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Energy Efficient Node Disjoint Multipath Routing for Wireless Sensor Network

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Abstract: Some of the major challenges confronting wireless sensor networks are usually associated with scarcity of energy and resource limitations. In order to achieve efficient utilization of energy and increase the operational lifetime of the wireless sensor network while at the same time providing consistent packets delivery, energy efficient node disjoint multipath routing scheme was recommended. For our scheme the node-disjoint multiple paths are discovered from the source node to the sink node. We make efficient utilization of the network paths based on path cost calculation and intelligently elect the most suitable paths for packet transmissions. The path cost calculation considers the number of hops, path with minimal energy node and latency rate, As a result the best paths will select based on latest path cost. The structure of the control messages were shown in different categories. The fragmentation of data packets on node-disjoint multipath were also set-up through the network. Results through simulations investigated explains how EENDM accomplished better outcomes than DD and also N-1 multipath routing technique when compared with the benchmarks lifetime of network, control message overhead, consumption of energy node and average packet delay.

Key words: Wireless sensor networks · Multipath routing · Energy efficient · Node disjoint

INTRODUCTION

The operations of routing in wireless sensor networks is indeed a complicated issue because it have unique features that largely varies from other types of networks such as MANET(mobile ad-hoc network), wired and wireless network. In view of these varying unique features, recent years have witnessed numerous multipath routing procedures being developed and recommended [1, 2] and as well as numerous overview [3] of wireless sensor network routing. A lot of consider Most of the protocols were considered before being recommended because of their distinct characteristics in wireless sensor networks. There are various schemes of routing that are categorized on what type of operation that specific protocols are being used for, such as protocols that is normally based on negotiation, or protocol based on query, or protocol based on QoS and also protocol based on multipath. Some benefits of these protocols includes, for instance, negotiation based protocols have the capability to eradicate redundant data, this process is done through the insertion in conversation messages extraordinary data descriptors. The routing protocol which begins the sink node initial preparation and communicate through the transmission of query data over the network are the query based protocols. In the case of protocol based on QoS, the sensor nodes are permitted to engage in negotiations and implement a tradeoff comprising of the two factors namely consumption of energy and certain QoS metrics so that the sink node can receive the data being transmitted [4]. The last protocol under review multipath based routing, operates by not using only a path to send packet but instead several multiple paths and the advantage of this approach is to increase reliability and robustness through enhance network performances. Most multipath routing protocols always attempts setting up numerous pair of multiple paths from source and destination for data transfer. And because of the protocol effectiveness, in recent years lot of research have been conducted on multipath routing [5] The rationale behind the investigation of classical multipath routing are, firstly for load balancing; because traffics emanating to and fro from the source and destination are distributed over several pair of multiple

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node disjoint paths. Secondly the delivery of reliable data is guaranteed through multipath routing. These procedures through multipath allow for several duplicate packets to be transmitted besides various paths, so path failures are more robust. Wireless sensor network applied these type of operations for multipath routing. In multipath routing load balancing is very essential because of it have the ability to distribute the application of energy over several nodes leading to prolong network lifetime. Whenever the same data delivery are sent through multiple paths, the tracing of surveillance applications is immensely enhanced and is more precise at the expense of extra energy cost [5, 6]. The research paper will highlight packet load balancing in node disjoint multipath routing scheme.

Releated Work: In wireless sensor networks routing is an essential technique for discovering multiple paths, so in the past years, apart from the numerous recommendations being made, it has also generated a lot of attention from researchers. Generally multipath routing covers a broader research area [5] so to fulfill the objectives, the research highlighted on specific areas only which are related to our proposed scheme. Directed Diffusion (DD) is among the oldest multipath routing protocol recommended [7] because it is based on data-centric routing, which denotes every communication must be for a named data. Most sensor nodes are normally associated with application aware and interest cache is recorded. The advantage of this approach makes is to ensure that diffusion attains energy efficiency and this is done by choosing the most suitable paths, cached and before being transmitted to the network, the data is processed. Though DD is a good routing protocol, there are some drawbacks such as interest broadcasting and path reinforcement that generates lot of energy consumption during control traffic and usage. Some [8], researchers have recommended a protocol known as N-to-1 multipath routing which have the ability to discover several node-disjoint paths through the sink and a source node. The sink act as root, with the nodes being organizes to be a spanning tree structure. To discover the multipath, the protocol operates through traversing the tree. The dissemination of traffic are implemented by the multiple paths which contributes to effective data transmission in terms of enhanced reliability and data security. The drawbacks of N-to-1 routing protocol happens during calculation, because the node's energy levels within the cost function is not considered. Dissemination of traffic is another issue of concern since the protocol is deprived of an efficient load balancing properties that can spread traffic effectively through utmost energy utilization. There have been several efficient multipath routing protocols in WSN having multiple sink nodes [9] that have been recommended by researchers. Whenever the protocol intends to communicate with the next hop, the cost function is used, representing the function of residual energy and hop count respectively. Once the protocol initialization is completed, only then the path construction phase begins. Then the source node unicast a route request message which will be received by all neighbors. Multiple routes construction and maintenance are known to be costly because it is usually associated with high control overhead when compared with usage of energy. To achieve energy efficiency in routing protocols can be done normally through decreasing the overheads associated with control traffic at the time of routes construction and path maintenance phases respectively and also the necessity to choose the most suitable routes with minimal energy usage by applying the best cost function. For the research, our recommendation entails an attempts at reducing consumption of energy by way of disseminating and balancing the load over multipath paths. To construct the multiple paths, this is achieve by applying a procedure known as the cost function which is founded on several conditions namely number of hop, path with the least energy node number and latency ratio. The following sections illustrate our recommendations more specifically.

Description of Eendm Scheme: In this section, we first define some assumptions. Then, we provide the details of our scheme. The scheme is made of four phases such as, neighbour discovery process phase, multipath constructions phase, data disseminating and maintenance phase.

Assumptions: Generally multipath network are grouped into two categories, disjoint and braided models. The model chosen for this scheme primarily placed emphasized on disjoint model. The Figure 1 explains a specific node-disjoint multipath routing model that is inclusive of a source node, a sink node, as well as several intermediate nodes. The assumption proposed was that, every sensory data being generated at the various source nodes are transmitted to a central point, that is, data processing centre. In the Figure 1 is a description of several node-disjoint paths that are not the common node or shows any link between the routes being discovered. Consequently, if there is any node or failures associated

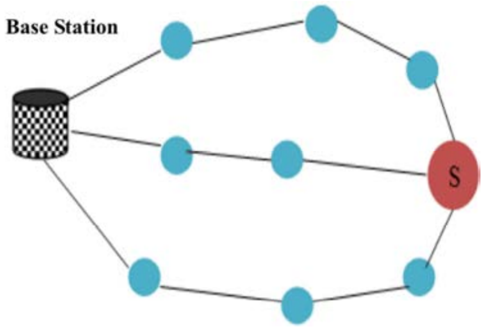


Fig. 1: Network model

with that particular link in a pair of node-disjoint paths, only that route is affected consisting of the failure node. Since this class of path disjointedness delivers much greater aggregated network resources, node-disjoint paths are more useful than link-disjoint and partially disjoint.

In our scheme, our assumptions were that M identical storage, process and communication abilities which are dispersed randomly across a specific area. Only a sink node own powerful resources to perform any tasks or communicate with the sensor nodes. Every sensor node carries a radio transmitter that comprises of a constant transmission range of R, with the assumption that the network is connected and dense. For instance, when a random set of nodes is specified, data can be transmitted from a node to the next node through a multi-hop method. Due to the existence of multiple paths among a set of nodes, every node is allocated a unique identifier (ID). The nodes location unaware, that is, there is no GPS (Global Positioning System) equipped device. Another assumption proposed was, the sensor node and sink is immobile, which simply implies, support for mobility is non-existence and it possesses enough battery for providing sensing and transmission functions. Usually the battery has limited life span and cannot be replaced or re-energized. Likewise, the transmitter power of the node is fixed for data transmission and reception respectively. At every time period, a sensor node denotes m, m □ 1, 2,..., M, which is capable to obtain the residual energy level $e_{m,residual}$ description of the its battery. As soon as a stimulus is noticed or an incident happens, the neighbouring nodes initially broadcast the information and choose one of them to be the source node. The theory assumption implies a specific path comprising of N nodes and in that scenario N< M is denoted as a group of nodes which conveyed the generated data through the source node X to the intended destination, the sink node Y. The assumption proposed earlier on, describing the density of the network, there is still the probability of having multiple paths among the source node X and the sink node Y. For this reason, the likelihood of using multipath routing instead of single path routing, with the proposition that the multiple routes being used are disjoint. For instance, the route A, which is made of K nodes and as well as route B, comprising of R nodes, illustrates two groups jointly uniquely different from each other excluding the source node X and the sink node Y respectively. To choose the best path for path construction phase, the path cost function is used once the REEQ reach to sink node. The path cost calculation is given by the following equation:

$$P_c = E + H + D \tag{1}$$

With H representing the number of hops to the sink node y when select next hop; E representing the minimum energy node in the path and D is signifying end-to-end delay. Therefore the path cost function takes the minimum node energy in the path, the number of hop i.e. distance to sink and end-to-end delay from the sink into consideration.The selection benchmark used to choose the best path in our proposed node disjoint multipath scheme is the path cost function, with the notion of employing in our proposed scheme. In definition the path A, is comprising of K nodes, the path cost PA denotes the calculation of specific link costs li (i+1) along the path. This is illustrated below as:

$$pA = l_1 + l_2 + ... + l_{K(k+1)} = \sum_{i=1}^{K-1} l_{i(i+1)} \tag{2}$$

Energy Model: At Figure 2 illustration, represents consumption of energy fundamental features in wireless sensor networks that was recommended by [10] and it was later acknowledged to be the regulatory ideologies for sensor networks in terms of energy consumption.

In Figure 2 illustrations shows the elements consuming higher energy includes sending, receiving and idling and the least amount of energy consumptions are sensing, programming and sleeping. For the research work sensing energy consumption, programming and also sleeping were not taken into consideration for subsequent studies. The consumption of idle energy is usually spent by the nodes in order to avert a collision, which is representing the MAC layer operations and also to ensure the MAC layer energy consumption cannot have adverse

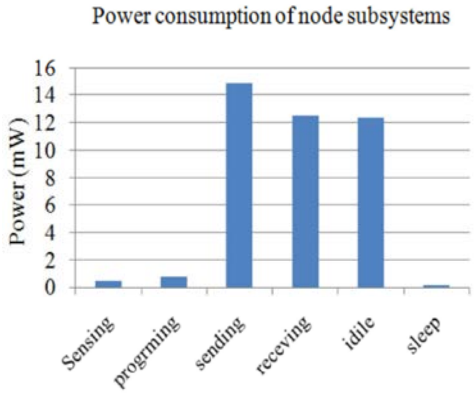


Fig. 2: Energy consumption source

influences on our energy studies in the network layer. Although one of the main purpose is to propose an energy efficient multipath scheme that is confined to the network layer and so we do not focus on idle energy consumption. Thus, the sending energy ETX (k,d) and the receiving energy ERX (k) was the central point of reference, therefore the overall consumption of energy is regarded to be the energy consumption of sending and receiving a packet multiplied by the total times transmission. For wireless networks, whenever nodes are positioned within the transmission range of nodes being transmitting, the prospect of receiving packets for free is higher even when the nodes are not part of it and not on duty. This occurrence is known to be the transmission properties of wireless sensor networks. Therefore, the computation of total energy consumption is

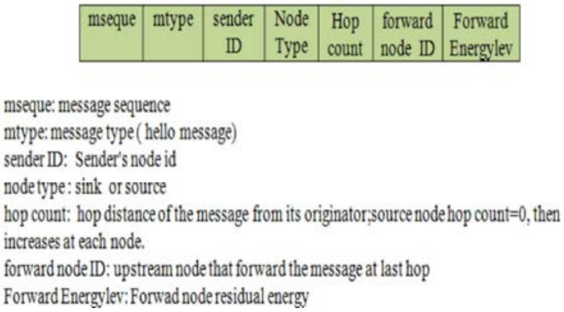
$$E_{MULT} = (E_{TX}(k, d) + N \times (E_{RX}(k))) \times NR \quad (3)$$

where N denotes the sum of nodes, NR signifies the transmission times in the network, k stands for the packet size and d is the distance between two nodes. For the purpose of argument, the assumption envisages was that, every sensor nodes designated with the similar transmission radius. In order to transmit a “k-bit message” at a distance d, the energy dissipation is given by the equation as:

$$E_{TX}(k, d) = k\times E_{txElec} + k\times \varepsilon_{amp} \times d^2 \quad (4)$$

where E_{txElec} signifies the energy for transmitting a single bit data, ε_{amp} denotes the signal amplifier value. Besides, the energy consumption of receiving is

$$ERX(k) = k\times E_{rxElec} \quad (5)$$



mseque	mtype	sender ID	Node Type	Hop count	forward node ID	Forward Energylev

mseque: message sequence
mtype: message type (hello message)
sender ID: Sender's node id
node type : sink or source
hop count: hop distance of the message from its originator;source node hop count=0, then increases at each node.
forward node ID: upstream node that forward the message at last hop
Forward Energylev: Forwad node residual energy

Fig. 3: The format of hello message

In equation 5, E_{rxElec} represents the energy consumption of receiving one bit data. For ease of use, it is assumed that energy consumption of transmitting a bit is similar to that of receiving one, as illustrated in Equation 6.

$$E_{rxElec} = E_{txElec} = E_{elec} \quad (6)$$

Starting from Equations 4, 5 and 6, after computations, the result of aggregate energy consumption is attained. The amplification factor for the transmit electronics is ε_{amp} =100 pj/bit/m^2 and the energy cost of operating transmitter and receiver electronics is E_{elec} = 50 nJ/bit.

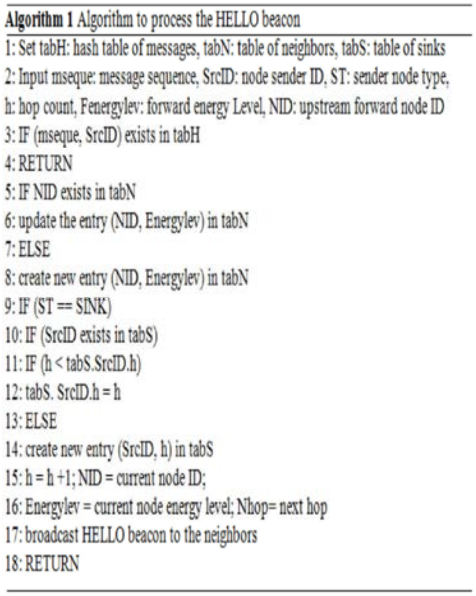
Neighbour Discovery Process Phase: The HELLO message is part of the control messages substituted among the nodes during neighbour discovery process phase. At Figure 3 demonstrates the various fields through the HELLO message. The initial field’s message sequence indicates a number generated by the message originator. The number keeps on increased every time when a new message is created. The number is reset to 1 as soon as it reaches the full 65535, since the field size is 2 bytes. Together with the node ID, message received can be verified when needed. The form of field message signifies information which is known to be HELLO message and furthermore the field sender ID consists of the node ID of originating message. For ease of identification the type of node field indicates if the originating message is a source, a sink or a normal sensor node. The hop count present the hop distance of the message which have been relayed through the originating message. The forward node ID comprises of the ID upstream node, which relayed the messages at last hop. (because it has the obligation for relaying messages in the previous node). The forward node energy level field describes the normalized node energy level of the node

mesque	mtype	Sender ID	Sink ID	Sink hop

Fig. 4: Sink awareness message

which transmits message at last hop. If the HELLO message arrives and the messages received are first time occurrences, every node creates its neighbouring node table such as the forward node energy level and forward node ID. Subsequently, the node validates if type of node is established to be sink. When this happens, the sender ID is compared to the sink table of the node. Then a new entry is produced in the sink table when necessary, along with the hop count refresh only if hop distance is lesser than the value recorder. Then finally, the HELLO message originating through the sink node is re-transmitted with the field's forward node ID, hop count and the forward node energy level updated. The algorithm 1 produces more elaborate stages in constructing the HELLO message in a sensor node. The selective flooding of HELLO messages coming from the sink assists every node to acknowledge the existence of the sink node and to compute the shortest hop distance to sink node. Each node will send the sink awareness message to its neighbours as shown in Figure 4.

The receiving node updates the corresponding entry in its neighbouring node table. The completion of the neighbour discovery process phase means every node gets the sink table and also the neighboring node table.



Algorithm 1 Algorithm to process the HELLO beacon

```
Set tabH: hash table of messages, tabN: table of neighbors, tabS: table of sinks
Input mseque: message sequence, SrcID: node sender ID, ST: sender node type, h: hop count, Fenergylev: forward energy Level, NID: upstream forward node ID
IF (mseque, SrcID) exists in tabH
    RETURN
IF NID exists in tabN
    update the entry (NID, Energylev) in tabN
ELSE
    create new entry (NID, Energylev) in tabN
IF (ST == SINK)
    IF (SrcID exists in tabS)
        IF (h < tabS.SrcID.h)
            tabS. SrcID.h = h
    ELSE
        create new entry (SrcID, h) in tabS
h = h +1; NID = current node ID;
Energylev = current node energy level; Nhop= next hop
broadcast HELLO beacon to the neighbors
RETURN
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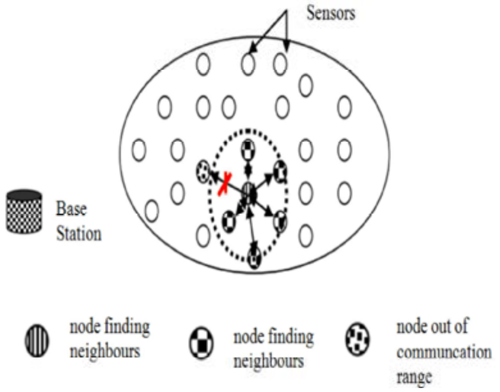
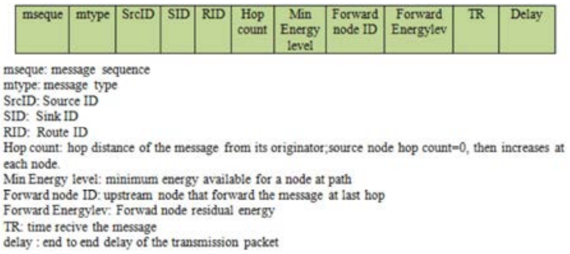


Fig. 5: Neighbour discovery process

Multipath Construction Phase: The multipath construction phase is started once a pair of nodes senses the stimulus and the chosen source node start to transmit gathered data to the sink node. As our intention is to find out node disjoint multiple paths, the RREQ message will send to every node along with distinct route ID by source node. This is further illustrated in Figure 7, however, RREQ message cannot all arrive at the destination sink node and others might drop during the transmission to the intermediate nodes so as to avert paths having to share common nodes (in order to form the node disjoint nodes). The Figure 6 explains the structure of a RREQ message. The fields SrcID and SID specified the node ID of the source and also sink. The field of RID is the route id which is allocated by the source node in order to differentiate among the various routes that lead to the same sink. In order to send a message to a specific destination by the source node, the initial step is for the source node to examine its cache to see if there are any routes to that destination. If none exist, a new route request is created. In order to select the next hop node, the node will choose a neighbour node that has minimum hop count to sink which were introduced in HELLO message, the selected node computes locally the Min energy level, TR and delay. Therefore as shown in the figure 6 the TR field indicating to the time of packet received and the Delay field indicating to the delay of packet transmission thus the end-to-end delay can be calculated by using the information in RREQ message as the source node transmit RREQ message and when the RREQ message from the source node is received by the intermediate N1, it will store the time of this event on the field TR1 and forwards it to its best suitable next hop. Therefore when the RREQ message coming from N1 is



mseque	mtype	SrcID	SID	RID	Hop count	Min Energy level	Forward node ID	Forward Energylev	TR	Delay

mseque: message sequence
mtype: message type
SrcID: Source ID
SID: Sink ID
RID: Route ID
Hop count: hop distance of the message from its originator;source node hop count=0, then increases at each node.
Min Energy level: minimum energy available for a node at path
Forward node ID: upstream node that forward the message at last hop
Forward Energylev: Forwad node residual energy
TR: time recive the message
delay : end to end delay of the transmission packet

Fig. 6: The format of a RRQ message

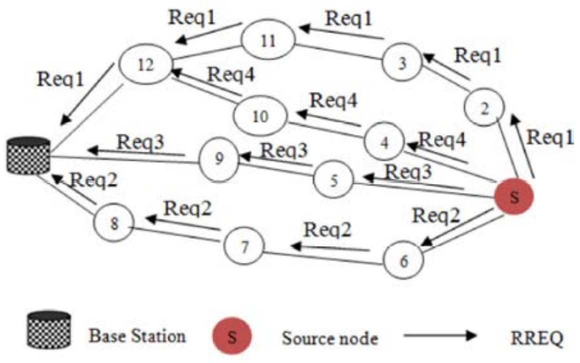


Fig. 7: The RREQ message

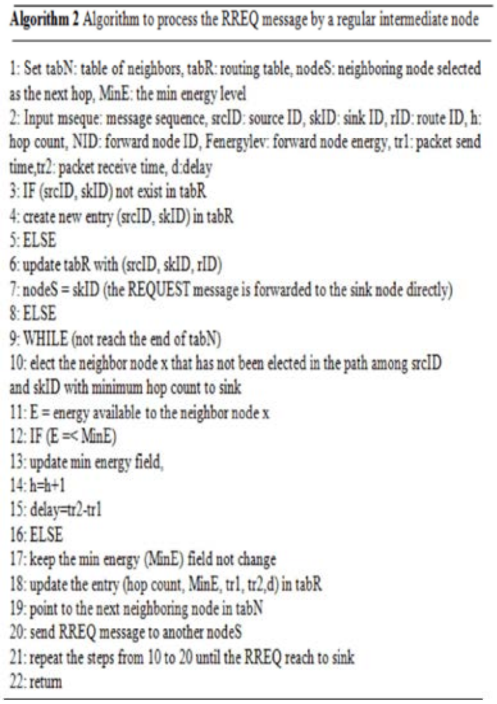
received by the neighbour node N2, the node N2 will computes the difference among the TR1 field and the current time TR2 which represents the measured delay of the link between N1 and N2 and it will stores in the delay field. By accumulating this time, the sink node can compute end-to-end delay for each of the available paths

The feedback information received through the lower layer are then used in the EENDM. The energy information will provides to network layer by MAC layer and each node have sufficient information concerning its energy availability, The intermediate node after obtaining the RREQ message then compares its available energy with the Min Energy level filed, there will no changes effected when the value in the field is smaller or is equivalent to the node available energy, otherwise, the node's available energy is positioned in the Min Energy level field of the RREQ message. So when all RREQ messages received by the sink, the sink will estimate the number of available disjoint paths to the source and the minimum energy available on each of these paths.

The remaining of the fields conveys the similar information as contained in control message that was presented. There are two conditions for choosing the source of best path. In the first place, neighbouring node should not have elected for another route which connects similar pair of source and sink nodes. And lastly, the select of best path must be the lowest path cost within the entire paths as shown in the equation 7.

$$P_c = E + H + D \tag{7}$$

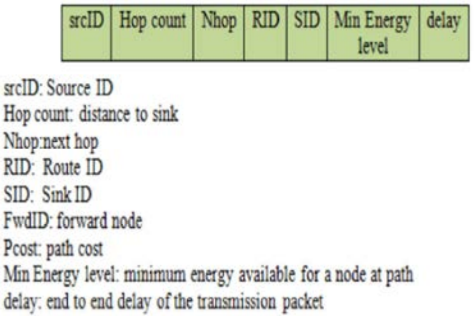
As demonstrated in Figure 7, the node 10 relays the message REQ4 to node 9. Therefore; when the node 9 receives another message i.e. REQ1 that come from node 11, the node 9 will drop it since node 9 has been chosen previously by another route. Whenever a neighbour is chosen, the routing table is updated and also the table of neighbours is also updated concurrently. With this set up, future path search is achieved as the node can avoid to chosen a neighbour which have already been taken and used for the route that connects similar pair of sink and source nodes. In conclusion, hop count, delay, Min Energy level, forward node ID and forward node energy level is updated by the node before forwarding the RREQ message to the chosen neighbour. The Algorithm 2 elaborates the process of RREQ message through regular intermediate sensor node.



Algorithm 2 Algorithm to process the RREQ message by a regular intermediate node

```
1: Set tabN: table of neighbors, tabR: routing table, nodeS: neighboring node selected as the next hop, MinE: the min energy level
2: Input mseque: message sequence, srcID: source ID, skID: sink ID, rID: route ID, h: hop count, NID: forward node ID, Fenergylev: forward node energy, tr1: packet send time,tr2: packet receive time, d:delay
3: IF (srcID, skID) not exist in tabR
4: create new entry (srcID, skID) in tabR
5: ELSE
6: update tabR with (srcID, skID, rID)
7: nodeS = skID (the REQUEST message is forwarded to the sink node directly)
8: ELSE
9: WHILE (not reach the end of tabN)
10: elect the neighbor node x that has not been elected in the path among srcID and skID with minimum hop count to sink
11: E = energy available to the neighbor node x
12: IF (E =< MinE)
13: update min energy field,
14: h=h+1
15: delay=tr2-tr1
16: ELSE
17: keep the min energy (MinE) field not change
18: update the entry (hop count, MinE, tr1, tr2,d) in tabR
19: point to the next neighboring node in tabN
20: send RREQ message to another nodeS
21: repeat the steps from 10 to 20 until the RREQ reach to sink
22: return
```

In the case of the sink node, the RREQ message which was received are treated in a different way. It will check the source ID and create a new entry in the source



srcID	Hop count	Nhop	RID	SID	Min Energy level	delay

srcID: Source ID
Hop count: distance to sink
Nhop:next hop
RID: Route ID
SID: Sink ID
FwdID: forward node
Pcost: path cost
Min Energy level: minimum energy available for a node at path
delay: end to end delay of the transmission packet

Fig. 8: Route reply message

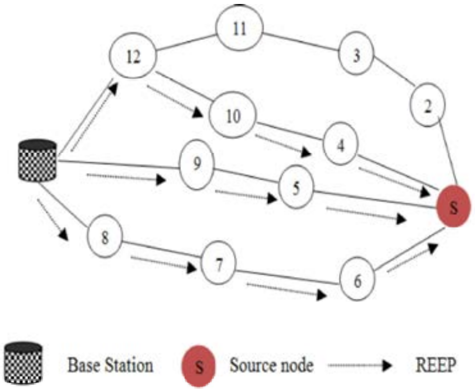
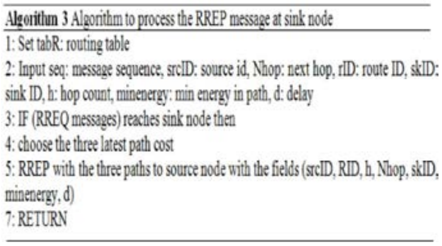


Fig. 9: Multipath Selection Process

table if the entry already does not exist. The routing table is formerly updated with the information being conveyed in the message. In Algorithm 3, sink node highlights the pseudo-code of the RREP message and how it procedures are being carried out. The sink node evaluates and measures the routes by considering the path cost presented in the equation 2. It then chooses three paths with minimum costs and unicasts the RREP message through the selected minimum cost paths. The sink node forwards the route reply messages to the source node which contain as shown in Figure 8 illustrate the structure of the reply message.



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Algorithm 3 Algorithm to process the RREP message at sink node
1: Set tabR: routing table
2: Input seq: message sequence, srcID: source id, Nhop: next hop, rID: route ID, skID: sink ID, h: hop count, minenergy: min energy in path, d: delay
3: IF (RREQ messages) reaches sink node then
4: choose the three latest path cost
5: RREP with the three paths to source node with the fields (srcID, RID, h, Nhop, skID, minenergy, d)
7: RETURN
```
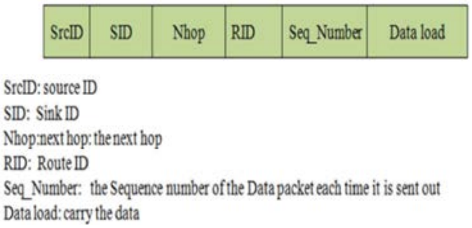

Data Disseminating Phase: When multiple paths have been determined, the source node start to send data packets to every routes by attaching the allocated rates.



SrcID	SID	Nhop	RID	Seq_Number	Data load

SrcID: source ID
SID: Sink ID
Nhop:next hop: the next hop
RID: Route ID
Seq_Number: the Sequence number of the Data packet each time it is sent out
Data load: carry the data

Fig. 10: The packet format

During the process, the event data and most of the control fields are transported by the data message. The packet format is shown in Figure 10 contains the source ID, sink ID of the message, next hope, route ID and data load. the Source ID and Sink ID fields represent the packet source node and for the sink node. The data load field is useful for transporting data packets. Accordingly as soon as the paths has been selected, the source S can balance its load to existing traffic on the whole available route. At that moment the scheme fragment the packet into k division of sub packets of equal size. Then it transmits the specific k sub packets with K (available) routes. Subsequently in the sink the whole K sub packets were received. At this time, the k sub packets combine together with the sink node and to get original data. We now turn our attention to the description of data splitting in illustration as follows; assuming there packet having a size 15 data unit (kbit/s) which it transmits through the source to sink node. At the same time, several other nodes are also available among source and sink. As soon as discovery of 3 active routes from source to sink is established in order to transmit data, then the source node fragment the packet size of 15 data unit (kbit/s) into 3 sub packets and every sub packets is made of data comprising of 5 kbit data unit. By using the multiple paths, the data arrives safely to the sink node, therefore the 3 sub packets combine together and recover the full packet efficiently in the sink node. Therefore at Figure 11, the source S there

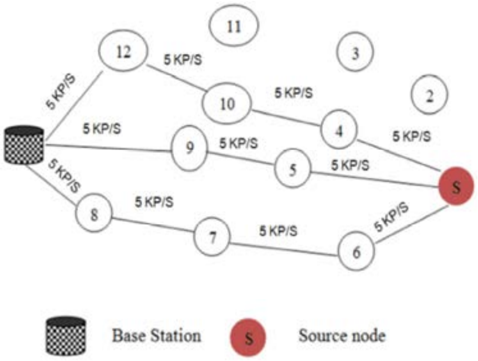


Fig. 11: packet splitting

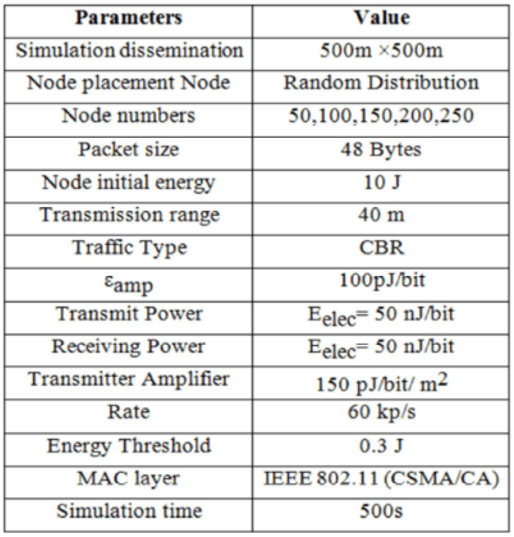
utilizes multiple paths P1, P2 and P3. the node S transmitting to every routes having equivalent value of rate of data, that is, 15/3 = 5 Kbit of data to ensure load balance its current traffic across the whole available route.

Confirmation Packet: In order to enable confirmation of the receiving the packets, NACK and ACK hybrid method were used. For this method, the sink node receive packet from the node and the sender node wait awhile for a period of time, if there are both NACK message and the ID packet, then the source node retransmit the same packet again, else the next packet is transmitted. In the method, data is transmitted among the sequence packets which are to be transmitted, if it is missing. Therefore the sink node in addition with sequence checking of packets received, will notify the sender with the NACK and the lost packet ID. for the latest packet can be used as an ACK message, since after transmitting the packets, no additional packets remains to be transmitted, so the packet sequence is compared, which is moreover used to create reliable ACK message. The benefit of using the hybrid method is because of lesser overhead cost, since there is no point in transmitting back and forth reply messages for every packet relayed to its neighbouring node and so consumption of energy is significantly reduced. Furthermore, it is worthy to take notice of how NACK and ACK messages notifies the sender whether confirm or not confirm from the of sink node.

Route Maintenance Phase: At this phase, every node keeps a neighbour table; that comprises of information about a neighbour nodes' energy level. Additionally, once the node fall under the threshold level, there is transmission of a message explaining its inability to participate in routing processes. Every node that is within radio range of failing node update its neighbour table through the deletion of the failing node and then the source begins a new route discovery processes in order to construct new path. The reason for this is to be certain the packet cannot be relayed to a node having inadequate energy, so that packet reach destination safely and not missing. Reliability of data transmission is guaranteed by this approach.

Simulation Setup: Our scheme is implemented in ns-2 network simulator which is discrete event-driven and object oriented as the simulation platform. In our simulations, we consider a square region of area 500m × 500m, in which the wireless nodes are deployed randomly. There is one sink node which has no power constraints (sink node is deployed at the center of the area) and one source node in the network. We consider a variety of sensor networks of different sizes 50, 100, 150, 200 and 250. The simulation lasted for 400 sec. Each node has a fixed transmission range of 40 meters. The data packet size is 48 bytes and data rate is 60 kbps. We assign each node the same initial energy of 10 J at the beginning of each simulation in order to keep the simulation time within a reasonable time period. The radio energy model proposed by [10] was used to calculate the energy consumed during transmission and reception of messages. We further introduce an Omni antenna (Antenna Type) to each node and adopt the IEEE 802.11 MAC layer protocol provided in the ns-2 with a bandwidth of 1.6 Mbps and the energy consumptions for transmission and reception are E_{elec}= 50 nJ/bit. We split the data packet in 3 sub-packets and transmit the sub-packets through different paths simultaneously. The energy consumption of transmission and reception is computed according to formula 4 and 5.

Table 1: Parameter values used in simulation for proposed EENDM



Parameters	Value
Simulation dissemination	500m ×500m
Node placement Node	Random Distribution
Node numbers	50,100,150,200,250
Packet size	48 Bytes
Node initial energy	10 J
Transmission range	40 m
Traffic Type	CBR
ε_{amp}	100pJ/bit
Transmit Power	E_{elec}= 50 nJ/bit
Receiving Power	E_{elec}= 50 nJ/bit
Transmitter Amplifier	150 pJ/bit/ m^2
Rate	60 kp/s
Energy Threshold	0.3 J
MAC layer	IEEE 802.11 (CSMA/CA)
Simulation time	500s

RESULTS AND DISCUSSION

The Network Lifetime: The lifetime of the network is defined as the time at which the first node failure occurs, that is, the time at which some node's energy reserve is reduced to zero. The main point here is to determine the lifetime for numerous routing schemes. It can be seen that in the Figure 12, the lifetime of the network depict a reducing returns anytime the size of the network start to grow bigger. When this trend is compared with some schemes, an increment of 23% 76% is witnessed by the network lifetime with EENDM which is significantly higher

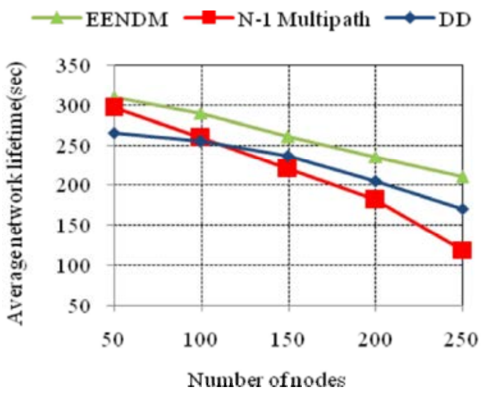


Fig. 12: Average Node Lifetime

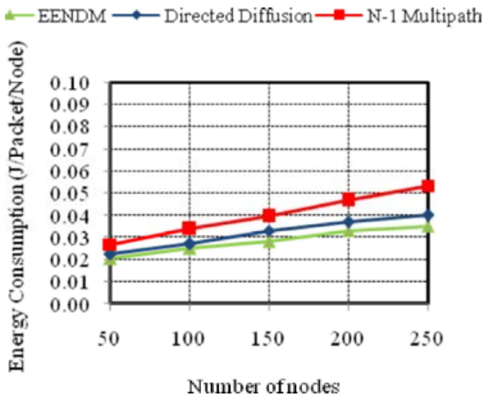


Fig 13: Average Energy Consumption

than DD and N-1 multipath routing respectively. Also assessing the graph, maximum network lifetime can be attaining by EENDM. Moreover the lifetime of the network with EENDM worsen more slowly when compared with other routing schemes anytime there is increment in size of network.

Average Energy Consumption: The average energy consumption is calculated across the entire topology. It measures the average difference between the initial level of energy and the final level of energy that is left in each node. Energy consumption of the node is the subsequent metric to be conducted. From the Figures 13 illustrated, EENDM energy consumption is much lesser when compared to other routing schemes. Moreover together with Directed Diffusion (DD) performances are much better in comparison with N-1 Multipath routing. EENDM keeps node energy consumption of node at reduced state through increment of network size normally occurs. To illustrate this further, the Figure 13 is an example of showing comparison of directed diffusion and N-1 Multipath routing, 13% and 34% respectively is the enhancement by using EENDM multipath routing anytime the nodes of 50 to 250 increases the size of the network. The energy efficiency of EENDM is more consistent as the results shows from the experiment conducted and the effect of increasing the size of the network shows smaller effects and comparing it to other routing schemes their performances diminishes when the network size becomes bigger.

The initial energy level and the total number of data obtained through the sink were computed on the basis of energy consumption. When assessments of the methods were investigated, EENDM and directed diffusion outperform N-1 Multipath routing. In the case of directed diffusion, its overall performance is attributed to the ability to discover the shortest delays within the paths. Also directed diffusion schemes periodic transmit low rate exploratory through the source, which assist in diverting to other route if it occurs that the current path quality is diminishing to a certain level. In EENDM, using a combination of ACK, ACKN the most efficient way of decreasing consumption of energy. As every packet are not permitted to transmit a response packet when the hybrid scheme is being used moreover the routes being created based on the number of hops and the shorter routes being created, the packet transmission consumes minimum energy.

Average Control Packet Overhead: It is the ratio of the average amount of control message treated by the node and the amount of data packets received by the sinks. There are several routing schemes each having distinct technique and if a network is much bigger, it is necessary to needs a greater amount of exchange of control messages so as to be able to find and create more routes. This implies greater amount of energy is consumed and needed during the initial construction phase. Further when the network is a bigger one, it means it will take extensive time distance that separates the sink and the source nodes. There are many intermediate nodes which have to be navigated to enable a data packet to arrive at the destinations sink nodes. Control message overhead of several routing are illustrated in the Figure 14 and to get this value is through computation of two elements, that is, the ratio of the average amount of control message treated by the node and the amount of data packets received by the sinks. Here the control message overhead, portrays directed diffusion as having to expend greater amount of energy during transmission and receiving control messages when compared with another routing schemes, because it needs periodic interest broadcast and path

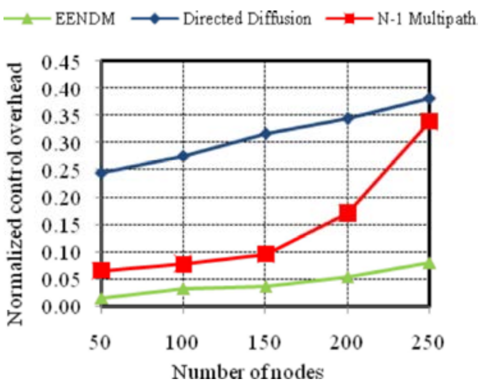


Fig. 14: Ratio of control message overhead and data traffic received

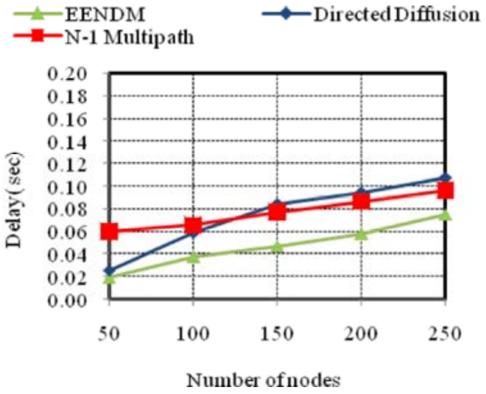


Fig. 15: Average Delay

reinforcement which consumes extra energy. In the Figure 14, 79% and 76% is enhancement of EENDM than DD and N-1 multipath routing respectively and showing the EENDM having smaller control message overhead.

End-to-end Delay: It defines as the average time taken by a data packet to arrive at the destination. Only the data packets that successfully delivered to destinations that counted. The average packet delay is described in the Figure 15, showing that in comparison with another schemes the EENDM having the shortest delay is a great benefit to the scheme. Through the use of the EENDM, as estimated the data packet is routed through several node-disjoint paths, so with this method, the network congestion and the transmission interferences possibilities are mostly avoided. In the Figure 15, 22% and 30% enhancement of EENDM which it has shortest average delay than N-1 multipath and DD respectively.

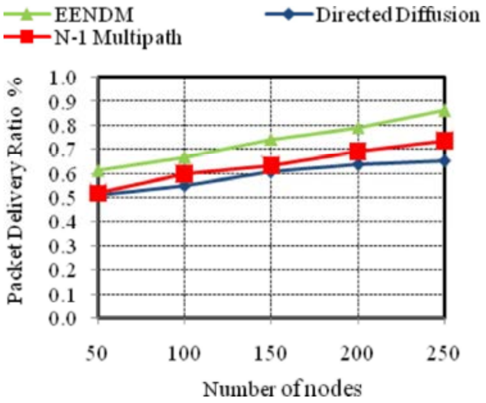


Fig. 16: Average Packet Delivery Ratio

Packet Delivery Ratio: Packet Delivery Ratio is the ratio of the number of delivered data packets to the destination and the number of the send packets by the source as shown in Equation below. This illustrates the level of delivered data to the destination.

PDR =Σ Number of packet receive Σ/ Number of packet sent

The packet delivery ratio is described in the Figure 16, it is simply the ratio of the number of delivered and transmitted data packet to the destination. It is usually portrays the state of data packets sent to the destination. From the Figure 16, our proposed EENDM provides enhancement of nearly 32% when compared with directed diffusion and another 17% when compared with N-1 Multipath. Through the use of dispersion method reliability is attained, implying EENDM performs much better by attaining the best delivery ratio in comparison with other schemes.

CONCLUSION

In this paper, we proposed an energy efficient node disjoint multipath routing for wireless sensor network in order to provide efficient energy utilization for sensor nodes and maximize the lifetime of the senor network. These includes some phases such as neighbour discovery process phase, multipath construction phase, data disseminating phase, confirmation packet and route maintenance phase. We have illustrated the format of different control messages. The proposed EENDM endeavors to allocate the traffic to each path simultaneously. An innovative energy efficient node disjoint multipath routing (EENDM) was compared with some routing schemes such as N-1 multipath and directed diffusion, with the proposed EENDM performing better than the others schemes in network lifetime, Average Energy Consumption, Control Packet Overhead, Average Delay, Average Packet Delivery Ratio even when network size increases.

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