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Link Distance Link Cost Link Error Based Energy Efficient Cross Layer Reliable Routing for Wireless Sensor Network

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***Abstract*: In this paper, a new energy efficient cross layer routing protocol is introduced for wireless sensor networks (WSNs). Energy consumption and routing is the most challenging and demanding in designing routing protocol for WSNs. We develop LDCE routing protocol based on (Link distance, link Cost, link Error). The paper focus on drawing benefits from interaction of physical, MAC and routing layers by defining new cross layer scheme (LDCE) which is energy efficient. We first study how link error rate affect retransmission and how it affects the choice between a path with a large number of short distance hop and another with smaller number of large distance hop. Simulation and results shows that LDCE can lead to up to 30% - 70% energy saving.**

Keywords: Cross Layer design, wireless sensor networks, routing, energy consumption, protocol , medium access layer.

I. Introduction

Wireless Sensor Networks (WSNs) comprises of a large number of low cost sensor nodes that have strictly restricted sensing, computational and communication capabilities. In addition to this, sensor nodes have limited battery life which is not rechargeable in many applications. Due to energy resource limitations of the sensor nodes, it is important to use energy efficiently for each sensor node. This will result in prolonged network lifetime and functionality. WSNs have gained worldwide attention, academically as well as industrially, because of its great potential for many applications in various scenarios such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring, hazardous environment exploration, and seismic sensing [1]. WSNs have distinctive features and limited resources like dynamic topology, vast number of nodes, application and environment dependency are the distinctive features of WSNs. Resource constraints include short communication range, low bandwidth, limited processing, and limited energy resource. Due to the wide scale of the network, it is not practical, or even not possible, to replace or recharge the batteries of the sensors. Hence, duration of battery is considered lifetime of a sensor. In this respect, energy efficiency is crucial and essential in WSNs to prolong network lifetime. In WSN many functions cannot be assigned to a single layer like energy management, security, quality of services, mobility management among the others cannot be completely implemented by combining and exploiting mechanisms implemented in all layers. An efficient implementation of these functions can thus be achieved by avoiding a strict layering approach in which the protocols at each layer are developed in isolation, but rather within an integrated and hierarchical framework to take advantage of the interdependencies between them The main design difficultly in this cross layer approach resides in characterizing the essential information that should be exchanges between layer.

In most cases researches did not go over complex cross layer design implementation but tried to propose a cross layer design to be able to solve the problem at the hand. In most of the proposals only two or perhaps three layers need to share information, and thus had extended the original strict layered structure to provide a solution to the problem with performance improvement. Cross layer design started a gain lot of attention from the researches with its performance improvement and the need for cross layer interaction for different applications and the mobile ad hoc behavior. Although different cross layer design architecture had provided a means for protocols to interact with the protocols of other layers, there may be some interaction that may be expected by the designer which if occur would create some loops. These kinds of loops caused due to unintentional interactions could compromise the stability of the entire system.

All the applications that are using the standard layered architecture should adapt to the cross layer design architecture. This would take considerable amount of time and cost for marketing cross layer design approach. An application would find a particular cross layer design to be more appropriate to another available cross layer design. Once a system wide cross layer design approach is standardized, it cannot be changed easily and it should be maintained in rapid change in technology and requirements. Any modification should be carefully without affecting the system performance and does not create loops with unintended interactions between the protocols. The cross layer design should first consider the totality of the design while considering the long term architecture value rather than designing for a specific purpose or just to improve the performance in the current trend.

In this paper we have concentrated on *Link Distance* and *Link Cost* for the selection of the *best routes*. We have also incorporated link error rate in the link cost, which shows that upto 30% to 70% of energy could be saved even in realistic operating conditions. By this we select the routes with proper geographical distance between the nodes at the two ends of the hop. Link distance has been considered for power saving in [2], [3]. In [4, 5, 6] authors have used the concept of sending the packets to the maximum farthest intermediate nodes only, once the route is discovered. In paper [6] authors have talked about link distance and link cost but link error has not been considered which is considered in this paper. Link delay has been used as the metric for calculation of the routes in [7, 8]. A simple cross layer design between PHY and MAC layers for power conservation based on transmission power control is proposed in [9]. In this paper, the use of multiple paths between each sensor node and the sink node is considered. It is shown that the network lifetime can be improved by efficiently routing (i.e., balancing) the traffic inside the WSN. Assuming the network lifetime as the time for the first node in the WSN to fail, a perfect routing protocol would slowly and uniformly drain energy among nodes, leading to the death of all nodes nearly at the same time. Typically, an ideal routing protocol would avoid the fast drain of sensor nodes with high energy consumption. To achieve this, we propose balancing the energy consumption throughout the network by sending the traffic generated by each sensor node through multiple paths, instead of always forwarding through the same path. In fact, always routing through the same path will quickly deplete the energy of the sensor nodes contained in. The problem then consists of determining the set of routes to be used by each sensor node and the associated weights.

II. Cross Layer Interaction

Cross layer interaction means allowing communication of layers with any other possibly non-adjacent layers in the protocol stack. Traditionally, the network protocols are divided into several independent layers. Each layer is designed separately and the interaction between layers is performed through a well-defined interface. The main advantage of layering is architectural flexibility but layering approach is not efficient for wireless networks. Cross layering came into existence because of highly variable nature of links used in the wireless communication systems and due to resource poor nature of the wireless mobile devices there has been multiple research efforts to improve the performance of the protocol stack by allowing cross layer interaction by wireless systems. Because of QoS, energy consumption, poor performance, wireless links, mobility, packet loss, delay problems observed in the wireless networks much attention is paid in the cross layer interactions. Typically, sensor nodes avoid direct communication with distance destination since high transmission power is required to achieve reliable transmission. Instead in WSNs, sensor nodes communicate by forming a multi hop network to forward messages to the collector nodes, which is also called the sink node. In reference to energy efficient routing in multi hop becomes crucial in achieving energy efficient network. In addition to using multi hop communication for reducing the energy requirement for communication, an efficient routing protocol is needed to decrease the end-to-end energy consumption when data send to sink node.

Major sources for power consumption are idle listening, retransmission resulting from collision, control packet overhead, unnecessarily high transmitting power, and sub-optimal utilization of the available resources. If any of the quoted causes are reduced power could be saved to some extent. Recent algorithm for minimum-energy routing in wireless networks typically select minimum-cost multi-hop path. In this scenario where the transmission power is fixed, each link has the same cost and minimum hop path is selected. In situation where the transmission power can be varied with the distance of the link, the link cost is higher for longer hops; the energy aware routing algorithms select a path with a large number of small distance hop. We should find how it leads to an efficient choice between a path with large number of short distance hops and another with a smaller number of large distance hops. Use of minimum energy paths for packet transmission may not always minimize the operational lifetime multi hop wireless network.

Multi hop wireless network typically possess two important characteristics:

1) The battery power available on the lightweight mobile nodes is relatively limited.

2) Communication cost in terms of transmission energy required are often much higher than computing costs on the individual devices.

Energy aware routing protocols are such that they select routes that minimize the total transmission power aggregated over all nodes in the selected path. If all the nodes use the same transmission power, irrespective of the link distance, and if the links are error-free, then conventional minimum-hop routing like OSPF[10] will be most energy efficient. However, minimum-hop solutions are not applicable in variable-power scenarios, where the nodes can dynamically vary their transmitter power levels. In such cases greater energy efficiency can be obtained if the nodes choose the transmission power depending on the distance between the transmitter and receiver nodes. For any wireless link signal transmitted with power Po over a link with distance D gets weak or attenuated and is received with power

$$Pr \ \alpha \ \frac{P_t}{D^K} \quad K \geq 2 \tag{1}$$

where K is a constant that depends on the propagation medium and antenna characteristics. Therefore, the transmission power for these links is chosen proportional to D^K. To calculate energy efficient paths, each link is assigned cost proportional to the energy required for a single transmission across the link. Minimum energy paths in this case will be paths with minimum aggregate path cost. Therefore, in these environments a path with a large number of small hops are typically chosen over an alternate path with a small number of large. This is the strategy used by a number of energy efficient routing techniques e.g. PAMAS [7].

In paper [11] a molecular algorithm is developed to solve the longest path problem. Till now in literature no molecular algorithm is presented on weighted graph G = (V,E). The proposed molecular algorithm can be performed in molecular operation special effort is spent on designing on scaling method for weight values in order to obtain an appropriate encoding for the problem. In paper [12] authors intend to improve energy consumption and data delivery ratio. In former author used the hybrid PULL PUSH and in the latter author used the fault tolerant mechanism. The most commonly used techniques for fault recovery is replication or redundancy of components that are prone failure. In this paper LOHD techniques is improved with considering energy parameters in order to extend the lifetime of the sensor network and we introduce fault tolerant method in order to increase the reliability and data delivery ratio. It has been observed that in both constant-power and variable-power, ignoring the error rate of the link can lead to the selection of paths with high error rates and high retransmission overhead. Minimizing the energy path is the most efficient WSN. While doing this main focus should be on the total operational lifetime of the network and to maximize it. Mainly there are two routing objectives, one is to minimize the energy requirements to transfer the individual packets and the other is to maximize the lifetime of the network. Mostly strategies to maximize network lifetime typically take into account the variable traffic volume passing through different nodes and avoid rapid depletion of battery.

In latter part of the paper we leverage our minimum energy path selection technique to define Link Distance link Cost link Error (LDCE) that can be used to increase the operational lifetime of the network. In this protocol the choice of the route are based on the node specific parameters and link specific metrics i.e. first we find route with the minimum link distance, then the link cost is calculated which is based on the transmit power and remaining or the residual battery. LDCE accommodated scenarios where the nodes can adjust their transmission power dynamically which is based on the distance of the nodes and also incorporates the effect of link layer error rated and packet retransmission. While calculating the link distance we are not simply going to the concept of the shortest hop path, instead we try to transmit the data to the node which in appropriate route and is at the farthest position the sensing range.

The rest of the paper is organized as follow: In section III we discuss the LDCE scheme, section IV gives details of the simulation, and section V concludes the paper.

III. LDCE(Link Distance Link Cost Link Error) base Cross Layer Route Discovery for WSNs.

We consider wireless sensor network that has a high density of nodes is less mobile. Initially all the batteries are fully charged. For convenient analysis we assume that every node in the network have the same transmission and knows its geographical position itself and its neighbors. Transmission radius can be located by Global Positioning System (GPS). Message exchanged during transmission or reception has a unique identity number, which consist of additional information like sender id and timestamps etc.

We have considered *Link Distance* and *Link Cost* and *Link Error* for the calculation of the *best feasible route.* MAC and the PHY layer information are explored for routing. Link Cost and Link distance both are different because *link distance* highly depends on the network topology and it is difficult to control the actual link distance in a route. A hop can be included in a route only if its link distance is no more than a defined value. *Link Cost* is based on the cross layer design that rejects the paths with nodes, having less battery support than the specified threshold i.e. < 50 %. Our routing technique guarantee:

- It uses short paths that are feasible by checking in for the link cost and the link distance.
- It is localized and scales well to large network, as in our case, we consider a high density network: in which each node only needs information about its local neighborhood to make routing decision. It also handles dynamic change & mobility efficiency as long as a node neighborhood is included.
- It is online as the routing decision of packets depends only on the previously routed packets.
- Our algorithm always uses the path that guarantees the highest value of life

The related knowledge for investigating the relationship between the end-to-end throughput and the link distance is as follows. Models are discussed:

*Two-Ray Ground Model***:** This model is often used for open field. The two ray ground reflection model considers both the direct path and a ground reflection path. It is shown that gives more accurate prediction at a long distance than the free space model. The received power at distance d is predicted by

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \qquad (2)$$

where Pt is the transmitted signal power, Gt and Gr are the antenna gains of the transmitter and the receiver respectively. L is the system loss and ht and hr are the heights of the transmitter and receiver antennas respectively. The equation shows a faster power decrease with increases in distance. However, the two-ray model does not give a good result for short distance due to the oscillation caused by the constructive and destructive combination of the two rays. Instead, the free space model is still used when d is small.

Shadowing Model: The received power at certain distance is a random variable due to multipath propagation effects, which is also known as fading effects. In fact, the above two models predict the mean received power at distance d. The shadowing model consists of two parts. The first one is known as path loss model, which also predicts the mean received power at distance *d* denoted by Pr(do).

$$\left[\frac{P_r(d)}{P_r(d_0)}\right]_{dB} = -10\beta \log(\frac{d}{d_0}) \qquad (3)$$

where Beta is called the path loss exponent, and is usually empirically determined by field measurement. The second part of the shadowing model reflects the variation of the received power at certain distance. It is a log-normal random variable, that is, it is of Gaussian distribution I measured in dB. The overall shadowing model is represented by equation (4):

$$\left[\frac{P_r(d)}{P_r(d_0)}\right]_{dB} = -10\beta \log(\frac{d}{d_0}) + X_{dB} \qquad (4)$$

*Shannon's Theory***:** states that theoretical maximum rate at which error-free bits can be transmitted over a noisy channel can expressed in the form $C = W\log_2(1 + S/N)$, where C is the channel capacity in bits per second, *W* is the bandwidth in hertz, and *S /N* is the ratio of signal power to noise power, S is the average signal power and N is the average noise power

When the source node wants to transmit data, it broad cast the route request message (R-REQM) once and maintains its routing table. Due to which when the source node sends the data packets it only needs to know its neighbor nodes. As the paths are discovered only when they are needed for routing. It reduces overhead and rerouting process. Although some information is needed to be calculated to store the record in the routing table, the energy expense is less as compared to energy expense in transmitting and receiving. The format of the R-REQM is shown in Figure.1. The *Source ID* contains the node ID of the message to destination, *Sequence Number* is the packet sequence, *Link Distance (Hop Count)* is the number of nodes between the source and the destination node, *Energy threshold* gives information about the energy level for the node to take part in transmission and reception, i.e. every node should have battery support < 50 % then only it can take part in routing. *Signal strength threshold* is the minimum distance the node has to be selected for data transmission the node has to be located in order to receive all the data transmitted to that particular node. *Destination ID* is node where the data has to be reach. For data transmission suppose node S wants to transmit to node D. If node D is in the transmission radius of node S then, node S transmits directly to node D.

Source ID	Sequence Number	Link Distance (Hop Count)	Link Cost (Energy Threshold)	Signal Strength Threshold	Destination ID

Figure 1. R-REQM FORMAT

If node D is not in transmission radius, source S broadcast the R-REQM. After establishing the different paths, the paths are stored in the routing table as shown in table 1. The shortest path to reach the destination is obtained from the concept of paper [4].

Fields	**Description**
Destination	Address of destination node
Sequence Number	Sequence number of the previous message
Next Hop	Next node address
Hop Count	No. of hops between S and D
Lifetime	Validity of the route

*Table 1***.** Routing Table

In traditional routing, shortest path is considered for transmission without any checks on that route, which may create problems like: node battery deplete, Change of topology etc. This decreases the reliability of successful transmission. Continuous usage of same shortest path increases overload on the nodes of that path resulting in route fading.

We are approaching to find a much best feasible path instead of just the traditional shortest path routing e.g. DSR, AODV [13]. DSR and AODV has drawback of re-routing and route re-establishment, while in LDCE, if the first shortest path do not passes the feasibility analysis then second shortest path can be selected from routing path. For feasibility analysis we check for link cost i.e. battery support of all the node for the selected route. We find that shortest path in which all the nodes have battery support>50 % as in table 2. Those nodes whose remaining battery supports<50% are dropped and that route will not be considered as feasible path. Traditional shortest path routing may create problem whereas heavily loaded nodes and feasible routing algorithm necessarily use long path. For selected route:

(a) *Link distance* is calculated i.e. the number of hops or nodes between the source and destination in that route. Link distance is the distance from the source node to first farthest intermediate node in the transmission radius. It would be termed as 1^{st} link distance. We calculate to reach from source to destination how many link distances are required. It can be well understood from figure 2 given.

From figure 2 we can observe that for source node {a} the other node in the radio range are {c, d, b, g}, but we send the data to the farthest intermediate node {g} and it is denoted as the 1^{st} link distance. Now {g} sends data to {f} and it is called the 2^{nd} link distance. In this way when the node wants to send the data first the entire possible route to reach the destination node is calculated. Then the link distance is calculated. The link with minimum link distance is chosen for transmission.

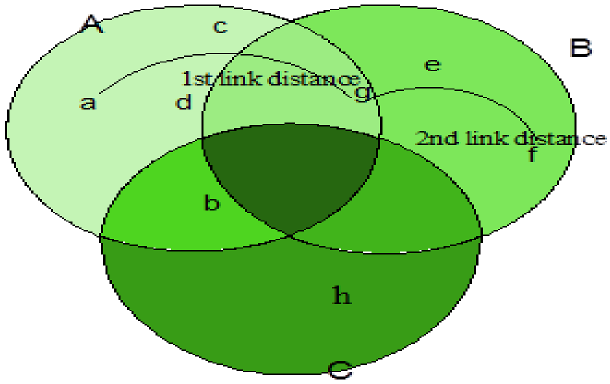

Figure 2. Calculation of Link Distance

(b) *Link cost calculation*

Remaining energy in %	**Feasibility (R)**
80-100	✓ High
79-50	✓ Medium
49-30	× Low
29-00	× Very Low

Table 2. Relationship Between Remaining Energy and Feasibility

For the calculation of the link cost the information that is needed is (i) transmit power (ii) remaining battery capacity of the node at any time t .(iii) Fully charged battery

Link cost can be calculated as follow by [14].

$$C(\pi, t) = \sum_{k\pi} C_i(t) \quad (5)$$

$$C_i(t) = \rho_i \left[\frac{F_i}{E_i(t)}\right]^{\alpha} \quad (6)$$

Where

ρi = transmit power of node i.

Fi = full charge battery capacity of node i.

Ei (t) = remaining battery capacity of node i at time t.

α = +ve weighting factor

c) Link Error Analysis

Here we demonstrate that how the error rate associated with a link affects the energy associated with the reliable transmission and the how error rate decrease the probability of reliable delivery. Let us assume for any link (a,b) between source node s and destination or receiver node b, let $T_{a,b}$ denote the transmitting power and $P_{a,b}$ packet error probability. The packet size is constant and the energy required of packet transmission is $E_{a,b}$. There are two types of problem for a signal transmitted over a wireless medium: attenuation due to the medium, and interference with ambient noise at the receiver. Due to the characteristics of the wireless medium, the transmitted signal suffers attenuation proportional to D^k, where D is distance between the source and the receiver. Ambient noise is not dependent on the distance between the source and the destination, but it purely depends on the operating conditions of the receiver.
The bit error rate associated with a link is a function of the ratio of this received signal power to the ambient noise. In the constant-power scenario, transmission power is independent of the characteristics of the link and is a constant. For those receiver located farther away from a transmitter will suffer greater signal attenuation will have a larger bit-error rate. In the variable-power scenario, a transmitter node adjusts to ensure that the strength of the (attenuated) signal received by the receiver is *independent of* distance and is above a certain threshold level Th. Accordingly, the optimal transmission power associated with a link distance D in variable power is :

$$T_{optimal} = \text{Threshold level} * \alpha * D^K \quad (7)$$

where α is proportionality constant and K is coefficient of attenuation. In presence of link error both fixed power and variable power strategy may not result into best optimal and feasible path. If the link are error free the LDCE result more energy efficient.
As we have considered the concept of not sending the data to each and every node of the shortest path , and sending the data to farthest intermediate node in the sensing range and considering it as the link distance. It becomes necessary to understand the tradeoff between choosing a path with multiple short hops or the one with single long hop i.e. to the farthest intermediate node as in figure 3. Let there is a Source node S and a Receiver R and the distance between them is assumed as D. H is the number of hops, H-1 is the number of forwarding node between the source and the receiver. Let these nodes be indexed as i: i = {2,…,H) and node 1 refer to the source node and node H+1 is receiver node.
Total energy spent in transmitting a packet without checking for it successful reliability of transmission from S to R over H-1 node is:

$$E_{total} = \sum_{i-1}^{H} E_{optimal}^{i,i+1} \quad (8)$$

For H-1 intermediate node the energy characteristics, we have to computer the E_{total} for H-1. Minimum transmission energy is when the each hops is equal to the length D/H. For the E_{total} is given as

$$E_{total} = \sum_{i=1}^{H} \beta \frac{D^K}{H^K} = \frac{\beta D^K}{H^{K-1}} \quad (9)$$

Energy spent in reliable delivery, we assume that how the number of hop affects the transmission error and retransmission. Increasing the number of intermediate node increase the transmission error in the entire routing.
Consider that each of the N links has independent error rate of P_{link}, the chances of transmission error over the entire path P is:

$$P = 1-(1-P_{link})^H \quad (10)$$

The larger number of P_{link} agree to smaller value of optimal number of forwarding farthest intermediate node. This shows that higher value of H increases the retransmission overhead also increase the energy consumption. Thus multiple shorter path are not always beneficial in comparison to the smaller number of long distance hops.

The network load density decreases as the data packet size increases. Network Load density is calculated as the density of the nodes that have packets to send and contend for channel access. For a network, its load density is the number of active source nodes and forwarding nodes. LDCE calculates the link distance and the hop count during the route discovery by changing a node's searching range for its next hop based on the load density. Un useful path information is deleted to simplify and reduce the overhead incurred. When the link cost Ci and the link distance is obtained, the source node that has data to send checks both and process further.

For LDCE route discovery process the following steps are performed in the node, as explained in figure 3.

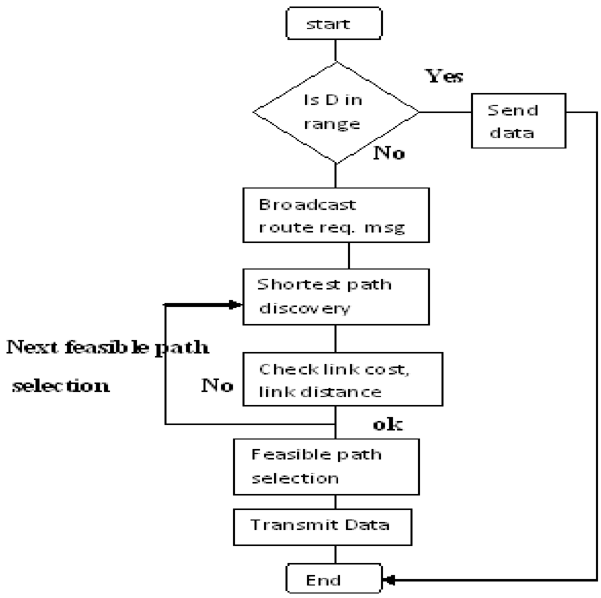

Figure 3. Flowchart for LDCE algorithm

Two cases occur that will effect end-to-end throughput when the network size is small or large.

- **Network size is small**

In a network nodes are randomly located, some node that wants to send data acts as the source and receiver node is the destination. In small size network it may be possible that the source want to send data to destination node and that destination is in the radio range of the source node. So the data can be sent directly to that destination node. First of all the possible routes are discovered to reach the destination. All these routes may have different link distance; we first select the routes that have the minimum link distance and calculate the corresponding end-to end throughput. This value is not more than mobile ad-hoc transmitting range. The link distance is equal to the geographic distance between the source and the destination divided by the minimum number of farthest intermediate node. In a network that has i connections, let N = {N1, N2... Ni} be the geographical distances between the sources and their destinations for these i connections. Let h = {h1, h2... hi} be the number of intermediate hops in each connection, which is also the vector of the number of transmitting (contending) nodes in the routes. Since every node is within the CZ (carrier sense zone) of any other node in the network, the overall number of nodes that will contend for the channel is D. Let d = {d1, d2... di}, where dj is the link distance for each intermediate hop in the connection j, and dj = Dj / hj. Let c = {c1, c2,...., ci} be the set for all the data rates for these connections. Using Shannon's theory and the two-ray ground radio propagation model, the highest available data rate in every link for this connection (which is defined as cj) is

$$c_j = W\log_2\left(1 + \frac{kP_{tr}}{n_{rj}d_j^4}\right) \quad (11)$$

As CSMA is used, when a node is transmitting a packet, all other nodes can sense it and they will not attempt to transmit. Therefore there is no chance of channel interference. Packets with different size have different transmitting rate and time taken. The amount of time a node occupies a channel for its purpose depends on the data rate. The end to end throughput is defined as the number of bits that are successfully transmitted by any node in the connection.

- **Network size is large**

In this section we are briefly discussing about the effect of the link distance on the end to end throughput when the network size is large. In this case the source and the destination are located far away. The route that is discovered has large number of hops and therefore large number of farthest intermediate nodes. A source that has data to forward i.e. active node has to contend with all other active nodes within its carrier sense range to access the channel. As the distance between the source and destination is large, most of the active nodes in its carrier sense are farthest intermediate node. As the number of connection increases throughput decreases as number of connection in the network increases. It can be concluded that when the network size is small and it is lightly loaded, it is possible to improve the through put by reducing the link distance, because the data could be send directly to the destination node without the help of the intermediate node. In large network size (heavily loaded) it is more important to keep the number of contending nodes small by using the concept of sending the data to the farthest intermediate node in the radio range of the sender.

IV. Simulation and Results

In this section we report on simulation based studies that examine the performance of our suggested technique for computing energy efficient routing paths. The performance of our algorithm is evaluated using discrete event simulator NS-2. The simulation of a network of 100 nodes in a 1000 * 1000 m^2 area is shown. Initially all the battery is charged fully. When the process starts the initial energy is progressively reduced by data transmission/ reception. When the battery totally discharges the node cannot take part in the communication process. Each node has a radio propagation range of 250 meters and channel capacity was 2 Mb/s. Performance metrics are node energy consumption which is the average energy spent by node to transmit data from source to destination. Data delivery ratio is number of data packets sent by the source and the number of data packets received by destination. Average time between time between the data packet send by the source and the time the destination receives it. Figure 4 shows, in LDCE as the number of nodes in the network increases its performance does not decreases. In Figure 5 as the number of nodes increase protocol AODV degrades its performances because it has to re-route the whole process. Figure 6 shows comparison between end-to-end delay and speed for both AODV and LDCE. In LDCE comparative energy consumption is less, as network performance increases in many ways.

Simulation Parameters	**Value**
Transmission Range	250 m
Simulation time	>800 s
Topology Size	1000m * 1000 m
Number of nodes	100
Number of destination	1
Traffic type	Constant bit rate
Packet rate	5 packets/s
Packet Size	512 bytes
Radio range	350 m
Transmit power	660mW
Receive power	35mW
Initial energy in batteries	10 Joules
Signal Strength Threshold	-80 dbm
Energy Threshold	0.001 mJ

Table 3. Simulation Parameter

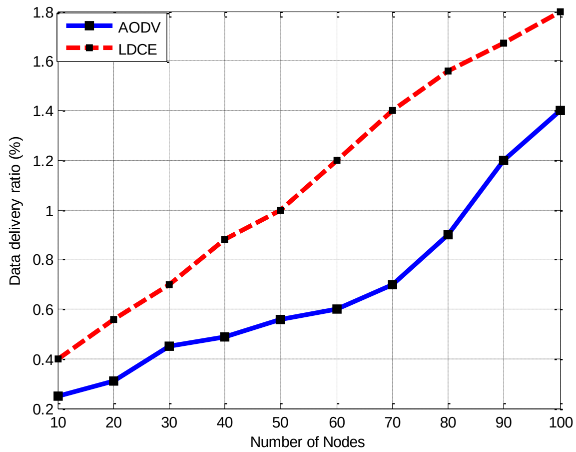

Figure 4. Data Delivery ratio vs number of nodes

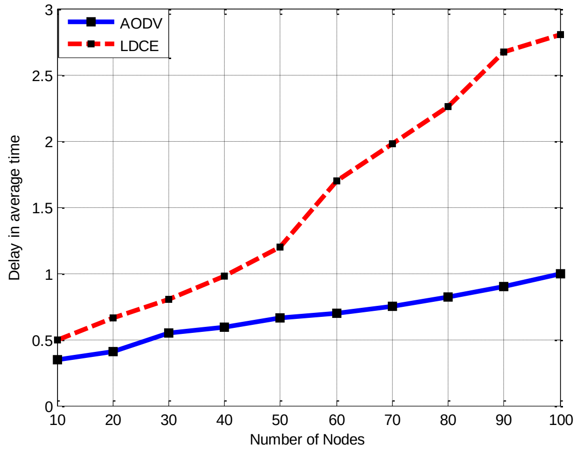

Figure 5. Delay in average time Vs Number of nodes

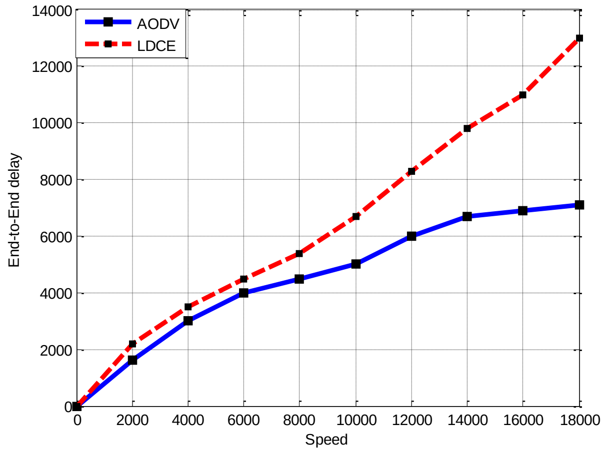

Figure 6. Speed Vs End to End delay graph

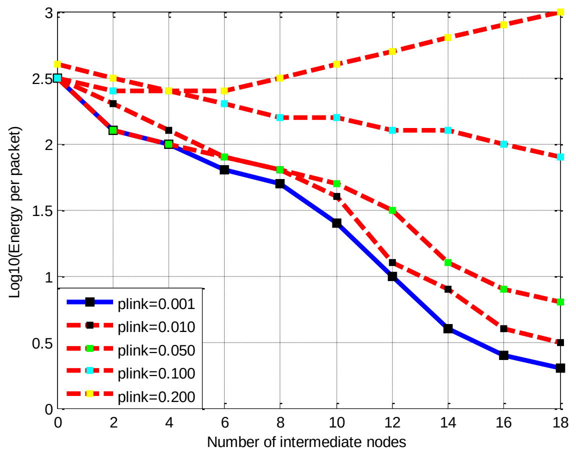

Figure 7. Total energy cost vs. Number of intermediate forwarding nodes

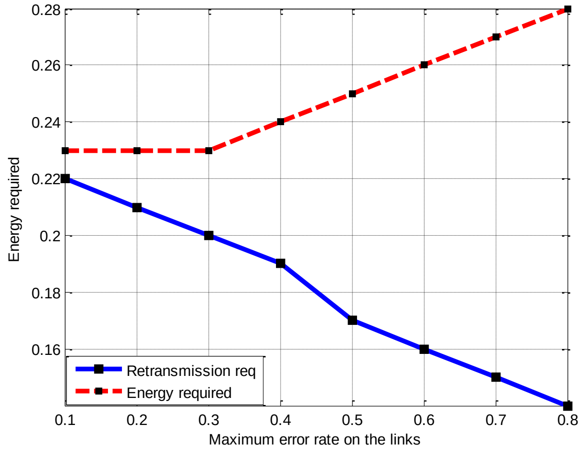

Figure 8. Maximum error rate on the link vs. Normalized energy required

Figure 7 shows that for low values of the link error rated, the probability of transmission error is relatively insignificant, and so on the presence of multiple short ranges hops nodes leads to a significant reduction in the total energy consumptions. However when the error rates are higher than around 10% the optimal value of number of hops H is small. In such case any potential power saving due to the introduction of an intermediated nodes are neglected. In Figure 8 we can see that energy requirement for retransmission is much lower.

V. Conclusion

Cross Layering is the best approach to save energy in wireless sensor networks. Energy efficiency can be improved at various layers. The knowledge of physical MAC, and network layer should be shared with each other properly. The conventional layered approach has several drawbacks in the system design. The proposed scheme LDCE improves the end to end delay, through put and also reduced the overhead to some limits. Traditional protocol selects the route with the smallest hop count. Instead we tried to obtain shortest feasible path keeping the constraints of link distance and link cost and link error. Our future work would be to effectively address this problem with efficient cross layer design and guaranteed delivery of data and retransmission issues and to verify the simulated result experimentally. On one hand is the most successful modular layered architecture design providing the very essence of abstractions and on the other hand is WSNs some functions cannot be assigned to a single layer and require cross layer design for improving performance. Although different literature shows many advantage with CLD many of the cross layer design proposals are aimed at achieving performance improvements often at the cost of good architecture. The cross layer design approach has a great future in the wireless network if they were designed by considering the totality of the design, including the interactions with other layers and also what other potential suggestions might be barred because they would interact with the particular proposal being made. They must also consider long term architecture value of the suggestion.

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