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HYBRID CSMA/CA-TDMA BASED MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor network consists of several tiny sensor nodes connected to each other in Ad hoc environment and coordinate with each other to form a network. The sensor nodes are typically battery powered, energy optimization and efficiency is extremely important in WSNs. Such networks have the ability to be self organized and failure-adaptive to provide an efficient and reliable network. Wireless sensor networks have a wide variety of applications such as intruder alert and tracking, environmental monitoring, industrial process monitoring, and tactical systems. In wireless sensor network deployments, reliably reporting data while consuming the least amount of power is the ultimate goal. Energy conservation is needed especially at MAC layer level. Medium access control (MAC) is an important technique that ensures the successful operation of the network. The performance of MAC protocols in congested wireless networks can be enhanced by the combined carrier-sense multiple access with collision avoidance (CSMA/CA) with that of time-division multiple access (TDMA). One of the main functions of the MAC protocol is to avoid collisions from interfering nodes and enhance the channel access performance in wireless networks. Designing power efficient MAC protocol is one of the ways to prolong the life time of the network. The proposed hybrid CSMA/CA-TDMA scheme can preserve the scalability property. Hybrid CSMA/CA-TDMA Schemes uses the transmission strategies based on Markov Decision Process (MDP) to access both contention period and contention-free period. This paper also deals with the performance comparison of proposed Hybrid CSMA/CA- TDMA scheme in NS-2 simulator.

Keywords: wireless sensor networks, CSMA/CA-TDMA, MAC protocols, Markov decision process.

1. INTRODUCTION

Wireless Sensor Networks have wide applications in intrusion detection, defense, climate control, medical systems, environment monitoring, robotic exploration, smart spaces, disaster management, target tracking, wildlife habitat monitoring and scientific applications. The Wireless sensor networks are made up of one or more battery-operated sensor devices with embedded processor, small memory and low power radio. Coverage and communication range for sensor nodes compared to other mobile devices is limited due to low power capacities of sensor nodes. Sensor networks are organised of large number of nodes to cover the target area. In wireless sensor network the nodes communicate with each other to give a common task. Efficient Utilization of limited amount of energy has been the primary concern in designing MAC protocols for WSNs As there was a challenge for WSN designers is to develop a system that will run for years, they used not only robust hardware and software, but also stable energy sources.

Medium Access Control (MAC) [1] is used to avoid collisions by keeping two or more interface nodes from accessing the medium at the same moment, which is necessary to the successful operation of shared-medium networks. The unique characteristics of WSNs require an energy-efficient MAC that is quite different from traditional ones developed for wireless voice and data communication networks. The main attribute of MAC layer are power conservation, average end-to-end delay, network throughput and control overhead.MAC protocols for wireless sensor networks are usually classified into two categories; contention based and scheduled based mac protocols. In Contention-based schemes nodes access the network in random manner and competitive order which is designed for minimum delay and maximum throughput. Contention-based schemes require sensor nodes to keep their radios on to receive possible incoming messages. These schemes are not energy-efficient because of idle listening. Scheduling-based schemes are contention-free schemes in which nodes access network in scheduled manner and try to detect the neighboring radios of each node before allocating collision-free channels to a link.

The rest of the paper organized as follows. In section 2 we review different MAC protocols for wireless sensor networks. In Section 3 we explained the proposed hybrid CSMA/CA- TDMA scheme and section 5 is the conclusion.

2. RELATED WORKS

The MAC protocols taken in to account for survey are S-MAC, T-MAC, B-MAC, C-MAC, D-MAC, E-MAC, ML-MAC, LE-MAC, TRAMA and Wise MAC. Wei Ye, Heidemann and Estrin [2] proposed a MAC protocol in which the technique used is the Adaptive listening. Fixed duty cycle, virtual cluster and CSMA are the schemes used in S-MAC. Van Dam and Langendoen developed T-MAC [3], a contention-based Medium Access Control protocol for wireless sensor networks. Adaptive duty cycle, overhearing and FRTS are the schemes which are used in the T-MAC.

Polastre, Hill and Culler introduced B-MAC [4], called Berkeley Media Access Control for low power wireless sensor network that provides a flexible interface to obtain ultra low power operation, virtual collision avoidance, and high channel utilization. Sha Liu, Kai-Wei Fan and Prasun Sinha presented the design of a low duty-

cycle MAC layer protocol called Convergent MAC (CMAC) [5]. CMAC avoids synchronization overhead while supporting low latency. Gang Lu, Bhaskar and Cauligi developed DMAC [6], an energy efficient and low latency MAC that is designed and optimized for data gathering trees in wireless sensor networks. DMAC is designed to solve the interruption problem and allow continuous packet forwarding by giving the sleep schedule of a node an offset that depends upon its depth on the tree. Thomas Trathnigg, Moser and Reinhold Weiss proposed the EMAC [7], an energy efficient MAC protocol for low-traffic delay-tolerant wireless sensor networks. EMAC uses asynchronous distributed transmission scheduling to achieve high energy efficiency. Suh, Man Shrestha, and Young-Bae Ko established a medium access control protocol for delay sensitive wireless sensor networks, named LE-MAC [8] (Latency and Energy aware MAC) that aims to minimize data delivery latency as well as energy consumption.

Manish Kumar, Atul Kumar Pandeyb, Dipankar Pala and Anand Mohanc introduced an energy-efficient multi-layer MAC [9] (ML-MAC) protocol is proposed for wireless sensor networks. Venkatesh Rajendran, Obraczka and Garcia put forward the collision free traffic adaptive medium access protocol (TRAMA) [10]. TRAMA reduces energy consumption by ensuring that no collisions occur during unicast, multicast, and broadcast transmissions have, and allow the nodes to switch to a low-power in idle state. The scheme used here is TDMA. Hoiydi and Decotignie established an ultra low power MAC protocol for the downlink of infrastructure wireless sensor networks called WiseMAC [11] (Wireless Sensor MAC). WiseMAC is a novel energy efficient medium access control protocol based on synchronized preamble sampling.

3. HYBRID CSMA/CA-TDMA SCHEME

Hybrid carrier-sense multiple access with collision avoidance (CSMA/CA) and time-division multiple access (TDMA) protocols such as the IEEE 802.15.4 standard based medium access control (MAC) protocol are useful in realizing low-power and low-rate wireless networks [12]. TDMA is a collision-free channel access mechanism whereas CSMA/CA is a contention-based MAC protocol and is used by the wireless nodes to send the channel access request in a hybrid CSMA/CA-based wireless network.

Distributed and Centralized Hybrid CSMA/CA-TDMA Schemes uses the transmission strategies based on Markov decision process (MDP) to access both contention period and contention-free period. In order to check whether a channel is free for transmission CSMA/CA required a carrier sensing. For transmitting the packets during contention access period (CAP) the node competes with other nodes and sends the packets to coordinator using the CSMA/CA mechanism. But during the contention-free period (CFP), the node can transmit packets in a collision-free manner using TDMA slots without any carrier sensing.

Table-1. Comparison of different MAC protocols.

Protocol	Type	Technique used	Scheme used	Energy saving	Latency	Energy efficiency	Throughput	Advantage	Disadvantage
SMAC	Contention based	Adaptive listening	Fixed duty cycle, virtual cluster, CSMA	Power savings over standard CSMA/CAMAC	Low	Medium	Low	Low energy consumption when traffic is low	Sleep latency, problem with Broadcast
TMAC	Contention based	Future request to send	Adaptive duty cycle, overhearing, FRTS	Uses 20% of energy used in S-MAC	High	High under variable traffic	Low	Adaptive active time	Early sleeping Problem
BMAC	Contention based	Low power listening	LPL, channel assessment software interface	Better power savings, latency, and throughput than S-MAC	High	Low	Medium	Low overhead when network is idle, simple to implement, Consumes less Power	Overhearing, bad Performance at heavy traffic. Long transmission latency
CMAC	Contention based	Avoids synchronization overhead	Aggressive Ack. Anycast. convergent packet forwarding	Consumes less energy than existing solutions	Low	High	High	High throughput, low latency & consumes less energy	Mainly designed for low duty cycles
DMAC	Contention based	Staggered schedule	Converge cast communication	Energy saving and low latency	Low	Low	High	Energy saving and low latency	Aggregate rate is Larger

TRAMA	Contention based	Adaptive assignment	TDMA	Higher energy efficiency & throughput	Low	Low	High	Higher energy efficiency & throughput	Time is divided into random access period
Wise MAC	Contention based	Synchronized preamble sampling	Minimized preamble sampling, schedule	Better than SMAC and Low Power Listening	High	Medium	Medium	Low power for low traffic, Do not incur overhead due to synchronization	Energy consumption at sender and receiver, and at non target receiver, increase latency at each hop

A node sends a reservation request for TDMA slot by using CSMA/CA during CAP if it requires a certain bandwidth. The coordinator checks the availability of the TDMA slots and it informs the node about the allocation of the TDMA slot when it receives the request for a specified bandwidth. Congestion and collision during CAP can be reduced
by this TDMA slot allocation mechanism. The hidden node collision problem due to the signal attenuation caused by channel fading is also considered in this method.

In hybrid CSMA/CA- TDMA scheme uses two MDP-based channel access schemes, that are MDP-based distributed channel access (MDCA) and MDP-based centralized channel access (MCCA) schemes. These two schemes will help to improve the performance of hybrid CSMA/CA-TDMA for wireless sensor. Increased traffic load and channel fading causes congestion in the network. In such scenarios the proposed CSMA/CA-TDMA provides better performance than other MAC protocols. Network performance can be improved with MDCA scheme by detecting congestion in an intelligent way. Information of packet arrival rate and instantaneous buffer level at all the network nodes are required for MCCA scheme for its superior performance. Energy consumption of MCCA scheme is very less than the existing hybrid CSMA/TDMA scheme but the computational effort are high. If information about traffic of all the nodes is unknown, the MDCA scheme performs better than the traditional schemes. MDCA scheme requires does not contain information about the actions and the assignment of TDMA slots to the nodes, so the beacon frame is shorter in this scheme.

4. PERFORMANCE ANALYSIS

We use NS-2.28 simulator to study the influence of different parameters of Hybrid CSMA/CA- TDMA schemes on its performance and then we carry out a comparison of CSMA/CA- TDMA with SMAC and TMAC.

A. Packet Delivery Ratio

The ratio of the data packets delivered to the destinations to those generated by the CBR sources. It specifies the packet loss rate, which limits the maximum throughput of the network. The Figure-1 compares the delivery rate of Hybrid CSMA/CA- TDMA schemes with SMAC and TMAC.

B. Packet Drop

Packet loss occurs when one or more packets of data travelling across a computer network fail to reach their destination. Figure shows the packet drop comparison graph.

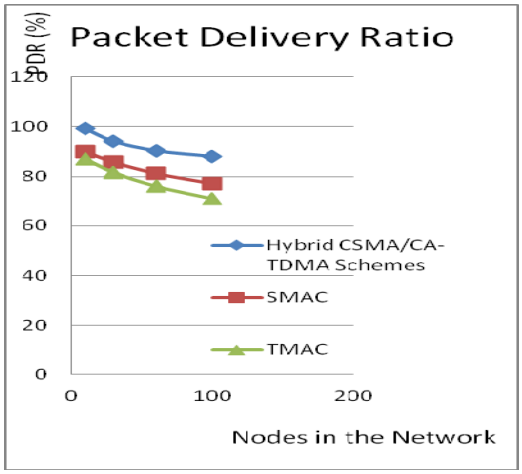

Figure-1. PDR Graph.

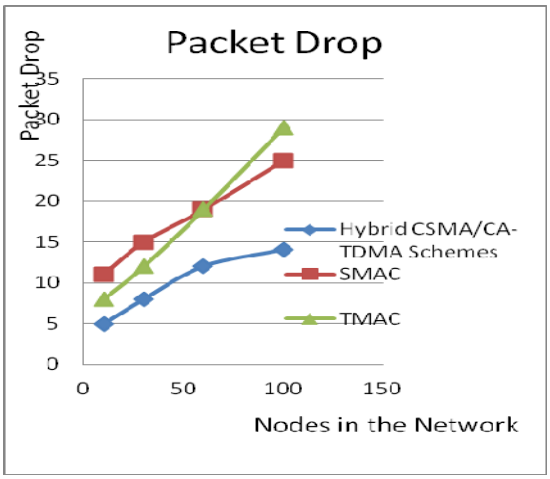

Figure-2. Packet Drop Graph

5. CONCLUSIONS

Wireless sensor networks have a wide variety of applications in almost all the fields of life. Combined carrier-sense multiple access with collision avoidance (CSMA/CA) with that of time division multiple access (TDMA) improves the performance of MAC protocols in

congested wireless networks. The proposed hybrid CSMA/CA-TDMA Schemes uses the transmission strategies based on Markov Decision Process (MDP) to access both contention period and contention-free period. Proposed scheme uses two MDP-based channel access schemes, that are MDP-based distributed channel access (MDCA) and MDP-based centralized channel access (MCCA) schemes. MDCA scheme performs well under congestion in the networks and information about traffic of all the nodes is unknown. The beacon frame is shorter for the MDCA scheme. Energy consumption of MCCA scheme is very less than the existing hybrid CSMA/TDMA scheme but the computational effort are high.

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