6. EEHRP: Energy Efficient Hybrid Routing Protocol for Wireless Sensor Network

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ABSTRACT

A key challenge in the Wireless Sensor Networks (WSNs) is to route the aggregated data from different applications to sink in an efficient and reliable way under mobility consideration for improving throughput, energy consumption and delay. In this context, the paper proposes efficient; delay tolerant Energy Efficient Hybrid Routing Protocol (EEHRP). The core of EEHRP is optimization of multiple metrics for selection of the best route. Multi-Objective optimization is a NP-hard problem from optimization theory. EEHRP tries to obtain a Pareto optimal solution for selecting the best route based on multi-objective optimization. Simulation results demonstrate that, EEHRP is energy efficient, has less delay as compared with state-of-the-art solutions.

Keywords- *Delay; Energy Consumption; Multi-objective; Routing; Wireless Sensor Network (WSN).*

INTRODUCTION

With increased application areas of WSN, the data handling requirements are demanding careful attention to reduce the energy consumption and minimize the latency in communication. Since nodes used for data collection and communication with proper route to the sink are scarce with energy, availability of communication bandwidth, computational speed and storage memory. Also the lifetime of the WSN depends on the energy usage during communication of aggregated packets to destination as sensor nodes consumes more energy in communication than computation and sensing. Also unlike with traditional networks like WI-FI it is difficult to change the energy source of sensor node in the WSN and is the most distinguishing attribute since depletion of node energy results to network failure. For applications in IOT where huge data is collected from different sources (non-smart and smart objects) need reliable transport to destination with efficient route. Hence, a proper balance needs to be achieved between the reliability and energy conservation for an efficient routing in WSN. The effort to choose the efficient route need to consider the single or multi-hop communication, time required to reach destination (transmission delay), energy consumption in deciding the path, the number of packets transmitted and the number of nodes involved in transmission [1].

WSNs are used to collect useful information from the applications. It is different from the other traditional network like ad-hoc and cellular due to First, WSN has large number of sensors deployed and difficult to get the global addressing hence it is important to deal with data rather than its identification. Second, mass data communication happens in one and multi-hop from source node to Cluster head and finally to sink. Third, the nodes used for sensing and communication are scares with resources like energy, memory and communication bandwidth. Fourth, Mobility of nodes in the network increases the overheads with energy depletion and reduces the life-time. Fifth, WSN are application specific and data collected will be based on common phenomenon with increased redundancy [2-3].

The potential sources of energy consumption and delay is the collisions due to multipath data propagation, when a receiver node receives more than one packet at the same time. All packets that cause the collision have to be discarded, and the re-transmissions of these packets increase the energy consumption. Also, the delay introduced in retransmission of packets needs to be calculated for performance evaluation. As the packets generated by the nodes are of different in numbers and, they are routed to BS in the different time slot [2 - 4].

The different methods used to reduce energy consumption during finding the shortest route may include duty-cycled scheduling and synchronization of routes which does not guarantee the efficient and reliable delivery in time. In this connection, with increased data handling capacity and finding the efficient route in terms of reduced latency, energy consumption, and routing overheads, demands for the development of lightweight multi-objective protocol. With increasing demand of applications with energy saving and reduced latency in communication, Multi–objective routing is a promising technique to achieve the better QoS parameters in WSN. Furthermore, this novel routing can also guarantee the minimum delivery latency from each source to the sink. The policies of routing in WSNs are impacted by countless thought-provoking issues. These issues must be overthrown prior to effective communication in WSNs. Node placement, Energy concerns, Data transfer model , Node/link heterogeneity, Fault acceptance, Scalability, Network activity, Transmission means, Association, Exposure, Data accumulation[5].

The focus of paper is elaborated with different sections as; section II presents an overview of related works focusing on the requirements of Multi-objective in WSN-IOT. Section III gives information about proposed EEHRP. Section IV describes assumptions and system model. Section V and Section VI describes the energy and mobility models of EEHRP. Section VII discusses simulation setup and results, and finally paper is summarized with fruitful conclusion in section VIII with future work.

RELATED WORK

Many researchers based on various, criteria, design issues and applications in order to increase energy efficiency have proposed several multi-objective routing protocols [4]. Nevertheless, no routing protocol is ideal, which can be used the different routing schemes are proposed in [6] with different addressing scheme on the basis of location, structure and working methods. In [7], the lightweight routing protocol (LNDIR) is proposed which works on the state of nodes radio. It adjusts the duty cycle while scheduling the activities of nodes in the network to achieve minimum latency with increased energy efficiency. In [8], author proposes the method to reduce the communication delay and overheads between source node and destination with congested network. It also takes into account the routing paths while transmitting the data. Multi-Objective Evolutionary Algorithm based on Decomposition (MOEA/D) [9] is intended to resolve the energy preservation, MOP problem simultaneously by means of precise awareness about problem specific knowledge and Euclidean distances amongst the weight vectors. AACOCM [10] proposes a multi-objective model based on energy consumption, network delay, and packet loss rate for route optimization AACOCM attempts to lessen energy, delay, and PLR. Functioning of AACOCM is dependent on ordinary-, greedy-, unusual- ant nodes. Here routing tree is built, data is transmitted and feedback is taken from destination. As convergence ratio is more, AACOCM is appropriate for the large-scale network. [11] Proposes scalable, multi-objective framework based on native awareness of every node where routing is determined by Source_id, Unicast/Multicast, LRC and Purpose. LRC and RO is eliminated by avoiding low-energy, hazardous areas. Simple Hybrid Routing Protocol (SHRP) [12] chooses the finest route built on the metrics such as hop-count, LQI, and Residual-energy. In SHRP, the route is updated if there is a variation in the value of the metrics or periodically Typically, SHRP prefers a route that has smaller hop-count and larger Residual-energy. SHRP tackles the fragile connection and dead neighbor problem using LQI. DyMORA [13] is an extension of SHRP which is banking on multi-objective hybrid strategy and Hierarchical Routing Algorithm (HRA). DyMORA makes fewer comparisons for selecting Pareto optimal route. Due to MO mechanism it needs more processing time.

EEHRP: ENERGY EFFICIENT HYBRID ROUTING PROTOCOL

Most of the conventional routing protocols direct the data based on single metric. They adopt a policy where a threshold is set for a metric as a reference. A fraction of total number of nodes is responsible for sending the data from source to the base station and other nodes are in the sleep mode. This strategy causes quick exhaustion of the energy amongst the energetic nodes. In due course, these energetic nodes will exhaust their energy and will become inactive. This phenomenon will end up with a partitioned network. To alleviate this problem EEHRP takes on route selection based on multiple metrics. Optimization of multiple metrics simultaneously helps to balance the energy amongst various nodes in the network with different paths available from source to base station. The proposed EEHRP tries to find out the optimal route based on a fitness function derived from multiple metrics such as energy, overhead, response time LQI, hop count. The fitness function is given by the following equation [5].

$$f(nij)=\alpha.m_{energy}(n_{ij})+(1-\alpha).[\ \beta.m_{overhead}(n_{ij})+(1-\beta)$$

$$[\gamma.m_{rtime}(n_{ij})+(1-\gamma)[\delta.m_{lqi}(n_{ij})+(1-\delta)[\eta.m_{hops}(n_{ij})]]]]\ \text{-------------}\ (1)$$

Where α, β, γ, δ, ε are weighing factors.

ASSUMPTIONS, SYSTEM MODEL OF EEHRP

A. ASSUMPTIONS TO IMPLEMENT EEHRP:

Node Assumptions

- All nodes are homogeneous.
- Nodes don’t have GPS capabilities.
- Every single node has a UID.
- The Base Station (BS), CHs are static and few nodes (20% of the total no of nodes) are mobile.

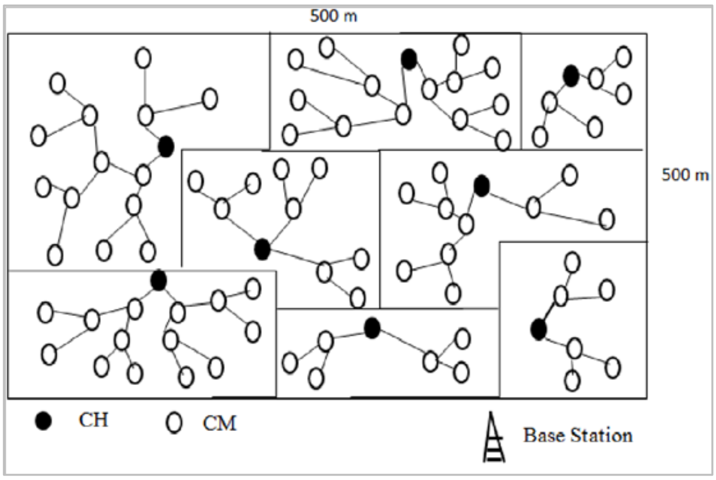
Network Assumptions

- There is a single BS in the network.
- The network is divided into clusters; every cluster has a CH and CM.
- CH election is based on the outcome of multi-objective function.
- Within the clusters a BHT is formed by all the CMs the root of the BHT is a CH.
- Intra cluster communication is single hop.
- The links are bidirectional.

B. SYSTEM MODEL OF EEHRP:

The whole target territory is split into tiny clusters. Every cluster has CH and CM. The sensor nodes are indiscriminately placed within the objective territory and that they are immobile. All the sensor nodes are similar regarding initial energy. The CMs are accountable for sensing the events within the close region. Every one of the CMs goes with themselves for choosing the CH. The CMs communicate solely with the CH of that cluster or the CMs of the similar cluster. They’re not allowed to speak to CMs or perhaps CH of the opposite cluster directly. The CHs have a second level of hierarchy. The CHs can connect with the CHs of another cluster. The Base Station (BS) could be a high-energy node arranged far from the topographic point. The CM, CHs and the sink node are immobile. At the outset, the density of sensor nodes within the topographic point is very high because it helps for the cluster based routing.

As appeared in Fig. 6-1, WSN is exhibited as a graph (G). Here, the vertices of the graph are nothing but sensor nodes. The graph G= (V, E) where V= {V1…..Vn} is set of vertices, and E {(ni, nj) Vi X Vj | i ≠ j} is a set of edges between vi and vj. The intra-cluster and the inter-cluster communication is categorized into different levels of hierarchy. At the first level in the hierarchy, CMs within the cluster elect a CH based on a fitness function mentioned in section III. The CMs will logically organize themselves like a BHT. As we move, up in the BHT the value of the fitness function increases. The root node of BHT is CH. The procedure is repeated for every cluster. After consecutive rounds of communication, the role of CH is switched among the various CMs to balances the energy within the entire network. At the second layer of the hierarchy, all the CHs will organize themselves into BHT and the process is same as that of intra-cluster communication. The designated CH will forward the accumulated data to the BS.



Figur 6-1 A Clustered Wireless Sensor Network

EQUATIONS OF ENERGY-EFFICIENCY OF EEHRP

Each node is non-rechargeable and has the opening energy of E0. Energy depletion while transferring a packet beginning with ith node to jth node uses a free-space as well as multi-path fading model banking on the distance amongst source and target. The source and target node has radio electronics for energy depletion. Depending upon distance and whether a node is a child or parent node in BHT the energy depletion varies for all packet of size Ps.

When the child node transfers Ps bytes of data, then the energy depletion is specified as: (Ref. eq. 1 to 5) [14]

$$E_{DISSI}(N_i) = E_{elec} * P_s + E_{amp} * P_s * \|d_{ij}\|^4 \ if \ \|d_{ij}\| \geq d_0 \text{ ----------- } (1)$$

$$E_{DISSI}(N_i) = E_{elec} * P_s + E_{amp} * P_s * \|d_{ij}\|^2 \ if \ \|d_{ij}\| < d_0 \text{ -------------- } (2)$$

Where, E_{elec} is electronic-energy centered on coding, distribution, modulating, filtering and amplification. d_{ij} is the distance amongst i^{th} and j^{th} node. When the j^{th} node accepts the packet of size P_s the energy dissipation is specified as:

$$E_{DISSI}(N_j) = E_{elec} * P_s \text{ --------------- } (3)$$

The energy cost of all nodes is amended after transferring or reception of packet of size P_s.

$$E_{remain+1}(N_i) = E_{remain}(N_i) - E_{DISSI}(N_i) \text{ --------------- } (4)$$

$$E_{remain+1}(N_j) = E_{remain}(N_j) - E_{DISSI}(N_j) \text{ --------------- } (5)$$

The procedure of data transferal and energy cost amendment is recurrent until every node is dead.

EQUATIONS OF MOBILITY-AWARENESS OF EEHRP

In EEHRP, movable nodes are well thought-out to be traveling alongside a one-dimensional territory also the pause-time of the nodes are exponentially disseminated. EEHRP utilizes Random-Way-Point (RWP) model for mobility. In this model interval for the travel phase is governed by endpoint and speed. The end-users don’t have control on this. The following section illustrates thru mathematical equations how the mobile state dissemination go forward over time.

Notations

[a1, au] – Area where the sensor node can travel

λ - Exponential distributed pause time

d – Destination Point

r(d) – Random Distribution

V_{max} – Upper bounded Speed

K(t) – Instantaneous State of the node

$\emptyset$(t) – Instantaneous Phase of the node either {Move or Pause}

A(t) – Instantaneous Position belongs to [a_1, a_u]

V(t) – Current Speed belongs to [$-V_{max}$,V_{max}] in case $\emptyset$=move

D(t) – Current destination belongs to [a_1, a_u].

P(a, v, d, t) – Cumulative probability at time t in case $\emptyset$=move

Q(a, t) – Cumulative probability at time t in case $\emptyset$=pause at position A(t)$\in$[a_1, a]

When the mobile node move in the region a first they select d according to r(d). Then they select the speed permitting to the distribution $f_V(v|d,a)=0$ for v>0. $f_V(v|d,a)=0$ belongs to the interval [$-V_{max}$, V_{max}],$\forall$ d,a. the dynamism of the mobile node can be described in terms of Markov-Process in which K(t) is characterized by$\emptyset$(t)$\in$ $\emptyset$={move,pause}. The probability at time (t) of a mobile node is (Ref. Eq. 6 – 13) [15]

$$P(a,v,d,t) \triangleq \emptyset r\{\emptyset(t)=move, A(t)\in[a_1,a], D(t)\in[a_1,d], V(t)\in -V_{max},v)\} \text{ ------------ (6)}$$

$$Q(a,t) \triangleq \emptyset r\{\emptyset(t)=pause, A(t)\in[a_1,a] \text{ ----------- (7)}$$

Introducing the densities

$$p(a,v,d,t)= \frac{\partial 3P(a,v,d,t)}{\partial a \ \partial v \ \partial d} \text{ ------------ (8)}$$

$$q(a,t)= \frac{\partial Q(a,t)}{\partial a} \text{ ------------ (9)}$$

Subsequent pair of equations can be obtained

$$\partial p(a,v,d,t)\partial t = -v \ \partial p(a,v,d,t)\partial a + \lambda \ fV(v|d)r(d)q(a,t) \text{---------- (10)}$$

$$\partial q(a,t)\partial t = \lambda q(a,t) + \int v \ p(a,v,d,t) \ dv \text{ ----------- (11)}$$

Boundary Situation

It depicts the chance of a mobile node hitting the boundary is null

$$p(a_l,v,d,t)=0 \ ; \ p(a_u,v,d,t)=0 \ \forall \ v,d,t \text{ ------------ (12)}$$

$$s(a_l,t)=0 \ ; \ s(a_u,t)=0 \ \forall \ t \text{ ------------ (13)}$$

The initial situation

$$p(a,v,d,0)=p0(a,v,d) \ ; q(a,0)=s0(a) \text{ ------------- (14)}$$

Which is an appropriate pdf for mobile node's original position, speed, and endpoint. The procedure for building neighborhood relationship is given in Fig. 6-2.

A. EEHRP FLOWCHART

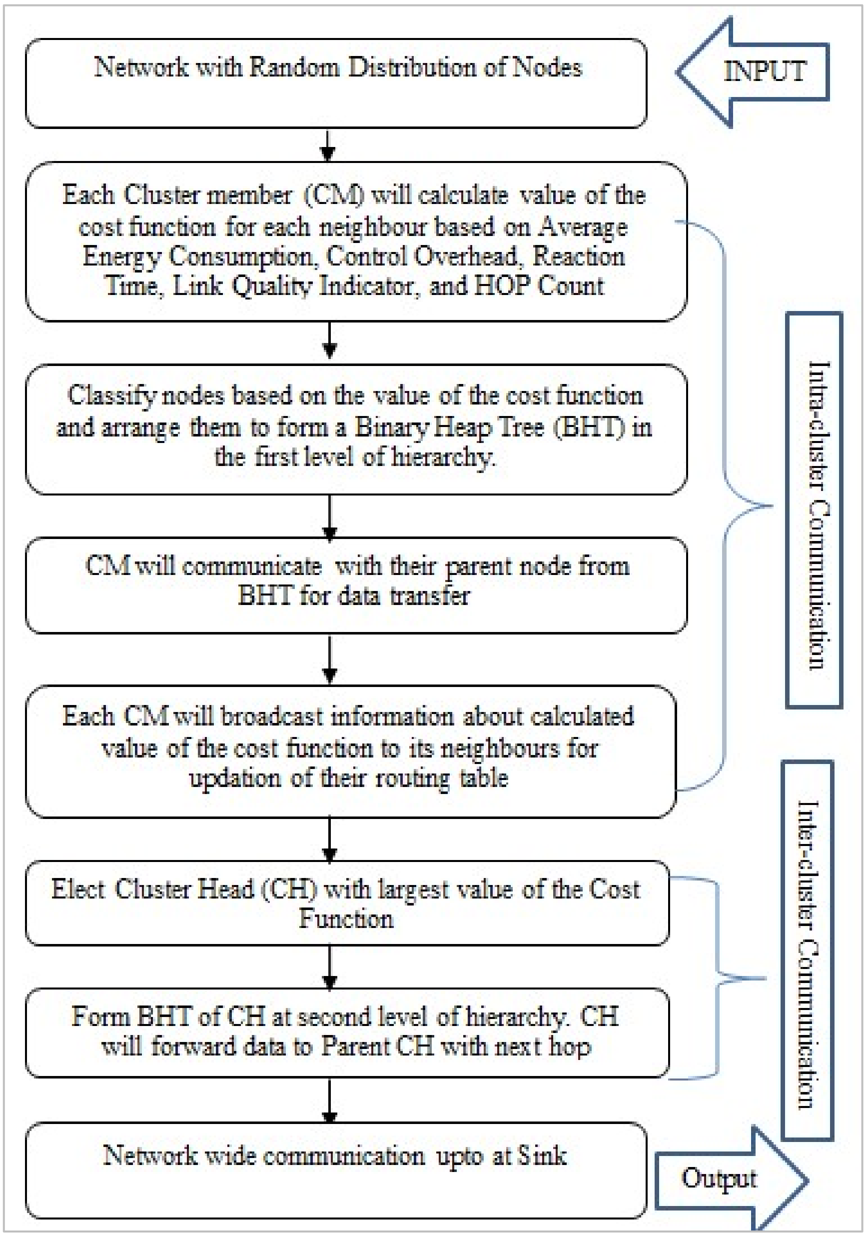


Figure 6-2 Flowchart of EEHRP

SIMULATION AND RESULT ANALYSIS

The simulation is carried out using Network Simulator (ns2.34). The aim of the simulation is to comment on the QoS parameters and compare the Throughput, Average Residual Energy (ARE), and End-to-End delay, Control Overhead in EEHRP, SHRP, and DyMORA[13]. SHRP is not multi-objective but uses single value metric and used to validate the performance of EEHRP, following simulation parameters stated in Table 6-1 are used.

Table 6-1 SIMULATION PARAMETERS

Wireless Physical	
Network interface type	Wireless Physical
Radio propagation model	Two-Ray Ground
Antenna type	Omni-directional Antenna
Channel type	Wireless Channel
Link Layer	
Interface queue	Priority Queue
Buffer size (ifqLen)	50
MAC	802.11
Routing protocol	EEHRP, DyMORA, SHRP
Energy Model	
Initial energy (Joule)	20
Radio Model	TR3000
Idle power (mW)	13.5
Receiving power (mW)	13.5
Transmission power (mW)	24.75
Sleep Power (µW)	15
Node Placement	
Number of nodes	50, 60, 70, 80, 90 and 100
Number of sink	1
Placement of the Sink	Bottom right corner of the simulation area
Placement of nodes	Nodes are placed randomly in the given area
Node placement	Random
Number of simulation runs	10
Miscellaneous Parameters	
Area(m)	500 * 500
Simulation time (s)	2000
Packet size (bytes)	64
Hello Interval (s)	5
CH Election Interval (s)	20
Packet Interval (s)	0.2
Mobility	20% nodes are mobile

A. THROUGHPUT

Throughput is a degree of how quick data can be send through a network. Fig. 6-3 demonstrates the throughput of EEHRP, SHRP, and DyMORA. The reason why throughput of EEHRP is higher than DyMORA and SHRP is the hybrid nature of the protocol. For development of EEHRP multiple metrics are optimized simultaneously from different layers of WSN. EEHRP has throughput higher by a factor of 39.19 % and by a factor of 22.71% with reference to SHRP and DyMORA respectively. The throughput endorses the efficiency of EEHRP for data forwarding.

B. AVERAGE RESIDUAL ENERGY(ARE)

ARE is a ratio of sum of the residual energy of different nodes to the sum of total number of nodes. Fig. 6-4 shows the average residual energy. ARE of EEHRP is higher than DyMORA and smaller than SHRP in quite a few conditions due to tiered grouping. EEHRP beats DyMORA by a factor of 7.7 % and SHRP by 9.2 % in terms of ARE. This conservation of energy prolongs the life expectancy of the system and proves the usefulness of EEHRP.

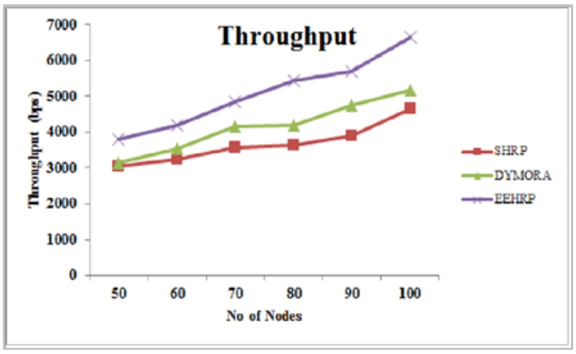


Figure 6-3 Throughput

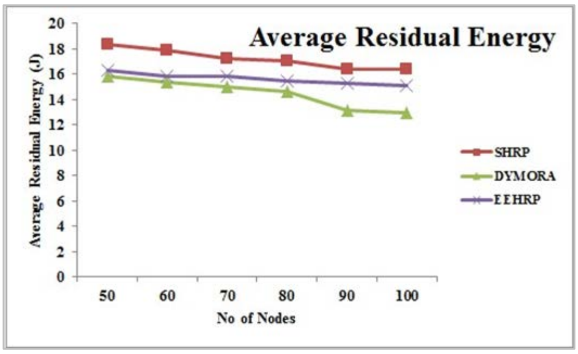


Figure 6-4 Average Residual Energy.

C. END-TO-END DELAY

The end-to-end delay (delay) is the time variance between the first data packet a source node produces after identifying an event and the time the data packet is received at the sink.. Since EEHRP uses reaction time as one of the optimization metric for finding the best route, the delay is less by a factor of 24% contrasted with DyMORA. SHRP is better protocol compared with EEHRP in terms of delay by 16.22% as seen in Fig 6-5.

D. CONTROL OVERHEAD (COH)

COH is the number of control packets essential for network communication. Fig. 6-6 illustrates the comparison of COH. EEHRP has lesser COH than DyMORA and greater COH than SHRP. SHRP picks the finest route centered on a single metric and is not a true MOHR protocol. Additionally, EEHRP is efficient in terms of COH equated with DyMORA. EEHRP improves COH by a factor of 10.85% as equated with DyMORA.

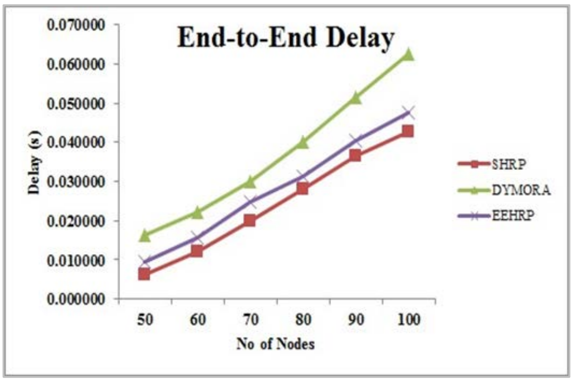


Figure 6-5 End-to-End Delay

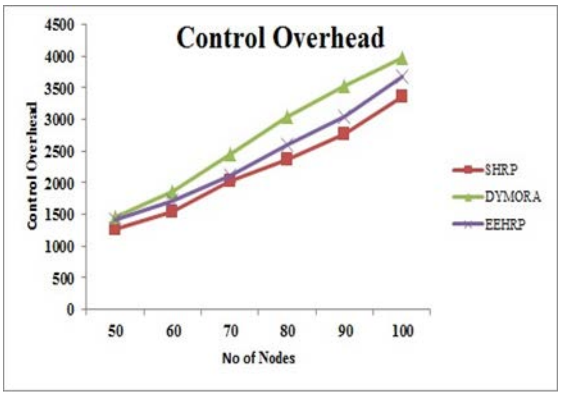


Figure 6-6 Control Overhead

CONCLUSIONS AND FUTURE WORK

This paper put forwards a novel QoS guaranteed energy competent Multi-Objective Routing Protocol called EEHRP for WSNs. The foremost aim of EEHRP is to pick best path up to base station reliant on multi-objective principles. EEHRP is verified and compared with SHRP, and DyMORA. EEHRP is better protocol in terms of energy efficiency, throughput, control overhead, and delay with reference to SHRP and DyMORA. The routing protocol can be further tested by replacing homogeneous sensor nodes with heterogeneous and by assigning mobility to them.

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