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A New Load Balanced Routing Protocol for Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks consists of sensor nodes which are controlled by either base station or without bases station. In our scheme, the sensor nodes are not depends on the base station. Due to unbalanced path status, the energy consumption will be morel. There is a need of Energy based Routing in the wireless sensor network. This requirement may lead to a number of routing protocols which effectively use the limited resources available at the sensor nodes. Many routing protocols will attempt to find the efficient and secure multipath routing. In order to determine the energy efficient routing, we proposed the Hierarchical Load Balanced Routing Protocol (HLBRP) which attains the high residual energy. It consists of three phases. In first phase, the concept of multipath routing is proposed. It uses load balancing to prevent congestion problems in the network. In second phase, the path stability is established based on link cost, link quality, link bandwidth and load balancing. In third phase, the energy residual consumption model is proposed. By simulate on results, the proposed HLMRP achieves better delivery ratio, throughput, less delay and energy consumption in terms of mobility, time and number of nodes than existing schemes.

Keywords: Energy Consumption, Data delivery ratio, mobility, time, Congestion, Load Balancing, throughput and link quality, multipath routing and WSNs.

1. INTRODUCTION

1.1. Wireless Sensor Networks(WSNs)

Sensors are the devices that capture the real-world phenomena and convert their captured information into the digital format which can be saved, transmitted, and processed [1]. Sensors will give an enormous societal benefit when it is integrated into numerous devices, environments, and machines. They can be used in the applications like, to avoid catastrophic failure of buildings, to preserve important resources, to increase productivity, for security enhancement, and for smart house keeping technologies, etc. For example, the new magnificent developments in the semiconductor technologies enables to manufacture microprocessors with more processing capabilities, but tiny in size. The small, low-energy, and low-cost sensor nodes, actuators, and controllers, and also embedded system for computation that will closely interact with the outside world form the Sensor Network. Sensor Networks are designed for performing only some dedicatedfunctions and it has been get applied in an increasing number of areas. But still military systems are holding the lion's share of the market for sensor devices and their applications.

The sensors are also used to monitor and protect civil infrastructures like bridges and tunnels, and also national power grid, pipeline infrastructures etc. Applications of sensors and sensor networks still followslike, to monitor large area to model and forecast environmental pollution and flooding, to collect the strength information of bridges by using vibration sensors, to control the usage of water, fertilizers, and pesticides to improve the quantity and also the quality of the crop, and many more.

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Routing Metrics

Distinctive routing metrics will be used for expressing a variety of goals of a routing protocol w.r.to the utilization of those resources, or sometimes the performance that perceived by an application. The commonly used routing metrics in WSN are:

- **Minimum Hop:** It is the most common metric used in routing protocols. Here, the protocol will try to discover a path from the source to destination, which is requiring the least number of hops or relay nodes. This approach that finds the minimum-hop paths is not considering the actual availability resources on each node, and hence the resultant route may not be optimal in terms of energy, delay, and congestion avoidance.
- **Energy:** Undoubtedly, energy efficiency is the most crucial aspect of routing in Wireless Sensor Networks. The various different interpretations of energy efficiency are [2]:
- **The minimum energy consumed per packet:** Here the objective is for minimizing the total expenditure of energy for the transmission of a single data packet from the source node to destination node. The overall total energy is actually the consolidation of the energy consumed at each node for transmitting and receiving the packet along the route from source to destination.
- **Maximum time to network partition:** Hear the goal is for reducing the energy consumption at the nodes which are critical to maintain the network such that all the sensor nodes can be accessed by reaching via at least one route. Premature expiration of the nodes which disconnects the network should be prevented.
- **Maximum variance in node power levels:** The idea is to disseminate the energy consumption over all the nodes in a network as in an equal range as possible.
- **Maximum (average) energy capacity:** Instead of focusing on the energy cost for propagating a packet, the objective is to increase the residual energy capacity of a node i.e., the current level of charge in the battery. The routing protocols which are using this metric may gratify routes, which are having the highest total energy capacity in the nodes along that path.
- **Maximum minimum energy capacity:** Here, the primary routing goal is not to maximizing the energy capacities of the entire path, but for selecting the path which has the highest minimum energy capacity. This strategy not just supports the routes with bigger energy reserves, additionally secures the low-capacity nodes from untimely termination.
- **Quality-of-Service:** This term stands for the defined performance measures, like end to end delay, throughput, packet loss, jitter i.e., the latency variation, error rate etc. Robustness: This metric is used when the goal to find routes, which will be stable for long duration of time and also reliable. Actually, this metric will be used without other metrics rarely. For example a routing protocol may discover several less-hop routes and then select path among those which is the best quality link.

2. RELATED WORK

Sridevi and Rumeniya [3] presented a review on the existing routing protocols for WSN by considering energy efficiency and QoS. It was focused on the main motivation behind the development of each protocol and explain the function of various protocols in detail. The protocols were compared based on energy efficiency and QoS metrics.

Kirida Ezhilarasi and M.Jenolin Rex [4] derived the optimal communication range and communication mode to maximize the Network Lifetime. The intra-cluster scheduling and inter-cluster multi-hop routing schemes were used to maximize the network lifetime. It was considered a hierarchal network with Cluster

Head nodes having larger energy and processing capabilities than normal SNs. The solution is formulated as an optimization problem to balance energy consumption across all nodes with their roles. A two tier network with the objective of maximizing network lifetime is presented while fulfilling power management and coverage objectives.

Sung Keun Lee et al. [5] proposed a routing protocol that can provide QoS that appropriately reflects changes in network status regarding reliability and delay, even in circumstances with a deficiency in sensor node resources. This algorithm has the advantage of minimizing the routing control messages and therefore can safely operate from an energy-efficient perspective, as the algorithm utilizes broadcast messages regularly transmitted by the sink node. It was observed that the sensor node establishes a routing table based on the shortest route towards a sink, the energy efficiency of the foothold, and the least amount of congestion.

Udit Sajjanhar and Pabitra Mitra [6] developed the Distributive Energy Efficient Adaptive Clustering (DEEAC) protocol. This protocol is adaptive in terms of data reporting rates and residual energy of each node within the network. It is a modification of the LEACH's stochastic cluster-head selection algorithm by considering two additional parameters, the residual energy of a node relative to the residual energy of the network and the spatiotemporal variations in the data reporting rates of a node relative to the network. Since this protocol evenly distributes energy-usage among the nodes in the network by efficiently adapting to the variations in the network, our optimal cluster-head selection saves a large amount of communication energy of sensor nodes.

Wendi Rabiner Heinzelman et al. [7] described a clustering-based routing protocol that minimizes global energy usage by distributing the load to all the nodes at different points in time. It outperforms static clustering algorithms by requiring nodes to volunteer to be high-energy cluster-heads and adapting the corresponding clusters based on the nodes that choose to be cluster-heads at a given time. At different times, each node has the burden of acquiring data from the nodes in the cluster, fusing the data to obtain an aggregate signal, and transmitting this aggregate signal to the base station.

Zahra Rezaei and Shima Mobininejad [8]conducted extensive research to address these limitations by developing schemes that can improve resource efficiency. It was also summarized some research results which have been presented in the literature on energy saving methods in sensor networks. Although many of these energy saving techniques look promising, there are still many challenges that need to be solved in the sensor networks.

V. Vinoba and A. Indhumathi [9] proposed a novel energy efficient routing protocol by using quadratic assignment technique. This protocol achieves energy efficiency by finding an optimal path to transfer the data from source to destination. In this work the proposed routing protocol, is to process the multiple route in finding the shortest path. It is also proposed that the Temporally Ordered Routing Algorithm which uses the Destination sequenced distance vector and find out the multiple route for neighbor node list table.

M.G.Annapoorani and M.S.Kokila [10] analyzed the fundamental characteristics and energy limitations of the WSN. To solve the energy limitation of WSN this system uses an efficient strategy to forward data toward the sink was developed. It enabled the nodes to choose multiple next hops. With this system, the remaining energy of the nodes will be increased and the life time of the whole network will be increased, too. The Tree approach designs the path for data routing that maximizes the data gained from the sensors under multiple possible neighbors as next hop. This solution is reduces the energy consumed for each node, and consequently increases the network lifetime.

Trupti Shah and Madhav Ingle [11] proposed a new scheduling method called Duty-cycle Backbone Scheduling (DCBS). It uses a light addressing and routing scheme. It employed heterogeneous scheduling. In DCBS to preserve network connectivity, backbone nodes work with duty-cycling and non-backbone nodes turn off radios to save energy.

Shaojie Wen et al. [12] presented an energy-efficiency opportunistic multicast routing protocol (E-OMRP) for themulticast energy consumption minimization problem. In mobile wireless sensor networks. The protocol divides the network into grids, so each node determines their own coordinates according to the grid. The nodes only need to know the topology of their own grid, instead of the topology of the entire network. In order to better represent the impact of the movement on transmission, the nodes in the same grid determine the priority in light of the transmission delay factor and expected transmission cost.

Loh and Yi Pan [13] proposed an energy-aware routing protocol, Energy Clustering Protocol (ECP) that routes essages via cluster heads. Unlike other clustered configurations, it exploits nodes at the boundaries of the cluster (border nodes) to assist in the forwarding of packets as well as to reduce dependency on and energy expenditure of cluster heads. It was also demonstrated that a hierarchical routing protocol design that can conserve significant energy in its setup phase as well as during its steady state data dissemination phase.

Xufei Mao et al. [14] studied that how to select and prioritize the forwarding list to minimize the total energy cost of forwarding data to the sink node in a wireless sensor network (WSN). It was observed that previous protocols, i.e., ExOR and MORE, did not explore the benefit of selecting the appropriate forwarding list to minimize the energy cost. The transmission power of each node was fixed and each node can adjust its transmission power for each transmission. Optimum algorithm was used to select and prioritize forwarder list.

Ying Hong Wang et al. [15] introduced the Hierarchy-Based Multipath Routing Protocol (HMRP). It has many paths to disseminate data packets to the sink. The data aggregation mechanism involves in every nodes apart from the leaf nods reducing the energy consumption in the networks. Based on the layered network, sensor nodes have multipath routes to the sink node through candidate parent nodes.

Jiann-Liang Chenet al. [16] introduced an adaptive method based on redundancy node and dual routing protocol for WSN. Redundancy node can divide the wireless sensor network into operating and sleeping modes. Dual routing protocol individually designs two kinds of different routing protocols in the sensor node, using the merits of these two different kinds of routing protocols to accomplish the mission of sending the data. The scenario set up is when the wireless sensor network has been used for a long time; the power kept in these sensor nodes is different. It is possible that some sensor nodes contain lower power because the heavy load of work, and some with more power because of less work load.

Mohammamd Shaheer Zaman and G Rama Murthy [17] proposed a new routing scheme which exploits the redundancy and geometrical properties of the wireless network. This approach was taken to combine the ideas of directional flooding, leveling, clustering and disjoint multipath routing to achieve an optimal routing scheme in terms of average energy consumed and total number of transmitted packets. Processing and structuring of the network before the implementation of the directional flooding algorithm improves the performance considerably when compared to the implementation of directional flooding algorithm without any pre-processing.

Saeed Rasoili et al. [18] proposed a new multi path routing algorithm for real time applications in wireless sensor networks namely QoS and Energy Aware Multi-Path Routing Algorithm (QEMPAR) which is QoS aware and can increase the network lifetime. Simulation results show that the proposed algorithm is more efficient than previous algorithms in providing quality of service requirements of real-time applications. It performed paths discovery using multiple criteria such as energy remaining, probability of packet sending, average probability of packet receiving and interference.

K. Vanaja and R. Umarani [19] deals with the fault managementto resolve the mobility induced link break. The proposed protocol is the adaptive faulttolerant multipath routing (AFTMR) protocol which reduces the packet loss due to mobilityinduced link break. In this fault tolerant protocol, battery power and residual energy aretaken into account to determine multiple disjoint routes to every active destination. Whenthere is link break in the existing path, AFTMR initiates Local Route Recovery Process.

3. IMPLEMENTATION OFPROPOSED ALGORITHM

Our proposed Multipath routing scheme consists of concept of proposed multipath routing, determination of optimal path deciding procedure, energy consumption model to provideimprove energy efficiency and network lifetime in sensor networks.

3.1. Inclined Multipath Routing

In the proposed multipath routing phase, the issues of direct transmission, quick multipath establishment and Screen broadcasting are solved. Inclined value is used to control the direction of packet's broadcasting and data transmission. According to cluster head route update table, the optimal paths are identified and discovered from source to destination node. It includes the topology organization, node's residual energy status, transmission delay and multipath route maintenance so forth. When the source node has packets to be transmitted, it firstly reports to source node. Source node chooses the node with minimum distance on the next contour lines along the inclined direction as the next hop within the transmission power coverage to discover the first optimal transmission path. The sub optimal path on next contour lines is chosen based on transmission power coverage.

Finally all the multiple paths are established from source to destination node as follows:

Step 1: Cluster head gets the details about all the cluster member node details and parameters by transmitting packets from source to destination node.

Step 2: Cluster head chooses the next cluster head on the contour lines within its transmission power coverage as the next hop according to high residual energy, low transmission delay of sensor nodes. Hence the first optimal path is discovered.

Step 3: In order to select optimal path, Cluster head chooses the second nearest nodes on the contour lines but not on the established paths within the transmission power coverage.

Step 4: Once the paths are established, the destination node will forward the paths' information back to the source node along the established multiple paths and it includes nodes' energy information, transmission delay, packet delivery rate and so forth. The packets are encoded using the linear erasure coding algorithm and the coded fragments are coded into multiple paths by load assessment method.

Step 5: The destination node decodes the received encoded fragments and reconstructs them into the source packet.

Step 6: Once multiple transmission paths and packets transmission is finished, the sensor node will go into an inactive state and wait for the next event trigger by the medium access control protocol.

Step 7: The multipath routing includes two parts namely error submission and routing repair. Routing error submission means that sensor node report to source node about detection of any fault node or invalid link. If the previous node of the fault node or link decides to make a repair, it will launch the routing repair process.

Step 8: In this, a node sends its packets to neighbors through multiple alternative paths. Optimal path is selected for data transmission from source to destination. If a problem occurred in selected path, it selects the next available shortest path for forwarding data to destination. The elliptical region restricted the look ahead around the packet forwarding path for reliable routing. The elliptical region is calculated using location information of the source and the destination from GPS systems.

Step 9: The sensor node initially stores the received packets and then selects the node on the next contour line and not belonging to other routing as the next hop to re-establish the routing. It sends the routing requests message to the destination node. The destination node receives and replies to the request when the route repair is accomplished. The packets in the cache queue are forwarded along this newly established stable path.

3.2. Optimal Path Deciding Procedure

In the proposed protocol, routing protocol is a reactive routing protocol. It is initiated by destination node based on query driven algorithm. The interested packets will be sent by destination node to the source node. The protocol is designed to work in interference environment where multiple source nodes take place. The Procedure for optimal path deciding procedure is as follows.

Step 1: Choose the path deciding factor is based on three things that are grit factor of path, distance from the next hop to destination node, and Signal to Interference Noise Ratio (SINR) of the link between itself and next hop node.

It is derived as,

$$Path\ Deciding\ Factor\ (PDF) = \frac{SINR\ Value \times Grit\ Factor}{Dis\tan ce\ to\ the\ Sink\ Node} \tag{1}$$

Step 2: If the node receives the route discovery packet, it will calculate signal strength of the packet and SINR for the link. It will be recorded in routing table and updated during route maintenance phase.

Step 3: The path grit factor is termed as logarithmic factor and it is given as,

$$f(p,q) = \frac{\log p}{\log q} \tag{2}$$

Where p is the minimum power available among all the nodes along the path and q is the total energy consumption of the path. q is set to zero because the minimum energy value should be its own residual energy.

Step 4: Include the distance in the path deciding factor for choosing next hop node. It will lead to reduction of number of hops in the path.

Step 5: Update the p and q values in the routing table upon receiving the route maintenance packet.

3.3. Energy Consumption Model

Energy consumption is assumed as e_l^m, for transmitting m bit fragments on path$_l$. The node's available energy is not varied during transmission. The total energy consumption of the unit byte's transmission on path is the sum of energy consumption of unit byte's transmission on each link of path namely,

$$e_l = \sum_{m=0}^{n_l-1} e_l^m \tag{3}$$

Where n_l is the lth node of the path.

Energy consumption vector of the unit byte is $E_a = [e_1, e_2, ..., e_n]^T$. The residual energy on path with maximum quantity of the transmitted fragments is

$$M_l^e = \min_{1 \le m \le n_l} \left\{ \frac{E_l^m}{ae_l^m} \right\} \tag{4}$$

Packet loss subsists during the transmission through load assessment method. Energy consumption of data transmission of the m^{th} link on path is;

$$E_l^m = ay_p \prod_{p=1}^{m-1} e_l^m q_l^{p-1} \tag{5}$$

3.4. Proposed packet format

Source ID	Destination ID	Discovery Packet Status	Energy Efficiency	Route maintenance	CRC
2	2	4	4	4	2

Figure 1: Proposed Packet format

In figure 1, the proposed packet format is shown. Here the source and destination node ID carries 2 bytes. Third one is discovery status of the node. It induces the whether the transmission of packets are travelled with highest link priority and least hop distance. In fourth field, energy efficiency status is indicated. It determines how much of energy spent for packet transmission. In fifth, the route maintenance is allotted to less packet loss. The last filed CRC i.e. Cyclic Redundancy Check which is for error correction and detection in the packet while transmission and reception.

4. PERFORMANCE ANALYSIS

We use Network Simulator (NS2.34) to simulate our proposed HBRP algorithm. Network Simulator-2(NS2.34) is used in this work for simulation. NS2 is one of the best simulation tools available for Wireless sensor Networks. We can easily implement the designed protocols either by using the TCL (Tool command Language) coding or by writing the C++ Program. In either way, the tool helps to prove our theory analytically.

In our simulation, 200 mobile nodes move in a 1200 meter x 1200 meter square region for 60 seconds simulation time. All nodes have the same transmission range of 250 meters. Our simulation settings and parameters are summarized in table 1.

4.1. Performance Metrics

We evaluate mainly the performance according to the following metrics.

End-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Packet Delivery Ratio: It is defined as the ratio of packet received with respect to the packet sent.

Throughput: It is defined as the number of packets received at a particular point of time

The simulation results are presented in the next part. We compare our proposed algorithm HBRP with HMRP and QEMPAR [18], AFTMR[19]in presence of energy consumption.

Figure 2 shows that the proposed scheme topology for ensuring the multipath routing. Source node sends the packet to destination node via intermediate nodes. In case if the node failure occurs, the node choose the alternative path to reach correct delivery of packets.

Figure 3 shows the results of average residual energy for varying the time from 10 to 50 ms. From the results, we can see that scheme HBRP has minimal energy consumption than the HMRP, AFTMR and QEMPAR scheme.

Table 1
Simulation settings and parameters of proposed protocol

No. of Nodes	200
Area Size	1200 × 1200
Mac	802.15.14
Radio Range	250m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	248 bytes
Mobility Model	Random Way Point
Transmitter Amplifier	100 pJ/bit/m^2
Package rate	3 pkt/s
Protocol	LEACH

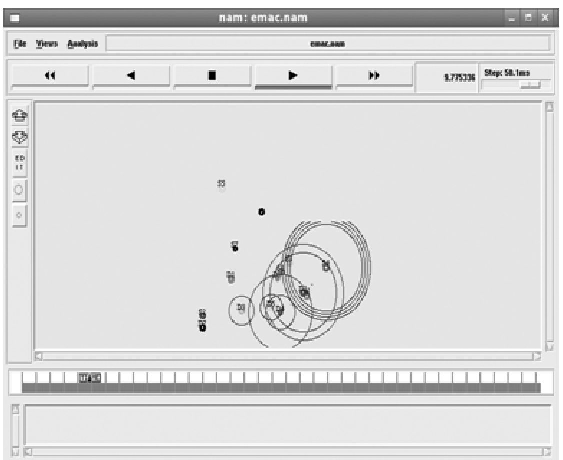

Figure 2: Topology of the proposed scheme.

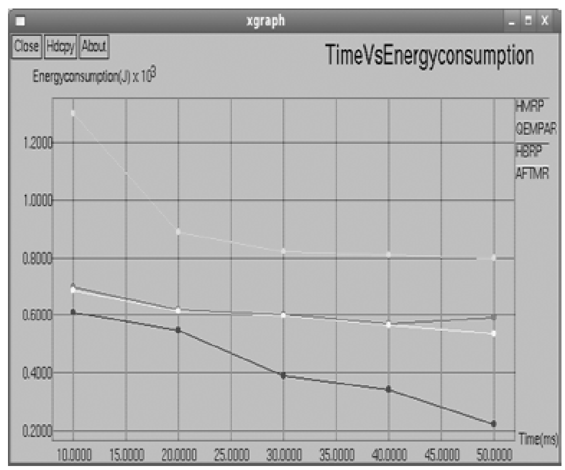

Figure 3: Time Vs Energy consumption

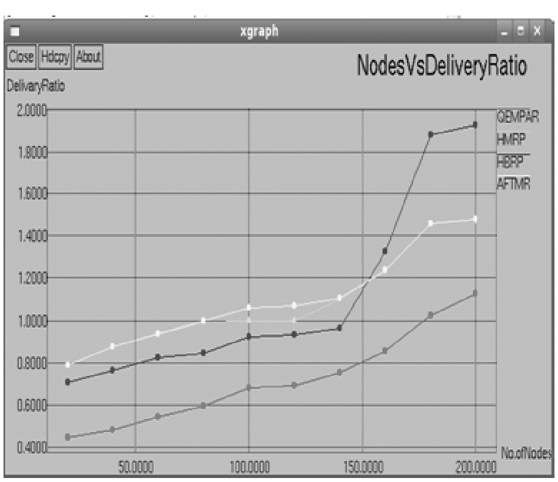

Figure 4: No.of Nodes Vs Packet Delivery Ratio.

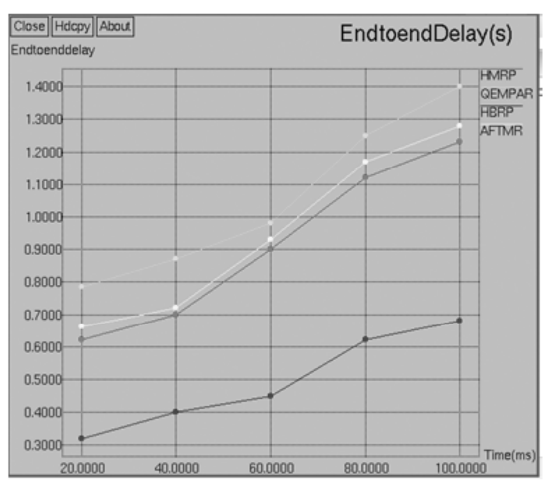

Figure 5: No.of nodes Vs Network Lifetime

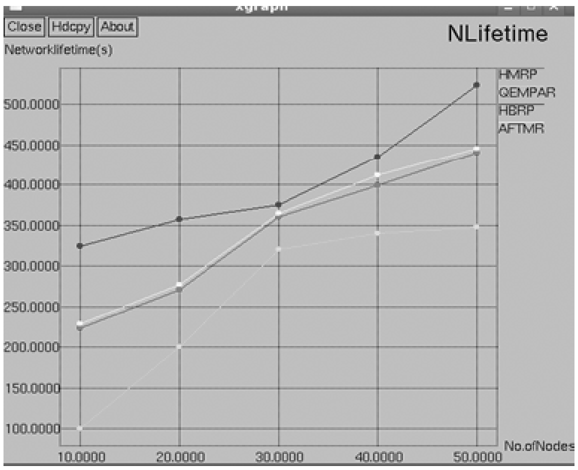

Figure 6: Time Vs End to end delay

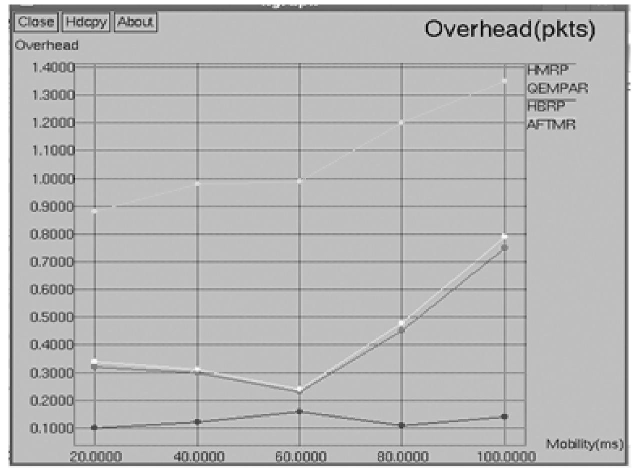

Figure7: Mobility Vs Overhead

Figure 4 presents the delivery ratio comparison for HBRP, HMRP, QEMPAR It is clearly seen that number of epochs consumed by HBRP is high compared to QEMPAR, AFTMR and HMRP.

Figure5, presents the comparison of network lifetime. It is clearly shown that the network lifetime of HBRPis higher than the HMRP, AFTMR and QEMPA

Figure 6 shows the results of Time Vs End to end delay. From the results, we can see that HBRP scheme has slightly lower delay than the HMRP, AFTMR and QEMPAR scheme because of authentication routines.

Figure 7, presents the comparison of overhead while varying the mobility from 20 to100ms. It is clearly shown that the overhead of HBRP is lower than the HMRP, AFTMR and QEMPAR

5. CONCLUSION

In WSNs, the energy efficient route is determined by choosing efficient strategy to forward the data to the base station. Due to that, the node consumes more energy unnecessarily. In this paper, we have developed a Hierarchical Load Balanced Routing Protocol(HLBRP) which attains balance between energy consumption and path stability to the sensor nodes. In the first phase of the scheme, concept of proposed multipath routing is explained. In second phase, the optimal path is determined to ensure the network connectivity. In third phase, residual energy consumption and secure routing is established.The proposed scheme uses following factors called path stability, residual energy and authenticity to favor packet forwarding by maintaining high residual energy consumption and secure routing for each sensor node. We have demonstrated theenergy consumption determination of each sensor node. By simulation results we have shown that the HLBRP achieves good throughput, high network lifetime, high residual energy while varying the number of nodes, time, node throughputand mobility.

REFERENCES

[1] Dargie, Waltenegus, and Christian Poellabauer. Fundamentals of wireless sensor networks: theory and practice. John Wiley & Sons, 2010.

[2] Singh, Suresh, Mike Woo, and Cauligi S. Raghavendra. “Power-aware routing in mobile ad hoc networks.” Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking. ACM, 1998.

[3] S. Sridevi and G. Rumeniya, “Energy-Aware QoS Based Routing Protocols for Heterogeneous WSNs: A Survey”, International Journal of Computer Science and Business Informatics, Vol. 11, No. 1, 2014, pp. 1-19.

[4] K. Kirida Ezhilarasi and M. Jenolin Rex, “Reliable and energy-saving forwarding technique for wireless sensor networks using multipath routing”, SSRG International Journal of Computer Science and Engineering, Vol. 1, Issue 9, 2014, pp. 11-15.

[5] Sung-Keun Lee, Jin-Gwang Koh and Chang-Ryul Jung, "An Energy-Efficient QoS-aware Routing Algorithm for Wireless Multimedia Sensor Networks", International Journal of Multimedia and Ubiquitous Engineering, Vol. 9, No. 2, 2014, pp. 245-252.

[6] Udit Sajjanhar and Pabitra Mitra, "Distributive Energy Efficient Adaptive Clustering Protocol for Wireless Sensor Networks", IEEE International Conference on mobile data management, 2007, pp. 326-330.

[7] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", IEEE Hawaii International Conference on System Sciences, 2010, pp. 1-10.

[8] Zahra Rezaei and Shima Mobininejad, "Energy Saving in Wireless Sensor Networks", International Journal of Computer Science & Engineering Survey, Vol. 3, No. 1, 2012, pp. 23-37.

[9] V. Vinoba and A. Indhumathi, "Optimal Path Selection on TORA algorithm Using Quadratic Assignment techniques in WSN", International Journal of Emerging Technology and Advanced Engineering, Vol. 4, Issue 7, 2014, pp. 843-850.

[10] M.G. Annapoorani and M.S. Kokila, "Energy Efficient Data Collection for Mobile Users in Wireless Sensor Networks Using SCFT Protocol", International Journal of Advanced Research in Computer and Communication Engineering, Vol. 3, Issue 8, August 2014, pp. 7795-7800.

[11] Trupti Shah and Madhav Ingle, "Energy Conservation by Duty Cycle Scheduling in Path Connected Clusters Wireless Sensor Network", International Journal of Application or Innovation in Engineering & Management (IJAIEM), Vol. 3, Issue 6, 2014, pp. 284-288.

[12] Shaojie Wen, Zhenyu Zhang, Wenzhong Yang, and Siquan Hou, "An Energy-efficient Opportunistic Multicast Routing Protocol in Mobile Wireless Sensor Networks", Journal of Networks, Vol. 9, No. 7, 2014, pp. 1819-1827.

[13] 11. Peter K. K. Loh and Yi Pan, "An Energy-Aware Clustering Approach for Wireless Sensor Networks", International Journal of Communications, Network and System Sciences, Vol. 2, 2009, pp. 91-102.

[14] Xufei Mao, Xiaohua Xu and Huadong Ma, "Energy-Efficient Opportunistic Routing in Wireless Sensor Networks", IEEE Transactions on Parallel and Distributed Systems", Vol. 22, 2011, pp. 1-9.

[15] Ying-Hong Wang, Chih-Hsiao and Tsaiand Hung-Jen Mao, "HMRP: Hierarchy-Based Multipath Routing Protocol for Wireless Sensor Networks", Tamkang Journal of Science and Engineering, Vol. 9, No 3, 2006, pp. 255-264.

[16] Jiann-Liang Chen, Yu-Ming Hsuand I-Cheng Chang, "Adaptive Routing Protocol for Reliable Sensor Network Applications", International Journal on Smart sensing and Intelligent systems, Vol. 2, No. 4, 2009, pp. 515-539.

[17] Mohammamd Shaheer Zaman and G. Rama Murthy, "Clustered and Leveled Disjoint Multipath Routing Algorithm for Wireless Sensor Networks", IEEE Conference, 2011, pp. 1-6.

[18] Saeed Rasouli Heikalabad, Hossein Rasouli, Farhad Nematy and Naeim Rahmani, "QEMPAR: QoS and Energy Aware Multi-Path Routing Algorithm for Real-Time Applications in Wireless Sensor Networks", International Journal of Computer Science Issues, Vol. 8, Issue 1, January 2011, pp. 466-471.

[19] K. Vanaja and R. Umarani, "An Adaptive Fault Tolerant Multipath Routing (AFTMR) Protocol for Wireless Ad Hoc Networks", European Journal of Scientific Research, ISSN 1450-216X Vol. 79, No. 2 2012, pp. 180-190.