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WIRELESS SENSOR NETWORK WITH RANDOMLY CONTROLLED ACCESS TO EXPERIMENTAL BOTANICAL FIELDS MONITORING

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The paper presents a probabilistic method to control access to the wireless sensor network (WSN). The presented network is used for monitoring a botanical field experiment. The proposed network is single-hop with a one-way transmission of network nodes to the base station using only one radio channel. In the model of the network we use Poisson arrivals see time averages (PASTA) with the parameter lambda divided into 3 groups. For these conditions we obtain the probability of collision of transmitted radio packets as the basic criterion for the correct operation of WSN networks.

Keywords: wireless sensor network, Poisson arrivals see time averages (PASTA system), collision probability, random control, monitoring.

1. PROBLEM FORMULATION

This paper presents the problem of the use of WSN to monitor botanical experimental fields. WSN network is a special type of random access control. Poisson stream treatments utilize the modeling of the network [1–5]. This type of organization of network traffic (network access control) perfectly suited to the task of monitoring environmental parameters botanical experimental field because most environmental parameters change very slowly. Since the rate of change of the size of the respondents are very small and for this difference in rate of change between the two values are very large, the paper proposes a slightly different approach to access control. Depending on the size of the rate of change to produce three test groups. The first group contains nodes equipped with sensors that take measurements very slowly changing the physical size of the environment. In the second group of network nodes are equipped with sensors to measure extremely low frequency changes. In the third group are the nodes to which sensors attached to measure the size of the changing faster. This means that some nodes suitable measurement information to the base station to carry out the average time T_1, the second group of the time T_2, a group 3 with the time T_3. This approach will allow you to achieve a higher quality realized by radio transmission The measure of the quality of transmission and provided the correct operation of the network is the probability of a collision of radio signals. We say that a collision occurred, if at the time of the emissions of a single measurement protocol at least one other node also started broadcasting. Of course, this situation is unacceptable and causes loss of information. The WSN network of single - hop random access control using one-way radio transmission from nodes to the base station, with a rare broadcasting manage to get a good transmission quality [4]. If further reduce the transmission rate of the nodes (creating 3 groups), we can expect a significant improvement in the quality or reduce the likelihood of collisions. This approach requires the development of a new model of communication in relation to the previous works [4, 6, 7] has been done in this work.

2. EVALUATION OF RECENT PUBLICATIONS IN THE EXPLORED ISSUE

WSN network is characterized by a specific architectural and communication specifics associated with one hand, and on the other with the requirements of the radio propagation conditions. May be mentioned, among others mobility of network nodes, change the configuration variables measuring environmental conditions, complex algorithms of (single-hop and multi-hop), often self-learning [2, 8, 9]. Basically, the use of WSN in specific applications often requires individual solutions to many complex problems [10]. A specific class of network WSN are using some probabilistic solutions that can be applied to both randomized algorithms access, process control network [11] and probabilistic analysis of the wireless network [12]. Randomized algorithms play an important role in any type of distributed system, they lead to faster and simpler solutions [13] In wireless networks can be considered essentially four main topics probabilistic analysis: 1) related to energy saving [14], (2) design and analysis - random access or sending random [15], (3) probabilistic network performance analysis assuming random network topology, and (4) probabilistic analysis of randomized algorithms [3, 16] the issue of WSN networks of single-hop one-way radio transmission that uses a radio frequency was studied in [4, 6, 7]. Ownership of the network, that is, in particular, the independence of the nodes that support sensors (plug and play), one-way transmission on one frequency providing software “with this simplicity and hardware nodes, extremely narrow band radio networks needed to support pretend it to be used in the monitoring of environmental parameters on need for botanical research the experimental field. This is a special type of WSN network in which nodes are transmitting measurement completely independent from the base station and base station can not communicate with them or not organized in the space of radio traffic at extremely simplifies the implementation of each of the network, making it cheap and easily accessible.

3. PROBABILISTIC NETWORK MODEL

In order to determine the specific requirements for the implementation of network monitoring environmental parameters are based on the expectations of the research team of botanists Table 1, in which the expectations formulated for deploying WSN Problem solving based on different average PASTA for scheduling nodes. The problem extended to several variants of the division into groups of nodes with different transmission times (3 groups) and different number of nodes in each group. This broadens the issues presented in the context of monitoring transmission quality for a wider range of variables. The obtained results allow us to infer that the extended use of the proposed WSN model of random network access control.

We analyze a network consisting of n nodes which are able to send information about the measured physical magnitude on one selected radio frequency to the receiving base, quite independently of each other. Duration of communication protocol is t_p, the nodes send the information to the receiving point in randomly selected moments, every T s. at an average.

Beginning and cessation of transmission of a particular node takes place in random moments of time but these moments are relatively rare. It is a one-way transmission, i.e. from nodes to the receiving base. The nodes are completely independent of one another and their on or off state is of no influence on the operation of the network. All the nodes or a part of them may be mobile provided that their nodes have been left within the radio range of the receiving base. If one or more nodes start sending while protocol transmission of time is going on from another node, then such a situation is called collision. Collision excludes the possibility of the correct receiving of information by the receiving base. Such a disturbed signal is ignored. The receiving base rejects the erroneous message and waits for a retransmission to be made after the average time. We must accept a certain loss of information in exchange for simplicity in respect of both system and equipment.

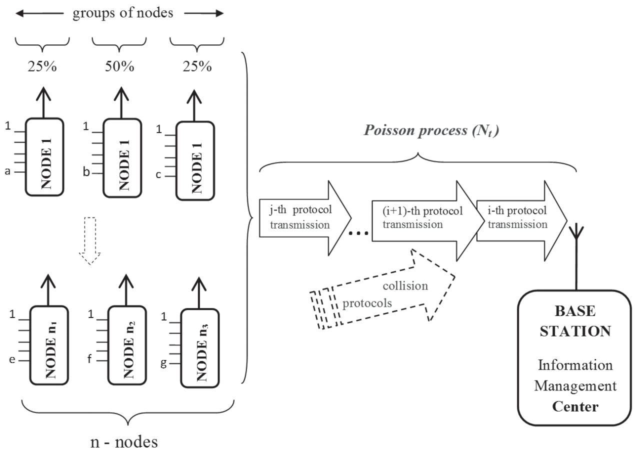

Fig. 1. Poisson modeling of network transmission protocols in WSN

As mentioned in the Introduction, we used to modeling our wireless network a Poisson process. Mathematically the process N is described by so called counter process N_t or $N(t)$ of rate $\lambda > 0$ (see [4, 6]). The counter tells the number of events that have occurred in the interval $[0, t]$ $(t \geq 0)$. N has independent increments (the number of occurrences counted in disjoint intervals are independent from each other), such that $N(t) - N(s)$ has the Poisson ($\lambda(t-s)$) distribution (mean $\lambda(t-s)$), for $t \geq s \geq 0, j = 0, 1, 2, \ldots$,

$$P\{N(t) - N(s) = j\} = e^{-\lambda(t-s)} \frac{[\lambda(t-s)]^j}{j!}. \quad (1)$$

Table 1

Requirements for the experimental fields botanical

nr	Type of measurement (the number of nodes needed /sensors)	Study monitored the frequency of size [s]	Frequency of sending a message [s]					
			Very slowly varying environmental parameters (T_1) [s]	Number of nodes (n_1)	Slowly varying environmental parameters) (T_2) [s]	Number of nodes (n_2)	Quick-environmental parameters (T_3) [s]	Number of nodes (n_3)
percentage of nodes in the group of time			25%	11	50%		25%	10
1	air Temperature / 5/5-10	900			900	5		
2	The temperature in the soil/5/5-10	3600	3600	5				
3	Humidity/5/5-10	900			900	5		
4	Moisture in the soil /5/5-10	3600	3600	5				
5	Atmospheric pressure /1/1	3600	3600	1				
6	Rainfall /1/5	900			900	5		
7	Wind Speed /5/5-10/	10					30	5
8	Wind Direction / 5/5-10	10					30	5
9	Insolation	300			900	1		
10	Selected size physicochemical /5/10	900			900	5		
Total nodes				11		21		10
The total number of nodes				42				

Let us state our main assumptions. Consider two cases, in the first case, the average time between transmissions all n nodes is the same. In the latter case, the nodes are divided into groups, each group with a different average transmission time.

Consider the first case. There are n identical nodes observing a dynamical system and reporting to a central location over the wireless node network with one radio channel. For simplicity, we assume our sensor network to be a single hop network with star topology. We also assume every node always has packet ready for transmission. We assume that nodes send probe packets at Poissonian times. The average time between transmissions (the wake-up- times) of a nodes is T (the epoch period), and the duration of the on-time t_p (the awake interval). Assume that the wake-up- times corresponding to nodes are independent each of other. Let N be the Poisson process representing the time counter of sending nodes. We say that a collision occurs in the time interval of t_p length, if at least two nodes start sending within this interval. We say that a collision occurs in time interval s, if there exist at least two nodes which start sending within this interval with the difference between the beginning of their sending time not exceeding the value of t_p. Then the Poisson process N has the rate $\lambda = n / T$. By (1)

$$P(N(t) = j) = e^{-\lambda t} \frac{[\lambda t]^j}{j!} (j = 0, 1, \ldots), \qquad (2)$$

where $\lambda = n / T$. In [4, 6, 7] we give the following theorem on the probability of collisions in the interval of s length in the case $s > t_p$.

Theorem 1. Let n be the number of nodes and let T be the average time between transmissions of a node. Then the probability of collisions in the interval of s length $(s > t_p)$ is given by

$$P(A_s) = \sum_{j=2}^{\infty} e^{-\lambda s} \frac{(\lambda s)^j}{j!} [1 - (1 - j \frac{t_p}{s})^j], \qquad (3)$$

where $\lambda = \frac{n}{T}$ and t_p is the duration time of a protocol.

Consider the second case. Let $N(t)$ be the Poisson process representing the time counter of sending nodes. We assume that there is n nodes, such, that $n = \sum_{i=1}^{k} n_i$ $(1 \le k \le n)$ and n_i is the number of nodes for which T_i is the average time between transmissions of a node $(i = 1, \ldots, k)$. Let $X_{(i)}(t)$ $(i = 1, \ldots, k)$ be the Poisson process representing the time counter of sending nodes for which T_i is average time between transmissions of a node. Then $X_{(i)}(t)$ has the rate $\frac{n_i}{T_i}$ $(i = 1, \ldots, k)$. Note, that $N(t) = \sum_{i=1}^{k} X_{(i)}(t)$, consequently the Poisson process $N(t)$ has the rate $\lambda = \sum_{i=1}^{k} \frac{n_i}{T_i}$. In [17] we give the following theorem on the probability of collisions in the case, when the average times between transmissions of nodes are not necessarily the same.

Theorem 2. Let n be the number of nodes, $n = \sum_{i=1}^{k} n_i$ and n_i be the number of nodes such that T_i is the average time between transmissions of a node, $1 \le k \le n$ is the number of groups. Then the probability of collisions in the interval of s length $(s > t_p)$ is given by

$$P(A_s) = \sum_{j=2}^{\infty} e^{-\lambda s} \frac{(\lambda s)^j}{j!} [1 - (1 - j \frac{t_p}{s})^j], \qquad (4)$$

where $\lambda = \sum_{i=1}^{k} \frac{n_i}{T_i}$ and t_p is the duration time of a protocol.

4. DISCUSSION OF THE RESULTS

The obtained theoretical correlation was used to present the results graphically. The division of nodes into groups according to the average time between transmissions overall transmission quality is improved using a smaller probability of a collision. The result is consistent with the expected dependence resulting from the earlier work described in [4, 6], indicating that the longer the average time between T transmissions nodes, the network works better (with fewer collisions). An important condition is that the duration of the protocol was much less than the average time between nodes transmissions *T*. In the present task duration protocol Fig. 2 shows the probability of collision for the measurement conditions specified in Table 1 So a group of sensor nodes supporting (a ... e) of the slowly changing measurement values with an average working time of granting 3600s (1 hour) accounts for about 25% of all nodes. The second group of nodes connected supports detectors (b ... f) with an average time of transmission 900s and accounts for 50% of all nodes. The third group of nodes connected to the nodes support sensors (c ... g) of varying sizes quickly measuring the average time between transmissions 30s. The conditions applicable to the field of experimental monitoring total number of nodes *n* = 42 pc (Characteristic P(As1) in Fig. 2). For these particular conditions used Usage of this solution is the possibility of collision on the level $0{,}7 \cdot 10^{-4}$. This result is very good, allowing for highly efficient monitoring. As can be seen by comparing the results of [6], $P(A_s) = 1{,}0 \cdot 10^{-2}$ we obtain improvement by about two orders of magnitude, by dividing the total number of nodes in a group at different times between transmissions better suited to handle a particular task network.

Is shown on fig. 2: T_1 = 3600s, T_2 = 900s, T_3 = 30s. P(As1) – when the network is running 25% of the nodes with an average transmission time of 3600s, 50% of the nodes running the middle 900s broadcasting time and 25% of network nodes operating with an average time between transmissions 30s. P (As2) - When the network is working 40% of the nodes with an average time between transmissions 3600s, 50% of the nodes is working with an average time between transmissions 900s and 10% nodes running with an average time between transmissions 30s. P (As3) - When the network is working 50% of the nodes with an average time between transmissions 3600s, 25% of the nodes is working with an average time between transmissions 900s and 25% nodes running with an average time between transmissions 30s. P (As4) - When the network is working 50% of the nodes with an average time between transmissions 3600s, 40% of the nodes is working with an average time between transmissions 900s and 10% nodes running with an average time between transmissions 30s. Attention: P (As2) and P (As4) almost overlap.

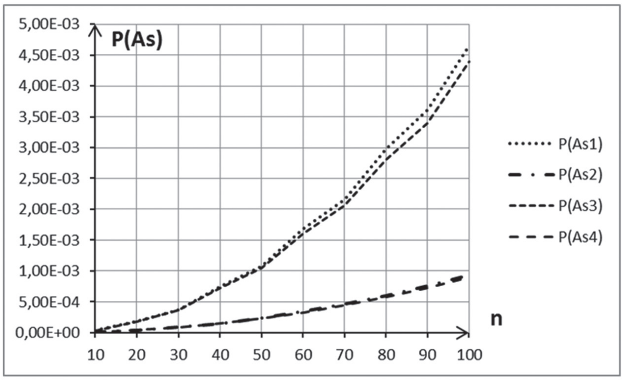

Fig. 2. Probability of collision

Using the derived relationships and calculations made for a wider range of other considerations secondary transmission times. Figure 3 shows the dependence T_1 = 10800s, 1800s = T_2, T_3 = 60s, and in Figure 4 when T_1 = 1800s, T_2 = 600 s, T_3 = 15s. In each figure shows four characteristics, respectively, P (As1) shows a situation where a group of nodes have 25% of the nodes broadcast with the longest average time of transmission (T_1), 50% of nodes with an average transmission time (T_2) and 25% with the shortest transmission time (T_3). Characteristic (curve) P (As2) is appropriate for divisions in groups of 40% / 50% / 10%. Curve P (As3) is appropriate for divisions in groups of 50% / 25% / 25%, the curve P (As4) is appropriate for divisions in groups of 50% / 40% / 10%.

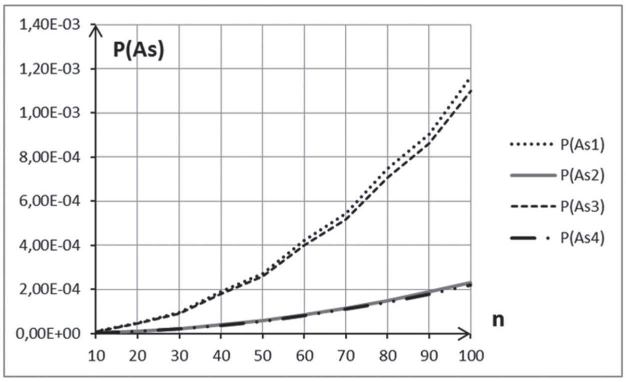

Fig. 3. Collision probability

Is shown on fig. 3: T_1 = 10800s, T_2 = 1800s, T_3 = 60s. P (As1) - when the network is working 25% of the nodes with an average transmission time 10800s, 50% of the nodes running the middle 1800s broadcasting time and 25% of network nodes operating with an average time of transmission 60s. P (As2) - When the network is working 40% of the nodes with an average transmission time 10800s, 50% of the nodes running the middle 1800s broadcasting time and 10% nodes running with an average time of transmission 60s. P (As3) - When the network is working 50% of the nodes with an average transmission time 10800s, 25% of the nodes running the middle 1800s broadcasting time and 25% of network nodes operating with an average time of transmission 60s. P (As4) - When the network is working 50% of the nodes with an average transmission time 10800s, 40% of the nodes running the middle 1800s broadcasting time and 10% nodes running with an average time of transmission 60s. Attention: P (As2) and P (As4) almost overlap.

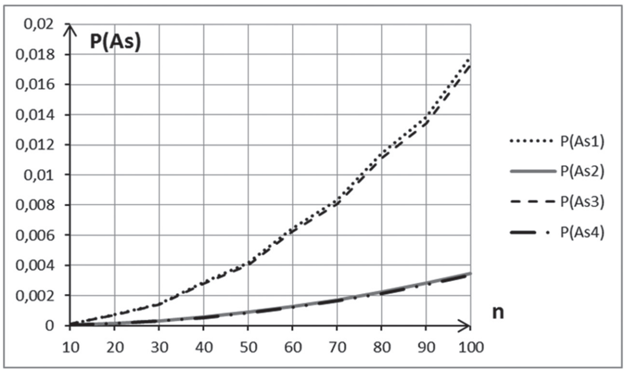

Fig. 4. Collision probability

Is shown on fig. 4: T_1 = 1800s, T_2 = 600 s, T_3 = 15s. P (As1) - when the network is working 25% of the nodes with an average transmission time of the 1800s, 50% of the nodes running the middle 600s broadcasting time and 25% nodes running an average transmission time of 15 seconds. P (As2) - When the network is working 40% of the nodes with an average transmission time of the 1800s, 50% of the nodes running the middle 600s broadcasting time and 10% nodes running an average transmission time of 15 seconds. P (As3) - When the network is working 50% of the nodes with an average transmission time of the 1800s, 25% of the nodes running the middle 600s broadcasting time and 25% nodes running an average transmission time of 15 seconds. P (As4) - When the network is working 50% of the nodes with an average transmission time of the 1800s, 40% of the nodes running the middle 600s broadcasting time and 10% nodes running with an average time of transmission 15s. Attention: P (As2) and P (As4) almost overlap.

CONCLUSIONS

In this paper we presented the model of the wireless sensor network in application to monitoring the experimental field. We presented the network model, the mathematical model and numerical simulation (verification of the presented mathematical model). The mathematical model was based on Poisson Arrivals See Time Averages (PASTA). The solution proposed helped expand the range of applications of

WSN solutions by introducing a group of nodes with different average transmission times. This results in a better quality of transmission at a certain required number of nodes. The presented mathematical model has been positively verified by performed numerical simulations.

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Беспроводная сенсорная сеть со случайно контролируемым доступом для мониторинга экспериментальных ботанических полей / С. Райба // Прикладная радиоэлектроника: научно-техн. журнал. – 2013. – Том 12. – № 3. – С. 431–435.

В статье приведено вероятностный метод управления доступом к беспроводной сенсорной сети (БСС). Представленная сеть применяется для мониторинга экспериментального ботанического поля. Предлагаемая сеть является одноперbegin приемной с односторонней передачей от сетевых узлов к базовой станции, используя только один радиоканал. В модели сети применено среднее значение за время наблюдения поступления пуассоновского потока (PASTA) с разделением параметра лямбда на 3 группы. Для этих условий определено вероятность коллизии передаваемых радиопакетов в качестве основного критерия для правильного функционирования сети БСС.

Ключевые слова: беспроводная сенсорная сеть, среднее значение за время наблюдения поступления пуассоновского потока (система PASTA), вероятность коллизии, случайное управление, мониторинг.

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Безпровідна сенсорна мережа з випадково контрольованим доступом до моніторингу експериментальних ботанічних полів / С. Райба // Прикладна радіоелектроніка: наук.-техн. журнал. –2013. – Том 12. – № 3. – С. 431–435.

У статті наведено імовірнісний метод керування доступом до безпровідної сенсорної мережі (БСМ). Дана мережа застосовується до моніторингу експериментального ботанічного поля. Пропонована мережа є одноперeприйомною з односторонньою передачею від мережних вузлів до базової станції, використовуючи тільки один радіоканал. У моделі мережі застосовано середнє значення за час спостереження надходження пуассонівського потоку (PASTA) з поділом параметру лямбда на 3 групи. Для цих умов визначено імовірність колізії радіопакетів, які передаються, як основного критерію для правильного функціонування мережі БСМ.

Ключові слова: безпровідна сенсорна мережа, середнє значення за час спостереження надходження пуассонівського потоку (система PASTA), ймовірність колізії, випадкове керування, моніторинг.

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