Juni Khyat
(UGC Care Group I Listed Journal)
ISSN: 2278-4632
Vol-11 Issue-8, August 2021

AN ANALYSIS OF LL-MAC AND Q-MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS

Ansuman Nayak[1],Dr.Biswonath Biswal[2]
Raajdhani Engineering College, Bhubanewaswar
[1]ansumannayak@rec.ac.in
[2]biswonathbiswal@rec.ac.in

Abstract

Energy Efficiency and low latency are considered to be most important performance metrics for the performance of Wireless Sensor Networks. Communication is a big part of energy consumption and MAC protocols directly control this communication. In this paper the comparison has been carried out between two MAC protocols LL MAC protocol and a new sleep schedule Q-MAC protocol. Both QMAC and LLMAC follow a stagger active schedule. The simulation results indicate that LLMAC protocol performs better for both the metrics than Q-MAC.

Keywords: *Wireless Sensor Networks, Medium Access Control, Latency, Energy conservation.*

1. Introduction

A wireless sensor network (WSN) is an emerging technology for a wide range of potential applications, including the forest fire detection, flood detection, tele-monitoring of human physiological data, battlefield surveillance and nuclear, biological and chemical attack detection and reconnaissance [1,2]. A WSN comprises a set of sensor nodes deployed for certain application. Sensor nodes are placed to work in ad hoc manner. The nodes communicate with each other in order to collect, process and relay the data.

The energy consumption has a effect on the lifetime of Wireless Sensor Network. Collision, overhearing, control overhead and idle listing are the four main sources of energy wastage [7]. Considering these sources of energy wastage there has been recent attention on developing energy efficient medium access control (MAC) protocols for WSN. The main idea behind all of these MAC protocols is duty cycle.

Various protocols such as SMAC [8], TMAC [9], E^2L^2 [10], RMAC [11], PSMAC [12], ET-MAC [13] are designed on basis of this mechanism and consumption of energy during transmission and reception of data not in idle listen time. Power consumption is divided into three domains: sensing, communication and data processing, which are performed by the sensors, the CPU, and the radio respectively [3]. Out of the above three domains communication is major source of energy consumption.

The primary goal of already existing MAC protocols is high QoS and bandwidth efficiency. The efficient use of energy in WSN is a critical issue because each sensor node has a limited power source and it is hard to recharge or replace the energy-depleted nodes due to the desolate or harsh environment of the target area. Another important performance is low latency, because in most monitoring applications, an event detected needs to be reported to a sink in real time. It is a big challenge to design an energy efficient and low latency protocol for WSN.

The paper is organized as follow: The discussion about Q-MAC static and dynamic schedules is in section 2. Section 3 has the discussion about LL- MAC. Out of two key metrics, Latency is discussed in section 4 and energy consumption is discussed in section 5. The paper has been concluded in section 6.

2. Q-MAC Protocol

provides minimum end-to-end latency and maximum energy efficiency [4]. In query based sensor network users put their query at sink node and then the sink node collects the data for the query. It depends upon type of query, data packets may be collected from a single node or from various nodes. This paper considers the query in which a single node sends a response. This response consists of a data packet which follows the path of query. This protocol is designed for two types of sleep planning to suit query processing in a multi hop network WSN as discussed below.

Static Sleep Schedule

Static sleep schedule is very simple as each node follows a predefined schedule. During the absence of query the nodes follow a static sleep schedule as shown in figure 1. Each node follows the stagger active schedule, during this schedule, the active time period of all nodes are synchronized such that the next hop node is made active before the current node's active period is over. We assume that node A is one hop, node B is two hop, C three hop, D four hop and E five hop away from sink node. Therefore, the active time of node B starts after node A's active time but before the end of active time of node A and this rule is for all other nodes.

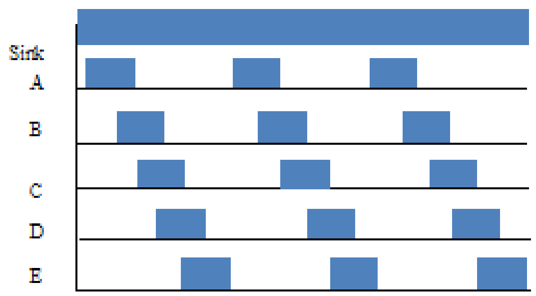

Fig.1: Static sleep schedule [4]

Dynamic Sleep Schedule

If each node knows its own position or distance from the sink node then the nodes can follow a dynamic sleep schedule in order to reduce the latency. When the sink node initiates a query and knows the destination location in advance then Q-MAC follows a dynamic sleep schedule i.e. query follows the path from node A, B, C, D and E. E is the destination node now, E creates a data packet corresponding to that query and sends back to sink node. This data packet follows the same path as the query but in reverse direction. All intermediate nodes calculate the time at which they have to forward the data packet based upon the following details:

- Time at which the query packet is forwarded,
- Distance of the destination node and
- The transmission time to forward a data packet to next node.

  Now each node becomes active only at a pre-calculated fixed time and save the energy.

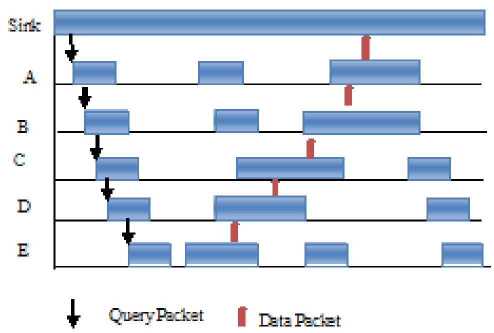

Fig.2: Dynamic sleep schedule

3. Low-Latency MAC Protocol

LL MAC protocol based upon an asynchronous schedule instead of the synchronous schedule. Each node broadcasts ASYNC package in which it records its own and neighbors schedule [5]. The neighbor's node who receives this schedule will store it, and generates its own schedule by modifying the schedule to a stagger one. When a node receives more than one schedule, it will choose the first schedule it receives as the reference.

Stagger Active Schedule

Stagger active schedule can significantly reduce the delay in WSN's. Single hop transmission time is represented by d where $d = t_{cs} + t_{tx}$ and all intermediate nodes will be kept active with in receiving and sending period, i.e. 2d. But each couple of sending and receiving nodes need d time to be simultaneous active. So we can use the stagger active schedule to ensure the data transmission. As shown in Figure3, node B's sleep time is d time latter than node A node C's sleep time is d time latter than node B, and so on.

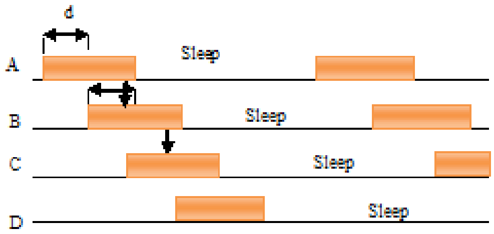

Fig.3: Stagger active schedule

A stagger active schedule has been formed by obtaining its neighbor's sleep time from the ASYNC message, and its own sleep time by adding or subtracting d offset. We add hop information to ASYNC package, which is the number of hops from the node itself to the sink.

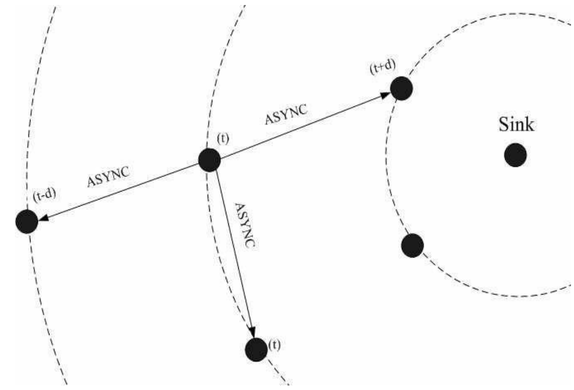

Fig. 4: ASYNC schedule [5]

When a node receives ASYNC package, it will compare the hop information with its own, if the neighbor's is bigger, it will add d to the neighbor's sleep time as its own in its schedule, if the neighbor's is smaller, it will subtract d, and if the neighbor's is the same as its, it will follow the received schedule, as showed in Figure 4. The protocol uses frame length as 5d during data transmission event to reduce the interference.

4. Latency Analysis

Latency and energy consumption are two important metrics which are used to evaluate the performance of sensor network. Both MAC scheme Q-MAC and LL-MAC follows the stagger active schedule. Total latency in a multi-hop network is sum of the delay introduced at each hop as the data packet moves from one sensor node to the other.

QMAC: $N * T_{data}$ (1)

LL MAC: $N*T_f/5+T_f/2$ (2)

In case of Q-MAC latency is the total delay produced to get the data packet from the destination node to sink node. Latency of a single packet transmission over N hops from destination node to the sink node is calculated based on the packet transfer time. T_{data} is the one hop data transfer time and T_f is frame length. AS compared to Q-MAC, LL-MAC has low latency. From the equation (2), we can see that average latency i.e. E [D (n)] α $T_f/5$; the slop of the line is $T_f/5$.

Considering the parameters of implementation: duty cycle =10%, Listening interval= 115ms, T_f= 1.15 sec., T_{tx}=103.50 ms, T_{cs}=11.50 ms. Fig.6 show that LLMAC has lower latency than Q-MAC protocol.

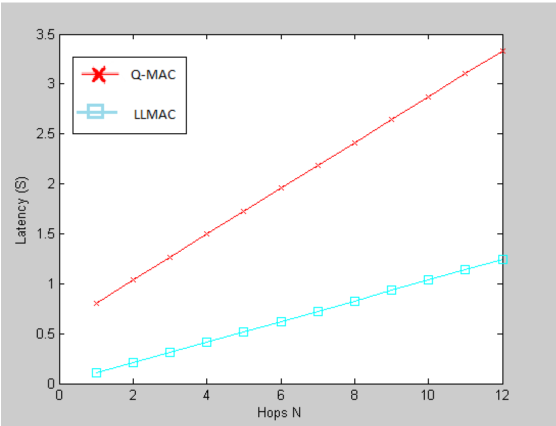

Fig. 5: Comparison of Latency of LLMAC and QMAC

5. Energy consumption

Energy consumption of a node is calculated based on the packet transmission time, hop length and active period of the nodes. In case of Q-MAC the energy consumption is less because intermediate nodes become active only at the data arrival time. The total amount of energy consumption in Q-MAC and LLMAC are:

$E_{Q\text{-}MAC} = E_{active} + (E_{tx} * H)$ (3)

$E_{LL}= E_i + (E_{tx} + E_{rx})\ E_{data}*(H-1) + E_{sleep}$ (4)

ISSN: 2278-4632
Vol-11 Issue-8, August 2021

To calculate the energy consumption of LL-MAC firstly we find out the amount of time that radio is on. Each node spent its own time in different modes: sleep, idle, transmission and receiving so, the energy consumption in each node is calculated by multiplying the time with the required power to operate the radio in that mode. Except the first and last sink node all intermediate node become active for both transmission and receiving so we multiply $E_{tx} + E_{rx}$ with E_{data^*}(H-1). The main parameters are listed in the table given below:

Table 1: Simulation parameters

Parameters	***Values***
Idle listing power	12mw
Transmission power	18mw
Receiving power	14mw
Radio bandwidth	1Mbps
Power consumption in sleep mode	0.002mw
Data packet length	100 bytes
Sending/Receiving slot(d)	20ms

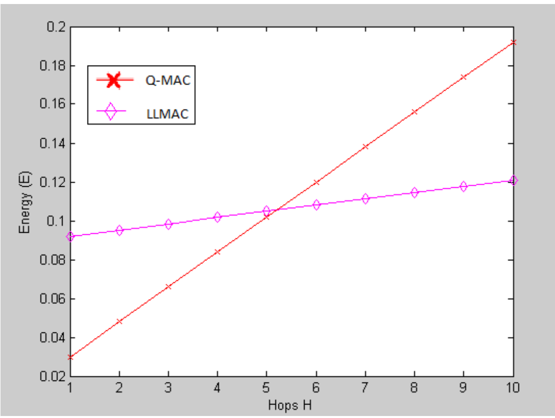

Fig.6: Comparison of the energy of LLMAC and QMAC

We evaluate the performance of MAC protocol based on two metric Latency and Energy consumption with the help of MATLAB. Simulation result shows that LL-MAC is have low latency than Q-MAC. Initially LL-MAC consumes more energy than Q-MAC but after sixth node it consumes less energy. Finally result show that LL-MAC protocol is much better than Q-MAC protocol.

Conclusion

The paper has presented the work, which has been carried out in the area of energy efficient Medium Access Control protocols. The latency and energy has been compared of Low Latency Medium Access Control (LLMAC) protocol and Query based Medium Access Control (QMAC) protocol. It has been found that the performance of LLMAC is better than the QMAC for both the parameters i.e. latency and energy. The comparative study has been carried out with the help of MATLAB.

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ISSN: 2278-4632
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