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Easy Net Everywhere Wireless Network Transport Protocol Stack

A description of the developed Easy Net Everywhere wireless network transport protocol stack is presented. The structure of protocols that implement data delivery to the destination node is described. The application conditions of each protocol are described, depending on the network configuration. The protocol stack is divided into groups. The first group includes protocols for exchanging data between nodes in the same network with a unique or group password. The second group includes protocols for data exchange between nodes of different networks with a unique password. The third group includes protocols for data exchange using packet routing. Each protocol has its own identifier. According to the identifier, the network node selects a protocol for transmitting data on the transmitter side and a protocol for receiving data on the receiver side. The network architectures for which the transport protocol stack was created are presented.
protocol, protocol identifier, wireless network, easy net everywhere, network node

Problem statement. The development of wireless systems for controlling remote and spatially distributed objects is currently topical.

Such systems must meet the requirements of reliability, resistance to interference, stealthy operation, and have a high detection threshold. Additional requirements: high bitrate and ease of use of the transport protocol stack.

Several well-known wireless networks such as Z-Wave, ZigBee, LoRaWAN are now established. These networks are capable of solving a certain range of problems subject to a number of limitations. These are limitations such as UART communication port speed (baudrate), number of channels, radio data rate (bitrate) and maximum distance of stable data exchange between network nodes.

It has been found that, based on a combination of characteristics, these wireless networks have limitations that make it difficult to perform some tasks.

To solve the task of control remote objects and collecting data from remote objects, the authors created a wireless network Easy Net Everywhere.

However, the transport protocols of the above wireless networks cannot be used in the Easy Net Everywhere network for various reasons.

Therefore, it is necessary to create a proprietary transport protocol stack through which the exchange of commands and data between network nodes can be realised.

Analysis of research and publications. In the process of implementation of the research topic "Creation a 2.4 GHz mobile network with adaptive amorphous topology for controlling a swarm of UAVs and robotic objects", registration no. 0120U104088. The authors analysed the characteristics of Wi-Fi, Z-Wave, WiMAX, ZigBee, LoRaWAN wireless networks.

Open access documents that present wireless technologies, wireless networks and standards for network protocols were analysed. Wi-Fi networking technology is described by the IEEE 802.11 standard [1, 2]. The protocol stack cannot be used in an Easy Net Everywhere network. The limitation for application is the long connection establishment time (up to 10 seconds).

ZigBee technology is described by the IEEE 802.15.4 standard for wireless networks with routing [3-6]. ZigBee technology allows you to build topologies, star or peer-to-peer

(P2P) topologies. If the network topology changes dynamically, the network cannot operate stably. This is a limitation for building networks with variable topology. Therefore, the protocol stack of this standard cannot be used in an Easy Net Everywhere network.

The Z-Wave network is described in the document ITU-T G.9959 [7-8]. Networking is a good solution for controlling objects over a short distance. However, to create network controllers, you must be a member of the Z-Wave Alliance and be certified.

WiMAX (Worldwide Interoperability for Microwave Access) technology is described by the standard IEEE 802.16. The standard describes time-sharing multiple access technology (TDMA) [9-10]. The technology requires the use of base stations, subscriber stations and other network equipment. The network technology is not compatible with Easy Net Everywhere.

LoRaWAN technology, has both advantages and disadvantages [11-13]. Advantages include a radio transmission distance of up to 10 km in open terrain. Disadvantages: data transmission delay can reach several tens of seconds and low bandwidth of 0.3-50 Kbps.

It is found that none of the transport protocol stacks of the considered wireless technologies and networks can be used in the Easy Net Everywhere network.

The publications [14-16] present the implementation of the Easy Net Everywhere network architecture and the main differences from the considered technologies. One of the differences is the bandwidth of network nodes up to 2 Mbps.

Task statement. For interaction of a network application developer with Easy Net Everywhere network nodes at the software interface level, the development of a transport layer protocol stack is required.

Protocols should consider inter-network communication, group and unique password access to network nodes. One of the protocols should realise text messaging between network nodes using a smartphone.

The protocol API shall provide serialisation and deserialisation of the protocol header and data to transmit and receive data using the UART port.

The length of the protocol header should be the minimum possible.

The development results presentation. An Easy Net Everywhere network is a fully connected network in which each node on the network can communicate with any other node on the network. All nodes in the network are equivalent by default (Fig.1).

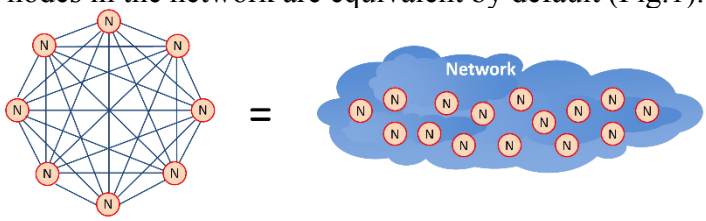

Figure 1 - Full mesh network architecture

Source: developed by the authors.

The Easy Net Everywhere network architecture allows the user to select a network model and, based on the selected model, create a network optimised for a particular task. Easy Net Everywhere implements the following models:

– the “LIGHT” model;
– the “PRO” model;
– the “ENTERPRISE” model.

For example, to build a Smart Home system that contains a small number of nodes in a small area in a low traffic environment, the use of routers is inappropriate. Therefore, the “LIGHT” network model would be the best choice for such a system. However, in a network

with many nodes and distances between nodes of more than 10 km, the use of routers is a necessity. In this case, the "PRO" network model should be used.

To build a system in which it is necessary to unite nodes into separate networks on territorial or functional grounds, it is necessary to use the "ENTERPRISE" network model.

The "LIGHT" network model uses the full mesh network mode without routing (Fig.2).

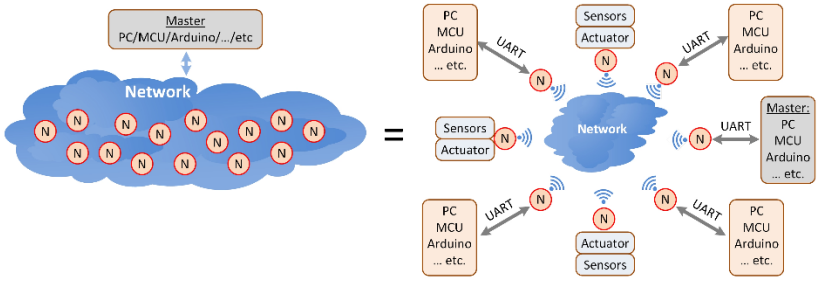

Figure 2 - Easy Net Everywhere network architecture based on the "LIGHT" model

Source: developed by the authors.

The LIGHT network consists of the following components: Net Node, Net Controller and a network master, which can be a PC or any microcontroller.

This model is recommended for creating small local networks with low traffic.

The "PRO" network model uses the network operation mode with routing and relatively high traffic in the presence of obstacles for the passage of network packets (Fig. 3). The "PRO" network includes the following components:

– "Net Node", "Net Controller" network nodes;
– "Router/Fast Router" routers;
– network master, which can be a PC or any microcontroller.

The use of routers allows the user to assign and modify packet routes, distribute network traffic, and bypass physical objects that are obstacles to packets (buildings, trees, etc.).

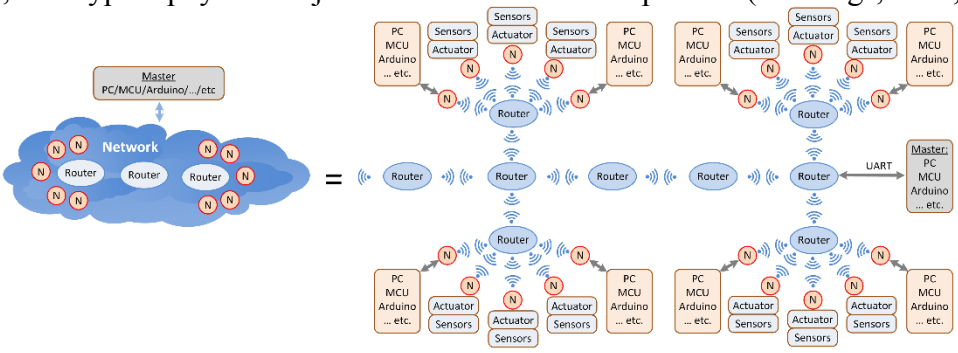

Figure 3 - Easy Net Everywhere network architecture based on the "PRO" model

Source: developed by the authors.

The "ENTERPRISE" network model uses a multi-network mode of operation using routers and bridges to create networks with relatively high traffic (Fig. 4).

The result of research, design and testing is the implementation of a transport protocol stack for data exchange between Easy Net Everywhere network nodes. Each protocol performs a single transaction during a communication session, the size regardless of the data being transferred.

A datagram transmitted over a network consists of a protocol header and a data field. The protocol header defines the method of data delivery to the recipient according to the delivery conditions:

– sharing data on the same network;
– inter-network data exchange;
– network nodes or groups of network nodes have a common login and password;
– network nodes have a unique password;
– data exchange using routing.

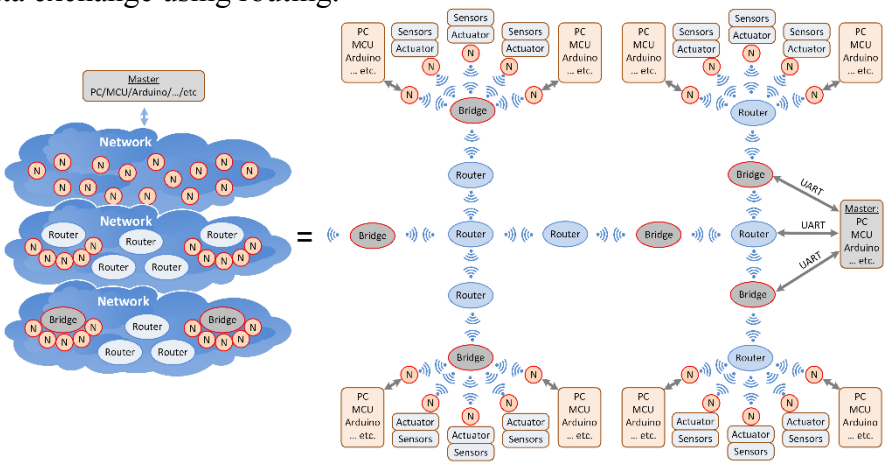

Figure 4 - Easy Net Everywhere network architecture based on the "ENTERPRISE" model

Source: developed by the authors.

Each protocol has its own identifier, the value of which placed in the *Protocol ID* field. The value of the protocol identifier is assigned by the API function.

The *Routers_Num field* is computable. It stores the number of routers on the datagram transmission route. The value of the field is assigned by the API function.

The structure of the Data field is determined by the value of the *Data Format ID* field and is filled in by the user. Up to 200 data structure formats can be used by the user.

The use of protocols is realised by the following algorithm:

– router list assignment;
– assignment the login and password of the destination node;
– data structure assignment;
– assignment of the network address and node address fields;

1. call of the `data_send()` function with passing of parameter arguments.The authors have developed the following transport protocols:

Simple text messaging protocol

Conditions of use:

– text messaging using a smartphone and "Serial Bluetooth Terminal" or similar programme.
– exchanging text messages and using the UART serial port.
– the sender node and the destination node are in the same network;
– the sender node and the destination node have a common login and password;
– the address of the destination node has already been set by the AT command AT+TARG *address*.

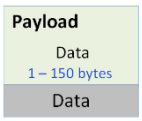

Figure 5 - Simple text messaging protocol

Source: developed by the authors.

Protocol fields:

Data - data to be transmitted.

Application example:

```
Hello, world!
```

Addressable text messaging protocol

Conditions of use:

– text messaging using a smartphone and "Serial Bluetooth Terminal" or similar programme.

– exchanging text messages and using the UART serial port.

– the sender node and the destination node are in the same network;

– the sender node and the destination node share a common login and password.

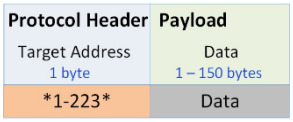

Figure 6 - Addressable text messaging protocol

Source: developed by the authors.

Protocol fields:

Target address - destination node address in the format *addr*.

Data - data to be transmitted.

Application example: `*123*Hello, world!` or: `*123* Hello, world!`

Further data exchange with this node can be done by sending a data packet without specifying the node address.

All other protocols exchange data on the network using the UART serial port.

A protocol for exchanging data on the same network without routing.ID: 0xF0

Conditions of use:

– the sender node and the destination node are in the same network;

– the sender node and the destination node have a common login and password;

– routing is not used.

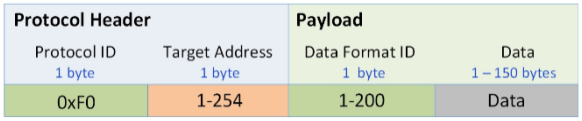

Figure 7 - Protocol for exchanging data on the same network without routing. ID: 0xF0

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;

Target address - destination node address ;

Data Format ID - the first byte in the data structure (ID) defines its format;

Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
      int8 target_addr,
      char* data_buffer
);
```

Protocol for data exchange in the same network with routing. ID: 0xF1

Conditions of use: the sender node and the destination node are in the same network; the sender node and the destination node have a common login and password; routing is used.

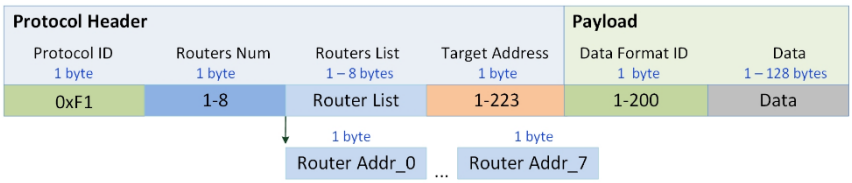

Figure 8 - Protocol for exchanging data on the same network with routing. ID: 0xF1

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;
Routers_Num - number of routers in the list;
Router_List - list of router addresses for routing packets;
Target address - destination node address ;
Data Format ID - the first byte in the data structure (ID) defines its format;
Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
      char* router_addr_list,
      int8 target_addr,
      char* data_buffer
);
```

A protocol for exchanging data on the same network without routing. ID: 0xF2

Conditions of use:

– the sender node and the destination node are in the same network;
– the sender node and the destination node have different login and password;
– routing is not used.

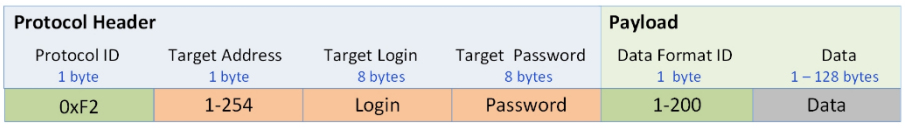

Figure 9 - Protocol for exchanging data on the same network without routing. ID: 0xF2

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;
Target address - destination node address;
Target Login - destination host login;
Target Password - destination host password;
Data Format ID - the first byte in the data structure (ID) defines its format;
Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
      int8 target_addr,
      char* target_login,
      char* target_password,
      char* data_buffer
```

```
);
```

Protocol for data exchange in the same network with routing. ID: 0xF3

Conditions of use:

- the sender node and the destination node are in the same network;
- the sender node and the destination node have different login and password;
- routing is used.

Figure 10 - Protocol for exchanging data on the same network with routing. ID: 0xF3

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;
Routers_Num - number of routers in the list;
Router_List - list of router addresses for routing packets;
Target address - destination node address ;
Target Login - destination host login;
Target Password - destination host password;
Data Format ID - the first byte in the data structure (ID) defines its format;
Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
	char* router_addr_list,
	int8 target_addr,
	char* target_login,
	char* target_password,
	char* data_buffer
);
```

Protocol for data exchange in different networks without routing. ID: 0xF4

Conditions of use:

- the sender node and the destination node are on different networks;
- the sender node and the destination node have different login and password;
- routing is not used.

Figure 11 - Protocol for data exchange in different networks without routing. ID: 0xF4

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;
Network Address - destination node network address;
Target address - destination node address ;
Target Login - destination host login;
Target Password - destination host password;
Data Format ID - the first byte in the data structure (ID) defines its format;

Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
      int8 net_addr,
      int8 target_addr,
      char* target_login,
      char* target_password,
      char* data_buffer
);
```

Protocol for data exchange in different networks with routing. ID: 0xF5

Conditions of use:

– the sender node and the destination node are on different networks;
– the sender node and the destination node have different login and password;
– routing is used.

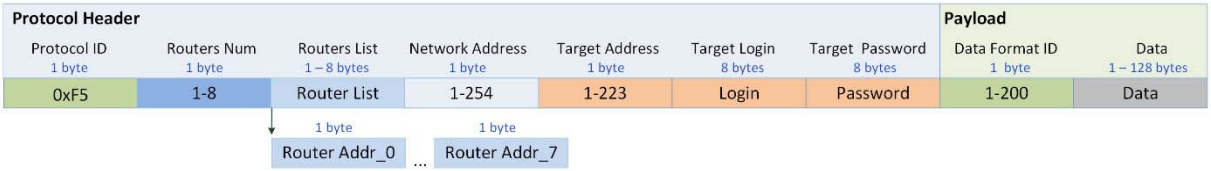

Figure 12 - Protocol for data exchange in different networks with routing. ID: 0xF5

Source: developed by the authors.

Protocol fields:

Protocol ID - protocol identifier;
Routers_Num - number of routers in the list;
Router_List - list of router addresses for routing packets;
Network Address - destination node network address;
Target address - destination node address;
Target Login - destination host login;
Target Password - destination host password;
Data Format ID - the first byte in the data structure (ID) defines its format;
Data - data to be transmitted.

API prototype protocol function:

```
void data_send(
      char* router_addr_list,
      int8 net_addr,
      int8 target_addr,
      char* target_login,
      char* target_password,
      char* data_buffer
);
```

The creation of the protocol stack was carried out within the framework of the research topic «Creation a 2.4 GHz mobile network with adaptive amorphous topology for controlling a swarm of UAVs and robotic objects», registration no. 0120U104088.

Testing of the operation of the protocols created was carried out.

Data exchange between the network nodes was carried out at a distance of 10 km with a bitrate of 250 Kbps. Test packet transmission period - 20 ms without routing and 250 ms with routing.

There were no failures or packet losses during the testing process.

Conclusions. The authors have created a transport protocol stack for Easy Net Everywhere wireless networking. The protocols implement: data exchange in one network

with unique and group password; inter-network data exchange with unique and group password; data exchange using routing.

The size of the service information in the protocol header is limited to the minimum required fields:

Protocol ID_0xF0 - 2 bytes, data field length -150 bytes.

Protocol ID_0xF5 - 28 bytes, data field length -128 bytes.

Test results showed the effectiveness of the developed protocols for data transmission in the network.

The problem of missing transport protocol stack in Easy Net Everywhere network has been solved successfully.

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Стек транспортних протоколів бездротової мережі Easy Net Everywhere

Метою статті є презентація розробленого та реалізованого стека транспортних протоколів бездротової мережі Easy Net Everywhere. Авторами в рамках науково-дослідної теми «Створення мобільної мережі 2.4 GHz з адаптивною аморфною топологією для управління роєм БПЛА і робототехнічних об'єктів», реєстраційний № 0120U104088, було проведено аналіз наявних бездротових мереж на предмет можливості використання транспортних протоколів цих мереж у мережі Easy Net Everywhere. Аналіз засвідчив, що для розв'язання задачі керування віддаленими і мобільними в просторі об'єктами необхідне розроблення пропрієтарних компактних транспортних протоколів.

Показано архітектури бездротової мережі, для яких створено транспортні протоколи, такі, як протоколи простого та адресного обміну текстовими повідомленнями, протоколи обміну даними в одній мережі без маршрутизації та з маршрутизацією, протоколи обміну даними в різних мережах без маршрутизації та з маршрутизацією. Описано структуру протоколів, які реалізують доставку даних вузлу-одержувачу. Описано умови застосування кожного протоколу залежно від конфігурації мережі. Стек протоколів розділено на групи. До першої групи належать протоколи обміну даними між вузлами однієї мережі з унікальним або груповим паролем. До другої групи належать протоколи обміну даними між вузлами різних мереж з унікальним паролем. До третьої групи належать протоколи обміну даними з використанням маршрутизації пакетів. Кожен протокол має свій ідентифікатор. Відповідно до ідентифікатора вузол мережі обирає протокол для передавання даних на стороні передавача і протокол для приймання даних на стороні приймача. Результати тестів показали ефективність розроблених протоколів під час передавання даних у мережі.

Таким чином, розв'язано завдання розроблення стека транспортних протоколів для мережі Easy Net Everywhere. За допомогою цих протоколів стає можливим керування віддаленими, розподіленими і мобільними в просторі об'єктами та отримання даних телеметрії з цих об'єктів.

протокол, ідентифікатор протоколу, бездротова мережа, easy net everywhere, вузол мережі

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