Identifying the Direction of Wind in Wireless Sensor Networks

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Abstract

This paper describes a novel method for determining the direction of a phenomenon such as wind in wireless sensor networks (WSNs). The method is based on a structured grid topology and mainly depends on analyzing the timestamp of each node in the grid at the base station. The topology and the routing protocol are evaluated by simulation using OmNet++ and MiXiM 2.1 framework. Throughput, latency and average power consumption are measured and compared in order to investigate the efficiency of our method.

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1. Introduction

Wireless Sensor Network (WSN) is a network of devices that have one or more types of sensors connected together via wireless communication to monitor cooperatively different environmental conditions such as temperature, humidity, sound, etc. in different locations. WSNs integrate and control a large set of distributed sensing devices (nodes) that use low power microcontrollers that are equipped with sensors, a radio transceiver and a source of power [1, 2]. Sensors perform sampling of specific event...
and then report of that sampled data to the Base Station (BS). BS is connected to a remote processor for final analysis and decisions.

Typically WSNs implements five layers; application layer, application support Sublayer, network layer, MAC layer and the physical layer [3, 4]. The physical and mac layer are implementing IEEE 802.15.4 standards and a full details about the specific standards of the physical layer and MAC layer can be found in [3]. The network layer implements the data service, which implements the mechanism for application software to route data through the WSN, and the management service, which supplies several controlling service functions; it can start a new network, discover failures and neighbor nodes suitable for routing. The Application Layer is used to configure the Network Layer.

2. Related work

There is a considerable body of research work related to structured grid WSN that allow place the nodes and setup a routing protocol to reach the BS [5, 6]. The aim of so called adaptive routing algorithm (ARA) suited especially for grid WSN. This algorithm takes into account the remaining energy of the sensor nodes and configures the paths in order to maximize the network lifetime. It also presented data aggregations techniques based on temporal and spatial correlation characteristic for monitoring and data acquisition sensor networks [13].

For cluster configuration of the WSN some algorithms where proposed [7, 8] to reduce the energy consumption. In [9] a hierarchical structure is adopted and multi hop before clustering is produced. Another location based routing protocol that utilize the cluster topology is proposed in [10]. Cao and Porta [11] used voronoi diagram as the coverage strategy that helped to cover the area and determine the coverage percentage for both grid and non-grid topologies. Combination of voronoi diagrams and Particle Swarm Optimization algorithm is explained clearly in [12]. The authors stated that Particle Swarm Optimization application in voronoi diagram approach can concede better coverage result.

3. Proposed scheme

In order to identify the direction of the wind, a grid such as Fig.2 (a) needs to be constructed. The identification of the direction is done by analyzing the timestamp of each node in the grid at the base station. The algorithm below represents our proposed method for detecting the wind direction.

For each node in the grid
If wind detected
begin
Report the time and broadcast it as a message
For each node receiving the message

\begin{verbatim}
begin
If the node in the routing table of the sender node,
Then broadcast the message 
Otherwise discard it 
If the message received in the BS 
Begin 
While (# of received messages <N or time <T) 
Send the message for analysis to the PC 
end 
end 
end
\end{verbatim}

Where \(N\) is number of nodes in the grid and \(T\) is an arbitrary waiting time before the analysis begins.

Considering for instance the direction of the wind at specific time; if the wind is approaching from the west, nodes \{4, 8, 12, and 16\} in Fig.2 (a) will detect first (i.e. any kind of wind event such as change in speed) and they will report the timestamp of the event to the BS according to the algorithm above. After some time, nodes \{3, 7, 11, and 15\} will detect the event and report it to the BS and so on for the rest of the nodes in the grid. If for example the wind direction is southeast, node 4 will detect first and nodes 3, and 8 will detect next and so on. Fig. 2 (b) shows an initial effective routing scheme to minimize collision as suggested in [13]. The BS send the received messages to the PC which analyzes these timestamps for this specific period of time and makes a decision about the direction of the wind.

![Diagram](image-url)

Fig. 2. (a) Grid network with 4X4 dimension and wind direction is east; (b) Routing protocol for our scheme
4. Results & discussions

The experiment achieved by simulating a wireless grid topology that consists of 20 nodes and one base station (BS) represented by node [0]. The simulation time is 300s and the distance between each node and another is 100m. The area of interest is 600m X 800m and the RSSI is -50 dBm. If the noise level exceeds RSSI, then interference is detected. We assume synchronization between nodes in all experiments.

The simulation is divided into two cases as described below.

Case 1:

The grid in this case consists of 4 columns and 5 rows. And the connection is as in Fig.2 (b) and each node is connected to its neighbor in the same row. This case has two approaches:

A. All nodes in each column send at different time of the simulation time, where the difference time to send between each two adjacent nodes in the same column is 0.1 milliseconds and the difference time to send between each two adjacent nodes in the same row is 10 milliseconds of the simulation time to avoid collision. So 100% of packets received at base station.

B. In this approach we repeat the same experiment as in approach A except that, all nodes in the same column send at the same time (contention based) to investigate the collision of our method. As a result, the number of received packets at the BS is 14 packets which indicate that 70% of the packets are received at the BS.

Fig.4 (a) shows frames that are interfered and retransmitted, frames that are not interfered, and frames dropped at each node during simulation period. Fig.4 (b) represents the latency of the nodes that BS received from in both approaches. The latency is higher for approach B at the last four nodes because MiXiM framework is taking account for number of retransmissions. The power consumption at each node is shown in Fig.4 (c). As expected, approach B is consuming more power than approach A since collisions are higher in approach B.
Case 2:
The simulation in this case consists of the same structure as in case (1) except that, each node sends to its neighbor of neighbor in the same row. For instance, node [4] will send to node [2] instead of node [3]. This case also has two approaches:

A. This approach is the same of approach A in case1.

B. This approach is the same of approach B in case1. Number of received packets at the BS is 13 packets, so; 65% of the packets are received at the BS.

Similar to Case1, Fig.5 (a) shows frames that are interfered and retransmitted, frame that are not interfered, and frames dropped at each node during simulation period. Fig.5 (b) represents the latency of the nodes that BS received from in both approaches. The overall latency for approach B is higher than approach A. The power consumption at each node is shown in Fig.5 (c). Approach B is consuming more power than approach A since collisions are higher in approach B.
In both cases, the wind direction is identified and guaranteed when there is a time delay between the nodes that are detecting the wind. To address this issue we introduced the two approaches A and B in both cases. The results suggest that introducing a timer between nodes is best since number of received messages to the BS in both cases is 70% and 65% only for a specific period of time. In addition, these two cases are chosen to investigate the possibility of increasing the life time of the grid by adding more columns of nodes between each two columns of nodes that are in range. Also, to determine the whether the collision will sharply increase or not because of the added columns of nodes. The results show that number of interfered and dropped frames in case 2 are around two times the interfered and dropped frames in case 1 and the latency and power are also softly increased. In general, case 1 is better than case 2 and the possibility of inserting columns of nodes to the grid to increase the lifetime is possible since number of received packets at the BS is almost the same.

Fig. 5. (a) Interference graph for approach B for case 2; (b) Latency’s graph per node in both approaches for case 2; (c) Average power consumption per node for case 2
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References