Requirements for radio module of wireless decentralized network

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Abstract. This paper considers the decentralized network and the features of its functioning. Within it are analyzed the problem of designing radio devices for wireless decentralized networks and the classification of their requirements. The requirements for the software are classified, specifying the structure of the network, protocols, and hardware - the frequency and transmit power, power consumption, dimensions, etc. There are disclosed recommendations for the transceiver design on some of the constituent elements of the radio module.

1. Introduction

The rapid growth of wireless data transmission networks is due to the development of information technologies, reduction of cost, overall dimensions and power consumption of electronic devices in general and small-sized receiver-transmitters including [1-3].

In the decentralized peer ad hoc network, all nodes are equal. Each node on the network can act as a repeater. Lack of leading allows network devices to operate independently of the composition and amount of the radio network participants [4, 5]. A generalized scheme of a decentralized network structure and radio module is shown in Figure 1.

![Figure 1. Generalized scheme of a decentralized network (a) and the radio module structure (b)](image-url)
This structure of the radio module is due to in part to the fact that it became possible to develop complex routing algorithms, compression and data integrity checks directly on the CPU of mobile devices using the operating system tools. This simplifies the process of development of special software and integration into the existing software environment and provides a broad set of software development tools. The receiver-transmitter is necessary to implement only the basic algorithms for broadcast [6].

Nevertheless, the construction of a wireless system in a decentralized network of data exchange is a complex scientific and technical problem in which is placed the radio module design task, taking into account the set of requirements of diverse requirements.

2. Requirements for the radio module of the wireless decentralized network

Basic requirements for the radio module, similar to the requirements of the transceiver, part of the radio module and meet the requirements for transmitters which are not subject to licensing in accordance with the decision of The State Commission for Radio Frequencies [7]. These include requirements to: the dimensional characteristics; value; the frequency at which the transceiver operates; autonomous work; computing power.

In turn, the requirements for the transceiver are formed under the influence of requirements, applicable to:

- the structure of the network (depending on the scenario of application, the volume of data transmitted and the reliability requirements);
- frequency (depending on the desired speed and the allowable size of the desired distance data);
  - power (depending on the communication range, the allowable energy and allowable size);
- nutrition (depending on the size characteristics and the nature of the data exchange requirements for power supply);
- antenna (depending on the transmission distance, signal direction and allowable size of the device).

The classification of requirements for radio module is shown in Fig. 2.
The network structure is determined by the application scenario: a set of requirements to the logic of building the information exchange specified in the terms of reference; network with one rank or a lot of rank. The key requirements are necessary degree of mobility of the nodes, the need to build a dynamic routing information exchange between members of the network, the relationship (rank) sites, the possibility of using the network coordinator, the requirements for the volume of transmitted data, the reliability of data delivery requirements.

The reliability of the network can be achieved using the following options:
- packages of delivery-confirmation of data (acknowledgment);
- checksum;
- error correction codes;
- high-level protocol with delivery control and data integrity.

The required data rate determines the carrier frequency and method of encoding (OOK, QPSK, GFSK, 2FSK, 4FSK) [8-10]. Great influence on the choice of the frequency used is provided by the limits of overall dimensions of the antenna since in such embedded solutions the antenna can be the dimensional unit.

The power increase leads to increase in the communication range, but likewise increases energy consumption, size, and complexity of the scheme. It should also be noted that high-power transmitters may interfere with other members of the network, in other words, significantly increase the load on the network.

The power supply system depends on the scenario of using the transmitters, which is influenced by the degree of mobility of devices; maximum permissible overall dimensions; maximum weight; requirements for tolerability (ammunition).
The transmitter must meet the requirements for frequency, output power, time- and speed-related characteristics of the network, have the computing power to ensure the functioning of the selected network type.

The radio transmitter may be a separate device, which is used to control a single processing core, such as a microcontroller, as well as system-on-chip (SoC), where the transceiver with the nucleus are combined in a single device. The choice depends on priorities: smaller dimensions and less processing power or more computing capabilities with a separate control unit. It is proposed to consider three options for the implementation of the transceiver:

- simple logic in SoC for small networks;
- complex logic in a single powerful computer core;
- full or partial support of the network stack by means of the operating system kernel [11-14], a simplified transceiver control.

For example, for a simple radio network can be implemented on a microcontroller STM32F031P4F6 (16/4) ST Microelectronics Transceiver CC1101 by the company Texas Instruments, and for a complex network used a STM32L030 microcontroller (64/8). In the case of software integration using the system-on-chip SoC 430 from Texas Instruments with the installation of the Linux networking stack.

The antenna is one of the key elements that determine the quality of the wireless network performance and moreover has a significant impact on the final size of the device. Its main characteristics are: length, gain, directivity, overall performance, and price of production. The most common types of antennas used in the mobile decentralized network nodes are whip, chip, and PCB antenna [10]. Whip antennas are high gain (2-10 dBi), with a wide acceptance angle and relatively high cost. Nonetheless, their use is rather difficult in compact devices. Chip antennas have average characteristics (0-5dBi) and small dimensions, characterized by the simplicity of installation and average cost. PCB antennas have good characteristics at high frequencies and low cost. The market has a large selection of ready-made solutions.

A distinctive feature of the receiver-transmitter decentralized network is the inability to predict the direction and distance to the site it is desired to link to. Therefore, there is a need for antennas with high radiation pattern and high gain. The ideal antenna must have a low cost, small size and still have good performance. However, during the design of the antenna it is usually necessary to reach a compromise between these characteristics.

Selecting an antenna for a receiving-transmitter self-organizing decentralized network is a challenging task and its solution is offered by a number of recommendations:

- recommendations for the definition of requirements for mobility network participants;
- recommendations for the definition of requirements for the mass-dimensional parameters of network nodes;
- recommendations on the choice of the carrier frequency used.

For non-mobile nodes can be topical use of directional antennas, however, for dynamically changing networks should be chosen antennas with maximum radiation pattern.

For devices with hard limits on the size of the structural elements may be most applicable PCB and chip antennas. Antenna size is usually determined by the wavelength, and hence the carrier frequency. The higher the frequency used, the smaller the overall size of the antenna. Therefore, due to strict requirements for mass-dimensional indicators of receiving and transmitting devices, high frequency transceivers may be a higher priority.

There transceivers, operating in the unlicensed zones 868 MHz and 2.4 GHz, have attained widespread use [10]. The use of transmitters at high frequencies can significantly reduce weight and size parameters of the antenna and the decentralized network nodes in the whole. Thus, the proposed recommendations take into account the basic requirements for the development of decentralized networks of nodes and allow to choose the best variant of the antenna.

Power supply of the radio module can be implemented based on the following elements [10, 11]:

\[ \text{Power supply} \]
not replaceable (solar panels, vibration, radio or other energy sources);
- rarely replaceable elements (batteries);
- often replaced elements (batteries or accumulators);
- stationary power supply (in the case of a limited autonomy).

3. Conclusions
Thus, for the design of the radio module for the decentralized network, the basic requirements are: dimensional characteristics; value; the frequency at which the transceiver operates; autonomous work; computing power.
Taking into account the considered requirements are implemented the following series of receiving and transmitting radio modules at frequencies of 433/868 MHz in the company "Open development" [15]:
- compact and low-power module OD-RF1101 with microcontroller, with data rate of up to 500 kbps;
- ISM module for loaded networks with short-range data transfer, with data rate of up to 500 kbps, range up to 1.5 km;
- OD-LORA module for data transmission over long distances (up to 15 km), with data rate of 37 kbps.

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