A MAC PROTOCOL WITH INTERFERENCE AVOIDANCE MECHANISM FOR WIRELESS SENSOR NETWORK

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Abstract— In a WSN a large no. of sensor nodes are placed for monitoring physical phenomena. Sensor node is a small battery powered device; it is not possible to recharge the battery of node. One of the ways to increase the life time of the network is by designing power efficient MAC protocol. S-MAC protocol which uses periodic sleep/wake schedule is used to reduce idle listening time but this reduces network capacity & increases end to end latency. So that, we have proposed MAC protocol which increases channel utilization by allowing multiple nodes to transmit there packets during a frame without interfering another nodes communication. Here we are using IEEE 802.15.4 MAC protocol which enhances network throughput, reduces end-to-end latency, low power consumption & moderates the overhead of four-way handshake mechanism. There are basically two type routing algorithms used with 802.15.4 are AODV and the Tree Based Routing Algorithm. Here we are using AODV to find performance of network.

Keywords— WSN; Tree based routing; interference avoidance; MAC sub layer ; end to end latency; energy efficiency; 802.15.4 MAC

I. INTRODUCTION

The number of sensor network deployments for real-life applications increases in recent years e.g., environmental monitoring, agriculture, military etc. Still energy consumption remains one of the obstacles to the implementation of this technology, especially in application scenarios where a long network lifetime and a high quality of service are required. Design of power efficient Medium Access Control protocol is one of the ways to prolong the life time of the network. An energy efficient MAC protocol should reduce the energy wastage due to idle listening, overhearing and collision. In Sensor MAC (S-MAC)[6] scheme the combination of periodic sleep/listen scheduling and four-way handshake mechanism is used to reduce idle/listening and avoid interference. But, this combination degrades network capacity and increases end-to-end latency. Sensor nodes periodically go to the fixed listen/sleep cycle & use of RTS/CTS increases latency. Under heavy traffic loads a pure CSMA access method will not works well; the four-way handshake mechanism is adopted to reduce interference due to channel reservation. There are two major problems

The four-way handshake mechanism with periodic sleep/listen scheduling reduces network capacity and results in high end-to-end latency. For the small packet size, the handshaking incurs very high overhead of energy consumption and channel utilization.

TDMA MAC protocol allows medium access through slot assignment. Because each node is allowed to transmit in its dedicated slots, it efficiently avoids inter-node interference and increases channel utilization in high traffic loads. The drawback of the TDMA protocols is that they incur costly signaling overhead to perform time synchronization and update slot assignment [12].

To avoid all these drawbacks, here we have used 802.15.4 MAC protocol which uses CSMA/CA to avoid interference. Its main objective is to provide higher network lifetime by avoiding inter-node interference. It provides Mac & physical parameters & also it allows different network topologies such as star, peer to peer & cluster tree topology. Network routing schemes are designed to give the power conservation, and low latency through guaranteed time slots.

II. LITERATURE SURVEY

To avoid high end to end latency of SMAC, Adaptive S-MAC proposed uses the coordinated adaptive sleeping mechanism. Adaptive SMAC allows a data packet to be moved more than one hop during a frame. Whenever a node over hears a RTS or CTS packet during its sleep period, it should wake up for a short duration to receive probable packets. If the neighbouring node wakes up while it is not the next-hop node, it incurs energy waste due to overhearing or idle listening. Therefore it introduces reduction in network lifetime as the neighborhood size increases [4].

The traffic adaptive medium access (TRAMA) is a TDMA based protocol that has been designed for energy efficient collision free channel in WSNs. In this protocol by ensuring collision free transmission and by switching the nodes to low power idle state when they are not transmitting or receiving the power consumption has been reduced. The TRAMA is more
energy efficient and has higher throughput than Sensor S-MAC protocol. However, the latency of TRAMA is more as compared to the other contention based MAC protocol [5]. TDMA MAC protocols rely on the frequent exchange of control packets due to the changes in traffic pattern, routing path, and node synchronization. Therefore they are appropriate when the traffic load is high and nodes exhibit a similar traffic pattern. Otherwise, contention-based MAC protocols provide higher adaptability to topology changes and traffic variations in large-scale sensor networks. But their performance highly depends on the efficiency and overhead of underlying collision avoidance mechanism.

III. PROPOSED SYSTEM

A. Network Nodes:

The most basic of the network is the device or node. A node can be a Full-function device (FFD) or reduced-function device (RFD). A network should have at least one FFD which operates as the PAN coordinator. It operates in three modes: a personal area network (PAN) coordinator, a coordinator or a device. An RFD is used for simple applications and do not need to send large amounts of data. An FFD can talk to RFDs or FFDs while an RFD can only talk to an FFD.

B. Network topology:

There are different types of network topologies are defined according to the networking requirements of the applications: star, peer to peer & cluster tree topology. In the star topology, a unique node operates as a PAN coordinator. If an FFD is activated it may establish its own network and become its PAN coordinator. The PAN coordinator chooses a PAN identifier, which is not currently used by any other network in the sphere of influence. The communication in the star topology is centralized i.e., each device joining the network and willing to communicate with other devices must send its data to the PAN coordinator, which dispatch them to the adequate destination devices. In the peer-to-peer topology also includes a PAN coordinator, which is nominated, by virtue of being the first device to communicate on the channel. However, the communication in the peer-to-peer topology is decentralized, where each device can directly communicate with any other device in its radio range.

For the peer-to-peer networks the cluster tree structure can be formed which is special case of peer to peer network in which most of the nodes are FFDs.

1. One & only one coordinator is declared as the PAN coordinator, which handles the whole network.
2. Any FFD in the network can be act as a coordinator and provide synchronization to other nodes or other coordinators;

3. An RFD connects to a cluster-tree as a leave node at the end of a branch i.e acts as a child node and associates itself with only one FFD.

The PAN coordinator

1. Forms the first cluster by establishing itself as Cluster Head (CLH) with a cluster identifier (CID) equals to zero
2. chooses an unused PAN identifier,

- A candidate device receiving a beacon frame from PAN coordinator may request to join the network to the CLH. If it accepts the request to join the network; it adds that device as a child device in its neighbor list. The new joined device adds the CLH as its parent in its neighbor list and starts transmitting periodic beacons forms child-parent topology. Other devices may join the network at this device by hearing these beacons. If for some reason the candidate device cannot join the network at the cluster head, it will search for another parent device.

For a large-scale network, it is possible to form a mesh of multiple neighboring clusters. The PAN coordinator can upgrade a device to become the CLH of a new cluster adjacent to the first one. Other devices gradually connect and form a multi-cluster network structure

C. Physical layer:

The physical layer is taking decisions about the data transmission and reception using a certain radio channel and according to a specific modulation and spreading technique. The IEEE 802.15.4 offers three operational frequency bands: 2.4 GHz, 915 MHz and 868 MHz. There is a single channel between 868 and 868.6 MHz, 10 channels between 902 and 928 MHz, and 16 channels between 2.4 and 2.4835 GHz. It allows dynamic channel selection, a scan function that searches a beacon from list of channels, receiver energy detection, link quality indication and channel switching. All these frequency are based upon Direct Sequence spread spectrum method. It performs Energy detection for use by a network layer as part of
channel selection algorithm or to perform CCA to detect channel is busy or not; it is an estimate of the received signal power within the bandwidth of a channel. The energy detection time should be equal to 8 symbol periods. It also performs Link Quality Indication to find out quality of a received signal by finding out ED of Receiver or a signal to noise ration. To find out the channel is free or not it performs Clear channel Assessment by using ED method or it uses carrier sense method to find channel state.

D. Routing Algorithm:
AODV algorithm is used to reduce cost and power consumption and improve reliability [3]. In this protocol, routing paths are searched only when needed. To find a route a route discovery operation is started & terminates when either a route has been found or no route is available after examination for all route possibilities. AODV determines a route to a destination only when a node wants to send a packet to that destination. Routes are maintained as long as they are needed by the source. Sequence numbers ensure the freshness of routes and guarantee the loop-free routing. It does not maintain path when one of the node not detect by other nodes. Nodes that are not on the active paths, they neither maintain any routing information nor participate in any periodic routing table exchanges. When the local connectivity of the mobile node is of interest, each mobile node can become aware of the other nodes in its neighborhood by broadcasting known as Hello messages.

AODV defines three messages: Route Requests (RREQs), Route Errors (RERRs) and Route Replies (RREPs). These messages are used to discover and maintain routes across the network from source to destination by using UDP packets. The routing information for routes in the network is stored in tables.

E. IEEE 802.15.4 MAC:
It provides Mac data service & management service interfacing to the MAC sub layer management entity (MLME). MAC service enables transmission & reception of MAC protocol data units across physical data service. The MAC sub-layer of the IEEE 802.15.4 protocol uses CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance) as a channel access protocol & also supports contention-free and contention-based periods. However, it eliminates the RTS/CTS mechanism to reduce the probability of collisions [1]. The MAC protocol supports two operational modes that may be selected by the coordinator:

- Beacon-enabled mode: Beacons are periodically generated by the coordinator to synchronize attached devices and to identify the PAN. A beacon frame is the first part of a super frame, which also embeds all data frames exchanged between the nodes and the PAN coordinator. Data transmissions between nodes are also allowed during the super frame duration. When the coordinator selects the beacon-enabled mode, it forces the use of a superframe structure to manage communication between devices. The superframe structure is defined by the PAN coordinator and transmitted to other devices inside every beacon frame, which is broadcasted periodically by the PAN coordinator. The superframe is divided into 16 same size slots and followed by an inactive period. The superframe is contained in a Beacon Interval, which is bounded by two consecutive beacon frames, and includes one Contention- Access Period (CAP) and may include also a Contention-Free Period (CFP). If a device wants to communicate with other device then it has to compete with other device in slotted CSMA/CA mechanism for completion of communication. All transmissions must be finished before the end of the superframe, i.e., before the beginning of the inactive period.

- If some guaranteed QoS is to be supported, then a Contention-Free Period (CFP) is defined. The CFP consists in Guaranteed Time Slots (GTSs) that may be allocated by the PAN coordinator to applications requiring low-latency or specific data bandwidth requirements. The CFP is a part of the superframe and starts at a slot boundary immediately following the CAP. The PAN coordinator may allocate up to seven GTSs and each GTS may occupy more than one time slot. With this superframe configuration, all contention-based communication must be finished before the start of the CFP, and a node transmitting a GTS must ensure that its transmission will be complete before the start of the next GTS. According to the standard, the GTS is used only for communications between a PAN coordinator and a device. The superframe structure can have an inactive period during which the PAN coordinator does not interact with its PAN and may enter in a low power mode to reduce the energy consumption of network.
Non Beacon-enabled mode: In non beacon-enabled mode, the devices can simply send their data by using unslotted CSMA/CA. There is no use of a superframe structure in this mode. Its messages transmitted without acknowledgement & data frames that follow acknowledgment of a data requests commands.

![Superframe Structure](image)

**Superframe Structure:**
The structure of a superframe is defined by two parameters:

1. **macBeaconOrder (BO):** This Bo gives the value of the interval at which the coordinator must transmit beacon frames. The value of the macBeaconOrder and the Beacon Interval (BI) is related as follows:
   
   $BI = a \cdot BaseSuperframeDuration \times 2^{BO}$ Symbols

2. **macSuperframeOrder (SO):** this SO gives the length of the active portion of the superframe, which includes the beacon frame. The value of the macSuperframeOrder and the Superframe Duration (SD) are related as follows:

   $BI = a \cdot BaseSuperframeDuration \times 2^{SO}$ Symbols

   If SO = BO => SD = BI and then the superframe is always active. According to the standard, if SO = 15, the superframe will not be active in beacon enabled mode and the network will operate in the non beacon-enabled mode. In this case, the value of SO is ignored.

![Superframe Structure](image)

The active portion of each superframe is divided into aNumSuperFrameSlots equally spaced slots of duration 2SO aBaseSlotDuration and is composed of three parts: a beacon, a CAP and CFP.

- **Beacon:** the beacon is transmitted at the start of slot 0 without the use of CSMA. It contains the information on the addressing fields, the superframe specification, the GTS fields, the pending address fields, etc.

- **CAP:** the CAP starts immediately after the beacon frame and ends before the beginning of the CFP or the CAP ends at the end of the active part of the superframe. The minimum length of the CAP is fixed at aMinCAPLength = 440 Symbols. This minimum length ensures that MAC commands can still be transferred to devices when GTSs are being used. To increase the beacon frame length to handle the GTS a temporary reduction in this minimum may be allowed. All the transmissions during the CAP are made using a slotted CSMA/CA mechanism to access the channel. However, the acknowledgement frames and any data that immediately follows the acknowledgement of a data request command are transmitted without contention. A device that cannot complete its transmission one Inter Frame Spacing period before the end of the CAP, must defer its transmission until the CAP of the next superframe.

- **CFP:** The CFP starts immediately after the end of the CAP and must complete before the start of the next beacon frame. All the GTSs that may be allocated by the PAN coordinator are located in the CFP and must occupy contiguous slots. The CFP may therefore grow or shrink depending on the total length of all GTSs. The transmissions in the CFP are contention-free and therefore not use a CSMA/CA mechanism to access the channel. Additionally, a frame may only be transmitted if the transmission ends one IFS before the end of the correspondent GTS.

**Association & Disassociation:**
An FFD may indicate its presence by transmitting beacon frames on a PAN to other devices. This allows other devices to perform device discovery. After successfully association is done with PAN an FFD that is not a PAN coordinator shall begin transmitting beacon frames. Association of a device starts after having completed either an active channel scan or a passive channel scan. The passive scan, allows a device to locate any coordinator transmitting beacon frames within its Personal operating space whereas there beacon request command is not required for passive scan[2].

The results of the channel scan are then used to choose a suitable PAN. A device shall attempt to associate only with a PAN that is currently allowing association. Following the selection of a PAN with which to associate, the next higher layers request that MLME configures the phyCurrentChannel to the
appropriate logical channel on which to associate, macPANId to the identifier of the PAN with which to associate and macCoordExtendedAddress or macCoordShortAddress to the address of the coordinator with which it associates.

An unassociated device by sending an associate request command to the coordinator of an existing PAN should initiate the association procedure. If the request command is received correctly, the coordinator shall send an acknowledgement. This acknowledgement does not indicate that the device has associated. The coordinator needs time i.e aResponseWaitTime symbols to determine whether the current sources available on a PAN are sufficient to allow another device to associate. If already associated, remove all information. The coordinator shall allocate a short address to the device and generate an association response command containing the new address and a status indicating the successful association, if sufficient resources are available. If there are not enough resources, the coordinator generates a response command containing a status indicating failure. The device waiting in aResponseWaitTime it either checks the beacons or extracts the association response command from the coordinator after aResponseWaitTime symbols. The device shall send an acknowledgement after reception of association response command & store the addressed of the coordinator with which it has associated. When a coordinator wants one of its associated devices to leave the PAN, it shall send the disassociation notification command to the device using indirect transmission. Upon reception of the packet, the device should send the acknowledgement frame. Even if the ack is not received, the coordinator shall consider the device disassociated. Same way if device want to leave the PAN it shall send a disassociation notification command to the coordinator & Even if the ack is not received, the device shall consider itself disassociated. An associated device shall disassociate itself by removing all references to the PAN.

Synchronization:
The standard defines mechanisms to synchronize the coordinators with their associated devices. This is important in beacon-enabled mode where each associated device must synchronize its transmission with the beacon transmissions from its coordinator. Hence, for PANs supporting beacons, synchronization is performed by receiving and decoding the beacon frames. For beaconless PANs, synchronization is performed by polling the coordinator for data.

Transmission:
In a beacon-enabled PAN, a device that wants to transmit data must locate the beacon frame of its coordinator and sends its data according to the superframe structure, using slotted CSMA/CA in the CAP or within its allocated GTS. In a non beacon-enabled mode, each device simply uses the unslotted CSMA/CA mechanism to transmit data.

Reception:
Any device may receive transmission from all devices and using the same channel, provided that these devices are in its POS. The MAC sub-layer must be able to filter unwanted frames. The filter depends on whether the MAC sub-layer is operating in promiscuous mode or not. In promiscuous mode, the MAC sub-layer discards all received corrupted frames, i.e. frames that do not contain a correct value in their FCS field.

GTS:
A Guaranteed Time Slot is a portion of the superframe that is dedicated to a given device. The GTS allows the corresponding device to access the medium without contention in the CFP. A GTS can only be allocated by the PAN coordinator, and it must be used only for communications between the PAN coordinator and a device. A single GTS may extend over one or more superframe slots. The PAN coordinator may allocate up to seven GTSs at the same time, provided that there is sufficient capacity in the superframe. The GTS must be allocated by a device before use and can be deallocated at any time at the discretion of the PAN coordinator or the device that originally requested the GTS. A device to which a GTS has been allocated can also transmit during the CAP. The PAN Coordinator is the responsible for performing GTS management. The PAN must have enough resources to store all required information to manage the seven potential GTSs. For each GTS, the PAN coordinator stores its starting slot, length, direction, and associated device address. All these parameters must be embedded in the GTS request command. The GTS direction specifies if the direction of data flow is from the device to the coordinator or from the coordinator to the device. Each device may request one transmit GTS and/or one receive GTS. A device is able to allocate and use a GTS only if it is currently tracking the beacons. If synchronization with the PAN coordinator is lost, all its GTS allocations will be lost. In extreme situations, the PAN coordinator may de-allocate one or more GTSs to preserve the minimumCAP length.

IV. PERFORMANCE EVALUATION

We are going to implement IEEE 802.15.4 MAC protocol in Network Simulator 2. Ns-2 is a powerful network simulator. It provides substantial support for simulation of TCP, routing, multicast protocols over wired and wireless networks, etc[9]. A rich set of protocol objects can then be attached to nodes, usually
as agents. The simulator suite also includes a graphical visualizer called network animator (Nam) to assist the users get more insights about their simulation by visualizing packet trace data. NS-2 is written in C++, with an Tcl interpreter as a front-end. The C++ defines the internal mechanism of the simulation objects, the OTcl sets up simulation by assembling and configuring the objects as well as scheduling discrete events. The C++ and the OTcl are linked together using TclCL NS2 outputs either text-based e.g. trace files or animation-based simulation results. Now, having this trace at hand would not be useful unless meaningful analysis is performed on the data.

For finding the performance of 802.15.4 MAC protocol in NS2 different parameters are checked with Peer to Peer Tree topology of a network & use of AODV routing protocol is used for routing. For simulation of 802.15.4 one node is nominates as PAN coordinator which will control the communication between cluster heads. Each node is finds its cluster head or parent node & communicates with other node through it. Different parameters like lifetime, End to End delay, and throughput of network need to be calculated

End to end delay =Received Packet Time- Sent Packet Time
Throughput= No. of correctly Received bits to the Transmitted packets.
Jitter =Actual Transmission time-Expected Transmission Time

Here in the Graph we have compare the 802.15.4 MAC that is Interference Avoidance MAC protocol with S-MAC Protocol. In Fig 5 Average delay of SMAC is higher than the IAMAC due to use of RTS/CTS transmission between the nodes to avoid collision but in 802.15.4 RTS/CTS is avoided to reduce overhead of control packets as well as delay.

In Fig 6 we have compare channel utilization of the SMAC & IAMAC. We got higher throughput for 802.15.4 than SMAC due to use of super frame structure which allowed no of transmission of data packets during a frame. Therefore fully utilizes the channel to have higher throughput.

CONCLUSION

In this paper we simulated IEEE 802.15.4 MAC to find the performance of wireless sensor networks in terms of lifetime, delay & throughput. It also reduces interference to increase lifetime & good quality of communication. It uses tree topology & AODV routing protocol which reduces control packet overheads. Use of superframe structure increases throughput & reduces end to end latency. According to the results this MAC provides higher lifetime compared to S-MAC while its end-to-end latency is less than S-MAC. Avoids collision using CCA will reduces energy consumption provides higher network Lifetime.

REFERENCES

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