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ANALYSIS OF THE FUNCTIONALITY OF A MOBILE NETWORK OF SENSORS IN THE CONSTRUCTION INVESTMENT SUPERVISION SYSTEM BASED ON UNMANNED AERIAL VEHICLES




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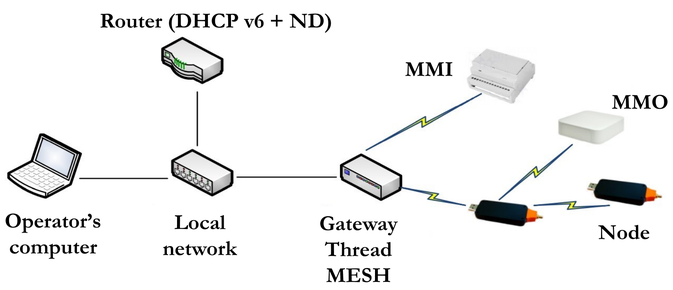
INTRODUCTION

The article presents the results of research and development work, co-financed by the National Centre for Research and Development in Poland (MAZOWSZE/0055/19-00). The project is related to the construction of devices according to the author's solution and testing their capabilities. It is a network of sensors for monitoring infrastructure elements and moving objects, e.g. people working on a construction project. The monitoring sensor network is a part of the space inspection and investor supervision system. The most important components of this system are: a UAV swarm, wireless charging stations for automatic docking, mentioned monitoring sensors and user software, integrating of all components, responsible for mission planning (UAV raids) and measurement data processing.

RESEARCH AREA

The tested system of monitoring sensors forms a MESH telemetry network. The network, thanks to self-organization, ensures data transmission from telemetric devices during UAV flights, regardless of area coverage by other networks such as Wi-Fi or GSM. The data to the end-user are transmitted via IP LAN. With this solution, the MESH network can be integrated into any network infrastructure. In practice, the router and the operator's computer can be one computer (logically the server) in the Ordering Party's network (Fig. 1).



MMI - infrastructure monitoring module
MMO - person monitoring module

Fig. 1. Sample network configuration

MATERIALS AND METHODS

MATERIALS

The tested MESH network consists of the following elements (Fig.2):

1. Internal user network or computer: reading data from sensors, viewing the location of employees, controlling actuators.
2. Gateway: gateway between LAN and telemetry system.
3. Node - module transceiver: long-range module, creates a network bridge, enables UAV telemetry data transmission.
4. MMO - person monitoring module: location, measurement of environmental conditions (temperature, humidity), heart rate measurement (detection of threats), 9DOF sensor - detection of falls, helmet-wearing control, inductive charging.
5. MMI - infrastructure monitoring module: control of outputs, reading of digital and analog inputs, measurements of physical values (temperature, stress sensors, etc.), 3 programmable digital interfaces.

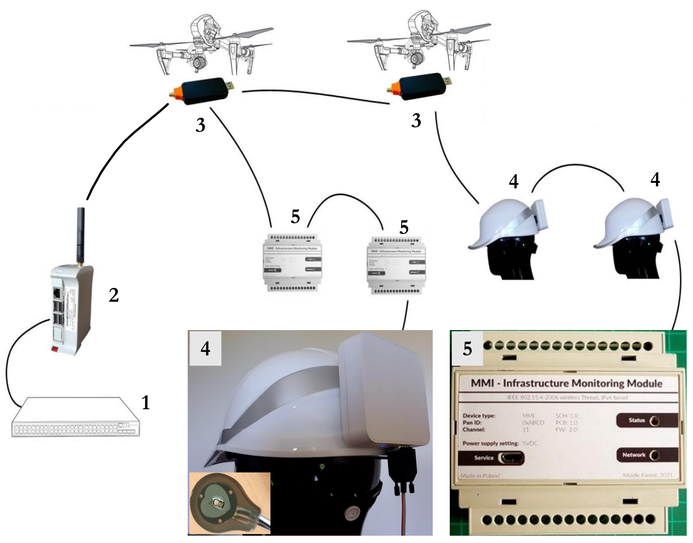


Fig. 2. One of the MESH telemetry network configuration scenarios

METHODS

As part of the research, procedures were developed for testing sensor networks in laboratory and field conditions. The possibilities were analyzed, among others:

- self-organization depending on the location of elements in the network,
- system operation without access to GSM network,
- receiving data from sensors without the necessity of building permanent networks,
- telemetry transmission of each UAV,
- remote monitoring of investments or infrastructure,
- maximum range between devices.

RESULTS

In laboratory tests, the following options were analyzed:

- self-organization depending on the location of elements in the network,
- system operation without access to the GSM network,
- receiving data from sensors without the need to build permanent networks

The nRF Thread Topology Monitor was used in the tests. It is a cross-platform tool that enables developers to visualize Thread mesh network topology in real-time.

Four scenarios related to the operation of the MESH telemetry network in laboratory conditions are presented below. The method of establishing connections confirms the effectiveness of the assumptions adopted in the project.

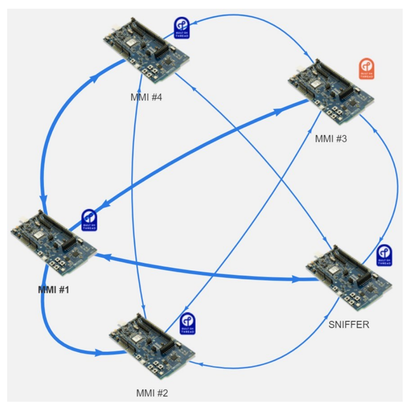


Fig. 3. MMI sensors within range (all within range of the router). All sensors are able to communicate directly with the router as well as within the mesh bridge through themselves to the router

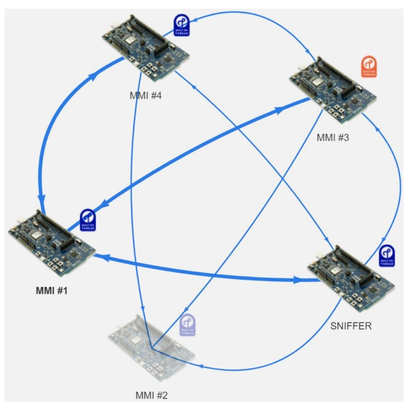


Fig. 4. One of the MMI sensors (MMI # 2) is out of range of the network. Outside the range of the router and other MMI sensors that could provide the mesh transport bridge service

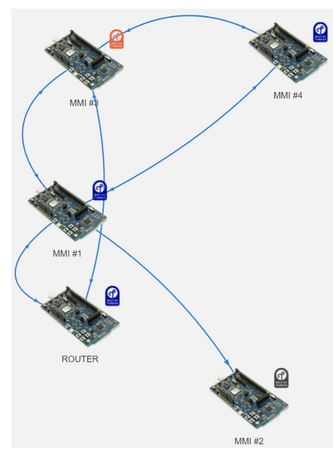


Fig. 5. The MMI sensor (MMI #1) establishes an effective connection via the other sensor (MMI # 2) which is within the range of the MMI sensor (MMI # 1) as well as the router. It acts as a transport bridge to the router. As a result whole network works the same way maximizing its effective range

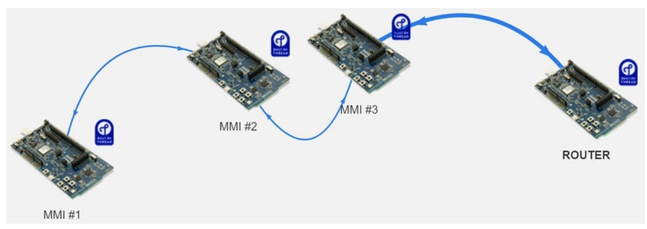


Fig. 6. Sensors connected in series - they transfer data to the router as part of their operation in their range circles. Each sensor provides a transport bridge for the next one on a line. It makes the effective range of all networks much extended within the use of only one gateway

Currently, research is underway to verify the applicability of the constructed MESH telemetry network in field (real) conditions. By the project's assumptions, the tested radio range between devices was 5 km (Fig. 7). The condition for the proper operation was mutual visibility of the antennas. The Round-Trip Time of the echo packet near the ground at a distance of 1 kilometer was about 20ms between nodes.

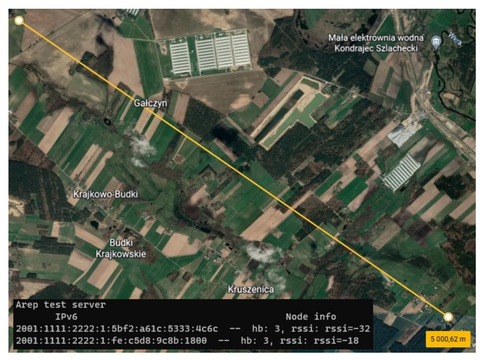


Fig. 7. Test of the maximum radio range between devices

The following tests are still planned: telemetry transmission of each UAV, remote monitoring of investments or infrastructure and maximum range between devices. Part of the research will be possible when the UAV swarm is ready. Other tests will be implemented in the coming weeks. The maximum range between devices is adversely affected, among others, by electromagnetic fields, terrain obstacles, and unfavorable terrain (Fig. 8). These factors will be taken into account in the selection of test sites.

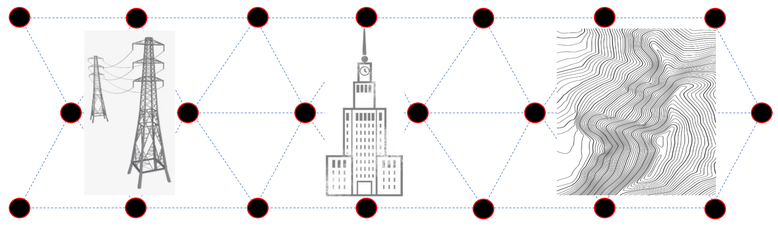


Fig. 8. Analysis of the impact of terrain obstacles on the shape of the telemetry network and signal transmission

DISCUSSION AND CONCLUSIONS

The constructed MESH telemetry network is an innovative approach to monitoring people and investments. The applied technical solutions make the system independent of the existing technical infrastructure. A significant extension of the capabilities of the constructed system is the placement of network nodes on the UAV. This is particularly important in the case of investments or planned measurement missions in areas where there is no GSM or Wi-Fi access (deserts, large water reservoirs, high mountain ranges). The tests carried out so far have proved the full efficiency of the applied system. Soon, after completing all the construction investment supervision system components, it will be possible to perform the last field tests.