Analyze Wireless Sensor Network Structures for Intellectual Monitoring System

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2022 International Conference on Information Science and Communications Technologies (ICISCT) | 978-1-6654-7229-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICISCT55600.2022.10146824

***Abstract*— As one of the modern trends in the development of data transmission networks, wireless sensor networks are of great importance for solving problems related to the creation of tools for remote intelligent monitoring of devices. Wireless sensor networks are used in environmental monitoring, smart home, smart energy, smart transportation systems, smart agriculture, smart medicine and many other fields. Therefore, it is appropriate to model and research the hybrid energy supply sources of telecommunication systems as information transmission technologies in the IoT-based intelligent monitoring system, not based on a general approach to researching the characteristics of wireless sensor networks, but based on the parameters and specific characteristics of the system in which it is used.**

Keywords—monitoring levels, communication architecture, wired and wireless network, WSN, WiMAX, Wi-Fi, Bluetooth, ZigBee, comparison analyses.

I. INTRODUCTION

Currently, wireless data transmission technologies are becoming more and more popular both in the field of consumer electronics and in industrial systems. Communication technologies such as Wi-Fi and Bluetooth have now become an integral part of everyday life. High-speed Wi-Fi, Wi-Max, Bluetooth, wireless USB technologies are mainly designed to serve computer peripherals and multimedia devices. They are optimized for high-speed transmission of large volumes of data, at the same time they have energy consumption and therefore are rarely used in solving industrial problems, in particular industrial automation problems [1], [37].

Nowadays, one of the most urgent issues in the intelligent monitoring of hybrid energy supply sources of telecommunication systems is the organization of information exchange between devices on the basis of a single-scale and high-performance network.

The following factors play an important role in the selection of wireless technology for networks in an intelligent monitoring system:

- field level data exchange intensity;
- big powerful autonomous power from sources use opportunity;
- radio network to build topology.

The ZigBee wireless communication standard was developed to introduce wireless sensor networks into the intelligent monitoring system. This standard was originally developed with a focus on intelligent monitoring system applications, taking into account the basic requirements for data transmission networks [2], [38].

Today, the development of sensor networks is one of the most promising areas of development of communication technologies in the industry. Thanks to the development of modern microelectronics, it became possible to place a processor, memory (operational and non-volatile), digital-analog and analog-digital converters, a radio frequency receiver, a power supply and sensors on a board. Sensors in the intelligent monitoring system can be diverse, for example: temperature, pressure, humidity, light, vibration, etc.; they are connected to the microcontroller through digital and analog pins. The set of sensors used depends on the functions that wireless sensor networks perform [3], [8].

II. REQUIREMENTS OF WIRELESS SENSOR NETWORKS FOR MONITORING

Wireless sensor networks used in the monitoring process are characterized by a low data rate compared to other network types, because they are designed to carry a small amount of traffic and are characterized by extremely low power consumption of devices that are often in the «sleep» state [4], [9], [10].

Based on these, the sensor networks used in the monitoring system have the following requirements:

- self-organization and treatment ability during the monitoring process;

- ability to transmit information over long distances at low power of transmitters (using retransmission);

- cheapness of data transmission nodes and their small size during the monitoring process;

- minimum restrictions on placement of wireless devices in data transmission;

- low power consumption and the ability to receive power from autonomous sources for data correction during the monitoring process;

- it is easy to install sensors during the monitoring process, there is no need for electric cables and data transmission (due to completely wireless technologies and battery power);

- the possibility of installing such networks in an existing and working object without interfering with the service process;

- reliability and fault tolerance of the entire system in case of failure of individual connections between nodes of the data transmission network;

- low cost of installation, commissioning and maintenance in the remote monitoring system.

These advantages of wireless sensor networks over existing wired data transmission networks create several advantages for an intelligent monitoring system. The main component of the wireless systems proposed for the intelligent monitoring system is the wireless data transfer node. Through such nodes, it is possible to develop a network of any scale of the intelligent monitoring system. The ability to connect the wireless data transmission node to various types of sensors makes the intelligent monitoring system universal [2], [5], [11]. A typical system using a wireless data node includes:

- **sensor network coordinator** - collects data from sensors of the monitoring system and connects to the sensor network entering the SCADA system through it;
- **wireless data transmission node** - creates a wireless environment for data collection and primary processing, high-level data exchange, data reception and transmission;
- **sensor network server**.

IoT-based intelligent monitoring of hybrid energy sources of telecommunication systems, along with sensors installed in structures, machines and environment, provides the following advantages for telecommunication systems [4], [6]:

- reduction of energy-related catastrophic failures in telecommunication systems;
- saving natural resources through the monitoring process, improving the efficiency of telecommunication systems by providing continuous energy;
- to improve the efficiency of telecommunication devices in emergency situations and strengthen internal security.

In the process of IoT-based intelligent monitoring of telecommunication systems hybrid power supply sources, the wireless sensor is connected to the network and measured, it consumes very little power, it has the ability to intelligently and software and quickly collect data, it is reliable and accurate for a long time, and it requires low cost to purchase and install, and almost does not require long-term maintenance [7], [36].

During the monitoring process, the wireless sensor requires the selection of optimal sensors and wireless communication link for the network, knowledge of the application, and troubleshooting. Battery life, sensor replace time, and size are key considerations in building a wireless sensor network.

Recent advances in technology have made it possible to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC). This capability allows for very low-cost sensor networks that can communicate with each other using low-power wireless data transfer protocols [12]. A wireless sensor network typically consists of a base station (or "gateway") that can communicate with multiple wireless sensors via radio communication. The data is collected at the wireless sensor node, compressed and transmitted directly to the gateway or, if necessary, transmits the data to the gateway using other wireless sensor nodes. The transferred data is provided to the system through the gateway connection.

III. Wireless Sensor Network Architecture

The main architecture of the wireless sensor network of the IoT-based monitoring system of hybrid power supply sources of telecommunication systems is presented in fig. 1. It mainly consists of a set of wireless sensor nodes, a communication network and a base station, which is also a sensor node but connected to a server or computer [13], [14].

A sensor node of Wireless Sensor Network of Monitoring System - is a front-end location or location to be monitored. The sensor node is equipped with relevant sensors and a radio unit for data transmission. A microcontroller is used to interface the sensor and the radio unit. The main task of the sensor node is to sense the data, process the data and send it to the base through the network. Sensor nodes are placed very close or directly within the observed event. Therefore, they usually operate unattended in remote geographical areas [15], [17].

A wireless sensor network base station - is a station that collects all data from sensor nodes through the network during remote monitoring and then sends the data to a server or computer for processing. In some networks of the cluster-based monitoring system, the base station is also used as the cluster head. A base station can be programmed to listen for data, or in other words, it can be programmed to only receive data sent by a sensor node or to request the desired data from a specific node. The second approach is called request-based communication, and it is used in this experimental work on wireless network setup [16], [18].

A communication network - is a medium through which data is transmitted wirelessly. The network is formed by

sensor nodes that act as routers. In some cases, they act as a guide equipped with their own sensors.

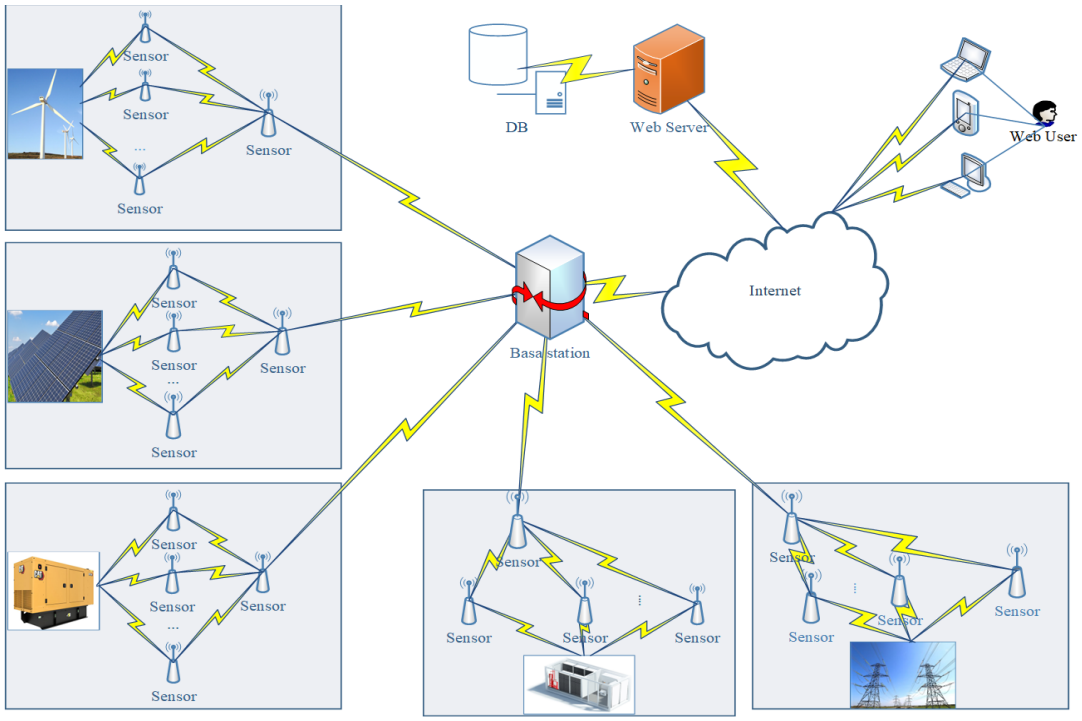
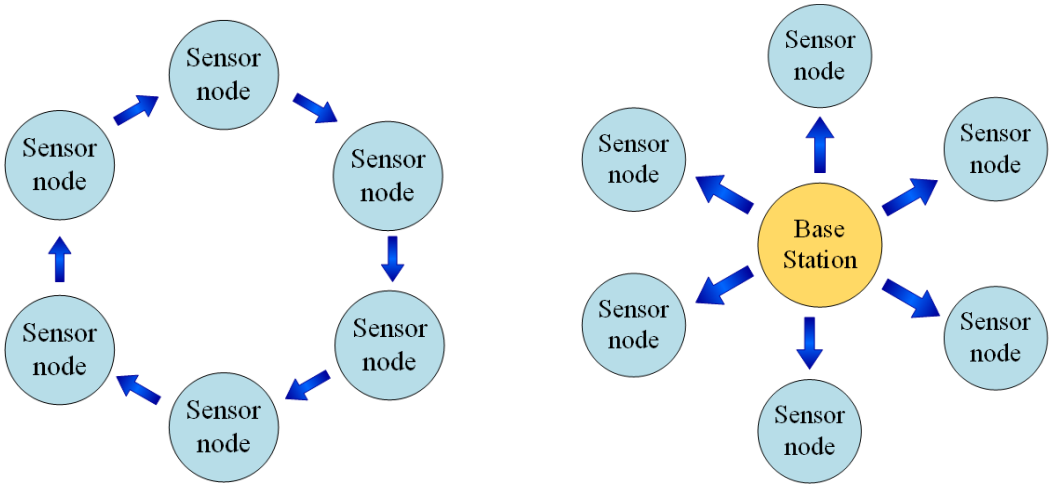


Fig. 1. Wireless sensor network architecture for remote monitoring system based on IoT for hybrid power supply sources of telecommunication systems

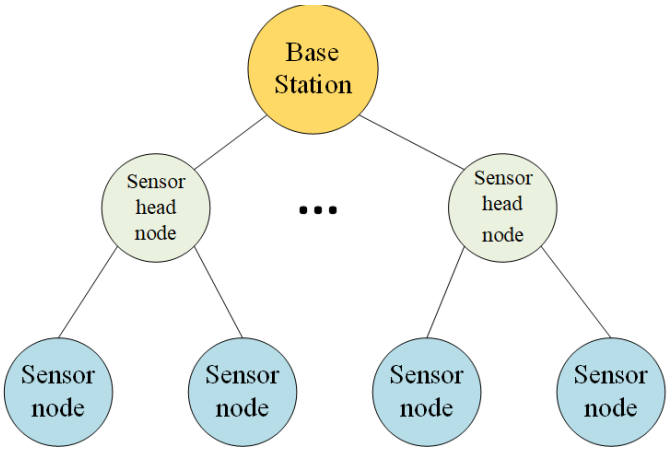
IV. Topology of Wireless Sensor Networks

In the IoT-based remote monitoring system of hybrid power supply sources of telecommunication systems, communication networks such as tree, star, ring (fig. 2) and mesh (fig. 3) are used to form a wireless sensor network topology. Star, ring, and tree topologies are similar to the way sensor nodes communicate, that is, sensor nodes communicate with only one node to receive or transmit. A star topology is where all sensor nodes are connected only to a base station. A ring topology is one in which data is planned to be transmitted from one part of the network to another only through a defined path, and the transmission path resembles a ring, as shown in fig. 2. If any node in the ring topology fails, the ring topology will fail and the communication may fail completely. A tree topology is a hierarchical topology in which a node at one level receives data only from another node below its hierarchical level. The highest level of this hierarchy is the base station. Mesh topology is a more modern topology compared to the rest [19], [20], [21].

A mesh network (topology) is a type of network in which each node must not only collect and distribute its own data, but also serve as a relay for other sensor nodes, that is, they must cooperate to distribute information in the network. Using a mesh network, it is possible to develop a remote monitoring system network based on the IoT of hybrid energy supply sources of telecommunication systems. When using the routing technique, the information from the sensors is spread along the path, hopping from node to node, until it reaches the monitoring center [22], [23], [24].



a) b)



c)

Fig. 2. Schematic diagram of star, ring and tree topologies

The fact that the routing network provides continuous connections to ensure the availability of all routes and allows for reconnection around disconnected or blocked paths using self-recovery algorithms is ideal for an IoT-based remote monitoring system [5], [25]. Therefore, a network whose nodes are connected to each other is a fully connected network. The self-healing capability enables remote monitoring of a routing-based network to function when one node fails or the connection deteriorates. As a result, for monitoring purposes, this network is usually very reliable because there are multiple paths between the source and destination on the network. Although primarily used in wireless scenarios, the concept also applies to wired networks and software interactions [26], [34].

Over the past decade, the size, cost, and power requirements of radio broadcasts have decreased, making it possible to fit more radio devices into each device network. Additional radios on each node allow it to support multiple functions such as client access, processing service, and scanning [27], [35].

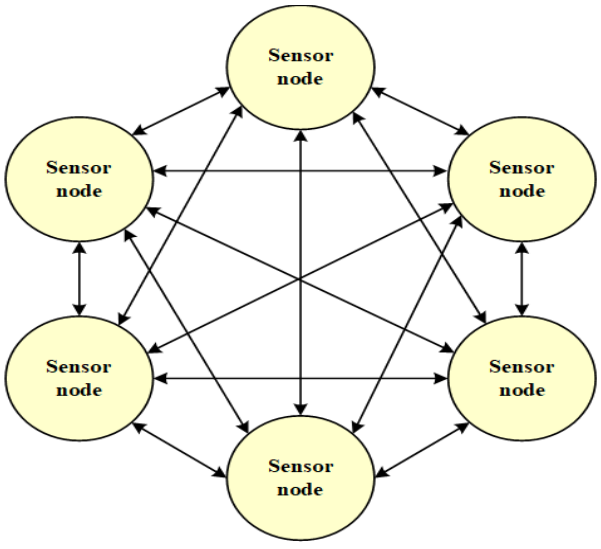


Fig. 3. Structure scheme of mesh topology

In addition, the decrease in the size, cost and power of radios has allowed network nodes to become more modular - now one node or device can have several radio cards or modules, which allows nodes to be adapted to handle unique functions and sets of frequencies. Any type of topology must also provide an appropriate type of routing of information through the network [7], [32].

V. Routing Methods in Wireless Sensor Networks

In the process of remote monitoring of hybrid energy supply sources of telecommunications systems based on IoT, the process of delivering data packets from one point to another in the network is carried out by routing. The routing process includes a specific method of selecting the data transfer path within the network, and Dijkstra, Belman Ford, and link-state algorithms are used in the remote monitoring process. At the same time, today there are many different types of routing that can be developed based on the application and distribution area. Three main types of routing are widely used [28], [29], [30]:

- Peer to peer routing;
- Single hop routing;
- Multi-hop routing.

A. Peer to peer routing.

Peer-to-peer routing is a method in which a node sends or receives information from only one node, schematically shown in fig. 4 [31].

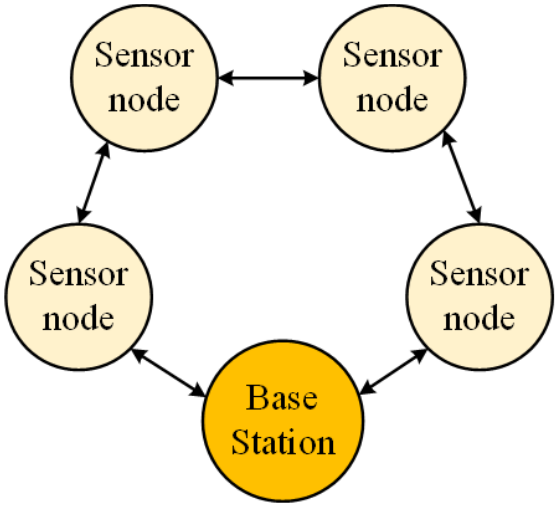


Fig. 4. Peer to peer routing

This type of routing can be seen in tree topology and ring topology. Nodes can be anywhere in the network hierarchy.

Recently, this type of routing is not used much because most networks are moving to mobile networks [33], [39].

B. *Single hop routing*

Single hop routing is similar to peer-to-peer routing, but one node in the pair is always the primary.

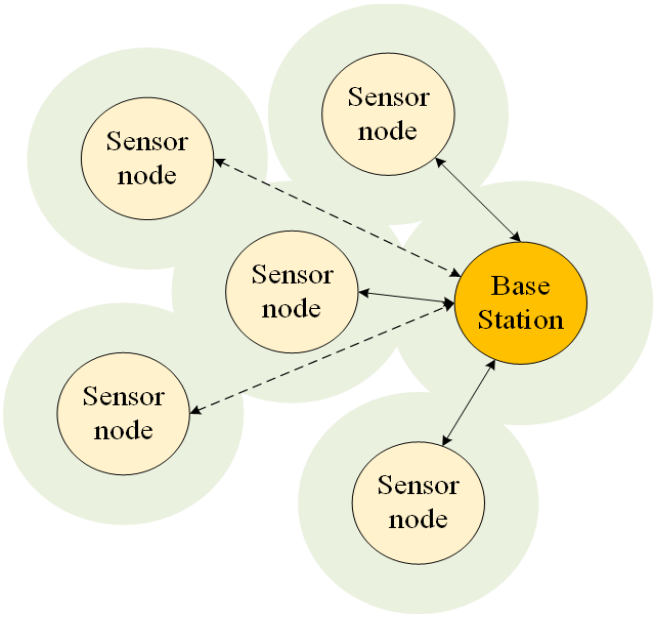


Fig. 5. Single hop routing

In this type of routing, each node is directly interconnected with a base station. A single-pass route limits the distance, and nodes cannot be distributed over a large distribution area. As shown in fig. 5, nodes that are not in range of the base station cannot communicate with the base station. One-hop routing is the simplest routing algorithm.

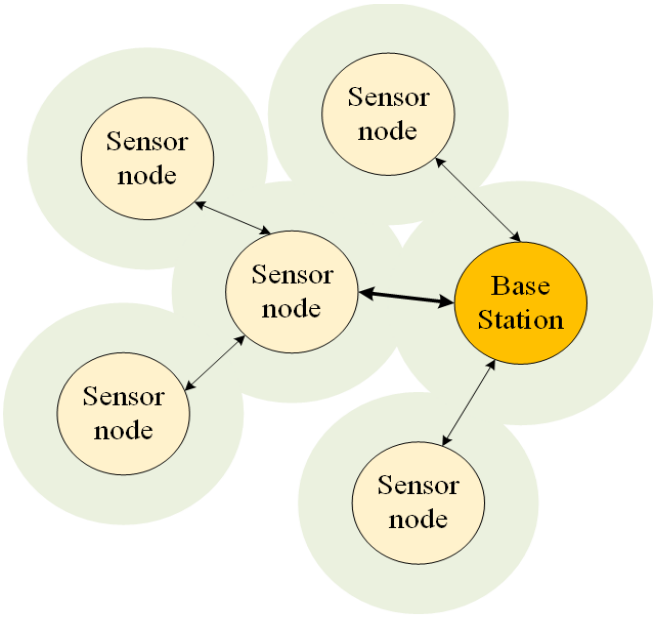


Fig. 6. Multi-hop routing

C. *Multi-hop routing*

Multi-hop routing - is a process in which data from sensor nodes reaches the base in several hops. This means that a sensor node outside the communication range of the base station node can also communicate with it through other nodes, as shown in fig. 6.

VI. Conclusion

Routing does not require specifying the path of data transmission, and data transmission may take different times depending on the state of the network. This type of routing is called dynamic routing, where the data path changes. This means that if a node fails, the network should automatically recover so that each node can communicate with the data collector. Of course, appropriate routing protocols are needed to discover routes between a source and a destination, or even to determine whether there is a path to a primary node. Considering this, dynamic multi-hop routing type of telecommunication systems is the most effective route type for network data transmission in IoT-based remote monitoring of hybrid energy supply sources.

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