Event Detection in Wireless Sensor Networks: Survey and Challenges

Aziz Nasridinov[1], Sun-Young Ihm[1], Young-Sik Jeong[2], and Young-Ho Park[1]

[1] Department of Multimedia Science, Sookmyung Women's University, Cheongpa-ro 47-gil 100, Yongsan-Ku, Seoul, 140-742, Korea
{aziz,sunnyihm,yhpark}@sookmyung.ac.kr
[2] Department of Multimedia Engineering, Dongguk University, 30, Pildong-ro 1-gil, Jung-gu, Seoul 100-715, Korea
ysjeong2k@gmail.com

Abstract. In typical wireless sensor networks (WSNs), sensor nodes have limited resources such as battery power, computing capability and memory. Creating an event detection method comprising with those resource limitations is not an easy task and this sets several challenges. In this paper, we first describe challenges in event detection in WSNs. Then, we investigate the previous studies that have been done for solving those challenges.

Keywords: Event detection, wireless sensor networks, survey.

1 Introduction

Wireless sensor networks (WSNs) are constructed of many tiny devices, called sensor nodes, randomly distributed over a large location. The sensor nodes are equipped with a sensing, data communicating, and processing units, which enable them to monitor the physical world, communicate and exchange the collected sensory data with other nodes, locally process and make decisions about monitored phenomena. This will lead to the detection of events and unusual data behaviors in a monitored environment. This feature is referred as *event detection*. Event detection in WSNs has received much attention in variety of applications, such as military target tracking and surveillance, meteorological hazards, wildlife monitoring, natural disaster relief and healthcare.

There are following requirements that should be satisfied in the event detection: timeliness, a high true detection rate, and a low false alarm rate [1]. However, in typical WSNs, sensor nodes have limited resources such as battery power, computing capability and memory. Creating an event detection method comprising with those resource limitations is not an easy task and this sets several challenges. Kerman et al. [6] described the most common challenges in event detection as: situational dependence, criticality of application, numerous and diverse data sources, and network topology. In this paper, we give a detailed explanation to the challenges in event detection in WSNs. Then, we investigate the previous works that have been done for solving those challenges.

James J. (Jong Hyuk) Park et al. (eds.), *Mobile, Ubiquitous, and Intelligent Computing*, Lecture Notes in Electrical Engineering 274,
DOI: 10.1007/978-3-642-40675-1_87,

The rest of the paper is proceeds as follows. Chapter 2 discusses challenges in event detection in WSN. Chapter 3 presents existing solutions. Chapter 4 highlights conclusions.

2 Challenges in WSNs Event Detection

Sensor nodes possess limited resources such as battery power, computing capability and memory. Creating an event detection method dealing with with those resource limitations is not a trivial task and this sets several challenges. Kerman et al. [6] described the most common challenges in event detection as: situational dependence, criticality of application, numerous and diverse data sources, and network topology. In this section, we give a detailed explanation to those challenges (Table 1).

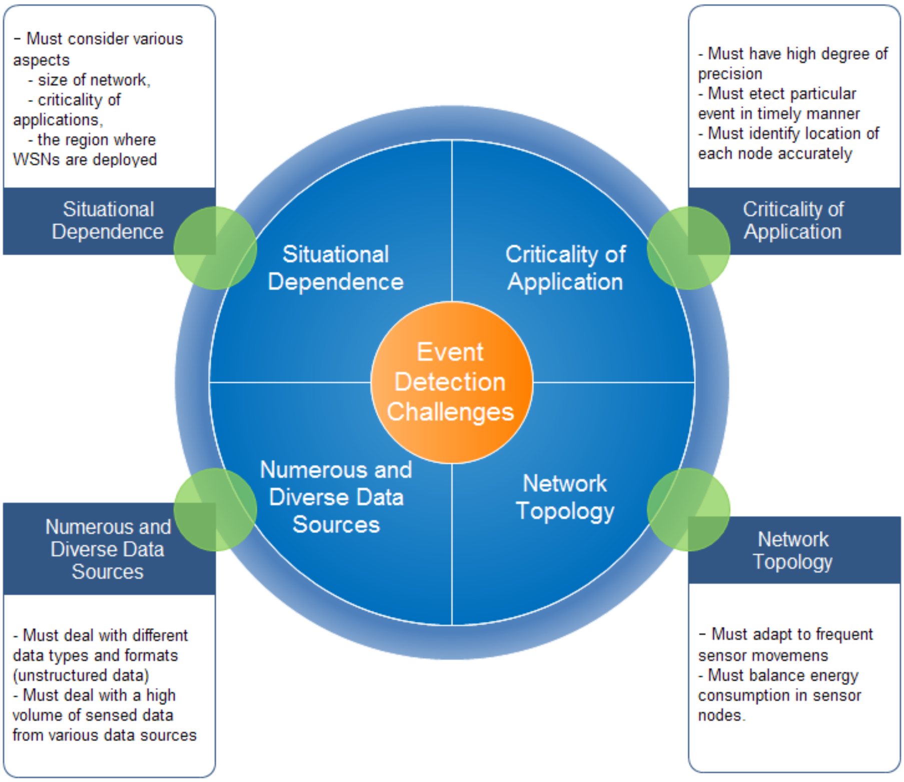

Fig. 1. Challenges in WSNs event detection [2]

Situational Dependence: Since, WSNs are used in a wide range of applications, event detection can be different according to specific situation. For instance, some metrics that are used to detect an event in military target tracking and surveillance cannot be applied to the healthcare applications. The network administrator must consider many different aspects in such environments. Among those aspects are the size of network, criticality of applications, and the region where WSNs are deployed (e.g. WSNs can be deployed in a plain land or in mountain region). Thus, designing an event detection approach that is adaptable to various situations is a challenging task.

Criticality of Application: WSNs are utilized in many critical applications such as measuring indicators of imminent catastrophic machine failures, detecting breaches within security perimeters, and observing human stasis parameters. Event detection approach in such critical applications must have a high degree of precision and detect particular event in timely manner. Moreover, location identification of each node provides the base for routing, density control, tracking, and number many of other communication network aspects. Thus, it is important in critical applications that each node reports its location accurately.

Numerous and Diverse Data Sources: WSNs can be deployed in various locations and consist of hundreds to thousands of sensor nodes meaning that there is a high volume of sensed data from various data sources. Moreover, sensor data can be unstructured meaning that it can contain video, images, text documents, audio, multivariate records, relational data, and spatio-temporal data. Thus, event detection approach must comprise different data types and formats coming from numerous and diverse data sources.

Network Topology: In typical WSNs applications, it is very important to construct efficient network topology, because it would reduce energy consumption and prolong network lifetime. However, in some WSNs, such the network topology changes frequently due to sensor mobility and sensor lifetime. Moreover, there is heterogeneity among sensor nodes such as different residual energy, transmission speed, transmission range, and nodal traffic. Thus, in such dynamic and heterogeneities WSNs, event detection approach must act according to movement of sensor node outside of the intended observed area, power consumption, sensor failures and finite sensor lifetimes, and balance the energy consumption in sensor nodes.

3 Event Detection Methods in WSNs

Most event detection methods fit into one of following three categories: statistical, probabilistic, and artificial intelligence and machine learning. This section describes those event detection methods in details.

A. Statistical Methods

Gupchup et al. [3] proposed event detection approach based on statistical signal processing techniques. They used Principal Component Analysis (PCA) technique to build a compact model of the observed phenomena that detects a various events from the collected measurements in environmental monitoring, such as seasonal trends or rain events. The authors use the divergence between actual collected measurements and model predictions to detect the existence of discrete events within the collected data streams. The experiment results show that proposed approach is able to detect the onset of rain events using the temperature modality of a wireless sensor network.

Meng et al. [8] proposed a compressive sensing method for sparse event detection in WSNs. In their approach, they formulate two problems of WSNs. First, there are a small number of active sensor nodes comparing to the total sensor nodes. Second, different events may occur concurrently and lead to the interference in detecting them individually. In order to solve these problems, the authors adopted a marginal likelihood maximization algorithm and a heuristic algorithm for the Bayesian framework. The authors insist that their approach lead to the higher detection probability than the traditional linear programming solution.

Vu et al. [9] study the Timely Energy-efficient k-Watching Event Detection problem (TEKWED) for composite event detection and alarming in WSNs. In order to solve this problem, they proposed a novel scheme that is able to detect events and deliver timely warnings in WSNs. Based on this scheme, an algorithm that considers topology of the network and routing capabilities is proposed. This algorithm builds a set of detection sets that have several advantages, including the short notification time, energy conservation, and tunable quality of surveillance requirements in event alarming applications.

B. Probabilistic Methods

Li et al. [7] deals with detecting of complex events and proposed a non-threshold based approach for complex event detection in 3D environment monitoring applications. The authors use energy-efficient methods to collect a time series of data maps from the sensor network and detect complex events through matching the gathered data to spatio-temporal data patterns.

Zoumboulakis et al. [10] proposed an approach for detecting complex events in sensor networks. They define complex events as sets of data points hiding interesting patterns and insist that these unusual patterns are difficult to detect using existing technologies. Inspired from time-series data mining techniques, the authors proposed an approach to convert raw real-valued sensory data to symbolic representations using a Symbolic Aggregate Approximation (SAX) algorithm and then use a distance metric for string comparison.

Ihler et al. [4] proposed a framework for unsupervised learning in this context, based on a time-varying Poisson process model that can also account for anomalous events. The authors demonstrate how the parameters of this model can be learned using statistical techniques. Through the extensive experiments, the authors show that proposed approach performs significantly better than a non-probabilistic and threshold-based technique. Moreover, the proposed model can be utilized in examining different degrees of periodicity in the data, and make inferences about the detected events.

C. Artificial Intelligence and Machine Learning Methods

Bahrepour et al. [2] studied the role of machine learning techniques in event detection and proposed an approach for detecting disastrous using WSNs. Specifically, proposed approach is based on detecting events using decision tree classifiers running on individual sensor nodes and applying a voting to reach a consensus among detections made by various sensor nodes. The authors explain the motivation behind choosing decision trees is their simplicity and explicit form of expression as if-then-else rules that fulfill the requirements posed by resource limitations of WSNs.

Abadi et al. [1] proposed REED, a system for robust, efficient filtering and event detection in sensor networks. Their approach extends the TinyDB query processor with facilities for efficiently executing multi-predicate filtration queries inside a sensor network. The proposed approach have three main features: running in limited amounts of RAM, can distribute the storage burden over groups of nodes, and are tolerant to dropped packets and node failures. It makes it suitable a wide range of event-detection applications that traditional sensor network database systems cannot be used to implement.

Kapitanova et al. [5] described disadvantage of current event detection approaches in relying on the usage of precise values to specify event thresholds. The authors insist that t crisp values cannot adequately handle the often imprecise sensor readings. Thus, instead of crisp values, the authors propose to use a fuzzy value, which decrease the number of false positives and improves the accuracy of event detection. The authors also demonstrated the advantage of proposed approach over well-established classification algorithms.

4 Conclusion

Due to several restrictions in WSN, creating an event detection method comprising with these resource limitations is not an easy task and this sets several challenges. In this paper, we first described those challenges in event detection in WSN. Then we investigated the previous works that have been done for solving these challenges and describe their limitations.

Acknowledgement. This work was supported by the IT R&D program of MKE/KEIT. [10041854, Development of a smart home service platform with real-time danger prediction and prevention for safety residential environments].

References

1. Adabi, D., Madden, S., Lindner, W.: REED: Robust, Efficient Filtering and Event Detection in Sensor Networks. In: Proceedings of the 31st Very Large Databases Conference, pp. 769–780 (2008)
2. Bahrepour, M., Meratnia, N., Poel, M., Taghikhaki, Z., Havinga, P.J.M.: Distributed Event Detection in Wireless Sensor Networks for Disaster Management. In: Proceeding of the IEEE International Conference on Intelligent Networking and Collaborative Systems, pp. 507–512 (2010)

3. Gupchup, J., Burns, R., Terzis, A., Szalay, A.: Model-Based Event Detection in Wireless Sensor Networks. In: Proceedings of the Workshop on Data Sharing and Interoperability on the World-Wide Sensor Web (2008)
4. Ihler, A., Hutchins, J., Smyth, P.: Adaptive Event Detection with Time-Varying Poisson Processes. In: The Twelfth International Conference on Knowledge Discovery and Data Mining, pp. 207–216 (2008)
5. Kapitanova, K., Son, S.H., Kang, K.-D.: Event detection in wireless sensor networks – can fuzzy values be accurate? In: Zheng, J., Simplot-Ryl, D., Leung, V.C.M. (eds.) ADHOCNETS 2010. LNICST, vol. 49, pp. 168–184. Springer, Heidelberg (2010)
6. Kerman, M.C., Jiang, W., Blumberg, A.F., Buttrey, S.E.: Event Detection Challenges, Methods, and Applications in Natural and Artificial Systems. In: Proceeding of the International Command and Control Research and Technology Symposium, pp. 1–19 (2009)
7. Li, M., Liu, Y., Chen, L.: Non-Threshold based Event Detection for 3D Environment Monitoring in Sensor Networks. In: Proceedings of the 27th International Conference on Distributed Computing Systems, pp. 1–9 (2007)
8. Meng, J., Li, H., Han, Z.: Sparse event detection in wireless sensor networks using compressive sensing. In: Proceeding of Conference on Information Sciences and Systems, pp. 181–185 (2009)
9. Vu, C.T., Beyah, R.A., Li, Y.: Composite Event Detection in Wireless Sensor Networks. In: Proceeding of the IEEE International Performance, Computing, and Communications Conference, pp. 264–271 (2007)
10. Zoumboulakis, M., Roussos, G.: *Escalation:* Complex event detection in wireless sensor networks. In: Kortuem, G., Finney, J., Lea, R., Sundramoorthy, V. (eds.) EuroSSC 2007. LNCS, vol. 4793, pp. 270–285. Springer, Heidelberg (2007)