Hindawi Publishing Corporation
International Journal of Distributed Sensor Networks
Volume 2014, Article ID 912574, 4 pages
http://dx.doi.org/10.1155/2014/912574

Editorial

Recent Trends in Wireless Sensor Networks with Applications

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Received 2 September 2014; Accepted 2 September 2014; Published 31 December 2014

We are pleased to announce the completion of this special issue. There were 27 submissions in total and 13 out of them were accepted after several rounds of review by the invited reviewers and the guest editors.

The wireless sensor networks are emerging as a useful configuration of sensor entities that are capable of providing solutions for diverse applications under various unexpected and difficult situations. Recently, these networks are permeating in almost all areas where sensing of some physical quantity is the primary application. In addition to sensing applications, these networks are used to further assist in evaluating different situations in tandem with numerous higher level applications. While the application of sensor networks seems to be diverse, there are many challenges that need to be mitigated in order to effectively implement practical systems. Due to the paucity of resources and unexpected nomenclature of these networks, it is difficult to control and perform management operations in an effort to satisfy the requirements imposed by various applications of the users.

The operations of the wireless sensor networks are seriously hampered by various limitations pertaining to energy management, optimum bandwidth utilization, and connectivity. In order to cater to personal, commercial, and military applications, it is important to improve the sensor network lifetime. The distributed and volatile structure of the sensor nodes that are sometimes deployed in eccentric environments, where it is difficult to control these networks, may render access to sensors or reduce lifetime if the energy is not efficiently managed. In monitoring applications, which is typically critical mission, it is important to ensure efficient management, accuracy, and reliability for sensing applications and associated hardware. The accuracy also plays an important role where wireless sensor networks are deployed for tracking applications. Efficient algorithms are implemented that process critical data gathered from the deployed sensors in order to accurately achieve tracking capability. The cognitive radios are emerging and evolving in response to requirements of the current bandwidth hungry users, which require reliability and higher throughputs in already congested and scarce spectrum. Although the cognitive radios are evolving with their own issues and challenges, the amalgamation with sensor networks is also promising, as numerous requirements of the sensor network users may be accommodated. The cognitive radio network paradigm introduces competition and requires a high degree of etiquettes in accessing network for efficient access to resources. The application of game theory in a multidisciplinary approach provides an amicable solution to the spectrum access competition in addition to its suitability to several other problems.

Some of the recent trends addressed by this special issue are energy efficiency, monitoring and tracking applications, cognitive radios, and the application of game theory to sensor networks. It is pivotal to incorporate a cross-disciplinary approach to resolve issues related to the fundamental problems in these networks.

Energy Efficiency. The use of energy resources in an efficient manner influences the wireless sensor network lifetime.

This efficiency in energy consumption can be achieved at different levels of sensor network designs. The incorporation of energy-efficient algorithm using the cross layer paradigm with alternate energy resources also improves the utilization, thus enabling multiple technologies with their inherent advantages and useful characteristics to be used in a single system. In order for the energy efficiency to be credible and useful for the entire wireless sensor networks, a mechanism must be defined to answer some of the following important questions.

(i) Is the physical layer implemented while keeping in view the energy efficiency requirements and standards?

(ii) Is the energy efficiency not compromised as a result of mitigating errors and the choice of routing methods?

(iii) The wireless sensor network consists of distributed sensor nodes striving to achieve consolidated objective of providing sensor data to a destination. Are the sessions between several entities in the network complying with energy efficiency requirements?

(iv) The applications also require being energy aware and must be capable of adjusting according to the requirements set forth by energy-efficient algorithms. Is the application layer in conformation with the energy efficiency requirements?

(v) The cross layer approach is emerging as a valuable method to increase energy efficiency in addition to other vital parameters. Does the system incorporate energy efficiency by using cross layer approach?

(vi) In order to achieve highly desired perpetual operation of the wireless sensor network, several renewable energy sources are utilized. Are we moving towards this method to increase the network lifetime?

Monitoring and Tracking. An important application of wireless sensor networks is the monitoring of physical quantities used for a wide range of applications. The monitoring applications are useful in helping people with disabilities, efficiently managing sensed medical data and diverse industrial applications. The sensors are capable of providing sensed data, which is sometimes not possible by conventional acquisition methods. The tracking applications with the implementation and use of wireless sensor networks are also useful in wide range of applications. While these applications are very attractive in combating some difficult-to-address issues, there are still open questions that are important in this area of research.

(i) Is the monitoring of physical parameter in conjunction with the wireless sensor network implementation?

(ii) Is the accuracy of data aggregation according to the stringent requirements imposed by the application?

(iii) Is the target classification accurate according to the requirements set forth in the specifications determined by the application?

(iv) Is the reliability of the wireless sensor networks in critical applications of monitoring and tracking within the acceptable error deviation?

Cognitive Radio Sensor Networks. Cognitive radios are emerging as an effective solution to mitigate spectrum scarcity and fulfill demands of bandwidth hungry users. The wireless sensor networks can also utilize the cognitive radio approach in order to efficiently manage the available frequency spectrum. Similar challenges are faced by sensor networks in exploiting the cognitive radio approach in spectrum utilization. The access policy must be carefully designed and implemented to proficiently use spectrum holes in a fierce competition among sensor nodes. The sensing policy and access policy must be implemented in coordination with each other such that the nodes are facilitated in establishing an equilibrium point in using the available bandwidth. The following questions are critical at the inception and implementation phases.

(i) The choice of sensing techniques is critical and affects the overall performance of the sensor network. What are the design, assumptions, and parameters for cognitive wireless sensor networks?

(ii) Is the application aware of the sensing parameters, which include duration of sensing, channels to sense, and schedule of sensing?

(iii) Are the sensors that are performing various functions in the network collaborating amicably with each other?

(iv) Are the channels appropriately classified for transmission of data or control signals?

(v) How is the channel assignment managed with the relevance to the activity of primary user?

(vi) Are the users efficiently accessing the available channels that are ready to use by the secondary users?

(vii) Are the transmission parameters, which generally include error correction scheme, power, modulation schemes, and routing policy, properly negotiated among the users?

(viii) Is the availability of data assured while considering the fact that cognitive radio network may not be available at all times?

Game Theory. Due to the autonomous and distributed nature of wireless sensor networks, the network is managed collectively by participating entities that are also expected to cooperate with each other. On the contrary, the nodes behave selfishly in order to maximize their own payoff. This situation creates competition among sensor nodes that needs to be addressed. An oblivious approach in managing these networks may result in chaos and reduced network performance. While the selfish behavior is natural among autonomous wireless sensor nodes, mechanisms must be introduced to inhibit the access policy for the available spectrum holes. This phenomenon raises several questions that need to be addressed. Some of the important questions are listed as follows.

(i) Is the game theoretic approach applied to areas where conflict among sensor nodes exists?

(ii) Is the element of cooperation effectively induced in the system?

(iii) Is the formulation of game appropriate to fulfill the requirements of applications of wireless sensor networks?

(iv) Does the routing protocol design incorporate the cooperative component from designing respective games?

(v) Is the game theoretic approach used to impede the effects of uncertainty in topology?

(vi) Are the issues of power control and energy saving adequately addressed by game theoretic model?

(vii) Is the wireless sensor security accomplished to an acceptable level?

The challenges, however, are many, some of which are explored and analyzed in the accepted articles in this special issue, with some interesting solutions and proposals.

M. M. Abbas et al. in their paper entitled "Solar Energy Harvesting and Management in Wireless Sensor Networks" present an energy harvesting and management model to ensure smooth and uninterrupted operation of sensor nodes in a network. In addition, they present and analyze the analytical behavior of the solar energy harvesting model. They analyze the performance of the proposed model via numerical simulations and discuss voltage-current and power-voltage characteristics. The proposed model is relatively simple and can be managed efficiently to obtain a better performance of the network in a perpetual fashion. This model also assures the connectivity and long operating life of the network.

A. Ahmad et al. in their paper entitled "RE-ATTEMPT: A New Energy-Efficient Routing Protocol for Wireless Body Area Sensor Networks" present reliability enhanced-adaptive threshold based thermal-unaware energy-efficient multihop protocol (RE-ATTEMPT) for wireless body area sensor networks (WBASNs). The operation of the proposed protocol is completed in four phases. Firstly, nodes broadcast HELLO messages to update their routing tables. Secondly, for data transmission, a priority based route is selected. Thirdly, sink assigns time slots to nodes for data transmission. Finally, after communicating within the allocated time slots, the process is completed. They conduct a comprehensive analysis using MATLAB simulations to provide an estimation of path loss and discuss the problem formulation with its solution via linear programming model for network lifetime maximization. The presented results show better performance of the proposed protocol as compared to the existing ones.

E. K. Wang et al. in their paper entitled "Lightweight Secure Directed Diffusion for Wireless Sensor Networks" propose a lightweight secure routing scheme in data fusion for wireless sensor networks, which they call lightweight secure directed diffusion (LSDD). It mainly provides authenticity and integrity in the routing process with relatively low overhead by extending a popular routing protocol-directed diffusion. Moreover, they demonstrate how LSDD can effectively defend multiple attacks such as DOS attacks and sinkhole attacks. They analyze the security capabilities and performance of the scheme.

W. H. F. Aly in his paper entitled "MND_{WSN} for Helping People with Different Disabilities" proposes a monitoring and navigation system MND_{WSN} to help people with three types of disabilities: being blind, deaf, and physically disabled, with different ages, genders, and profiles. The proposed system is based on wireless sensor networks (WSNs), where sensor nodes and cameras are scattered in the hallways at each room in the tested building. Smart phones are used to communicate with the sensor nodes in order to take instructions to navigate through the appropriate path. Dijkstra algorithm is used for navigation.

U. Baroudi et al. in their paper entitled "Smart Bolts Monitoring Using Wireless Sensor Network: Implementation and Performance Evaluation" propose an application of structural health monitoring (SHM), which is named as smart bolt mechanism. The proposed mechanism automates the process of monitoring bolts joints. The authors propose two methods for smart bolt algorithm (with real time wakeup clock (RTC) and without RTC). This work shows that smart bolt mechanism (SBM) with RTC is more efficient in terms of energy consumption and lifetime of the network. SBM without RTC is also efficient in terms of cost. Furthermore, the authors investigate different scenarios with different probabilities of bolt failures to explore their effect on power consumption and network lifetime.

Y. Zhou et al. in their paper entitled "Consensus Target Tracking in Switching Wireless Sensor Networks with Outlier" consider the problem of consensus based distributed tracking in wireless sensor networks (WSNs) with switching network topologies and outlier-corrupted sensor observations. They propose a robust Kalman filtering (RKF) scheme and an adaptive weight update strategy. In contrast to the existing decentralized/distributed Kalman filters, the proposed algorithm relaxes the requirement of Gaussian noise statistics. Unlike the existing consensus based filters, it does not need to perform consensus filtering on the covariance matrices, which reduce the computational and communicational burden.

Z. Hao and B. Liu in their paper entitled "A Rule Based Feature Selection Approach for Target Classification in Wireless Sensor Networks with Sensitive Data Applications" propose a rule based feature selection approach for target classification in wireless sensor networks with sensitive data application. The major method that the authors adopt deal with the feature selection problem in energy-constrained wireless sensor networks. The effectiveness and efficiency of this approach are validated with a set of benchmark datasets (UCI Machine Learning Repository).

In the paper entitled "Cluster-Based Architecture for Range-Free Localization in Wireless Sensor Networks," S. V. Manisekaran and R. Venkatesan propose cluster based architecture for range-free localization in wireless sensor networks. Initially, the cluster heads are selected based on the parameters such as link quality, residual energy, and coverage. An event based localization technique is applied to each cluster that involves straight line scanning of the clusters

with deployed multiple sinks. The scanning process helps in estimating the location of target nodes with reference to anchor nodes position. In the simulation results, the authors show that the proposed technique reduces the overhead and latency and increases the localization accuracy.

In the paper entitled "Spectrum Distribution in Cognitive Radio: Error Correcting Codes," S. A. Hussain et al. propose a transmission model based on error correcting codes dealing with a countable number of pairs of primary and secondary users. The authors obtain an effective utilization of spectrum by the transmission of pairs of primary and secondary users' data through the linear codes with different given lengths. In addition, the authors develop a number of schemes regarding an appropriate bandwidth distribution in cognitive radio with the help of methods used for error correcting codes.

S. A. Hussain et al. in their paper entitled "Spectrum Sharing in Cognitive Radio Using GSC with Suppressed Sidelobes" suggest two generalized sidelobe cancellers (GSCs) that operate in parallel. The first GSC is planned to attain the conflicting goal by generating the main beam in the cognitive user direction and the nulls along the directions of primary users. The second GSC generates two main beams at the positions of the highest amplitude sidelobes of the first one. The values of main beams are equal to the two sidelobe peaks. The subtraction of the outputs of the two GSCs results in the suppression of the highest pair of sidelobes. This process is repeated iteratively to get an adaptive algorithm. The authors show the effectiveness of the proposed algorithm by providing simulation results.

K. Yue et al. in their paper entitled "A Theoretic Approach for Prolonging Lifetime of Wireless Sensor Networks Based on The Coalition Game Model" propose a theoretic energy-efficient model based on the coalition game and Nash equilibrium models. The process of forming the coalition game model is simulated by the Markov process based on the absorbing coefficient. The authors present an algorithm to calculate the absorbing coefficient and find the state with the largest absorbing coefficient. For the difficulty of calculating the exact Nash equilibrium, they present a genetic algorithm to calculate the approximate Nash equilibrium point. Experimental results show that their model can guarantee longer lifetime and effective reachability for WSNs.

Q.-A. Minhas et al. in their paper entitled "Efficient Power and Channel Allocation Strategies in Cooperative Potential Games for Cognitive Radio Sensor Networks" employ the concepts of game theory to develop an efficient and sustainable cooperation mechanism for efficient cognition and improved spectrum utilization. The authors discuss different potential games for ad hoc cognitive sensor networks and formulate the potential functions for these games. They consider the underlay and overlay access schemes for optimal network performance in a cooperative environment through the potential function as the decision making parameter. It is noted that the formulation of the potential function changes for the overlay and underlay schemes. The main advantage offered by underlay systems is the additional opportunities that can be availed even in the presence of the primary user (PU), and the level of transmit power must be kept so as to minimize the interference for PU.

Y. Zeng in his paper entitled "Adaptive Collaborative Detection for Opportunistic Vehicle Sensor Networks" suggests a group detection scheme based on dynamically clustered cooperation scheme called group road detection scheme (GRD) in vehicle sensor networks (VSNs). GRD scheme includes algorithms of cluster invoked process, cluster generation, and runtime decision through vehicle collaborations. The simulations with testbed of 5 remote controllable vehicles show that GRD scheme provides effectiveness under different road scenarios and can help to improve detection performance effectively without much overhead.

Acknowledgments

Finally, we hope that the papers in this special issue would be beneficial for the research community to infer ideas and to work on future research topics related to this area. Also, we would like to express our gratitude to all the authors for their contribution and collaboration and to the many reviewers for their valuable comments, suggestions, and timely responses.

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