Analysis of MAC layer protocol of Wireless Sensor Network Using QualNet

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ABSTRACT

There is an uprising trend of enabling the smaller and sensitive information network to capitalize its worthiness using the Wireless Sensor Network. The various Network protocols can be implemented in order to achieve user specific need of sensing, gathering, processing and transmission of information among the sensor nodes. This paper is an attempt to analyze the various MAC layer protocol scenario implemented for Wireless Sensor Network (WSN) in a given environment. The experimental simulation is based on Mica Mote Energy model being simulated under QualNet. Many of the protocols varies from their performance metrics and the deployment size and application area. A discussion of energy conservation involved in the network, the packet transfer ratio and its effect on the signaling strength is reflected

Keywords

WSN, QualNet, MAC Protocol, MICA mote, Zigbee

1. INTRODUCTION

Wireless Sensor Network (WSN)[12] has been known in the field of Computer Networks since the era of Adhoc Networks and deployment of low powered, low cost non computing nodes gained importance in its approach of implementation so as to deploy as many sensor nodes as possible to the sensitive areas where the human interaction is next to impossible and also not advisable.

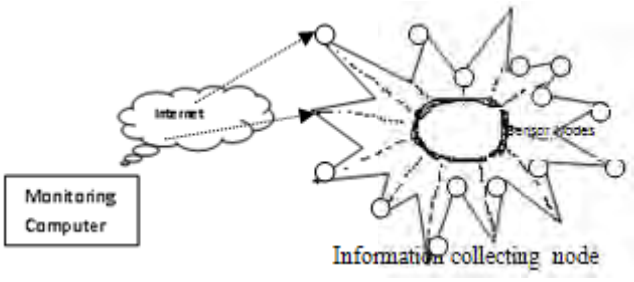


Fig-1 Typical Wireless Sensor Network

Few examples like Fire Breakout, Military Operations, Volcano monitoring etc to mention its wider application. Nowadays it is widely used in the areas of Habitat and Ecosystem Monitoring, Seismic Monitoring, Civil Structural Health Monitoring, Monitoring Groundwater Contamination, Rapid Emergency Response, Industrial Process Monitoring, Perimeter Security and Surveillance, Automated Building Climate Control also.

The Fig.1 shows a simple architecture of wireless sensor network. A node within the network gives information to the server node which is the collecting node that processes and forwards the information to the end user via Internet or Intranet architecture which is optional. Unlike the wired networks, the wireless channel is used and has several unique characteristics that need to be taken into account when designing wireless networks.

To provide efficient and reliable services, many factors have to be considered such as the application environment requirement, reliability of the protocol used in the network and the network consistency. MAC layer is a major reason to provide the reliability and efficiency for WSN. MAC is responsible for channel access policies, scheduling, buffer management and error control. In WSN we need a MAC protocol to consider energy

efficiency, reliability, low access delay and high throughput as major priorities to accommodate with sensor's limited resources and to avoid redundant power consumption

2. MAC Layer Protocols

2.1 Types of MAC Layer protocols

Schedule based protocol[1]: Usually it uses time division multiple access (TDMA). This type needs previous knowledge of network topology to establish schedule.

Advantages: no collision, predictable delay, increases the overall throughput, fairness.

Disadvantages: not good for large network, not scalable, works with stable topology, needs precise synchronization and previous knowledge of network topology which requires expensive hardware and large overhead.

Contention based protocol [1]: usually uses CSMA or ALOHA, there is no need for synchronization or topology knowledge because nodes compete to access the channel and only the winner will succeed.

Advantages: good for large scale, scalable.

Disadvantages: less performance for high load traffic, data packet size usually small, RTS and CTS are more energy consuming. RTS and CTS only used for unicast.

2.2 ALOHA[12]

ALOHA is a system for coordinating and arbitrating access to a shared communication Networks channel. Aloha is a multiple access protocol at the data link layer and proposes how multiple terminals access the medium without interference or collision. It is often used in Satellite communication and the radio communication system which is the main backbone behind many communication protocols like Ethernet.

There are two different types of ALOHA namely Pure ALOHA and Slotted ALOHA.

Pure .ALOHA, where the stations transmit frames whenever they have data to send and when two or more stations transmit simultaneously, there is collision and the frames are destroyed. Slotted ALOHA whereas has the time of the shared channel divided into discrete intervals called slots. The stations can send a frame only at the beginning of the slot and only one frame is sent in each slot.

2.3 Medium Access Collision Avoidance (MACA)

The broadcast nature of wireless networks makes it a challenge to design MAC protocols for WSN[3].

For its simplicity and efficiency, collision-avoidance handshake is a widely used scheme in MACA to reduce the prevalent collision networks where the sender sends an RTS (request-to-send) and the receiver replies with CTS (clear-to-send). There may occur the problems of overhearing this communication signal like Hidden Node and Exposed Node problems which can be optimized using different variants of this protocol.

2.4 Zigbee

ZigBee is based on an IEEE 802.15 standard. Though low-powered, ZigBee devices can transmit data over long distances by passing data through intermediate devices to reach more distant ones, creating a mesh network which is Adhoc in nature ; i.e., a network with no centralized control or high-power transmitter/receiver able to reach all of the networked devices. Communication is done via the Personal Area Network (PAN) coordinator[11]. PAN coordinator periodically broadcasts beacons for synchronization and management and it follows slotted channel access where device performs random backoff before channel is sensed thus avoiding collision.

3. SIMULATION TOOLS USED

3.1 MICA mote [13]

MICA mote is a commercially available product that has been used widely by researchers and developers. It has all of the typical features of a mote .MICA motes are available to the general public through a company called Crossbow. These motes come in two form factors i.e Rectangular and Circular.

The MICA mote uses an Atmel ATmega 128L processor running at 4 megahertz. The 128L is an 8-bit microcontroller that has 128 kilobytes of onboard flash memory to store the mote's program. It consumes only 8 milliamps when it is running, and only 15 micro amps in sleep mode.

This low power consumption allows a MICA mote to run for more than a year. At 8 milliamps, the ATmega would operate for about 120 hours if it operated constantly allowing it to extend battery life considerably. It also

has a 10-bit A/D converter so that sensor data can be digitized. Separate sensors on a daughter card can connect to the mote. Sensors available include temperature, acceleration, light, sound and magnetic sensors and GPS signal sensors. The more important component of a MICA mote is the radio. It has a range of several hundred feet and can transmit approximately 40,000 bits per second. When it is off, the radio consumes less than one microamp. When receiving data, it consumes 10 milliamps. When transmitting, it consumes 25 milliamps.

All of these hardware components together create a MICA mote. A programmer writes software to control the mote and make it perform a certain way. Software on MICA motes is built on an operating system called TinyOS. TinyOS is helpful because it deals with the radio and power management systems for you and makes it much easier to write software for the mote.

3.2 QualNet

QualNet[2] is the simulation tool which is flexible, scalable and effective for analysis and real time evaluation of protocols and physical scenarios like node mobility and failure. It is provided with Physical, MAC, Application, Network layers implementation protocols and standards along with magnificent GUI tool with drag and drop option.

3.2.1 QualNet Scenario

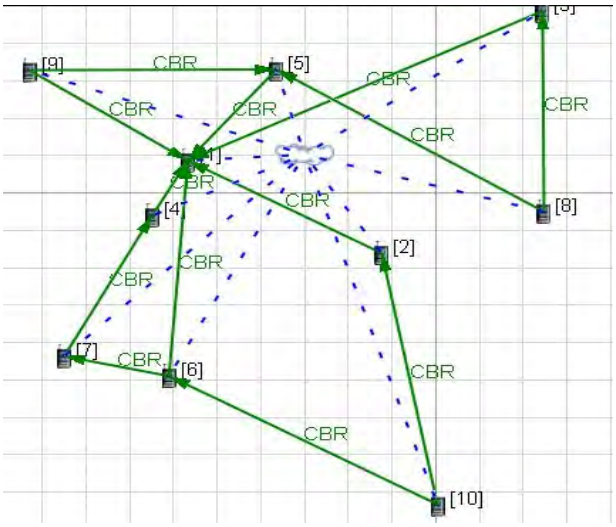


Fig-2 Scenario simulated on the span of 1500X1500 mtrs

Scenario as shown in Fig-2 is used for understanding of few MAC protocols implemented. It consists of 10 nodes having them placed randomly with a seed value of 3 over a sparse area of 1500X 1500 mtrs of geographical area coverage. Each individual node is identified as Node1 to node10.

Fig 2 is the snapshot of the scenario deployed in QualNet. Node2 to Node10 are the source nodes that sensed and sent the data message to the sink node. The events sensed by the sensor channel are propagated across the network through the wireless channel, node1 acting as sink node (PAN coordinator) that collects and sense the data and transfer it to the external device as well as the node4 has been elected as Coordinator for the purpose of intermediate collection and transfer of data towards the sink.

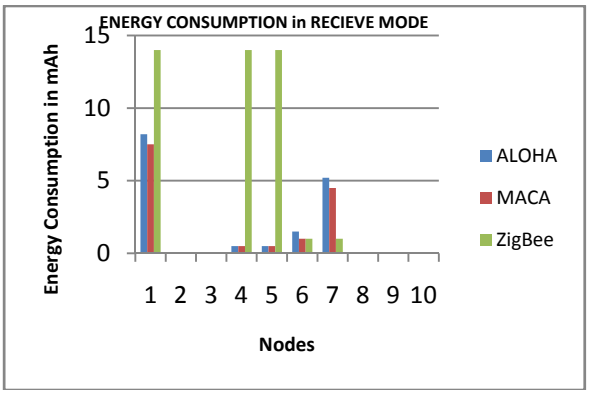
Table 1 Simulation parameters

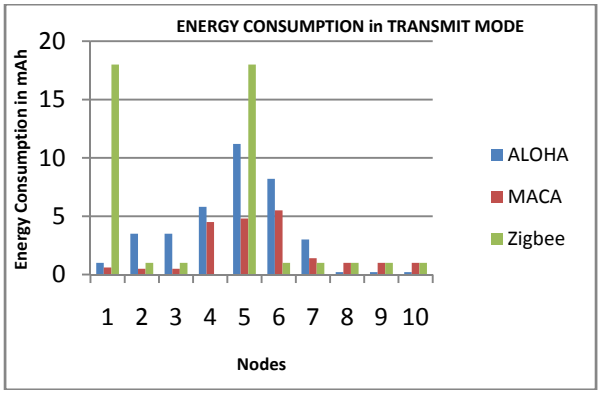
Simulation Parameters	Corresponding Values
Radio Type	IEEE 802.15.4
Routing Protocol	AODV
Network Protocol	IPv4
Modulation Scheme	O-QPSK
Packet Reception Model	PHY802.15.4
Energy Model Specificatio	MICA MOTE
Device Type Node1	Full Functional Device (PAN Coordinator)
Device Type Node4	Coordinator
Device Type Other Nodes	Reduced Functional Device
Physical Layer Traffic	Constant Bit Rate(CBR)
Simulation Time	1 Day
Battery Model	Linear Model with 300mAh

4. SIMULATION AND RESULTS

Various simulations have been done for various different configurations of MAC layer protocols with static (Without mobility) nodes and the PAN coordinators. The different graphs have been plotted against different performance parameters and the energy constraints. A general idea of the power consumption and throughput efficiency have been identified with the three scenarios implemented in the given design arena.

4.1 Energy consumption and battery life

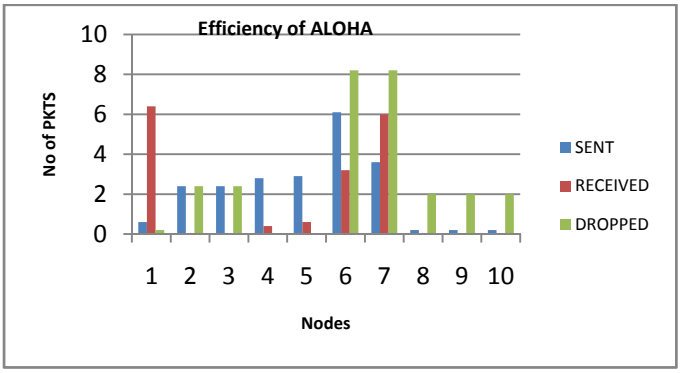


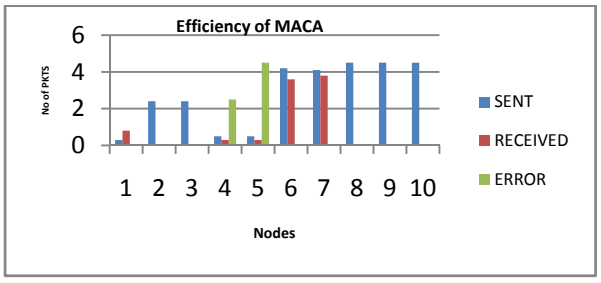


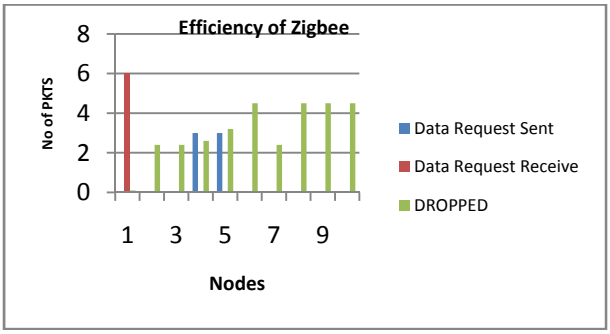
During the trans-receiving of the data packets in the network it is found that ZigBee seems expensive in terms of Energy Consumption except for those of the PAN coordinator node and coordinator node which are the most active node in the scenario whereas other nodes are allowed to switch off or sleep mode conserving the energy.

It is also found that since MACA and ALOHA is contention based where every node is equally likely tries to become sending and receiving node spending most of the energy. Thus if we look at the overall network energy conservation the protocol MACA succeeds over all the other.

4.2 Protocol & its performance



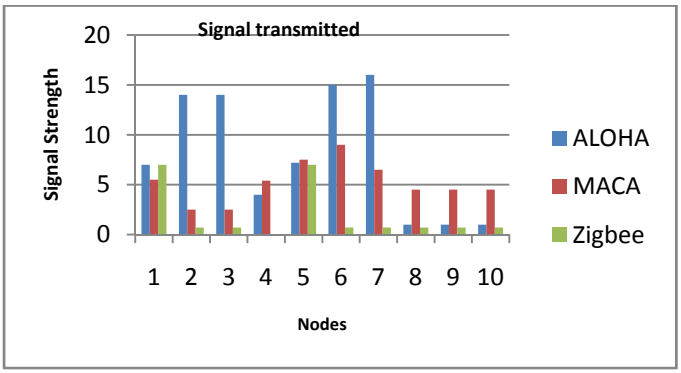


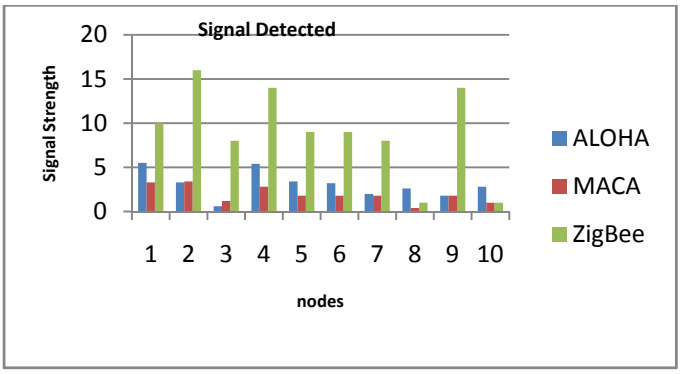


The measurement of performance in terms of throughput is the ratio of packet sent and received by the nodes.

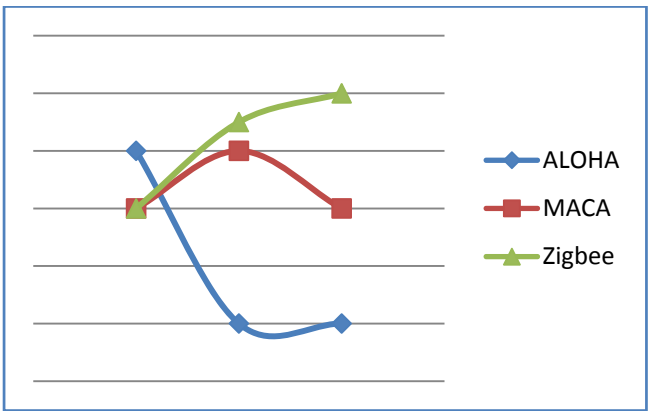
There is no proportion in number of data sent and receive in ALOHA and MACA whereas in case of Zigbee it is 100% throughput of number of data packets trans receiving even though there are few of packet drops during the transmissions.

4.3 Signaling strength of 802.15.4 radio





While considering the signals of the radio being detected and the transmission taking place, the two protocols ALOHA and MACA fails in attaining all the signals that has been through the nodes, but in case of Zigbee the entire signal is noted and used by the nodes.



It is evident from the conclusion above that, the behavior of Zigbee seems appropriate in the given scenario where it takes certain amount of energy to give better performance throughput than the other two protocols which lacks on efficiency as whole.

5. CONCLUSION

On analyzing the three protocols in the stipulated scenario, Zigbee works better having its specialized node as PAN coordinator whereas the other two can be used for normal node to node scenario. If the nodes are made mobile then the entire analysis vary from stationary to mobile nodes. The Efficient MAC protocols can provide significant benefits to mobile ad hoc networks, in terms of both performance and reliability. Many MAC protocols for such networks have been proposed so far but their is questionable and is not satisfactory[4]

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