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Design of an Energy Aware Multicast Routing Protocol with Optimal QoS Support for Adaptive Route Management over WSN - EAMU

[1]K. Raja, [2]R. Saminathan and [2]P. Anbalagan

[1]Department of Information Technology,
Annamalai University Annamalainagar - 608 002, Tamil Nadu, India
[2]Department of Computer Science & Engineering,
Annamalai University Annamalainagar - 608 002, Tamil Nadu, India

Abstract: Most of error issues in WSN nodes primarily focus on QoS throughput degradation, packet collision during transmission and reduced network lifetimes. Majority of error handling algorithms in WSN networks focus on providing effective utilization of single route for data transmissions and controlling errors on transmission route. These algorithms lead to maximal node utilization but decrease the energy of nodes used during transmission on selected route. Consistent support on QoS and controlled energy consumption is always felt by researching community. This paper proposes data transmission over error controlled QoS support routing scheme EAMU for localized systems where demand for service are high. EAMU suggests an optimal error identification approach for selection of a data transmission route, which follows route identification based on ratio of errors identified and its corresponding distance to sink as location aware to solve the problem. Providing optimal QoS is controlled by assigning a least transmission power to the nodes where each node is aware of location information and hence able to adjust their transmission power accordingly. EAMU is simulated using NCTUns2.0 whose performance shows minimal energy consumption of sensor nodes compared to SPIN.

Key words: Energy utilization · Optimal route · WSN · QoS

INTRODUCTION

Wireless Sensor Network (WSN) finds huge applications [1-3] in pervasive computing and embedded technology. The sensor networks can support on large deployment of independent sensor considered as nodes which has constraint in battery power with additional feature of mobility, limited memory capacity, minimal processing capabilities, capacity to handle minimal resource, need for energy conservation, which forms the basis of designing proactive routing protocols. Sensor nodes of WSN have the capability to organize into a self manageable network [4], such that these networks are highly susceptible to dynamic change in topology due to random mobility and consistent need for bandwidth. However, WSN networks are constrained towards energy supply, bandwidth, hence deployment of large sensor nodes, may suggest enormous challenges to the design, deployment and management of networks. These research challenges [5, 6] bring in awareness in terms of energy consumption, QoS management, aspects of security in networking protocol stack, hence researchers suggest on system-level power awareness such as scaling of dynamic voltage, hardware design for radio communication, issues in low duty cycle, partitioning of system, energy awareness in MAC protocols. This research issue had provoked multiple challenges towards development of QoS based routing schemes with effect on energy management for differentiated service aware system, can actuate or respond to any change of event over a defined time interval.

Most research works [7, 8] in WSN focuses on QoS provisioning by identifying optimal routes between a source and receiver nodes belonging to multiple domains. Researches towards route identification based on energy aware of WSN nodes and predictive routing has much

Corresponding Author: K. Raja, Department of Information Technology, Annamalai UniversityAnnamalainagar - 608 002, Tamil Nadu, India.

impact on real time implementation and applications. Much less work had been carried out on energy aware routing based on service capacity of WSN node [9, 10]. Even though service type and energy utilization of a wireless sensory node plays vital role towards route identification, its complexity lies in varying WSN topology.

Challenges in QoS with support for routing energy-awareness [11] are unique to WSN, since any change in node topology, multi-hops and sharing of wireless medium increases the data transmission complexity of network. Nodes in WSN can achieve the expected QoS only if its range of sensing is understood or effectively known before hand. Sensor node which is observed within another node's interference range lead to collisions when both try to transmit, which lead to retransmission of same data, which may lead to additional delay and low packet delivery rate. Phenomenon of transmission and retransmission of data suggest consumption of additional energy consumption, interference and suggest additional latency hence increase the end to end delay. QoS parameters such as channel interference, round trip time taken, end-to-end packet delay are the route metrics adopted while signal noise, senders signal strength, receiver's signal strength relate to error ratio [12].

The proposed EAMU approach lays emphasis to improve the performance of WSN based on selective route identification for defined energy capacity (in Joules) of node and service capacity of nodes engaged in transmission between any source and sink. Identifying the optimal QoS for a WSN depends on multiple sensitive metrics such as node communication range, interference ratio, topology of node, location management issues, type of services in use. The link information supports on congestion identifier which can be defined as ratio of measured arrival rate as input and defined service rate as output [5]. The essential requirement for QoS computation under congested scenario can be evaluated under the operational network throughput along with information inconsistency and uncertainty of topology.

EAMU adopts the following research phenomena:

- Node characterization to improve the packet delivery rate, suggest optimal QoS based on routes in use.
- Design on an optimal scheduling algorithm to propose an improved throughput.
- Design an algorithm where computation complexity is independent on size of network.

Literature Survey: An in-depth survey and review is carried out to analyze the existing effective WSN routing protocols which focus on establishing routing paths and node energy. Derbew *et al*. [1] work elaborates support to QoS in WSNs as well analyze on the QoS demand imposed on its major applications. An intensive research and analysis is conducted on routing approaches related to data aggregation [13], but major MAC layer retransmission issue is not discussed. Krishnamachari [8], work on WSN routing discusses on major suboptimal aggregation heuristics, such as Center at Nearest Source (CNS), Shortest Paths Tree (SPT) and Greedy Incremental Tree (GIT). The outcome of CNS, SPT is found to be similar to AODV protocol for MANET, yet the throughput of these schemes was not effective in terms of data loss and path establishment. Lin *et al* [14], discussed on consumption of energy and its tradeoffs between data aggregation and retransmission in wireless sensor network by using CSMA/CA MAC protocol. But Lin's work does not support on energy consumption frame work, hence power consumption in idle mode is not discussed and retransmission latency where the algorithm fails towards identifying an energy efficient data aggregation tree, hence guarantee on QoS is not acceptable.

Ian.F.Akyildiz *et al.* [7] work discusses on survey of routing protocols on sensor networks. The research work suggests on different protocols, such as "flooding" as an algorithm to relay the message from any source node to any destination node in network. Drawback of flooding observed is message redundancy, design complexity and not supported as energy aware. Gossiping [12, 15] overcomes the drawback of flooding, where a node determines its neighbor nodes to send data which continues until message reaches the expected destination node, due to which its redundancy and complexity decreases.

PASCAL (Power Aware Sectoring based Clustering Algorithm for WSN networks) is suggested [16] with high level of implementation, clustering and sectoring approaches [17]. This routing algorithm adopts WSN nodes as static with minimal or low mobility speed based on signal propagation and node visibility. Algorithm defines the packets to be forwarded by flooding, where in concept of node switching negotiates with neighboring node which improves the lifetime of network. Sorabhi *et al*, [18] work on Directional Source Aware Protocol (DSAP) which focus on WSNs routing approach, where any node adopts its local information as routing protocol and each node updates the neighbor node information at regular periods of interval. The integrity of the node is maintained which transmits packet to its known neighbor, being considered closer to destination. This process continues, until the packet reaches the destination. The algorithm adopts Directional Value as a vector value to choose a neighbor node to forward the packet to destination.

SPIN (Sensor Protocols for Information via Negotiation) [12] generates a data dependent routing mechanism. SPIN adopts naming procedure for meta data suggested using high level descriptors. During transmission, SPIN uses sensor meta-data to be exchanged between multiple sensors through data advertisement mechanism in order to select the route for transmission. This method re-solve issues of flooding, redundant information passing, node sensing areas overlapping, resource blindness and also improves energy efficiency.

Set of sub-optimal paths which are adopted to increase the lifetime of network is discussed by Shah *et al*. [9]. Such route paths are selected based on probability function, depending on the energy consumption of route path. The approach also elaborates that minimum energy usage of route path at any time will deplete the energy of nodes on route, where multiple paths are used with variable probability where the lifetime of network increases. Low-Energy Adaptive Clustering Hierarchy (LEACH) [12] follows hierarchical routing algorithmic approach which defines cluster of multiple sensor nodes based on the signal strength received and local cluster heads utilization as router interconnected to sink. This approach consumes less energy since the transmissions between nodes is carried out by cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes.

A reliable transport scheme (ESRT) for WSNs is proposed by Y. Sankarasubramaniam *et al*. in [10]. The transport solution is developed to support reliable event detection with minimal energy expenditure in WSN. M. Perillo *et al* [2] focus on application based supportive QoS through multi-objective optimization of data routing with sensor scheduling. The work can be extended over the network lifetime considerably when compared to intelligent scheduling approaches which do not support combined "power-aware" routing algorithms.

EAMU algorithm keeps anvil of energy consumption of all nodes in transmission within its domain range, since any failure of a node due to less energy node may lead to loss of data. Selection of a node with less energy may lead to node or link failure such that configuration of network is repeated and routing paths are recomputed for route selected in each communication pattern. This process may lead to reduced QoS and degrade the performance of network lifetime. Optimal route selection leads to selection of short routes resulting with depletion in batteries. Hence this research work adopts an end-to-end channel quality and awareness defined in terms of lifetime of route path.

EAMU: Major task of a wireless sensor node in a network performs data collection, data aggregation, transmit as well monitor / control events. An effective "power-aware" routing algorithm [19] over wireless sensor networks focus on procedures:

- To decrease the end-to-end delay
- To improve the network reliability
- To minimize the energy consumption during transmission of packet and data processing as well improves the lifetime of the network

Hence EAMU algorithm is designed to guarantee "on demand" QoS while considering limited energy supply available in nodes. The lifetime of a node [20] is conditionally defined by available energy, the algorithm is expected to utilize nodes for routing as well preserve their energy. Focus on error control procedures [19] over QoS routing is major factor to determine the life of a sensor network, since sensor nodes are driven by power consumption and possess resources of low energy. The major objective of EAMU is to improve lifetime of network by suggesting the link cost as a function of node's unused energy and calculating the defined link's transmission energy. EAMU's principle and frame work is as follows:

- Understand the pattern change of the node's reading / update in WSN network.
- To determine, eliminate any redundant information or data in node.
- To predict node failures and eliminate such nodes in route establishment.
- To support on residual energy of the sensor nodes.

Energy Aware Model: An energy model [14] is adopted where each node is initiated with an initial energy. This node forwards a packet by consuming one unit of energy. Initially in experimental setup, all WSN nodes are assumed to manage similar energy level.

Notations Proposed in Work:

Notation	Description
N	Set of WSN nodes, where N= $(n_1,n_2,\ldots n_m)$
B	Maximal propagation delay for data packets transmission
P	Rate of Packet arrival
S	Node defined as sink
Rn	Transmission radius of node n
E(ni)	Defines nodes energy consumption function, which is dependent on node transmission radius
E_T	Observed energy consumption rate, where sensor nodes operate in idle mode
T	Maximum times / number of retransmissions
L bits	Size of a data transmission
B bps	Sensor node's transmission rate
tx sec	Transmission of data packet (msecs)
Max Ei	Maximum energy life time routing
N_{ri}	Node residual energy
N_{ui}	Node Utilized energy
Se	Session Error rate

Consider an undirected graph G(V,E) (Fig. 1), where G ⊂ V, such that no two nodes in the subset defines an edge which can be defined as distance 'd' between nodes. For every vertex V in G, let there exists a vertex V ⊆ V', for each node ni ∈V, hence ni may also exist in V'.

Fig. 1 shows 4 neighbor WSN topology, where node A is represented with 2 edges, a,b. Similarly other nodes B,C, D and E are represented by corresponding edges. Each vertex gets connected to its neighboring vertices i.e. A, B, C, D and E. As each node identifies its location, as well its neighbors nodes' location by directional values, EAMU algorithm can send its message from the defined source to destination as well receive messages.

Each node adopts the following properties,

- Each WSN node in network is assigned a unique ID.
- Each node maintains the relative distance'd' between nodes (ie. total perimeter of nodes in a communication range in each direction).
- Each node computes the relative direction of another WSN node from its ID.

The nodes within a range are located on a euclidean plane such that each node follows a transmission range R ∈ $[r_{max}, r_{min}]$. Here r_{max}, r_{min} are defined as the maximum and minimum signal strength of node ni through which nodes can transmit data or communicate.

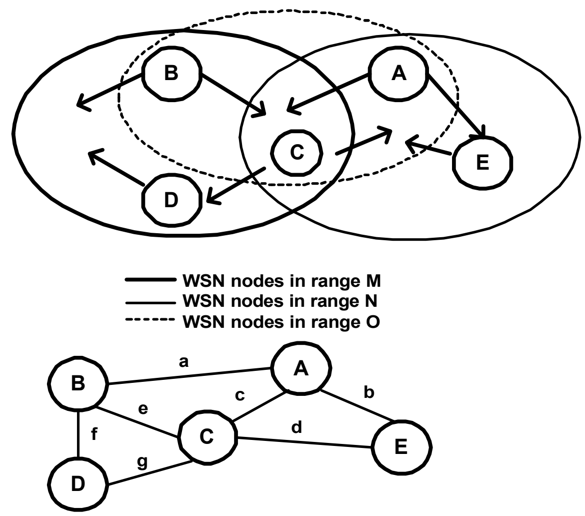

Fig. 1: WSN forming a graph network on mobility

The directed edge between two nodes (ei, ej) ∈ E if and only if distance 'd' between two nodes n_i, n_j whose vertices d(vi, vj) ≤ R here d(vi, vj) denotes the Euclidean distance between vertices vi and vj.

To model the behavior of energy utilization in WSN network, it can be assumed that every node 'n' starts with the same initial energy 'e0' and forwards a packet 'Pi' by consuming one unit of energy.

The algorithm is structured such that data-fusion reduces the amount of data transmission between nodes engaged in communication. The decision of identifying the node for transmission is made dynamically at each interval which depends on node properties as discussed in **EAMU_transmit ( )**. The decision of selecting a node for data forwarding is primarily important as it minimizes energy utilization overhead since each node is independent of other nodes to minimize overhead in route establishment [19]. The decision approves the function as percentile of optimal routes involved in forming the network within cluster [17] or intra-cluster.

The energy consumption $E(n_i)$ in sending a units of joules for data transmission between nodes:

$$E(n_i) = E_T + E_R \quad (1)$$

$$E_T = a \text{ x } (e_m + e_a \times d^{ni}) + a \times e_r \quad (2)$$

Here:

E(ni) = Indicates the energy dissipated at any single node 'ni'

E_T = Energy consumptions of data transmission
E_R = Energy consumptions of data receiver
Ec = Energy utilization factor

Energy dissipations in operating the transmitter radio (e_a) and receiver radio (e_r), transmitter amplifier (e_m)
d is the distance between nodes n_i and n_j
a is the parameter of power attenuation with (0 = n= 1) for a node 'i'
α is the error (0.001)
$r = e_a - e_r$

$$E(c) = \frac{E_T - E_R}{1 - d(n_i - n_j)^* R\,(\text{mod}1/r)^{\alpha}} \quad \text{if } n_i, n_j \in N \tag{3}$$

Initially the sensor nodes support on location identification based on node neighborhood which supports in forwarding packets. The protocols work on energy conservation and effective bandwidth utilization since traffic discovery at nodes increase phenomenon of flooding. A sending node acquires the address of the destination node before identifying the neighboring node for establishing the route path. When the message needs to be transmitted, the distance from each source node or forwarding node to the destination node measures the distance 'd' between nodes. 'Ec' explains the energy utilization (Eq-3) between set of nodes engaged in establishing a communication path and transmission of data between source to destination.

Eamu Algorithm: EAMU algorithm works on assumption of WSN nodes located within a region, such that their intermediate distance is relative to their signal strength. Any node which sends data or receives data consumes energy, if and only if an optimal multi-hop route is identified or selected. EAMU algorithm adopts the following assumptions:

- Event Handling: If any event is noticed at a node, then the node floods data packets to every of its neighbor.
- Data Handling: The nodes which are in WAKE mode are destined to receive data packets and SLEEP mode nodes don't receive packets [21]. Nodes which receive data packets check on its node identity along with assigned packet ID
- Error Handling: Any missing sequence number of packet denotes packet drop or loss as well duplication of packet which indicates Packet mislead [6].

WSN node acts as both sender and receiver, where a route is is computed if an energy efficient node is identified among the available route. Fig. 2a shows neighbour node discovery and route establishment process where node D identifies node B as neighbour node based on EAMU.

The process of route request and reply between nodes B and D is shown in Fig. 2, which formulates the route as shown in Fig. 2c.

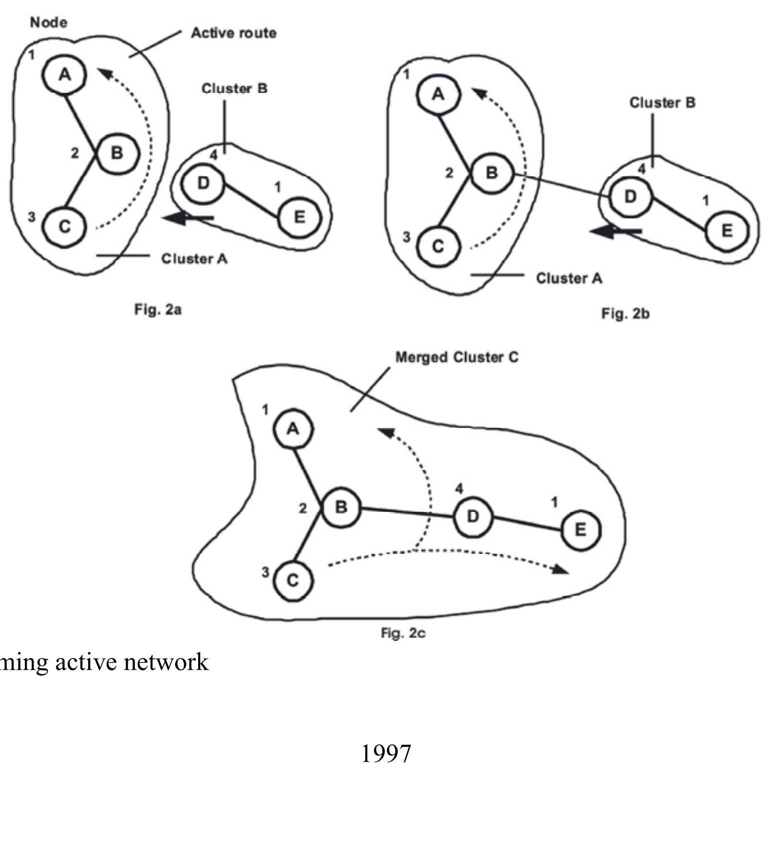

Fig. 2: WSN nodes forming active network

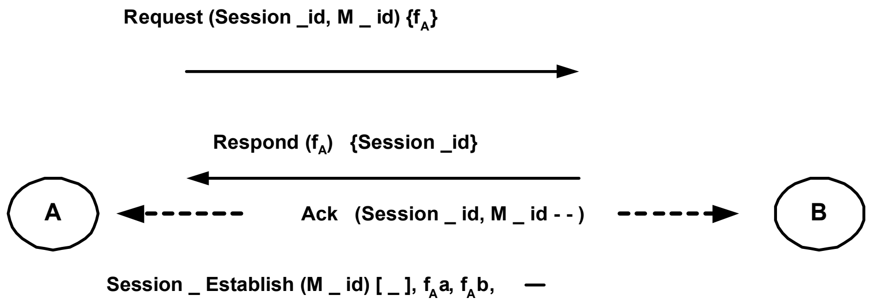

Fig. 3: Node activity during a session

Evaluation of QoS [15] is based on the previous behavioral knowledge of the system in service with the observations of related actions and with other entities [5]. The system had been integrated as an exclusive mechanism of providing QoS, which can be interpreted as a relation among multiple nodes which should support resource management and willingness to participate in various shareable services [20].

- Node 'n' maintains a unique ID 'M_id' within a cluster Ci.
- Node's activity 'F_A'is updated while leaving or joining a cluster Ci
- Any node 'n' in each cluster Ci should update its activity 'F_A' to neighbor node when it moves from one Cluster Ci to another cluster Cj.
- The Node 'n' update of 'F_A' is dependent on its neighbor update and hence any node's behavior 'M_id', status update can be controlled.

Fig. 3 shows the session maintenance between set of nodes A and B which are involved in establishment of route path. M_id defines the unique id of node within a cluster and any update on a node at any instant of time 't' is defined as 'F_A'. An 'M_id' is assigned to a node only when its within a cluster and engaged in a route establishment over period of time't'.

EAMU_TRANSMIT ( )

Input : [a] Data sent / received by sensor node.
[b] Transmission Power of node
[c] TSRSS : Transmission Send Receive Signal Strength of node
[d] ARSSI : Average TSRSS
[e] AEED : Average End to End Delay

Output: QoS metrics, Average Rate of transmission, Packet Loss

For each WSN node Ni

1. Define N = {n1, n2, …., nm}
2. Distance dj = Min (ni, nj)
   Set dj = 1 // initialize the distance to be selected between nodes

3. Identify the TSRSS (in mW)
   If SendSigStr (ni) > RecvSigStr (nj)
      W [ ] = ni, nj, .. nk // gather nodes of higher signal strength
      Gather ei // energy of node n in W
      Gather r [ ] // radius of node in range 'R'

4. while (W[ni] !=NULL)) {
      SendData (ni, &portno, TCP_Proto, packet, t_{ni}) // Transmit Data Packet @ t_{ni}
      nj = RecvData (packet, t_{nj})
      pkt_{loss} = packet(nj) - packet (ni)
      TRSSI = ei * r * pkt_{loss}
         goto step-2}
   ARSSI= TSRSS/N

5. t_{ni} & t_{nj} - the time taken for node ni and nj to send and receive
   do { // gather hops length for all nodes
      a=1;
      h[a] = Min (t_{ni}, t_{nj}) // Hop to Hop Delay for route
      a++; // another route
   }

6. Find the End to End Delay (EED) for route 'a'
   EED = Max (W[ ], b[ ])
   AEED=EED/N

7. do { Compute E (a) where 'a' being the route selected for transmission }
   if (h[a] > h[a++] && di < r[ ])
      E(a) = AEED * ARSSI

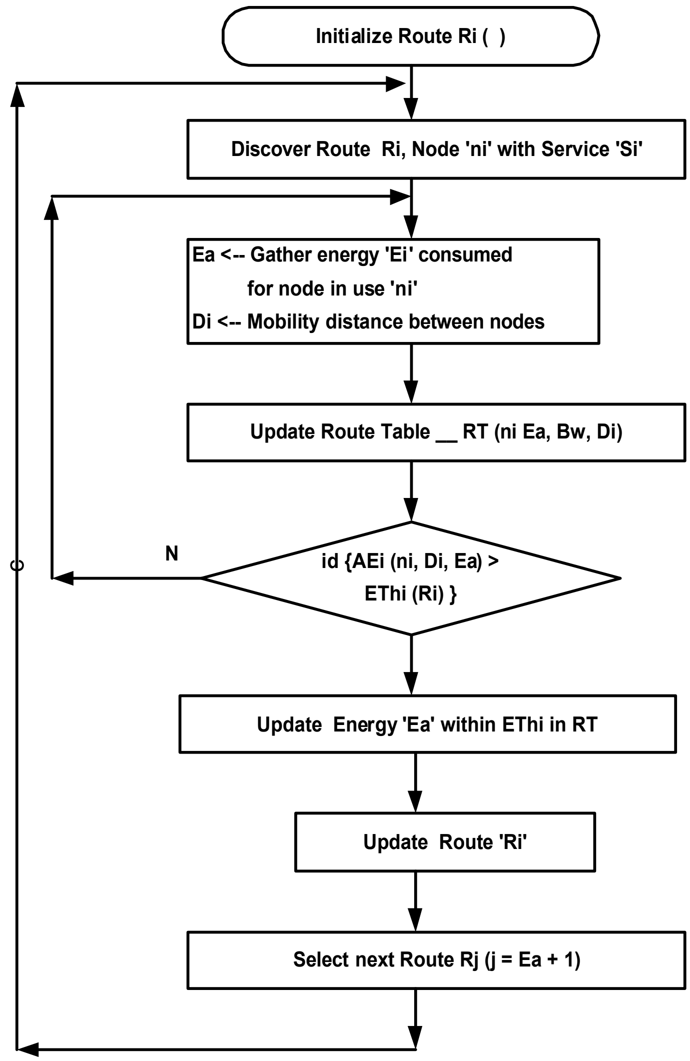

Fig. 4: EAMU procedure

Any WSN node is part of the network if it adopts EAMU procedure (Fig. 4) and forwards a packet, else it is considered as independent node and is not part of the network. To increase the node lifetime for routing over a session established, energy used in intermediate nodes for routing also plays a major role. This paper suggests consistent and local energy update of nodes where node is selected only if the condition of threshold energy is identified. In this update process, selection and reselection of node with lower than the threshold energy decreases the relation of session connectivity. While nodes with upper than threshold energy award session connectivity is conferred. Network lifetime and the number of active nodes will increase with EAMU which had been proved by simulation.

Experimental Approach: WSN was simulated in the presence of multiple QoS factors having effect on routing protocol performance. The simulation test-bed works on WSN scenario designed with two gateways and Wireless sensor nodes that belong to IEEE 802.11, IEEE 802.15 standards. The nodes can multicast data /signal packets for transmission during a session established over AODV/DSR protocol. Services such as FTP, messaging can be extended over WSN such that nodes participate in routing.

Simulation time for each scenario was set to 500 milliseconds and repetitive simulations for each scenario were performed to verify the reliability of our results. The network was modeled on an area having dimensions of 500 x 500 sq-meters. The packet size is variable in

Table 1: Simulation metrics

Network Layout	500 x 500
Number of nodes (N)	200
Energy – Initial	0.01 joules
Frequency	700
Connectivity range	60
Sensing range	30
Sink	300,300
Mobility	20 ms

nature adopting to IPv4 standards and the packet rate is 2 packets /sec. All nodes in this network are considered as source nodes communicating with constant bit rate 1 Mbps. Nodes are selected chosen as 50, 100, 150, 200 (Table 1) with the required set of input parameters. A node whose energy is less than threshold set is considered as dead and not selected for simulation. Target node is located within the range of communication such that all data being received can be considered for scenario analysis.

In the proposed scenario, routing is based on the AODV/DSR protocol, a simple and efficient routing protocol designed specifically for use in multi-hop wireless adhoc sensor networks. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure. The capability of sending route replies using cached routes had been disabled in simulations. The physical layer uses the Direct Sequence Spread Spectrum (DSSS) technology and the data rate was set to 11 Mbps (IEEE 802.11b standard). For all nodes, the transmit power was set to 0.005W and the packet reception power threshold was set to -95 dBm. The simulation was carried out with data transmission of sensor nodes, which are routed to the destination node through multi-hop intermediate nodes. The simulation node size varies between 25 to 100 nodes with 100% active source nodes and random topology has been considered in this implementation.

Analysis: Assumptions followed for EAMU analysis:

- Multi-hop (n = 2) is followed over a routing path
- Measurement data for an active period of duty cycle is transmitted as one packet
- EAMU algorithmic approach is experimented along with LEACH, SWIVES and SPIN algorithm
- CPU power consumption is ignored, but power consumed for data transmission is updated
- Error ratio over a designated channel is updated.

Fig. 5 shows the performance of EAMU over variable time schedule to establish route in respect to active nodes. Throughput of EAMU is found to achieve an average of 15070 bps over WSN nodes on mobility compared to SWIVE and SPIN which demonstrates an average of 14030 bps and LEACH with 12240 bps. The average throughput is maintained throughout the session which also improves as the number of nodes increases which is worthy observation.

Fig. 6 shows the delay encountered by SPIN and EAMU for QoS error handling schemes during the simulation run for scenarios. LEACH shows a higher delay of 7040ms while EAMU performs the minimal delay of 840ms along with SWIVES with 1029ms.

The packet delivery ratio (PDR) shown in Fig. 7 explains on performance of EAMU with an average of 47.84% delivery rate consistently where the performance improves to 53.27% when the number of nodes increases. SWIVE follows with 44.38% and SPIN with 37.45%. Performance of EAMU is dependent on number of bytes transferred per second with number of active nodes involved in route maintained.

EAMU exhibits the lowest energy overheads as shown in Fig. 8. Energy overhead of EAMU is competitive with that of SPIN. It can also be noticed that percentage of packet drop rate is reduced by 20 % (Fig. 8) in EAMU compared to SPIN over AODV routing protocol. Hence,

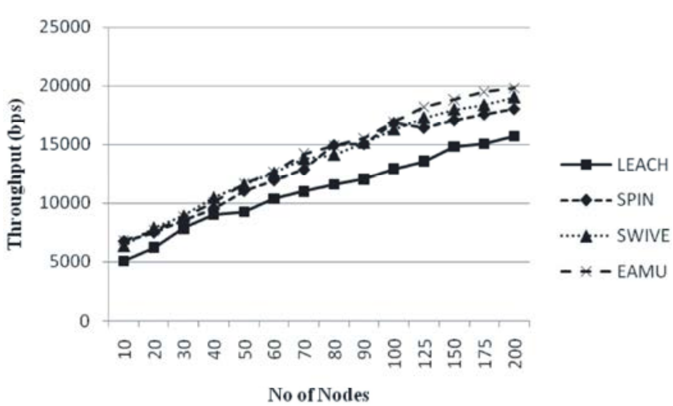

Fig. 5: Throughput observed with respect to active WSN nodes

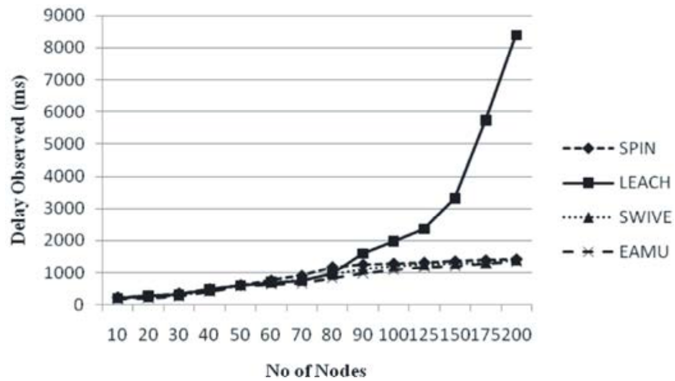

Fig. 6: Observed Delay (ms)

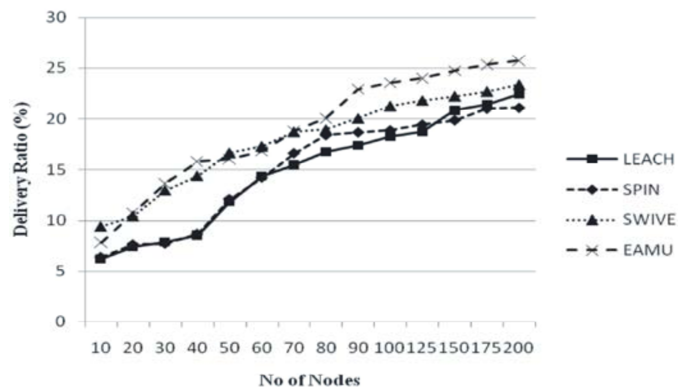

Fig. 7: Observed Packet Delivery Ratio

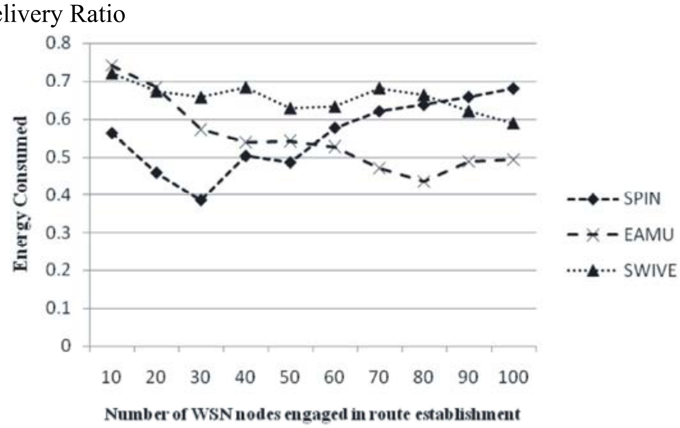

Fig. 8: Percentage of energy consumed for active WSN nodes during routing

EAMU approach conserves more energy and is more efficient than SPIN in DSR and AODV routing protocols. The energy consumed by WSN over a route for a complete round trip is discussed in Fig. 8. Three algorithms are used for comparison, where performance of EAMU is found to be much higher compared to SPIN and SWIVE. Much less energy had been consumed by EAMU in comparison over to SPIN and SWIVE schemes and result show that EAMU has better network life than that of the existing QoS based energy conservation schemes.

Summary and Future Work: Few research efforts have been made in QoS support for WSNs. The literature survey discusses on analysis of QoS requirements imposed by the main applications of WSNs and identified that the end-to-end QoS concept used in traditional networks may not be sufficient in WSNs. Traditional QoS context of WSN employs efficient resource utilization such as bandwidth, but minimal usage of energy should also be considered. Thus, QoS support in WSNs should include QoS control mechanisms also besides QoS assurance mechanisms employed in traditional networks, which eliminates unnecessary energy consumption in data delivery. EAMU scheme supports WSN networks in following research aspects, (a) providing required optimal QoS support for WSN networks, (b) controlling and minimizing energy consumption during routing process, (c) providing consistent energy efficiency over a multi-hop WSN networks, which supports on demand QoS which is required for the future of IoT networks [22].

REFERENCES

1. Derbew, Y. and M. Libsie, 2014. A Wireless Sensor Network Framework for Large- Scale Industrial Water Pollution Monitoring, HiLCoE Journal of Computer Science and Technology, 2: 95-101.
2. Perillo, M. and W. Heinzelman, 2003. Providing Application QoS through Intelligent Sensor Management, Proceedings of the 1st IEEE International Workshop on Sensor Network Protocols and Applications (SNPA ’03), May 2003.
3. Prasad, A.N., K.A. Mamun, F.R. Islam and H. Haqva, 2015. Smart Water Quality Monitoring System, 2015 2nd Asia-Pacific World Congress on Computer Science and Engineering, pp: 1-6.
4. Akyildiz F., *et al*., 2002. Wireless sensor networks: a survey, Computer Networks, 38: 393-422.
5. Pottie, G. and W. Kaiser, 2000. Wireless integrated network sensors, Communication of ACM, 43: 51-58.
6. Ye, W., J. Heidemann and D. Estrin, 2002. An Energy-Efficient MAC Protocol for Wireless Sensor Networks, Proceedings of IEEE Infocom 2002, New York, NY, June 2002.
7. Ian. F. Akyildiz, Weilian Su, Yogesh Sankarasubramaniam and Erdal Gayirci, 2002. A Survey on Sensor Networks,” IEEE Communications Magazine, August 2002.
8. Krishnamachari, B., D. Estrin and S. Wicker, 2002. Modeling Data-Centric Routing in Wireless Sensor Networks, USC Computer Engineering Technical Report, CENG, pp: 02-14.
9. Shah, R. and J. Rabaey, 2002. Energy Aware Routing for Low Energy Ad Hoc Sensor Networks, In the Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), Orlando, FL, March 2002.
10. Sankarasubramaniam, Y., B. Akan and I.F. Akyildiz, 2003. ESRT: Event to Sink Reliable Transport in Wireless Sensor networks, MobiHoc 2003, Annapolis, Maryland, June 2003.
11. Raghunathan, V., C. Schurghers, S. Park and M. Srivastava, 2002. Energy-aware wireless microsensor networks, IEEE Signal Processing Magazine, pp: 40-50.
12. Liu, X., 2012. A Survey on Clustering Routing Protocols in Wireless Sensor Networks, Sensors, 12: 11113-11153.
13. Lee, M. and W.S. Wong, 2005. LPT for Data Aggregation in Wireless Sensor Networks, IEEE GLOBECOM 2005.
14. Lin, F.Y.S., H.H. Yen and S.P. Lin, 2009. A Novel Energy-Efficient MAC Aware Data Aggregation Routing in Wireless Sensor Networks, Sensors, 9: 1518-1533.
15. Lin, C., 2001. On demand QoS routing in multihop mobile networks, Proceedings of Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), 3: 1735-1744.
16. Md. Aquil Mirza and Ramamurthy Garimella, 2009. PASCAL: Power Aware Sectoring Based Clustering Algorithm for Wireless Sensor Networks, 2009.
17. Sun, Y. and X. Gu, 1988. Clustering Routing Based Maximizing Lifetime for Wireless Sensor Networks, International Journal of Distributed Sensor Networks, pp: 5.
18. Sohrabi, K., 2000. Protocols for self-organization of a wireless sensor network, IEEE Personal Communications, 7(5): 16-27, October 2000.
19. Sausen, P.S. and M.A. Spohn, 2010. Broadcast routing in wireless sensor networks with dynamic power management and multi-coverage backbones, Information Sciences, 180: 653-663.
20. Lee, M. and W.S. Wong, 2005. An Energy-Aware Spanning Tree Algorithm for data aggregation in Wireless Sensor Networks, IEEE 2005.
21. Schurgers, C. and M.B. Srivastava, 2001. Energy efficient routing in wireless sensor networks,” In the MILCOM Proceedings on Communications for Network-Centric Operations: Creating the Information Force, McLean, VA, 2001.
22. Perera, C., C.H. Liu and S. Jayawardena, 2015. The Emerging Internet of Things Marketplace from an Industrial Perspective: A Survey, IEEE Transactions on Emerging Topics in Computing, 3: 585-598.