Energy Efficient Cross Layer Routing Protocol with Adaptive Dynamic Retransmission for Wireless Sensor Networks

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Abstract— **The wireless sensor networks consist of densely populated sensor nodes which are capable of transmitting critical data to intended sink node. The important and crucial part of wireless sensor networks is to utilize and save energy in more conservative way. Here is very much needed to support required application objectives by utilizing the developed energy efficient routing protocols which have severe energy limitations. The main focus of the work is to achieve prolonged network lifetime while considering overall energy consumption in the wireless network. In this paper, we propose efficient Cross Layer Routing Protocol (CLP) which is designed to adopt cross-layer strategy that consider the amount of energy consumed during routing from one node to another for Wireless Sensor Networks.** ***Mechanism is adopted to save transmission power between the two nodes and maintain the nodes neighbor's tables interleaving to utilize the transmission energy efficiently by making use of adaptive retransmission mechanism. The node's sleep time is prolonged by determining the nodes routing information from network layer. The simulations results show that CLP is efficient approach which yields good results and achieves significant improvement in terms of performance.***

Keywords- Routing Protocol, Wireless Sensor Network, Energy Efficiency, Dynamic Retransmission, Performance Analysis, Cross Layer

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a distributed autonomous collection of nodes for monitoring physical or environmental conditions such as temperature, soil moisture etc [1]. The main motivation behind for developing Wireless Sensor Networks (WSNs) is because of its widely usage for various applications such as habitat monitoring, automation, agriculture, and security.

Each sensor node usually consists of memory, which can be of different types, a radio transceiver, a micro controller, an electronic circuit for interfacing with sensor and a battery for energy. The processing capability and memory is limited in case of sensor nodes. Communication between the nodes will be in a wireless manner and they self organize themselves in an ad hoc fashion after the deployment.

The main characteristics of WSN [2] are nodes cannot be reenergized, node failures will not affect the overall working of the network, a node may be stationary or mobile, and nodes may be of heterogeneous or homogeneous, scalable for large scale of deployment, nodes are able to withstand unusual weather conditions.

Energy is a very important constraint in WSN to improve the overall network lifetime [3]. To improve energy constraints along with the mobility of nodes, given TCP/IP stack failed to fulfill the requirements because of its static nature. In order to overcome these constraints of TCP/IP stack, cross layer technique is been introduced. In TCP/IP stack only adjacent layer will communicate and each layer will add header and send to next layer, no other layer apart from adjacent layer know the failure in path, channel allocation, packet loss, delay etc [4].

In cross layer [5], the services can be provided from any layer to any layer and there is no need of providing service from lower to higher layer, because of this the throughput can be improved. The basic idea of cross layer technique is maintaining the functionality of the original layers , but interaction, co-ordination among different layers can be allowed, because of this transparency between the layers can be maintained, and number of control signals can be reduced.

II. RELATED WORK

There are many efforts seen to improve the network lifetime by developing energy efficient protocols and most of them have incorporated traditional layer approach [6,7,8,9,10]. There are several mechanism are available for reducing energy consumption such as period listening and sleeping, collision and overhearing avoidance and message passing etc. There are several performance and efficiency of the system drawbacks are exists in case of traditional layered network having layer independency. The promising cross layer design approach was adapted in various wireless networks. In this approach inter layers communication is achieved and also important information among the layers is exchanged to optimize the desired goal in wireless communication system. Many papers discuss and highlight the advantage of cross layer based approach.

Fatma et.al [11] adopted a cross layer strategy with routing and MAC layer together. The generated traffic at each sensor node is transmission among different path instead of single path. This has been carried out at routing layer allows significant energy conservation. At MAC layer retry limit is efficiently adjusted over each wireless links to achieve energy conservation there by increasing the network lifetime. There are papers which talks about high throughput and low delay in wireless networks [12, 13]. The details of high throughput and low delay in wireless ad hoc networks is available in [14] . The detailed analysis of delay-throughput for various network topologies has been carried in [15]. In [16] author has proposed a new geographic routing scheme by which a near optimal capacity is achieved with low delay.

Authors in [17] have developed an algorithm that shows delays in the packet delivery. In Paper [18] a cross layer algorithm which takes the advantages of the retry limit has been given. In [19], for the delivery of the packets, a retransmission deadline is assigned to each and every packet by the application layer. A. Sivagami et al in [20] have used collection tree protocol (CTP) to collect data from the sensor node. It uses either the four bit link estimation or Link estimation Exchange protocol (LEEP) to predict the bi-directional quality of the wireless link between the nodes and the next hop candidate is based on the estimated link quality. The residual energy of the node is an important key factor, which plays a vital role in calculating the lifetime of the network. S.Mehta et al in paper [21] have proposed a scheme to save power dividing the execution of back off algorithm by avoiding idle listening. In paper [22] algorithm makes the routing decision using the statistics of the energy consumed for each type of node activities including sensing, data processing, data transmission as a source node and routing process.

III. SIMULATION MODEL

The simulation model consists of N nodes distributed randomly on a two dimensional area. The sensor nodes are deployed densely and range of each node is within the proximity of another nodes. Most of the sensor nodes in the network are stationary and few of them have minimum mobility. The sensor nodes must provide collaborate to collect data by coordinating with neighbors. Each node in the network perform dual role as mobile host and mobile router for receiving and forwarding to the sink.

All nodes in the network use same frequency for transmitting and receiving (half duplex mode) and share information to others node in their sensing range. Nodes are initially charged with full energy. Any packet transmission of the node from one to another should be less than the maximum transmit power of the node.

IV. CROSS LAYER ROUTING PROTOCOL WITH ADAPTIVE RETRANSMISSION METHOD

The three important layers such as PHY, MAC and Routing are considered for making decision to transmit packets from source to destination. The intermediate node is considered for retransmission and computes new limited number of adaptive retransmission method during route failure. In a network all the nodes are equipped themselves of receiving and forwarding packets from source A to destination B. The nodes have to carry routing information from one node to another for the farthest distance with the support of intermediate nodes as mentioned in [23]. There is no guarantee of delivering of the packets to the intended destination or receiver due to interference or noise problems. Even packets may get collided (partially or fully) with each other and leads to loss of information. The protocol is design to restrict itself to the number of successive transmissions for a packet when it is dropped further. The success or failure of its transmission is notified to the source using some mechanism. The complete protocol operation is divided into four major sections.

A. Tracing the exact location of the destination

When Source node A has data to send, it checks for the exact location of the Destination node B. If the destination node B is in its sensing area then Source A sends an Route-Request(RR) message to Destination node B whether it is in the condition to receive data or not. In case, if B is in a condition to receive the data, it sends back ACK to source node A. Then data is sent to the destination and B sends ACK once again to source to confirm the delivery of the data successfully. In case, if B is not in its sensing range, A waits for B to be in the ready state. If source does not receive any ACK message within in fixed time frame, it resends the Route-Request (RR) message. During this period, other nodes are allowed to sleep for this fixed time frame.

B. Find the Route without prior knowledge

The routing decision is based on the prior knowledge available in its cache. But when a source node A has data to send to the destination node B which is not in its sensing range, there is no prior knowledge exists in its routing cache table.Now, source node issues a Route-Request (RR) message node at the maximum distance in its sensing range. The length of route request message is kept as small as possible to minimize the energy required. The confirmation message ACK is issued by an intermediate node which is at maximum distance to indicate that it is ready to receive data. Now the source initiates to send data to the intermediate node which is ready to receive the data. If the ACK message is not sent within the time frame, the source A once again resends the Route-Request (RR) message. In case, if there are two or more than two nodes at the same maximum distance then source nodes sends Route-Request message to all the nodes. After receiving the message, all the nodes will reply with ACK message and also power level information to the source node. Now, the

node which has maximum energy receives data from the source node
The data received by the intermediate node shall reply with ACK message back to confirm that it has received the data successfully. The energy is saved when nodes which are not involved in transmission goes for sleep mode. The node which has maximum sensing range will receive the data from the intermediate node.

C. Adaptive Method for Retransmission

Cross Layer Method is based on the information about the route and number of hops to determine the maximum number of transmission. When a node sends data to the destination, on the way there is a possibility of data collided on the intermediate node. Now source has to resend the data again and checks for the number of hops to destination. The maximum value is set and retransmission of the data would have done. The same procedure is followed for next intermediate hops and process of retransmission is carried by setting the maximum value depending on the number of hops. In case if there is failure in any of the intermediate nodes, then it will check the initial maximum value set and computes new maximum value depending on its position from source and number of hops left from the destination. To find the maximum packet failure node will examine its position from source and hops left the destination. Here the more chance is given to the success of packets which had approached to the destination. The packets which are nearer to destination will be taken care and usage of bandwidth will be higher and waste of bandwidth on the path will becomes lower. The maximum value chosen should depend not only on number of hops, but also on other factors like link quality, transmission probabilities and number of neighbor. Taking care of these parameters at different layers makes protocol to work still better way.

V. PERFORMANCE ANALYSIS

A. Simulation Environment

In this section, the performance analysis of Cross Layer Routing Protocol with Adaptive Retransmission is presented. The simulation experiments are carried out using NS2 [24] simulator, which is open free source of ISI. NS2 support simulations of MAC and other energy-efficient protocols which accurately model power consumed by the applications and also include detailed model of power consumption of NS2. In the simulation environment 100 nodes are deployed in 1500 m x 1500 m region. The source nodes are randomly chosen and sink node is far from the sensor region. Each simulation is carried out for 600 sec and results are average in 10 runs. Each source node sends a packet every 10 seconds and the number of source varies from 10 to 50. The performance analysis is carried out along with DSR routing protocol. Even though there are 100 nodes deployed in the phenomenon, 10 nodes are chosen as the sources which are capable of producing the sensing data.

B. Simulation Parameters

There are various parameters that are available in Wireless Sensor Networks and they are also termed as performance metrics or design parameters. Every parameter has its own importance. These parameters are listed below. These design parameters/performance metrics are used for the evaluation of routing protocols. These design parameters have a great impact on overall performance of a communication network. In this work, we have dealt with the first three performance metrics of a network i.e. Total Energy Consumption, Lifetime, and Packet Delivery Ratio (%). These three performance metrics are evaluated against duty cycle and number of sensing nodes with respect to routing protocols to see the performance.

1. Total Energy Consumption (in mJ)
2. Lifetime (in secs)
3. Packet Delivery Ratio (%)

C. Simulation Results and Analysis

In simulation parameters, we have considered three performance metrics out of the most important metrics are energy consumption and life time. For each protocol considered for simulation, we need to measure the total energy consumption that all source nodes successfully send the data packets to sink or destination. The performance of study of Cross Layer protocol is done through simulation using ns 2.
The figure 1 shows that Cross Layer Protocol (CLP) consumes the least energy than the DSR and AODV protocols. The Cross Layer Protocol (CLP) utilizes the cross layer information from MAC, Routing layers and tried to minimize the exchange of information between the layers. As the number of nodes increases, all the protocols start losing their energy consistently. The different nodes share more middle nodes in the Cross Layer Protocol (CLP), resulting in more nodes in sleep state and better energy efficient. Although ADOV lets nodes will continue to keep asleep and they don’t participate in the transmission activity and its routing paths contain fewer nodes.

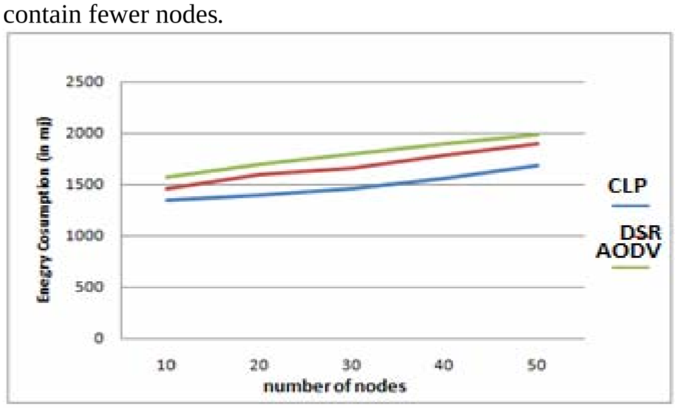

Figure 1. Energy Consumption vs. number of nodes

This makes more nodes keep asleep and it won’t optimize the transmission energy so that all communication links use the same transmission power. DSR and AODV consume more energy than Cross Layer Protocol (CLP). In DSR protocol, node has a fixed listen or sleep cycle, so a node must be waked up when its sleep period expires, even if the node hasn't any activity, resulting in unnecessary energy consumption. Cross Layer Protocol (CLP) effectively minimizes the total energy cost of the nodes.

Another metric network lifetime is used as metric to evaluate the performance of Cross Layer Protocol (CLP) design. It is defined that the network lifetime is time taken for 35 % of sensor nodes in the network to drain up their power. The change in the mobile rate to shows that performance of Cross Layer Protocol (CLP) is satisfactory.

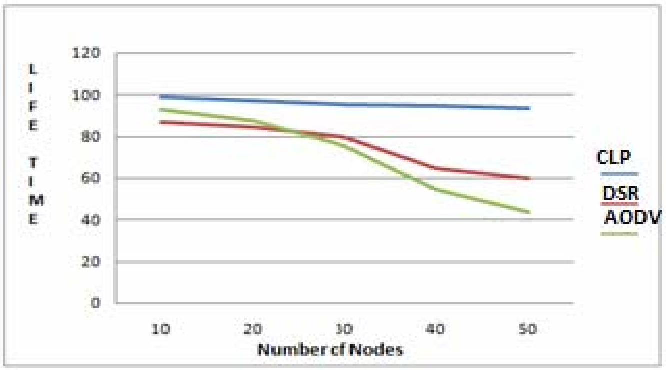

Figure 2. Lifetime vs. number of nodes

Figure 2 shows the network lifetime with respect to number of nodes and duty cycle. As the mobile rate increases, the life time of DSR and AODV changes, while Cross Layer Protocol (CLP) can alleviate this situation.

In case of DSR, it needs more time to set up the listen or sleep schedule with the neighbor. Small scale wireless sensor networks favor DSR to shorten the schedule synchronized process. The total numbers are varying from 10 to 50 which are randomly distributed in simulation area. The DSR is coupled with routing protocols and delivers the data from the sensor node to the sink. There is no need for AODV to use the initial phase to collect the information and for fair comparison. The energy consumption for the packet in Cross Layer Protocol (CLP) does include the energy used during the initial phase and compare Cross Layer Protocol (CLP) with DSR and AODV. In the figure 3 results shows that the energy based Cross Layer Protocol (CLP) is able to achieve higher delivery ration than DSR and AODV.

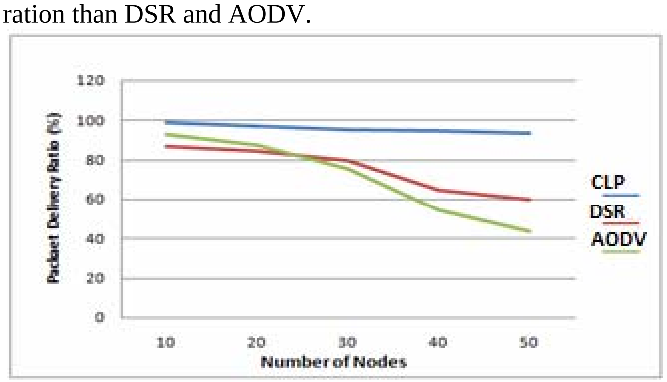

Figure 3. Packet Delivery Ratio vs. Number of Nodes

This is possible only because of performance improvement of collision free guarantees during data transmission. The AODV is more susceptible to the contention or hidden terminal collisions. The total number of sensor nodes increases improvement becomes more significant. In a instance as shown in Figure 3, for 40 sensor nodes case the received of the Cross Layer Protocol (CLP) is consistent in the packet delivery ratio as compared DSR and AODV out comes.

VI. CONCLUSION

In this paper, a cross layer approach is used to design a wireless sensor network. The energy efficiency can be improved at different layers of the protocol stack. It is very much important to organize the upper layer such as the network layer or the transport layer to meet the application layer requirements. The knowledge of lower three layers should be shared with each other properly. The conventional layered approach has several drawbacks in the system design. The MAC layer schedule or access control information from lower layer is used to avoid collision and saves energy consumption. Thus it is very much required to design leads to a more energy-efficient design and provide better system performance. CLP is a cross layer communication approach for WSNs, which replaces the entire traditional layered protocol architecture used for WSNs. The concept of unified cross layer adds both information and functionalities of traditional communication layers are merged in to a single module. CLP performs received based contention, local congestion control, and distributed operation in order to realize efficient and reliable communication in WSN. Cross Layering is the best approach to save energy in wireless sensor networks. Energy efficiency can be improved at various layers. In a cross-layer simulation platform, the state-of-the-art layered protocol configurations have been implemented along with CLP to provide a complete evaluation. Analytical performance evaluation and simulation experiment results show that CLP significantly improves the communication performance and outperforms the traditional layered protocol architectures in terms of both network performance and implementation complexity. The results of analytical simulation experiment show that CLP conserves more energy and leads to the better system performance. The limited number of adaptive retransmission has impact on the performance of network in terms of throughput and delay. This design saves energy and also improves it lifetime and performance of the network.

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