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Packet forwarding mechanism for mobile robots bounded by random walk model

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Abstract

With the evolution of technology search and rescue operations are now been executed with the help of mobile robots. Wired mobile robot deployment is very cumbersome and constrained. Thus, the need arises for appropriate wireless technology that may support the same or even better functionality. ZigBee is gaining popularity as supporting technology to facilitate the working of mobile robots for search and rescue operations. This is because ZigBee based nodes utilize the industrial, scientific, and medical frequency band that supports a data rate up to 250 kbps. This paper presents a packet forwarding mechanism for ZigBee based mobile wireless sensor network nodes. The results achieved through the reported work shows that the packet loss rate comes around to be 2 percent resulting in a 98 percent successful packet reception at the receiver end.

Keywords: Zigbee, packet, mobile, wireless sensor network, disaster management, search and rescue.

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1. Introduction

Wireless sensor network (WSN) is a collection of sensor nodes capable of sensing physical parameters, temperature, motion and sound [1]. WSN is constituted of many sensor nodes; however, numbers may vary depending upon the target applications from hundreds to thousands. Sensor nodes use appropriate sensors with allied conditioning units to sense the desired physical parameters. Sensor nodes are tailored with a suitable communication mechanism. It facilitates communication between nodes. Sensor nodes are constrained in their working by a limited amount of on-board processing capabilities, available memory, battery life and communication range [1].

The application areas of wireless sensor networks (WSNs) ranges from domestic applications like guided car parking systems and precision agriculture to military applications like monitoring the health of soldiers, to detecting intrusion in a certain location of importance. WSNs also finds use in structural health monitoring of buildings and machines. WSNs have already proven their worth in applications like disaster management and environment monitoring [2].

WSN nodes perform certain vital tasks to facilitate such diverse applications primarily; sensing, signal processing, data aggregation, channel sharing, query processing, data dissemination, caching, routing, and topology management.

The indispensable responsibilities of WSN is of packet forwarding. If the transmitted packet from the source does not reach its desired destination, the network loses its very purpose of existence.

This paper presents a simple solution to reduce information packet loss percentage making work reported unique. Mechanism reported has the potential to be implemented to sustain communication in case of disaster-affected irregular terrain. This is achieved by employing a dynamic packet forwarding mechanism.

The mechanism is based on received signal strength indicator (RSSI) value of the receiver node as perceived by the transmitter node for mobile wireless sensor network nodes (MWSNN). As a result, the packet loss percentage drops to meagre two percent.

Section 2, presents the literature review part. Section 3, presents the methodology. Section 4, simulation and result analysis. Section 5, presents concluding remarks on the work and possible future work that may be carried.

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2. Background

With the advancement in technology, search and rescue (SAR) operations after a natural calamity, like an earthquake, blizzard and avalanche are now being facilitated and even completely carried out by mobile robots. Thus, reducing the risk involved in endangering more human lives during a rescue operation.

Researchers have worked on various aspects of robot design, communication and deployment. ZigBee is among one of the popular wireless communication technologies. Sensor nodes that constitute WSN employ transceivers working at 2.4 GHz. This frequency band has a reasonable penetration capability. The reason for its popularity are the availability of low-cost transceivers, data rates of up to 250 kbps, available channel bandwidth of 5 MHz, and support for wireless communication from 10 meters to 75 meters range [3].

Researchers reported the dynamic inclusion of mobile robots in predefined groups employed for a SAR in the disaster-hit area [4]. In case a robot malfunctions or itself meet with causality. Gunn and Anderson [5] developed a novel mechanism of clustering mobile robots into groups. They developed the mechanism for a target application of search and rescue in an urban environment. The robots were capable of joining and creating new groups if they lose contact from the original group due to loss of communication.

Researchers even exploited the use of hexapod to scale difficult terrain for successfully performing search and rescue operation [6]. The advancement in the allied areas has resulted in an amalgamation of swarm intelligence, mobility of robots and fuzzy logic [7]. The focus was on selecting a leader of the swarm, whose responsibility is to guide the swarm towards a victim of a deserter.

Min et al [8], developed a relay node deployment strategy to facilitate to-and-from communication for prototype SAR mobile robots. They employed genetic algorithm (GA) and particle swarm optimization (PSO) techniques to finalize the proper positions of relay nodes for sustained communication between source and destination.

Researchers developed a surveillance robot [9] which could be controlled by an android based mobile handset. The communication was based on Wi-Fi. The drawback of this strategy is the use of Wi-Fi instead of ZigBee. In a disaster-affected area, Wi-Fi is less likely to be available. Thus, use of such a system would not be possible.

Researchers developed FireFly[10], a hardware platform. Which can support audio streaming with sensed data. The testing was done for cave-in incidence in coal mines. But, the observed constraint was that the work was carried out for static nodes only. And may fail for mobile robots under extreme conditions. Though the use of time division multiple access may be able to sustain communication under light use conditions.

To facilitate communication for mountaineers [11]. Researchers reported communication system had a mix of Bluetooth and ZigBee technology. But, again the deployed relay communication nodes were reported to be static in nature, that is, the relay nodes were immobile. Thus, not suitable for a rescue operation to be performed by mobile robots.

The use of RSSI value for position estimation has been reported in the literature [12]. The values perceived by three neighbour nodes is used to triangulate the transmitter. Thereby, allowing the neighbours to estimate the position of the transmitting node.

How a sensor perceives a phenomenon, its capability is modelled by its coverage model. Several coverage models have been reported in the literature ranging from simple omnidirectional Boolean disk model to directional sector coverage model [13].

Random walk [14], a stochastic method, has been exploited by researchers as a packet forwarding mechanism employed for mobile Adhoc networks.

3. Methodology

Natural disasters demand significant robustness from the network to sustain communication. This requirement is fulfilled by WSN because of its underlying architecture. In the disaster-hit area, the major issue is connectivity, which is inconsistent in the affected area.

The mechanism reported aimed to develop and simulate a robust packet forwarding mechanism which was based on ZigBee for mobile robots bounded by the random walk model. Allowing mobile robots to take one step at a time in any direction chosen randomly by robots. This model for movement is chosen to simulate the movement of robots in irregular terrain, of a disaster-affected area.

Secondly, to test the sustainability of wireless communication under a scenario where nodes may fail any time or obstacles may obstruct communication between mobile robots.

Due to incurred damages, the pre-existing infrastructure may not be available or is not capable any more to facilitate communication in a disaster-hit area.

The mobility model used for this work is the random walk mobility model. Wherein the robots are free to move in any direction at any given time. The test area is of 400 m^2.

The proposed mechanism selects an appropriate mobile relay node for forwarding packet based on the perceived values of RSSI. For simplicity, the communication pattern of the WSN node is assumed to be omnidirectional. If the node under consideration does not meet the criterion, then the next node is reviewed in a round-robin manner till the time transmitter has chosen a node which meets the criterion for transmission. For this work, the threshold value considered for RSSI was - 92 dBm.

In this work, Boolean disk sensing model [13] is used. The advantage of this model is the simplicity of implementation in a simulation environment. It is defined by following coverage equation

$$\boldsymbol{f}\big(\boldsymbol{d}(\boldsymbol{x},\boldsymbol{y}),\boldsymbol{\varphi}(\boldsymbol{x},\boldsymbol{y})\big)=\begin{cases}\mathbf{1}, & \boldsymbol{if}\ \boldsymbol{d}(\boldsymbol{x},\boldsymbol{y})\le \boldsymbol{R}\ \&\ \boldsymbol{\varphi}\le\boldsymbol{\varphi}(\boldsymbol{x},\boldsymbol{y})\le\boldsymbol{\varphi}+\boldsymbol{\omega}\\ \mathbf{0}, & \boldsymbol{otherwise}\end{cases}$$

Where,

$d(x, y)$ is the Euclidean distance between a sensor positioned at x and a space point y , and $\varphi(x, y)$ is their angle.

Figure 1 shows one possible scenario with one mobile sensor node connected to a server through five mobile relay sensor nodes.

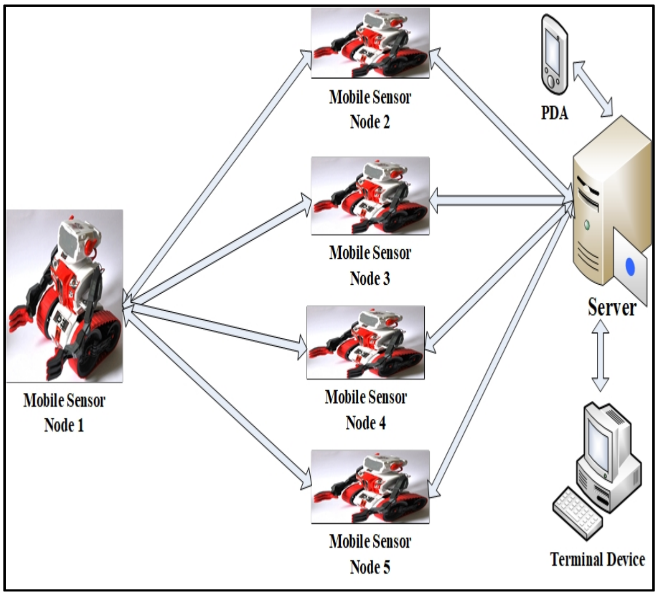

Fig. 1. Scenario depicting one mobile sensor node with five relay nodes connecting to the server.

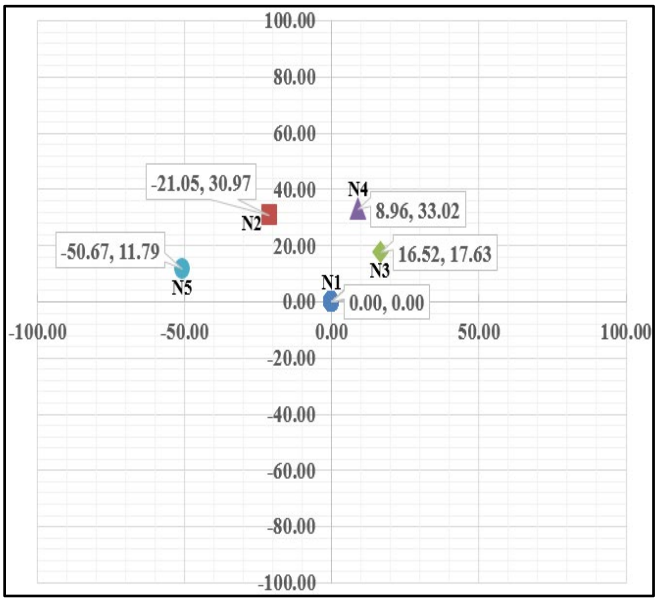

Fig. 2. Scenario depicting one mobile sensor node with five relay nodes deployed in an area of 200x200 m^2.

4. Simulation and Result Analysis

The simulation was performed on a novel platform developed using visual basic (VB) application. The mobile nodes under consideration were bounded in a mesh topology and utilize broadcast mechanism to communicate as shown in figure 2.

Assumptions

The parameters related to the simulation are as follows:

- Number of mobile nodes = 05
- Sensing model: Omnidirectional Boolean disk model
- Omnidirectional sensing area of each node = 0.5 m^2
- Communication model: Omnidirectional Boolean disk model
- Propagation model: Log-normal path loss model
- Communication area of each node = 50 m^2
- Test field area = 400 m^2
- Topology = Mesh topology
- Number of hops = 1

Pseudo Code

Step 1: initialize node; with (0, 0) as initial coordinates of each node

Step 2: scan for nodes in the vicinity

Step 3: evaluate the RSSI of neighbouring nodes

Step 4: relay packets through node meeting the criterion

Result and Discussion

Observations are reported in table 1 and the corresponding bar chart is reported in figure 3. The data in table three suggests that for a small area of 400 m^2, four relay nodes are enough to sustain communication.

Figure 3, highlights the percentage of node utilization. Mechanism reported in this work does not forward the packet in equal proportions to all nodes but to the node which has a higher chance of delivering the information packet to the destination.

This mechanism fails to sustain communication only two percent of the total attempts made for packet forwarding towards the destination and sustain communication. Reported failure percentage of the mechanism is quite negligible. This implies that out of 100 transmitted packets 98 packets were received successfully at the receiver.

Table 1. Utilization of relay nodes by node N1 (in %) for packet forwarding.

Utilization of relay nodes	Relay Node number			
	N2	N3	N4	N5
Selection percentage (in %)	70.20	20.84	04.79	02.16

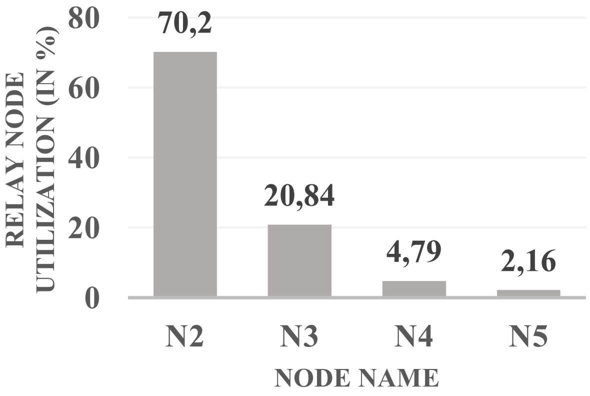

Fig. 3. Utilization of relay nodes by node N1 (in %) for packet forwarding.

5. Conclusion and Future Scope

Table 1, throws light upon the fact that the more the number of relay nodes the less is the packet loss rate for a small area of 400 m^2. Which is intuitive even for the random walk model, used to depict the search and rescue in a disaster-affected scenario.

The constraints of the study are only five number of mobile nodes were considered. Mechanism reported utilizes a mobile node, N2, more in comparison to other available nodes. This highlights the fact that to much use of N2 for communication might drain its batteries faster. Thus, there is a danger of network failure due to non-functioning mobile node.

The future work should remove these shortcomings of the mechanism reported in this paper.

Received signal power level depicts the sum of the message signal power level and interference. Therefore, it does not guarantee a quality signal, as a result, the transmitted packets get dropped or are received with erroneous data

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