Simulation Models for Assessing the Probabilistic and Energy Characteristics of Information Interaction in the Internet of Things

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Abstract—The mutual influence of probabilistic-temporal and probabilistic-energy characteristics of a wireless sensor system (WSS) is investigated. A simulation model of information interaction in the Internet of things is considered. When developing a simulation model, a multiple access system with synchronous-time access to the on-air transmission medium was taken, which can be represented by a queuing system of the M/D/1 type.

The simulation model allows you to describe the objects of information interaction of the Internet of Things, and can be used for experimentation in order to design, analyze and evaluate the functioning of the WSS of the Internet of Things. The complex of simulation models of information interaction includes: a model in a single-channel transmission medium, a model in a multi-channel transmission medium, a model with heterogeneous sensor nodes using relative service priorities.

Keywords - probabilistic-energy characteristics, simulation modeling, internet of things, priority service

I. INTRODUCTION

The step-by-step implementation of the concept of the Internet of Things in many areas of human activity (in production, agriculture, transport infrastructure, housing and communal services, environmental projects, etc. [1]) is accompanied by the growing popularity of wireless sensor networks (WSN), which, along with other technologies: identification, sensors, are recognized as key drivers for the development of the Internet of things. WSNs play the role of an infrastructural basis that provides information interaction in the Internet of things.

On the basis of the WSN, the interaction of smart things of the Internet of Things is implemented [2, 3]. As a rule, smart things use independent autonomous power sources and have a limited energy resource [4]. The life time (or working time) of the BSS is determined by the period of life of each thing included in its composition. As a result, when studying the processes of functioning of the WSN, an assessment of the energy indicators of the information interaction of smart things is considered a necessary task.

As characteristics of the interaction of smart things with autonomous power in the WSN, the following are proposed: probabilistic-temporal characteristics (PTC) of the message transfer process and probabilistic-energy characteristics. The random process of message transmission is described by the average time and the probability of timely delivery of the message, and the process of energy consumption by a smart thing is described by the power of the radio signal generated on the transmitting antenna. The permissible power level of the radio signal depends on the level (power) of interference in the radio channel.

It can be assumed that increasing the power of the radio signal at the output of the transmitting antenna of a smart thing, on the one hand, will increase the reliability of signal transmission and improve the quality of service, but, on the other hand, leads to an increase in energy consumption by smart things, and, in accordance with this, to shorten their lifespan. For the productive operation of smart things and the WSN in general, as well as for increasing the lifetime of the network, it is important to find a balance between the quality of information interaction and energy consumption, i.e., choose such a radio signal power that will provide the required speed and quality of message delivery.

The study of the mutual influence of the probabilistic-temporal and probabilistic-energy characteristics of the WSN is an urgent task of designing networks of the Internet of things and was touched upon earlier in [5], where an analytical model was proposed for assessing the energy characteristics of multiple access in over-the-air networks.

In this paper, we consider a simulation model of information interaction in the Internet of things, developed on the basis of the analytical model [5].

II. MODEL

When developing a simulation model, a multiple access system with synchronous-time access to the on-air transmission medium was taken, which can be represented by a queuing system of the M/D/1 type.

The simulation model allows you to describe the objects of information interaction of the Internet of Things, and can be used for experimentation in order to design, analyze and evaluate the functioning of the WSN of the Internet of Things [6]. Unlike the analytical solution, as a result of which the formulas were obtained and the probabilistic-temporal and probabilistic-energy characteristics were calculated [6], the simulation model will allow you to determine which parameters and how they affect the simulated system, as well as how these parameters are related to each other.

The purpose of using simulation modeling in this case is to verify the numerical experiments carried out earlier on the basis of the analytical model on the calculation of the PTC [5], as well as to conduct additional experiments.

When modeling the information interaction of smart things in WSN:

– the physical parameters of interaction of wireless network nodes are taken into account: the number of smart things - N, the distance between them – D [m], B – the frequency of the radio channel [Hz], the power of the radio signal at the transmitting and receiving antennas – $P_{пер}$ and $P_{пр}$ [W], the noise power in the radio channel – $P_{шум}$ [W] etc. The following are determined: the format and length of the transmitted messages, and the modes of their transmission [7].

To assess the quality of information interaction - a random process of transmitting messages in the WSN of the Internet of things, we use the given mathematical model presented in [8].

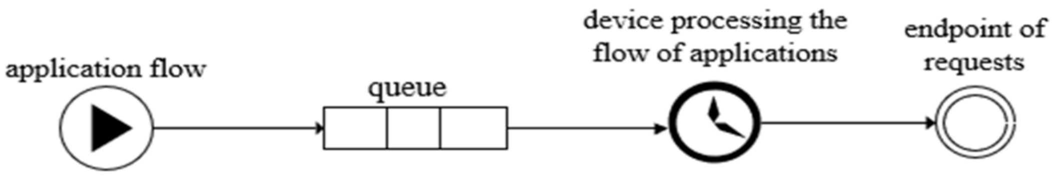

Fig.1. Message passing scheme

The WSN simulation model was implemented in the AnyLogic environment, and during its development, the features of multiple access with synchronous-time access to the air transmission medium used for transmitting messages by smart things were taken into account. The simulation model is shown in Figure 2 and includes several related modules: Applications – the flow of applications arriving in the system; Queue – a queue of applications waiting to receive applications in the system; Channel – a device that processes the flow of applications; End – the end point of applications.

To measure indicators in the model, timeMeasureStart was added – the beginning of the measurement period, timeMeasureEnd – the end of the measurement period. If the application is not waiting for acceptance, then the queue can discard it in Sink (end).

In the model, the arrival queues are Markovian, have a common distribution, and there is only 1 server for them. As a result of the work, the program provides probabilistic-temporal characteristics for analysis according to the M/D/1 model, such as: the number of applications in the queue, the average time the application was in the queue, the number of applications that left the system and the average time of applications in the system as a whole.

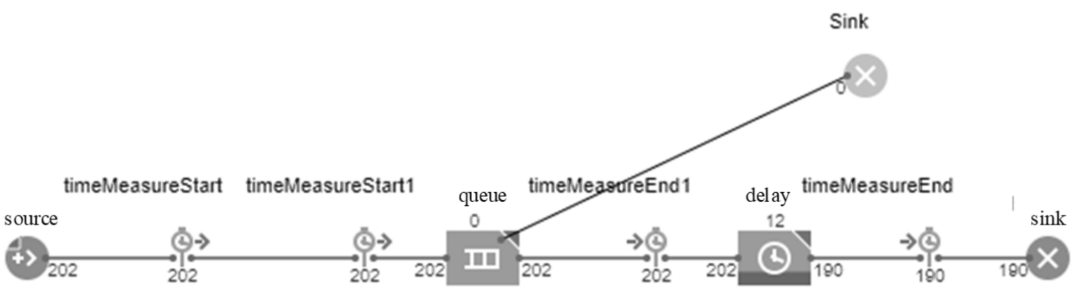

Fig.2. Simulation model of information interaction in the Internet of things

Further development of research based on the developed simulation model was carried out in the following areas:

1. Multichannel on-air transmission medium – M/D/N (Fig. 5, 6).

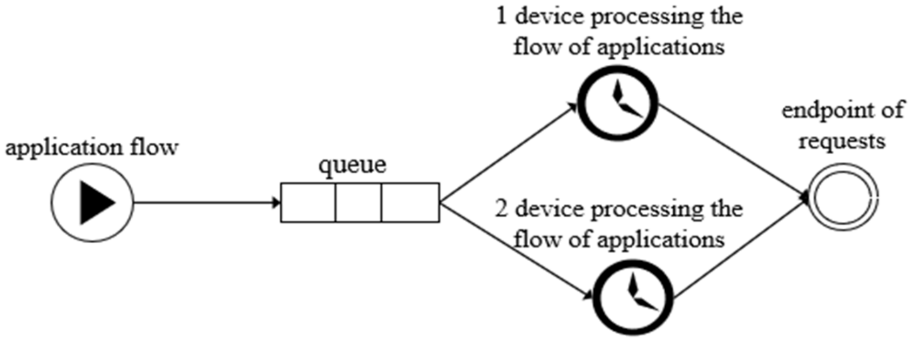

Fig.3. Message passing scheme with 2 processing devices

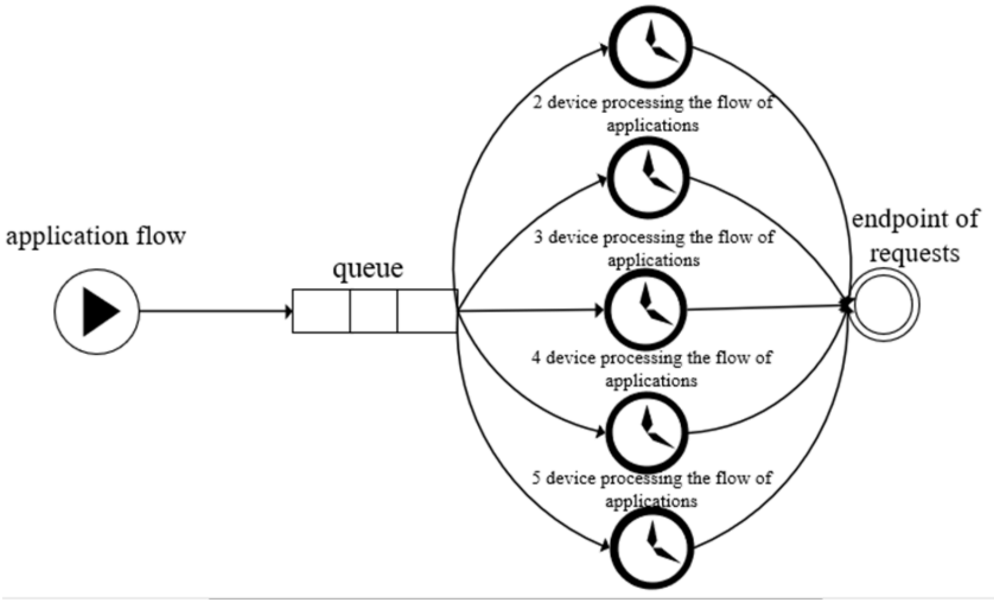

Fig.4. Message passing scheme with 5 processing

The results of the research are presented below:

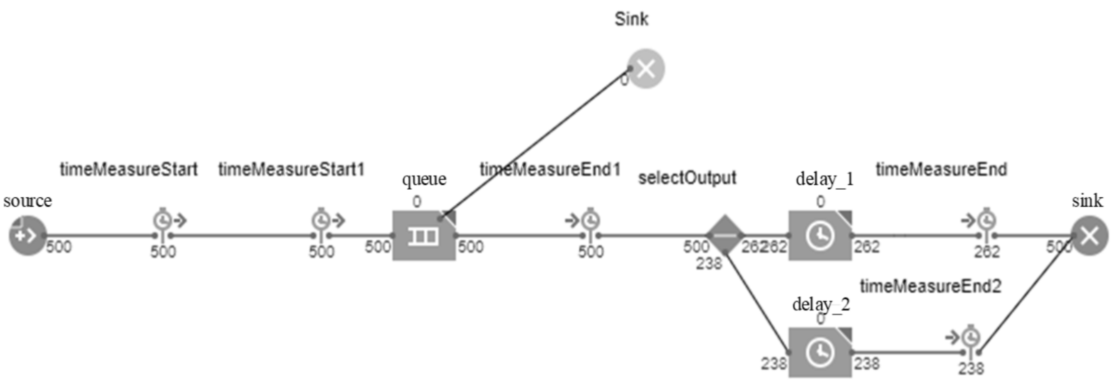

Fig.5. Simulation model. Multi-channel air data transmission medium (M/D/2)

Modeling for the case of a multichannel on-air transmission medium (M/D/N) was carried out with the following initial data λ=1 [message/s], $N \cdot T_{ок}$=0,362 [s], N=15000, Tλ0,00024 [s].

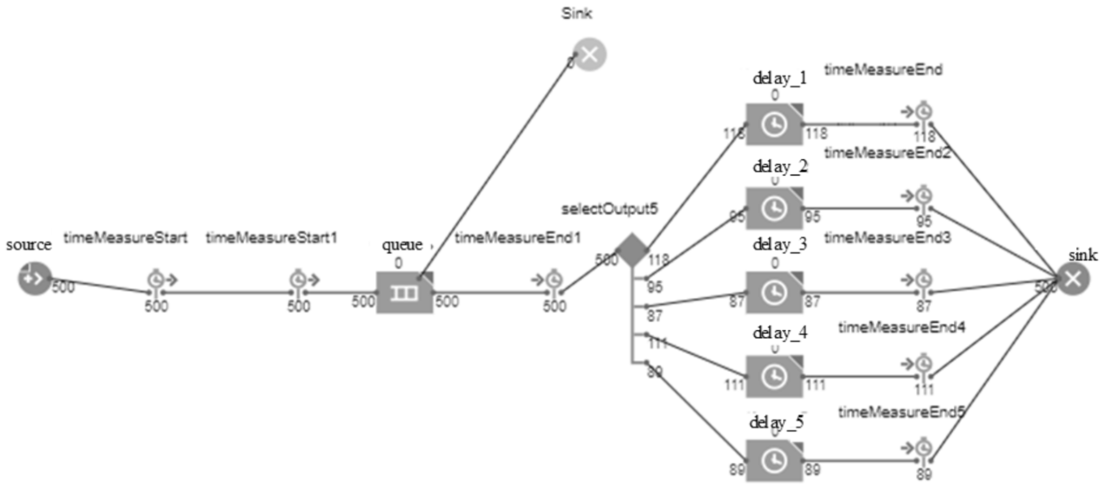

Fig.6. Simulation model. Multi-channel air data transmission medium (M/D/5)

2. Modeling the access system with priority service (Fig. 8).

Simulation modeling methods make it possible to study the impact of introducing a priority access procedure on the efficiency of the sensor network.

A single-channel wireless sensor network that supports messaging from k-type sensor nodes, where k is the number of priorities: k = 1, 2, 3... (k = 1 corresponds to service without priorities). All nodes in the network are respectively divided into k groups. The nodes of each group have their own admissible time of message transmission in the network – t_i(s) (i = 1…k). If the message is not transmitted within the time ti, then it is discarded. Let us assume, when modeling, that messages of the same fixed length (n) are transmitted and the flow of messages coming from a group of nodes of the i-th priority is the simplest with intensity λ_i. (i = 1…k) Priority service in a wireless network is carried out as follows: all nodes are polled and messages with the highest k-th priority are transmitted first, if there are none, then messages with the k-1st priority are transmitted, and so on.

The developed simulation model makes it possible to determine the influence of the number of priorities on the performance of the wireless network, which is proposed to be evaluated by the real-time information rate of the R_{PB} network (bps). The real-time information rate shows how much information (bits) is transmitted in real time per unit of time (s) over the sensor network. To determine R_{PB}, you can use the relation $R_{PB} = R_{1PB} + R_{2PB} + \ldots + R_{iPB} + \ldots + R_{kPB}$, ($i$ = 1…k), $R_{iPB} = n \lambda_i P_i$, ($i$ = 1…k), where P_i is the probability of timely delivery of messages from nodes of the i-th priority is determined by simulation, n is the length of the transmitted block.

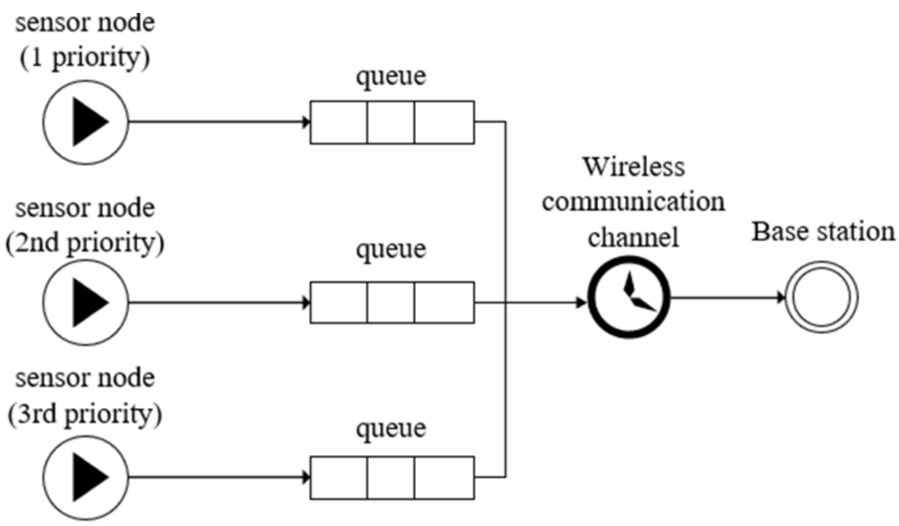

Fig.7. Message passing scheme with priorities

The created simulation model uses 3 priorities.

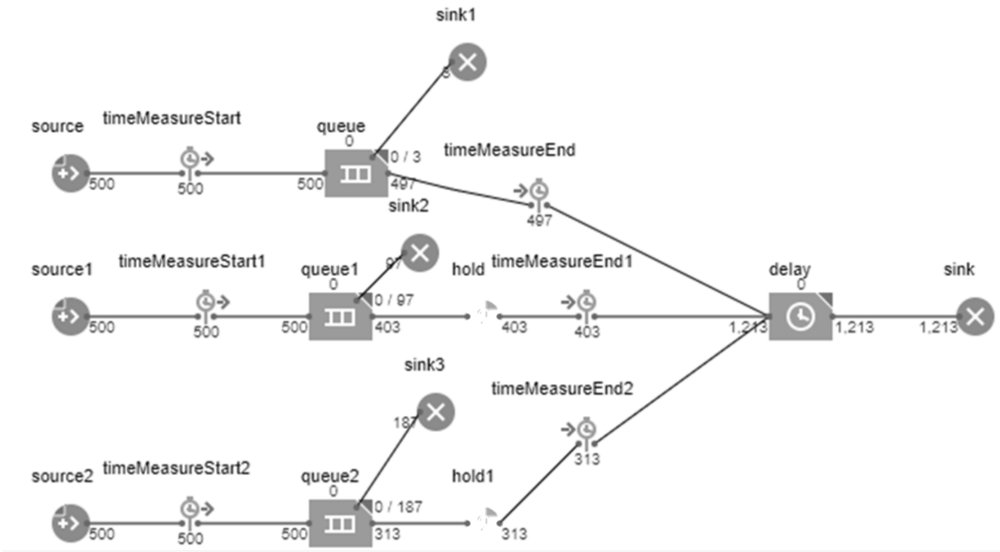

Fig.8. Simulation model of the access system with priority service

In this model, source is a high priority sensor node, source1 is a medium priority sensor node, and source2 is a low priority sensor node. The queue, queue1, queue2 blocks are the queue waiting for the next block to receive a message. The sink1, sink2 sink3 blocks are responsible for accounting for undelivered messages. The hold, hold1 blocks are responsible for blocking the sending of a message with a lower priority. delay – delays the message for a given period of time. The final sink block is responsible for accounting for correctly delivered messages. P_i is the probability of timely delivery of messages.

III. CONCLUSION

A complex of simulation models of information interaction in the Internet of things has been developed. Simulation models make it possible to describe the objects of information interaction of the Internet of things and can be used to conduct various experiments in order to design, analyze and evaluate the operation of the sensor network of the Internet of things. The complex of information interaction models includes: a model in a single-channel transmission medium, a model in a multi-channel transmission medium, a model with heterogeneous sensor nodes using relative service priorities.

The simulation model allows you to describe the objects of information interaction of the Internet of Things and can be used to conduct various experiments in order to design, analyze and evaluate the operation of the WSN of the Internet of Things. Unlike an analytical solution, a simulation model will allow you to clearly define which parameters affect the simulated system and how these parameters are related to each other.

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