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Comparative Study of Queen-MAC, TC-MAC and OD-MAC Protocols in Wireless Sensor Networks

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Abstract— Wireless sensor networks (WSNs) have become a leading solution in many important applications such as intrusion detection, target tracking, industrial automation, smart building and so on. MAC protocol of wireless sensor network research is the key problem. From the basic ideas, the paper introduces three MAC protocols i.e. Queen-MAC, TC-MAC and OD-MAC protocol in detail, which are analyzed and compared based on performance parameters, and finally summarizes the problems of MAC protocols and possible research direction in future combined with the current research status.

Keywords— Wireless sensor networks, MAC protocols, Performance parameters, energy efficiency, throughput.

I. INTRODUCTION

Wireless sensor networks are a new generation of sensor networks, have a very wide range of applications, their development and application will bring about far-reaching impact in human life and production of all areas. However, the most noteworthy limitation of the WSN is that every sensor node is operated by a built-in battery, which is hard to recharge or replace. Reducing unnecessary energy consumption is therefore a very important challenge that has been addressed at each layer of the protocol stack. Our specific focus is the medium access control (MAC) because MAC can control the on and off states of the wireless interface to enhance energy efficiency.

The protocols designed for WSNs greatly depend on the applications for which the network has been established. Nonetheless, in many applications, one of the more serious challenges is how to increase the network lifetime now limited by the energy restriction of sensor nodes. Several factors are involved in the energy loss of nodes: collisions, retransmissions, idle listening, overhearing, and protocol overhead. The radio of a sensor node uses more power. The node usually turns its radio off, goes to sleep mode to save energy, and wakes up according to its predetermined schedule to transmit data. This method is called a duty cycling or a sleep scheduling, which is widely proposed for use in the Medium Access Control (MAC) protocol of multi-hop networks.

If designed properly, a MAC protocol can result in low power consumption and consequently increase the network lifetime. Most MAC protocols proposed for WSNs are based on the use of a single channel [3-16]. Such MAC protocols, especially in high-density deployments, increase collisions as well as end-to-end delay, and ultimately reduce the network lifetime. Several multi-channel MAC protocols [3-18] have been proposed recently with various objectives, e.g., handling burst traffic, fairness, reliability in data collection, evading external interference, improving throughput, and end-to-end delay. However, energy saving is still an important issue.

The remainder of this paper is structured as follows. The studies on MAC protocols are summarized in Section II. Comparison study of MAC protocols in Section III is being focused. Finally, a conclusion is done and potential research directions are identified in Section IV.

II. STUDY OF MAC PROTOCOLS

Media Access Control (MAC) data communication protocol is a sub layer of the data link layer, which itself is layer 2. The MAC sublayer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet. When developing new protocols, it is necessary to investigate all the previous

studies thoroughly. There has been a tremendous amount of research on the design and implementation of MAC protocols in WSNs. Hence, surveys of WSN MAC protocols are conducted to summarize the varieties of designs and implementations.[2]

A. Queen-MAC Protocol

This protocol independently and adaptively schedules nodes wake-up times, decreases idle listening and collisions, increases network throughput, and extends network lifetime. Queen-MAC is highly suitable for data collection applications. A new quorum system, named dygrid, is proposed that provides an adaptive and low duty cycle. Dygrid can provide various rendezvous points and decrease network sensibility when used in a network. A network model for data collection applications is proposed and analyzed. Moreover, a lightweight channel assignment method is also proposed, which only depends on the group number of nodes. Dygrid quorum system and the proposed channel assignment method are utilized to propose an adaptive energy-efficient MAC protocol called Queen- MAC for data collection applications in wireless sensor networks, even though it can be used for data dissemination as well.[3]

Queen-MAC provides multi-channel access to the medium while it manages sleep/wake-up of nodes, independently. Simulations in OPNET Modeler 14.0 show that Queen-MAC increases the network lifetime while it reduces network latency. Simulations indicate that Queen-MAC surpasses QMAC and TMCP in various traffic loads while provides a lower average latency and higher delivery ratio. It also shows that the performance of Queen-MAC is more significant in higher node densities [3].

B. TC-MAC Protocol

Transport-controlled MAC protocol (TC-MAC) combines the transport protocol into the MAC protocol with the aims of achieving high performance as well as energy efficiency in multi-hop forwarding. Transport-controlled MAC (TC-MAC) protocol targeted to provide a low end-to-end latency, high throughput, and lightweight congestion control, without sacrificing the energy efficiency earned from the periodic listen-and-sleep scheme. The periodic listen-and-sleep scheme remains one of the best ways to eliminate idle listening, and TC-MAC is also based on it. However, TC-MAC uses the listen period more efficiently by supporting multi-hop channel reservations; it then uses the sleep period for data transmission according to the prior reservations. To utilize the sleep period more efficiently, TC-MAC allows data packets to contain schedule information for subsequent data so that further data can be transmitted.[4]

TC-MAC can therefore forward a greater amount of data through more hops as compared to previous MACs using the periodic listen and sleep scheme. In addition, TC-MAC supports the congestion control mechanism in a MAC-layer with a light overhead. The MAC-layer can trace how a shared channel is used by each flow, so TC-MAC traces the channel usage information through a traffic monitor, and then regulates the transmission rate of traffic flow sources in a way that achieves fairness among traffic flows. TC-MAC performs as well as an 802.11-like MAC in end-to-end latency and throughput, and is more efficient than S-MAC in energy consumption, with the additional advantage of supporting fairness aware congestion control[4].

C. OD-MAC Protocol

OD-MAC is an application-specific duty cycle adjustment MAC protocol used to decrease the probability of schedule misses of nodes. The goals of the proposed MAC protocol are twofold: (i) to conserve energy on nodes with low data traffic, and (ii) to decrease transmission latency on nodes with heavy data traffic. In the proposed scheme, nodes are not required to follow a single generic duty cycle. Each node can have different listen and sleep schedules with different duty cycles. Additional wake-up periods can be added on the receiver node, scheduled such that the receiver is in listening exactly when the data source node is ready to send the data packet. We develop algorithms for data scheduling to allow nodes to minimize energy consumption and transmission latency. [5]

Initially, each node only has a timetable without any schedule. The synchronizer broadcasts a generic synchronization packet and establishes the generic schedule for all nodes. After all nodes follow the generic schedule, a node that collects data periodically can send an application-specific synchronization packet for the on-demand data schedule. When a node receives the specific synchronization packet, the node adds a specific schedule into its timetable as that sent by the sender. When a node receives a another schedule from other nodes, it adjusts its timetable to satisfy the request if there have available time periods can be arranged. Some neighboring nodes may be failed to send data to the receiver at active time due to signal collisions on the radio

channel, the sender will go to sleep state for energy conserving and wait for next wake-up time to try to transmit data again[5]

TABLE I: COMPARISON STUDY OF MAC PROTOCOLS

	Queen-MAC Protocol	TC-MAC Protocol	OD-MAC Protocol
Energy Conservation	Excellent	Good	Very Good
Network Life Time	Very Good	Good	Excellent
Average packet delay ratio	Excellent	-----	Very Good
Packet latency	-----	Good	Very Good
Multipath	Yes	Yes	Yes
Low duty cycle	Yes	Yes	Yes

III. Comparison of MAC Protocols

With the traditional data link layer protocols, MAC protocol of wireless sensor networks has new

Features and requirements:

- Energy consumption
- Adaptive and low duty cycle
- Decrease idle listening
- Decrease collision
- Increase network throughput
- Extend the network lifetime
- Increase average delivery ratio
- Improve the network coverage

Described above is mainly based on MAC protocol which relevant to applications and difficulty of wireless sensor, the protocol is difficult to say which is more superior. Based on the performance requirements above, here is the comparison of MAC protocols described in Table I.

As shown in the Table I, energy consumption of Queen-MAC Protocol is best as compare to TC-MAC and OD-MAC protocols. Network life time of OD-MAC protocol is better than other MAC protocols. Also average packet delay ratio of Queen-MAC protocol is better as compare to OD-MAC and TC-MAC protocol. Packet latency of OD-MAC protocol is best as compare to other protocols. All theses protocols are multi-channel, multi-hop MAC protocols.

IV. Conclusion

Recent development in MAC protocols have been surveyed in this paper. Eight MAC protocols according to different parameters as explained. Through simulations, it is observed that Queen-MAC performs better than OD-MAC protocol with lower power consumption and lower latency in a random topology. OD-MAC protocol is better from other protocols in case of network life time. Queen-MAC protocol is better in case of Idle listening as compare to OD-MAC and TC-MAC protocol. Average packet delay ratio is less in TC-MAC as compare to OD-MAC and Queen-MAC Protocol. It is observed by varying the value of speed of mobility and the handover threshold that high delay was there in TC-MAC as compare to Queen-MAC and OD- MAC as both are for multi-hop wireless sensor networks.

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