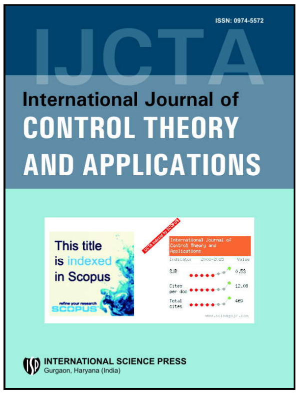

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An Energy Efficient Architecture for Border Area Surveillance System Using WSNs

Ashwini Kumar Singh[1], Santosh Kumar[1] and Ankur Choudhary[1]

[1] Department of Computer Science and Engineering, Graphic Era University, Dehradun, Uttrakhand, India,
Email: ashwini.21mar@gmail.com, amu.santosh@gmail.com, ankur.21.india@gmail.com

Abstract: Wireless Sensor Network (WSN) has been emerging in the last decade as a powerful tool for connecting physical and digital world. Monitoring and surveillance of large surface represent a challenge for peoples. In some environments, this task can be so hard, costly and takes lots of time and risk. Automatic monitoring is the best solution in many cases. WSN is used as a monitoring tool in many domains: military domain, space domain and agronomic domain. The objective of this paper is to propose a system where energy efficient wireless sensor network is used for surveillance and intrusion detection in a large cross-border area. The potential benefits of using WSN in border surveillance are huge; however, a very few attempts of solving many critical issues about this application could be found. This paper presents the specification level of this architecture and a formal verification of this specification. The potential applications of this surveillance system are also discussed.

Keywords: Wireless Sensor Networks, Border Surveillance, Intrusion Detection, Remote Monitoring, Routing Protocols, Sensor Deployment

1. INTRODUCTION

Automatic surveillance is an important research area and has been studied for many years [1]. Safeguarding cross-border areas is a vital task for motherland's security on intruders from other nations. One of the biggest challenges of border security [2] is to secure sheer magnitude area of border regions. Countries like India have long land borders and intrusion is a long-standing problem. Security personals work in around the clock and in different environment from snow to dense forest and from harsh hills to desert. A wireless sensor network consists of large number of unattended tiny devices equipped with different sensors to perform certain tasks [3, 4]. They can be used in challenging places where it is inconvenient for human to be present. The sensors on the devices extract physical information from environment, such as temperature through a temperature sensor, pressure through a barometer, noise through a microphone, and even an image through a camera or thermal camera. The collected data then are sent over to the control command for further processing. We can also perform preprocessing of raw data to decrease the size of data.

There has been a great interest to utilize WSN for military applications and especially in border protection [5, 6]. To reach its full proposed functionality, researchers of WSN used in border protection have to solve many interesting challenges, such as energy efficiency [7, 8], communication and hardware reliability and security issues [9]. In the proposed surveillance system, sensor nodes are deployed in hybrid fashion, at the extreme conditions the deployment is random and in some regions it is deterministic. Deterministic deployment of sensors will minimize the cost and can be used for target localization [10]. Multi-hop communication may occur to send the data at sink node. Monitoring will be at base station and suitable information can be communicated to the desired place through satellite communication. Further we can make our surveillance system intelligent by using machine learning technique for speech recognition and image processing to identify the intruders and we can also use some sensors which can detect the type and number of weapons with the intruders. The typical architecture of sensor network and a sensor node is given in figure 1.

The rest of the paper is organized as follows: Section II gives a review on related works on border surveillance systems using WSN. Section III presents the overview of the proposed system architecture followed by the specification, the simulation and verification of this architecture in Section IV. Experimental results and discussion are provided in Section V. Finally, conclusion is addressed in Section VI.

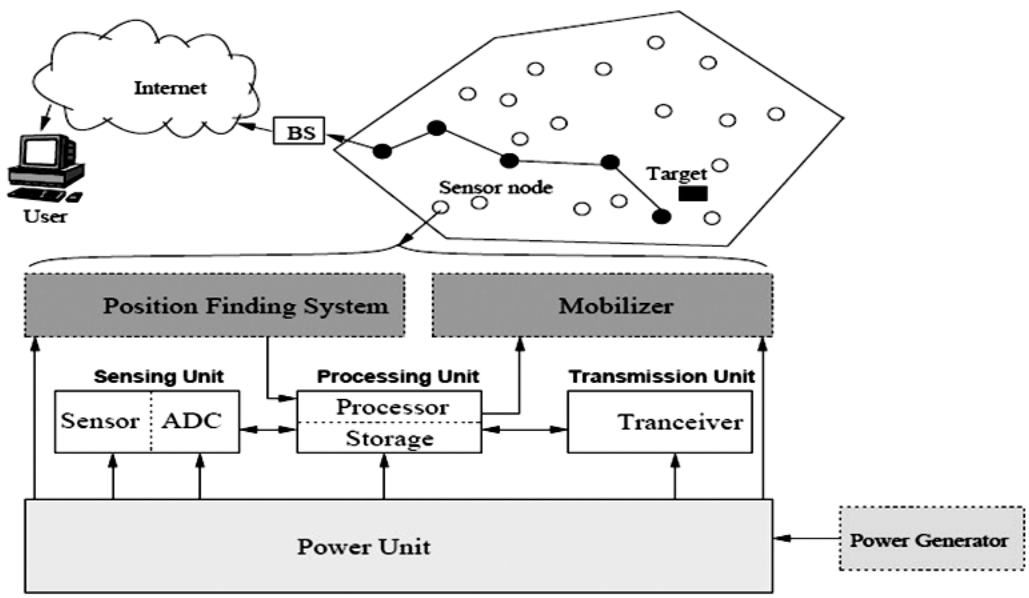

Figure 1: Architecture of Sensor Node

2. RELATED WORK

One of the major benefits of wireless sensor networks is their capability to link the gap between the physical and logical worlds, by gathering certain useful information from physical world and communicating that information to more powerful coherent devices that can process it. WSN will eventually eliminate the need for human involvement in many information gathering and monitoring [11] applications, especially in confined or dangerous spaces. The low-cost and small size features of WSN enables the deployment of number of nodes in any field of interest. Sensor nodes contains: Processing unit, RF transceiver and Energy source. Multiple sensor nodes self-form themselves to form a network to exchange information and deliver data to a common node called the sink node.

WSN has been applied in many applications [12], such as habitat monitoring [13], Point of Attention Building monitoring [14], pipeline monitoring [15], smart agriculture [16], and smart electrical grid [17].

Researchers, also, have extended the concept of land WSN into marine sensor network [18, 19]. Because RF signals do not work under water, acoustic signals are used for communication. Marine wireless sensor networks offer an unmatched option to a wide range of different domains, such as monitoring coral reefs, fish habitats, and oil leaks from off shore facilities.

It has been a long time since surveillance has become an activeresearch field. Several cameras have been designed to keep a check on intruders. Vittal [20] used thermal cameras, which continuously scan the corresponding areas of the border and were inturn connected to digital signal processing unit, which continuously compare the images obtained with the reference image andpreviously captured images and thus, any change in the successiveimages indicated dubious movements, which were immediatelyreported by means of wireless communication. In [21], the authors assume that most of the intrusions are performed within a narrow slice of the longer border region. They propose a localized sleep-wake up protocol called Localized Barrier Coverage Protocol (LBCP) for maximizing the network lifetime. LBCP does not guarantee global barrier coverage like a centralized method does, but performs well under given assumptions. In [22], the authors claim that sensor deployment may be linear instead of uniform random in some deployments such as dropped from an aircraft. A detailed survey about mobility models can be found in [21-23]. Though these mobility models may be acceptable for representing the movement of an individual intruder, the intrusion preferences over the whole border region are generally not random.

3. PROPOSED ARCHITECTURE

The architecture that we propose consists of two principal parts: A number of sensors having different sensing abilities, which are capable of detecting moving objects, Base Station (BS) which will act as sink. The base station is the Centre that receives the information and takes decisions against intrusion. It can be located near the base camp of security forces to insure the rapid involvement in case where such intervention is required. A scenario for deployment of hybrid sensors for border area surveillance system is shown in figure 2.

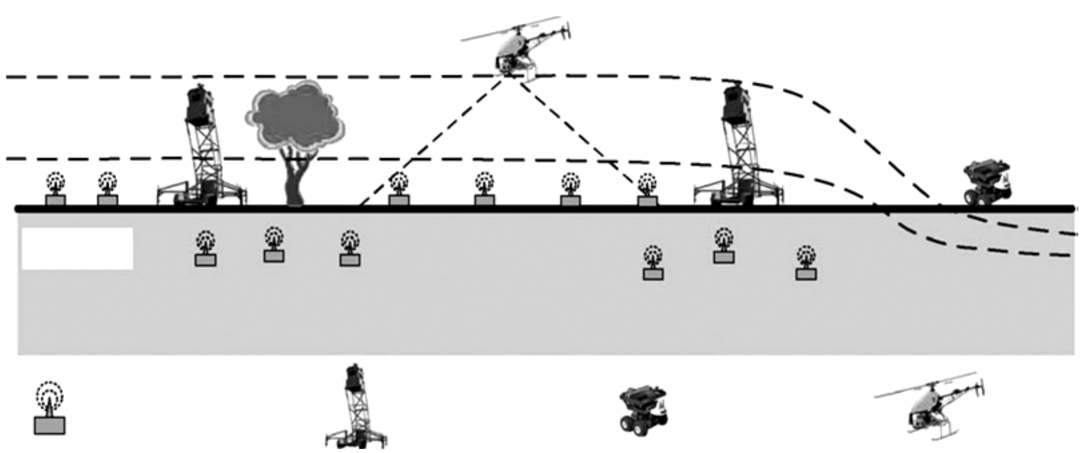

Figure 2: Combination of ground, mobile, underground and multimedia sensors for border surveillance.

The main requirements for the selection of a sensor include low-power operation, reasonable size, low cost and sensor should not give false positive or negative readings. Sensor scalability is another important factor. We have to maintain a balance between the number of the sensors required and the coverage area. Here we will use minimum energy cost k-barrier coverage technique [24] for sensor deployment. This technique will reduce the number of sensor nodes required for covering the area of attention. Here we will consider only a border-belt area for random deployment and inside the border area we will use deterministic deployment to cover the maximum area with minimum number of sensors.

In this architecture we will deploy the sensors in two layers; first layer we will use Passive Infrared Sensor as it has better detection property for direct movement detection and in second layer we will use image and metal detection sensors to estimate the actual number of intruders, arms and ammunition they are carrying with them. Here the sensors of layer1 communicates with the sensors of layer2 with an energy efficient clustering protocol known as TSSEP (Threshold Sensitive Stable Election Protocol) [26] which communicates only when the sensed value is greater than a threshold value and also considers the heterogeneity in terms of initial energy of sensor nodes.

As we are using sleep-wake scheduling scheme [25] for minimizing energy consumption at layer2 sensors, the sensors of layer1 make awake to the image and metal detection sensors at second layer. Figure 5 shows the periodic sleep and listen schedule for sensor nodes and in figure6 we can see the arrangement for different sleep-wake schedule to nodes according to their distance from BS. On demand wakeup protocol is used for layer2 sensors, the design of on demand wakeup protocol employs a novel hardware component known as on-demand wakeup trigger (OWT) at receiver node. The OWT consumes almost zero power and is always on. When the sensors at layer1 receives signals greater than a threshold value its transmitter is set to transmit data, it first sends out an RF beacon that is handled by the OWT component in sensors at layer2 to generate a hardware interrupt. This interrupt serves as an RF trigger to wake up the sensors receiver's main radio and then the signals from

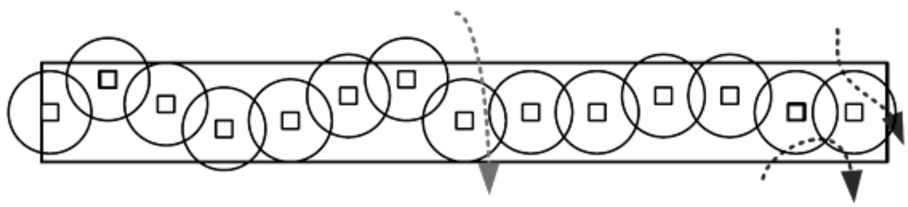

Figure 3: An example of barrier coverage

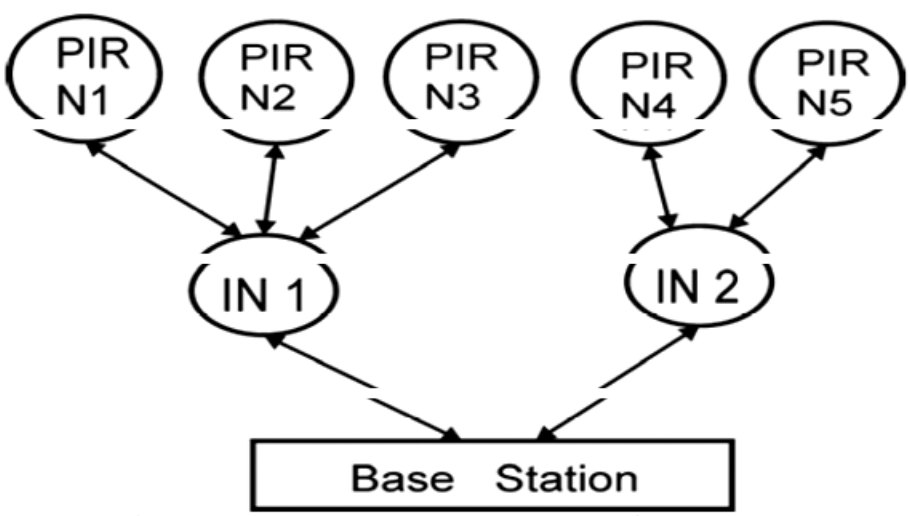

Figure 4: Sensors placement

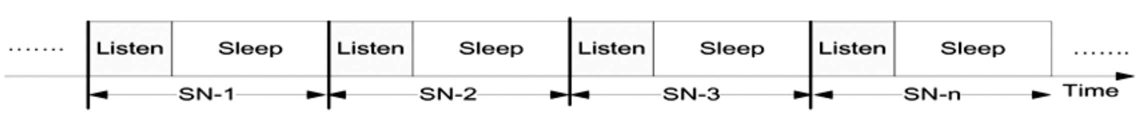

Figure 5: Generic periodic sleep and listen schedule for network nodes.

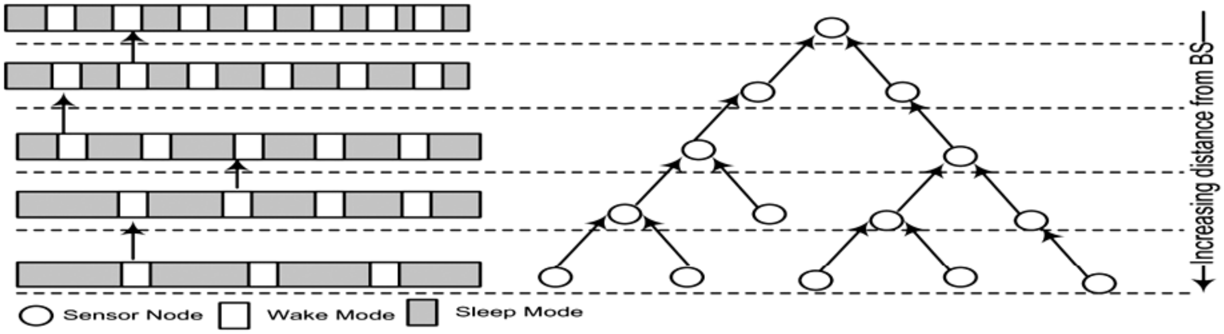

Figure 6: Assignment of different sleep-wake schedule to nodes according to their distance from BS.

layer1 is received by sensors at layer2. Hence the energy consumed by the main radio is reduced in on-demand wakeup. After receiving the data from layer1, layer2 sensors take the desired data and send it to the base station using TSSEP protocol.

The direction of the movement of objects can be detected using the relative positions of the sensor nodes. An object id is also associated with the every detected object. The message structure to the BS has Node position (x, y coordinates) and unique identifier numbers of detected objects as a field which helps to estimate the number and location of detected intruders. The BS analyses the received data and takes the desired decisions. The BS may further connected to defence head-quarters and defence ministry through IOT (Internet of Things) in order to provide real time data to the concerned authorities.

4. SIMULATION AND RESULT ANALYSIS

To get the performance of proposed architecture, we have simulated using MATLAB having consideration of scenario followed bythe parameters discussed in table 1.We have also compared the performance results with the other cluster based routing protocols like LEACH, TEEN and SEP and found that TSSEP outperforms over others in terms of energy consumption. Hence our proposed architecturefor border area surveillance system improvesoverall lifetime of WSNs.

Table 1
Summary of the Simulation scenario and parameters used

Parameters	*Value*
Field size	$100m \times 100m$
Base Station Position	$d_{to\ BS} < 5\ KM$
No of nodes,	100 *nodes*
Cluster Head probability	0.5
Sensor Node's initial energy	0.0025 *J*
The data packet size	4000 *bits*
Bandwidth	(0 -10) *mbps*

The performance is measured in terms of network lifetime. We have considered a scenario with initial number of live nodes is 100. We have simulated it for 4500 rounds and the result is shown in figure 7.

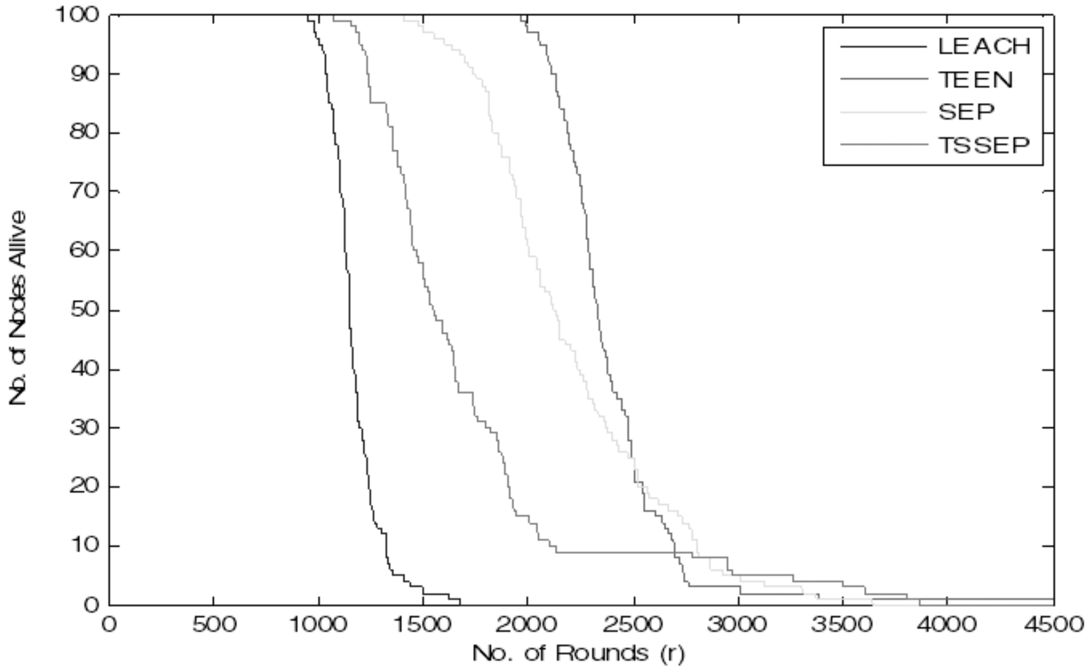

Figure 7: Result in terms of No. of nodes alive vs No. of rounds.

5. CONCLUSION

This paper proposes an energy efficient architecture for border area surveillance system using wireless sensor networks which makes use of TSSEP protocol for cluster formation and on demand wakeup protocol for communication between different layers of sensor nodes. We have simulated our architecture using different clustering protocols and find that TSSEP protocols outperforms when compared with LEACH, TEEN and SEP protocols. The architecture successfully identifies the intruders with their count and arms and ammunition carrying with them. We can also estimate the speed and direction of movement of trespassers. Our proposed system is robust enough in handling noisy data as it uses threshold based protocol. It is efficient enough to maximize the lifetime of WSNs. The system does not need any additional training for its users and works well from day one. This system ensures that whenever an intruder tries to cross the border an alarm will inform the security personals to take the necessary action against them with proper planning and information about them. Thus, making our border security system much more robust with minimum casualties and effort. This work can be extended by making this architecture intelligent in terms of energy efficiency which can further improves the lifetime of WNSs.

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