19. Education-2030. Incheon Declaration. Ensuring universal inclusive and equitable quality education and lifelong learning for all. URL: http://unesdoc.unesco.org/images/0024/002456/245656R.pdf
20. Executive Summary: The Future of Jobs. 2016. URL: http://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf
21. World Declaration on Higher Education for the Twenty-first Century: Approaches and Practical Measures // Herald of the highest school. 1999. No. 3. P. 29–35.
22. Information and communication technologies in education / ed. by Dendev B. Moscow: UNESCO IITE, 2013. 320 p.
23. Groisman V. Digital Community: Ukraine and EU are preparing a joint project in the digital market // European truth. URL: http://www.eurointegration.com.ua/rus/articles/2016/06/29/7051397/
24. Quick guide – Developing students' digital literacy. URL: https://digitalcapability.jiscinvolve.org/wp/files/2014/09/JISC_REPORT_Digital_Literacies_280714_PRINT.pdf
25. National Educational Glossary: Higher Education. Kyiv: Publishing House «Pleiades», 2014. 100 p.
26. Borodkina I. L., Borodkin G. O. Digital Literacy as a Factor in the Reform of Higher School // Young Scientist. 2017. No. 8. P. 395–399. URL: http://molodyvcheny.in.ua/files/journal/2017/8/87.pdf
27. Borodkina I. L., Borodkin G. O. The quality of education and its assessment at a higher school in the context of the implementation of the principles of the Bologna Declaration // Empirical studies for reforming education in Ukraine. 2017. P. 200–202.
28. Borodkina I. L., Borodkin G. O. Statistical analysis of the results of testing in assessing the quality of education in higher education // Materials of the 1st International Scientific Conference «Ukraine-EU: Cross-cultural Comparisons in Educational Research». 2017. P. 17–22. URL: http://undip.org.ua/upload/files/conference_proceedings_Kyiv_May%2022-23.pdf

Borodkina Iryna, *PhD, Associate Professor, Department of Computer Science, Kyiv National University of Culture and Arts, Ukraine, e-mail: borir@ukr.net, ORCID: https://orcid.org/0000-0003-3667-3728*

Borodkin Heorhii, *Senior Lecturer, Department of Computer Science, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine, e-mail: george.borodkin@gmail.com, ORCID: https://orcid.org/0000-0002-6488-6512*

UDC 004.72:531.7.08
DOI: 10.15587/2312-8372.2018.135486

Dudnik A.

DEVELOPMENT OF METHOD OF INCREASING THE PERFORMANCE OF TOUCH NETWORKS OF MEASUREMENT OF DISTANCES

Об'єктом дослідження є безпровідна сенсорна мережа протоколу ZigBee, що в даному дослідженні пропонуються для виконання функції вимірювання відстані між об'єктами. Основні сфери застосування – це охоронні об'єкти, такі як склади, магазини, виставки та експозиції, де важливо контролювати переміщення цінних речей на обмеженій території з великою концентрацією людей. Сенсори, що виконані на гнучкій основі, прикріплюються до цінних предметів та весь час передають між собою інформацію про відстань відносно один одного. Одним з найбільш проблемних місць є обмежена пропускна спроможність каналів передачі даних. Також, для описаних вище приміщень характерні різного роду перешкоди, як механічні (стіни, перегородки, металеві полиці тощо), так і радіоперешкоди, наприклад, безпровідні мережеві інтерфейси телефонів покупців та інші.

В ході дослідження використовувався метод підвищення продуктивності безпровідних сенсорних мереж, що перебувають у складі комп'ютеризованих систем вимірювання відстані, побудованих на основі декомпозиції нижніх рівнів еталонної моделі OSI.

Отримано ті ж самі показники пропускної спроможності, що й у аналогів, але навантаження, яке при цьому витримував мережевий вузол було у 2,5 рази більшим. Це пов'язано з тим, що запропонований метод підвищення продуктивності має ряд особливостей, які покращують характеристики продуктивності, зокрема в зонах невпевненого прийому майже в два рази.

Завдяки цьому забезпечується можливість роботи мережі з максимальною швидкістю 32,5 Мбіт/с. У порівнянні з аналогами, у яких максимальна швидкість становить 12,5 Мбіт/с, це забезпечує більш точні результати вимірювання відстані. Також, завдяки цьому запасу швидкості, забезпечується краща завадостійкість, а також можливість розташування мережевих вузлів на більших відстанях.

Ключові слова: *сенсорна мережа, механічні величини, комп'ютеризована система вимірювання, інформаційно-вимірювальна система.*

1. Introduction

The timely determination of the position of an object included in the wireless sensor networks results in the generation of false information in a computerized system for measuring the distance between objects. Such a disadvantage, in turn, can lead, for example, to untimely detection of theft of valuable things, a source of ignition, etc. Particularly favorable environment, for this kind of negative effects is a clogged environment [1]. Among the various classes of computer information systems and networks, a special place is occupied by systems and networks whose transport service is based on the use of radio ester as a data transmission medium for computerized distance measuring systems (wireless sensor networks) [2]. Therefore, when creating the scientific basis for the construction of

 ISSN 2226-3780

computerized systems for measuring mechanical quantities, the importance of wireless sensory networks is important. Therefore, the solution to this problem is urgent by modifying the existing classical reference model of the interaction of open systems (EM OSI/ISO). According to this model, most of the data transmission and data measuring and measuring systems are designed, created and operated. Equally important is theoretical analysis and the search for optimal methods for modeling and increasing the productivity of data transmission channels for computerized distance measuring systems [3, 4].

2. The object of research and its technological audit

One of the most problematic places for wireless sensor networks is the lack of timely transmission of information, as well as transmission errors. This, in turn, is the cause of a disturbing situation and leads to a high probability of error in measuring the distance. *The object of this study* is the components of the wireless sensor network.

The problem area of this network is the sensor module, which depends on the limitation of the power supply of the battery, which in turn affects the impedance of its data transmission, due to limit the power of its signal. In Fig. 1 depicts a simplified model of the transport system for transmitting sensor networks between two separate network devices.

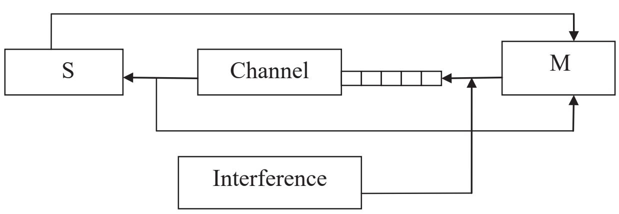

Fig. 1. Conceptual model of the fragment of the transport system of the wireless sensor network: *S* – subordinate one-channel device (slave); *M* – main multichannel main unit (master)

The model works as follows. By command of the main device, the subordinate transmits data about its distance from neighboring devices, through a wireless channel, which is affected by various types of interference. This scheme is fairly simplified, since there may be several main or subordinate units between the main and the subordinate device, as shown in Fig. 2.

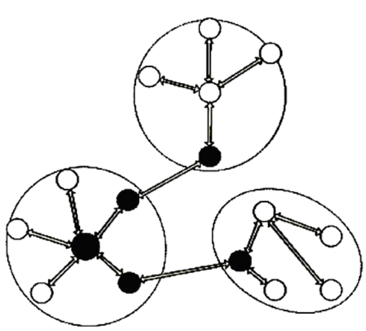

Fig. 2. The variant of the topology of sensor networks: the main devices are painted

Considering the specifics of the operation of the ZigBee data transmission network (IEEE 802.15.4), we also consider the work of a device built using the recommendations for the wireless data transmission technology in wireless information systems, the structure of which is depicted in Fig. 3 [5].

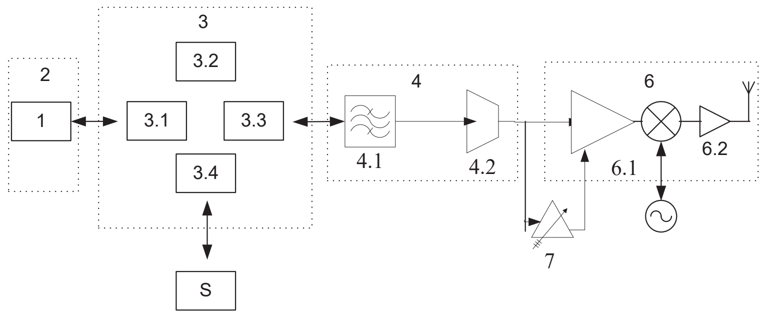

Fig. 3. Wireless data transmission device: 1 – network level interface 2, 3 – OSI layer layer sublayer module, 3.1 – host interface block, 3.2 – built-in microcontroller, 3.3 – application/receiver unit 3.4, bus interface block, *S* – memory, 4 – sub-level MAC channel level module, 4.1 – bandwidth controller, 4.2 – radio frequency receiver/transmitter, 6 – physical level module, 6.1 – physical interface, 6.2 – antenna, 7 – automatic frequency setting unit

The technology of this device is as follows. The control unit 1 sends the command to send the package and the package itself to the subscalling level of the LLC level 3 channel. In the sublayer of the OS-level pool layer LLC through the host-interface block 3.1, after passing the corresponding transformations using the applications of this module, the package becomes a frame. After that, the built-in microcontroller 3.2 transmits the frame to the receiver/transmitter 3.3 block and, via the bus interface unit 3.4, records the transfer status data into memory S, where they are stored for a while. The receiver/transmitter 3.3 unit directs the frame to the MAC sub-level of the channel level 4. In the module sub-level MAC link-level EM OSI/ISO modules, the frequency band controller 4.1 selects the optimal frequency band for this frame and directs the frame to the RF receiver/transmitter 4.2. In this module, both the transformation of the frame into electromagnetic oscillations and their modulation according to the contents of the frame occurs. After that, the oscillations are transmitted to the OSI 6 physical layer module, and the information about the picked up unit 4.1 is transmitted to the frequency range of the automatic frequency setup 7. The OSI physical layer unit 6.1 submits electromagnetic oscillations to the frequency set by block 7. The oscillations are directed to the antenna 6.2, which transmits the signal to the radio.

In this paper we propose a method for increasing productivity, which consists in improving the algorithm of service requests in the data transmission channel, as shown in Fig. 1. And also in the modernization of the structural scheme of the data transmission device, shown in Fig. 3.

3. The aim and objectives of research

The aim of research is to develop new and improve existing technology solutions to increase the productivity of wireless sensor networks that are part of the distance measurement systems. To achieve this aim you need:

1. Propose a mathematical model for handling applications in the queues of data transmission channels for wireless sensor networks in single-channel and multi-channel devices.

2. To investigate the adapted queue management algorithms that can optimize the distribution of applications in the queues of wireless sensor devices.

3. Develop an algorithm for functional alignment of the lower levels of the OSI reference model in order to improve the performance of wireless sensor networks in areas of uncertain reception and to investigate the effect of extending the standard frequency band.

4. Insert into the block diagram of the wireless data transmission device the corresponding changes based on the algorithm of the functional association of the lower levels of the reference model OSI.

4. Research of existing solutions of the problem

Issues of the study of information-measuring systems, including the study of technologies for modeling, control and interaction of computerized systems for measuring mechanical quantities (in particular, the distance between objects), are devoted to the work of modern scientists, among them:

– works [6–8], which are devoted to measuring the distance of the means of measuring equipment;
– works [9–13], devoted to the measurement of distance by means of wireless sensory networks;
– works [14–18], which, in addition to measuring distance, are also devoted to the analysis of the characteristics of the sensory networks themselves.

In [6], it is suggested to use the Internet to control the measuring head, but in the analysis and correction of the measurement results, the Internet does not take part. The content of work [7] is devoted to the development of analog interfaces of information measuring systems, but it does not consider the means of increasing their productivity. In [8], this refers to the correction of measurement errors through the information-measuring system, but it is proposed to use cable communication. In work [9] a general overview of existing technologies of sensor networks is conducted and only their weaknesses are analyzed. In papers [10, 11] algorithms of localization are considered that can improve the process of measuring the distance between objects. The work [12, 13] addresses the existing problems of the integration of sensory networks and the ways of their solution. In works [14–18] we are talking about methods of localization using satellite navigation systems, in particular [18] also refers to energy-saving technologies for sensor networks.

In this paper, it is proposed to consider recommendations for improving the technical characteristics of wireless sensor networks. It also affects the accuracy of the localization process and the measurement of the distance between objects in uncertain reception areas and with insufficient noise immunity.

5. Methods of research

As the main indicator of the technical characteristics of wireless sensor networks, the belt delay time in the transmission channels (W_{queues}) is used. This time is one of the indicators of network speed, which in turn also affects the accuracy of the localization process and the measurement of the distance between objects. This is extremely important in cases where the distance is determined based on the total time of arrival of the signal between neighboring devices. This indicator is its direct component.

First, a mathematical bits delay model in a multichannel device (that is, connection with more than 2 adjacent devices) will be proposed. This process will be considered with some inaccuracy, since it is presented as stationary, without taking into account transient processes (for example, establishing a connection). Transaction, which is an indivisible object in the system of simulation of general purpose, equates to a bit that moves from the source of information to the consumer. Each phase was modeled by SMO *G/M/n* with failures and discipline of FIFO. The GPSS imaging modeling system provides the collection and statistical processing of transacti data held at each point of the model, as well as the intensity of the failures. The bite delay time in the transmission channels (W_{queues}) of the given network is determined according to the formula for calculating the delay time in the queue of the multichannel device with expectation:

$$W_{queues}=\frac{1}{\sum_{i=1}^{N}\lambda_i}L_{queues}, \qquad (1)$$

where λ is the intensity of receiving bits transmitted to the i-th state; L_{queues} – the average number of bits transmitted and determined by the following formula:

$$L_{queues}=\frac{\sum_{i=1}^{N}\rho_i^{n+1}P_0}{n\cdot n!\left(1-\sum_{i=1}^{N}\rho_i/n\right)^2},$$

where n – number of distributed subchannels of wireless data transmission, which for this case consists of 23 subchannels; P_0 – the probability that the subchannel is currently busy is determined by the formula:

$$P_0=\left(1+\frac{\sum_{i=1}^{N}\rho_i}{1!}+\frac{\sum_{i=1}^{N}\rho_i}{2!}+\ldots+\frac{\sum_{i=1}^{N}\rho_i^n}{n!}+\frac{\sum_{i=1}^{N}\rho_i^{n+1}}{n!\left(n-\sum_{i=1}^{N}\rho_i\right)}\right)^{-1},$$

where ρ is the load on this wireless data transmission network, determined by the formula:

$$\rho=\frac{\sum_{i=1}^{N}\lambda_i}{\mu}, \qquad (2)$$

where λ is the intensity of the receipt of bits to the data transmission network at that state; μ is the intensity of service of bits in the data transmission network. Substituting all these values into formula (1), we obtain the following resultant formula:

$$W_{queues}=\frac{1}{\lambda}\frac{\left(\left(\frac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)^{n+1}\left(1+\frac{\frac{\sum_{i=1}^{N}\lambda_i}{\mu}}{1!}+\frac{\frac{\sum_{i=1}^{N}\lambda_i}{\mu}}{2!}+\cdots+\frac{\left(\frac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)^n}{n!}+\frac{\left(\frac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)^{n+1}}{n!\left(n-\frac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)}\right)\right)^{-1}}{n\cdot n!\left(1-\frac{\frac{\sum_{i=1}^{N}\lambda_{i,}}{\mu}}{n}\right)^2}.$$

ISSN 2226-3780

Master unit «*Master*» transmits bits at odd moments of time, and the subordinate device «*Slave*» – in a pair. This model has a hierarchical structure because the device, which for a particular section of the network is the main, for another site can be subordinate. An experimental study of this model was carried out using the *GPSS* instrument tool, with 10^6 runs. From the obtained results, it was found that the delay time correlation corresponds to the actual available ratio of network parameters [19].

A single-channel communication model is proposed (when the device has a connection with only two neighboring ones), the results of which would reflect the time and the quantitative parameters of the mechanical data transmission measurement data. The simulation model is presented by an open one-channel mass service system. The model, according to Kendal's classification, is a model of the *G/M/1* class with discipline (application processing algorithm) FIFO. The time delay of bits in the transmission channels (W_{queues}) of the given system will be determined according to the formula for calculating the delay time in the queue of the one-channel device with expectation [19]:

$$W_{queues} = \frac{L_{queues}}{\sum_{i=1}^{N} \lambda_i \left(1 - P_N\right)}, \qquad (3)$$

where L_{queues} – The average number of bits to be transmitted is determined by the following formula:

$$L_{queues} = \sum_{i=1}^{N} nP_n,$$

where P_n is the probability that the data link is n bits and is determined by the formula:

$$P_n = P_0 \sum_{i=1}^{N} \rho_i^{\,n},$$

where P_0 is the probability that the subchannel is currently busy, is determined by the formula:

$$P_0 = \frac{1 - \sum_{i=1}^{N} \rho_i^{\,n}}{1 - \sum_{i=1}^{N} \rho_i^{\,n}}^{(n+1)},$$

where ρ is the load on the wireless data network, determined by the formula (2). Substituting these values into formula (3), we obtain the following resultant formula:

$$W_{queues} = \frac{\sum_{n=0}^{N} n \dfrac{1 - \dfrac{\sum_{i=1}^{N}\lambda_i}{\mu}}{1 - \left(\dfrac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)^{(N+1)}} \left(\dfrac{\sum_{i=1}^{N}\lambda_i}{\mu}\right)^{n}}{\sum_{i=1}^{N} \lambda_i \left(1 - P_N\right)}.$$

The algorithm of the functional association of the lower levels of the reference OSI model (Fig. 4) is proposed.

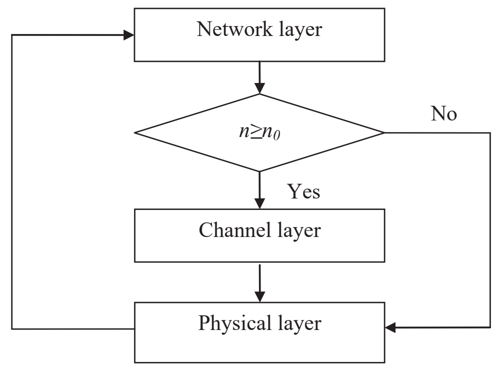

Fig. 4. Block diagram of the signal quality status analysis algorithm

This technology in works [20, 21] has been applied to research networks IEEE 802.11, and in this paper it is proposed to apply it to sensor networks of the standard ZigBee (IEEE 802.15.4) using the algorithms «FIFO», «Priority service», «Weighted queues». This made it possible to obtain from the formula (5) the results shown in Fig. 5, 6.

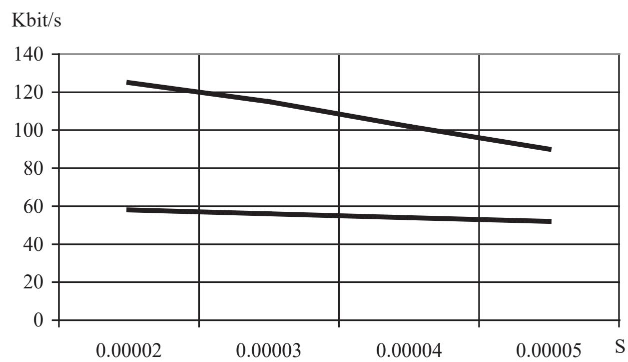

Fig. 5. Depending on the bandwidth of the transmission channel from the processing delay time

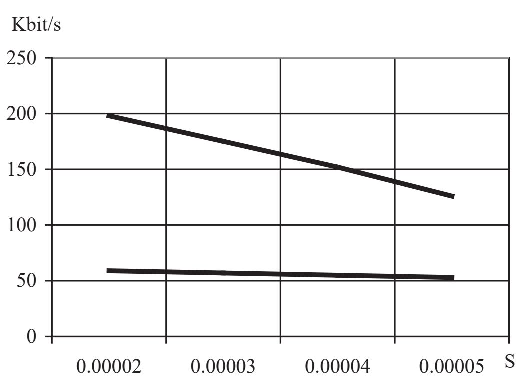

Fig. 6. Chart of dependence of the bandwidth of the canal of transmission from the time delay to the processing with the expansion of the bandwidth

The algorithm is based on controlling the bits of the physical level frame. It is designed for the purpose of obtaining the required information from frame fields that contain information about the data medium. In this method, the network level sends queries for the physical state of the signal at the given time at certain intervals. Information about the status of the signal is contained in the field in which the first bits contain information about the speed of transmission, and others about the signal status [20].

The queue management algorithms are required to work in times of temporary overloads with the maximum load of transmitting channels of the sensor network. It is part of a computerized system for measuring mechanical quantities.

This is required when the network device cannot cope with the transmission of bits to the source interface at the rate at which they are transmitted. If the cause of the overload is the inadequate performance of the processor unit of the network device, then the raw bits temporarily accumulate in the input queue of the corresponding input interface. There may be several queues up to the input interface if different service requests differ in several classes.

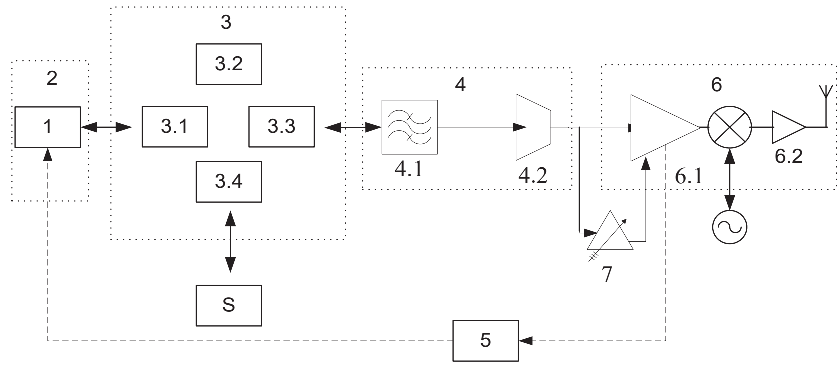

Fig. 7. Wireless network device with a system for improving the quality of transmission of metering indicators in areas of uncertain reception or insufficient immunity: 1 – control unit 1, which is part of the NMS, the network level module 2, 3 – OSI layer level sublayer module OSI, 3.1 block host interface, 3.2 – built-in microcontroller, 3.3 – application block receiver/transmitter, 3.4 – bus interface block, S – memory, 4 – MAC sublayer module link level, 4.1 – Bandwidth controller, 4.2 – radio frequency receiver/transmitter, 5 – signal analyzer, 6 – physical level module, 6.1 – physical level interface, 6.2 – antenna, 7 – automatic frequency setting unit [21–22]

In the same case, when the reason for the overload is the limited throughput of the source interface, bits are temporarily stored in the initial queue (or queues) of this interface. Conceptual models of networks with the use of various algorithms for managing queues in networks are represented by an open multiphase mass service system. Each phase was modeled SMO *G*/*M*/*n* constructed according to the conditions of one or another queuing algorithm. The resulting formula for determining the delay time of bits in the transmission channels (W_{queues}) of this network is formula (1), because the model of this network is also presented in the form of multichannel QoS with expectations. We describe the operation of this system: the bits coming from the sensor, which transmits the measurement data, are in the queue for service. Next, they are in turn redistributed to the workstations that are their addressees. They then turn in the queue for processing to the desired destination [19–21].

Typically, each level of the signal corresponds to a number from 0 to 6. Based on the data obtained, the network layer generates an idea of changing the states of communication, constantly comparing the current and the previous state ($n<n_0$ or $n\geq n_0$). In case when the state change corresponds to $n<n_0$, the network level sends a re-request. This cycle will take place until the situation becomes the opposite ($n\geq n_0$) (the branch is «yes»). Only then will the network level send to the channel package and will order an order for its transfer. Then the channel level, in the presence of a free channel, will order the generation of bits to the physical layer, according to the specific package [20].

The features of this algorithm were taken into account in the structural scheme of a wireless data transmission device line that would serve as a communication function between applications of the physical and network levels of the reference OSI model. That is, it would work on the basis of this algorithm. It is for this reason that in the existing block diagram of the wireless communication device, shown in Fig. 3, the signal quality analyzer 5 is introduced (Fig. 7).

When constructing the device, the blocks are divided into modules according to their belonging to one or another level of the reference model.

6. Research results

As a result of the simulation, the parameters of the network operation were received, in particular the delay in the queues of the transmission channels of adjacent devices, which corresponds to the bandwidth of the transmission channel in the case when the load on this channel is maximal [19].

3 models of the corresponding structure were considered, in which 3 different traffic control algorithms were used in various IEEE 802.11 standards, namely «FIFO», «Priority service», «Weighted queues». A study was conducted to compare the characteristics between these algorithms according to the bandwidth criteria of transmission channels, the maximum rate of transmission of indicators, the transmission rate of indicators, and the number of subchannels. Following a series of comparative studies, the Analityc hierarchy process (AHP) decision-making procedures were used to obtain the following aggregate coefficients based on these algorithms, namely:

– the algorithm «FIFO» – 0.228;
– algorithm «priority service» – 0.222;
– the algorithm «Weighted queues» is 0.55.

As a result of these comparisons, it was investigated that the algorithm of «weighted queues» is twice as good as the other two. Studies have been conducted that showed that the results obtained using the *G*/*M*/*n* model for modeling transmission of sensor measurements by sensor networks are the most accurate among other models.

The model of sensory network at the conceptual level is explored. Based on the simulation results of this network at the standard band of the ZigBee network (2400–2483.5 MHz ISM band), the characteristic (1) yielded a characteristic in Fig. 5. The standard band was expanded by 80 MHz and the formula (1) removed the characteristic that is shown in Fig. 2.

As a result, it is concluded that the bandwidth expansion, albeit at the very least, worsens the speed of ZigBee sensor metering over time, but significantly improves other parameters, including bandwidth. The one-channel sensory network is investigated. The transmission of measurement indicators, in this case, will take place from one measuring device to another. Dependence of the transmission bandwidth (C) from the delay time for processing in the feeder channel, as shown in Fig. 8, was obtained by the formula (3).

 ISSN 2226-3780

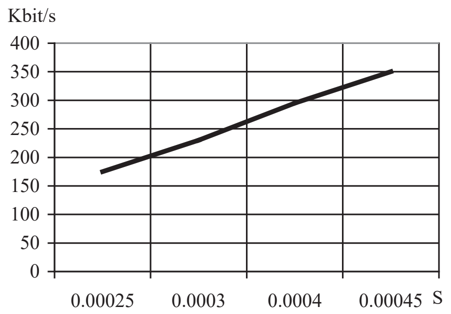

Fig. 8. Depending on the channel capacity of the transmission channel from the delay time for processing in the feeder channel

In Fig. 8 there is a linear increase in the load indicating the stable behavior of the servicing devices in the simulation of stationary processes using models G/M/1.

An experiment was conducted with a standard algorithm for the operation of the touch device whose structure is depicted in Fig. 7, the results of which are shown in Fig. 9.

The saturation point X_0 is determined by the formula:

$$X_0 = \frac{1}{V_d R_d},$$

where X_0 – the largest load for this network; V_d – visit factor for node d; R_d is the time the bits are hosted for the node d.

In the transmission channels of this network, the redistribution of flows will occur with the help of the queuing algorithm «Weighted queues».

Next, the experiment was modified, according to the algorithm depicted in Fig. 4, and its description. On the basis of research data, the formula (1) obtained the characteristics given in Fig. 10.

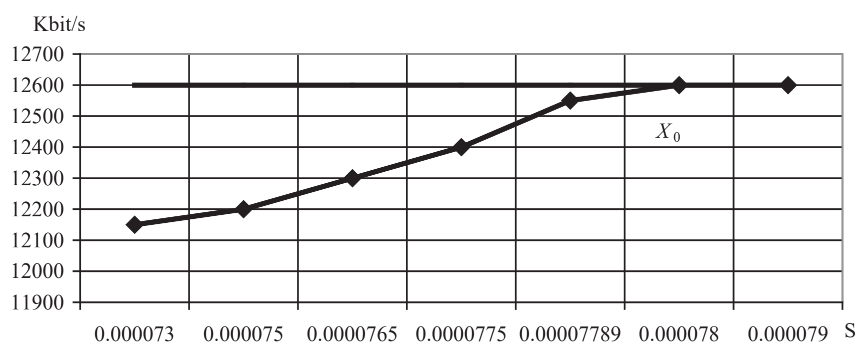

Fig. 9. Chart of the delay time dependence on the load of the transmission channel

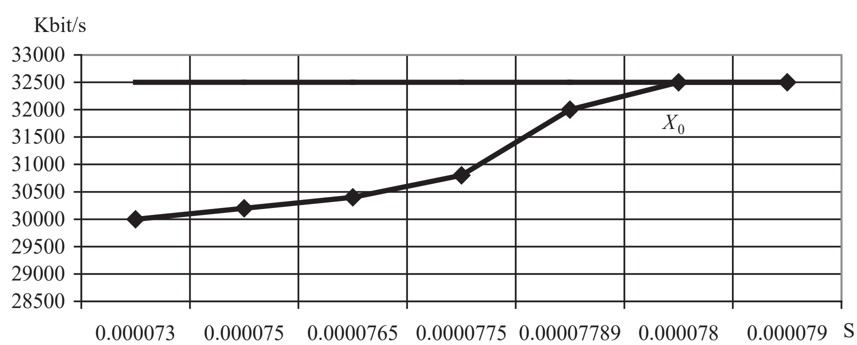

Fig. 10. Chart of time delay dependence on load of the transmission channel

As shown in Fig. 10, this algorithm introduces into the work of the sensor network a rather positive change. This is evident from the fact that with a significant increase in the load in the transmission channels, the delay time for bits in the queue for processing almost did not change. That is, the data transmission channel of the device running on this algorithm can withstand the load almost 2.5 times than with the standard algorithm. It is likely that such an improvement is due to a reduction in the percentage of false packets and requests for their re-sending, which also require a certain amount of time to process. And also the transition to a standard with more power when the signal level falls. It definitely improves the stability of the sensor network, greatly reducing the likelihood of no signal in uncertain reception areas.

7. SWOT analysis of research results

Strengths. The strength of this development, in comparison with analogues, is the ability to maintain stable performance of the bandwidth, with a significantly higher load. This development will not cause additional costs for more powerful batteries for touch devices, nor does it require additional technical support after its introduction.

Weaknesses. The weak side of the development is that there will be additional costs for the upgrade of touch devices. This is due to the replacement of microcontrollers and/or their reprogramming to the proposed algorithm.

Opportunities. Implementation of the proposed development into the sensor network will enable it to transmit data without falling performance, while maintaining a 2.5 times load than analogues.

Threats. At the first stage of the system implementation, it is necessary to allocate additional funds for the implementation of the software and hardware complex.

8. Conclusions

1. A mathematical device was developed for studying the process of service requests in the queues of data transmission channels for wireless sensor networks, which enabled the results of research with sufficient accuracy.

2. It was found that the adapted algorithm «Weighted queues» according to the criteria of transmission capacity of transmission channels, the maximum rate of transmission of indicators, the transmission rate of metrics, the number of subchannels is 2 times better than others.

3. An algorithm that combines the lower levels of the OSI reference model, in combination with the extension of the standard bandwidth, has improved, which improved the data transfer rate by almost 200 Kbps.

4. The block diagram of a wireless data transmission device has been upgraded, having functionally combined the blocks corresponding to the lower levels of the reference OSI model. This allowed the device,

with constant rates of bandwidth, to withstand 2.5 times the load.

References

1. Kuzmych L. V. Neparametrychna identyfikatsiya shchilnosti rozpodilu virohidnosti v skladniy postiyno zminnii zavadoviy obstanovtsi // Kompleksne zabezpechennia yakosti tekhnolohichnykh protsesiv ta system (KZIaTPS – 2018): proceedings. Vol. 2. Chernihiv: ChNTU, 2018. P. 178.
2. Wireless sensor networks: a survey / Akyildiz I. F. et al. // Computer Networks. 2002. Vol. 38, No. 4. P. 393–422. doi: http://doi.org/10.1016/s1389-1286(01)00302-4
3. Erkin A. N. Osobennosti proektirovaniya besprovodnyh ZigBee – setey na baze mikrokontrollerov firmy Jennic // Besprovodnye tekhnologii. 2010. No. 2. P. 20–24.
4. Localization in Wireless Ad-hoc Sensor Networks using Multilateration with RSSI for Logistic Applications / Wang X. et al. // Procedia Chemistry. 2009. Vol. 1, No. 1. P. 461–464. doi: http://doi.org/10.1016/j.proche.2009.07.115
5. IEEE Standard for Information technology-- Local and metropolitan area networks – Specific requirements – Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs). doi: http://doi.org/10.1109/ieeestd.2006.232110
6. Kvasnikov V. P., Khaein T. M. Kontseptsiya povirky koordynatno-vymiriuvalnykh mashyn cherez Internet // Metrolohiya ta prylady. 2013. No. 6. P. 48–53.
7. Sposoby pobudovy analohovykh interfeisiv informatsiyno-vymiriuvalnykh system mekhanichnykh velychyn / Kvasnikov V. P. et al. // Vymiriuvalna ta obchysliuvalna tekhnika v tekhnolohichnykh protsesakh. 2013. No. 1. P. 164–169.
8. Ornatskyi D. P., Mykhalko M. V., Osmolovskyi O. I. Analog interface for remote measurements by differential-transformer inductive sensors // Eastern-European Journal of Enterprise Technologies. 2014. Vol. 1, No. 2 (67). P. 52–57. doi: http://doi.org/10.15587/1729-4061.2014.21078
9. Akyildiz I. F. Wireless sensor networks: A survey. Computer Networks // IEEE Communications Magazine. 2008. P. 250.
10. Towards an Integrated Solution for Node Localization and Data Routing in Sensor Networks / Boukerche A. et al. // 2007 IEEE Symposium on Computers and Communications. 2007. doi: http://doi.org/10.1109/iscc.2007.4381550
11. A Novel Location-Free Greedy Forward Algorithm for Wireless Sensor Networks / Boukerche A. et al. // 2008 IEEE International Conference on Communications. 2008. doi: http://doi.org/10.1109/icc.2008.402
12. Brooks R. R., Iyengar S. S. Multi-Sensor Fusion: Fundamentals and Applications. Prentice Hall, Englewood Cliffs. NJ, 2009. P. 120.
13. Hofmann-Wellenho B., Lichtenegger H., Collins J. Global Positioning System: Theory and Practice. 14th ed. Springer-Verlag, 2013.
14. Intanagonwiwat C., Govindan R., Estrin D. Directed diffusion // Proceedings of the 6th annual international conference on Mobile computing and networking – MobiCom '00. 2000. doi: http://doi.org/10.1145/345910.345920
15. Niculescu D., Nath B. Ad hoc positioning system (APS) using AOA // IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428). 2003. doi: http://doi.org/10.1109/infcom.2003.1209196
16. The cricket compass for context-aware mobile applications / Priyantha N. B. et al. // Proceedings of the 7th annual international conference on Mobile computing and networking – MobiCom '01. 2001. doi: http://doi.org/10.1145/381677.381679
17. Savvides A., Han C.-C., Strivastava M. B. Dynamic finegrained localization in Ad-Hoc networks of sensors // Proceedings of the 7th annual international conference on Mobile computing and networking – MobiCom '01. 2001. doi: http://doi.org/10.1145/381677.381693
18. Yu Y., Govindan R., Estrin D. Geographical and Energy Aware Routing: a recursive data dissemination protocol for wireless sensor networks. URL: https://pdfs.semanticscholar.org/11ca/e1f847d741052bffba9af8d9fbd39973fd94.pdf?_ga=2.235051969.1371947614.1530007013-1007961932.1515747226
19. Dudnik A. S. Problemy ta perspektyvy rozvytku ekonomichnoi kibernetyky: monograph // Metod zastosuvannia suchasnykh bezprovodovykh tekhnolohiy v informatsiynykh ekonomichnykh systemakh. Kyiv: VD TOV «Agrar Media Group», 2013. P. 172–179.
20. Dudnik A. S., Bondarenko Yu. V. Systema pokrashchenoho peredavannia danykh bezprvodovykh kompiuternykh merezh standartu IEEE 802.11 // Nauka i molod. 2012. No. 11 (12). P. 113–116.
21. Dudnik A. S., Shevtsova Ye. V., Zubarieva O. O. Sposib pidvyshchennia produktyvnosti bezprvodovykh kompiuternykh merezh na osnovi mizhrivnevoi vzaiemodiyi ta prystry dlia yoho realizatsii // Problemy informatyzatsiyi ta upravlinnia. 2011. No. 4 (36). P. 45–50.
22. Prystriy pidvyshchennia yakosti peredavannia danykh v bezdrotovykh merezhakh v zonakh nevpevnenoho pryiomu abo z nedostatnoiu zavadostiykistiu: Pat. No. 60400 UA. MPK N04V 7/005 / Dudnik A. S. et al. No. u201007469; declareted: 15.06.2010; published: 25.06.2011, Bul. No. 12. 4 p.

Dudnik Andrey, *PhD, Associate Professor, Department of Network and Internet Technologies, Taras Shevchenko National University of Kyiv, Ukraine, e-mail: a.s.dudnik@gmail.com, ORCID: http://orcid.org/0000-0003-1339-7820*