Direction Determination in Wireless Sensor Networks Using Grid Topology

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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 Qualnet 5.2 framework. Throughput, latency and average power consumption are measured and compared in order to investigate the efficiency of our method. We evaluate various parameters like Average End-to-End Delay (sec.), Residual Battery Capacity (mAhr), Throughput (bits/sec.), and Jitter (s) using IEEE 802.15.4 AODV (Ad-hoc on demand distance Vector Routing Protocol) by applying Grid Topology.**

Keywords —IEEE 802.15.4; Direction; Phenomenon; Wireless Sensor Networks; WSN; Routing Protocol: AODV, Qualnet 5.2.

I. Introduction

A wireless sensor network (WSN) is [1] usually consists of several sensor nodes distributed either inside or very close to a geographical region of interest with a view to sense, collect, and disseminate data relating to one or more parameters. Energy efficiency can be achieved at both node and network levels. At the node level, radio management, modulation, computation, packet forwarding, and interaction among layers can be made energy efficient.

Wireless sensor networks (WSNs) are the hot of current researches in computer networks [2]. WSNs are the combination of many technologies, such as wireless communication, sensors, embedded computing and distributed information processing, and they are widely used in military, environmental, medical, transport and other fields. Coverage control is one of the key technologies for applications of WSNs. It affects the monitoring quality as well as the energy consumption greatly.

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Sensor networks are deployed and utilized for various applications in both civilian and military settings. They tend to be very application-specific. Recently, unattended wireless sensor network (UWSN) has become a subject of attention in the security research community of sensor networks [3-6]. In the unattended settings, a sensor is unable to communicate to sinks at will or in real time. Instead, it collects data and waits for an explicit signal to upload accumulated data to sinks (or mobile sinks). For sensor nodes are not tamper-resistant and the sink presence is intermittent, sensors must safeguard their critical readings temporarily. The special design and character of sensors and their applications make WSNs different from traditional networks.Fig.1 represents the Wireless Sensor Network [7].

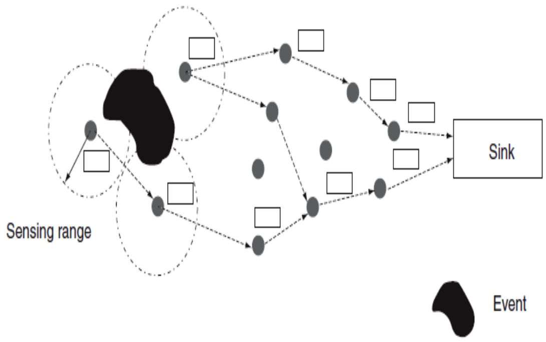

Fig.1 A Wireless Sensor Network

In this work a technique for Grid Topology is applied to overcome such limitations. We evaluate various parameters like Average End-to-End Delay (sec.), Residual Battery Capacity (mAhr), Throughput (bits/sec.), and Jitter (s) using IEEE 802.15.4 AODV (Ad-hoc on demand distance Vector Routing Protocol) by applying Grid Topology.

The rest of the paper is organized as follows. A brief overview of the Protocols is given in Section 2. Importance is presented in Section 3. Then the Network Simulation is discussed in Section 4. Next, in Section 5,

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Performance Analysis is presented. Finally, we conclude the paper in Section 6.

II. BRIEF THEORY

2.1 Routing Protocols

2.1.1 Ad-hoc On-demand Distance Vector (AODV) Routing Protocol:

The Ad-hoc On-Demand Distance-Vector Protocol (AODV) [8] is a distance vector routing for mobile ad-hoc networks. AODV is an on-demand routing approach, i.e. there are no periodical exchanges of routing information. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. The protocol consists of two phases:

A. Route Discovery
B. Route Maintenance

A. Route Discovery

A node wishing to communicate with another node first seeks for a route in its routing table. If it finds one, the communication starts immediately, otherwise the node initiates a route discovery phase. The route discovery process consists of a route-request message (RREQ) which is broadcasted. If a node has a valid route to the destination, it replies to the route-request with a route-reply (RREP) message.

B. Route Maintenance

The second phase of the protocol is called route maintenance. It is performed by the source node and can be subdivided into: i) source node moves: source node initiates a new route discovery process, ii) destination or an intermediate node moves: a route error message (RERR) is sent to the source node.

2.2 MAC Protocols

2.2.1 IEEE 802.15.4 MAC

The IEEE 802.15.4 [9] defines the PHY and MAC layers for a low-rate wireless personal area network (LR-WPAN). An LR-WPAN is a simple, low cost, low power, low QoS, and low data-rate communication network. It facilitates ease of installation, reasonable battery life, and reliable data transfer among devices within the limited range of around 10 meters. This protocol was not specifically designed for WSNs, but its capability to fit with different WSN requirements by appropriately tuning parameters has enabled it as a front runner for several WSN applications.

IEEE 802.15.4 supports two different device types that can communicate in an LR-WPAN network: a full-function device (FFD) and a reduced-function device (RFD). The FFD can operate in three modes to serve as a PAN coordinator, a coordinator, or a device. An FFD can communicate to RFDs or other FFDs, while an RFD can communicate only to an FFD. RFD does not have the capability to relay data messages to other end devices. The PAN coordinator is the primary controller of the PAN. All devices operating on a network have unique 64-bit addresses. This address may be used for direct communication within the PAN, or a short address may be allocated by the PAN coordinator when the device associates and used instead. The PAN coordinator might be mains powered, while the devices will most likely be battery powered.

III. RELATED WORK

Mohammed Alasli *et al.* [13] analysed Quality of Service parameters of WSN based on IEEE 802.15.4 Grid topology using OmNet++. They analysed the QoS parameters like Throughput, latency and average power consumption. 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.

IV. NETWORK SIMULATION

This section describes simulation scenario and various simulation parameters considered for performance analysis.

4.1 Simulation Scenario

The main objective of this simulation study was to evaluate the performance of MAC protocol like IEEE 802.15.4 in wireless sensor network using AODV. The simulations have been performed on QualNet version 5.2, software that provides scalable simulations of wireless sensor networks. In the scenario there are 156 nodes connected in the form of grid. The terrain area is taken as 100m×100m. The scenario is simulated for 500s. The type of wireless propagation model is Two Ray ground propagation. The traffic type used is TRAF-GEN. There is one PAN coordinator where all the Grids have one Coordinator that collects data from different nodes (FFDs). The packet size used is 38 bytes and message inter-arrival time is 1s. Fig.2 shows simulation scenario setup.

4.2 Simulation Parameters

To evaluate QoS parameters performance for IEEE 802.15.4 MAC using AODV routing Protocol. We have considered the following QoS performance metrics:

- **Average Jitter:** Average Jitter is the variation of the packet arrival time. In jitter calculation the variation in the packet arrival time is expected to be low.
- **Throughput:** Throughput is the average rate of successful data packets received at destination. It is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second.
- **Average End-to-End delay:** It indicates the length of time taken for a packet to travel from the TRAF-GEN (Traffic Generator) source to the destination. It represents the average data delay an application experiences during transmission of data.

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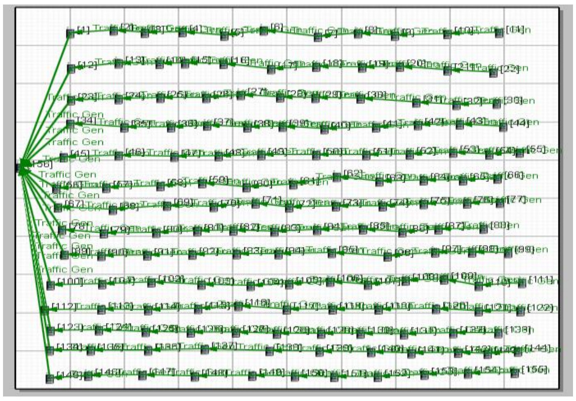

Fig.2 Simulation Scenario

- **Residual Battery Capacity (mAhr):** This is the amount of energy present in battery in mAhr after completion of data transfer for a particular time interval.
- **Energy Consumption (mWh):** This is amount of energy consumed by nodes during the periods of transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is mWh.
- **Percentage of time in Sleep mode**: It indicates the percentage of time in sleep mode. It indirectly relates to duty cycle .The more is the percentage of time in sleep mode, the less is the duty cycle.

V. PERFORMANCE ANALYSIS

This section presents simulation results of various performance metrics for evaluation of IEEE 802.15.4 MAC using AODV routing protocol.

Fig.3 shows performance of Average Jitter at Traffic-GEN Server. Generally Average Jitter is expected to be low.

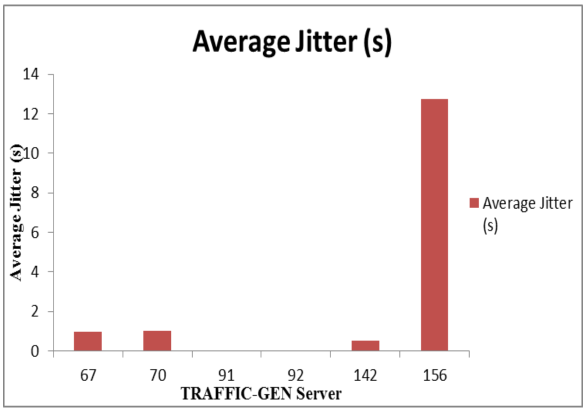

Fig.3 Average Jitter

Fig.4 shows performance of Throughput at Traffic-GEN Server.

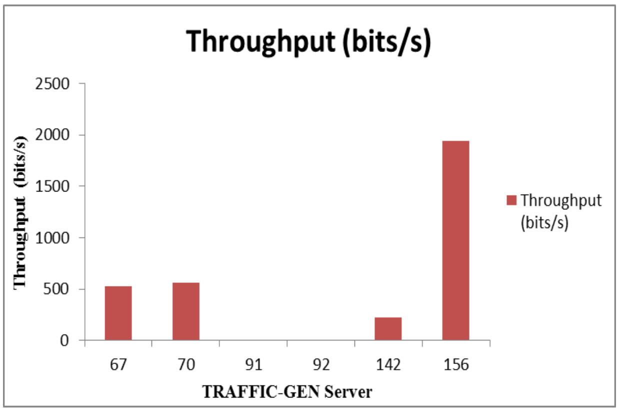

Fig.4 Throughput

Fig.5 shows Residual Energy Capacity of each node in the network.

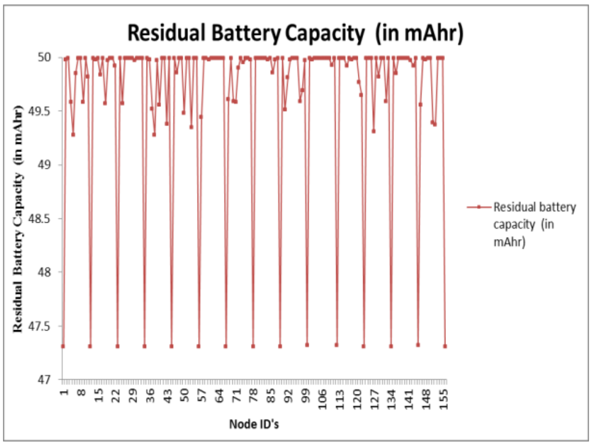

Fig.5 Residual Energy Capacity

Fig.6 shows Total Data Units Received at Traffic-GEN Server.

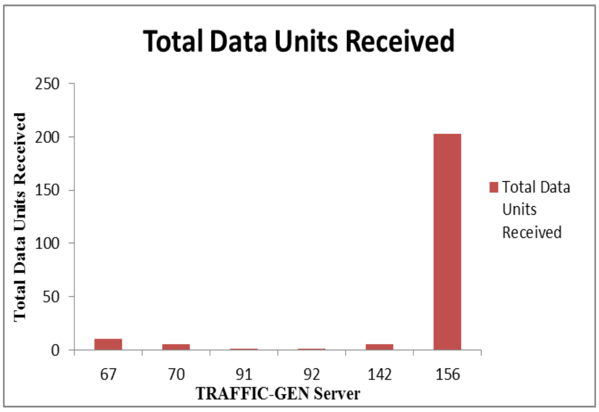

Fig.6 Total Data Units Received

Fig.7 to Fig.10 shows energy consumed by the IEEE 802.15.4 AODV Protocol in case idle, receive, sleep and transmit modes.

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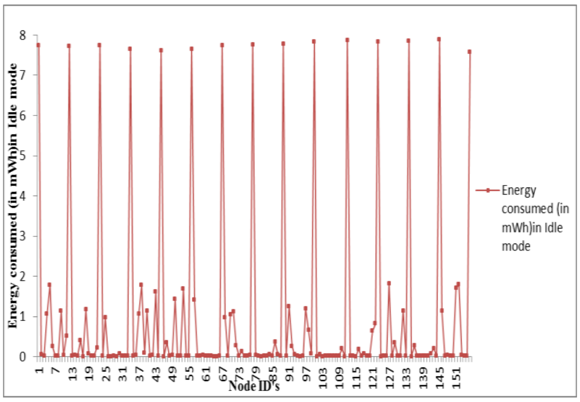

Fig.7 Energy consumed in Idle mode

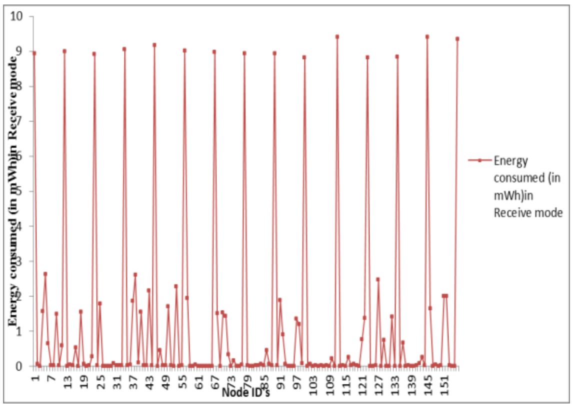

Fig.8 Energy consumed in Receive mode

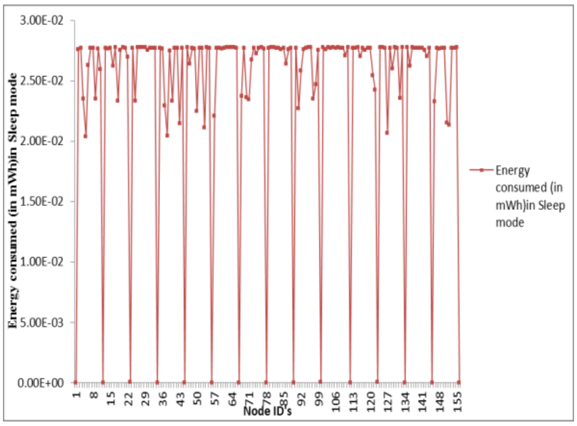

Fig.9 Energy consumed in Sleep mode

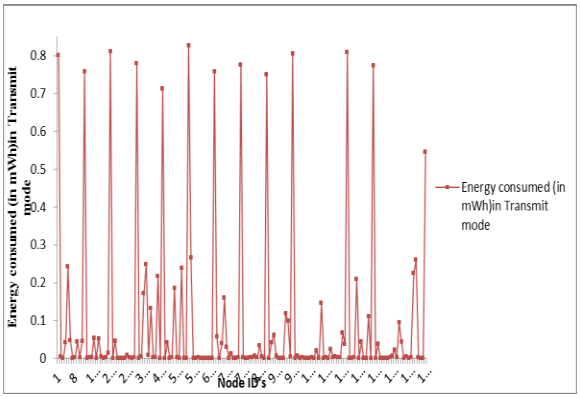

Fig.10 Energy consumed in Transmit mode

VI. CONCLUSION

In this work Average Jitter is low except at PAN-Coordinator. Residual Battery Capacity is high that may prolong the life of the Network. Similarly the energy consumed in Idle, Receive, Sleep and Transmit mode is shown in Fig.7 -10.

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