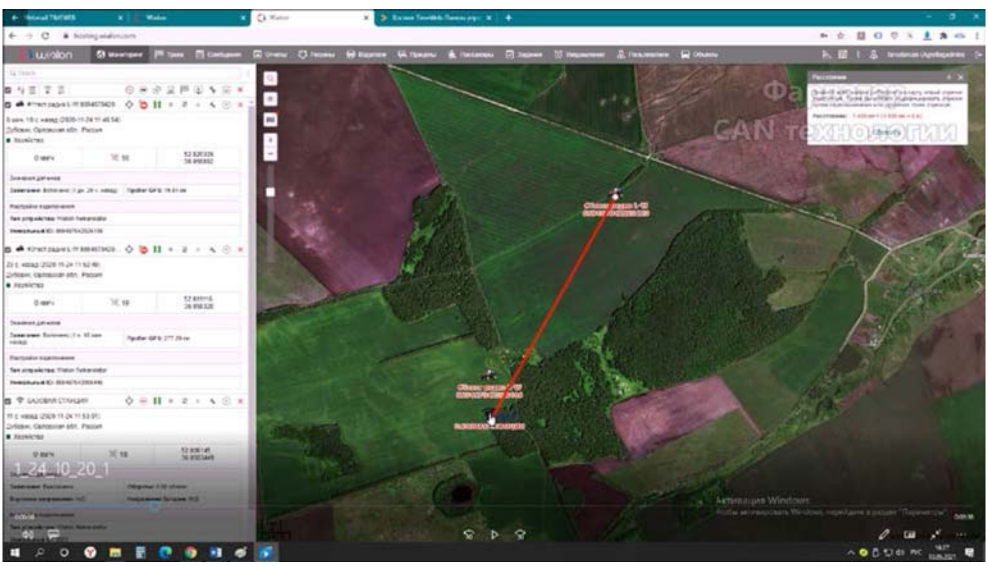

Fig. 3. Demonstration of tracks and broadcasting messages in the interface of the Wialon monitoring system of a field series of experiments

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.

References

1. V.V. Dementienko, D.V. Makaev, I.I. Ivanov, A.P. Yurov, *Driver status monitoring as an integral part of the vehicle monitoring system*, Actual directions of scientific research in the XXI century: theory and practice, v.**4**, № **5-3 (25-3)**, pp. 78-82 (2016)
2. B.V. Ovcharuk, *Feasibility and prospects of introducing satellite monitoring of the rolling stock of road transport*, Alternative energy sources in the transport and technological complex: problems and prospects for rational use, vol. **1**, № **1 (1)**, pp. 122-125 (2014)
3. M.I. Romanchenko, *Results of calculating the norms of operational fuel consumption for trucks with gasoline engines based on GPS technologies*, Innovations in the agro-industrial complex: problems and prospects, № **4 (12)**, pp. 12-19 (2016)
4. F. Cardoso, A. Serrador, T. Canas, *Algorithms for Road Safety Based on GPS and Communications Systems WAVE*, Procedia Technology, №**17**, pp. 640-649 (2014)
5. G.A. Giannopoulos, *The application of information and communication technologies in transport*, European Journal of Operational Research, v. **152**, № **2**, pp. 302-320 (2004)
6. A.M. Orozco, S. Céspedes, R. Michoud et al., *Design and simulation of a collision notification application with geocast routing for car-to-car communications*, Eur. Transp. Res. Rev., №**7**, p.36 (2015)
7. A.I. Zhodzishsky, A.D. Linkov, E.A. Shebanov, T.E. Tarasenko, *Monitoring System for Critical Objects and Transportation of Dangerous Goods*, Fundamental problems of electronic instrumentation, vol.**12**, № **7**, pp. 66-67 (2012)
8. D.Yu. Zhulyabin, *Models of channels for wireless communication systems. Modeling, optimization and information technology*, Science Magazine, № **1 (14)**, pp. 25-47 (2014)

9. A.V. Gorchakova, *Analysis of the application of digitalization in logistics*, Construction techniques and technologies, № **4 (24)**, pp. 51-55 (2020)
10. G. Dezi, G. Dondi, C. Sangiorgi, *Urban freight transport in Bologna: Planning commercial vehicle loading/unloading zones,* Procedia - Social and Behavioral Sciences, №**2(3)**, pp. 215-230 (2010)
11. A.E. Sokolov, *Technical vision system for traffic accounting at intersections*, Novosibirsk State University Bulletin. Series: Information Technology, v.**10**, № **1**, pp. 87-93 (2012)
12. Ch. Fu, Ch. Chun-jen, L. Chi-jen, *A Linear-Time Component-Labeling Algorithm Using Contour Tracing Technique*, Computer Vision and Image Understanding, vol. **93**, pp. 206–220 (2004)
13. I.S. Dymov, R.E. Derevianko, D.A. Kotin, *Automated system to prevent the driver from falling asleep while driving. Bulletin of MSTU*, Proceedings of the Murmansk State Technical University, v.**20**, № **4**, pp. 659-664 (2017)
14. I.B. Lashkov, A.M. Kashevnik, *Determination of dangerous conditions of a driver based on mobile video measurements of his facial characteristics*, Information technology and computing systems, № **2**, pp. 84-96 (2019)
15. T. Hyuga, K. Kinoshita, K. Nishiyuki, Yu. Hasegawa, *Driver Status Monitoring System in Autonomous Driving Era Driver Status Estimation with Time-series Deep Learning*, Omron technics, vol.**50**, pp. 200-214 (2019)
16. A.V. Ostroukh, A.V. Vorobyova, A.M. Kolbasin, *Digital system for remote diagnostics of road transport*, Industrial ACS and controllers, № **11**, pp. 3-10 (2018)
17. . Ju. Doo-Hee, Je. Gu-Min, A. Hyun-Sik, *Remote Vehicle Diagnostic System Using Mobile Handsets*, Proceedings of the 2006 International Conference on Wireless Networks, pp. 493-496 (2006)
18. A.I. Korobeyev, A.I. Chuchaev, *Unmanned vehicles: new challenges to public safety*, Lex Russica, № **2 (147)**, pp. 201-212 (2019)
19. A. Kane, O. Chowdhury, A. Datta, Ph. Koopman, *A Case Study on Runtime Monitoring of an Autonomous Research Vehicle (ARV) System*, Runtime Verification, pp.102-117 (2015)
20. Yu.S. Shapovalova, *Application of intelligent transport systems based on GLONASS in public transport*, Magistracy Bulletin, № **7-2 (94)**, pp. 56-58 (2019)
21. Ph. Blythe, T. Rackliff, R. Holland, J. Mageean, *ITS applications in public transport: Improving the service to the transport system*, Journal of Advanced Transportation, №**34**, pp. 325-345 (2000)
22. A.R. Abaev, *Problems of the development of cellular communications in the tourist area of Lake Baikal*, Irkutsk State University Bulletin, v.**5**, №**1**, pp. 3-15 (2012)
23. I. Dianov, V. Serganov, A. Uporov, A. Puksov, *Improving the reliability of transmission of technological information in cellular networks*. *Solutions based on specialized GSM / GPRS terminals*, Wireless technologies, № **4**, pp. 30-33 (2007)
24. D.Yu. Zhulyabin, *Models of channels for wireless communication systems. Modeling, optimization and information technology*, Science Magazine, № **1 (14)**, pp. 25-47 (2014)
25. I.P. Glebov, A.V. Yurlova, E.N. Pavlova, Yu.O. Ershov, A*pplication of Agrosignal software as a factor in increasing the innovative activity of agricultural enterprises*, Agrarian scientific journal, № **12**, pp. 84–88 (2018)

26. A.Yu. Izmailov, Ya.P. Lobachevsky, Yu.S. Tsench, E.S. Luzhnova, E.N. Ilchenko, S.E. Lonin, I.S. Alekseev, *On the synthesis of a robotic agricultural mobile unit*, Bulletin of the Russian agricultural science, № **45**, pp. 63-68 (2019)
27. B. Almadani, Sh. Khan, R. Sheltami Tarek, M. Shakshuki Elhadi, M. Musaddiq, B. Saeed, *Automatic Vehicle Location and Monitoring System based on Data Distribution Service*, Procedia Computer Science, vol. **37**, pp. 127-134 (2014)
28. A. Cilfone, L. Davoli, L. Belli, G. Ferrari, *Wireless Mesh Networking: An IoT-Oriented Perspective Survey on Relevant Technologies*, Future Internet, **11(4):99**, pp. 302-314 (2019)
29. Vehicle monitoring system GPS / GLONASS Wialon. Official website [Electronic resource] - Access mode: https://wialon.ru/ (date of treatment 04/14/2021)
30. S.A. Rodimtsev, A.I. Psarev, A.N. Chuikin *A module for uninterrupted data transmission from vehicle control and monitoring devices in conditions of insufficient GSM cellular coverage*. Application for the grant of a patent of the Russian Federation for a useful model No. 2020140548, dated 08.12.2020, Federal Institute of Industrial Property (FIPS) (2020)