Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 63 (2015) 165 – 170
Procedia Computer Science

The 6th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2015)

Energy Efficient Approach for Surveillance Applications Based on Self Organized Wireless Sensor Networks

Ali Benzerbadj[a,*], Bouabdellah Kechar[b], Ahcène Bounceur[c], Bernard Pottier[c]

[a]*Research Laboratory in Industrial Computing and Networks (LRIIR), University of Oran 1 Ahmed Benbella, Algeria*
Lecturer University Center of Ain Témouchent, Algeria
[b]*Research Laboratory in Industrial Computing and Networks (LRIIR), university of Oran 1 Ahmed Benbella, Algeria*
[c]*Laboratory of the Sciences and Techniques of the Information, the Communication and the Knowledge (Lab-STICC), University of Western Brittany, France*

Abstract

Surveillance applications based on Wireless Sensor Networks (WSNs) are energy consumption sensitive. Such applications require low energy consumption in order to extend network lifetime. In this paper, we are interested in event detection around strategic sites (e.g., oil or military sites). We propose energy efficient approach which consists of identifying and using network boundary nodes as sentries, i.e., they are always in active mode and are responsible of detecting events, sending and relaying alert messages to the sink. Remaining nodes are used as relay nodes only. They alternate between active and sleep modes in order to reduce energy consumption. Simulation results show that our approach increases significantly network lifetime and provides an acceptable percentage of alerts delivered to the sink.

Peer-review under responsibility of the Program Chairs
Keywords: Event detection, perimeter monitoring, barrier coverage, boundary node, sentry node, network lifetime.

1. Introduction

Wireless Sensor Network (WSN) consists of set of battery-powered sensor nodes with limited resources (energy, memory, processing, range communication and bandwidth) which are spatially distributed and are able to communicate through wireless links in order to forward sensed information to base station[1]. Nowadays, WSN are used in several domains such as military, transport, industry, health, environment etc[2]. There are many challenges to be solved such as energy consumption, coverage, connectivity, reliability and security.

Among surveillance applications, detection of intruder along a border has been an object of many contributions[3,4,5,6]. However, this paper focuses on intrusion detection around strategic site instead of borderline. In fact, we were interested to barrier coverage where intruders are detected when they try to cross the perimeter of the monitored area[7,8]. Sensors will be densely deployed on the perimeter of considered area in order to avoid sensing voids. Energy is an issue of prime importance in such applications. In fact, WSN lifetime should be extented because batter-

* Corresponding author. Tel.: +33758307068;
E-mail address: ali.benzerbadj@univ-brest.fr (Ali Benzerbadj).

Peer-review under responsibility of the Program Chairs
doi:10.1016/j.procs.2015.08.328

ies of sensor nodes cannot be easily replaced or recharged in monitored area due to presence of potential danger and stealthiness required by such applications.

Several research works have addressed the problem of energy consumption in surveillance applications. A common approach is to select a subset of the deployed nodes to be in active mode while remaining nodes are put in sleep mode. In[9], the authors describe the design and implementation of energy efficient surveillance system for military use in order to detect and track the positions of moving vehicles. Surveillance focuses on full coverage problem where every physical point in the area needs to be covered. The system is organized into layered architecture. It provides two key services that are respectively responsible for energy management and collaborative detection and tracking of events. Sentry service conserves energy in WSN by selecting a subset of sensor nodes to act as sentries in order to monitor events while remaining sensors are put in sleep mode until an event occurs. Node becomes sentry if it is one of the internal nodes of the diffusion tree which constitutes reverse route to the sink or none of its neighbors either is a sentry or is covered by a sentry.

In[10], where mission-critical surveillance of whole area using video sensor nodes is addressed, a subset of the deployed nodes are selected to be active based on the redundancy level of video sensor nodes so that area coverage and network connectivity are preserved. Furthermore, Authors provide a model based on behavior functions modelled by quadratic Bezier curves which allow nodes, when they are active, to adjust their frame capture rate according to their redundancy level and to application criticality. The result is energy conservation. In such applications, nodes with high capture speed, can be chosen to act as sentry nodes to enhance events detection and alert on them.

In this paper, given that we are interested in intruder's detection in the perimeter of a strategic site, immediately after the deployment, we indentify boundary nodes of WSN deployed around the monitored area in order to use them as sentries while remaining nodes will alternate between sleep and active modes to save energy.

Before the start of surveillance mission of WSN, nodes exchange HELLO messages containing their coordinates and identifiers in order to discover their vicinity. Then, sink node sends boundary discovery packet in order to identify boundary nodes of WSN using an enhanced release of the algorithm presented in our previous work[11]. The packet is routed using Greedy Perimeter Stateless Routing (GPSR) protocol. Each time the packet is forwarded using the perimeter mode of GPSR, the forwarder node is designed as boundary node. All boundary nodes will be always in active mode while others will have a sleep period during each cycle of time.

When sentry node detects an event, it sends alert message towards the sink using GPSR protocol at network layer level and an asynchronous contention based Medium Access Control (MAC) protocol[12,13] at access layer level.

A cross layer design[14,15,16,17] based on control command [1] and control message [2] provided by Castalia simulator[18] is used to allow MAC layer to get information from network layer. In fact, before sending alert, transmitter node must know if the radio of the receiver is duty cycled or not in order to save more energy. This information is stored in the neighbors table at network layer level. Nodes with duty-cycled radio are woken up by sending a series of preambles before sending alert.

Our main contribution is to save energy by putting internal nodes of the WSN in sleep mode. We also try to forward to the sink a high percentage of alert messages generated by sentry nodes.

The remainder of the paper is organized as follows. We describe the WSN used for surveillance in section II. The proposed approach in described in section III. Simulation results are presented in section IV. Finally, we conclude and present future work in section V.

2. WSN description

Fig. 1 describes the model of surveillance used in which nodes are static and are densely deployed on the perimeter of the site in order to avoid sensing voids. We assume that WSN is stationary and each node is aware of its location using Global Positioning System (GPS) device and has duty-cycled radio. Node can be equipped with appropriate scalar or multimedia sensor such as motion sensor, microphone, camera etc[19,20]. We consider two kinds of nodes, boundary and non boundary nodes. Boundary nodes have mainly the role of sentry while non boundary nodes act

[1] Goes from up to down layers
[2] Goes from down to up layers

only as relay. When an event is detected by sentry node, an alert is sent to the sink node through relay nodes in order to take the suitable decision. We suppose also the existence of voids inside the perimeter formed by boundary nodes. Voids can be the result of the random deployment or nodes failure. In order to handle the routing of alerts around voids, we use GPSR protocol[21] which is considered as void tolerant protocol. The tracking of intruder is not handled.

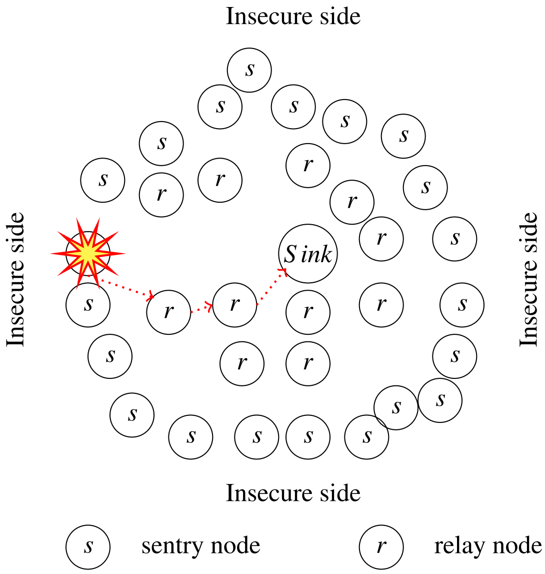

Fig. 1. WSN based surveillance scenario.

3. Proposed approach

The proposed approach takes place in two phases, initialization and surveillance. During initialization phase, where all deployed nodes are supposed to be in active mode, neighborhood discovery is launched. The latter is followed by boundary nodes identification. Once the identification of boundary nodes is finished, non boundary nodes are put in sleep mode. Surveillance phase starts immediately after that.

3.1. Initialization phase

Each node broadcasts HELLO message containing its identifier and its geographic position. Every time a node receives HELLO message, it adds the received information to its neighbors table. When neighborhood discovery stage is finished, sink node initiates boundary nodes discovery by sending packet to a Virtual Destination (VD) in the WSN. VD is a node assumed to belong to the deployment field but it is disconnected from all other nodes. The packet will be forwarded using algorithm 1. Each time it is forwarded using perimeter mode, the forwarder node identifies itself as boundary node. When the packet returns back to the node where it enters for the first time, after it was sent by the sink, the perimeter mode, we are sure that we have identified all boundary nodes of WSN. Thus, duty cycle[3] of all non boundary nodes is changed to a value lower than one and monitoring phase starts.

[3] Duty cycle = $\frac{activity\ period}{(activity+sleep)\ periods}$

3.2. Surveillance phase

When sentry node detects an event, it generates an alert message and sends it towards the sink using multi-hops routing. Next hop is given by GPSR protocol, using either greedy or perimeter mode. Greedy mode is executed on the initial Unit Graph (UG) by forwarding the packet to the nearest neighbor from the sink while perimeter mode requires planar graph such as Gabriel Graph (GG)[21].

Every time a node u has to forward a packet to a node v among its neighbors using perimeter mode, it ckecks if the edge (u, v) belongs to GG or not. If it belongs, node v will be a candidate to be the next hop. In fact, next hop is selected among all these candidate nodes based on the right hand rule[21] and the fact that the edge (u, v) does not intersect the line between, the node where the packet enters perimeter mode for the first time, and the final destination node. In the case where there is intersection, GPSR protocol moves to the next face of the GG and continues routing packet on that face[21].

Algorithm 1 Distributed algorithm to discover boundary nodes

Require: Neighbors set of u, x, y and id. of VD.
Ensure: return next hop id. if exists else -1.

```
Packet received from Application or MAC layer
if Greedy forwarding succeeds then                ▷ Try to forward it using greedy mode of GPSR
    return next hop
else                                              ▷ Try to forward it using perimeter mode of GPSR
    if Perimeter forwarding succeeds then
        node identifies itself as boundary node.
        return next hop
    else
        return -1
    end if
end if
```

When the alert packet arrives at MAC layer, we use a cross layer design to allow the transmitter to get information from the network layer about the status of the next hop, either sentry or non sentry node. This interaction between network and MAC layers allows us to save energy. Indeed, if the next hop is a sentry node, the transmitter sends alert packet without a series of preambles.

However, when the next hop is a non sentry node then, as depicted by Fig. 2, sender node transmits a series of preambles that lasts as long as sleeping interval of receiver before sending alert packet. We assume that all internal nodes have the same sleeping period. If the receiver wakes up during this period, it waits until the series of preambles ends to receive alert. Others cases can happen (e.g., internal to internal and internal to sentry).

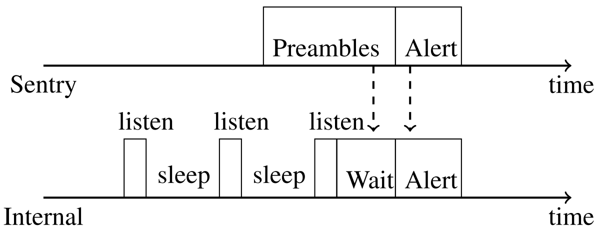

Fig. 2. Communication between sentry and internal node

4. Simulation results

To evaluate our approach, we make a series of simulations under Castalia simulator. We consider randomly deployed WSN where all nodes are static and have equal communication and sensing ranges and sysmetric links. We use a simple collision model where collision happens at receiver if two nodes transmit at the same time. Table 1 summarizes others simulation parameters. Fig. 3 shows that average energy consumption per node using our approch

Table 1. Simulation Parameters.

Parameters	Values
Monitored area	70 meters × 70 meters
Number of nodes	60
Radio	CC2420
Radio range	50 meters
Listen period	10 milliseconds
Duty Cycle of non boundary nodes	0.5
Battery capacity	18720 Joules (2 AA batteries)

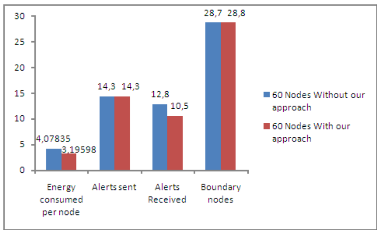

Fig. 3. Comparison of performance results

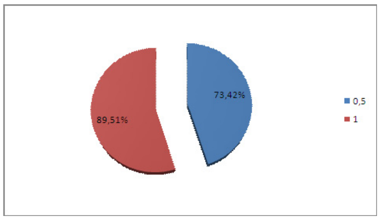

Fig. 4. Percentage of delivered alerts to the sink

is lower than if we use an approach when all nodes are considered as sentries. In fact, among 60 nodes deployed randomly in field of 70 meters per 70 meters, our approach identifies 28,8 perimeter nodes on average on 10 made simulations. Only 29 nodes instead of the initial number of 60 nodes are used as sentries while the remaining nodes will have a duty cycle equal to 0.5 and will alternate between active and sleep modes. Thus, our approach saves 21,63 % of energy per node on average. On the other hand, we can notice from Fig. 4 that the percentage of alerts delivered to the sink is about 73,42% from the total number of alerts sent. This percentage is encouraging in comparison with the percentage of alerts received when all nodes are considered as sentries, which is equal to 89,51%. This can be explained by phenomenon of collision depicted by Fig. 5.

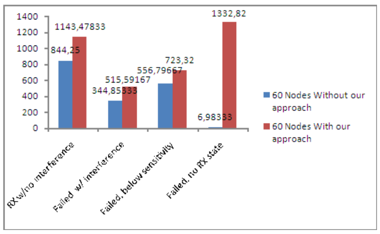

Fig. 5. Average number of packets received per node (physical layer)

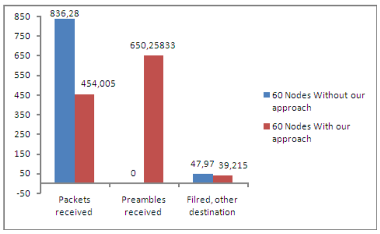

Fig. 6. Average number of packets received per node (MAC layer)

Fig. 5 shows average number of packets received or not per node. Detail of packets received is depicted by Fig. 6. We note that, even if node using our approach receives more packets due to the reception of preambles when it is waiting for alert, it consumes less energy as we have noticed since Fig. 3. This is the result of the duty cycling of radio of internal nodes.

5. Conclusion

We have presented an approach which minimizes energy consumption in order to extend WSN lifetime and insures an acceptable percentage of alert messages delivered. Our approach identifies and uses perimeter nodes of the WSN as sentries while radio of other nodes is duty-cycled. We use the geographic protocol GPSR, which is a void tolerant prococol in order to forward alerts to the base station. At the access level, an asynchronous contention based MAC protocol to manage activity of nodes is used. A cross layer design is provided to optimize more the energy consumption by avoiding the sending of useless preambles. Simulation results, in terms of energy consumption and percentage of alerts delivered are encouraging. Indeed, even when all nodes are active, we have noticed a loss of alerts due to interference.

As part of our future work, we want to enhance our approach by extending the cross layer design used. In fact, we want that alert message arrives at the sink by following the most reliable path and with the lowest energy consumption. Furthermore, we want to take into account the latency by the creation, every time there is an intrusion, of reserved path between sentry node and the sink. All nodes belonging to this path act as sentries for a certain period and then return back to their original status when the danger disappears.

References

1. P. Rawat, K. Singh, H. Chaouchi, J. Bonnin, Wireless sensor networks: a survey on recent developments and potential synergies, The Journal of Supercomputing 68 (1) (2014) 1–48. doi:10.1007/s11227-013-1021-9.
2. T. Arampatzis, J. Lygeros, S. Manesis, A survey of applications of wireless sensors and wireless sensor networks, in: Intelligent Control, 2005. Proceedings of the 2005 IEEE International Symposium on, Mediterrean Conference on Control and Automation, IEEE, 2005, pp. 719–724.
3. Emad Felemban, Advanced Border Intrusion Detection and Surveillance Using Wireless Sensor Network Technology, International Journal of Communications, Network and System Sciences 06 (05) (2013) 251.
4. R. Bellazreg, N. Boudriga, K. Trimeche, S. An, Border surveillance: A dynamic deployment scheme for wsn-based solutions, in: Wireless and Mobile Networking Conference (WMNC), 2013 6th Joint IFIP, IEEE, 2013, pp. 1–8.
5. R. Bellazreg, N. Boudriga, S. An, Border surveillance using sensor based thick-lines, in: Information Networking (ICOIN), 2013 International Conference on, IEEE, 2013, pp. 221–226.
6. C. Komar, M. Y. Donmez, C. Ersoy, Detection quality of border surveillance wireless sensor networks in the existence of trespassers' favorite paths, Computer Communications 35 (10) (2012) 1185–1199.
7. S. Kumar, T. H. Lai, A. Arora, Barrier coverage with wireless sensors, in: Proceedings of the 11th annual international conference on Mobile computing and networking, ACM, 2005, pp. 284–298.
8. Y. Wang, G. Cao, Barrier coverage in camera sensor networks, in: Proceedings of the Twelfth ACM International Symposium on Mobile Ad Hoc Networking and Computing, ACM, 2011, p. 12.
9. T. He, S. Krishnamurthy, J. A. Stankovic, T. Abdelzaher, L. Luo, R. Stoleru, T. Yan, L. Gu, J. Hui, B. Krogh, Energy-efficient Surveillance System Using Wireless Sensor Networks, in: Proceedings of the 2Nd International Conference on Mobile Systems, Applications, and Services, MobiSys '04, ACM, New York, NY, USA, 2004, pp. 270–283. doi:10.1145/990064.990096.
10. C. Pham, A. Makhoul, R. Saadi, Risk-based adaptive scheduling in randomly deployed video sensor networks for critical surveillance applications, Journal of Network and Computer Applications 34 (2) (2011) 783–795. doi:10.1016/j.jnca.2010.10.002.
11. A. Benzerbadj, B. Kechar, Redundancy and Criticality based Scheduling in Wireless Video Sensor Networks for Monitoring Critical Areas, Procedia Computer Science 21 (2013) 234–241. doi:10.1016/j.procs.2013.09.031.
12. J. Polastre, J. Hill, D. Culler, Versatile low power media access for wireless sensor networks, in: Proceedings of the 2nd international conference on Embedded networked sensor systems, ACM, 2004, pp. 95–107.
13. M. Buettner, G. V. Yee, E. Anderson, R. Han, X-MAC: a short preamble MAC protocol for duty-cycled wireless sensor networks, in: Proceedings of the 4th international conference on Embedded networked sensor systems, ACM, 2006, pp. 307–320.
14. B. Fu, Y. Xiao, H. J. Deng, H. Zeng, A Survey of Cross-Layer Designs in Wireless Networks, Communications Surveys & Tutorials, IEEE 16 (1) (2014) 110–126. doi:10.1109/SURV.2013.081313.00231.
15. B. KECHAR, A. LOUAZANI, L. SEKHRI, M. F. KHELFI, Energy Efficient Cross-layer MAC Protocol for Wireless Sensor Networks, in: Proceedings of the Second International Conference on Verification and Evaluation of Computer and Communication Systems, VECoS'08, British Computer Society, Swinton, UK, 2008, pp. 61–71.
16. M. C. Vuran, I. F. Akyildiz, XLP: A Cross-Layer Protocol for Efficient Communication in Wireless Sensor Networks, Mobile Computing, IEEE Transactions on 9 (11) (2010) 1578–1591. doi:10.1109/TMC.2010.125.
17. C. Suh, Y.-B. Ko, D.-M. Son, An energy efficient cross-layer MAC protocol for wireless sensor networks, in: Advanced Web and Network Technologies, and Applications, Springer, 2006, pp. 410–419.
18. Castalia, https://castalia.forge.nicta.com.au/index.php/en/.
19. I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, Wireless sensor networks: a survey, Computer networks 38 (4) (2002) 393–422.
20. I. F. Akyildiz, T. Melodia, K. R. Chowdhury, A survey on wireless multimedia sensor networks, Computer networks 51 (4) (2007) 921–960.
21. B. Karp, H.-T. Kung, GPSR: Greedy perimeter stateless routing for wireless networks, in: Proceedings of the 6th annual international conference on Mobile computing and networking, ACM, 2000, pp. 243–254.