ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ ԳԻՏՈՒԹՅՈՒՆՆԵՐԻ ԱԶԳԱՅԻՆ ԱԿԱԴԵՄԻԱ
ԻՆՖՈՐՄԱՏԻԿԱՅԻ ԵՎ ԱՎՏՈՄԱՏԱՑՄԱՆ ՊՐՈԲԼԵՄՆԵՐԻ ԻՆՍՏԻՏՈՒՏ

Միրեսմաիլ Միրնաբիբաբոլի

ԱՆԼԱՐ ՍԵՆՍՈՐԱՅԻՆ ՑԱՆՑԵՐՈՒՄ ՑԱՆՑԻ ԿՅԱՆՔԻ ՏԵՎՈՂՈՒԹՅԱՆ ԵՎ ՇԱՐԺՈՒՆԱԿՈՒԹՅԱՆ ՍՊԱՍԱՐԿՄԱՆ ԲԱՐԵԼԱՎՈՒՄ ԱՐԴՅՈՒՆԱՎԵՏ ԵՐԹՈՒՂԱՎՈՐՄԱՆ ԿԻՐԱՌՄԱՄԲ

Ե.13.04 - «Հաշվողական մեքենաների, համալիրների, համակարգերի և ցանցերի մաթեմատիկական և ծրագրային ապահովում» մասնագիտությամբ տեխնիկական գիտությունների թեկնածուի գիտական աստիճանի հայցման համար

ՍԵՂՄԱԳԻՐ

ԵՐԵՎԱՆ – 2013

NATIONAL ACADEMY OF SCIENCES OF ARMENIA
INSTITUTE FOR INFORMATICS AND AUTOMATION PROBLEMS

Miresmail Mirnabibaboli

THE ENHANCEMENTS OF NETWORK LIFETIME AND SUPPORTING MOBILITY BY UTILIZING SUITABLE ROUTING IN THE WIRELESS SENSOR NETWORK

ABSTRACT

For obtaining candidate in technical sciences in specialty 05.13.04 – “Mathematical and software support of computational machines, complexes, systems and networks”

YEREVAN – 2013

Ատենախոսության թեման հաստատվել է ՀՀ ԳԱԱ Ինֆորմատիկայի և ավտոմատացման պրոբլեմների ինստիտուտում:

Գիտական ղեկավար՝	տեխ. գիտ. դոկտոր	Մ.Վ.Մարկոսյան
Պաշտոնական ընդդիմախոսներ՝	տեխ.գիտ.դոկտոր	Հ.Հ.Հարությունյան
	տեխ.գիտ.թեկնածու	Ա.Վ.Կնյազյան
Առաջատար կազմակերպություն՝	Հայաստանի պետական ճարտարագիտական համալսարան	

Ատենախոսության պաշտպանությունը կայանալու է 2013թ. Դեկտեմբերի 25-ին, ժամը 15:00-ին, ՀՀ ԳԱԱ Ինֆորմատիկայի և ավտոմատացման պրոբլեմների ինստիտուտի 037 «Ինֆորմատիկա և հաշվողական համակարգեր» մասնագիտական խորհրդի նիստում, հետևյալ հասցեով՝ 0014, Երևան, Պ. Սևակ 1:
Ատենախոսությանը կարելի է ծանոթանալ ՀՀ ԳԱԱ ԻԱՊԻ-ի գրադարանում:
Սեղմագիրն առաքված է 2013թ. Նոյեմբերի 25-ին:

Մասնագիտական խորհուրդի գիտական քարտուղար,
ֆիզ. մաթ. գիտ. դոկտոր Հ. Գ. Սարուխանյան

The subject of thesis is approved in Institute for Informatics and Automation Problems of NAS RA.

Supervisor:	Doctor of technical sciences	M.V. Markosyan
Official opponents:	Doctor of technical sciences	H.H.Haroutunian
	Candidate of technical sciences	A.V.Knyazyan

The leading organization: State Engineering University of Armenia

The defense of thesis will take place on 25 of December of 2013, at 15:00, during the committee of specialized council 037 "Informatics and Computing Systems" of Institute for Informatics and Automation Problems of NAS RA, address: 0014, Yerevan, P. Sevak str. 1.
The thesis is available in library of IIAP of NAS RA.
The abstract is distributed on 25 November of 2013.

Scientific secretary of the specialized council,
Doctor of phys. and math. sciences H. G. Sarukhanyan

GENERAL CHARACTERIZATION OF THESIS

Relevance of subject:

Wireless sensor network (WSN) is a distribution of autonomous sensors which cooperatively monitor physical or environmental conditions, such as temperature, vibration, pressure, sound and so on. WSNs are used in many areas, including home automation, machine health monitoring, industrial process control and monitoring, healthcare applications, etc. The areas of use of WSNs enlarge day by day and the implementation of multifunctional and reliable WSNs is an important task.

The detection process in WSNs mostly depends on sensor node's physical conditions and the solutions of detection problems are largely hardware side than software. After detection the routing process comes and the node has to find whom and how to transfer the sensed data. After that finds the route, the turn passes to data transfer process. As usually the volume of transferred data is rather small, that process doesn't take much effort from sensor node.

Low energy consumption is a critical task in WSNs, especially in a sensor networks which are comprised of nodes that are considered lightweight with limited battery power. But as usually almost all sensor nodes have limited battery power and keeping the energy becomes very actual task in WSNs.

The most critical process in sensor networks is the routing because of high energy consumption, end-to-end delay, control of packet overhead and so on. Thus, it is required to have a good routing mechanism in WSNs for reducing energy consumption in sensor nodes and for increasing the network lifetime. The faster is routing process, the longer is sensor node lifetime and the less is energy consumption. Hence, the development of better ways and methods of routing is very important task of WSN.

There are many works in scientific literature devoted to the problem of increasing the lifetime of WSNs. However, the problem still remains an urgent task.

Purposes and objectives of work:

The purpose of this thesis is the research of mechanisms and algorithms of WSNs functionality and the finding of ways for increasing the lifetime of WSNs. For this reason the following objectives are formulated and solved:

- Review and summarizing of the research results in the development and operation of sensor networks to identify the main factors which have influence on the lifetime of sensor nodes and on network in general.

- Consideration of the existing algorithms and development of a new routing algorithm which reduces the active time of work of sensor nodes in order to decrease energy consumption.
- Development of a method which will increase network lifetime of WSNs by load balancing of traffic in network, by supporting mobility and by cooperation of nodes by clustering.
- Evaluation of the efficiency of the proposed algorithms on the network simulation model.

The subject of research:

- WSNs architecture and topology
- The architecture of sensor nodes, critical points of energy consumption
- Existing methods of routing in WSNs, their metrics and limitations

Methods of research:

For implementations of new routing algorithms for WSNs NS-allionone-2.29 simulator with Diffusion 3.2.0 code have been chosen. NS-2 is one of the best simulators for implementation of WSNs and the new algorithms have been implemented in it. About 300 nodes distributed throughout about $400 \times 400 m^2$ have been used for these implementations. The 802.11b protocol is used for simulation of wireless scenario Diffusion 3.2.0 in NS-allinone-2.29. The nodes have been randomly expanded in grid according to energy consumption in PCM-CIA WLAN card as NS-2.

Scientific novelty:

- Routing algorithm of WSN has been developed, which reduces the energy consumption of sensor nodes by selecting the best node for the next hop.
- Routing algorithm (EECB) of WSN has been developed, in which the clustering technique, cooperation of nodes and supporting the mobility are used. The new algorithm reduces the delay in netwoek and the energy consumption of sensor nodes, and hence increases the WSN lifetime in comparison with existing methods.

Reliability of results:

Using real physical WSNs for adjustment of scientific researches of thesis is very costly, therefore the simulators are used. There are lots of simulators for WSNs implementation and NS-2 is one of strongest and the most reliable of those. The new algorithms are implemented in NS-2 and the results have been compared with previous algorithms which have also been implemented in the same simulator. Besides, the results of thesis are implemented in the real WSNs (references of application are presented).

Main points presented for the defense:

- Algorithm for reducing the energy consumption in WSN by preventing the flooding of interest message in order to find the aims and by suitable choosing of neighbor node which is close to the destination node.

- Algorithm for increasing the network lifetime by cooperation of nodes in order to prevent the activity mode of nodes, by creation of agent sink and agent event and by reducing the traffic load bar when sink wants to find any event.
- Method for decreasing the delay in the network by supporting of sink movement in order to keep the network and by preventing the packet loss when a sink node is replaced.

Practical significance of results:

The results are important for the organization of works in real environments, such as:

- Reducing the average energy consumption of sensor nodes for sending data and finding destination node.
- Increasing network lifetime and extending the service life of sensor networks by decreasing average energy consumption.
- Improving end to end delays by suitable choosing of neighbor node and clustering
- Supporting the replacement of sink node in order to keep the network and prevent the packet loss into WSN when data or interest messages have been sending.

Implementations:

The new routing algorithm of WSNs with developed software package has been implemented in YTRI (Yerevan Telecommunication Research Institute) in Armenia and ICT (Information Communication Technology) research center ministry in Iran-Mazandaran (2011-2013).

Approbation:

The basic scientific and practical results of the thesis have been presented and judged by international scientific committee of referees in international journals and conferences. All of them are special in the wireless sensor network field, such as: SENSORCOMM(2011), ThinkMind(TM), IARIA in France, ITNG(2013), IEEE in USA and CEIC in Iran. Also the work has been presented on scientific and technical seminars in YTRI and IIAP.

Publications:

The main results of thesis have been published in 6 scientific publications which are listed in the end of the abstract.

Structure of dissertation:

The thesis contains introduction, three chapters, conclusion, bibliography with 102 references and 4 appendixes. The main text includes 106 pages, 53 figures, 4 tables and 14 formulas. The full text of theses with appendixes includes 136 pages.

THE MAIN CONTENT OF THESIS

In Introduction the actuality of the work is justified; the purposes and objectives of work, as well as the main points presented for the defense are formulated; the practical significance of results and the scientific novelty are presented.

In Chapter 1 the functional and structural features of sensor networks are presented. The topologies of sensor networks are discussed; the architecture of simple sensor node is presented and the research of routing protocols is done. Also the purpose of thesis is justified and the research tasks are formulated.

In §1.1 the functional principles and topology of Wireless Sensor Network and the architecture of sensor nodes are presented.

In recent years the interest from industrial and research perspectives to wireless sensor networks (WSN) has increased. A WSN can be generally described as a combination of large quantities of small nodes (network of devices), which sense the environment, gather the information from monitored field and communicate it to the appropriate area through wireless. The gathered data is passing via wireless network to controller or monitor, which is named sink. Sink can use the data locally, or can resend it to other devices via network. An example of WSN usage can be the detection of fire in the forest. Thus, the supervised area can include a few hundreds of square meters or thousands of square kilometers, and the duration of the supervision can last for years. Hence, natural disasters can be perceived earlier by installing networked embedded systems closer to places where such phenomena's can occur. The observed environment can be inaccessible by the human all the time and robustness of detectors is very important.

A *sensor node* in a WSN is capable of gathering sensory information and communicating with other connected nodes in the network. The main components of a sensor node are *a microcontroller, transceiver, external memory, power source* and one or more *sensors* (Fig. 1)

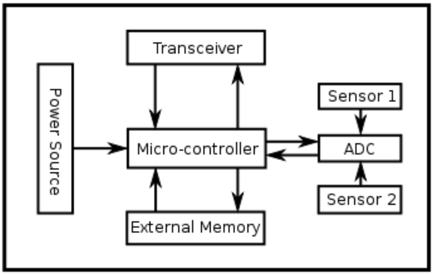

Fig. 1 Components of sensor node

A WSN is a good solution when running a mains supply to the sensor node is difficult or impossible. But as wireless sensor node is usually placed in hard to reach region, the regular changing of battery can be inconvenient and costly. Thus, as can be concluded from sensor nodes features, one of the main objectives is the energy consumption, which is mainly used on communication/data transfer process.

Network topology of sensor applications is an important point in reducing the cost and complexity and improving the overall reliability of the system. In WSNs deployment are used traditional network topologies. The common topologies of sensor networks are Peer to Peer (Point to Point), Star, Tree and Mesh.

In §1.2 the purpose of thesis is justified and the research tasks are formulated. The working process of sensor node can be divided into 3 parts, *detection, routing* and *data transfer*.

The detection process mostly depends on sensor node's physical conditions and the solutions of detection problems are largely hardware side than software. After detection the routing process comes and the node has to find whom and how to transfer the sensed data. After it finds the route to the sink, the turn passes to data transfer process. As usually the volume of transferred data is rather small, that process doesn't take much effort from sensor node. Thus, the most critical process of sensor networks is the routing.

The routing process is critical not only for reducing control packet overhead, maximize throughput and minimize the end-to-end delay, but also for take into consideration the energy consumption and sensor nodes lifetime. Energy consumption and nodes lifetime is more actual, especially in a sensor network which is comprised of nodes that are considered lightweight with limited battery power.

Thus, it is required to have a good routing mechanism in WSNs for reducing energy consumption in sensor nodes and for increasing the nodes and so also the network lifetime.

In §1.3 is presented the research of routing protocols and methods in WSNs. Routing is a path determination process between source and destination for data transfer. In WSNs for implementation of incoming data routing is mostly used the network layer. Generally in multi-hop networks the source node is unable to reach the sink directly and intermediate sensor nodes have to relay their packets. Solution of this issue is the implementation of routing tables which contain the lists of node option for any given packet destination. Construction and maintenance of routing table is one of the main tasks of routing and for its solution are using different routing protocols and algorithms.

The performance of routing protocol is closely related to the architectural model and depending on the current application, for sensor networks have been considered different architectures and design constraints. Routing protocols in WSNs can be classified in four ways (Fig. 2):

- According to the way of routing paths are established;
- According to the network structure;
- According to the protocol operation;
- According to the initiator of communications.

Every protocol of WSN routing can be used depends on current objective to get the best solution. But according to the research results of WSN routing protocols and algorithms, it can be concluded that one of the best routing protocols, which is less energy-intensive and in the same time have other good conditions, like mobility, multipath usability, effective data aggregation, and so on, is Directed-Diffusion.

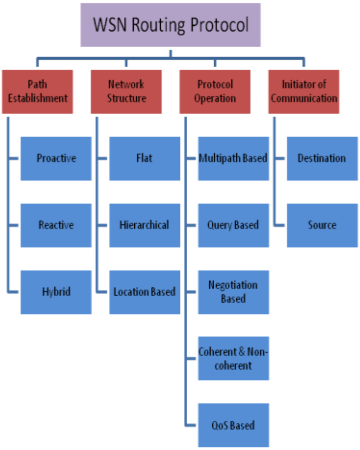

Fig. 2 Classification of routing protocols in WSNs

In Chapter 2 the research and development of methods for routing improvement in WSNs is presented. The metrics and limitations of base routing protocol algorithms are described and the development of new routing algorithms based on Directed-Diffusion is presented.

In §2.1 the algorithms base routing protocol (Directed-Diffusion) are discussed. There are a number of protocol variants that are optimized for different situations and Directed-Diffusion is actually more a design philosophy than a concrete protocol. There are different implementations of Directed-Diffusion and in energy consumption perspectives Two-Phase pull (TPP) and Power Consumption Directed-Diffusion (PCDD) methods show the best results.

In §2.2 are presented new routing algorithms based on Directed-Diffusion. In order to decrease energy consumption and to increase the lifetime of the WSNs, in this work is developed a new hierarchical routing algorithm by sending data in multi hops form. The produced algorithm is based on Directed-Diffusion and is able to determine optimize routing in term of energy consumption end to end delay and other parameters including: free volume of buffer, sending defeat, distance of candidate node to sink and distance of the current node to candidate node. The new algorithm selects the best node for the next hop in order to send its assumed packages to the destination by calculation of the integral. As a result, it causes the minimum cost of the network life time. By division of nodes and duties and by making changes in the Directed-Diffusion, flat routing is divided into hierarchical routing.

Directed-Diffusion has some limitations and in order to reach the goals of this work those limitations must be improved.

First of all, in interest propagation phase of Directed-Diffusion the sink just flood or broadcast the interest in the whole network. As a result, it is possible that any signal node can receive a redundant copy of an interest and has to process it. Hence, by this redundant interest messages and flooding (Fig. 2.8) the batteries of sensor network get drain out quickly by which the network life time of WSN decreases. Thus, the main problem is the efficiently utilization of this energy resources of sensor during the interest diffusion phase.

Secondly, exploratory messages are also the problem of Directed-Diffusion. Exploratory events are used for receiving high quality events but this protocol signaling can cause great energy consumption in the network as same as the flooding of interest messages. The interest propagation and the exploratory messages are the main problems of Directed-Diffusion. Thus, by improving these two factors can be enhanced the network life time of WSNs.

Actually, in the start of the network work, the duty division takes place based on local clustering and the nodes complete to be a cluster head. After a period, a node with more remained energy than its geographical area nodes is selected as the cluster head node. If the reminder energy of the cluster head node is less than the threshold, it will enterprise a new cluster replacement and the competitor node with maximum reminder energy will be replaced by previous cluster head node. It means that the sensors with maximum reminder energy are selected as a cluster (Fig. 3).

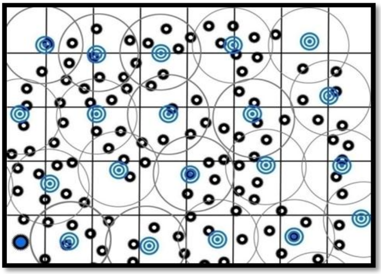

Fig. 3 Illustration of arrangement and clustering of network nodes

This is like some sensors get very close locations. Thus, the sensor selects the wireless with the maximum reminder energy as the first cluster. This selection can be done based on the factor (2.1) of selection of alternative cluster head (Fig. 2.9). Each wireless sensor with a maximum factor other than primary cluster head is selected as the alternative cluster head.

$$CH\_R_F = E_{Ni} - \log_{10}(d_{Ni\ to\ primary\ CH}) - \log_{10}(AVG\_D_{Ni\ to\ primary\ CH}) \quad (1)$$

E_{Ni} is the energy of the candidate node for replacement, $d_{Ni\ to\ primary\ CH}$ is the distance between alternative node to the primary cluster head and *AVG_D* D shows delay between the alternative node and the cluster head. Finally, the node with the maximum CH_R_F is selected as the cluster head. After division and classification of network (Fig. 2.10), the duties of each node are specified. In other words, each node which senses an event in its own limitation moves from standby status to active status.

When a node senses an event, a packet named event with a determined lifetime is created and it is sent to the cluster head. The cluster head node sends the discovered packet to the adequate relay node by use of a specified function, in order to send the adequate cluster head. The research will deal with this issue in the next parts of this dissertation; there is an important point in sending packet by cluster. In other words, if the sink node is in the sending limitation of cluster head radius or there is not any relay node, data will be send to the sink node directly. Otherwise, the cluster head selects the node with the highest amount of route choice (will be discussed in next parts) as the next hop.

According to this method a routing algorithm for WSN has been developed. But one of the problems in the pervious method of routing is the data sending through the provided gradients. It means that the discovering data is not sent from node and optimize stage. Instead, the data is sent to the sink node only and only from requester nodes. It should be taken to the point that the ignorance of the neighbor and candidate nodes' energy in the moment of sending is an important weakness. Although in the previous method two phase pull protects the network lifetime by positive and negative reinforcement, the weakness is not removed. Our suggested method will reduce this weakness by taking some pre-sending parameters. That is why the selected node is the best node for sending. When the event occurs (for example, explosion in a region), the closest node which discovers this event selects one of the neighbor nodes based on the selection function. It could be either cluster head or relay node.

One of the purposes of the work is to reduce the energy consumption and increase the network lifetime in routing. Thus, to reach those goals there is need to improve the factors which cause the waiting of network energy. We intend to do it by use of suitable parameters which cause it. One of the parameters in sending the discovery packet includes the distance of the sender node to the candidate node. The closer a node to the sender node, the less will be energy consumption based on distance.

Thus, the main critical parameters are discussed. Those are the distance of candidate node from the sender node, the amount of reminder energy in the candidate node, the amount of buffer's free memory in the candidate node, mean of end to end delay, radius of optimizes sending.

There is another problem in routing of the sensor network. It is the problem of unwanted mobility. Therefore, if the natural and non-natural factors (including landslides, storm and passage of an animal) replace a necessary node, the data packet will be lost and will not reach to destination. Thus, in dissertation is tried to consider the other issue, namely protection of mobility. The mobile node can be a usual or a sink node, which is considered by cases. It should be known, that if a node is lost because of mobility, network must construct the routing map again, which is a great disaster in term of decline in the network lifetime, because the entire primary task should be taken place again to recognize the sink situation, if a node changes its place illusion. It makes his closest neighbor as middle node, which reaches the information to the cluster head, because it is a sub-set of the cluster. Also the middle node updates its information by that time period. As soon as a node is replaced itself, it sends information to the middle node locally. This causes stability of routes, prevention of information lose and re-discovery of the route.

Thus, another routing algorithm in WSNs is developed, which also decreases energy consumption of sensor nodes and at the same time improves mobility problems, such as packet loss or delivery rate in the network, network lifetime and so on.

In Chapter 3 the development of software package and simulation environment for estimation of parameters, as well as the main results are presented.

The building of WSN testbed and running real experiments on it is difficult and costly. Moreover, running real experiments are always time consuming. WSN simulation is important for its development as protocols, schemes and new ideas can be evaluated in a very large scale. Simulation is essential for studying WSNs and is the common way to test new applications and protocols in the field.

In §3.1 are researched the metrics and limitations of existing simulators for WSNs and the energy system and simulation scenarios are presented.

There are lots of simulation tools which are used in WSNs. Main of those tools are NS-2, TOSSIM, EmStar, OMNeT++, J-Sim, ATEMU, Avrora and so on. Also for WSNs simulation is used MATLAB. By comparison of WSN simulators metrics and limitations, it can be concluded, that the implementation of WSN for the objectives of dissertation is preferable to do by NS-2. The reasons are that NS-2 is open source, which saves the cost of simulation. It allows implementing a WSN with lot of number of sensor nodes and contains flexible models for energy-constrained wireless ad hoc networks. Also there is a huge quantity of online documentation for NS-2. Another reason to use NS-2 is that for the previous methods the simulations for energy consumption evaluation are also done by NS-2.

Before consideration of simulation details, we deal with definition of the energy system model. We have assumed a system including sensor N distributed in an environment. Equally, a sink node has been located in a distance from the sensor environment. The entire sensors are uniform with a unique. The sensors are not equipped with GPS; they are able to regulate their sending power as well as recognize the distance based on the energy of received signal. Model of the sending energy for "l" bit data is based on LEACH. The received energy does not follow this model. It means that if the distance between sender to receiver (d) is more than d0 (reference distance), it is used the multiple routes model (with route wasting impact of α), else the open space model (with route wasting impact of 2) is using (Fig. 4).

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d)$$
$$= \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \quad (2)$$

Where E_{elect} is the necessary energy to activate the electronic orbit and ε_{mp} and ε_f are the energies of power activating reinforcement for the two situations of multiple route and open space.

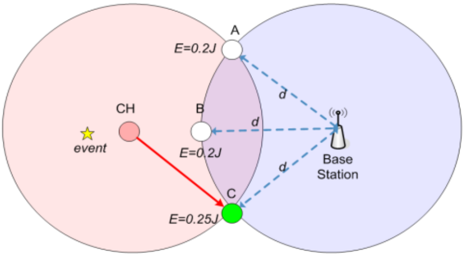

Fig. 4 Selection of path based on amount of energy

In the simulation scenario for the first developed algorithm are used 250 nodes which are distributed throughout 160 * 160 square meters. For the second developed algorithm are used 400 nodes in the 400×400 m2 and packets 4000 bit/per, with regard to the point that sending data has been assumed in standard IEEE 802.11b. As was mentioned, in NS-2 is used C++ for creation and controlling of simulation model. Thus, for implementation of simulation scenarios appropriate C++ codes are written and a software package is made.

In §3.2 are presented the main results of simulations. The main tasks of this dissertation are the decreasing of energy consumption in WSNs and hence the increasing of network lifetime. Hence, in order to evaluate the efficiency of developed algorithms, we have compared the developed algorithms with Two-Phase-Pull (TPP) and Passive Clustering Directed-Diffusion (PCDD) algorithms, which are the best algorithms in low energy consumption perspectives.

The comparison graphs of the developed first algorithm with PCDD and TPP for different parameters are presented on Figures 5-9.

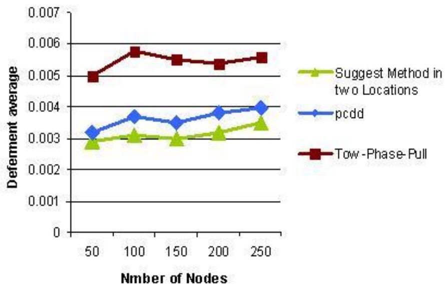

Fig. 5 Comparison of delay in 2 locations

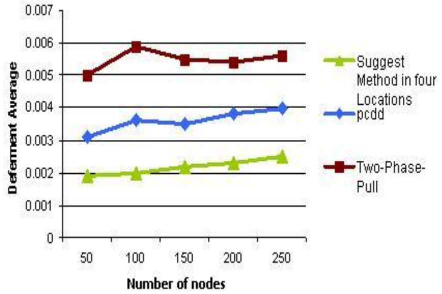

Fig. 6 Comparison of delay in 4 locations

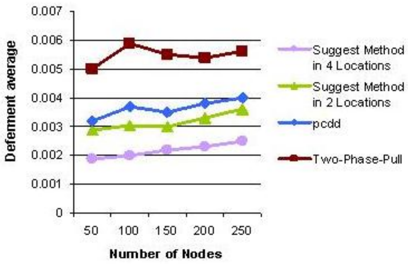

Fig. 7 Comparison of the delay rate

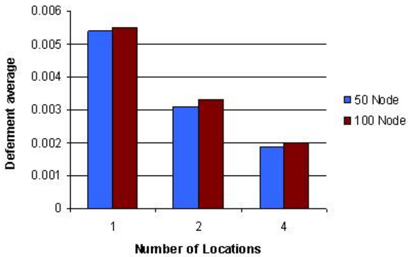

Fig. 8 Comparison of the average delay consumption in one, two, and four locations

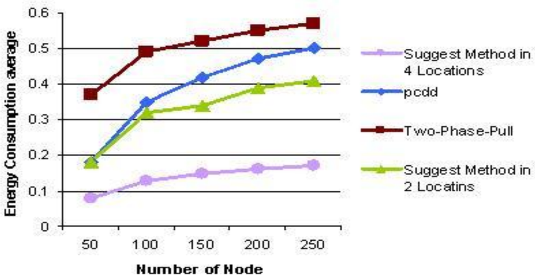

Fig. 9 Comparison of the average energy consumption

According to graphs can be concluded that for both two and four locations the delay is lower than for PCDD and TPP. When the number of locations increases, the delay of network decreases. In case the number of regions rises, sink finds the source sooner than for TPP and PCDD. Hence, as the delay of network decreases, the delivery rate increases and for suggested algorithm it is better than for PCDD and TPP, which is illustrated on Fig. 7. Although previous methods had fluctuations while our algorithm rises slightly.

As the suggested algorithm decreases average energy consumption in WSN in comparison with TPP and PCDD algorithms, the lifetime of network increases. But the main problem of this algorithm is the delivery rate, and for some cases the event delivery faces 50% loss. This problem is solved in the second algorithm by using moveable sink.

Before presentation of the results for the developed second algorithm we will analyze the effect of mobility on event delivery and network traffic volume. The effect of expedition rate changes will be analyzed as well.

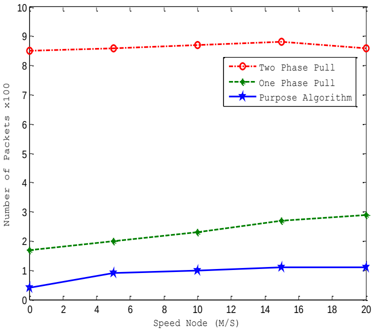

Fig. 10 The effect of mobility on traffic load bar

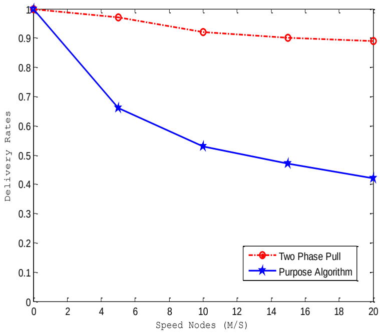

Fig. 11 The effect of mobility on delivery rate

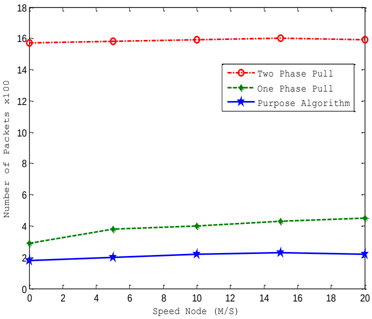

Fig. 12 The amount of event delivery

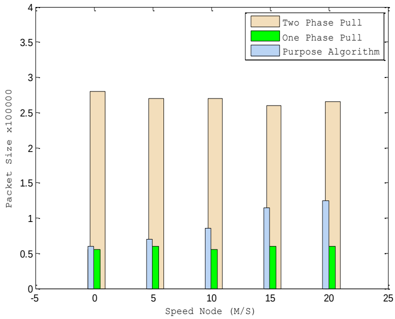

Fig. The overhead rate comparison in proposed algorithm and basic propagations

Fig. 10 shows the effect of mobility on network traffic capacity and in Fig. 11 shows event delivery rate for a 300 node network. The developed algorithm is compared with One Phase and Two Phase Pull Directed-Diffusion algorithms. As can be seen on graphs, the proposed algorithm can maintain the event delivery rate to an acceptable rate than basic propagation. Since the event delivery rate in basic propagation reduces in different speed due to the movement of the sink, the result is satisfactory.

According to Fig. 12, in response to the changes in speed the data delivery rate in basic propagation finally reduces to above 40%. If a user can tolerate a 50% loss in event sensor, the basic propagation can be used for sink with low speed. By increasing exploratory data rate, event delivery rate and the overhead are increased.

Fig. 13 shows the capacity of overhead controlling packets for the basic propagation model, One Phase Pull and the proposed algorithm in case of different speeds. The random movement in a network with 300 nodes is applied and analyzed.

Now we can analyze the comparison of our developed second algorithm, which is named EECB (Energy Efficient Credit Base), with TPP and PCDD algorithms.

The comparison graphs of the developed second algorithm with PCDD and TPP for different parameters are presented on Figures 14-17.

Here we talk about end to end delay, which is the time between packet complete sending and receiving, in other words, end to end delay is the time when a packet exports from a node and traverses into network until will be received by another node. This parameter depends on several factors such as: noise of environment, traffic load bar and etc. On Fig. 14 is presented the average delay in network in case of using TPP, PCDD and EECB algorithms by clustering and using of selection function and the distance parameter in function selection. As can be seen, the delay for EECB is lower than for TPP and PCDD. In the TPP and PCDD algorithms the process of routing map finding is started only from the sink to sources, but in EECB the routing map finding starts both from sink to source and from source to sink. Therefore, the delay for EECB is lower than for TPP and PCDD algorithms. Also in Fig. 14 is shown that with increasing the number of nodes, the amount of delay is raised but with this increasing, we can see that EECB is better than other previous methods. In case of increasing the number of nodes the delay for all algorithms grows, but for EECB it grows more slowly than for TPP and EECB.

The delivery rate is the percentage of received packets from sent all packets. It is calculated by the formula (3).

$$\text{Delivery rate} = \frac{\textit{Number of incoming packet}}{\textit{Total number of packets}} \times 100 \qquad (3)$$

On Fig. 15 is shown the comparison of delivery rate in case of different methods. With increasing of the number of nodes delivery rate decreases, but for EECB it decreases more slowly than for TPP and PCDD. This is the result of removing flooding propagation and controlling of traffic load bar and overhead in EECB. PCDD shows better results than TPP because of flooding decreasing, but the result for EECB is better because of using clustering and selection function.

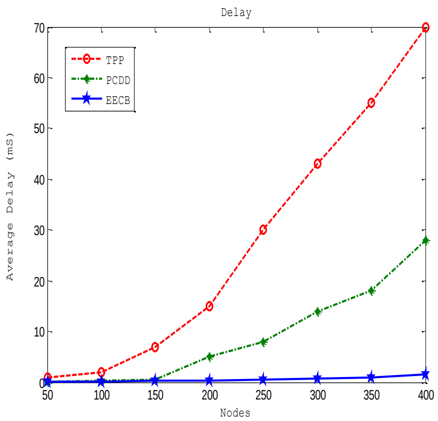

Fig. 14 Comparison of average delay

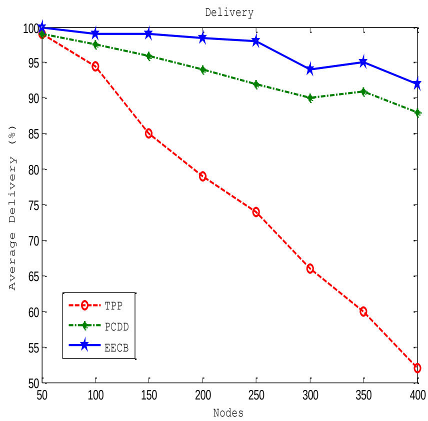

Fig. 15 Comparison of average delivery

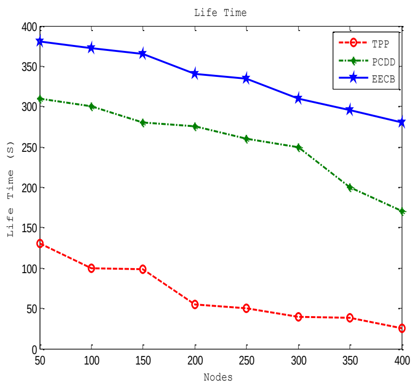

Fig. 16 Comparison of lifetime

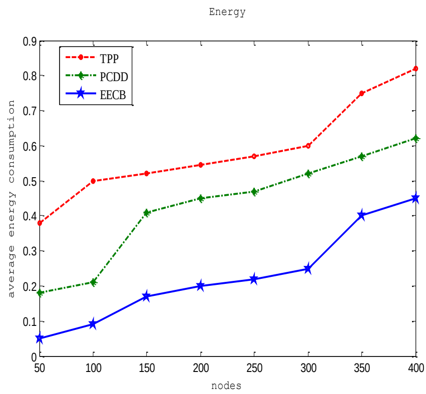

Fig. 17 Comparison of average energy consumption

Lifetime has many definitions but in this thesis we have used the definition that the lifetime is the time when 10% of network nodes from total number of nodes remained "alive". In the Fig. 16 is presented the rate of lifetime. As can be seen, the lifetime for EECB is better than for TPP and PCDD, which is the result of removing flooding propagation and decreasing traffic load bar in EECB. The lifetime for PCDD because of using decreasing of flooding is better than for TPP. But in EECB is used clustering and selection function, which reduce the energy consumption and as a result increases network lifetime, as the lifetime is directly related to energy consumption. The comparison graph of average energy consumption is shown on Fig. 17, and for EECB it is lower than for TPP and PCDD.

THE MAIN RESULTS OF THESIS

1. A new routing algorithm is developed which is based on Directed-Diffusion.[2,3,5]
2. Another routing algorithm (EECB) is developed, which is the improved version of the developed first algorithm. It improves mobility problems, such as packet loss or delivery rate in the network, network lifetime and so on.[7]
3. There are several simulation tools which are used for research of WSNs. According to research results NS-2 simulator is chosen as an environment for simulations of developed algorithms, Energy system model is defined and for each algorithm are implemented simulation scenarios in NS-2. [3, 4 ,5, 6]
4. The developed first algorithm decreases the average energy consumption in network from 20 to 200% in comparison with PCDD algorithm, and 45-420% in comparison with TPP algorithm depends on the number of locations and the number of nodes. At the same time it decreases the average delay from 15 to 65% in comparison with PCDD, and from 40 to 260% in comparison with TPP, again depends on the number of locations and nodes. One of the problems of this algorithm is the delivery rate, and for some cases the event delivery faces 50% loss as the sink mobility is not supported on this algorithm. [1, 2, 3, 4]
5. EECB algorithm decreases the average delay in network from 1 to 14 times in comparison with PCDD algorithm, and from 1 to 20 times in comparison with TPP algorithm, depends on the number of nodes. At the same time it improves the network lifetime from 1.2 to 2 times in comparison with PCDD, and from 3 to 11 times in comparison with TPP, again depends on the number of nodes. [7, 2]
6. In EECB algorithm the sink mobility is supported and as a result it improves the delivery rate of packets. In EECB the delivery rate is 2.5-4.5% better than for PCDD and 4-75% better than for TPP.[7]

LIST OF PUBLICATIONS

1. Mirnabibaboli M., Hakimi Z.. The Energy Balancing Algorithm in Routing of WSNs - CEIC 2009, The 2nd National Conference on Computer/Electrical and IT Engineering (CEIC'09), SAMA, Hamedan, Iran, 2009, pp. 498-503
2. Mirnabibaboli M.. Improving Directed Diffusion in order to Increasing Network Lifetime in the WSNs- The 4th Conference on New Technologies in Science, Engineering National Conference of New Technical Engineering, Mashhad, Iran, 2010, pp. 138-150
3. Mirnabibaboli M., Mirfattahi M., Markosyan M.. Improving the Directed Diffusion in Order to Reduce the Average of Energy Consumption in Wireless Sensor Networks - SENSORCOMM 2011, The Fifth International Conference on Sensor Technologies and Applications, France, 2011, pp. 223-228
4. Miresmaeil M., Mottaghi A., Yousefli A.. The Diffusion of Two Phase Pull Rumors (TPPR) in order to Decreasing Average Energy Consumption in Routing of Wireless Sensor Networks - CEIT 2011, The 3rd National Conference on Computer Engineering and Information Technology, SAMA, Hamedan, Iran, 2011, pp. 122-128
5. Mirnabibaboli M., The porpuse of new algorithm in order to Electronic Health by Wireless Sensor Network - The First International Scientific-Research Conference of Iranian, Computer Scince and IT, Yerevan, 2011, pp. 206-223
6. Mirnabibaboli M., Markosyan M., Hejr H.. Supporting of Mobility by Cooperation Nodes in the Wireless Sensor Network Routing - Information Technology: New Generations (ITNG), 2013 Tenth International Conference, Moscow, Las Vegas, USA, 2013, pp. 531-537
7. Mirnabibaboli M.. Introduction of a Moveable Sink Node in order To Increase Network Lifetime in Routing of Wireless Sensor Networks - Mathematical Problems of Computer Science 40, Yerevan, Armenia, 2013.

ԱՆԼԱՐ ՍԵՆՍՈՐԱՅԻՆ ՑԱՆՑԵՐՈՒՄ ՑԱՆՑԻ ԿՅԱՆՔԻ ՏԵՎՈՂՈՒԹՅԱՆ ԵՎ ՇԱՐԺՈՒՆԱԿՈՒԹՅԱՆ ՍՊԱՍԱՐԿՄԱՆ ԲԱՐԵԼԱՎՈՒՄ ԱՐԴՅՈՒՆԱՎԵՏ ԵՐԹՈՒՂԱՎՈՐՄԱՆ ԿԻՐԱՌՄԱՄԲ

ԱՄՓՈՓՈՒՄ

Ատենախոսության նպատակն է անլար սենսորային ցանցերի (ԱՍՑ) ֆունկցիոնալության մեխանիզմների և ալգորիթմների հետազոտումը և ԱՍՑ-ի կյանքի տևողության մեծացման տարբերակների որոնումը: Նշված նպատակին հասնելու համար ձևակերպվել և լուծվել են հետևյալ խնդիրները՝

- Սենսորային ցանցերի մշակման համար կատարված հետազոտությունների արդյունքների վերլուծում այն հիմնական կետերը գտնելու համար, որոնք ազդում են ԱՍՑ-ում հանգույցների և ցանցի կյանքի տևողության վրա:
- Գոյություն ունեցող երթուղավորման ալգորիթմների հետազոտում և նոր ալգորիթմի մշակում, որը նվազեցնում է սենսորային հանգույցների աշխատանքի ակտիվ փուլը՝ էներգիայի սպառումը նվազեցնոլու նպատակով:
- ԱՍՑ-ի կյանքի տևողության մեծացման նպատակով նոր մեթոդի մշակում, որը հիմնված է տրաֆիկի համաչափ բաշխման, շարժունակության սպասարկման և կլաստերավորման միջոցով հանգույցների համագործակցության ապահովման վրա:
- Առաջարկվող ալգորիթմների արդյունավետության գնահատում ԱՍՑ-ի վիրտուալ մոդելի կիրառմամբ:

Ատենախոսությունում ստացվել են հետևյալ հիմնական արդյունքները՝

1. Մշակվել է նոր երթուղավորման ալգորիթմ, որը հիմնված է Ուղղորդված-Դիֆուզիայի ալգորիթմի վրա:
2. Մշակվել է մեկ այլ երթուղավորման ալգորիթմ՝ «EECB», որը մշակված առաջին ալգորիթմի կատարելագործված տեսակն է: Այն լուծում է շարժունակության խնդիրները, ինչպիսին են ցանցում փաթեթների կորուստը, առաքման արագությունը, ցանցի կյանքի տևողությունը:

3. Մշակված ալգորիթմների համար ներդրվել են էներգիայի մոդելներ և սահմանվել են սիմուլյացիայի սցենարներ: Սիմուլյացիայի սցենարների իրագործման համար մշակվել է ծրագրային փաթեթ «C++»-ի և «NS-2» սիմուլյատորի կիրառմամբ:
4. Մշակված առաջին ալգորիթմը նվազեցնում է ցանցում էներգիայի սպառման միջին քանակությունը 20-200%՝ համեմատած «PCDD» ալգորիթմի հետ, և 45-420%՝ համեմատած «TPP» ալգորիթմի հետ՝ կախված հանգույցների քանակից: Միաժամանակ այն նվազեցնում է ցանցում միջին հապաղումը 15-65%՝ համեմատած «PCDD» ալգորիթմի հետ, և 40-260%՝ համեմատած «TPP» ալգորիթմի հետ՝ դարձյալ կախված հանգույցների քանակից: Այս ալգորիթմի գլխավոր թերություններից է առաքման կորուստի մեծ տոկոսը, այսպես, որոշ դեպքերում իրադարձության առաքումը կարող է ունենալ 50% կորուստ, քանի որ այս ալգորիթմում հաշվի չի առնվում ստացող հանգույցի շարժունակությունը:
5. «EECB» ալգորիթմը նվազեցնում է ցանցում միջին հապաղումը 1-14 անգամ՝ համեմատած «PCDD» ալգորիթմի հետ, և 1-20 անգամ՝ համեմատած «TPP» ալգորիթմի հետ՝ կախված հանգույցների քանակից: Միաժամանակ այն բարելավում է ցանցի կյանքի տևողությունը 1.2-2 անգամ՝ համեմատած «PCDD» ալգորիթմի հետ, և 3-11 անգամ՝ համեմատած «TPP» ալգորիթմի հետ՝ դարձյալ կախված հանգույցների քանակից:
6. «EECB» ալգորիթմում հաշվի է առնված ստացող հանգույցի շարժունակությունը, որի արդյունքում փաթեթների առաքման կորուստը նվազում է: «EECB»-ում առաքման կորուստը 2.5-4.5%-ով ավելի փոքր է քան «PCDD»-ի դեպքում, 4-7.5%-ով ավելի փոքր է քան «TPP»-ի դեպքում:

УЛУЧШЕНИЕ ВРЕМЕНИ ЖИЗНИ СЕТИ И ПОДДЕРЖКИ МОБИЛЬНОСТИ ЗА СЧЕТ ИСПОЛЬЗОВАНИЯ ЭФФЕКТИВНОЙ МАРШРУТИЗАЦИИ В БЕСПРОВОДНЫХ СЕНСОРНЫХ СЕТЯХ

АННОТАЦИЯ

Целью работы является исследование механизмов и алгоритмов функциональности беспроводных сенсорных сетей (БСС) и нахождения путей для увеличения времени жизни БСС. Для достижения этой цели сформулированы и решены следующие задачи:

- Анализ и обобщение результатов исследований в разработке и эксплуатации сенсорных сетей для выявления основных факторов, которые оказывают влияние на срок службы сенсорных узлов и БСС в целом.
- Анализ существующих алгоритмов и разработка нового алгоритма маршрутизации, который уменьшает активное время работы сенсорных узлов, с целью уменьшить потребление энергии.
- Разработка метода, который увеличит время жизни сети в БСС с помощью балансирования трафика в сети, поддержки мобильности и сотрудничества узлов путем кластерирования.
- Оценка эффективности предложенных алгоритмов на имитационной модели сети.

Вышеуказанные задачи были решены с помощью новых алгоритмов маршрутизации и разработкой соответственных программных пакетов.

В диссертации получены следующие основные результаты:

1. Разработан новый алгоритм маршрутизации, который основан на алгоритме Направленной-Диффузии.
2. Разработан другой алгоритм маршрутизации: „EECB“, который является улучшенной версией первого алгоритма. В этом алгоритме решаются проблемы мобильности, такие как потеря пакетов, скорость доставки, время жизни сети.
3. Для разработанных алгоритмов были внедрены модели энергии и сформулированы сценарии симуляций. Для реализации сценариев

симуляций разработан программный пакет на „C++“ с использованием „NS-2“ симулятора.

4. Разработанный первый алгоритм уменьшает средний расход энергии в сети на 20-200% по сравнению с „PCDD“ алгоритмом, и на 45-420% по сравнению с „TPP“ алгоритмом, в зависимости от количества узлов и локаций. Одновременно он уменьшает среднюю задержку в сети на 15-65% по сравнению с „PCDD“ алгоритмом, и на 40-260% по сравнению с „TPP“, снова в зависимости от количества узлов. Один из главных недостатков этого алгоритма является большой процент потери пакетов. Так, в некоторых случаях рассылка события может иметь потерю в 50%, так как в этом алгоритме не рассчитывается мобильность получающего узла.
5. “EECB” алгоритм уменьшает среднюю задержку в сети на 1-14 раз по сравнению с „PCDD“ алгоритмом, и на 1-20 раз по сравнению с „TPP“ алгоритмом, в зависимости от количества узлов. Одновременно он улучшает время жизни сети на 1.2-2 раз по сравнению с „PCDD“ алгоритмом, и на 3-11 раз по сравнению с „TPP“, и снова в зависимости от количества узлов.
6. В алгоритме “EECB” рассчитана мобильность получающего узла, в результате чего процент потери пакетов уменьшается. В „EECB“ процент потери на 2.5-4.5% меньше чем в „PCDD“, и на 4-7.5% меньше чем в „TPP“.