

ADVANCES AND FUTURE TRENDS IN WIRELESS SENSOR NETWORKS

Himanshu Sah, Himanshu Sharma, Hemant
*Department of Electronics and Communication Engineering
Dronacharya College of Engineering, Gurgaon, India*

Abstract-

Wireless Sensor networks (WSNs) have become one of the most interesting areas of research in the past few years. A WSN is composed of a number of wireless sensor nodes which form a sensor field and a sink. These large numbers of nodes, having the abilities to sense their surroundings, perform limited computation and communicate wirelessly from the WSNs. Recent advances in wireless and electronic technologies have enabled a wide range of applications of WSNs in military, traffic surveillance, target tracking, environment monitoring, healthcare monitoring, and so on. There are many new challenges that have surfaced for the designers of WSNs, in order to meet the requirements of various applications like sensed quantities, size of nodes, and nodes' autonomy. Therefore, improvements in the current technologies and better solutions to these challenges are required. The future developments in sensor nodes must produce very powerful and cost-effective devices, so that they may be used in applications like underwater acoustic sensor systems, sensing based cyber-physical systems, time-critical applications, cognitive sensing and spectrum management, and security and privacy management. This paper also describes the research challenges for WSNs.

Index Terms-

Future trends, recent advances, research challenges, wireless sensor networks

I. INTRODUCTION

With the advances in the technology of micro-electro-mechanical system (MEMS), developments in wireless communications and WSNs have also emerged. WSNs have become the one of the most interesting areas of research in the past few year

s. Here, we look into the recent advances and future trends in WSNs.

WSNs are usually composed of small, low-cost devices that communicate wirelessly and have the capabilities of processing, sensing and storing. The development of WSNs was motivated by military applications such as battlefield surveillance. WSN are being used in many industrial and civilian application areas, including industrial process monitoring and control described by Kay and Mattern (2004), machine health monitoring described by Tiwari (2007), environment and habitat monitoring, healthcare applications, home automation, and traffic control presented well by Kay & Mattern (2004) and Hadim (2006). A WSN generally consists of a base-station (also called as gateway sometimes) that can communicate with a number of wireless sensors via a radio link. Wireless sensor nodes collect the data, compress it, and transmit it to the gateway directly or indirectly with the help of other nodes. The transmitted data is then presented to the system by the gateway connection. This paper discusses the recent advances in WSNs that enable a wide range of applications and future development in applications like underwater acoustic sensor systems; sensing based cyber-physical systems, time-critical applications, cognitive sensing and spectrum management, and security and privacy management. Rest of the paper is organized as follows. Section 2 describes the recent advances in WSNs. We discuss future trends in WSN in Section 3. Section 4 describes the research challenges for WSN. Finally Section 5 presents the conclusion.

II. ADVANCES

Recent advances in wireless and electronic technologies have enabled a wide range of applications of WSNs in military sensing, traffic surveillance, target tracking, environment monitoring, healthcare monitoring, and so on. Here we describe such type advances in WSN and their applications in various fields.

2.1.

Sensor Localization and Location-Aware Services

2.2.1. Smart Home/Smart Office

Smart home environments can provide custom behaviors for a given individual. Considerable amount of research has been devoted to this topic. The research on smart homes is now starting to make its way into the market. It takes a considerable amount of work and planning to create a smart home. There are many examples of products currently on the market which can perform individual functions that are considered to be part of a smart home. Several useful applications which take advantage of information collected by WSN are presented by Hussain et al. (2009).

2.2.2. Military

New and emerging technologies, such as networks, support military operations by delivering critical information rapidly and dependably to the right individual or organization at the right time. This improves the efficiency of combat operations. The new technologies must be integrated quickly into a comprehensive architecture to meet the requirements of present time.

Improvement in situation awareness (Chien-Chung Shen, 2001) is must requirement. Doumit and Agrawal (2002) described some other important application is detection of enemy units' movements on land/sea, sensing intruders on bases, chemical/biological threats and offering logistics in urban warfare. Command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems are well described by Akyildiz (2002).

2.2.3. Industrial & Commercial

Since the long time wireless transmission of data is being done in industrial applications, but recently it has gained importance. Successful use of wireless sensors in systems such as supervisory control and data acquisition has proved t

hat these devices could effectively address the needs of industrial applications. The critical process applications of WSNs in industry are monitoring temperature, flow-level, and pressure parameters.

With the rapidly increasing technological advances in wireless technology and its subsequently decreasing prices, numerous wireless applications are being developed in industry. WSN in manufacturing industries can monitor and optimize quality control.

2.2.4. Traffic Management and Monitoring

Every big city is suffering from traffic congestion around the world. A sincere effort is being made to solve the traffic congestion. Congestion can be alleviated by planning managing traffic.

A real-time automatic traffic data collection must be employed for efficient management of rush-hour traffic. Research on this topic is considered as part

of the Intelligent Transport System (ITS) research community. Chinrungrueng (2006) explained ITS to be the application of the computers, communications, and sensor technology to surface transportation.

The vehicle tracking application is to locate a specific vehicle or moving object and monitor its movement. This work also describes design of WSN for vehicular monitoring. As the power source (battery) is limited, it is important that a design of sensor node is power efficient.

2.2. Topology and Coverage Control

Topology control is one of the fundamental problems in WSNs. It has great importance for prolong lifetime, reducing radio interference, increasing the efficiency of media access control protocols and routing protocols. It also ensures the quality of connectivity & coverage and increase in the network service as well. A significant progress in research can be seen in WSNs topology control. Many topology control algorithms have been developed till date, but problems such as lack of definite and practical algorithm, lack of efficient measurement of network performance and idealness of mathematical model still exist. Several graph models used in topology control, the present hot spots and the future trends on the research of topology control are presented by Jardosh and Ranjan (2008).

2.3. Quality of Service (QoS) Provision

QoS support is challenging due to severe energy and computational resource constraints of wireless sensors. Various service properties such as the delay, reliability, network lifetime, and quality of data may conflict; for example, multi-path routing can improve the reliability; however, it can increase the energy consumption and delay due to duplicate transmissions. Modeling such relationships, measuring the provided quality, and providing means to control the balance is essential for QoS support.

There are various research opportunities in enhancing the QoS of WSNs. One of the researches is the project described by Abidin (2009) that analyzes and enhances the performance of a WSN by deploying a simple max-min fairness bandwidth allocation technique.

2.4. Mobility management

Mobility is one of the most important issues in next generation networks. As WSNs are becoming the next elements of the future Internet, it is crucial to study new models that also support mobility of these nodes. WSNs are applicable in variety of cases that make it difficult to produce a standard mobility scenario. Following are some cases where the mobile support is necessary presented in Camilo (2008).

Intra-WSN device movement is probably the most common scenario in WSNs architectures, where each sensor node has the ability to change from its local position at run time without losing the connectivity with the sensor router (SR). In the case of inter-WSN device movement, sensor nodes move between different sensor networks, each one with its SR responsible to configure and manage all the aggregated devices. A research project of IETF working group NEMO, an example of WSN movement is described in RFC-3963 by Devarapalli (2005). Sensor network deployed in a moving bus is a real scenario of this type. It is possible to have a scenario where a sensor network can use another sensor network in order to be connected through Internet. M-ANEMO (Wakikawa et al., 2007) project is also an example.

2.5. Security and Privacy Concern

The field that paid less attention is the privacy concern on information being collected, transmitted, and analyzed in a WSN. Such private information of concern may include payload data collected by sensors and transmitted through the network to a centralized data processing server. The location of a sensor initiating data communication, and other such context information, may also be the focus of privacy concerns.

In real world applications of WSNs, effective counter measures against the disclosure of both data and context-oriented private information are indispensable prerequisites. Privacy protection in various fields related to WSNs, such as wired and wireless networking, databases and data mining, has been extensively studied by Li and Das (2009). Effective privacy-preserving techniques are needed for the unique challenges of WSN security.

III. FUTURE TRENDS

The future developments in sensor nodes must produce very powerful and cost-effective devices, so that they may be used in applications like underwater acoustic sensor systems, sensing based cyber-physical systems, time-critical applications, cognitive sensing and spectrum management, and security and privacy management. In this section we will look into all possibilities of further development in WSN applications.

3.1. Cognitive Sensing

Cognitive sensor networks are used for acquiring localized and situated information of the sensing environment by the deploying a large number of sensors intelligently and autonomically. Managing a large number of wireless sensors is a complex task. As Guang-Zhong Yang (2008) described, a significant research interest can be seen in bio-inspired sensing and networking. Two well known examples of cognitive sensing are swarm intelligence and quorum sensing:

1. Swarm intelligence is developed in artificial intelligence for studying the collective behavior of decentralized, self-organized systems.
2. Quorum sensing is an example of bio-inspired sensing and networking. Quorum sensing is

the ability of bacteria to communicate and coordinate behavior via signaling molecules.

3.2. Spectrum Management

As application of low-power wireless protocols is increasing, we can envision a future in which wireless devices, such as wireless keyboards, power-point presenters, cell phone headsets, and health monitoring sensors will

be ubiquitous. But the pervasiveness of these devices leads to increased interference and congestion within as well as between networks, because of overlapping physical frequencies.

Cognitive radios and multi-frequency MACs are some approaches that have been developed to utilize multiple frequencies for parallel communication. A generic solution is provided by Zhou (2009) as SAS: a Self-Adaptive Spectrum Management middleware for WSNs, which can be easily integrated with an existing single frequency.

3.1. Coordination in Heterogeneous Networks

Since the sensor nodes are energy constrained so the main obstacle in the coordination with other networks is limited energy of sensor nodes. Sensor networks are very useful for applications like health monitoring, wildlife habitat monitoring, forest fire detection and building controls. To monitor the WSN, the data produced by sensor nodes should be accessible. This can be done by connecting the WSN with existing network infrastructure such as global Internet, a local area network or private internet. Liutkevicius (2010) described two types of interconnection techniques: gateway based interconnection technique and overlay based interconnection technique.

3.2. New Models and Architectures

WSN is a self-organized network of battery-powered wireless sensors that can sense, process, and communicate. We have discussed many technical challenges so far that deserve sincere consideration. These challenges are not limiting the progress in WSNs so much as lack of perfect WSN architecture.

Some of recently developed architectures are discussed here: the environment adaptive and energy efficient capabilities should be integral for WSN architecture. A hierarchical structure and sub-facets functions architecture model EAWNA is proposed by L. Liu (2010) that also has other objectives like scalability, customized services,

environment adaptive and energy efficiency. Conventional network architecture designs are based on layering approach. The idea of the layered architecture can also be used with sensor network architecture design. Cubic and cross-layer (CCL) by C. Lin (2007) is suitable sensor network architecture because of application-specific nature of sensor networks. Lukkien et al. (2008) proposed Wirelessly Accessible Sensor Populations (WASP) project is to develop an integrated model for implementing applications using WSNs. In this project a model has been developed to program complete WSN as a whole rather than programming individual node because of the inconsistent behavior of individual nodes.

IV. RESEARCH CHALLENGES

1. **Power:** Power is always been a challenge for WSNs designs. One of the ways to prolong the network lifetime is to design the energy efficient algorithms and hardware that uses power intelligently.
2. **Hardware Cost:** One of the main challenges is to produce low cost and tiny sensor nodes. Current sensor nodes are mainly prototypes with respect to these objectives. Low cost of sensor nodes can be achieved by recent and future progress in the fields of MEMS.
3. **Security:** Security is one of the major challenges in WSNs. Most of the attacks that are performed on WSN are insertion of false information by compromised nodes within the networks. Development of security schemes for WSN also faces challenges related to constrained environment.
4. **System Architecture:** Researches in the field of WSN is going on around the world but still there is no unified system and network architecture, on the top of that different application can be built.
5. **Real World Protocols:** protocols need to be developed for real world problems considering the theoretical concepts and synthesizing novel

solutions into a complete system-wide protocol for real world application.

6.

Analytical and Practical Results: Till date very few analytical results exist for WSNs. All new applications only get confidence when they are tested & analyzed practically and results are compared with existing schemes.

V. CONCLUSIONS

The inherent nature of WSNs makes them deployable in a variety of circumstances. They have the potential to be everywhere, on roads, in our homes and offices, forests, battlefields, disaster struck areas, and even underwater in oceans. This paper surveys the application areas where WSNs have been deployed such as military sensing, traffic surveillance, target tracking, environment monitoring, and healthcare monitoring as summarized in Table 2. The paper also surveys the various fields where WSNs may be deployed in the near future as underwater acoustic sensor systems, sensing based cyber-physical systems, time-critical applications, cognitive sensing and spectrum management, and security and privacy management. These application areas are being researched extensively by various people across the industry and academician.

REFERENCES

1.

R. Kay and F. Mattern, "The Design Space of Wireless Sensor Networks" *IEEE Wireless Communications* Vol.11.No.6 (2004) pp 54–61.

2.

A. Tiwari, P. Ballal and F.L. Lewis, "Energy-efficient wireless sensor network design and implementation for condition-based maintenance" *ACM Transactions on Sensor Networks (TOSN)* Vol.3.No.1 (2007) pp 1-7.

3.

S. Hadim, N. Mohamed, "Middleware: middleware challenges and approaches for wireless sensor networks" *Distributed Systems Online, IEEE* Vol.7.No.3 (2006) pp 1-1.

4.

S. Hussain, S. Schaffner and D. Moseychuck, "Applications of Wireless Sensor Networks and RFID in a Smart Home Environment" *Proceedings of the*

2009 Seventh Annual Communication Networks and Services Research Conference (2009) pp 153-157.

5. Chien-Chung Shen, C. Srisathapornphat and C. Jaikaeo, "Sensor Information Networking Architecture and Applications" *IEEE Personal Communications* (2001) pp 52-59.

6. S. S. Doumit and D. P. Agrawal, "Self-Organizing and Energy-Efficient Network of Sensors" *IEEE* (2002) pp 1-6.

7. I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "A Survey on Sensor Networks" *IEEE Communications Magazine* (2002) pp 102-114.

8.

J. Chinrungrueng, U. Sununtachaikul and S. Triamlumlerd, "A Vehicular Monitoring System with Power-Efficient Wireless Sensor Networks" *ITS Telecommunications Proceedings, 6th International Conference on* (2006) pp 951-954.

9. A. Tiwari, A. Lewis, and S-G. Shuzhi, "Design & Implementation of Wireless Sensor Network for Machine Condition Based Maintenance" *Int'l Conf. Control, Automation, Robotics, & Vision (ICARV), Kunming, China, 6–9 Dec. 2004.*

10. S.W. Arms, C.P. Townsend and M.J. Hamel, "Validation of Remotely Powered and Interrogated Sensing Networks for Composite Cure Monitoring" paper presented at the 8th International Conference on Composites Engineering (ICCE/8), August 7–11, 2001.

11.

N. Wang, M. H. Wang and N. Q. Zhang, "Wireless sensors in agriculture and food industry: Recent development and future perspective" *Computers and electronics in agriculture* Vol.50.No.1 (2006) pp 1-14.

12. S. Jardosh and P. Ranjan, "A Survey: Topology Control for Wireless Sensor Networks" *Signal Processing, Communications and Networking, 2008. ICSCN '08. International Conference on*, (2008) pp 422-427.

13.

H. Z. Abidin and F. Y. A. Rahman, "Provisioning QoS in Wireless Sensor Networks using a Simple Max-Min Fair Bandwidth Allocation" 2009

World Congress on Computer Science and Information Engineering Vol.1 (2009) pp 44-48.
14.

T. Camilo, P. Pinto, A. Rodrigues, J. Sa Silva and F. Boavida, "Mobility management in IP-based Wireless Sensor Networks" World of Wireless, Mobile and Multimedia Networks. International Symposium on, Vol.23.No.26 (2008) pp 1-8.

15.
V. Devarapalli, R. Wakikawa, A. Petrescu, P. Thubert, "Network Mobility (NEMO) Basic Support Protocol" RFC-3963, January 2005.

16. R. Wakikawa, P. Thubert, T. Boot, J. Bound and B. McCarthy, "Problem Statement and Requirements for MANEMO" Internet draft (2007) pp 1-23.

17. Na Li, N. Zhang, Sajal K. Das and B. Thuraisingham, "Privacy preservation in wireless sensor networks: A state-of-the-art survey" Ad Hoc Networks 7 (2009) pp 1501-1514.

18.
K. Lorincz, DJ Malan, TRF Fulford-Jones, A. Nawoj, A. Clavel, V. Shnayder, G. Mainland, M. Welsh and S. Moulton, "Sensor networks for emergency response: challenges and opportunities" Pervasive computing, Vol.12 (2004) pp 16-22.

INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL Volume 1, No 3, 2010

© Copyright 2010 All rights reserved Integrated Publishing Association

REVIEW ARTICLE ISSN - 0976-4259

341

19.
A. Wood, G. Virone, T. Doan, Q. Cao, L. Selvaio, Y. Wu, L. Fang, Z. He, S. Lin and J. Stankovic, "ALARM-NET: Wireless sensor networks for assisted-living and residential monitoring" SiteSeerX (2006) pp 1-14.

20.
U. Anliker, J.A. Ward, P. Lukowicz, G. Tröster, F. Dölz, M. Baer, F. Keita, E. Schenker, F. Catarsi, L. Coluccini, A. Belardinelli, D. Shklarski, M. Alon, E. Hirt, R. Schmid, and M. Vuskovic., "AMON: A Wearable Multi-parameter Medical Monitoring and Alert System"

IEEE Transactions on Information Technology in Biomedicine Vol.8.No.4 (2004) pp 415- 427.

21.
Dario Iafusco, Maria Katrin Errico, Colomba Gemma, Francesco and Prisco, "Usefulness or Uselessness of GlucoWatch in Monitoring Hypoglycemia in Children and Adolescents" PEDIATRICS Vol.113.No.1 (2004) pp 175-176.

22. Guang-Zhong Yang, "Cognitive sensing for body sensor networks" Sensors, 2008 IEEE (2008) pp 26-29.

23.
G. Zhou, L. Lu, S. Krishnamurthy, M. Keally and Z. Ren, "SAS: Self-Adaptive Spectrum Management for Wireless Sensor Networks" Computer Communications and Networks, 2009. ICCCN 2009. Proceedings of 18th International Conference on, Vol.3.No.6 (2009) pp 1-6.

24.
I. F. Akyildiz, D. Pompili and T. Melodia, "Underwater acoustic sensor networks: research challenges" Ad Hoc Networks 3 (2005) pp 257-279.

25.
M.C. Domingo and R. Prior, "Energy analysis of routing protocols for underwater wireless sensor networks" Computer Communications. Vol.31.No.6 (2008) pp 1227-1238.

26. A. Liutkevicius, A. Vrubliauskas and E. Kazanavicius, "A Survey of Wireless Sensor Network Interconnection to External Networks" Novel Algorithms and Techniques in Telecommunications and Networking, (2010) pp 41-46.

27.
AJG Sanchez, F. Garcia-Sanchez, F. Losilla, P. Kulkowski, J. Garcia-Haro, A. Rodríguez, JV López-Bao and F. Palomares Article: Wireless Sensor Network Deployment for Monitoring Wildlife Passages Sensors, Vol.10.No.8 (2010) pp 7236-7262.

28.
Y. Zeng, N. Xiong, J. Hyuk Park and G. Zheng Article: An Emergency-Adaptive Routing Scheme for Wireless Sensor Networks for Building Fire Hazard Monitoring Sensors, Vol.10.No.6 (2010) pp 6128-6148.

29.
A. Zafeiropoulos, P. Gouvas, A. Liakopoulos, G. Me

- ntzas and N. Mitrou Article: NEURON:
Enabling Autonomicity in Wireless Sensor Networks
Sensors, Vol.10.No.5 (2010) pp 5233- 5262.
30.
- M. Alaei and J. M. Barcelo-Ordinas Article: A Method for Clustering and Cooperation in
Wireless Multimedia Sensor Networks Sensors, Vol.
10.No.4 (2010) pp 3145-3169.
31. L. Schor, P. Sommer and R. Wattenhofer,
"Towards a zero-configuration wireless sensor
network architecture for smart buildings"
Conference on Embedded Networked Sensor
Systems archive (2009) pp 31-36.
32. L. Liu, "Research on Environment-Adaptive
Architecture Model of Wireless Sensor
Networks" Second International Conference on
Networks Security, Wireless
Communications and Trusted Computing (2010) pp 1
30-133.
- 33.
- C. Lin, Y.X. He, C. Peng and L. T. Yang, "A Distributed Efficient Architecture for Wireless
Sensor Networks" 21st International Conference on
Advanced Information Networking and
Applications Workshops Vol.2 (2007) pp 429-434.
- 34.
- J. Lukkien, F. Siegemund, R. Verhoeven, R. Bosman,
L. Gomez and M. Hellenschmidt, "The WASP
Architecture for Wireless Sensor Networks"
Communications in Computer and Information
Science Vol.11 (2008) pp 430-447.
35. I. F. Khan and M. Y. Javed, "A Survey on
Routing Protocols and Problem of Holes in
Wireless Sensor Networks" In proceeding International
Conference on Advanced Computer
Theory and Engineering (2008) pp 161-165.