RESEARCH ARTICLE OPEN ACCESS

A Survey on Data Collection Protocols for Wireless Sensor Networks

Yongxian Jin

(College of Mathematics, Physics and Information Engineering, Zhejiang Normal University, Jinhua Zhejiang 321004, China)

----------**********----------

Abstract:

With the development of science and technology of the times, the wireless sensor network has been inextricably linked with people's lives, the traditional network has been insufficient to meet the needs of people in all aspects. This paper introduces the concept of wireless sensor networks, the basic structure and characteristics of wireless sensor networks, analyses the research status on wireless sensor networks and the problems to be solved, and finally expounds the research status on data collection protocols for wireless sensor networks, and puts forward prospects.

Keywords — **Wireless sensor networks, data collection, data fusion, routing protocol**

----------**********----------

1 INTRODUCTION

Wireless sensor network (WSN) is the product of the combination of micro-electromechanical system, computer, communication and sensor technology. It is also a comprehensive intelligent information system which integrates information acquisition, information transmission and information processing. It has broad application prospects [1,2]. In 2003, Technology Review of the United States[3] listed sensor network technology as the top ten technologies that will change human life in the future. It can be predicted that the wide application of wireless sensor networks is an inevitable trend, and its emergence will bring great changes to human beings.

2 THE BASIC STRUCTURE ,APPLICATIONS AND CHARACTERISTICS OF WIRELESS SENSOR NETWORKS

2.1 The basic structure of wireless sensor networks

Wireless sensor networks are composed of a large number of densely distributed sensor network nodes, which are usually scattered in the environment to be monitored, and have the functions of data collection and data transmission to the client (control center). In sensor networks, network nodes can be deployed by means of airplane spreading or manual placement. Nodes coordinate with each other through distributed algorithm, and form a wireless sensor network by self-organization without interference[4,5].

Fig. 1 shows the basic structure of a wireless sensor networks. There are mainly the following parts:

(1) Network users. It is responsible for collecting all kinds of information from the network, analyzing and processing it, and also can send all kinds of commands and operation instructions to the network.

(2) Transmission mode. Including Internet or communication satellite, it is the bridge and link between users and wireless sensor networks.

(3) Sink node. It is the convergence point of information transmission in wireless sensor networks, so it is also called Sink node. Sink nodes have enough energy and radio power to transmit information from nodes with limited energy in sensor networks to media or to transmit user instructions to ordinary nodes.

(4) Sensor network. It is the core part of the sensor network. In the sensing area, a large number of nodes self-organize the network, monitor and sense information, and send it to the Sink node, or accept operation commands from the Sink node to change their working status.

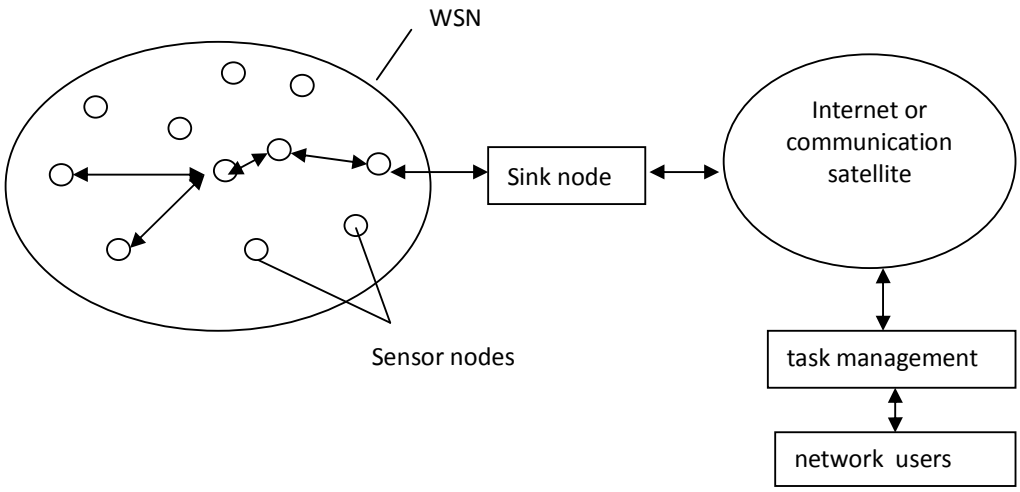

Fig. 1 Basic structure of Wireless Sensor Networks

2.2 The applications and characteristics of wireless sensor networks

As a new type of intelligent information acquisition system, wireless sensor network has a wide range of applications. In the civil field[6-9], sensor networks can be used in medical health, traffic surveillance and control, industrial production automation, ecological environment monitoring and protection, residential security monitoring, etc. In the military field[10], the network is mainly used in battlefield surveillance, battlefield reconnaissance, target location, identification, tracking and so on. Compared with traditional networks, wireless sensor networks have the following remarkable characteristics[11-13]:

(1) Limited resources. This is mainly manifested in the following aspects: 1) limited power supply. The battery energy of each node is limited and difficult to replenish or replace. 2) Communication energy is limited. It shows that the transmission distance and communication bandwidth are very limited. The wireless communication bandwidth of sensor nodes is usually only a few hundred Kbit/s rate, and natural factors such as environment and climate also affect the intensity and distance of transmission signals. 3) Limited storage and processing capacity. The low cost and low energy consumption of sensor nodes determine their small memory capacity and weak processing capacity.

(2) Dynamic topological structure. The main reasons for the change of sensor network topology are as follows: 1) The failure of sensor nodes is caused by the exhaustion of energy, etc. 2) The location of nodes changes or new nodes join. 3) Node energy-saving algorithms used in the network, such as node dormancy and routing optimization algorithm.

(3) Self-organization. This is due to the fact that in many applications, wireless sensor network nodes are usually scattered randomly in areas where people are not easy to reach or dangerous, the location of nodes can not be precisely set in advance; on the other hand is due to the topological dynamics of sensor networks. A self-organizing network can not only configure and manage the network automatically, but also form a multi-hop network that perceives and forwards data automatically, and can adapt to the dynamic changes of network topology.

3 RESEARCH STATUS AND CHALLENGES OF WIRELESS SENSOR NETWORKS

At present, a lot of research has been done on wireless sensor networks in the world. The most famous research institutions and achievements are: Georgia Institute of Technology in the United States, which studies the transmission

layer, network layer, data connection layer, physical layer and task management scheduling of wireless sensor networks. MIT studies data management and adaptive communication architecture for wireless sensor networks. The University of California, Berkeley, studied the architecture of sensor networks and secure communication protocols, operating systems and data management. Smart Dust, TinyOS and TinyDB were proposed and designed. The American Institute of Information Science studies scalable collaborative architecture and network service API in highly distributed and dynamically reconfigurable wireless sensor networks. Cornell University has put forward the idea that wireless sensor networks are regarded as distributed databases, published the way of data management and acquisition for continuous query of sensor networks, and developed Cougar, a database management system for wireless sensor networks based on embedded Linux. Harvard University has proposed the basic architecture of a network system consisting of multiple wireless sensor networks and applications, and implemented a prototype system HourGlass.

The application prospect of wireless sensor networks is very attractive. WSN is considered to be one of the most important technologies affecting human life in the future. This new technology provides a new way for people to obtain and process information. Because of the characteristics of WSN itself, there is a big difference between WSN and traditional network technology, which poses many new challenges to people. For example: (1) Cost problem. In a wireless sensor network, a large number of micro-sensors are needed, and their cost will restrict their development. (2) System energy supply. (3) Efficient structure of wireless sensor networks.

The most restrictive factor in the design of wireless sensor networks is the limited energy budget of sensor nodes when they work. Therefore, the first and most important challenge for WSN design is energy efficiency [14]. This requirement runs through all aspects of sensor node and network design.

4 RESEARCH STATUS OF DATA COLLECTION PROTOCOL FOR WSNS

Data collection is the basic function of wireless sensor networks and the basis of most applications. In the actual application process, due to the limited resources of sensor nodes, how to effectively collect data and maximize network lifetime is the main problem of wireless sensor network research, and also a hot issue of researchers. Data collection can be defined as the process of collecting data of interest to users in the monitoring area and transferring it to the sink node through cooperation among sensor nodes.

The core issue of data collection protocol in wireless sensor networks is routing protocol, which directly determines the performance of data collection protocol. Routing protocols should be designed for direct data collection services. Therefore, data collection and routing protocols in wireless sensor networks are essentially reciprocal. The research of routing protocols in wireless sensor networks is beginning with Flooding protocol and has been paid more and more attention. In flooding protocols, a node generates or receives data and broadcasts the data to all neighboring nodes. Packets do not stop propagating until they expire or reach their destination. However, the protocol has the following drawbacks[14,15]: implosion (nodes receive multiple identical data from neighboring nodes), overlapping (nodes receive similar data from multiple nodes in the same monitoring area successively), blind resource utilization (nodes broadcast data in any case regardless of their own resource constraints).

Since then, researchers have begun to study data collection and routing protocols, and have achieved some important research results [16-31]. Literature[18] studies how to reduce data transmission in multi-task shared sensor networks and how to reduce data transmission in the process of multi-object counting aggregation. Reference[19] proposes an energy-efficient data collection protocol based on geographic location information. This protocol combines the original geographic location routing protocol GeRaF with the MAC layer protocol S-MAC and the heuristic topology control protocol STEM of wireless sensor networks, and integrates routing, topology control and MAC into a single layer, which reduces the idle energy consumption of nodes and opens communication control. As a result, the delivery rate of network data transmission is significantly increased, multi-hop delay and energy consumption are greatly reduced, and the energy consumption of nodes is more balanced, thus prolonging the lifetime of the whole network. Document [20] focuses on data collection methods, including time-spatial correlation model of data, distributed data processing and collection methods, mobile node path optimization and multi-mobile node collaboration data collection.

In many sensor network applications, data collection needs to transmit a large amount of sensing data. A large amount of sensing data is transmitted over the network, which results in a large amount of communication overhead. Therefore, reducing the amount of data transmission can reduce the energy overhead and prolong the network life cycle. At present, many methods have been proposed to reduce data transmission. For example, sampling-based data collection methods, data compression-based data collection methods and data sharing-based data collection methods.

(1) Data collection method based on sampling. Reference[21] first sampled a small number of sensor node data to the fusion center, which selectively activated the nodes according to the estimated perception environment, thus

meeting certain error bounds. This dynamic sampling method can save energy cost effectively. In reference [22], an on-line algorithm is proposed to minimize the approximate ratio error with a given upper bound of energy overhead. This algorithm is based on region sampling, dividing the network into several non-overlapping regions, and calculating the approximate aggregation results to meet the preset energy budget. Reference [23] adopts Kalman filter-based estimation method to automatically and dynamically adjust sampling rate, so as to reduce transmission and improve estimation accuracy.

(2) Data collection method based on data compression. Reference[24] studies the effect of data compression operations on network performance. Reference[25] summarizes several methods of data compression. Reference[26] studies the effect of spatial correlation on data compression in sensor networks. Reference[27] proposes a distributed data compression method based on spatial correlation of data. Reference[28] studies unstructured data compression methods. Reference [29] studies data compression methods in sparse networks.

(3) Data collection method based on Multi-task data sharing. Multi-application shared sensor networks can improve the utilization of networks[30]. However, multi-task sharing of a sensor network can increase the computational and communication overhead of the network, thus reducing the lifecycle of the network. Reference [31] studies the problem of multi-task data sharing.

For wireless sensor networks, most of the nodes energy is consumed in communication, that is, data receiving and transmitting. Data collection in wireless sensor networks needs to be accomplished through the organic collaboration between nodes. Because sensor nodes are powered by batteries and have limited computing, communication and energy resources, an important or key problem to be solved in data collection is how to save energy to prolong the life cycle of wireless sensor networks. Considering that the communication cost is several orders of magnitude higher than the computation cost in wireless sensor networks[32], data fusion technology[33,34] is often used in data collection to minimize the total number of transmissions in sensor networks. Data fusion technology, that is, nodes use local processing capability to process data collected or received from other sensor nodes in the network, eliminate redundant information, and then transmit the processed data.

5 SOME NEW IDEAS FOR FUTURE RESEARCH WORK

WSNs still has a lot of challenges because of its limited resources, the variability of topological structure and so on. For a long time, they are all important indicators to improve WSNs, such as data reliability, network security, energy efficiency. However, the scalability and security in the existing protocols are not perfect enough. Many protocols rarely think about security. Therefore, security mechanisms of protocols need further improvement. In addition, it is also important to improve the adaptability of routing that can meet the needs of diverse applications. Aimed at the limitation of the routing protocols, we can consider cross-layer cooperation, for example, combining with a MAC layer protocol, which maybe achieve better results. To sum up, we need to make a further research and innovation for WSNs.

6 CONCLUSION

Wireless sensor network is a convenient new type of self-organizing network, which has been widely used in military, industrial, medical and other fields. It is a network composed of innumerable cheap micro-sensors. Due to the limited energy of sensor nodes and the vulnerability to interference from the external environment, the lifetime of the network can not be guaranteed, and the reliability of data transmission is greatly reduced. Therefore, it is very important to design an energy-efficient data transmission protocol or routing protocol.

REFERENCES :

[1] Sun Limin, Li Jianzhong, Chen Yu, Zhu Hongsong. Wireless Sensor Network. Beijing: Tsinghua University Press, 2005.

[2] Li Xiaowei, Xu Yongjun, Ren Fengyuan. Wireless Sensor Network Technology. Beijing: Beijing University of Technology Press, 2007.

[3] Ten emerging technologies that will change the world. Technology Review, 2003, 106(1):22-49. http://www.techreview.com/articles/ emerging0203.asp.

[4] Yan X Q, Wang W, Li W et al. A publish/subscribe architecture for sensor networks and application[C]. Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation, ICMA2006, China, 2006.

[5] Ding J, Sivalingam K, Kashyapa R et al. A multi-layered architecture and protocols for large scale wireless sensor

networks[C]. Proc. IEEE SVTC, 2003.

[6] Mainwaring, J.Polastre, R.Szewczyk, D.Culler, J.Anderson. Wireless Sensor Networks for Habitat Monitoring[C]. In: Proc of the 1st ACM international workshop on Wireless Sensor Networks and applications, 2002.

[7] Tia Gao, Dan Greenspan, Matt Welsh, Radford R Juang, Alex Alm. Vital Signs Monitoring and Patient Tracking Over a Wireless Network[C]. In: Proc of the 27th IEEE EMBS Annual International Conference, Shanghai, 2005.

[8] Meyer S, Rakotonirainy A. A survey of Research on Context-aware Homes[C]. Workshop on Wearable, Invisible, Context-aware, Ambient, Pervasive and Ubiquitous Computing, 2003.

[9] Karpinski M, Senart A, Cahill V. Sensor Networks for Smart Roads[C]. In Proceeding of 2nd IEEE International Workshop on Sensor Networks and Systems for Pervasive Computing (PerSeNS), 2006.

[10] Du X, Chen H. Security in wireless sensor networks[J]. IEEE Wireless Communications, 2009, 15(4), 60-66.

[11] Vieria, M.A.M, Coellho, C.N and etc. Survey on wireless Sensor network devices, Emerging Technologies and Factory Automation, 2003[C]. Proceedings ETFA'03. IEEE Conference,2003.

[12] Sun Yugeng, Zhang Jing, Sun Yongjin, Wireless Self-organizing Sensor Networks. Journal of Sensors[J], 2004, 2: 331~348.

[13] Estrin D, Govindan R, Heidemann J, et al. Next century challenges: scalable coordination in sensor networks[C].Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking. 1999. New York, NY, USA: ACM, MobiCom '99, http://doi.acm.org/10.1145/313451.313556.

[14] Walfenegus Dargie,Christian Poellabauer, translated by Sun Limin, Zhang Yuan and Liu Qingchao. Basic Theory and Practice of Wireless Sensor Networks. Beijing: Tsinghua University Press, 2014.

[15] Tang Yong, Zhou Minting, Zhang Xin. Research Progress of Wireless Sensor Network Routing Protocol [J].Journal of Software ,2006, 17(3): 410-421.

[16] Akkaya K, Younis M. A survey on routing protocols for wireless sensor networks[J]. Ad Hoc Networks, 2005, 3(3): 325-349.

[17] Xie Wenbin, Xing ming. Research progress of energy efficient data collection in wireless sensor networks [J].Computer Science,2008, 35(8): 35-41.

[18] Fang Xiaolin. Research on Energy Efficient Data Collection in Wireless Sensor Networks [D]. Ph.D. Dissertation, Harbin University of Technology, March 2014.

[19] Zheng Guoqiang. Research on Energy Efficient Data Collection Technology for Wireless Sensor Networks [D]. Ph.D. Dissertation, Xi'an University of Electronic Science and Technology, June 2011.

[20] Wang Chao. Research on Energy Efficient Data Collection Method for Wireless Sensor Networks [D]. Ph.D. Dissertation, Beijing University of Posts and Telecommunications, April 2012.， 2012.4.

[21] Willett R, Martin A, Nowak R. Backcasting: adaptive sampling for sensor networks[C].Proceedings of the 3rd international symposium on Information processing in sensor networks. 2004. New York, NY, USA: ACM, IPSN '04.

[22] Lin S, Arai B, Gunopulos D, et al. Region Sampling: Continuous Adaptive Sampling on Sensor Networks[C].Data Engineering, 2008. ICDE 2008. IEEE 24th International Conference on. 2008.

[23] Jain A, Chang E Y. Adaptive sampling for sensor networks[C].Proceedings of the 1st international workshop on Data management for sensor networks: in conjunction with VLDB 2004. 2004. New York, NY, USA: ACM, DMSN '04.

[24] Krishnamachari B, Estrin D, Wicker S B. The Impact of Data Aggregation in Wireless Sensor Networks[C].Proceedings of the 22nd International Conference on Distributed Computing Systems. 2002. Washington, DC, USA: IEEE Computer Society, ICDCSW '02.

[25] Kimura N, Latifi S. A Survey on Data Compression in Wireless Sensor Networks[C].Proceedings of the International Conference on Information Technology: Coding and Computing. Washington, DC, USA: IEEE Computer Society, ITCC '05.

[26] Pattem S, Krishnamachari B, Govindan R. The impact of spatial correlation on routing with compression in wireless sensor networks[J]. ACM Trans. Sensor Networks, 2008, 4(4):1–31.

[27] Pradhan S, Kusuma J, Ramchandran K. Distributed compression in a dense microsensor network [J]. IEEE Signal Processing Magazine, 2002, 19(2):51–60.

[28] Fan K W, Liu S, Sinha P. Structure-Free Data Aggregation in Sensor Networks. Mobile Computing [J], IEEE Transactions on, 2007, 6(8):929–942.

[29] Gao J, Guibas L, Milosavljevic N, et al. Sparse data aggregation in sensor networks[C].Proceedings of the 6th international conference on Information processing in sensor networks. 2007. New York, NY, USA: ACM,

IPSN ’07

[30] Kansal A, Nath S, Liu J, et al. Sense Web: An Infrastructure for Shared Sensing [J]. IEEE MultiMedia, 2007, 14(4):8–13.

[31] Tavakoli A, Kansal A, Nath S. On-line sensing task optimization for shared sensors[C].Proceedings of the 9th ACM/IEEE International Conference on Information Processing in Sensor Networks. 2010. New York, NY, USA: ACM, IPSN ’10.

[32] Pottie G and Kaiser W. Wireless sensor networks[J]. Communications of the ACM, 2000, 43(5): 51-58.

[33] Intanagonwiwat C, Govindan R, and Estrin D. Directed diffusion: A scalable and robust communication paradigm for sensor networks[C]. ACM/IEEE International Conference on Mobile Computing and Networks, Boston, 2000.

[34] Heidemann J, Silva F, Intanagonwiwat C, Govindan R, Estrin D, and Ganesan D. Building efficient wireless sensor networks with low-level naming[C]. 18th ACM Symposium on Operating Systems Principles, New York, 2001.

[35] SOLIS I and OBRACZKA K. The impact of timing in data aggregation for sensor networks[C]. IEEE International Conference on Communications (ICC), Paris, 2004.

[36] YUAN W, KRISHNAMURTHY S V, and TRIPATHI S K. Synchronization of multiple levels of data fusion in wireless sensor networks [J]. IEEE GLOBECOM, San Francisco, 2003, 1:221-225.

