UDC 004.057.4 https://doi.org/10.32515/2664-262X.2025.12(43).1.342-349

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Research of Technical Characteristics of the Easy Net Everywhere Wireless Network

The results the Easy Net Everywhere wireless network technical characteristics study are presented. The network nodes with NRF24L01+, NRF24L01+PA+LNA, E01-ML01DP5 and E01-2G4M27D transceivers were investigated. The performance study was carried out using a transmitter node, a receiver node, a UART terminal, a current meter and a logic analyzer. The timing characteristics in different operating modes were investigated. The current consumption of the network nodes in data transmission mode and in deep sleep mode was measured. The results of measuring the technical characteristics of the wireless network nodes showed that the Easy Net Everywhere network has good technical characteristics. Recommendations are given for selecting the bitrate for nodes to operate in the network. Recommendations are given for selecting transceivers for battery-powered stand-alone devices.

bitrate, datagram, wireless network, easy net everywhere, network node, network characteristic

Problem statement. Nowadays it is actual to create wireless networks for controlling remote and spatially distributed objects.

The main requirements for such networks are: low battery current consumption, high bitrate, stable communication distance between network nodes, traffic crypto-security and resistance to interference.

Several wireless networks are known such as Z-Wave, ZigBee, LoRaWAN. These networks can solve a certain range of problems subject to a number of constraints. It has been found that, based on a combination of characteristics, these wireless networks are, in some cases, not capable of accomplishing their objectives. In order to solve the problem of controlling remote objects and collecting data from remote objects, the authors created a wireless network Easy Net Everywhere. The choice of network for the realization of user projects depends on the main technical characteristics of the network.

Analysis of research and publications. In the process of creating the Easy Net Everywhere wireless network, the authors analyzed the characteristics of wireless networks Wi-Fi, Z-Wave, WiMAX, ZigBee, LoRaWAN.

The technical characteristics of the networks that were described in open access documents were analyzed.

Wi-Fi networking technology is described by the standard IEEE 802.11 [1,2]. The disadvantage is the long time of connection establishment (up to 10 seconds) and high current consumption of the node (300 mA and more).

ZigBee technology is described by the standard IEEE 802.15.4 for wireless networks with routing [3-6]. ZigBee technology allows you to build topologies, star or peer-to-peer (P2P). If the network topology changes dynamically, the network cannot operate stably. The maximum communication distance between network nodes is 100 meters.

The Z-Wave network is described in the document ITU-T G.9959 [7-8]. To create network equipment, you must be a member of the Z-Wave Alliance and have a certificate. The maximum communication distance between network nodes is 100 meters.

WiMAX technology (Worldwide Interoperability for Microwave Access) described by the standard IEEE 802.16. The standard defines time-sharing multiple access technology (TDMA) [9-10]. The technology requires the use of base stations, subscriber stations and

other network equipment.

LoRaWAN technology, has both advantages and disadvantages [11-13]. The 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 0,3-50 Kbps.

The works [14-16] present the implementation of Easy Net Everywhere network architecture and the main differences from the considered technologies. The results of analyzing the main characteristics of wireless networks are presented in Table 1.

Table 1 - Main characteristics of wireless networks

Parameter	Z-Wave	Zigbee	LoRa	Easy Net Everywhere
Transmitter power	0 dBm/ 1 mW	0 dBm/ 1 mW	до 30 dBm/ 1000 mW	до 27 dBm/ 500 mW
Communication range between network nodes	up to 100 m	up to 100 m	up to 10 km	up to 10 km
Transmission speed	100 Kbps	250 Kbps	up to 19.2 Kbps	250 Kbps; ●1 Mbps; 2 Mbps
Transmission delay	Tx: 1% Rx: 99%	< 5 ms	1 ms to tens of seconds	● < 1 ms
Number of channels	16	16	127	127
Mobility of nodes	low	low	low	● high
Difficulty of installation	average	average	high	● low
Object orientation	devices and sensors	devices and sensors	devices and sensors	● humans, devices and sensors
Text messaging using Bluetooth	no	no	no	● есть, 150 байт/транзакция
Wireless user interfaces	no	no	no	● Bluetooth/BLE
GPS Navigation	no	no	no т	● there is, GPS/GLONASS/ Galileo/Beidou
Drone control	unsuitable	unsuitable	unsuitable	● suitable

Note: ● – network advantage Easy Net Everywhere.

Source: developed by the authors sourced [3-6], [7-8], [11-13],[16]

The problem is the lack of publicly available data on the technical characteristics of this network.

Task statement. In order to publish information about the characteristics of the Easy Net Everywhere network, the following characteristics of the network nodes should be investigated:

total transmission time of a datagram with receipt acknowledgement;
total transmission time of a datagram without receipt acknowledgement;
time during which the radio channel is busy during datagram transmission;
current consumption of the network node in the data reception mode;
current consumption of the network node in data transmission mode;
current consumption of the network node in deep sleep mode.

The research results presentation. The study of Easy Net Everywhere wireless network characterization was carried out using the following transceivers:

NRF24L01+, NRF24L01+PA+LNA (Fig. 1);

transceivers E01-ML01DP5, E01-2G4M27D (Fig. 2).

Figure 1 - NRF24L01+ and NRF24L01+PA+LNA transceivers

Source: https://www.joom.com

The NRF24L01+ (LoRa) transceiver has a power of 0 dBm, which enables stable communication between network nodes up to 350 meters away in the Easy Net Everywhere network (declared value: 100 м).

The NRF24L01+PA+LNA (LoRa) transceiver has a power of 20 dBm, which enables stable communication between network nodes up to 6000 meters away in the Easy Net Everywhere network (declared value: 1000 м).

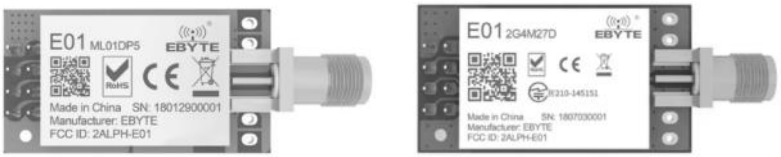

Figure 2 - Transceivers E01-ML01DP5 and E01-2G4M27D

Source: https://www.cdebyte.com

The E01-ML01DP5 transceiver has a power of 20 dBm, which enables stable communication between network nodes up to 5000 meters away in the Easy Net Everywhere network (declared value: 2100 м).

NRF24L01+PA+LNA transceiver has a power of 27 dBm, which can establish stable communication between network nodes at a distance of up to 10000 meters in the Easy Net Everywhere network (declared value: 5000 м).

The tests were conducted with an SMA antenna, which has a gain of 3 dBi (Fig. 3).

Figure 3 - Transceiver antenna

Source: https://www.manfrottospares.com

In the Easy Net Everywhere network, datagrams are transmitted in two modes:

datagram with receipt acknowledgement;

datagram without receipt acknowledgement.

In the with receipt acknowledgement mode, delivery of the datagram to the receiving node is guaranteed (Fig. 4a). This mode is used in network applications where data loss is unacceptable.

In the case when the node-transmitter cannot receive an acknowledgement for the transmitted datagram (Fig. 4b), several more attempts are made to retransmit the datagram.

Mode without acknowledgement of reception does not guarantee lossless data delivery. The mode is used in network applications in which data is transmitted in a continuous stream.

This mode is useful for transmitting large amounts of data, such as surveillance camera images, drone control, etc.

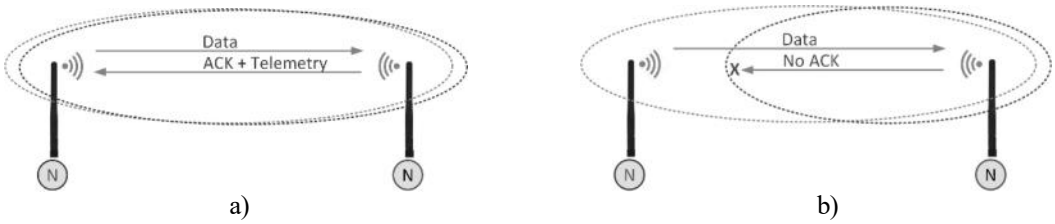

Figure 4 - Datagram transmission modes

Source: developed by the authors

A measurement scheme (Fig. 5) was used to investigate the performance of the Easy Net Everywhere wireless network. The datagram with a specified period is received by the node-transmitter using the UART interface. The transmitter node transmits the datagram to the receiver node.

The received datagram is shown on the terminal display. The UART:Tx, UART:Rx and RF:Transmit signals are fed to a logic analyzer, which is used to measure the timing characteristics.

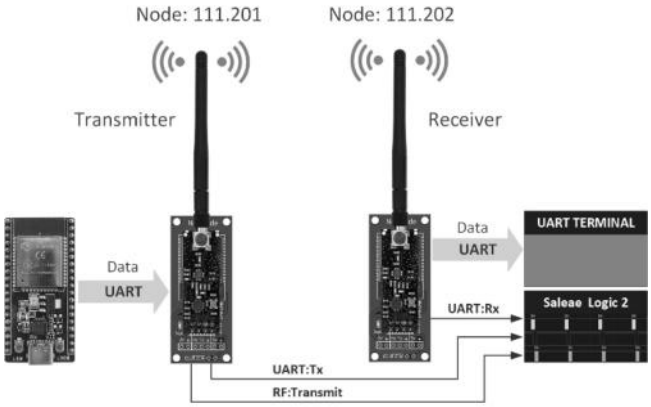

Figure 5 - Measuring Easy Net Everywhere wireless network characteristics

Source: developed by the authors

The structure of the Easy Net Everywhere network datagram is shown in Fig. 6.

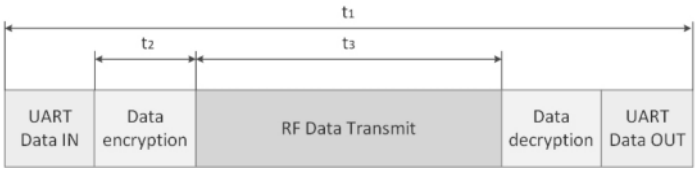

Figure 6 - Easy Net Everywhere network datagram structure

Source: developed by the authors

where:
t_1 – total transaction time;
t_2 – data encryption time;
t_3 – radio transmission time.

The authors have measured time characteristics in the mode with receipt acknowledgement. The dependence of temporal characteristics on bitrate and datagram length was obtained. The measurement results are presented in Table 2.

Table 2 - Mode with acknowledgement of datagram receipt. Dependence of time characteristics on bitrate and datagram length

RF bitrate	30 bytes			60 bytes			120 bytes			150 bytes		
	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms
9,1	10,2	0,8	7,2	13,8	0,8	11,5	24,1	0,8	19,5	28	0,9	23,6
1 Mbps	7,0	0,8	5,3	10,5	0,8	7,9	17,8	0,8	13,0	21,0	0,9	15,7
2 Mbps	6,4	0,8	4,8	9,7	0,8	7,4	16,5	0,8	12,1	19,8	0,9	14,7

Source: developed by the authors

The authors have measured the time characteristics in the mode without receipt acknowledgement. The dependence of temporal characteristics on bitrate and datagram length was obtained. The measurement results are presented in Table 3.

Table 3 – Mode without acknowledgement of datagram receipt. Dependence of time characteristics on bitrate and datagram length

RF bitrate	30 bytes			60 bytes			120 bytes			150 bytes		
	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms	t_1 ms	t_2 ms	t_3 ms
250 Kbps	5,6	0,8	4,2	8,8	0,8	6,9	15,5	0,8	11,2	18,3	0,9	13,4
1 Mbps	4,2	0,8	2,9	6,5	0,8	4,3	11,4	0,8	7,0	13,5	0,9	8,5
2 Mbps	3,9	0,8	2,6	6,0	0,8	3,9	10,5	0,8	6,1	12,2	0,9	7,4

Source: developed by the authors

The results of the Easy Net Everywhere network data rate measurement are presented in Table 4.

Table 4 - Actual data transmission speed in Easy Net Everywhere network

UART, baud	Datagram length	RF bitrate	Period of datagram transmission	Transmission speed
921600	150 bytes	250 Kbps	15 ms	10 kB/s
921600	150 bytes	1 Mbps	10 ms	15 kB /s
921600	150 bytes	2 Mbps	10 ms	15 kB /s

Source: developed by the authors

The authors also measured the current consumption of the transmitter node. Measurement conditions:

Transceivers: NRF24L01+; NRF24L01+PA+LNA; E01-ML01DP5; E01-2G4M27D.

Bitrate: 250 Kbps; 1 Mbps; 2 Mbps. Datagram length: 150 bytes. Modes: without receipt acknowledgement (AT+ASK-). Period of datagram transmission T = 20 ms; with receipt acknowledgement (AT+ASK+). Period of datagram transmission T = 30 ms, 100 ms; bluetooth (AT+BLE-): switched off. The measurement results are presented in Table 5.

Table 5 - Transmitter node current consumption

Transceiver	T = 20 ms /ACK- / **I, mA**			T = 30 ms /ACK+ / **I, mA**			T = 100 ms/ACK+/ **I, mA**		
	250 Kbps	1 Mbps	2 Mbps	250 Kbps	1 Mbps	2 Mbps	250 Kbps	1 Mbps	2 Mbps
NRF24L01+	45	40	42	43	43	43	44	44	44
NRF24L01+PA+LNA	108	62	56	76	59	52	69	56	55
E01-ML01DP5	93	55	49	63	50	47	60	48	47
E01-2G4M27D	365	112	84	170	83	70	120	72	61

Source: developed by the authors

Conditions for measuring the current consumption of a network node in deep sleep mode: Transceivers: NRF24L01+; NRF24L01+PA+LNA; E01-ML01DP5; E01-2G4M27D.

Measurements: current consumption in idle mode (transceiver is switched on); current consumption in deep sleep mode (transceiver is switched off); current consumption in deep sleep mode (transceiver in receive mode).

The measurement results are presented in Table 6.

Table 6 - Transceiver idle and deep sleep current consumption

Transceiver	Standby Mode, I mA	Deep sleep mode, I uA/mA	
		Transceiver OFF	Transceiver ON (reception mode)
NRF24L01+	43	1 uA	15 mA
NRF24L01+PA+LNA	52	2 uA	23 mA
E01-ML01DP5	44	2 uA	15 mA
E01-2G4M27D	52	9.7 mA	22 mA

Source: developed by the authors

The time when the transmitter node enters the deep sleep mode. It was measured from the moment of sending the AT command "AT+Sleep.Tx" to the moment when a logical "1" appears on the GPIO_NUM_33 pin of the controller.

Time for the transmitter node to come out of deep sleep mode. It was measured from the moment the "#" character was sent to the node to the moment the logical "0" appeared on the GPIO_NUM_33 pin of the controller.

Time for the receiver node to enter deep sleep mode. It was measured from the moment of sending AT-command "AT+Sleep.Rx" to the moment of appearance of logical "1" on the GPIO_NUM_33 pin of the controller.

Time for the receiver node to come out of deep sleep mode. It was measured from the moment the "#" symbol was sent to the transmitter node to the moment the "@ Ready" message appeared on the UART output of the receiver node.

Time of nodes readiness for data exchange when leaving the deep sleep mode. It was measured from the moment the "#" character was sent to the transmitter node to the moment the "@ 202 Ready " message appeared on the UART output of the transmitter node.

The measurement results are presented in Table 7.

Table 7 - Time of nodes entering and leaving the deep sleep mode

Measured parameter	Transmitter node	Receiver node
Entering deep sleep mode	1,6 ms	1,6 ms
Exiting deep sleep mode	88 ms	90 ms
Readiness to data exchange	200 ms	

Source: developed by the authors

Conclusions. The study results of the Easy Net Everywhere wireless network nodes technical characteristics showed that the Easy Net Everywhere network has high technical characteristics. The specification values depend on the transceiver used, datagram length, bitrate, operating mode and datagram transmission period. All transceivers have the same quiescent current consumption characteristics. In transmit mode, the current consumption increases. In deep sleep mode, all transceivers except the E01-2G4M27D transceiver consume current up to 2 uA, so these transceivers can be recommended for use in battery-powered stand-alone devices. The E01-2G4M27D transceiver consumes 9.7 mA in deep sleep mode, so its use is not rational in battery-powered devices. A good choice of transceiver for Easy Net Everywhere nodes is the NRF24L01+PA+LNA. The optimum bitrate for transceiver

operation is 1 Mbps. The resulting wireless network specifications of the Easy Net Everywhere network are incomplete. There is no data available on the maximum distance of stable communication between network nodes. Therefore, the goal of further research is a series of tests that will obtain data on the maximum communication distance of nodes in the network.

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Дослідження технічних характеристик бездротової мережі Easy Net Everywhere

Метою статті є публікація результатів дослідження технічних характеристик вузлів бездротової мережі Easy Net Everywhere з використанням недорогих і доступних трансиверів діапазону 2.4 GHz. Для розв'язання задач з управління віддаленими та розподіленими в просторі об'єктами 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 створено бездротову мережу Easy Net Everywhere.

Авторами було проведено дослідження технічних характеристик створеної мережі та порівняння їх із характеристиками відомих бездротових мереж. Представлено результати дослідження технічних характеристик вузлів бездротової мережі Easy Net Everywhere спільно з трансиверами NRF24L01+, NRF24L01+PA+LNA, E01-ML01DP5 і E01-2G4M27D. Дослідження технічних характеристик здійснювалося за допомогою вузла-передавача, вузла-приймача, UART-терміналу, вимірювальних приладів та логічного аналізатора. Було досліджено часові характеристики мережі в різних режимах роботи. Було виміряно споживання струму вузлами мережі в режимі передавання даних і в режимі глибокого сну. Було виміряно час входу вузла в режим глибокого сну і час виходу з нього. Результати вимірювання технічних характеристик вузлів бездротової мережі показали, що мережа Easy Net Everywhere має технічні характеристики, які дають змогу вирішувати широке коло завдань. Наведено рекомендації щодо вибору бітрейта для роботи вузлів у мережі та рекомендації щодо вибору трансиверів для автономних пристроїв, які використовують живлення від батарей.

Уперше було досліджено технічні характеристики бездротовий мережі Easy Net Everywhere. Результати дослідження показали значну перевагу характеристик досліджуваної мережі над мережами, розглянутими у статті. Цінність дослідження полягає в тому, що розробники та констуктори пристроїв і систем спеціального призначення отримують інформацію про можливості досліджуваної мережі. Однак, отримані технічні характеристики вузлів бездротової мережі мережі Easy Net Everywhere є неповними без даних про максимальну дистанцію стабільного зв'язку між вузлами мережі. Тому метою подальших досліджень є отримання даних про максимальну дистанцію взаємодії вузлів мережі.

бітрейт, дейтаграма, бездротова мережа, easy net everywhere, мережевий вузол, характеристика мережі

Одержано (Received) 08.05.2025 *Прорецензовано (Reviewed) 14.05.2025*
Прийнято до друку (Approved) 24.06.2025