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Increasing Mac Efficiency For WSNs

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ABSTRACT

Wireless Sensor Networks(WSNs) contain nodes which generally will never be attended after they are deployed into either hostile or remote areas. These nodes are supposed to work with their limited as well as non-rechargeable resources (i.e., Batteries). Once the battery has been discharged, it is very difficult to recharge or replace the battery. Hence, that node is considered dead. This makes energy efficiency one of the most important design objectives for the sensor networks. These sensor nodes stay asleep for a long period and are supposed to become active as soon as something is detected. This characteristic and/or application motivates for a MAC that is not the same as the traditional wireless MAC such as IEEE 802.11

This paper provides ways to reduce the shortcomings of the wireless sensor networks caused by the existing protocols and utilize the available bandwidth and energy as efficiently as possible.

A modification of the existing protocols is proposed to increase the energy efficiency and throughput which in turn increases the life span of the wireless sensor network.

Keywords: Energy Efficiency, MAC protocol, WSN

INTRODUCTION

Media Access Control (MAC) protocols exist that are designed with wireless sensor networks in mind. INET (Internet Network Architectures) has various protocol implementations along with IEEE 802.15.4 models.

Typically, there are two categories of MAC protocols for wireless sensor networks, depending on the management of communication on the channel:

- Time-Division Multiple Access (TDMA): Nodes are given time slots in which they can send messages.
- Carrier-Sense Multiple Access (CSMA): These use carrier sensing and back-offs to avoid packets from colliding.

The protocols available in INET:

1. B-MAC: It is also known as Berkeley MAC. A commonly used protocol for WSNs. It comes under TinyOS. It utilizes low-power listening (LPL) to reduce power consumption caused by idle listening. Nodes sleep for a period

of time after which they wake up and sense the media for preambles. If nothing is detected, the nodes goes to sleep. If a preamble is detected, it will wait and receive all the packets following the preamble. In case the sensor wants to send some data, it will first send a preamble for the sleep period and then sends the data packets. After the data packets (data packet + ACK), the nodes go back to sleep mode. The preamble does not have addressing information hence the preamble as well as data packets are received by all the nodes which are within range.

2. X-MAC: It is a development over B-MAC. In Berkeley MAC, the entire preamble is sent not taking into consideration whether the node woke up at the beginning of the preamble or at the end. All nods receive this preamble. X-MAC sends a strobed preamble i.e., a preamble that is the same size as the one in B-MAC but it is sent with pauses in between. A pause is long enough for the receiving node to send an ACK packet if it is already awake. The preamble also contains the address of the node which should receive the preamble. Hence, the nodes that are not addressed can go back to sleep. These changes increase the energy efficiency of the protocol.
3. L-MAC: It is an abbreviation for Lightweight MAC. L-MAC is TDMA based. All nodes are given a time slot during which only they can carry out transmissions. A transmission contains a control message and the data unit(s). Control messages contain the destination of the data, length of the data unit and information about which time slots are occupied. All nodes wake up at the start of a time slot and if no transmission is detected the time slot is assumed to be empty and the nodes go back to sleep. Only one message can be sent in a time slot. In the first five minutes, the network is setup and no data packets are sent. The network is set up by nodes which claim a time slot. They send a control message during the time slot they want to reserve for themselves.
4. S-MAC: It is based on 802.11 MAC protocol that meets the energy needs of sensor network nodes. It is a low power RTC-CTS based MAC protocol that makes use of loose synchronization between nodes to allow for duty cycling in sensor networks. The three main techniques employed by this protocol are: periodic sleep, virtual clustering and adaptive listening. At the start of the awake period, a node exchanges synchronization and schedules information with its neighbours to ensure that its neighbours wake up in synchronization. Schedules are adhered to locally and this mitigates the need for a system wide schedule. Nodes at the border of two virtual clusters adhere to the schedules of both the virtual clusters to maintain connectivity across the network.

OBJECTIVE

The main objective of this research paper is to propose a new/or upgrade an existing MAC protocol

The total collisions between packets must be very low in a MAC protocol for a WSN. This is because, if a collision does take place then the sensor needs to sense the collision of the packet and resend the packet. This cause an unnecessary use of power. If collision is avoided, power can be saved and life of the battery will not be affected by a significant amount.

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The power per packet must be low as well. This is a requirement because very high number of packets are sent and received by a sensor and if sending a single packet takes a huge portion of the limited battery, then energy efficiency cannot be obtained.

The packet loss should be minimized. A packet will be lost when a sensor sends a packet but the receiving node was in sleep mode. This causes packet loss and this also causes an increase in traffic which might lead to collision.

The total power consumption of the network needs to be reduced as well.

METHODOLOGY

S-MAC proposes that every node uses synchronous message to notice scheduling information of their own, it also utilizes RTS-CTS mechanism to send an appointment time for a long message. It divides long messages into many short messages for burst transfer. To reliably transmit and notify neighbours of the ongoing communication process, the receiving node must send a response for every short message. S-MAC is efficient for less sensor network data transmissions. When the data increases, the number of packets from a transmitter increases and in turn the receiver has to send more ACK packets accordingly. Acknowledgement sent after each data packet reduces efficiency. The growth of time and energy also increases.

To tackle this shortcoming, ES-MAC (Energy-Efficient S-MAC) was proposed.

The communication in EES-MAC is as follows:

When the sender node sends information to the receiving node, the receiver does not send an acknowledgement for every packet it receives. Instead, it leaves a final ACK packet as confirmation that it has received the packets. The receiving node records the listening moment of the nodes that are conflicting by finding its neighbour table in the data packet process and notifies the sender. When the neighbours of the receiver go to listen to the channel, the receiver sends a short message to the sender and notifies the neighbours to sleep. After all the data packets are received, the sender is sent an acknowledgment packet stating that all the data packets have been received. If the receiver has not received all the data packets within the specified time, the serial number of the packets that were not received can be inferred by recording the number of data packets. The receiver will send these serial numbers to the sender and the sender in turn will resend them.

Legend:

- T: it refers to the receiver's neighbours that might end up conflicting with the time of listening.
- RSP (RE-send Packet): this refers to the sequence number of the data packets which the sender has to send and the receiver did not receive
- PC (Packet and Claim): By referring to T, the sender sends the PC packages when the neighbours might conflict at the listening stage, in order to avoid conflict with its neighbours.
- RTS: short form for Request To Send
- CTS: short for Clear To Send

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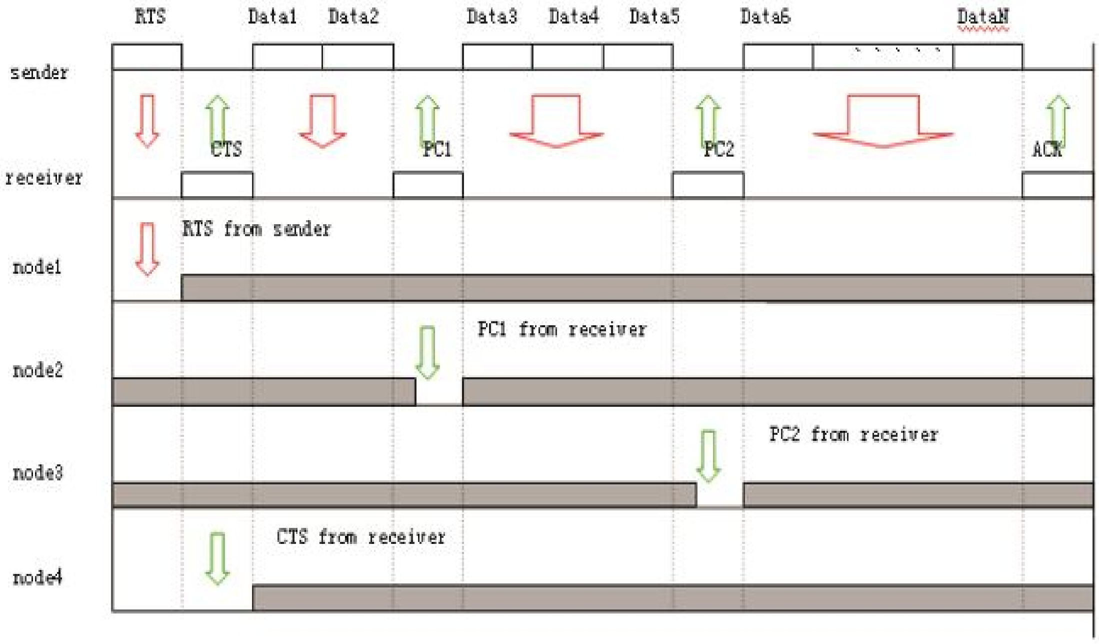

Figure 1.The transmission of ES-MAC protocol (shaded parts are the sleep states). Adapted fromDu Lijuan et al. / Physics Procedia 33 (2012) 444 – 448. Retrieved fromhttps://www.sciencedirect.com/science/article/pii/S1875389212014009

Before sending data to the receiver, the sender checks the information table of its neighbours to find the sleep and listen states of the receiver. If the sender is in the listening state and the receiver is in the sleep state, the sender will go to sleep, wakes up and listens to the receiver to turn into listening state. Afterwards, it listens whether the channel is free or not. When the channel is idle, it can communicate with the receiver. Firstly, the sender sends a RTS packet to the receiver, the receiver after receiving the RTS sends a CTS which includes the T that is the time when the neighbours might conflict. After the sender receives the CTS, it will record T and the sender then begins to send data packets addresses to the receiver. When T comes, the sender stops sending data packets and sets the state of the radio into waiting state and waits for the PC which will be sent by the receiver. T is included in the PC packet received by the sender. When the sender receives the PC, it continues to send the data packets. This process gets repeated till the sender sends all the data packets. Later, the T item of the PC package is set to 0 because after the last PC is sent, there is no neighbour nodes who might conflict with the transmission. When the receiver receives the last data packet, it sends an acknowledgement which notifies the sender and the other nodes that the communication/transmission is complete.

In the figures given below, ES-MAC and S-MAC protocols are compared to check which consumes more energy and time. After energy and time consumption caused by sending the RTS, CTS, ACK, PC AND DATA is given a definition, the sum of these is calculated to compare the time and energy consumption of the two protocols.

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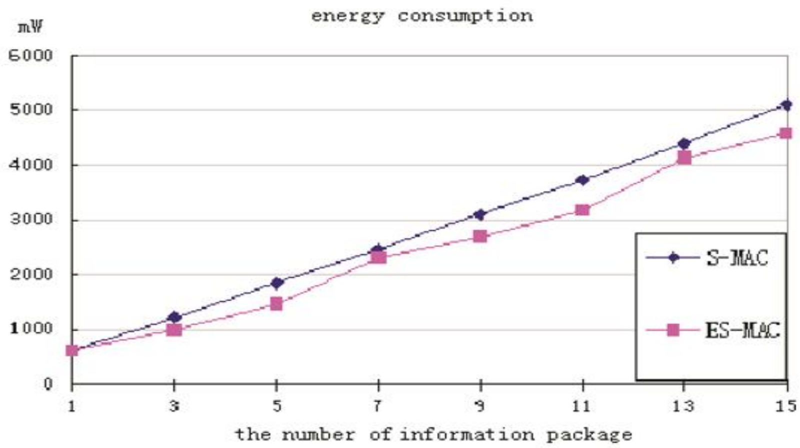

Figure 2.The total energy VS.The number of packets. Adapted from Du Lijuan et al. / Physics Procedia 33 (2012) 444 – 448. Retrieved from https://www.sciencedirect.com/science/article/pii/S1875389212014009

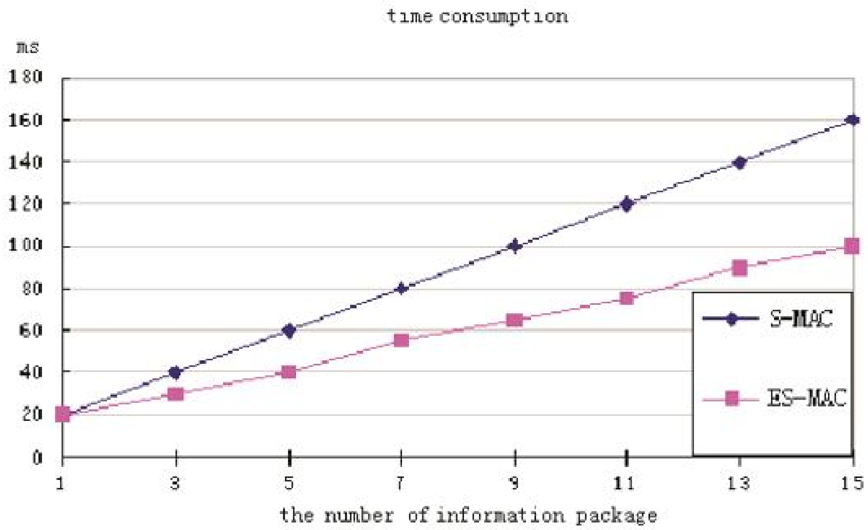

Figure 3.The total time VS.The number of packets. Adapted from Du Lijuan et al. / Physics Procedia 33 (2012) 444 – 448. Retrieved from https://www.sciencedirect.com/science/article/pii/S1875389212014009

Referring to figure 2 and 3,

When the number of packets increases, ES-MAC consume significantly less amount of energy and also manages to use lesser time when compared to S-MAC. The reason behind this is : in ES-MAC protocol, the receiver does not send an acknowledgement packet for every packet received. Instead, it sends a small amount of PC packets which decreases energy loss and unnecessary waste of time. ES-MAC is more efficient when the number of packets increases. ES-MAC reduces energy consumed while decreasing the network delay and finally extend the use of communication time and improve network's throughput.

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The design of ES-MAC protocol can be improvised by shortening the awake period when the channel is idle. Presently, the nodes remain awake throughout the entire awake period even if no sending or receiving is done by the nodes. This alteration aims to improve ES-MAC by listening to the channel for only a short period of time after the synchronization phase of the nodes is carried out and if no data is received during this window the node returns back to sleep. If data packets are received, the node stays awake till either no data is received or the awake period comes to an end.

This design change can cause the loss of data packets which can be taken care of by as follows:

Before the sender sends the RTS packet, the data package is numbered as DATA1, DATA2, and so on. It calculates the communication time which also includes the sleep time. The receiver then receives the RTS packet from the sender. The time remaining can be calculated from the sleep time and number of packets can be known which will be numbered as DATA1, DATA2, … In the transmission, whenever the receiver receives data packets, it removes them from the table. Before the communication comes to an end, the receiver checks the table and if the table is empty, it means that there is no loss of data packets and the receiver then sets the ACK as 0 in the RSP. On the contrary, if there is packet loss then the receiver sets the ACK as the first number of the packets that were not received from the table and then sets the time as to how long all the packets were received as time in the ACK packet. After this the receiver sends the ACK to the sender. The sender on receiving the ACK first check the RSP item. IF the RSP item is 0, this means that the receiver successfully received all the packets and if it is not 0 then the receiver has not received all the packets and resends the number of data packets which are equal to the RSP and then it waits for the next acknowledgement from the receiver. This process carries on till the RSP in the ACK packet is not 0.

RESULTS AND DISCUSSION

In the recent years, major progress has been made in the development of low power micro sensors. The emergence of these low power micro sensors has led the practitioners to envision the networking of many sensors which are scattered over a wide area. The typical architecture of a sensor network contains many sensory devices that can probe the environment and report the collected data via radio to the command centre also known as a sink. Such sensors are generally powered with the help of small batteries and these sensors can be deployed in a completely unattended setup. Therefore, replacing a sensor’s battery is not possible or not considered to be practical. Energy constraints like these limit the sensor’s lifetime and therefore make efficient design and proper management of sensor networks a challenge.

Recent advances of technology in ultra-high integration and low-power electronics has enabled the development of tiny battery-operatedwireless sensors. A sensor alongside its sensing abilities also carries out signal processing and data transmission. Any given sensor spends majority of its energy in the communication of data which includes transmission, reception and being idle.

Energy is a scarce resource when it comes to sensors in a network. Accessing the medium is a major consumer of the sensor’s energy especially when the transmission is over a longer distance or when the radio receiver is kept on for a long time. The output power of

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the transmitter is directly proportional to the square of the distance and it significantly get magnified in a noisy environment. Energy-conscious MAC can save energy by limiting the potential of collisions , minimizing the use of control messages, utilizing most of the available frequency band to shorten the transmission time, turning the radio into low power sleep mode when it is idle and finally, avoiding the excessive transitions among active and sleep states.

The design of ES-MAC protocol can be improvised by shortening the awake period when the channel is idle. Presently, the nodes remain awake throughout the entire awake period even if no sending or receiving is done by the nodes. This alteration aims to improve ES-MAC by listening to the channel for only a short period of time after the synchronization phase of the nodes is carried out and if no data is received during this window the node returns back to sleep. If data packets are received, the node stays awake till either no data is received or the awake period comes to an end.

CONCLUSION

Designing a MAC protocol which significantly improves the energy efficiency to extend the lifetime of a sensor in a network is a challenging problem. It is mainly due to the constraint on the resources. Various MAC protocols have been proposed by researchers. This research paper discussed a few of the MAC protocols developed and proposed a change of one such existing protocol. The awakening time of each sensor node is shortened which decreases the energy consumption without losing data packets. No specific MAC protocol is accepted as a standard. The reason being: there is a lack of similarity at the lower layers and the sensor’s hardware.

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