TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 12, No. 9, September 2014, pp. 6868 ~ 6873
DOI: 10.11591/telkomnika.v12i9.4863

Dynamic Optimization Algorithm of Wireless Sensor Network

Yong Ding
Zhejiang Economic & Trade Polytechnic, Zhejiang, 310018, China
E-mail: ricky.ding@163.com

Abstract

This paper analyzes the existing real network and modeled dynamic optimization of wireless sensor network; it realizes the integration of node deployment and selection, and sets the optimization parameters. The simulation experiment shows the proposed algorithm with better optimization fitness value and less evolutionary generation, it balanced the wireless sensor network node energy consumption, improved network coverage and reduced network energy consumption and prolong the network lifetime.

Keywords*: wireless sensor network, dynamic optimization, node selection*

1. Introduction

A wireless sensor network (WSN) [1-3] consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. The wireless sensor network is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node [4-6] has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the wireless sensor network can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

Network node layout optimization problem can be seen in the sensor network [7, 8] nodes generally limited energy resources such case, by placing the sensor nodes and routing options and other means, and ultimately enable a variety of wireless sensor networks to optimize resource allocation, and thus perception, monitoring, sensing, communications and other services to improve the quality. According to the node deployment cover classification, area coverage, point coverage and fence covered three methods. Network coverage optimization problem [9, 10] can be seen in the sensor network node energy and other resources generally limited cases, by placing the sensor nodes and routing options and other means, and ultimately enable a variety of wireless sensor network to optimize resource allocation, and thus make sense, monitoring, sensing, communications, and other quality of service improved. How Depending on the application environment needs, the network has become a different coverage control in wireless sensor networks a basic but urgent problem.

Technological advancements in wireless communications and embedded systems have led to the proliferation of wireless sensor network applications, each with varying application

Received November 20, 2013; Revised June 27, 2014; Accepted July 16, 2014

requirements (i.e., lifetime, throughput, reliability, etc.). Sensor node tunable parameters enable wireless sensor network designers to specialize/tune a sensor node to meet application requirements, but however, parameter tuning is a challenging process that requires designer expertise to consider sensor node complexities and changing environmental stimuli. Munir [11] developed lightweight, online optimization algorithms for sensor node parameter tuning, which enables dynamic optimizations to meet application requirements and adapt to changing environmental stimuli.

Okazaki [12] introduced Ant-based Dynamic Hop Optimization Protocol (ADHOP), a self-configuring reactive routing protocol for dynamic Wireless Sensor Networks (WSNs). This approach is inspired on HOPNET, a multi-hop and self-configuring hybrid routing protocol based on Ant Colony Optimization (ACO) for Mobile Ad Hoc Networks (MANETs). The ADHOP design considers several restrictions since WSNs tend to be more stringent than MANETs in respect to resource availability, such as energy consumption, processing power, memory, and bandwidth. There are many challenges in designing routing protocols for WSNs, and topology change is a factor that affects the network lifetime of WSNs. And with the robustness of routing protocols for MANETs, dealing with dynamic topologies becomes a less arduous task. Moreover, ADHOP acting together with ACO allows us to deal with the restrictions of WSNs and yet improve the route discovery and the route maintenance through pheromone.

In order to better solve the coverage optimization problem, this paper analyzes the existing real network and modeled dynamic optimization of wireless sensor network; it realizes the integration of node deployment and selection, and sets the optimization parameters.

Dynamic optimization algorithm of wireless sensor network is given in Section 2. Section 3 is experiment and evaluation.

2. Dynamic Optimization Algorithm of Wireless Sensor Network

Wireless sensor network is composed of a large number of wireless sensor nodes. A node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. A mote is a node but a node is not always a mote. Physical sensor nodes have been able to increase their capability in conjunction with Moore's Law. The chip footprint contains more complex and lower powered microcontrollers. Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, and possibly secondary communication interface.

Each node has the same range communication range r and C. w_i is assumed that the wireless sensor nodes position x_i, y_i, the distance between the wireless sensor nodes of w_i is:

$$d\left(w_i, P\right) = \sqrt{\left(x_i - x\right)^2 + \left(y_i - y\right)^2}$$

In binary measurement model, the wireless sensor node w_i on target detection probability is:

$$c_{xy}\left(w_i\right) = \begin{cases} 1 & d\left(w_i, P\right) < r \\ 0 & Other \end{cases}$$

In fact, monitoring of environmental and noise interference, the wireless sensor nodes measuring the probability of the target should be presented certain characteristics of the probability distribution. The measurement model is:

$$c_{xy}\left(w_i\right) = \begin{cases} 0 & r + r_e \le d\left(w_i, P\right) \\ e^{\left(-\sim_{1}{}^{a}{}_{1}\right)} & r - r_e < d\left(w_i, P\right) < r + r_e \\ 1 & d\left(w_i, P\right) \le r - r_e \end{cases}$$

Where, $r_e(0< r_e<r)$ is a wireless sensor node measurement reliability parameters. $\sim_1$ $\sim_2$ $_1$ $_2$ are measurement of characteristic parameters of wireless sensor node. $^{a}{}_1$ $^{a}{}_2$ as input parameter, which are defined as:

$$^{a}{}_1 = r_e - r + d\left(w_i, P\right)$$
$$^{a}{}_2 = r_e + r - d\left(w_i, P\right)$$

When $r_e \approx 0$, the probability of detection model is similar to the binary model. When $r_e > 0$, the probability of target detection of wireless sensor node may be less than 1, which means that the measurement process requires the use of a plurality of wireless sensor nodes simultaneously measure the target, in order to increase the probability of the target measurement, their joint measuring probability is:

$$c_{x,y}\left(w_{ov}\right) = 1 - \prod_{w_i \in w_{ov}} \left(1 - c_{x,y}\left(w_i\right)\right)$$

Where, w_{ov} is wireless sensor nodes set of measurement target. Let C_{th} for wireless sensor nodes measuring probability threshold, the target effective measurement conditions is:

$$\min_{x,y}\left\{c_{x,y}\left(w_i, w_j\right)\right\} \le C_{th}$$

Suppose the network consists of N sensor nodes. The nodes state vector is W, which, by the state of node i is w_i , when the node i is in working condition, w_i = 1; On the contrary, in a dormant state, w_i = 0. Wireless sensor node to be selected in each selected state vector solution can be W=[$w_1, w_2, \ldots w_N$] expressed.

The energy consumption rate for sensors in a wireless sensor network varies greatly based on the protocols the sensors use for communications. Minimizing the energy consumption of a wireless sensor network application is crucial for effective realization of the intended application in terms of cost, lifetime, and functionality. However, the minimizing task is hardly possible as no overall energy cost function is available for optimization. Optimizing a specific component of the total energy cost does not help in reducing the total energy cost as this reduction may be negated by an increase in the energy consumption of other components of the application.Network energy consumption is an important factor to determine the network node selection.

In order to adapt to changes in the measurement environment, wireless sensor networks should be able to cycle dynamically using wireless sensor network node selection optimization strategy to analyze the current state of the optimal node options. Assuming that the monitoring period is T, node i in working condition, in which period the relative energy consumption indicators is:

$$e_i = \frac{e_i^c}{e_i^i}$$

Where, e_i^c is actual energy consumption of node i in a monitoring period, e_i^i is initial energy of node i. Because power consumption is small when the node is in sleep state, so assuming dormant energy consumption of nodes to 0. Then the entire wireless sensor networks total energy is:

$$E = \sum_{i=1}^{N} e_i w_i$$

In addition to the total energy consumption of wireless sensor network, the network lifetime is also used to evaluate the results of node selection and optimization as an important indicator. Maximizing the network lifetime means maximizing the number of successful transmissions, by routing the network traffic efficiently, until the first node failure due to battery depletion. The definition of the network lifetime as the time of the first node failure is a meaningful measure in the sense that a single node failure can make the network become partitioned and further services to be interrupted. Assuming that the initial energy of all wireless sensor nodes is equal, the remaining energy is gradually reduced in the monitoring process. The current time remaining energy q_i of node i is:

$$\text{—}_i = q_i \Big/ \sum_{i=1}^{N} q_i$$

In order to balance energy consumption of each node, using $³_i$ fix monitor energy consumption of node i,

$$e_i^{'} = e_i \big/ \overline{\ }_i = \frac{e_i}{q_i} \sum_{i=1}^{N} q_i$$

It can avoid the depletion of energy causes the network node failure. Which can be obtained network energy consumption evaluation $¤_E$ is:

$$¤_E = \sum_{i=1}^{N} e_i^{'} w_i = \sum_{i=1}^{N} q_i \sum_{i=1}^{N} \frac{e_i w_i}{q_i}$$

Wireless sensor network coverage it is important for a sensor network to maintain connectivity. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. If there is no available route from a sensor node to the data sink then the data collected by that node can not be processed. Each node has a communication range which defines the area in which another node can be located in order to receive data. This is separate from the sensing range which defines the area a node can observe. In order to overcome the low initial network coverage and redundancy issues such as energy consumption, while using node deployment optimization and selection optimization method to create overall balance indicator ϕ to determine the dynamic optimization program:

$$¤ = \left\{ ¤_C, ¤_E \right\}$$

Where, $¤_C$ is coverage for wireless sensor networks. Establish the following model to facilitate optimization algorithm design.

$$¤ = \begin{cases} \max\left(¤_C\right) \\ \max\left(\dfrac{1}{¤_E}\right) \end{cases}$$

In order to evaluate the overall performance of the related algorithm, set the parameters

$$¤_{opt} = \max\left(¤\right) = \max\left(\frac{\sim ¤_C}{¤_E}\right)$$

Within each monitoring period $¤_E$ is evaluted by the total energy consumption and the network lifetime, the calculation formula as follows. Monitoring of energy consumption e_i^M depends on the wireless sensor node monitoring power P_i^M and monitoring cycle T,

$$e_i^M = p_i^M T$$

Set the standard frequency f_0, the wireless sensor nodes compute power p_0^C, standard computing tasks execution time t_0^C. The operating frequency of Node i is f_i,

$$t_i^C = \frac{f_0}{f_i} t_0^C$$

Calculating power and operating frequency f_i of node i is proportional to the square,

$$p_i^C = \left(\frac{f_i}{f_0} \right)^2 p_0^C$$

Final energy consumption is calculated:

$$e_i^C = p_i^C t_i^C = \frac{f_i}{f_0} p_0^C t_0^C$$

Set data transmission time is t_0^T; When the critical distance is d_0 , the minimum transmit power is p_0^T , the actual transmit power p_i^T and the distance d_i proportional to the square,

$$p_i^T = \frac{(4\pi)^2}{G_t G_r \lambda^2} \frac{d_i^2}{d_0^2} p_0^T$$

Where, G_t, G_r, λ and β denote transmit gain, receive gain, carrier wavelength and loss factors. The transport energy consumption

$$e_i^T = p_i^T t_0^T = \frac{(4\pi)^2 \quad p_0^T t_0^T}{G_t G_r \lambda^2} \frac{d_i^2}{d_0^2}$$

In summary, the actual energy consumption of single node i in a monitoring period is:

$$e_i^c = p_i^M T + \frac{f_i}{f_0} p_0^C t_0^C + \frac{(4\pi)^2 \quad p_0^T t_0^T}{G_t G_r \lambda^2} \frac{d_i^2}{d_0^2}$$

3. Experiment and Evaluation

Selection optimization strategy dynamic performance is verified by simulation wireless sensor network node, simulation environment settings are as follows: wireless sensor network monitoring area is 150 * 150m, total wireless nodes are 165, each wireless sensor node sensing radius of 7m, communication radius C = 3r = 24m, measurement reliability parameters re=0.5r=4m. Probabilistic measurement model parameters α_1=1, ~$_2$=0 $_1$=1 $_2$=0.5 c_{th}=0.7, the wireless node performance parameters as follows:

Table 1. Parameters of Wireless Nodes

G_t	G_r		λ	p_0^T	d_0	f_0	p_0^C
2	2	0.74	0.15m	25mW	12m	25MHz	25mW

GA population size is set to 150, the maximum evolution generation is 200, network initialization, 165 wireless sensor nodes are randomly arranged in the monitoring area.

From the results of Table 2, the coverage is increased, and the single-cycle energy consumption is reduced of the proposed algorithm.

Table 2. Network Comparison of Initial and Optimization

Type	No optimizat	The proposed algorit
Coverage	91.3%	94.7%
Single-cycle energy consumptior	19.8	12.6

4. Conclusion

This study analyzed the existing real network and modeled dynamic optimization of wireless sensor network. The simulation experiment shows the proposed algorithm with better optimization fitness value and less evolutionary generation, it balanced the wireless sensor network node energy consumption, improved network coverage and reduced network energy consumption and prolong the network lifetime.

Acknowledgements

The article was supported by the Social Science Major Program of Zhejiang (Grant number: 20120973).

References

[1] A Munir, A Gordon-Ross. *An MDP-based Application Oriented Optimal Policy for Wireless Sensor Networks*. Proc. of IEEE/ACM CODES+ISSS, October 2009.

[2] R Verma. Automated Application Specific Sensor Network Node Tuning for Non-Expert Application Developers. M.S. Thesis, Department of Electrical and Computer Engineering, University of Arizona, 2008.

[3] M Huber, A Kuwertz, F Sawo, U Hanebeck. *Distributed Greedy Sensor Scheduling for Model-based Reconstruction of Space-Time Continuous Physical Phenomenon*. Proc. of IEEE FUSION. 2009.

[4] H Hamed, A El-Atawy, AS Ehab. On Dynamic Optimization of Packet Matching in High-Speed Firewalls. *IEEE Journal on Selected Areas in Communications*. 2006; 24(10): 1817-1830.

[5] X Wang, S Wang. Collaborative signal processing for target tracking in distributed wireless sensor networks. *Journal of Parallel and Distributed Computing*. 2007; 67: 501-515.

[6] Jie Li , Tianyou Chai, Lisheng Fan, Li Pan. *K-covered wireless sensor network optimization.* 2010 3rd International Symposium on Systems and Control in Aeronautics and Astronautics (ISSCAA). 2010; 967 – 970.

[7] Slama I, Ghedira, Mohamed Chedly, Jouaber B, Afifi H. *Cluster based Wireless Sensor Networks' optimization under Energy Constraints*. 3rd International Conference on Intelligent Sensors, Sensor Networks and Information. 2007; 745 – 750.

[8] Hojjatoleslami S, Aghazarian V, Aliabadi A. DE Based Node Placement Optimization for Wireless Sensor Networks. 2011 3rd International Workshop on Intelligent Systems and Applications (ISA). 2011; 1 - 4.

[9] S Hojjatoleslami, V Aghazarian, M Dehghan, N Ghazanfari. *PSO based node placement optimization for wireless sensor networks.* Joint International Computer Science and Information Technology Conference (JICSIT). 2011.

[10] S Hussain, A Wasey Matin, O Islam. Genetic algorithm for hierarchical wireless sensor networks. *Journal of Networks*. 2007; 2(5): 87-97.

[11] Munir A, Gordon-Ross A, Lysecky S, Lysecky R. Online algorithms for wireless sensor networks dynamic optimization. IEEE Consumer Communications and Networking Conference (CCNC). 2012; 180 - 187.

[12] Okazaki AM, Frohlich AA. Ant-based Dynamic Hop Optimization Protocol: A routing algorithm for Mobile Wireless Sensor Networks. IEEE GLOBECOM Workshops (GC Wkshps). 2011; 1139-1143.