EFFICIENT ENERGY AND LOAD BALANCING DATA AGGREGATION ALGORITHM FOR WIRELESS SENSOR NETWORKS

M.Jayekumar[1] and Dr.V.Nagarajan[2]

[1]Department of Electronics and Communication Engineering, Manakula Vinayagar Institute of Technology, Puducherry, India;email: placement@mvit.edu.in

[2]Department of Electronics and Communication Engineering, Adhiparasakthi Engineering College, Melmaruvathur, Tamil Nadu, India; email: nagarajanece31@gmail.com

Abstract: *Wireless Sensor Network is prominent among researchers and users for its unique data gathering and remote monitoring processes in adverse on-demand environments. Sensor nodes are battery dependant computational devices that have limited lifetime; to prolong the lifetime of these devices, energy optimization in WSNs becomes significant. Data aggregation conserves energy by integrating and transmitting data from different sources to the target node through a common aggregator. Extensive data aggregation techniques were proposed for energy optimization and to support data intensive transmissions in these networks. Cluster based adaptive and distributed data gathering protocols concentrate on extending lifetime of node and network with adequate data gathering. On account of change in multiple header and updation phases, the process of extending lifetime fails and transmission pause time increases. Transmission pause time in turn increases aggregation delay that reflects in end-to-end delay. Asynchronous information transmission increases routing loops which adds up data duplication and as well retards the flow rate after cluster head re-election. We put forth a distributed, fore hand status updating, data handling and node replacement algorithm called Efficient Energy and Load Balancing Data Aggregation (E2LBDA) Algorithm to minimize aggregation pause time and to avoid routing loops. Our algorithm further enhances the lifetime of the nodes by sharing data based on residual energy. Our manifold process not only improves energy conservation and network lifetime, but also minimizes delay and upholds network throughput.*

Keywords: *Energy Efficient Routing, Load balancing, Duty Cycle, Data Aggregation, Buffer management.*

1. INTRODUCTION

Wireless sensor networks are deployed with collection of sensor nodes that are distributed to monitor environment and communicates with other sensor nodes cooperatively. Sensors are built using micro electro-mechanical systems which has led to develop limited resources nodes. Wireless sensor networks are used in various applications such as environmental monitoring, industrial applications, surveillance applications, health monitoring and other supervisory applications. Many types of sensors are available such as a) light sensors b) temperature sensors c) humidity sensors d) pressure sensors e) GPS modules f) seismic and rainfall sensors [1]. In a WSN, the sensors nodes are utilized to collect information and forward it to the base station. Since multiple sensors are deployed, each sensor dissipates its energy in forwarding messages to base station. To overcome this issue, data aggregation concept has been defined, which combines data from multiple sensors and forwards it to the base station.

The energy consumption for data aggregation is very low when compared with traditional forwarding mechanisms; it also avoids duplication of data with higher efficiency and network scalability. The data aggregation protocols are classified into a) Structure approach and b) structure free approach. In former approach, the battery drains faster in analyzing and arranging network topology, leading to network failure. In structure free approach, the battery power is not wasted in establishing network topology [2]. Data aggregation for large wireless sensor networks has been made possible by reducing the set of nodes to be in active state, which reduces network utilization [3]. In case of heterogeneous networks, data aggregation happens through tradeoff between data quality and energy utilization [4]. Data aggregation is made easier through mobile sinks with rendezvous points in effective manner with lower energy consumption [5]. Aggregation using tree based topology has been reliable by providing time slots in which node forwards data and with predefined transmitting power, thus improving the network lifetime [6].

Devi et al., [7] anticipated an energy efficient selective opportunistic routing (EESOR) protocol that constructs routing table with all neighboring nodes and updates it periodically. The shortest distant node is selected between source and destination that forwards acknowledgment packets through opportunistic route. Simulation results of [7] represent that EESOR protocol is reliable in terms of packet delivery ratio, prolongs network lifetime with minimal delay.

Jain et al., [8] proposed a methodology to reduce energy consumption of nodes for data communication between node and sink. In work [8], to make all nodes available in transmission range, network restructure is projected. The maximum energy consumption between node and sink is marked as threshold value. Node that has edge with single sink is identified as unique node. The remaining nodes are connected to the sink without exceeding the threshold value. This process is recursive and keeps on tracing the energy consumption of sink which extends network lifetime.

Leu et al., [9] proposed Regional Energy Aware Clustering with Isolated Nodes (REAC-IN) which consider residual and regional energy of nodes for selecting cluster head. The node joins the cluster head by receiving join-CH message and if node fails to receive the message, then that node is meant to be an isolated node. Based on distance between isolated node and destination, the isolated node decides whether to communicate with the destination or cluster head. Simulation results of REAC-IN protocol show the enhancement of network lifetime and provide stability to the network.

Alshawi and Alalewi [10] proposed a new routing methodology known as FD star lite. It identifies the source node from sink node through key value by iteration. For optimal path selection, the identified node’s key value is compared with previously available node’s key value. If key value of identified node is found to be smaller than already available node’s key value, then the smaller key value is considered and again initiates the source identification process. Simulation results of [10] show that optimal path is identified with less energy consumption and less traffic.

Jesus et al., [11] studied various distributed data aggregation methods that is summarized as in Fig.1.

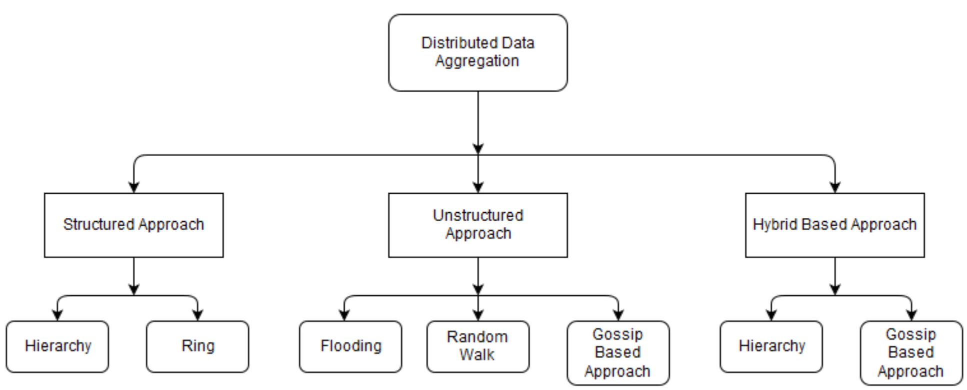

Fig.1 Distributed data aggregation types

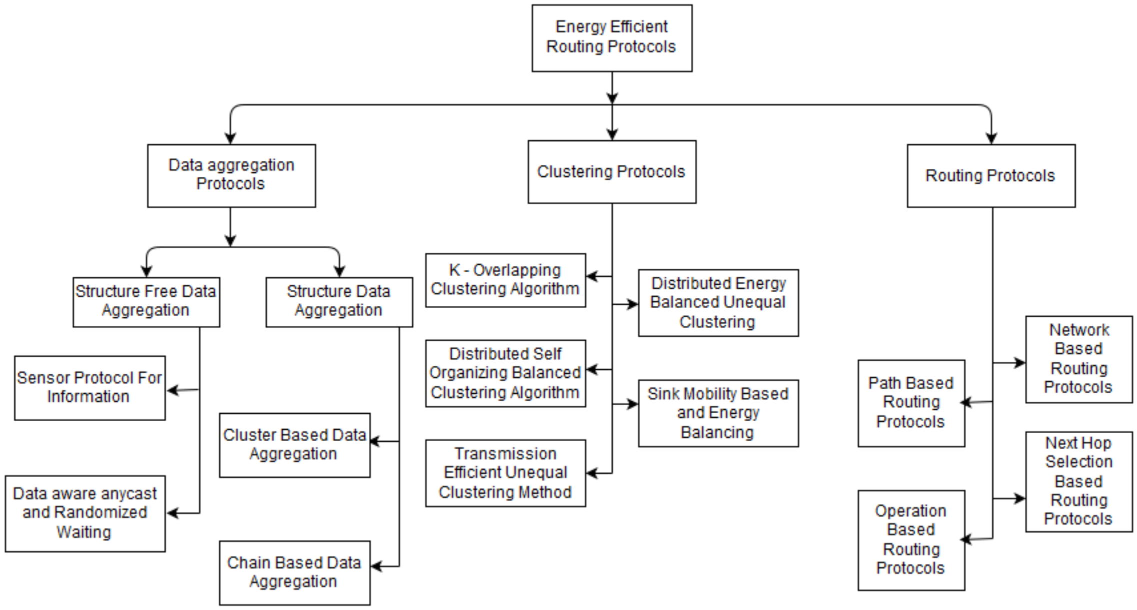

Fig.2 Energy efficient routing protocol classification

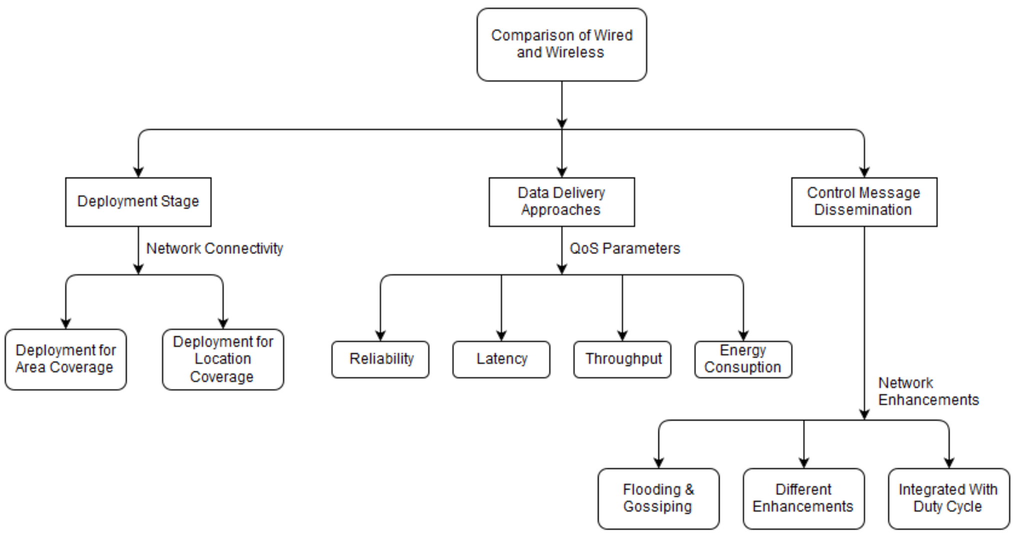

Fig.3 Wired and wireless comparison

Yadav.S and Yadav.R.S [12] reviewed different energy efficient routing protocols that are illustrated in Fig.2. Dhand and Tyagi [13] suggested the importance of data aggregation and studied various clustering based data aggregation protocols which are classified as a) homogeneous single hop (eg: LEACH) and b) homogeneous multihop clustering protocols (eg: M-LEACH) and c) heterogeneous single hop (eg: EECHE) and d) heterogeneous multihop clustering protocols (eg : Stable election protocol).

Krishnan et al., [14] reviewed several existing methods in data aggregation and notified the challenges and its solutions in data aggregation process. It involves: Tree based approach, In-network aggregation, Grouping and Reliability. Protocols that support sink reliable transmission, delay sensitive transport protocols and time critical event first (TCEF) reduces congestion and achieves stability with minimal energy consumption. Wang and Liu [15] analyzed the issues in data collection strategy of wired and wireless sensor networks as illustrated in Fig.3. Krishnamachari et al., [16] considered data centric routing protocols and compared it performance with and address centric. The network model depends on position and number of the source node and network topology. To evaluate these factors, source placement models such as event radius and random source models are considered. Simulation results of [16] show that data centric routing models perform better than traditional routing schemes.

Lee and Chang [17] proposed a fuzzy based clustering approach called LEACH-ERE. It uses clustering rounds and random integer of the nodes for cluster head selection process. If the generated random integer is greater than predefined threshold, then node enters cluster head candidate list. The nodes broadcast candidate messages with chance value, on receiving candidate message nodes compare its value with the received value. If node's value is greater, then it becomes cluster head and broadcasts cluster head messages to all the other nodes. Simulation results of Lee and Chang [17] shows that LEACH-ERE performs better in prolonging network lifetime than existing techniques.

Xia and Jia [18] projected a clustering method using hybrid compressive sensing for optimizing network lifetime by reducing number of transmissions. This sensing method identifies shortest route between the cluster head and the nodes. The sink segregates the network regions into clusters and forwards its coordinates to all the nodes. The cluster head advertises nodes to join the network. Simulation results of Xia and Jia show that the method in [18] can reduce transmission when compared with previous methodologies and can even equally perform in homogeneous network with irregular sensor field.

Rao et al., [19] discussed an algorithm known as PSO - ECHS which is an extension of particle swarm optimization. Initially cluster head is selected on the basis of remaining energy and distance. The nodes in the network forward remaining energy and location parameters to the base station so as to verify if it meets the predefined threshold value, to become a cluster head. Cluster formation phase takes place with parameters such as cluster head residual energy, distance from sensor node to cluster head, distance from cluster head to sink and cluster head node degree. Simulation results of [19] represent lower energy consumption with extending network lifetime.

Velmani and kaarthick [20] elaborated on velocity energy efficient and link aware cluster tree algorithm that consists of set up stage and steady stage. In set up stage the cluster formation and data gathering tree is constructed and in steady stage data transmission takes place. Cluster head election takes place by comparing values with threshold values. The nodes send data to cluster head on prescribed time window and forwards data to sink through data collection tree. Simulation results show that the algorithm in [20] increases data aggregation performance by reducing traffic.

Luo et al., [21] examined an energy saving opportunistic routing algorithm. Normally, transmitted data are subdivided into two types namely a) the node which collects data by its own and b) the data that is aggregated from relay nodes. The algorithm in [21] identifies the next relay node in an energy efficient way by selecting the node with highest priority from forwarding nodes to disseminate incoming data. Simulation results of [21] surpass existing methods in extending the network lifetime.

Petrioli et al., [22] proposed an Adaptive Load Balancing Algorithm – Rainbow (ALBA-R), a cross layer mechanism which selects relay nodes for load balancing and solves routing issues around a dead end. Simulation results shown in ALBA-R provide tremendous results on comparison with previous available techniques with lower energy and overhead.

Alghamdi [23] elucidated on load balancing ad-hoc on demand multipath distance vector protocol (LBAOMDV). Source nodes broadcasts route request packets (RREQ) to identify route between source and destination and lays multiple reverse paths. Route reply packets (RREP) identify multiple forward paths and data transfer takes place through qualified list paths. Simulation results for LBAOMDV algorithm represents better performance in load balancing with minimal amount of energy.

Palani et al., [24] presented a hybrid routing protocol, a combination of proactive and reactive routing protocol for load balancing. The destination nodes broadcast message to identify its neighbors and forms directed acyclic graph (DAG). Nodes which have DAG information are considered as DAG members. If source node is a DAG member it employs proactive routing protocol otherwise it utilizes reactive protocol. Simulation results represent that [24] improves load balancing with prolonging network lifetime.

Zhao et al., [25] suggested a multi-layer framework which consists of functionalities such as sensor layer, cluster head layer and mobile data collector known as SenCar layer. At sensor layer, a load balancing clustering (LBC) algorithm have been proposed for improvement of network life by forming nodes as clusters. It employs multi user multiple input output antenna technique has been utilized. A framework has been proposed namely load balancing clustering and dual data uploading (LBC-DDU). Simulation result in [25] shows that it prolongs network lifetime on comparison with existing methods.

Ren et al., [26] discussed about an Energy Balanced Routing Protocol (EBRP), which considers the deepness, energy density and remaining energy of the node to make packets flow towards the sink with minimal amount of energy. To enhance routing issues, loops are detected and eliminated. Loops are detected by EBRP in three phases namely a) one hop loop b) origin loop and c) queue loop and are eliminated by disconnecting the link that is far from the sink node and it preserves the link that node forwards packets to the sink. Simulation results of [26] show that EBRP performances better in energy balancing and in prolonging network lifetime.

Afsar [27] proposed an energy efficient multi layered architecture protocol (EEMA), an adaptive formation of clusters that changes in each round. The cluster head election takes place by evaluating the possibility of becoming a cluster head P_{CH} and broadcasts it to neighboring nodes within its range and waits for stipulated time. The node receives and compares it with its value, and then node elects itself as cluster head and advertises other nodes in the group. Similarly, super cluster heads with higher energy are formed to aggregate data from the bottom layers. After cluster and super cluster formation data communication takes place. Simulation results for EEMA [27] excel in data aggregation by enhancing network lifetime and decreasing delay.

Sinha and Lobiyal [28] examined prediction model for cluster head rotation and for data aggregation. In cluster head rotation this model is subdivided into two phases namely a) head nomination and b) head selection. For data aggregation, temporal data prediction based aggregation is discussed. To overcome most probability occurrences from near accurate predictions, this model are characterized into a) successive and b) non successive predictions. Simulation results of [28] represent energy savings of node due to prediction based models with reliable data.

Sajjanhar, U and Mitra, P. [29] projected a distributive energy efficient adaptive clustering (DEEAC) protocol in which residual energy and hotness value of nodes reflect in cluster head selection. Simulation results of DEEAC protocol [29] excels in extending network lifetime on comparison with LEACH protocol.

Gherbi et al., [30] anticipated a distributed energy efficient adaptive clustering protocol with data gathering (DEACP) protocol. The cluster head selection process includes parameters such as residual energy, node weight, distance between the nodes and distance between nodes and base station. Simulation results of DEACP protocol [30] prolongs network lifetime through load balancing.

In general, clustering in WSN is energy effective as it minimizes overlapping requests and improves directed broadcasts. The cluster head selection process increases routing loops, duplication of packets and pause time of transmissions. Network sustainability and network output degrade in the presence of loops, replication and delayed transmissions in WSN. Though transmission overhead is less, energy utilization increases as the number of attempts for reconnection increases. To overcome the drawbacks in communication and energy utilization, Efficient Energy and Load Balancing Data Aggregation (E2LBDA) algorithm is proposed.

2. NETWORK MODEL

2.1 Network Model

Consider a network with 'n' sensor nodes out of which a few serve as Source Nodes (SN) and one node acts as sink node (S_k) that is connected by intermediate nodes (I). The nodes are deployed in a random order possessing lesser mobility under Random Way Point (RWP) model, in X*Y region. Few among the sensor nodes act as Monitoring Nodes (MN). The count of MN depends upon the transmission range and network region. Intermediate nodes with higher energy are regarded as Primary Aggregator (PA). The nodes that are idle and possessing second higher energy are regarded as Secondary Aggregator (SA). Intermediate node selected as aggregator after multipath is considered as a Backup Aggregator (BA). The primary aggregator node initiates broadcast to request data from the active source nodes. MN are deployed to track nodes energy in the early stage of transmission, buffer as well as the flow rate in the post transmission. MN also announces recommendations for changing the aggregator node.

To conserve energy and to extend the Time-To-Live (TTL) period of the nodes, the nodes are switched over between active and sleep states. A node in active state is capable of performing transmission and reception. Switching over between various node transmission states for conservation of energy and lifetime prolonging is called duty cycle. Duty cycle is the ratio between active time period of the node and total lifetime of the node. A node in idle state is moved to sleep state with its radio receiver alone turned on. In this state, the node awakes in periodic intervals to listen broadcasts if any. This mode is called Low Power Listening (LPL) mode. The nodes are assumed to have lesser mobility.

2.2 Energy Model

Each node has same energy at the time of deployment. Nodes drain their energy at the time of broadcast, transmitting and receiving data. Energy consumption varies as the hop count varies from the source to the sink. Common nodes and Aggregator nodes have different energy consumption rate. The aggregator nodes accept multiple inbound edges and a single outbound edge to the sink. Data transmission to the sink is sequential in the order of aggregating data. The energy consumed by a node (E) with respect to receiving energy (E_{rx}), transmitting energy (E_{tx}), listening energy (E_l) and energy spent in sleep state (E_s) is given by [31]-[33],

$$E = E_{tx} + E_{rx} + E_s + E_l \qquad (1)$$

The transmitting energy (E_{tx}) is given by

$$E_{tx} = d_t \times E_{ut} \times t_t \qquad (2)$$

where, d_t is the data transmission rate, E_{ut} is the energy spent for transmission and t_t is the transmission time.

If d_r is the data receiving rate, E_{ur} is the energy spent for receiving and r_t is the transmission receiving time, and then E_{rx} is given by

$$E_{rx} = d_r \times E_{ur} \times r_t \qquad (3)$$

If E_0 is the initial energy of a node, Half drain energy (H_E) level of a node is regarded as the semi energy drain from the initial energy and is given by

$$H_E = \frac{E_0}{2} \qquad (4)$$

Residual energy of the node (R_E) is given by

$$R_E = E_0 - E \qquad (5)$$

3. EFFICIENT ENERGY AND LOAD BALANCING DATA AGGREGATION (E2LBDA) ALGORITHM

The proposed E2LBDA algorithm works in three transmission modes: (i) Energy efficient data transmission mode, (ii) Switch from PA to SA mode and (iii) Balanced data dissemination mode.

The overall working of E2LBDA algorithm is given in Fig.4.

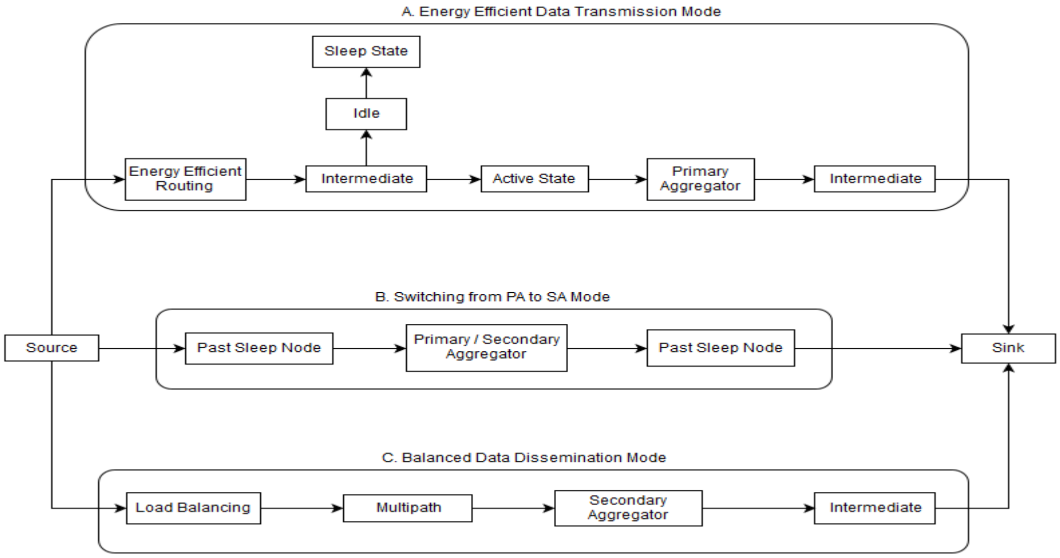

Fig.4 Overview of E2LBDA Algorithm

3.1 Energy Efficient Data Transmission Mode

The primary aggregator initiates broadcast to the source, requesting data transmission. Active source transmit data through their neighbor to deliver to the aggregator node. The aggregator initiates single path transmission to the sink initially. The nodes that are not utilized for transmission with the aggregator are moved to sleep state. The current active aggregator node is monitored by the MN for its energy utilization. MN updates the energy of the primary aggregator to the other in-range secondary aggregator nodes. PA energy drops early depending upon the amount of data it handles. Forehand update of PA energy helps the source to continue through loss less transmission.

Energy consumed by an aggregator node (E_a) is given by [34]

$$E_a = k \times \zeta_a(\frac{d_r}{k}) \quad (6)$$

where, k is the number of aggregation levels, d_r is the data rate and ζ_a is the aggregation function.

MN holds the list of active source nodes and updates the replica to the alternate aggregator nodes. This prevents additional broadcasts and adding up neighbors in the routing path. Consider $\{SN_1, SN_2, \ldots, SN_n\} \in n$ are the current active transmitting source nodes. The MN maps each sequence of transmission $\{T_{1q}, T_{2q}, \ldots, T_{nq}\}$ with the corresponding source node. This can be represented as,

MN updates the transmission sequence as $\{SN_1{:}T_{1q}\},\{SN_2{:}T_{2q}\}, \ldots, \{SN_n{:}\ T_{nq}\} \in \{SN{:}T\}$to SN where, q can take value from $\{1,2,\ldots,L\}$ and L is the maximum number of transmissions. MN also monitors the active time period of the common intermediates based on energy. MN recommends the source nodes to change its intermediates at time‘t’ when the PA reaches the half drain level.

3.2 Switching from PA to SA Mode

The MN announces the source nodes to change their aggregator when the current active aggregator energy falls beyond half of its initial energy of the secondary aggregator. MN updates the source list with the last transmission performed by the PA. The half drain energy of the aggregator (H_{Ea}) is computed by

$$H_{Ea} = \frac{E_{0a}}{2} \quad (7)$$

where E_{0a} is the initial energy of the aggregator node. MN requests the secondary aggregator (SA) to pursue the primary aggregator data gathering process.SA requests MN for the last source list and transmission sequence it holds. On receiving the source list and the past transmission sequence, SA initiates aggregation from the next sequence of transmission.

After the change in primary aggregator, MN updates its current source list and transmission sequence as $\{\overline{SN}:\overline{T}\}$. MN broadcasts the new list to the requesting SN and SA.

New update of MN implies: MN= $\{\overline{SN}:\overline{T}\}$ and $\{SN_1 : T_{1(q+1)}\}$, $\{SN_2 : T_{2(q+1)}\}$,…., $\{SN_n : T_{m(q+1)}\}$ $\in \{\overline{SN}:\overline{T}\}$

The source with sequence mapped information list helps to prevent duplication of data after change of aggregators. SN aggregates the next transmission sequence based on the last MN updated sequence. The primary aggregator is moved to sleep state with its radio receiver energy turned on. The next change in aggregator node involves multipath transmission with the aid of PA and load balanced transmission. This helps to retain the data flow rate among the links of lesser energy nodes.

3.3 Balanced Data Dissemination Mode

After handing over the transmission to the secondary aggregator, the MN performs additional task of buffer monitoring besides residual energy update of AN (R_{EA}). MN works in all time active state, monitoring node and aggregator's buffer capacity and dissemination rate. MN recommends multipath transmission under three conditions:

(i) If buffer capacity of SA is not sufficient to handle incoming packets
(ii) Energy of a node drops to half drain state and
(iii) Packet delivery factor is less in sink.

The prime two conditions suit for the nodes and the aggregator. In a multipath transmission if more than one aggregator node is deployed, then the energy consumed by the set of total aggregator nodes (E_{ta}) for L transmissions is given by

$$E_{ta} = \sum_{i=1}^{L} E_a(i) \tag{8}$$

The probability (ρ) of selecting a node as a new aggregator node out of in-range nodes ($\{A_r\}$) is given by

$$\rho = \frac{1}{A_r} \tag{9}$$

where $A_r \in n$ For data dissemination in balanced manner, the new aggregator node will be chosen based on transmission range (T_R) and initial energy (E_0) i.e., $T_R(n)<T_R(AN)$ and $E_0(n)<E_{0a}(AN)$ at t=0. As well, MN checks for the buffer length, queuing time and link rate of the multipath nodes. Buffer length (B_L) is monitored to check if the node is overloaded due to limited acceptance rate or lesser energy. Buffer Length utilization is computed using [35]

$$B_L = (1-T_f)\times B_L + \frac{P_a}{B_L}\times T_f \tag{10}$$

where, T_f is the transmission factor. Transmission factor is computed by the number of packets a node receives (P_a) and the maximum packets it transmit (P_d) observed at a time t. P_a is the packet arrival rate that is given by [36]

$$P_a = \frac{d_{in}}{t_{in}} \tag{11}$$

where, d_{in} is the data entering the buffer, t_{in} is the time of data entering the buffer. Similarly, Packet dispatching (P_d) rate is given by

$$P_d = \frac{d_{out}}{t_{out}} \tag{12}$$

where, d_{out} is the transmitted buffer data, t_{out} is the time at which data exits the buffer.

Balanced data dissemination in multipath is followed whenever Number of packets (N_p) that are to be transmitted is greater than the buffer length ($N_p > B_L$). Number of packets arrived is given by

$$N_P = \frac{P_a}{l_r} \tag{13}$$

where, l_r is the link delay.

If the sink is located 'h' hops away from the aggregator then, packet delivered at the sink (P_{dr}) is given by [37]

$$P_{dr} = \prod_{i=SN}^{SN+h-1} (1-P_l) \tag{14}$$

where, P_l is the packet loss ratio. The additional packets are transmitted through the current active nodes that are supporting multipath transmission. When a multipath is enabled, the former primary aggregator node is awakened to support multipath transmission at low data rates. Multipath load sharing minimizes queuing delay, in-node packet loss or wait time. After enabling multipath, MN looks up for further primary or secondary aggregator nodes that is either in one-hop or multi-hop. MN broadcasts periodic HELLO messages to the identified aggregator to verify the path availability. MN recommends the BA as a back-up route node when either of the multi paths fails or mediate node lifetime is zero. The lifetime (N_{LT}) of a normal sensor node with initial energy E_0 is computed by [38]

$$N_{LT} = \frac{E_0 - R_E}{E} \tag{15}$$

The BA is selected based on higher residual energy after undergoing a series of transmissions. A distance node with higher residual energy is opted for data gathering with the source list and transmission sequence updates from the MN.
The algorithm for change of aggregator nodes is given below.

Step 1: for all n ϵ X*Y do

Step 2: Choose PA such that

$E_0(PA) > E_0(SA) > E_0(I)$

Step 3: PA initiates data gathering phase

Step 4: SN chooses Routing path

SN → PA → S_k

Step 5: Sleep state ← SA

Step 6: MN records{SN_1, SN_2,..SN_n}:{T_{1q},T_{2q},..T_{nq}}

Step 7: Compute energy of PA i.e., E_a

$$E_a = k \times \zeta_a(\frac{d_r}{k})$$

Step 8: If E_a < E_{0a}/2 then

Step 9: SA is chosen from n, for all n ϵ {A_r}

Step 10: SA → Active State

Step11: MN update $\{SN_n : T_q\}$ to $\{\overline{SN_n} : \overline{T_q}\}$

Step 12: Sleep state ← PA

Step 13: Routing path : SN → SA → S_k

Step 14: end if

Step 15: If E_a (SA) < E_{0a}(SA)/2

Step 16: PA : → Active state

Step 17: MN update {SN_n} : {T_q} → PA

Step 18: Multipath Routing : SN→PA→SA → S_k

Step 19: MN searches 'n' from BA

where BA ϵ Sleep state

Step 20: MN broadcasts wake up messages to BA over successive time {t, (t+1), (t+2),…, (t+m)}

Step 21:If multipath through PA or SA is not efficient,

Step 22: Move (PA or SA) to sleep mode set {BA}

Step 23: New multipath routing:

SN→PA→BA→SA→ S_k

Step 24: MN update current {SN_n} : {T_q} to BA

Step 25: end if

Step 26: end if

Step 27: end for

Algorithm 1. Aggregator Replacement

Recall that nodes in sleep state are capable of forwarding or relaying the packets. The algorithm for load balancing among the multipath nodes is described as follows.

Step 1: for all n ∈ X*Y do load balancing when SA is appointed

Step 2: if current aggregator node =SA then

Step 3: Compute B_L, E_a, P_a and P_{dr}

Step 4: if $B_L < P_a$ then

Step 5: Transmit (P_a-B_L) through next path

Step 6: Update $\{SN_n\}$: $\{T_q\}$ → next path node

Step 7: end if

Step 8: if E_a<E_{0a}/2 then

Step 9: SA → sleep state

Step 10: new multipath: SN →PA→ BA→ S_k

Step 11: update $\{SN_n\}$: $\{T_m\}$ → (BA, PA) + (n, BA)

Step 12: end if

Step 13: if $P_{dr}(L) < P_{dr}(L+1)$ then

Step 14: Check conditions in step 4 as well as in step 8

Step 15: end if

Step 16: end for

Algorithm 2: Load Balancing strategy at SA

4. SIMULATION RESULTS

The performance of E2LBDA algorithm is compared with Distributed Energy Efficient Adaptive Clustering (DEEAC) [29] and Distributed Energy Efficient Adaptive Clustering Protocol with Data Gathering (DEACP) [30] methods that are implemented using Network Simulator-2. We consider 100 sensor nodes dispersed with Random mobility in a 1000X1000 scenario. The scenario consists of a sink node which accepts multipath and single path communications from the aggregator node. The sink is located at multi hop distance from the aggregator. Table 1 shows the simulation parameters used for valuation.

Table 1. Simulation Parameters

Parameter	Value
Network Area	1000x1000
Protocol	Dynamic Source Routing
No. of Sensor Nodes	100
Network Topology	Flat Grid
IEEE Standard	802.11
Broadcasting Range	250mts
Application Type	Constant Bit Rate
No. of Packets	1500
Initial Energy	10 Joules

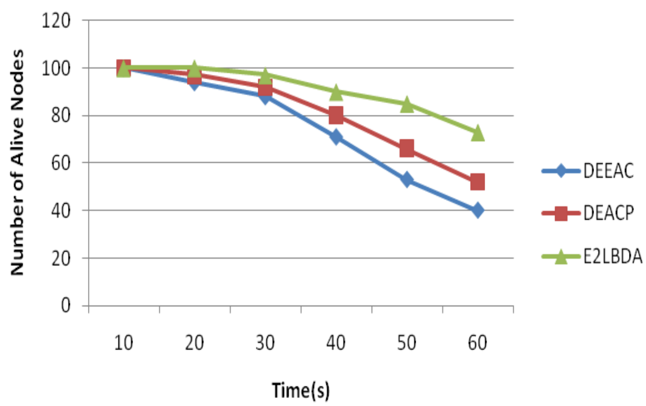

Fig.5 Time vs Number of Alive Nodes

As time increases, due to data transmission and routing process, node drops its energy. If a node attains no energy state, it is called dead node. As the time progresses, the number of dead nodes increases. Fig.5. illustrates the alive nodes count with change in time. As the communication increases, residual energy of the node decreases. In E2LBDA algorithm, the early drain and overloading of a single node or aggregator is prevented by data sharing and duty cycling. The half drain node are replaced with a better residual energy nodes that pursue further transmissions preventing the nodes from exhausting. When compared to DEACP and

DEEAC, E2LBDA upholds 28.77% and 47.14% of alive nodes in the network respectively.

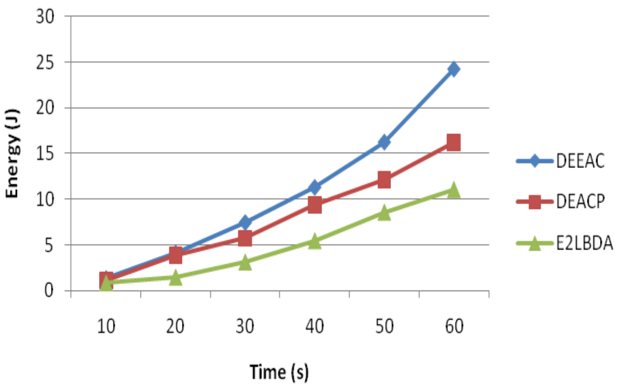

Fig.6 Time vs Energy

Energy consumption increases as time increases and as the node utilizes its energy for broadcasting, routing and transmission. A group of nodes utilized for transmission increases the energy consumption of the network. Fig.6. illustrates the energy consumption with time. In E2LBDA, the energy of nodes are balanced by periodically switching them into active and sleep states such that the number of early drain is retarded. As the nodes are switched and load is shared between nodes, a single node energy consumption of the network is maintained less. Proposed E2LBDA minimizes energy consumption by 31.79% compared with DEACP and 54.4% compared with DEEAC respectively.

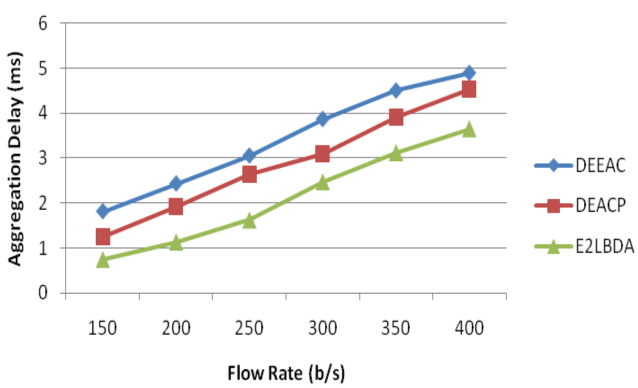

Fig.7 Flow Rate vs Aggregation Delay

As the number of data transferred per unit time in a link increases, aggregation delay increases. The time spent in collecting incoming data increases with increase in flow rate. Fig.7. shows the aggregation delay with respect to flow rate. Flow rate increases throughput, which in turn increases the aggregation delay. The pause time measured at the time of cluster re-election increases the delay in DEEAC and DEACP algorithms. As the process is avoided and multipath concurrent aggregation is enabled in E2LBDA, aggregation delay is less. Our E2LBDA algorithm consumes 19.48% and 25.45% lesser aggregation time than DEACP and DEEAC respectively.

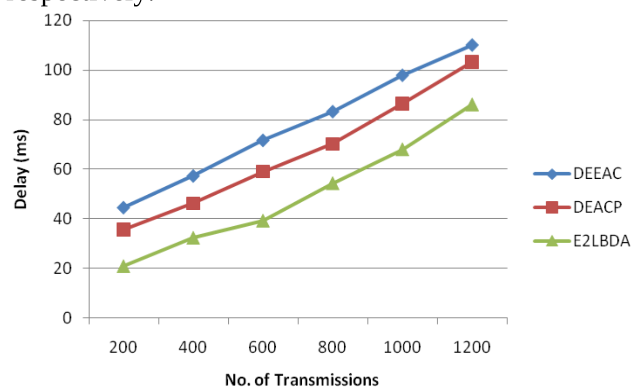

Fig.8 Number of Transmissions vs Delay

Number of transmission increases the end-to-end delay in the network. The delay includes aggregation, dissemination and retransmission delay. Fig.80 illustrates the delay observed with respect to increase in transmissions. The delay is computed for aggregation and dissemination process. In E2LBDA, multipath concurrent transmission is ensured that counts almost same transmission time. E2LBDA algorithm ensures the availability of nodes through monitoring node and thus transmission pause time is less which does not take additional transmission time. Our proposed E2LBDA algorithm requires 16.6% and 21.71% lesser delay for the attained throughput than DEACP and DEEAC algorithms respectively.

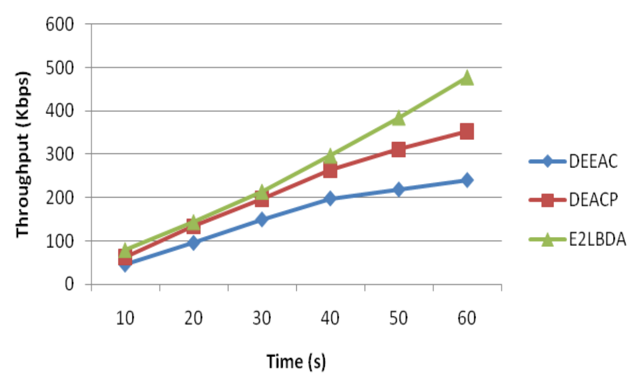

Fig.9 Time vs Throughput

As time progresses, the amount of data transferred increases which leads to the increase in the flow rate and aggregation process time. Fig.9. illustrates network throughput plotted against time. As time extends, throughput increases. In E2LBDA, availability of nodes after energy drain and seamless aggregation is ensured that retains the constant aggregation and dispatching of data to the sink node. More over the duty cycle algorithm prolongs the node lifetime and improves the chances of data transfer in the proposed algorithm. Proposed E2LBDA algorithm improves network throughput by 26.08% and 49.57% compared with DEACP and DEEAC respectively.

5. CONCLUSION

We proposed a distributed forehand update based node replacement algorithm integrated with load balancing in wireless sensor networks. E2LBDA operates in an adaptive routing manner with the timely updates from a monitoring node (MN). Energy failure due to overloading and delayed data dissemination is avoided by in-node state switching, external neighbor selection and transmission sequence update processes. The manifold process is initiated from energy conservation to retaining data rate through adaptive neighbor selection, individual data handling capability and residual energy. Our integrated approach minimizes aggregation delay and end to end delay, thereby retaining the throughput with lesser energy consumption and considerable alive nodes. The proposed algorithm aids the wireless sensor network based Educational Institutes to effectively aggregate the delay-sensitive data in an energy efficient manner. As well, with centralized network supervision, data aggregation and load balancing features, the E2LBDA algorithm facilitates the large Organizations in real-time global connectivity.

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