

A Comprehensive Survey On Applications And Medium Access Protocols In Wireless Sensor Networks

A.Sivajayaprakash¹, G. Malarselvi²

^{1,2} Center for Applied Research in Education

^{1,2} SRMIST, Chennai-603203, India

Abstract- *Wireless sensor network is one of the special categories of network in wireless communication. Unlike other wireless networks, nodes in the wireless sensor networks are often scattered across the network environment and all those nodes are mostly supported by the batteries in order to achieve the assigned job which leads to the uncertainty in sensor nodes lifetime. To overcome this issue MAC protocols implemented in WSN play a major role, where the efficient design of MAC layer protocols by keeping in mind the energy efficiency will significantly improve the lifetime of sensor nodes. This paper gives the extensive review of some of the important applications of WSN and a broad range of already existing MAC layer protocols and compares its pros and cons.*

Keywords- Applications, MAC Protocols, Wireless Sensor Networks.

I. INTRODUCTION

Wireless Sensor Network is established by number of sensor nodes that can be converse data each other using transceivers through wireless links. Typically, the sensor nodes are deployed over the geographical area and also spatially. Network type is deciding by based on the environment. It may deploy below water, underground, on land, and spatially. A sensor node is configured with the processing unit, sensing unit, communication unit, Power unit. Power is stored either in batteries or capacitors. The main power source of sensor node is batteries these batteries are either rechargeable and non-rechargeable. A sensor is an electronic device which can sense or found physical and environmental conditions and respond for that condition. the environmental conditions are like heat, sound, light etc. Typically, sensor device makes the output as electrical signal, and it transmit to the controlling unit for in addition process.

II. APPLICATION OF WIRELESS SENSOR NETWORKS

A. Applications

Wireless Sensor Network applications are classified into two major categories that is mesh-based and star-based. In mesh-based application nodes are made the connection by

multi-hop radio connectivity. Otherwise in the start-based application nodes are may create a connection by using single-hop radio connectivity. Reconfigurable sensor network, Nanoscopic sensor application, Sensor and Robots, Highway monitoring, civil and environmental engineering application, Wildfire Instrumentation, Military applications, Habitat monitoring, these applications are under the category 1. Home control, building automation, Industrial automation, Medical application these applications are under the category 2.

B. Medical Application

So many medical centers and also hospitals are using wireless sensor network technology-based applications [1]. disaster response, in hospital emergency care, pre-hospital emergency care, stroke patient rehabilitation is some of the applications which are using wireless sensor network technology. We can home monitor the chronic patient and older patient by wireless sensor networks, in this because we may reduce the number of days for hospital stay. WSNs can allow accumulate for long lasting medical data that populates database of clinical data this enables longitudinal studies across populations and allows physicians to study the effects of medical intervention programs. Health care applications are currently focusing asthma, heart problems, stress monitoring, emergency response. Some of the health care applications are Cardiovascular diseases, Cancer Detection, Alzheimer, depression, and elderly people monitoring, Glucose Level Monitoring, Asthma and UbiMon.

C. Industrial Automation

WSNs is used in industrial automation for providing control mechanism, conservation mechanism, efficiency and also safety [1]. WSN applications are also used for stretching previous manufacturing & process control system reliability, facilitates the asset management by keep following the monitoring of critical equipment, energy cost is decreased by perfect manufacturing process, to detect worst performing equipment, minimizing the user interference by automate the data acquiring from the remote node. to facilitates protective maintenance programs, sensing applications gives the descriptive information. For augmenting public and employee

safety by deploying monitoring networks. Some of the commercial and industrial utilization

- Repositories, navy administration, workshops, supermarkets, office buildings.
- Gas, water, and electric meters
- preventive maintenance, status changes, diagnostics, energy use.
- Smoke, CO, and H₂O detectors
- Refrigeration cage or appliance

D. Nanoscopic sensor application

WSN has the curious interest in biological sensing especially labs on chip concept. especially a nanoscopic microscale confocal imaging array is a device which is combine the micro electromechanical system, ultra-small lasers, lenses, and plumbing. micromachining silicon or polymers are used to build these devices. biowarfare pathogens can found by using this technology and also it can use diagnostic tool in medicine. A single nanoscopic micro-CIA is essentially a massively scaled-down confocal microscope. Confocal microscope works by lighting the laser using fluorescent in a particular molecule. A single small point is illuminates for making the clear image of sample at any time. Scan the laser image multiple times in a second and imaging each small point, then it built its 3-dimensional image.

E. Military application

WSN Device is the smallest and most functional of all, and they play a very important role in the fields of military, civil force and air force [1]. WSN using in military for gathering and passing information, enemy tracking, battlefield surveillance or target classification. Different algorithms are used for different types of inputs, such as seismic, acoustic signal. This sensor nodes detects the location of enemies and their moves. This WSN is highly trusted in the military field because of the unique attributes like quick exploitation self-organization, error acceptance. The following applications are example of Some military application of sensor networks. monitoring battle damage assessment nuclear, friendly force, and ammunition, battle field surveillance, equipment, biological and chemical attack detection and reconfigure, reconnaissance of opposite force and terrain, targeting.

F. Home automation

Wireless sensor network devices may control and manage cooling, heating system from anywhere [1]. It can also

detect in high accuracy electric, water and gas usage. The main aim of home automation in reduce the manpower and provide the high security in home environment. For designing the home automation the following technology used. 1. Bluetooth, 2. Internet, 3. Zigbee, 4. Short Message Service. Bluetooth – cell phones, Laptop, tablets these are some example of which are using Bluetooth technology using. This is suitable for short range of the environment. Zigbee – it gives the secure and trusted communication and it suite for small area network. Wi-Fi based automation system – in Wi-Fi based automation system all home devices are connected into the pc-based webserver. Drawback of this system is it consumes more power. There are 3 different techniques are uses for implementing home automation systems are, GPRS, Speech and Internet.

III. CHARACTERISTICS AND PROBLEM OF DESIGN ISSUES IN WIRELESS SENSOR NETWORKS

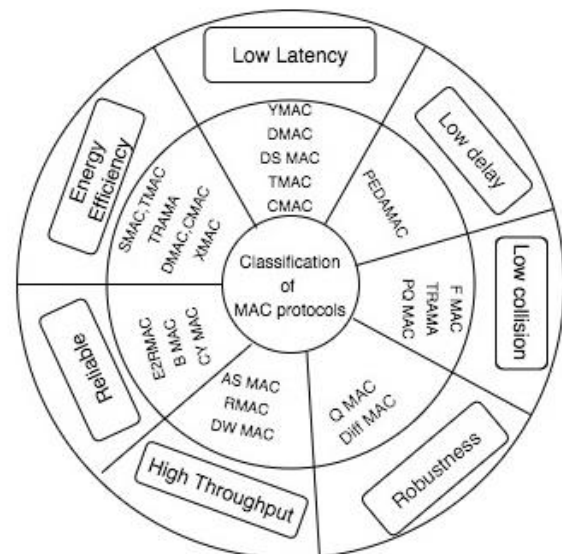


Figure 1. MAC Protocol

A. Delay

Pate et al. [2] proposed the data packets are processed in mac layer before transmit this time is known as delay time or delay. MAC protocol design choice and network traffic load are the two-major factor of delay. To satisfy the QoS requirement in time critical applications delay bound guarantee should support by the MAC protocol. The precise semantics of the QoS requirements are application dependent. needs of QoS's precise semantics are based on application. Typically, careful message scheduling is providing the guarantee delay bounds both locally and globally. Probabilistic and deterministic are the two different types of delay guarantees.

B Probabilistic

Generally, it classified by an expected value, a variance and a confidence interval.

C. Deterministic

Between the message arrival and message transmission deterministic is ensures the predictable number of state transitions.

D. Throughput

Yadav et al. [3] proposed Typically throughput is referred by the message servicing rate of communication system. Commonly throughput is calculated as messages per second or bits per second. In wireless communication network, for data transmission the channel capacity is splited. in the beginning while load on the communication system rises throughput is increased. when load touch the particular threshold level, throughput gets rise, and in some other situations throughput start to decrease. Increase the throughput When decrease message delay time it is the main objective of MAC protocol.

E. Robustness

Yadav et al. [3] proposed the level of wrong information and mistakes sensitivity of the protocols is calculated by availability, collaboration of reliability and also the dependability requirement. this is known as the robustness. robustness tracks simultaneously the followings reconfiguration, error detection, error repression, error masking and restart. because of this reason it is called multidimensional activity. in the wireless sensor network environment robustness cannot accomplish because WSN is a time-varying network.

F. Scalability

Yadav et al. [3] The efficiency of the communications device is known as its scalability for meet its performance characteristics. Scalability of Wireless sensor network environment is a critical factor because it uses many number of sensor node for communication. In these networks, scalability becomes a critical factor. In wireless network scalability achievement is a challenging task. there are two different methods used to reach scalability one is to ignore dependency on universal stable network states second one is to localize exchange between the nodes which are communicating by the development of step by step structure and data aggregation ideas. sensor nodes are clubbed into

clusters, copious scalable shared medium access protocols that allows to design, likewise data aggregates from various sensor nodes permits the improvement of traffic pattern which can be accomplish efficiency to calculate the MAC protocol to the more number of sensor nodes.

G. Stability

Yadav et al. [3] proposed at the sustained periods of time traffic loads vacillation handling capacity is known as the stability of communication system. MAC protocol stability is generally referred depends upon the message delay or throughput. while message delay or waiting time is bounded, depending on message delay mac protocol stability is calculated. In the data transmission queue's bounded backlog message is used to classified this system depends upon the throughput, while load getting increases the throughput is not affect then the MAC protocol is consistent. In wireless sensor network, difficult to accommodating load fluctuations while maintaining system stability. Careful scheduling is a best approach to adapt to high fluctuations in the traffic load for MAC protocol.

IV. COMMON PROTOCOLS FOR MEDIA ACCESS*A. Fixed assignment*

Kazem Sohraby et al. [4] proposed Each and every node utilize its allocated resources exclusively without competing with some other nodes. Total channel bandwidth is statically allocated to node whether the node has data packet to transmit or not. General protocols FDMA, TDMA, CDMA are belonging this fixed assignment.

FDMA – available of total channel bandwidth is divided into multiple sub-channels. Various carrier frequencies of the radio spectrum are allocating for communicating nodes for avoiding the overlap or interference between the different nodes.

TDMA – Number of different nodes are accessing same radio frequency by different time slots.

CDMA – It is a spread spectrum scheme that is number of nodes can transmit data simultaneously.

Drawback: Very difficult to determine, deflect, or demodulate the original signal due to wideband noise.

B. Demand assignment

Kazem Sohraby et al. [4] proposed It allocates the channel in foreordain manner to which nodes are currently

need to communicate. Channel is allocated to a node in distinct amount of time depends upon the time taken for transmit a data packet. It requires network control mechanism, logical control channel, data channel. Demand of channel access is may delay the data transmission. Centralized and Distributed are the two-different kind of Demand assignment protocol. Polling – A master control mechanism concern all nodes in network, either node has data to transmit or not. If it has controller is allocating the channel to the ready node, which utilize the entire information rate to transmit its traffic. If node has no information to transmit it deny the controller request. Effectiveness of the polling scheme is according to the reliability of the controller.

C. Reservation

Kazem Sohraby et al. [4] proposed this design set time slots for carrying engaging messages, it is generally very tiny than data packets. This is also called minislots. If node has data to transmit, it sends a reservation message for requesting data slot to the master in a reservation minislot.

D. Random assignment

Kazem Sohraby et al. [4] proposed It does not pre-allocate the channel to nodes also avoids the wastage for bandwidth allocation to the stable nodes. But it does not have any control mechanism for ordering schedule to nodes are access the medium. Number of nodes are combating to access the transmission medium. Due to this deficiency collision occurs. ALOHA – this protocol is just permit the nodes to transmit the data if the node has data to transmit. Slotted ALOHA – all communicating nodes are aggregated and the data packets are having unique size. In this case collision may occur at starting of slot and colliding packets are overlap totally in time. For reform the performance of ALOHA protocol CSMA, CSMA/CD, CSMA/CA schemes are developed. CSMA – This protocol is categorized into Non-persistent CSMA and Persistent CSMA. Persistent CSMA – If a node has data packet to transmit, first check the channel either it is busy or free. Because of that reason packet transmission interference is reduced. Suppose the channel is free node sends the data packet and wait for the acknowledgement. If time is exceeding the value of timeout for getting acknowledgement sending node surmise the data packet is lost cause of collision or noise interference. To increase the network throughput should be avoid needless channel waste. This is achieved by p-persistent CSMA scheme. CSMA/CD – The network propagation delay is very small relative to the data packet transmission time. CSMA scheme has the high throughput comparing the ALOHA

protocols. Carrier sensing scheme slowdown the number of collision and length of collision interval.

Drawbacks: Repeatedly nodes are dispatching the data packets, although collision occurred. For long data packets, entire amount of unwanted bandwidth waste is significant liken with the propagation period. Furthermore, nodes might be suffering needless long delays waiting for the transmission of the total packet to finish before attempting to transmit the packet once more. In wireless network, the time-varying properties of the remote channel, coupled with the prompt diminish of the signal power over distance, makes it arduous for the transmitting sensor node to infer unambiguously whether the occurrence or the absence of a collision at the getting node. This disadvantage is severely limits the applicability of collision detection–based schemes in WSNs.

CSMA/CA – In Shared medium access environment CSMA/CA carrier sensing is the better approach for improve the throughput efficiency. This scheme is may affected by two problems which called hidden- and exposed-node problems.

CSMA is a scheme that is designed for ignore the collision. collision is ignoring by feel the signal in the transmitter proximity. by this reason hidden and exposed node problems are increased. hidden node is placed surrounding of destination node, but not in the transmitting node surrounding. An exposed-node is exactly opposite to the hidden node, that is node locate within the border of transmitting node but not to the destination. To avoid the hidden- and exposed-node problems may use some approaches. 1. Busy tone approach, 2. Using a ready-to-send, clear-to-send, handshake.

V. MAC PROTOCOLS FOR WIRELESS SENSOR NETWORK

A. Schedule-based MAC protocols

Rajan et al. [5] proposed Schedule-based MAC protocols for Wireless sensor network ignore the contention among nodes for resource allocation. Time, frequency, CDMA code are the General resources. To accomplish top level energy efficiency in order to prolong the network lifetime is the important objective of schedule-based MAC protocols. Every node is allocated particular time slots. Depend on its assigned schedule, sensor changes between active mode and sleep mode. These MAC protocol classifications are shown in Figure 1.

Active mode - The sensor node utilizes its allotted slots within a logical frame to send and receive data frames.

Sleep mode - suppose the slot does not allocate to sensor nodes it goes into sleep mode. In sleep mode, the sensor nodes switch off its radio transceivers for saving energy. Number of disparity on the primary TDMA protocol have been preferred for media access control in WSNs.

SMACS

Rajan et al. [5] proposed It is one of the medium access protocol for creating random network topologies without the need to install establish virtual synchronization between the network nodes. The hybrid TDMA/FH method is a key feature of SMACS it is referred to as a non-synchronous schedule communication. In a network, every node maintains a TDMA-like frame, is known as the superframe, for communication with neighbour nodes. The length of a superframe is stable but it split into small number of frames. The size of each and every frame is not similar it might be differ in time for a only one node and node to node also. SMAC requires that all the node run a neighbourhood discovery protocol periodically for searching the neighbour nodes. Every node creating a link with every neighbour discovered node by allocating time slot to this link. The link establishment protocol has to ensure that no intrusion occurs amongst adjacent links. This is carried out by randomly assigning channel, elected from a huge number of channels FDMA, or spreading code CDMA to each and every link. Utilizing the superframe structure, each node maintains its own time slot schedules with all its neighbours, and node are needed to tune their radios to the correct frequency channel or CDMA code to transmission.

B. Bluetooth

Kabara et al. [6] proposed It is also a growing technology for media access in wireless network which is using integrated TDMA based protocol. This technology is alternative for wired connection and infrared based connection. It is using a global shot-range radio link. The frequency range of Bluetooth is 2.45GHz ISM

Piconet – The number of devices is sharing a single medium or channel is called piconet. Every piconet contains a master unit for maintain the medium accessing for sub nodes. Sub nodes are club into a group it has 7 sub nodes. Every channel is split into 625-ms slots. An exclusive frequency hopping pattern is assigned in every piconet and it is defined by the master's Bluetooth device address which has 48 bits and clock. Other devices that is the sub devices are following that piconet assigned frequency hopping. Every piconet define the different hopping sequence without interference.

Scatternets - A large ad-hoc network id formed by interconnect the piconet through bridge node. This is called a scatternet. Inside of the each piconet master defines the 3-bit exclusive address for every sub nodes.

Time division duplex protocol is used for channel allocation for sub nodes and polling protocols is used for allocating time slot for all sub nodes.

Bluetooth Frame – A single polling period is called the Bluetooth frame, which contains two slots while a data packet transfer between the piconet master and sub nodes which sub node is to communicate in next slot is defined by the piconet master in previous slot. Length of the data packet may be 1,3 or 5 slot sizes and it can be transmitting in continual slots. Suppose a data packet size greater than 1 slot then the communication may be asynchronous. Energy consumption is the major criteria in wireless sensor network, in Bluetooth technology propose the four-different type of operation modes.

Active – The nodes are receiving the data packet only if the address of data packet is its own otherwise the node goes to sleep. The sub node checks the address and Packet transmission from the master.

Sniff - the purpose of sniff mode is decrease the duty cycle of sub node's listen process. The master is transmitting data packet to sub node in particular time particular regular time slots only sniff time gap is predetermined hold – sub node goes some periods of time to sleep this is called hold mode. After finished the hold time it immediately come to active mode park – in this mode the sub node goes to sleep for undefined time, the master only awakes the sub node into active mode. Four types of communications are proposed by Bluetooth for communicating between nodes inside the piconet and also across the piconet.

Intra piconet unicast – node to node (inside the piconet).

Intra piconet broadcast – sub node to all participants (inside its piconet).

Inter piconet unicast – piconet to piconet.

Inter piconet broadcast – piconet to all scatternet node.

C. LEACH - Low-energy adaptive clustering Hierarchy

Rana Tejas [7] proposed Nodes are organized into a cluster and it uses the hierarchal approach. Every node is performed by the head of cluster at every time. It uses the TDMA for transmitting the data between nodes and its head. TDMA schedule is prepared by cluster head node and it is pass to all nodes which are in its same cluster. The schedule defines which node is to be active and which node to be

inactive for a particular time slot. Thus, because collision is avoided. Simultaneously cluster node is setup the cluster phase after that nodes are synchronized. The base station has a mechanism for synchronizing nodes and it sends a signal for synchronizing to each node.

LEACH follows the transmitter-based code assignment for decreasing the collision among the inter-cluster. The data packets are transmitting between the cluster head and node by using the DSSS - direct sequence spread spectrum. In DSSS it defines the separate spreading code for every cluster. This spread code is used to transmit the data packets to cluster head from all nodes in its cluster. Spread code is allocated by FIFO basis. Cluster head receives the data packets from cluster node, aggregate it first and then it sends to base station. Among the base station and cluster head communication is made by using fixed spreading code and CSMA. Cluster head transmit the data packet to base station only while channel is free.

Typically, in schedule-based protocol sensor nodes are turn on only when its turn for transmit or receives the data packet. Otherwise sensor node goes to sleep or inactive state. The advantage of schedule-based protocol is reduced the energy waste. To use TDMA, the node must be connected to an organization into cluster.

This makes the nodes interconnected only with the respective cluster head. Therefore, nodes are cannot make a communication as peer to peer. Also, nodes are need to notice all time slots. Particularly it is very difficult and costly for synchronization between distributed sensor nodes. The scheduled based protocols are also need FDMA or CDMA mechanism for ignore inter-cluster interference and communication. TDMA protocols has have specific level of scalability, also it is not easy to adapt for node mobility, In TDMA is very difficult to change topology and network traffic.

VI. CONCLUSION

In the recent times, numerous medium access control protocols for the wireless sensor network have been proposed. Anyhow, no protocol is acknowledged as standard. Since the MAC protocol will be application specific. Accordingly, there won't be one standard MAC protocol for the WSNs. The scheme based (TDMA) have collision free access to the medium but the coexist is critical. Also, there is difficulty in redesigning to the adjustment in the network topology because of the adding and removing of nodes. The dispute based (CSMA) have low latency and high throughput. Howsoever, it suffers from the collisions still. The Frequency Division

Multiple Access (FDMA) strategy also permit collision free access to the media but the additional circuitry needed to dynamically communicate with various radio channels builds the cost of the sensor nodes. This contradicts the important goal of the wireless sensor networks (WSNs). CSMA (Code Division Multiple Access) plan defines the collision free access to the medium. Howsoever, the top of the computational complexity is the limitation in the lower energy utilizations required of the sensor network. LEACH is a cluster-based sensor network and its important objective is diminishing the energy consumption and system delay.

REFERENCE

- [1] Ramson, SR Jino, and D. Jackuline Moni, Applications of wireless sensor networks—A survey, 2017, 325-329.
- [2] Rinkuben, Patel N, Nirav V. Bhatt. Design and Implementation of QoS Aware Priority based MAC for Delay Sensitive Areas of WSN, 2017, 3411-3420.
- [3] Yadav, R., Varma, S., & Malaviya, N, A survey of MAC protocols for wireless sensor networks, 2009, 826-836.
- [4] Kazem Sohraby, Daniel Minoli
Taieb Znati, Wireless Sensor Networks Technology, Protocols, and Applications, 2017, 143-196.
- [5] Rajan, Amala, and Malini Soman. "A survey on MAC protocols for wireless sensor networks and cognitive radio sensor networks design, 2015, 112-119.
- [6] Kabara, Joseph, and Maria Calle, MAC protocols used by wireless sensor networks and a general method of performance evaluation, 2012 834784. –Bluetooth
- [7] Rana Tejas, Performance Analysis of Clustering Protocols for Wireless Sensor Network, 2017, 134-169.