Layered CSMA- A MAC protocol for multi-hop wireless sensor networks

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Abstract: **A Wireless Sensor Network is a network of numerous wireless sensor nodes where every node is equipped with capability of receiving and forwarding the data to the other nodes by using radio frequency. The sensor nodes receive data packets from different nodes and forward these packets towards a central location called sink (Base station). These nodes consume energy for sensing, computations and communications purposes. The nodes have a limited power backup in form of battery, so the MAC protocols for WSNs aim to minimize the energy consumption of nodes. In WSN, the network performance is mainly measured by energy efficiency and lifetime of sensors. The MAC layer is responsible for the establishment of a reliable and efficient communication link between WSN nodes and is responsible for energy waste. The newly proposed contention based MAC protocol Layered-CSMA in this paper uses an improved variant of CSMA which had major problems like hidden/exposed nodes. The proposed protocol is aimed at minimizing the energy consumption in network thereby increasing the network lifetime. The proposed method divides the network area into different layers based on their geographical locations. Each layer is assigned a different status. The lower status means the layer is at a greater distance from the base station. The results confirm that the proposed scheme outperforms the existing LCSMA technique in multiple ways. The energy consumption is greatly reduced and the constraint to work only in linear topology is also removed. The key idea of this model is creating multiple layers wherein a node with lower status always sends data to another node with higher status and ultimately making it reach the central location base station. The methodology has been simulated in matlab and graphical results generated to establish validity of the model.**

***Index Terms*—WSN, Energy efficiency, MAC layer, CSMA.**

I. INTRODUCTION

Wireless Sensor Networks have emerged as an important new area in wireless technology. In the nearfuture, the wireless sensor networks are expected to consist of thousands of inexpensive nodes, each havingsensing capability with limited computational and communication power which enable us todeploy a large-scale sensor network.[1] A wireless network consisting of tiny devices which monitor physical orenvironmental conditions such as temperature, pressure, motion or pollutants etc. at different areas. Such sensor networks are expected to be widely deployed in a vast variety of environments for commercial, civil, andmilitary applications such as surveillance, vehicle tracking, climate and habitat monitoring, intelligence,medical, and acoustic data gathering.

The computational operations ofnodes and communication protocols must be made as energy efficient as possible. Among these protocols datatransmission protocols have much more importance in terms of energy, since the energy required for datatransmission takes 70 % of the total energy consumption of a wireless sensor network.

II. WIRELESS SENSOR NETWORK

A Wireless Sensor Network is a collection of wireless sensor node forming a temporary network without the support of any established infrastructure or centralized administration. The sensor nodes consume energy for sensing, computations and communications purposes. The routing protocols for WSNs are designed to minimize the energy consumption of nodes in perform of communication.In WSN, energy efficiency and lifetime of sensors have a significant impact on applicability and network performance. One of the key characteristics of sensor nodes is that they are energy constrained. If the diameter of the network is large, the power of sensor nodes will be drained very quickly. Furthermore, as the number of sensor nodes increases, collision becomes a significant factor which defeats the purpose of data transmission.Typically sensor nodes rely on finite energy sources like battery.

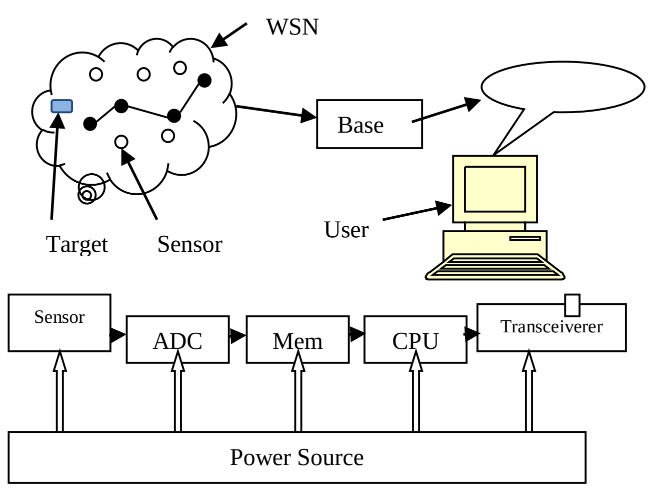

Fig. 1: Wireless Sensor Network

A. Routing Protocols

In the clustered routing architecture, a number of nodes are grouped as a cluster, and cluster head node, which is selected, based on certain parameters, collects, processes, and forwards the data from all the sensor nodes to the base station as a single hop or a multi-hop. Depending on how the sender of a message gains a route to the receiver, routing protocols can be classified into three categories, namely, proactive [4], reactive and hybrid protocols. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. According to nodes' participating style, routing protocols can be classified into three categories, namely, direct communication, flat, and clustering protocols. In direct communication protocols, a sensor node sends data directly to the sink. Under flat protocols, all nodes in the network are treated equally. In the clustered routing architecture, nodes are grouped into clusters, and a dedicated cluster head node collects, processes, and forwards the data from all the sensor nodes within its cluster. The proposed protocol is base station centralized i.e. this protocol utilizes a high-energy base station to set up clusters and routing paths, performing rotation of cluster heads, and carrying out other energy-intensive tasks.. The cluster head has to be a node with better level of energy and optimum location to minimize the energy consumption while hopping.

B. L-CSMA

The base research propose a CSMA-based protocol, called L-CSMA, specifically devised for linear networks; it reduces the impact of the hidden terminal problem, without the use of RTS/CTS packets, therefore preventing the increase of the exposed node problem. L-CSMA assigns different levels of priority to nodes when accessing the channel, depending on their positions in the line: nodes closer to destination have higher priority. The priority is managed by assigning to nodes different durations of the carrier sensing phase; nodes closer to destination, sense the radio channel for a shorter time. The LCSMA can be summarized as follows:

- The basic idea behind L-CSMA starts from the observation that, with traditional CSMA protocols, when a source node has many packets to send over an established route, they compete for accessing the radio channel with those that were previously transmitted and are still being forwarded by some relays in the route.
- To take advantage of the linear topology and to avoid congestion of data blocks at relays, we assign to nodes in the route different levels of priority in the access to the channel: nodes closer to the destination have higher priority with respect to those closer to the source.
- Once the node knows the number of hops to reach the source (i.e., its position in the hop sequence with respect to the source), the node will select the proper sensing duration.
- Isn't ideal for large geographical area

III. RELATED WORK

Ruizhi Liao et al. 2014, surveyed random access based MAC protocols for MU-MIMO enabled WLANs. The author first provided background information about the evolution and the fundamental MAC schemes of IEEE 802.11 Standards and Amendments, and then identified the key requirements of designing MU-MIMO MAC protocols for WLANs. After that, the most representative MU-MIMO MAC proposals in the literature were overviewed by benchmarking their MAC procedures and examining the key components, such as the channel state information acquisition, de/pre-coding and scheduling schemes. Classifications and discussions on important findings of the surveyed MAC protocols were provided, based on which, the research challenges for designing effective MU-MIMO MAC protocols, as well as the envisaged MAC's role in the future heterogeneous networks, were highlighted. **Quomar jabein *et al.* 2016 [20]** proposed a cross layer scheme to accomplish the flow contention of TCP in multi-hop adhoc networks. The proposed scheme collected the useful information from physical and MAC layer for approximation of channel utilization per station. The contention window (CW) had been adjusted to control the competition between stations. The proposed method also achieved the fair channel access by each station to achieve to equivalent throughput. The value of bandwidth allocation to each flow was calculated and sent to the next layer for getting the fair bandwidth allocation to each flow. Then, control the sending rate of TCP flow to resolve the problem of contention between flows. Each flow got almost equal throughput and fairness has been improved. In this paper, the contention window size was changed for per-station fairness. The author calculated the Fair Bandwidth Ratio and channel utilization. This information sent to the transport layer for per-flow fairness by adjusting TCP rate. Simulations proved the effectiveness for proposed scheme. With achievement of better fairness this scheme also achieved the good total throughput. The performance of the proposed method was examined using by network\ simulator [NS-2] on various topologies of multi-hop adhoc network.

Chiara Buratti *et al.* 2015 consider a multi-hop wireless linear network, where multiple nodes were evenly spaced over a straight line. Two scenarios were addressed: a network where only one source generated traffic to be transmitted via multiple hops to the destination, and the case of linear sensor networks, where all nodes in the line generate data. A novel contention-based Medium Access Control (MAC) protocol, L-CSMA, specifically devised for linear topologies, was proposed. CSMA (Carrier Sensing Multiple Access) suffered from the well known hidden/exposed node problems: the scope of L-CSMA was to reduce their impact, while minimising the protocol overhead. L-CSMA assigned different levels of priority to nodes, depending on their positions in the line: nodes closer to destination had higher priority when accessing the channel. The priority was managed by assigning to nodes different durations of the carrier sensing phase. This mechanism sped up the transmission of packets which were already in the path, making the transmission flow more efficient. Results showed that L-CSMA outperformed existing contention-based MAC protocols. A mathematical model to derive the performance in terms of packet success probability and throughput was provided. The key idea of the model was the definition of the generic state at network-level, instead of node-level, and its representation through a set of bits indicating the status (activity or not) of the corresponding link. The model was validated through comparison with simulations. **Anuradha *et al.* 2016 [19],** presented comparative survey of various MAC protocols. The research showed the comparison of different MAC protocols based on the various important requirements such as energy awareness and QoS support. According to the comparison table, the contention-free PACT protocol provided a reasonable solution in terms of QoS and low latency through the use of passive clustering. It also uses an adaptive duty cycle to increase overall network life time. The EMAC protocol was contention free protocol, required control packet for MAC operation and was also used to piggy bag various other information at low energy costs. Here latency increases as nodes had to wait for their desired time slot. LMAC protocol provided collision free communication but the latency could increase because a node had to wait for its time slot. It extended network lifetime as compared to S-MAC and EMAC. DEMAC took the individual node's energy levels into account and thus providing a solution in terms of energy awareness. Contention-based protocols like, S-MAC, TMAC, TEEM and EM-MAC, used periodic listening and sleeping scheme in order to prolong the network lifetime. The TEEM protocol provided more sleeping time to nodes in comparison to S-MAC and TMAC. EM-MAC substantially outperformed other MAC protocols studied in terms of energy-efficiency. GMAC was a hybrid protocol having advantages of both contention-based and contention-free protocols in it. **V. Richert *et al.* 2017 [22]**, proposed MAC protocol in this paper to be used as an improved variant of CSMA which implemented weak signal detection (WSD). The newly proposed MAC protocol called CSMA/WSD was a contention-based protocol which allowed more throughput by performing a loss diagnosis. The development of this new CSMA/WSD protocol was the first step to upgrading the basic CSMA MAC protocol for usage in critical environments. This technique enabled dividing collisions from weak signals and took appropriate decisions to reduce energy consumption. The CSMA/WSD protocol was presented as a flowchart and implemented in OMNeT++ by using theMiXiM framework structure. Implementation tests were performed to prove the validity of the implemented protocol in different scenarios. Different simulation scenarios showed that this protocol offered a higher throughput, a smaller mean backoff time, and less average delay in critical environments.

P. Sahoo *et al.* 2017 [23], proposed a new channel access scheme and beacon scheduling schemes were designed for the IEEE 802.15.4e enabled WSNs in star topology to reduce the network discovery time and energy consumption. In addition, a new dynamic guaranteed retransmission slot allocation scheme was designed for devices with the failure Guaranteed Time Slot (GTS) transmission to reduce the retransmission delay. To evaluate these schemes, analytical models were designed to analyze the performance of WSNs in terms of reliability, delay, throughput and energy consumption. These schemes were validated with simulation and analytical results and as observed that simulation results well matched with the analytical one. The evaluated results of the designed schemes improved the reliability, throughput, delay, and energy consumptions significantly.

IV. PROPOSED METHODOLOGY

Layered-CSMA protocol

The following points explain in detail the working of proposed architecture.

- In this proposed protocol (**Layered-CSMA protocol**), we introduce a new concept of 'status' for each layer formed.
- The same status applies to every node in the layer. So effectively, the status of layer is contained within node itself.
- The layers contain sensor nodes and a layer main unit.
- The energy of main unit reduces faster than normal sensor nodes so we re-choose main unit at regular intervals to be a node with a higher energy level as compared to sensor nodes.
- Every layer has a status number based on its distance from the base station. The lower status means the layer is at a greater distance from the base station.
- Now, every node when added to a layer gets its status set same as the layer itself.
- Every layer has unique status.
- So, a main unit wanting to send data to the base station sends it to the next nearest node with a higher status number.
- The main unit collects data from sensors and transmits data. After certain network state changes, the base station resets the main unit configuration of each layer thereby ensuring that the main unit is not always the same node but any node for a certain period with high energy level.
- This framework ensures that no single node is made to work as a main unit for a layer for longer intervals thereby reducing the energy of all nodes gradually and increasing on the network lifetime.

V. SIMULATION RESULTS AND ANALYSIS

Performance Evaluation

Graph 1: This graph shows the comparison between the numbers of sent messages between the different nodes in the existing system and the proposed system when the number of nodes in the network is 100. The graph clearly shows the dead nodes(whose energy level has gone to 0), main units at a particular time and the normal nodes.

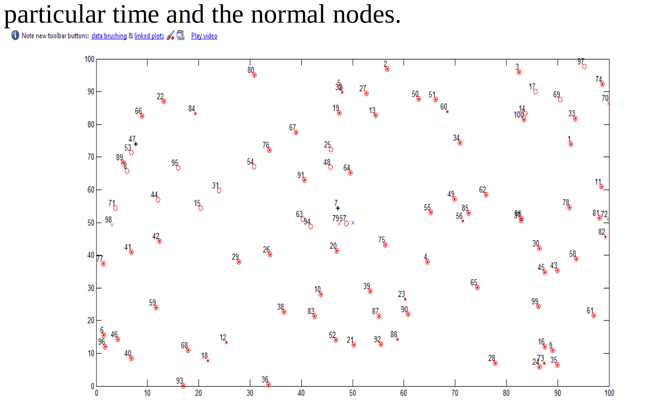

Figure 2: A Wireless Sensor Network consisting of 100 nodes

Graph 2: These graphs show the comparison between the Energy and round in the existing system and the proposed system when the number of nodes in the network is 100.

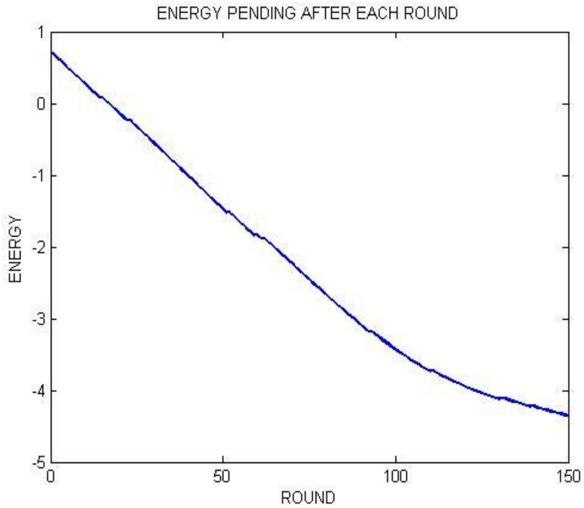

Figure 3: Graph plotted between Energy pending after each Round

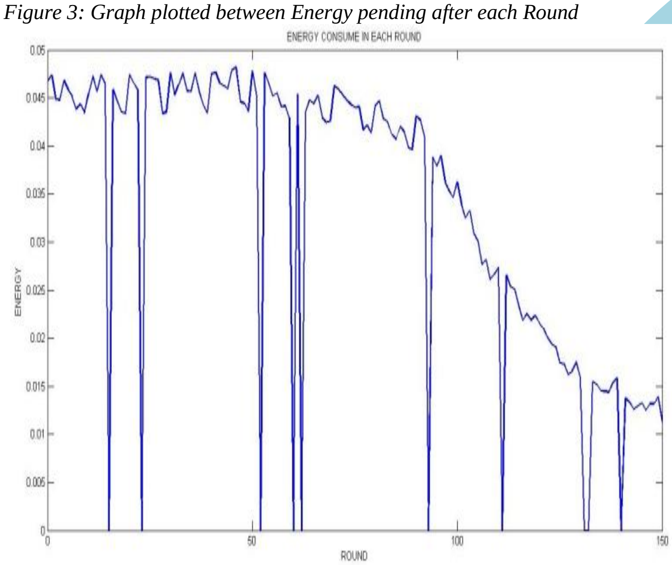

Figure 4: Graph plotted between Energy consumed in each round and Rounds

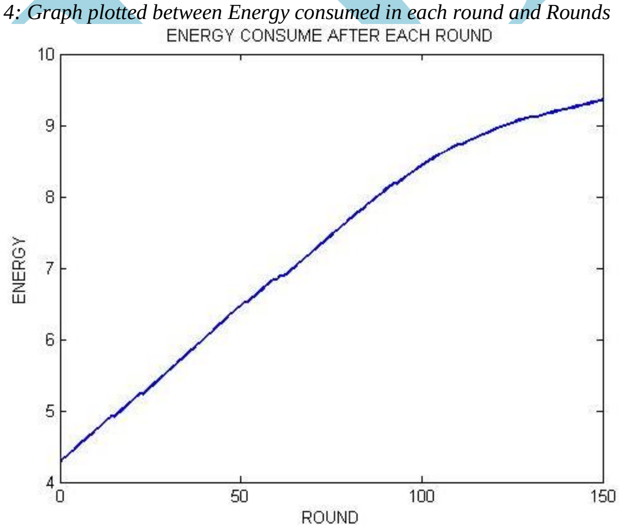

Figure 5: Graph plotted between total Energy consumed after each round vs Rounds.

Graph 5: This graph shows the comparison between the number of nodes dead in each round vs round in the existing system and the proposed system when the number of nodes in the network is 100.

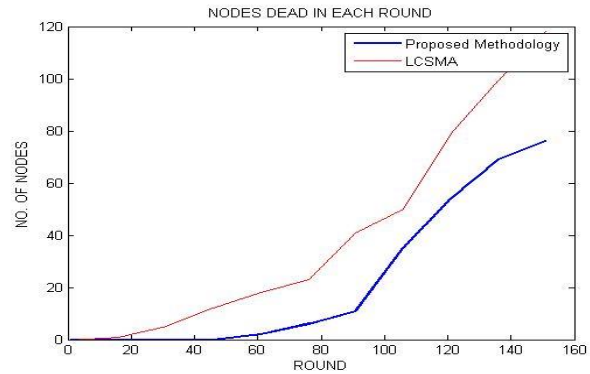

Figure 6: Graph plotted between Number of nodes dead and Rounds for base and proposed technique.

The above graphs make it clearly evident that the base technique not only is more flexible to work with any topology it also helps us in preserving the energy and thereby increasing the network lifetime.

VI. CONCLUSION

After having gone through the different literatures published on this topic of WSN mac layer protocols, energy enhancement is a major issue there and to improve the lifetime of network, we propose here a technique which enhances both these aspects through a single mechanism. This method ensures minimum loss of energy during transmission. The base research by Chiara Buratti [17] composed a MAC layer protocol called L-CSMA which was basically designed for linear topology. It assigned priority to all nodes based on their distance along the linear path. The proposed algorithm increases the lifetime of the network by inducing the concept of multiple layers. The layer has a status which applies as such to all nodes in the network. The status depends on the distance of each node from the base station (sink). The biggest status no. implies close to sink. So packet structure is changed to include the status of sender node in the packet. Each layer has a main unit which acts as the interface for this layer to the base station. The choice of main unit depends on the energy level of node. So the node with more than an optimum amount of energy is considered as a main unit candidate. This also helps in degrading the energy level of nodes gradually so the net lifetime of network is enhanced greatly. Thre results confirmed the effectiveness of the proposed technique. In comparison to base technique, the proposed protocol is not bound to linear topology and works well for all network architectures.

The further extensions of this work can try to improve layering by optimizing layer positions and main unit selection can also be optimized. This will further enhance energy conservation. The introduction of check packet can be used to detect and prevent some active and passive attacks on WSN.

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