Abstract—Wireless sensor networks are appealing to researchers due to their wide range of application potential in areas such as target detection and tracking, environmental monitoring, industrial process monitoring, and tactical systems. However, lower sensing ranges result in dense networks, which bring the necessity to achieve an efficient medium access protocol subject to power constraints.

In this paper, we describe several MAC protocols, classified as either contention based or schedule based, proposed for sensor networks while listing the advantages and disadvantages of each.

Index Terms—MAC protocols, wireless sensor networks, Medium access control.

I. INTRODUCTION

These days, there are many applications that require very small hardware devices with wireless communication for recording and measuring different values of the environment for example, monitoring buildings and their surrounding terrain, medical observations like pacemaker which should be small enough for the patient to carry around, traffic flow information for congestion prevention and warning of accidents and even in agriculture to monitor growth of field crops on large areas. In such cases, a wireless solution with a battery which can be completely exchanged periodically is more eligible as compared to wired sensors which are more expensive.

II. WIRELESS SENSOR NETWORKS

A wireless sensor network is a collection of tiny sensor nodes organized into a cooperative network that are deployed either inside the phenomenon to be sensed or very close to it. Sensor nodes are battery operated and each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion [1].

Sensor nodes may be deployed in a physical environment at random or installed at deliberately chosen spots. Deployment may be a one-time activity or it may also be a continuous process, with more nodes being deployed at any time during the use of the network—for example, to replace failed nodes or to improve coverage. Depending on the actual needs of the application, the form factor of a single sensor node may vary significantly in size and cost which directly result in corresponding varying limits on the energy available as well as on computing, storage, and communication resources. Depending on the application, a sensor network must support certain quality-of-service aspects such as: real-time constraints, robustness, tamper-resistance, eavesdropping-resistance and unobtrusiveness or stealth. A number of communication modalities can be used such as radio, diffuse light, laser, inductive and capacitive coupling, or even sound. Sometimes, multiple modalities are used by a single system. The communication modality used not only influences the design of medium access protocols and communication protocols, but also affects other properties that are relevant to the application [2].

III. SENSOR NETWORK PROTOCOL STACK

The protocol stack combines power and routing awareness, integrates data with networking protocols, communicates power efficiently through the wireless medium, and promotes cooperative efforts of sensor nodes.

A. Power, Mobility and Task Management Planes

These planes help the sensor nodes coordinate the sensing task and lower overall power consumption. The power

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management plane manages how a sensor node uses its power. The mobility plane detects and registers the movement of sensor nodes, so a route back to the user is always maintained, the sensor nodes can keep track of who their neighbour sensor nodes are, and the sensor nodes can balance their power and task usage. The task management plane balances and schedules the sensing tasks given to a specific region.

B. Application Layer

Different application software can be can be built and used on the application layer based on the sensing tasks. Three application layer protocols for sensor networks are sensor management protocol (SMP), task assignment and data advertisement protocol (TADAP), and sensor query and data dissemination protocol (SQDDP).

C. Transport Layer

The transport layer helps to maintain the flow of data if the sensor network application requires it. The transport layer is required when a system is planned to be accesses through the Internet or other external networks.

D. Network Layer

The network layer takes care of routing the data supplied by the transport layer. It is usually designed based on power efficiency, sensor networks are mostly data-centric, and data aggregation is useful only when it does not hinder the collaborative effort of the sensor nodes.

E. Data Link Layer

The data link layer is responsible for multiplexing data streams, data frame detection, medium access, and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.

The MAC protocol in a wireless multi-hop self-organizing sensor network has two goals. Firstly, to create the network infrastructure i.e. establish communication links for data transfer. Secondly, it must fairly and efficiently share communication resources between sensor nodes. It must have built-in power saving mechanisms and strategies for proper management of node mobility or failure.

F. Physical Layer

The physical layer is used for providing simple and robust modulation, transmission, and receiving techniques. It is responsible for frequency selection, carrier frequency generation, signal detection, modulation and data encryption.

IV. MAC PROTOCOLS

A medium access control (MAC) protocol coordinates actions over a shared channel. An effective MAC protocol for wireless sensor networks must consume little power, avoid collisions, be implemented with a small code size and memory requirements, be efficient for a single application, and be tolerant to changing radio frequency and networking conditions. Many MAC protocols use a request to send (RTS) and clear to send (CTS) style of interaction. This works well for ad hoc mesh networks where packet sizes are large (1000s of bytes). However, the overhead of RTS-CTS packets to set up a packet transmission is not acceptable in wireless sensor networks where packet sizes are of the order of 50 bytes. Recently, there has been new work on supporting multi-channel wireless sensor networks. In these systems it is necessary to extend MAC protocols to multi-channel MACs. Consequently, multi-frequency MAC protocols consist of two phases: channel assignment and access control. The advantages of multi-channel MAC protocols include providing greater packet throughput and being able to transmit even in the presence of a crowded spectrum, perhaps arising from competing networks or commercial devices such as phones or microwave ovens [3].

The medium access control protocols for the wireless sensor network have to achieve two main objectives: Firstly, the creation of the sensor network infrastructure and then to share the communication medium fairly and efficiently.

To design a good MAC protocol for the wireless sensor networks, the following attributes are to be considered: Energy efficiency, Latency, Throughput and fairness. However among all of the above aspects the energy efficiency and throughput are the major aspects. Energy efficiency can be increased by minimizing the energy wastage.

There are four major sources of energy waste in wireless sensor network: Collision, Overhearing, Packet Overhead and Idle listening. The main goal of any MAC protocol for sensor network is to minimize the energy waste due to idle listening, overhearing and collision.

To evaluate and compare the performance of energy conscious MAC protocols, the following matrices are being used by the research community:

**Energy Consumption per bit:** The energy efficiency of the sensor nodes can be defined as the total energy consumed / total bits transmitted. The lesser the number, the better is the efficiency of a protocol in transmitting the information in the network.

**Average Delivery Ratio:** The number of packets received to the number of packets sent averaged over all the nodes.

**Average Packet Latency:** The average time taken by the packets to reach to the sink node.

**Network Throughput:** The total number of packets delivered at the sink node per time unit [4].

The MAC protocols for the wireless sensor networks can be classified broadly into two categories as follows:

A. Contention Based

Contention occurs when two nearby sensor nodes attempt to access the communication channel at the same time. Contention causes message collisions, which are very likely to occur when traffic is frequent and correlated, and they decrease the lifetime of a sensor network. A MAC protocol is contention-free if it does not allow any collisions.

The contention based protocols can relax time synchronization requirements and can easily adjust to the topology changes as some new nodes may join and others may die few years after deployment. These protocols are
based on Carrier Sense Multiple Access (CSMA) technique and have higher costs for message collisions, overhearing and idle listening.

B. Schedule Based

The schedule based protocol can avoid collisions, overhearing and idle listening by scheduling transmit and listen periods but have strict time synchronization requirements.

V. CONTENTION BASED MAC PROTOCOLS

These protocols known as CSMA-based are usually used in the multi-hop wireless networking due to their simplicity and their adequacy to be implemented in a decentralized environment like WSN. To decrease collisions and to reduce considerably other sources of energy wastage, the Wake-up/Sleep mechanisms and/or the control messages RTS/CTS/ACK are used to design energy efficient MAC protocols for WSN like S-MAC, T-MAC, B-MAC.

A. IEEE 802.11

The IEEE 802.11 is a well known contention based medium access control protocol which uses carrier sensing and randomized back-offs to avoid collisions of the data packets. IEEE 802.11 used for wireless local area networks (WLAN) is used for high speed data exchange. A typical bandwidth today is 54 Mbit per second and is theoretical possible up to 300 Mbit per second (IEEE 802.11n). To be reliable here means especially be highly available. It is not enough to say that every request will be handled eventually. Latency is important for reducing waiting periods, too. Sensor networks may be distributed on a large area. It could be difficult to provide a large number of wired access points. In sensor networks you typically have to transmit measured values. This means you have a many to one communication. These values are periodically updated. Their size is small, often a few bytes suffice. That is why the update interval is high in comparison to the time needed for transmission over the network. Most of the time there is no activity in the network. So always listening to the media would be too expensive in the view of energy costs. The basic idea is to shut the radios usually down and let them only wake up from time to time to reduce energy wastage caused by collision, overhearing and idle listening. A node goes to sleep periodically if it is not engaged in transmission or reception, of which it is not a party, to reduce collision and overhearing. A cycle in SMAC consists of a listen and a sleep state. A node normally follows predetermined schedules to wake up or go to sleep with the following exceptions: (i) A node goes to sleep if any of its neighbours are communicating, and the node is not a party. (ii) A node wakes up at the end of its neighbour’s transmission if it needs to relay the packet. This is done by overhearing neighbour’s RTS and CTS exchanges before the node goes to sleep and serves the purpose of reducing latency caused by sleeping. This behaviour is called adaptive listening. Schedules are periodically exchanged by broadcasting SYNC packets among neighbouring nodes to induce synchronized listen behaviour as much as possible and thus to reduce latency caused by sleeping. Synchronized neighbours form a virtual cluster, but synchronization can only be achieved to a certain extent in an ad hoc environment.

Disadvantages: 1) High cost, bigger size and design complexity of sensors.

B. PAMAS: Power Aware Multi-Access Signaling

Power Aware Multi-Access (PAMAS) is one of the earliest contention based MAC protocol in which nodes that are not transmitting or receiving are turned “OFF” in order to conserve energy. This protocol uses two separate channels for data and control packets. It therefore requires the use of two radios in different frequency bands at each sensor node.

Advantages: 1) Energy efficiency.

Disadvantages: 1) High cost, bigger size and design complexity of sensors.

2) Moreover, there is significant power consumption because of excessive switching between sleep and wake up states [4][5].

C. Sensor S-MAC

Sensor S-MAC a contention based MAC protocol is a modification of the IEEE 802.11 protocol specially designed for the wireless sensor network in 2002. In this medium access control protocol sensor node periodically goes to the fixed listen/sleep cycle. A time frame in S-MAC is divided into two parts: one for a listening session and the other for a sleeping session. Only for a listen period, sensor nodes are able to communicate with other nodes and send some control packets such as SYNC, RTS (Request to Send), CTS (Clear to Send) and ACK (Acknowledgement). By a SYNC packet exchange all neighbouring nodes can synchronize together and using RTS/CTS exchange the two nodes can communicate with each other. The basic S-MAC scheme where node 1 transmits data to node 2 is shown in the figure.

The main idea of SMAC is to put nodes to sleep from time to time to reduce energy wastage caused by collision, overhearing and idle listening. A node goes to sleep periodically if it is not engaged in transmission or reception, to reduce idle listening. It also goes to sleep if its neighbours are involved in communication, of which it is not a party, to reduce collision and overhearing. A cycle in SMAC consists of a listen and a sleep state. A node normally follows predetermined schedules to wake up or go to sleep with the following exceptions: (i) A node goes to sleep if any of its neighbours are communicating, and the node is not a party. (ii) A node wakes up at the end of its neighbour’s transmission if it needs to relay the packet. This is done by overhearing neighbour’s RTS and CTS exchanges before the node goes to sleep and serves the purpose of reducing latency caused by sleeping. This behaviour is called adaptive listening. Schedules are periodically exchanged by broadcasting SYNC packets among neighbouring nodes to induce synchronized listen behaviour as much as possible and thus to reduce latency caused by sleeping. Synchronized neighbours form a virtual cluster, but synchronization can only be achieved to a certain extent in an ad hoc environment.

Advantages: 1)Reduces energy consumption, while supporting good scalability and collision avoidance, but the
main contribution of SMAC is its fixed duty-cycle approach which reduces idle listening.

Disadvantages: 1) Lack of complete synchronization introduces sleep delay which results in increased packet latency. Static sleep-listen periods result in high latency and lower throughput.

**D. Timeout T-MAC**

T-MAC works under variable traffic load. In T-MAC, listen period ends when no activation event has occurred for a time threshold TA. The decision for TA is presented along with some solutions to the early sleeping problem. Variable load in sensor networks are expected, since the nodes that are closer to the sink must relay more traffic. T-MAC gives better results under these variable loads. TMAC protocol tries to enhance energy savings in SMAC by further reducing the idle listening. Anode in the listen mode will go back to sleep after time TA, if there is no activation event. The choice of TA is critical for the performance of TMAC. The following equation defines the minimum value of TA:

\[ TA > CW + TxRTS + T \]  

(1)

Where CW is the contention window size, TxRTS is the transmission time of the RTS packet and T is the turn-around time after the end of the RTS packet and the arrival of the CTS packet. A static value of TA is chosen to be 1:5 times the minimum value of TA. The early sleeping problem is noticed in the unidirectional source to sink communication. Figure below explains this problem.

Node C is aware of node A transmission to B, however node D is not and will go to sleep after TA seconds. When A transmission to B is over, C cannot transmit its data to D since D is sleeping. The future request to send packet technique is proposed to overcome the early sleeping problem. When node C overhears the CTS packet coming from node B, it will immediately send a Future Request to Send (FRTS) packet to inform node D to wake up when A's transmission to B is finished. In order to avoid collision at node B between the data packet coming from node A and the FRTS packet coming from node C, node A first transmits a Data-Send (DS) packet of size equal to the FRTS packet, but this DS packet contains no useful information. After sending the DS packet, node A starts transmitting its data packet to node B.

**Advantages:**

1) TMAC energy savings are better than SMAC.
2) Excellent energy savings because nodes enter sleep mode rather than idle listening after TA seconds of no activity during the listen period.

**Disadvantages:**

1) Synchronization of the listen periods within virtual clusters is broken which leads to the early sleeping problem.
2) FRTS technique may result in more energy loss during heavy traffic.
3) Throughput (bytes per node per second) is less than SMAC at heavy traffic due to the early sleeping problem.

**E. WiseMAC**

WiseMAC is based on the preamble sampling technique which consists in regularly sampling the medium i.e. listening to the radio channel for a short duration, to check for activity. The novel idea introduced by WiseMAC consists in letting the access point learn the sampling schedule of all sensor nodes. Knowing the sampling schedule of the destination, the access point starts the transmission just at the right time with a wake-up preamble of minimized duration \(TP\). The access point keeps an up-to-date table with the sampling schedule of all sensor nodes. The sampling schedule information is gained through the inclusion in every acknowledgement packet of the remaining time until the next scheduled sampling [6].

The duration of the wake-up preamble must be computed such as to compensate for the drift between the clock at the access point and on the sensor nodes. This drift is proportional to the time since the last re-synchronization (i.e. the last time an acknowledgement was received from a given sensor node). Let \(\mu\) be the frequency tolerance of the timebase quartz and \(l\) the interval between two communications. The required duration of the wake-up preamble is

\[ TP = \min(4\mu l; TW) \]  

(2)

If the traffic is high, the interval \(l\) between communications will be small, and so the wake-up preamble \((4\mu l)\). If the traffic is low, the interval between communications will be large in average, but at maximum equal to TW. This important property, illustrated in the figure below, makes the WiseMAC protocol adaptive to the traffic.

An important detail of the WiseMAC protocol is the presence of a frame pending bit in the header of data packets. A sensor node receiving a data packet with this bit set will continue to listen after having sent the acknowledgement.
The next packet will be sent by the access point right after having received the acknowledgement. This scheme permits to use a wake-up interval that is larger than the average interval between the arrivals for a given node. It permits to reduce the queuing delay at the access point, especially in the event of traffic bursts.

**Advantages:** 1) Very low power consumption when the channel is idle. 2) Collisions are not possible using WiseMAC for a downlink channel as the access point is the only initiator of communications [7].

**Disadvantages:** 1) The long wake-up preambles cause a throughput limitation and a large power consumption overhead in reception.

**F. ALOHA MAC**

The ALOHA protocol is an interesting example of a MAC protocol of the contention-type. It is the precursor of Ethernet and its subsequent standardization as IEEE 802.3 (CSMA-CD). The ALOHA protocol was originally implemented (early 1970’s) to allow distributed stations on the islands of Hawaii to communicate over a common radio channel. Specifically, all nodes used a common frequency band for their packet or frame transmissions to a satellite (the “uplink” band was a common frequency band for all nodes). The satellite in turn broadcast to all the nodes on the “downlink” frequency band each frame it received successfully. Successful receipt of a frame at the satellite means that there is no collision or overlap between a frame from one node and other frames from other nodes arriving at the satellite. When a frame is received correctly at the satellite, it broadcasts an ACK also. Of course each frame has the address of the destination node for which it is intended, as well as the address of the source node. If a sending node does not see on the downlink within a reasonable time an ACK for a frame it sent up, it assumes that a collision occurred and re-transmits the frame after some random delay. Another mechanism enabling this without ACK frames from the satellite is for the sending node to monitor the downlink frequency band to listen for its frame being re-broadcast by the satellite; this will only happen if its frame got to the satellite in the first place without collision or interference. The satellite ignores frames that are received corrupted by errors due to collisions or overlaps. The concept of the ALOHA system is applicable with modifications in other situations, such as a LAN of nodes attached to a common coaxial cable bus (the Ethernet concept). The basic characteristics of ALOHA are the following:

- **Fixed length frames, shared channel or medium.**
- **Frames carry address of destination node.**
- **Nodes transmit on common channel and listen to common channel for transmission from other nodes.**
- **A node starts a frame transmission whenever it is ready to send, regardless of the state of the channel.**
- **A node can tell if its frame arrived at the destination node without collision, or if a collision occurred with another frame in an overlapping time interval thus corrupting both frames.**

There are two basic types of ALOHA system, pure ALOHA and slotted ALOHA. In pure ALOHA a node can start transmission at any time. In slotted ALOHA, all nodes have synchronized clocks marking frame boundary times (the clock period is the time for one frame transmission) and a node wishing to transmit does so at the start of the next frame slot.

**Advantages:** 1) ALOHA depends on the ability of a node to detect that a collision has occurred.

**Disadvantages:** 1) The node transmits without checking the state of the channel. (In ALOHA, a node cannot necessarily “listen” to the uplink transmissions of another node, because these transmissions are directed by the transmitting antennae to the satellite station and not to the other nodes).

**G. Berkeley Access Control (B-MAC)**

The Berkeley Media Access Control (B-MAC) is similar to Aloha with Preamble Sampling, which duty cycles the radio transceiver i.e. the sensor node turns ON/OFF repeatedly without missing the data packets. B-MAC is designed for an Ad-Hoc network of nodes with N-sender to 1-receiver transmissions. The basic idea of B-MAC is to keep the protocol simple. Like the other protocols B-MAC uses periodically sleep/wakeup cycles. The mechanism used here is called Low Power Listening. LPL means in the wakeup time the node listens for incoming data transmissions. If there is no data received, called a “false positive”, a timeout interrupts the listen state. Otherwise the node waits for complete packet transmission. To ensure that the received packet is complete from the beginning there is a preamble time of 100ms added after the wakeup.

The sleep periods of the nodes can differ to each other as B-MAC is asynchronous. When there is data to send a node switches the radio mode and starts to send an announcement. This announcement must be long enough to make sure that the receiver notices, even if the receiver starts sleeping at the beginning. Afterwards the sender transmits the target address and starts sending data. Clear channel assessment (CCA) is used for clear channel detection. For energy reduction a better separation between signals and noise on the channel is useful. Therefore the noise must be analysed. In case of a false positive a sample was put into a queue. It makes sense to capture and analyse more than one sample because the noise caused by the environment changes continuously. An optional feature is using acknowledgements. B-MAC has an application interface for flexible configuring parameters like this. Other options are for example the check interval. A good value for this sometimes depends on the user case so this can be adjusted by a higher layer application [3].

**Advantages:** 1) BMAC uses Low Power Listening.
2) Does not need complicated and expensive synchronization methods as it is asynchronous
3) Clear channel assessment reduces the amount of energy that is needed.

**Disadvantages:** 1) Allows very small implementations because of the limited available energy.
2) Fairness is not guaranteed by LPL.
VI. SCHEDULE BASED MAC PROTOCOLS

These protocols known as deterministic are employed to avoid collisions by associating a slot time for each sensor node in a given cluster, and to mitigate the effects of overhearing problem, because in this situation each node knows his corresponding slot time to transmit data packet.

A. Traffic Adaptive Medium Access Protocol (TRAMA)

TRAMA is a TDMA-based algorithm and proposed to increase the utilization of classical TDMA in an energy efficient manner. For each time slot a distributed election algorithm is used to select one transmitter within two-hop neighbourhood. This kind of election eliminates the hidden terminal problem and hence, ensures all nodes in the one-hop neighbourhood of the transmitter will receive data without any collision.

Time is divided into random-access and scheduled-access (transmission) periods. Random-access period is used to establish two-hop topology information where channel access is contention-based. A basic assumption is that, by the information passed by the application layer, MAC layer can calculate the transmission duration needed which is denoted as \( SCHEDULE\_INTERVAL \). Then at time \( t \), the node calculates the number of slots for which it will have the highest priority among two-hop neighbours within the period \( [t, t + SCHEDULE\_INTERVAL] \).

The node announces the slots it will use as well as the intended receivers for these slots with a schedule packet using a bitmap whose length is equal to the number of its neighbours. Additionally, the node announces the slots for which it has the highest priority but will not be used. Bits correspond to one-hop neighbours ordered by their identities. Since the receivers of those messages have the exact list and identities of the one-hop neighbours, they find out the intended receiver. When the vacant slots are announced, potential senders are evaluated for re-use of those slots. Priority of a node on a slot is calculated with a hash function of node’s and slot’s identities.

Advantages: 1) Higher percentage of sleep time and less collision probability is achieved compared to CSMA based protocols.
2) Since intended receivers are indicated with a bitmap, less communication is performed for multicast and broadcast type of communication patterns compared to other protocols.
Disadvantages: 1) Delays are found to be higher compared to contention-based protocols due to higher percentage of sleep times.
2) Transmission slots are set to be seven times longer than the random access period. However, all nodes are defined to be either in receive or transmit states during the random access period for schedule exchanges. This means that without considering the transmissions and receptions, the duty cycle is at least 12.5 %, which is a considerably high value [8].

B. Self Organizing Medium Access Control for Sensor Networks (SMACS)

The objective of the self-organization protocol at the link layer is to form a connected multi-hop network for a collection of randomly placed wireless sensor nodes. The algorithm must start the network cold. No information is available locally at the time each node starts. The node must find its radio neighbours, and participate in a group effort to form an ordered method of channel access.

Conventional TDMA has a centralized element since a single TDMA schedule must be calculated. Also all the terminals participating in the schedule must be synchronized at the slot level. In conventional TDMA systems, such as satellite communications, this tight slot synchronization is needed for purposes of bandwidth efficiency. In sensor networks it is possible to relax this network-wide slot synchronization requirement and as a result do away with the need for a single master. Here, we introduce the concept of Non-synchronous Scheduled Communications (NSC). Non-synchronous refers to the notion that slot boundaries in the entire network need not be aligned and scheduled refers to the idea that every node is aware of the times it needs to turn its radio on and off in order to communicate with neighbours [9].

Disadvantages: 1) In this protocol the time slots are wasted if the sensor node does not have data to be sent to the intended receivers.

C. Energy Aware TDMA based MAC

Energy Aware TDMA Based MAC protocol assumes the formation of clusters in the network. Each of the cluster sensor nodes is managed by the Gateway. The Gateways collects the information from the other sensor nodes within its cluster, performs the data fusion, communicates with the other gateways and finally sends the data to the control center. The assignment of the time slots to the sensor nodes within its cluster is performed by Gateways. The Gateways inform to the other nodes about the time slot when it should listen to other nodes and the time slot when it can transmit own data.

This TDMA based MAC protocol consist of four main phases: data transfer, refresh, event triggered- rerouting and refresh-based rerouting. The data transfer phases is for sending the data in its allocated time slot. During refresh phase, the nodes update its state (energy level, state, position etc) to the gateway. The gateway requires this nodes state information for performing rerouting during event triggered-rerouting. The refresh-based rerouting occurs periodically after the refresh phase. During both these rerouting phases the gateway execute the routing algorithms and sends new routes to the sensor nodes.

D. Data Gathering MAC (D-MAC)

The unidirectional paths from possible sources to the sink could be represented as data gathering tree. DMAC represented in the figure below is an improved Slotted Aloha algorithm where slots are assigned to the sets of nodes based on the data gathering tree shown.
During the receive period of a node, all of its child nodes have transmit periods and contend for the medium. Low latency is achieved by assigning subsequent slots to the nodes that are successive in the data transmission path. DMAC protocol suggests continuous data forwarding as opposed to SMAC which is shown below. In order to accomplish this, nodes on the chain path from source to the sink must wake up sequentially, by having staggered schedules. The schedule of every node is shifted. It shares half of its wakeup period with its downstream node (child) and the other half with its upstream node (parent). RTS/CTS control packets are not necessary.

Only ACK packet and data retransmission are implemented to ensure packet delivery. DMAC adapts itself to the network traffic through three schemes: (1) First, if a node has more than one packet to transmit, it will set the more data flag in the MAC header to request its parent node to extend its wake up time, (2) Second, if two or more nodes have the same parent node, the parent node will extend its wake up time to allow all its child nodes to transmit their data to it. This is called a data prediction scheme in DMAC, and (3). Third, if two interfering nodes at the same tree level have different parent nodes, then one of them can use the More-To-Send packet to request its parent node to extend its wakeup time.

Advantages: 1) DMAC achieves very low latency but can still be energy efficient.

VII. FUTURE RESEARCH

As we have seen, most of the MAC protocols focus primarily on the energy efficiency of the wireless sensor network. Thus, a lot of work remains to be done in the other areas of the MAC layer such as network security to protect against eavesdropping and malicious behaviour and with nodes mobility due to the increasing interest in medical care and disaster response applications where the mobile sensors can be attached to the patient, doctor or first responder. Also, most of the protocols for the wireless sensor network have been evaluated through simulations. The performance of these MAC protocols needs to be evaluated on the actual sensor system.

VIII. CONCLUSION

MAC protocols are generally application specific and hence there is no standard MAC protocol available for Wireless Sensor Networks. Schedule based MAC protocols have collision free access to the medium, though, in this, synchronization is critical. It is also difficult for it to adapt to the changes in the network topology due to addition and deletion of nodes. On the other hand, the contention based protocols have low latency and high throughput but still suffer from collisions.

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