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E-BEESENSOR: ENERGY EFFICIENT AND DYNAMIC WIRELESS SENSOR NETWORK ROUTING PROTOCOL

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ABSTRACT

This dissertation proposes a new routing protocol is extending the existing BeeSensor routing protocol and hence it is named as E-BeeSensor protocol. E-BeeSensor based on Energy consumption for WSNs. Energy is consumed in sending or receiving the packets between the nodes. Here we are measuring the Energy consumption in different states and adding a new Energy consumption field in Routing Table as well. Energy consumption based Routing is thus a new benchmark in which the routing will consider the energy consumption for selecting the path. Doing so will reduce the chances of network failure. We show that mechanism is stable, counter-active, reliable and fair. The NS2 simulation results show that E-BeeSensor routing protocol achieved better performance of energy efficiency, packet delivery ratio, and reduced latency and control overhead with comparing to performance of the existing routing protocols BeeSensor and AODV.

KEYWORDS: AODV, BeeSensor, Hop, E-BeeSensor, Energy Consumption, Wireless Sensor Network, Packet Delivery Ratio.

INTRODUCTION

Wireless sensor networks (WSNs) are a subcategory of mobile ad hoc networks (MANETs), efficient design and implementation of WSNs has become a very important area of research in recent years, WSNs are produced at first time for military applications only, but with the rapid development of Micro-Electro-Mechanical Systems (MEMS) technology, WSNs have exceeded many obstacles in a short period of time. [1]

In WSNs there are tens or hundreds or thousands autonomous sensor nodes, each node of WSNS have sensors, processor, wireless transceiver and battery (Fig. 1.1). The sensor node equipped with a number of functions such as sensing the environment and communication capabilities between each other. Hence, the sensor nodes have the ability to form a communication network during the moving state and continuous changing of topology. In order to cover the biggest events possible, the nodes publish to wide areas. These nodes can also be available in moving vehicles and can interact with different types of environment. The purpose of a sensor node is to send the monitoring data– for instance temperature – and communicate it to a base station.

The most important different between WSNs and traditional ad hoc networks that it is not possible to recharge or replace batteries, for that routing in WSNs has been a challenging task primarily because of limited processing, communication and energy resources available at a sensor node. Consequently, routing protocols must be designed with low processing complexity and minimum communication overhead.

The intelligence displayed by insect colonies – commonly referred to as Swarm Intelligence (SI) – serves as an ideal model for developing routing protocols for WSNs because such colonies ‘‘consist of minimalist, autonomous individuals that through local interactions self-organize to produce system-level behaviors that show life-long adaptively to changes and perturbations in the external environment.

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BeeSensor protocol is one of latest proposed routing protocol which has been engineered by taking inspiration from relevant features of Bee Ad Hoc and Bee Hive [2] protocols inspired by the foraging principles of honey-bees.

The important contribution of this paper is to propose ExtendBEESENSOR (E-BeeSensor) protocol which has been designed by taking inspiration from relevant features of BeeSensor.

For E-BeeSensor there are many important assumptions, each node will be

a. Find their depth d from sink node (sink node depth =0).
b. Maintain a table which contains the energy level of all the neighbor nodes and their buffer occupancy.

2- Initially
   a. All the source nodes will find the shortest path towards destination.
   b. All nodes will be in sleep mode except source node.
3- When any of the source nodes wants to send the data, that node should activate the path through which data is going to be sent.
4- When energy level of any node goes below threshold, as given by its parent, or congestion is detected at that node then,
   a. That node informs its parent.
   b. Parent will find another path towards destination.
5- When any node detects all its lower depth nodes below current threshold value
   a. It calculates new threshold and,
   b. Start sending data on those paths again.

To evaluate the performance of E-BeeSensor, we have compared it with well-known SI algorithm, BeeSensor [1], and well-known classical ad hoc routing protocol, AODV [3]. In our experiment

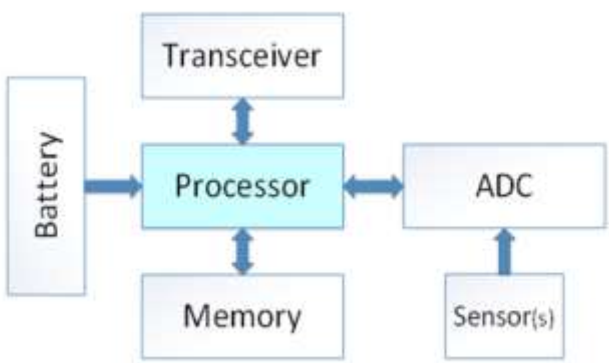

Figure 1.1: Internal architecture of a sensor node

used different numbers of nodes and different scenarios. The results of our experiments demonstrate that the new proposed E-BeeSensor protocol achieved better performance than AODV, and BeeSensor. The results shown that the E-BeeSensor achieve the best performance with the least energy, control overhead latency, and higher packet delivery ratio.

RELATED WORKS

The main difference between WSNs and other types of wireless ad hoc networks that is WSNs have specific traffic patterns in the form of multicast (one-to-many) and converge-cast (many-to-one) trees [4], the nodes of WSNs are small and equipped with limited non-rechargeable battery, little memory, low-end processors, and small bandwidth wireless links. A vast majority of intended applications of WSNs require the deployment of the sensor nodes in large numbers, ranging from thousands to millions, and hence the scalability of used protocols is also a major concern [5].

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In 2004, H.F. Wedde, M. Farooq, and Y. Zhang were the first to present BeeHive [6], a novel routing algorithm for wireless networks inspired by the communicative and evaluative methods and procedures of bees.

More specifically, BeeHive is built around two types of agents, the short distance and the long distance agents which are proactively generated at the nodes and are designed after the way bee foragers respond to bee dances. The responsibility of both types of agents is to explore the network and to evaluate the quality of paths that they traverse, in order to update node routing tables. Short distance agents are allowed to move only up to a restricted number of hops in the network, whereas long distance agents have to collect and disseminate routing information in the complete topology. Moreover, BeeHive has been extensively tested and evaluated. Its results conclude that while it achieves similar or better performance compared to state-of-the-art routing algorithms, bee agents occupy smaller bandwidth and require significantly less processing time compared to the agents of existing algorithms. BeeHive has been an inspiration to further research and enhancements.

In 2005, H.F. Wedde et al have proposed BeeAdHoc [15], a routing algorithm for energy efficient routing in MANETs. By utilizing two types of agents, scouts and foragers, BeeAdHoc is able to reactively search for routing solutions, consuming less energy compared to existing state-of-the-art approaches.

Now will briefly review the well-known **Classical and SI** routing protocols for WSNs.

Classical routing protocols

Ad-hoc On-demand Distance Vector (AODV) protocol discovers routes by broadcasting a RREQ. Intermediate nodes keep broadcasting RREQ until it reaches the destination or a node with a valid route which responds with a RREP. A node which is aware of its surrounding environment (e.g., neighbor nodes) locally broadcasts a HELLO message; also the route request (RREQ) packets are sent if a sender is finding a route to BS. In this case, the path is made by route reply (RREP) packet unicasting to sender.

The AODV uses the route discovery mechanism with broadcasting instead of the source routing. Each node has a local routing table (RT) for quick response time to requests and establishment. Each row of RT shows the next hop from this node to the destination. The route discovery process is implemented when a node needs to communicate with other nodes and route information does not exist in its RT. The protocol uses the sequence number for more maintenance of the routing information among nodes.

This sequence number will cause the efficient use of network bandwidth by minimizing the network load for the control and data traffic. When a node wishes to send data to the BS, the source node creates a RREQ packet. This packet contains the source node's IP address, source node's current sequence number, the destination IP address, and destination sequence number that are broadcast in the source transmission range. Broadcasting is done via flooding. Finally, this packet will receive a node that possesses a current route to the destination.

Firstly, the receiver checks the RREQ packet. If the intermediate node has an entry in RT for the desired destination, the intermediate node will make a decision by comparing its entry sequence number with RREQ packet sequence number. If the intermediate node has not received this RREQ before, meaning that it is not the destination and does not have a current route to the destination and RREQ sequence number is bigger than saved sequence number, it rebroadcasts the RREQ [7, 8]. When the intermediate node is capable of replying, it means that it has a sequence number greater than or equal to that contained in the RREQ. If a node receives a packet with the same broadcast ID and source address, it drops this RREQ packet (sometimes maybe a node receives multiple copies of the same RREQ packet) [8].

Furthermore, it maintains multiple next hop nodes and uses link-layer feedback to avoid paths with high packet loss. Since these WSN-based enhancements in AODV make it energy-efficient, it can serve as a baseline protocol in terms of latency as well as total energy consumption.

Sensor Protocol for Information via Negotiation (SPIN) [9] is a data-centric protocol that negotiates high level meta-data descriptors to perform energy-efficient routing. The data are advertised by the sources and nodes interested in the data may send a request to the advertising node.

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Directed diffusion [10] is another popular routing paradigm for WSNs, which introduces the idea of aggregation to eliminate data redundancy. The sink node floods the query containing the attributes of the required data. The source nodes located in the targeted region respond with the data which are then routed (and aggregated on the way) along the reverse links. The routes can be reinforced positively or negatively leading to increase/decrease in the data delivery rate.

Low Energy Adaptive Clustering Hierarchy (LEACH) [10] organizes the sensor nodes into clusters – each cluster having a cluster head. The role of the cluster head is to collect data from its members and communicate it to the base station. The nodes take turns acting as cluster heads in order to extend the network's lifetime.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [11] is a variant of LEACH protocol in which the nodes form a chain along which the data are communicated to a designated node. This node ultimately transmits it to the base station.

Although it avoids the overhead of cluster formation, it is based on the same assumption as LEACH: every node can directly reach the base station.

Shared Wireless Info-station Model (SWIM) [12] targets low latency in data delivery but at the cost of an additional memory requirement. It works in three phases: nodes (1) sense the events, then (2) exchange them with their neighbors, and finally (3) deliver the stored events to the base station once they come into its vicinity.

ACtive QUery forwarding in sensor nEtworks (ACQUIRE) [13] is a data-centric algorithm that resolves complex queries in an energy-efficient manner. The motivation is to resolve the query locally with the help of neighboring nodes. Only partially unresolved queries are forwarded further in the network and the process continues until they are fully resolved.

SPEED [14] is a QoS-aware routing protocol for sensor networks. SPEED caters to requirements of soft real-time applications by guaranteeing a target delivery-bandwidth across the sensor networks.

Maximum Energy Welfare (MaxEW), proposed in [15], is based on an energy-welfare metric computed by averaging and equalization of the energies of the sensor nodes. The objective is to maximize the energy welfare of a nodes neighborhood during the routing process, thus increasing the energy efficiency of the network as a whole.

The authors of [16] proposed an energy-efficient broadcast routing in a WSN following two methods. First, Dynamic Power Management with Scheduled Switching Modes (DPM-SSM) is applied on the top of an uninformed flooding protocol.

As a result, state transitions in DPM-SSM, from active to sleep and vice versa, depend on the residual energy of a node. In the second scheme, a connected dominating set algorithm is applied to construct a routing backbone. Nodes take turns to become part of this backbone resulting in reduced and balanced energy consumption.

Energy-efficient Beaconless Geographic Routing (EBGR) is a stateless, loop-free and energy-efficient event-to-sink routing scheme for WSNs [17]. Nodes involved in the event routing compute their ideal next hops based on energy-optimal forwarding distance.

The authors of [17] also derive bounds on the hop count for event-to-sink routing. To efficiently route multimedia contents, the authors of [18] proposed a geographic routing scheme optimized for finding near-shortest node-disjoint paths.

With the aim of optimizing the energy-efficiency of a WSN, the authors of [19] proposed a lossy compression scheme assuming that the data generated by sensor nodes are highly correlated. Differential pulse-code modulation, with the quantization of the difference between two consecutive samples, is used for noise removal and compression of the sampled data.

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SI routing protocols

Here, a brief literature for swarm based routing protocols is given to WSNs (Dorigo, 2001). Swarm based routing protocols are classified into three categories: Ant based, bee based and slim based.

In the following subsections, will provide a quick overview of four SI-based protocols for sensor networks: Flooded Piggybacked Ant Routing (FP-Ant), Flooded Forward Ant Routing (FF-Ant), Sensor-driven Costaware Ant Routing (SC-Ant) and Energy-Efficient Ant-Based Routing (EEABR) [4].

FP-Ant is a flooding based variant of AntNet. In FP-Ant, each data packet is encapsulated in a separate forward-ant, which is then stochastically flooded towards the sink node. A receiving node, say i, rebroadcasts the forward-ant only if it is closer to the destination. If node i hears the same replica of a forward-ant from one of its neighbors, it abstains from rebroadcasting, in order to further optimize the flooding process.

The backward ants back track the paths followed by forward ants and update the pheromone tables. The forward ants in FF-Ant, unlike FP-Ant, do not carry data packets. The procedures for restrictive flooding of forward ants and for pheromone updating are identical to those in FP-Ant. The data packets – in FF-Ant – are unicast to the destination using probabilistic forwarding.

SC-Ant is an energy-efficient algorithm in which – in contrast to FP-Ant and FF-Ant – the forward ants are unicast to their destinations. The forward ants are equipped with the sensors which can estimate the forward direction towards the destination.

Consequently, the forward ants take the least cost path to travel towards the destination. Pheromone update and probabilistic forwarding of data packets in SC-Ant are identical to that of FF-Ant. EEABR is based on Ant Colony Optimization (ACO) met heuristic [17]. Each node in the network launches forward ants at regular intervals to a specific destination. The forward ants carry the addresses of the last two visited nodes only. Other information is stored in the tables at the intermediate nodes. When the forward-ant reaches the destination node, it is converted into a backward-ant which in turn updates the probability of the path followed by the forward-ant to reach the destination node.

METHODOLOGY INVESTIGATED

In this section, we aim to describe our system model for the proposed routing protocol E-BeeSensor. The most important contribution of our proposed routing protocol is how to reduce the energy, control overhead and delay which is used to reach from the source nodes to destination nodes and also how to increase the packet delivery ratio.

We suppose our network model has been restricted by some assumptions.

1- Each node will
    a. Find their depth d from sink node (sink node depth =0).
    b. Maintain a table which contains the energy level of all the neighbor nodes.

In E-BeeSensor, each sensor node is responsible to find their depth d from sink node which is the distance from the desired node to the sink node, therefore sink node depth is zero (d=0), this is very important to know the shortest path from source to destination, and reduce the time which required to change the path by selecting a suitable node when occur a collision in one of the intermediate nodes.

After that each sensor node is responsible to maintain a table which contains the energy level of all the neighbor nodes, this is very important to know the energy level of each node which help to decide which node is more suitable for the next hop for each transmission, if the low energy level node is used this may be lead to use the total energy of that node and this will lead to turnoff this node, this is very important to increase the life time of the network because it will distribute the utilization of nodes and preferred the node which have the higher energy level.

2- Initially
    a. All the source nodes will find the shortest path towards destination.
    b. All nodes will be in sleep mode except source node.

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Usually, in WSN the nodes are homogenous each node is placed in one of the two mechanisms based on the current state: active or sleep. In the active mechanism, a node uses efficient protocol on the network energy instead of turning off the transceiver for saving energy, while a node in the sleep mechanism has no interaction with other network nodes due to the fact that its transceiver is turned off and that the node energy consumption is lower [21].

In the active mechanism, each node will be in one of the three operational modes: transmit, receive, or idle. In the first mode (transmit), more node energies are consumed for turning on the transceiver and packet's transmit. In the second mode (receive), the node with its transceiver turned on receives a packet, demodulation, and decoding [22] where these operations (packet processing and turned on transceiver) cause energy consumption in the node. After the packet's receiving or sending operations, a node is placed in the idle mode. In the idle mode, each node listens to the communication channel without any sending or receiving in an active manner. In this mode, some functions in the hardware can be switched off, but all circuits are maintained to be ready to operate. Figure (3.1) illustrates these states and communications.

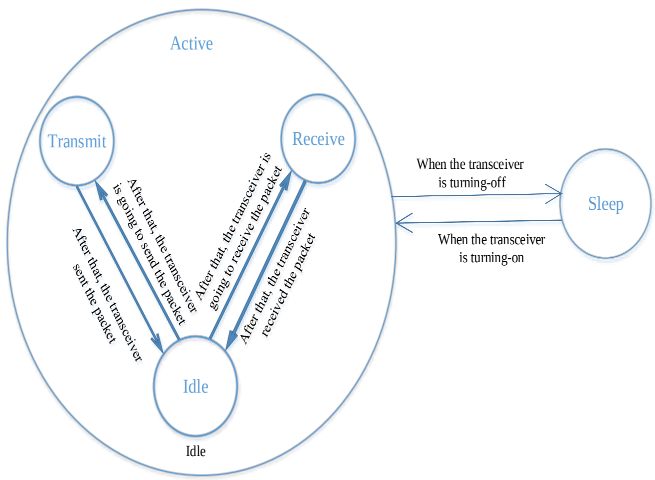

Figure (3.1): Node states.

Each node is able to communicate with other nodes in its transmission range. The maximum distance between two nodes is covered by the transmission range. The transmission range is determined by the signal strength. Thus, higher transmission powers will increase the number of nodes shared with the medium (connectivity degree) [43], and consequently, the probability of finding the destination among the node neighbors will be heightened. Of course, higher transmission range will have more disadvantages like collision problems. When two or more nodes want to send a packet at the same time over the same transmission medium or channel, collision will occur.

3- When any of the source nodes wants to send the data, that node should activate the path through which data is going to be sent.

4- When energy level of any node goes below threshold, as given by its parent or congestion is detected at that node then,

a. That node informs its parent.
b. Parent will find another path towards destination.

If the intermediate node don't have the threshold amount of energy then the node must inform its parent, and then the parent must find another path contain intermediate nodes have energy equal or more than threshold amount of energy and use this path to transmit the data from the source node to the destination node.

5- When any node detects all its lower depth nodes below current threshold value

a. It calculates new threshold and,
b. Start sending data on those paths again.

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Is the case that some nodes detects that all its lower depth nodes are below the current value, in this case the node cant transmit the data to the destination, then this node must calculates a new threshold amount below the first threshold, this process of calculates a new threshold must be continues until find a suitable path between the source and destination.

Practical Results and Analysis

Simulation Platform: For the simulation of this work we have to need the following setups requirement for the same

1) Cygwin: for the windows XP
2) Ns-allinone-2.32.

Network Scenarios: For WSNs, there are multiple network scenarios needs to be prepared in to order to evaluate the performance of packet scheduling methods. In our practical analysis we are varying two main parameters such as number of sensor nodes and another one is number of source and destination pairs which we called as traffic flows.

Mac protocol: 802.11
Scenarios-1: 49/61/81/100/121/144 Sensor nodes
Scenarios-2: 49/100/150/196/256 Sensor nodes
Routing Protocols: AODV/BeeSensor/E-BeeSensor
Packet Scheduler: FCFS

Performance Metrics:

- PDR vs. number of sensor nodes
- Latency vs. number of sensor nodes
- Control overhead vs. number of sensor nodes
- Energy Efficiency vs. number of sensor nodes

Below table 1 showing the all network configurations and parameters for network scenario 1 [converge cast scenario] and table 2 shows the network configuration for network scenario 2 [target tracking application of WSNs].

Number of Nodes	49/61/81/100/121/144
Traffic Patterns	CBR (Constant Bit Rate)
Network Size (X x Y)	1000 x 1000
Max Speed	5 m/s
Simulation Time	100s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV/BeeSensor
MAC Protocol	802.11
Packet Scheduler	FCFS
Number of Flows	5

Table 1: Network configuration for scenario 1

Number of Nodes	49/100/150/196/256
Traffic Patterns	CBR (Constant Bit Rate)
Network Size (X x Y)	1000 x 1000
Max Speed	5 m/s
Simulation Time	100s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s

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Routing Protocol	AODV/BeeSenso
MAC Protocol	802.11
Packet Scheduler	FCFS
Number of Flows	5

Table 2: Network configuration for scenario 2

Results Analysis
Scenario 1: converge cast scenario

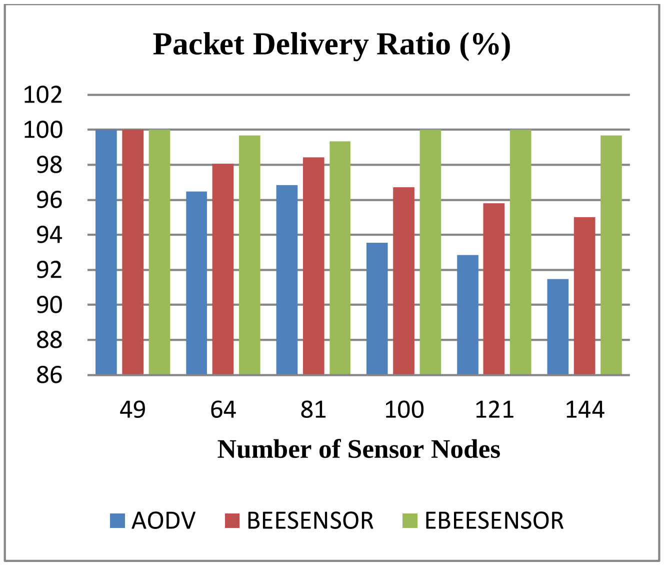

Figure 4.1: Packet Delivery Ratio

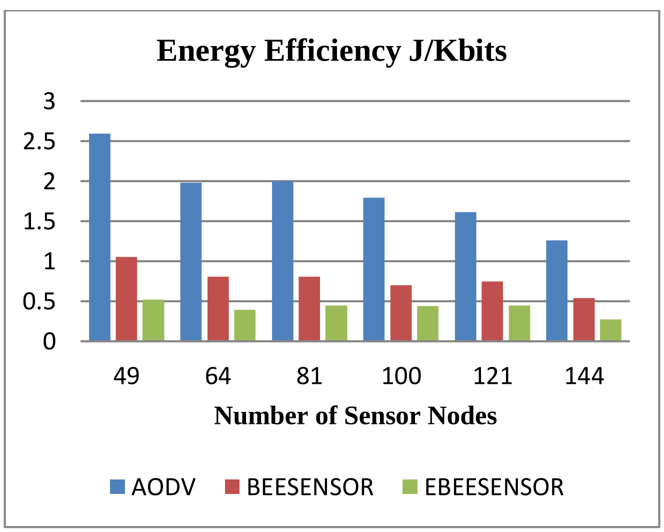

Figure 4.2: Energy Efficiency

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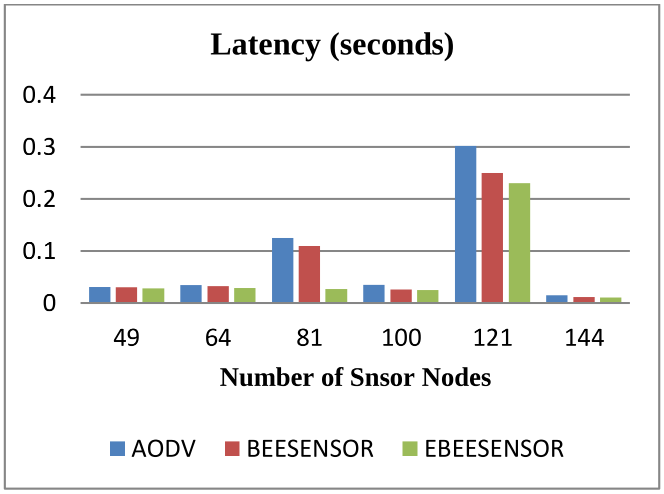

Figure 4.3: Latency

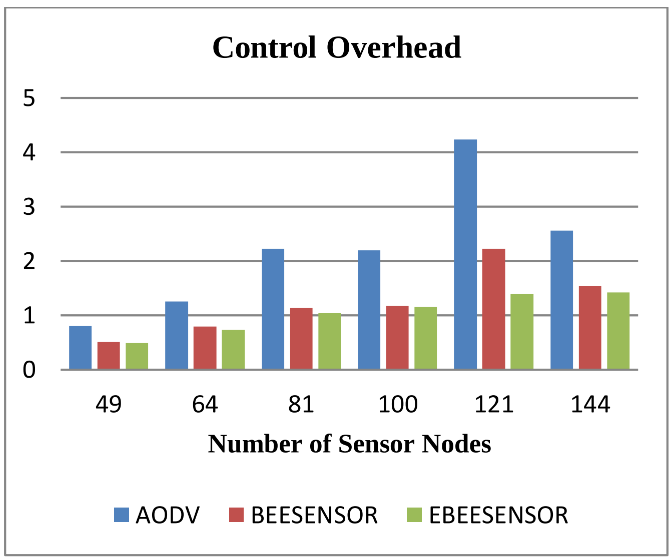

Figure 4.4: Control Overhead
Scenario 2: target tracking application of WSNs

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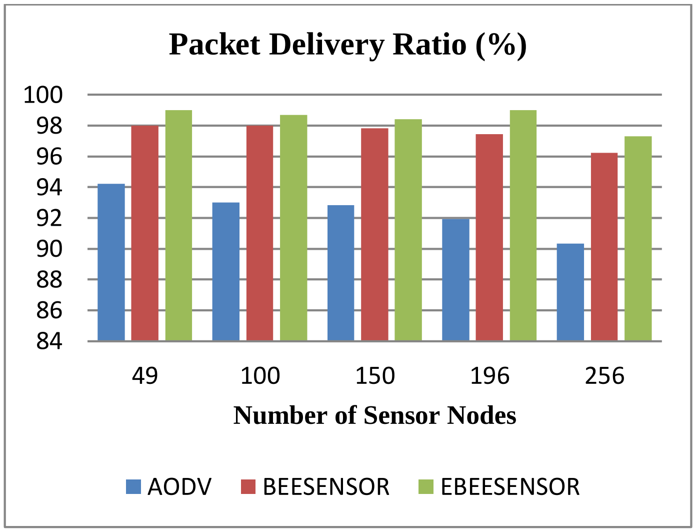

Figure 4.5: Packet Delivery Ratio

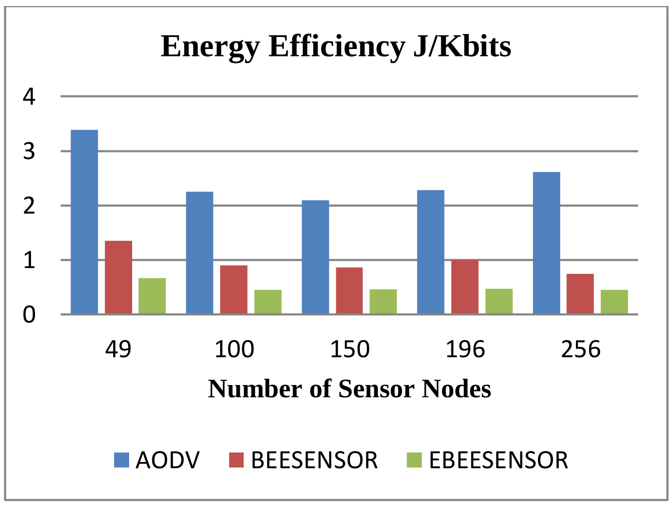

Figure 4.6: Energy Efficiency

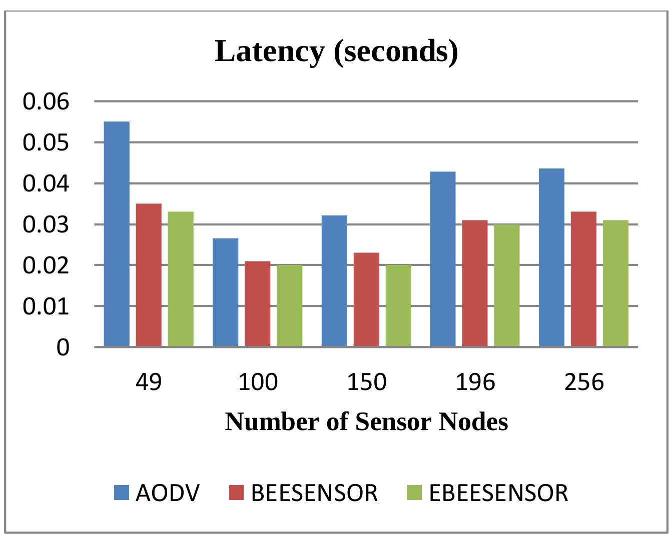

Figure 4.7: Latency

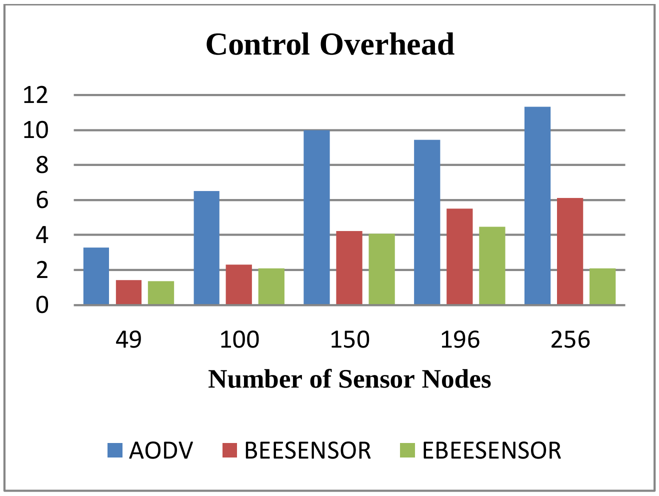

Figure 4.8: Control Overhead

From above practical analysis, it is clear that proposed E-BeeSensor protocol outperforming existing BeeSensor and AODV in packet delivery ratio, control overhead, latency and most importantly energy efficiency.

CONCLUSION AND FUTURE WORK

The main aim of this paper is to investigate the performance of recently presented efficient and scalable E-BeeSensor wireless sensor network routing protocol with different network conditions. The performance showing improved results as compared to existing protocols.

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