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Implementation of an Adaptive MAC Protocol in WSN using Network Simulator-2

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ABSTRACT- A Wireless Sensor Network (WSN) consists of a large number of sensor nodes which are distributed over an area to perform local computations based on the information collected from the environment. In the network each node is equipped with a battery, which is almost very difficult to change or recharge. To save the energy and to increase the lifetime of battery powered sensor devices, this paper introduce a technique of adaptive sleep-wake up period. This sends sensor nodes to sleep mode when there is no data for transmission and makes the sensor nodes to wake-up before transmission takes place i.e. by dynamically changing the sleep-wake up period of each sensor nodes depending on the the incoming traffic rate. The results of the proposed Adaptive MAC protocol is simulated and analyzed to see an improvement of energy consumption without affecting the throughput and latency parameters as compared to the existing fixed duty cycle protocol. This method does not affect the transmission delay in large extent. The implementation of this method is carried out using NS-2.34 simulation tool.

Keywords: Wireless Sensor Network, Batteries, adaptive, sleep-wake up, NS-2.34, energy.

I. INTRODUCTION

A distributed system having a large number of small battery-powered devices sensing and collecting information about the environment is called a Wireless Sensor Network (WSN) [1]. In WSN, a node is made up of a sensor, embedded processor, adequate amount of memory and transceiver circuitry [2]. The smart sensors in WSN have a limited battery life and low rate radio communication [3].

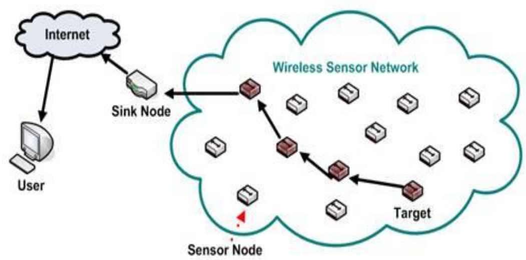

Figure 1: Basic Wireless Sensor Network architecture [4].

The sensor node consists of central unit, communication module with limited powered battery. As shown in the figure 1 the nodes in the WSN are deployed in an infrastructure free environment where the prior knowledge about the network topology is unknown.

WSNs are now used in many civilian applications including the environment and habitat monitoring due to various advantages arising from their inexpensive nature, limited size, weight and ad hoc methods of deployment.

A sensor node is a tiny device that includes three basic components, such as a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and also a wireless communication subsystem for data transmission. In addition, a power source supplies the energy needed by the device to perform the programmed tasks as shown in figure 2.

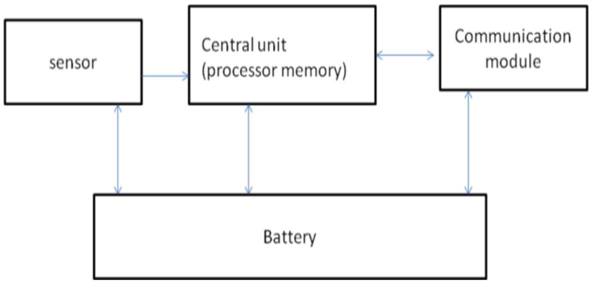

Figure 2: The Sensor node architecture.

The rest of the paper is organized as follows. Sections II explains the energy conservation mechanisms, section III the conventional MAC protocols for energy saving. Section IV gives the proposed Adaptive MAC protocol, section V highlights and discusses the simulated results to compare results of adaptive MAC protocol with the conventional MAC protocol. Finally, Section VI concludes the paper.

II. ENERGY CONSERVATION MECHANISMS.

The large amount of energy is consumed in wireless sensor network due to the basic operations like;

Collision: Collision occurs when two or more nodes want to transmit the data at the same time. The packets can get corrupted and it may be required to be retransmitted. So a lot of time and energy gets wasted during this transmission and reception. Collisions should be avoided because of the extra energy wasted in frame retransmission.

Overhearing: Overhearing is the energy consumed by the nodes by being constantly listening and decoding the frames that are not for them.

Idle listening: Idle listening refers to the energy consumed by the nodes while constantly monitoring the network and ready to receive signals while there is no activity in the network.

Control packet overhead: These Control Packets do not contain any application data but are essential for the communication. The transmission and reception of these packets is overhead on the sensor network. Control messages and long headers in frames need to be avoided as much as possible, as they imply extra expensive communication costs.

III. THE CONVENTIONAL MAC PROTOCOLS FOR ENERGY CONSERVATION.

The different energy efficient conventional MAC protocols for WSNs are Sensor-MAC, Time-out MAC Barkely-MAC, X-MAC etc. The basic ones are discussed as below.

A Sensor MAC

The Sensor MAC (S-MAC) protocol was introduced in [5] to solve the energy consumption related problems of idle listening, collisions, and overhearing in WSNs using only one transceiver. S-MAC considers that nodes do not need to be active all the time given the low sensing event and transmission rates .The S-MAC protocol is shown in Figure 3.

The S-MAC supports multi-hop operation and it has some key features such as: Periodic listen and sleep time, Collision avoidance, Overhearing avoidance. The S-MAC protocol has fixed duty cycle.

There are two states in a time frame: active state and sleep state. S-MAC [7] adopts an effective mechanism to solve the energy wasting problems, that is periodical listening and sleeping. When a node is idle, it is more likely to be asleep instead of continuously listening to the channel. S-MAC reduces the listen time by letting the node go into periodic sleep mode.

The main drawback of S-MAC [6] is the use of fixed duty cycle as this result in considerable amount of energy waste, since the communication subsystem is activated even though no communication takes place.

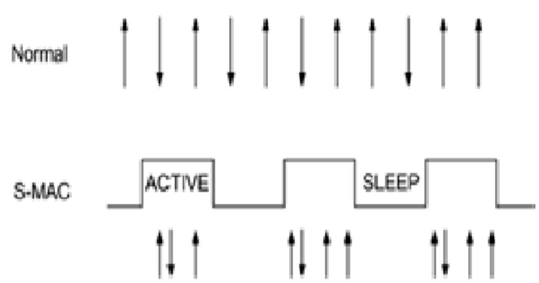

Figure 3: The S-MAC Protocol [6].

B. Timeout-MAC

The Timeout-MAC (T-MAC) protocol [5] introduces the idea of having an adaptive active/inactive (listening/sleeping) duty cycle to minimize the idle listening problem and to improve the energy savings over the classic CSMA and S-MAC based protocols [7].

T-MAC also reduces the inactive time of the sensor nodes compared to S-MAC. Hence, it is more energy efficient than S-MAC. The T-MAC protocol is shown in figure 4. The T-MAC protocol suffers from the known early sleep problem, which reduces the throughput.

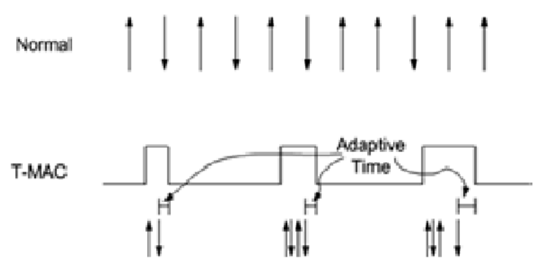

Figure 4: The T-MAC Protocol [6].

IV. PROPOSED ADAPTIVE MAC PROTOCOL FOR ENERGY CONSERVATION.

The Adaptive-MAC (A-MAC) protocol introduces an adaptive duty cycle mechanism, which lets the length of cycle to increase in an exponential style according to the traffic for energy conservation and latency reduction requirements.

A-MAC protocol is fundamentally different approach from previously proposed protocols in that each node can adjust its own sleep and wakeup period dynamically depending on the traffic .When a node is participating in the communication, the node can operate with a higher duty cycle. When a node is idle for a longer period of time, the node lowers its duty-cycle.

Adaptive Active Period

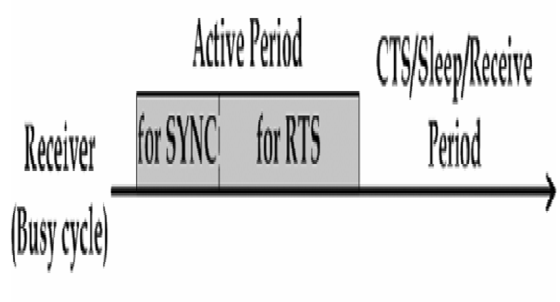

Figure 5 (a): A-MAC protocol with Adaptive active period of busy receiver [8].

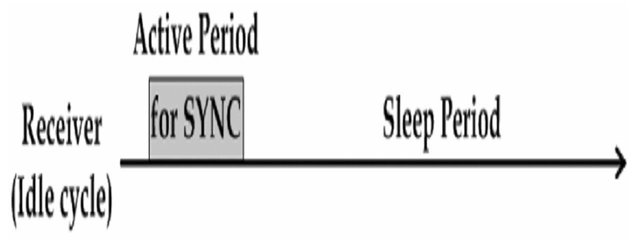

Figure 5 (b): A-MAC protocol with Adaptive active period of an idle receiver [8].

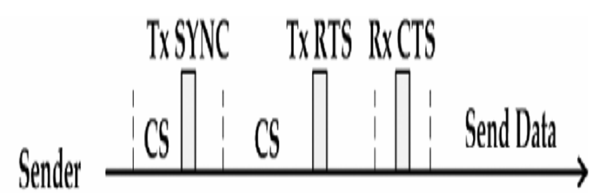

Figure 5 (c): A-MAC protocol with Adaptive active period Busy sender [8].

In A-MAC, each node can dynamically adjust the duration of its active period depending on the traffic. The idea is that if there is no traffic in a cycle, it removes the unnecessary RTS/CTS periods from the active period. The SYNC packet contains an extra bit called preamble bit at the beginning of the packet as depicted in figure 5(a). If this bit is set, then the SYNC packet tells all the listeners to extend their wakeup period to include RTS period since RTS and CTS will follow in this cycle. Thus, if a node has a data packet to transmit, it first constructs a SYNC packet by setting this preamble bit and broadcasts the SYNC packet to all of its listeners during SYNC period[8]. This special SYNC packet is called communication SYNC while the regular SYNC packet is called clock SYNC.

Thus, a receiver node first checks SYNC packet and if this preamble bit is set, the node extends its active period to listen for RTS packet [9].Otherwise, the node goes back to sleep immediately.

V. RESULTS.

A. NS-2 SIMULATION TOOL

Network Simulator (Version 2), widely known as NS2, is simply an event-driven simulation tool that has proved useful in studying the dynamic nature of communication networks. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2.

NS-2 is a discrete event network simulator that has begun in 1989 as a variant of the REAL network simulator. Initially intended for wired networks, the Monarch Group at CMU have extended NS-2 to support wireless networking for wireless network as well. Most WSNs routing protocols are available for NS-2, as well as an 802.11 MAC layer implementation NS-2's code source is split between C++ for its core engine and OTcl, an object oriented version of TCL for configuration and simulation scripts. The combination of the two languages offers an interesting compromise between performance and ease of use.

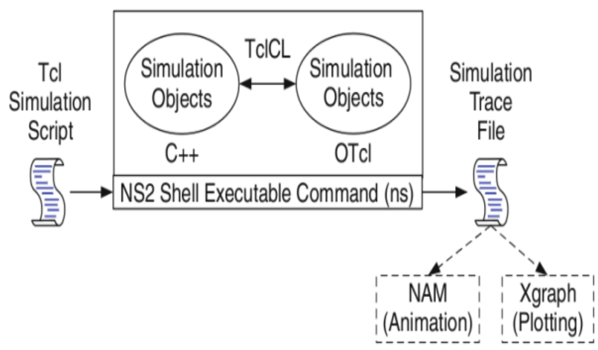

Figure 5: Basic Architecture of NS2 [11]

B. RESULTS OF A-MAC PROTOCOL

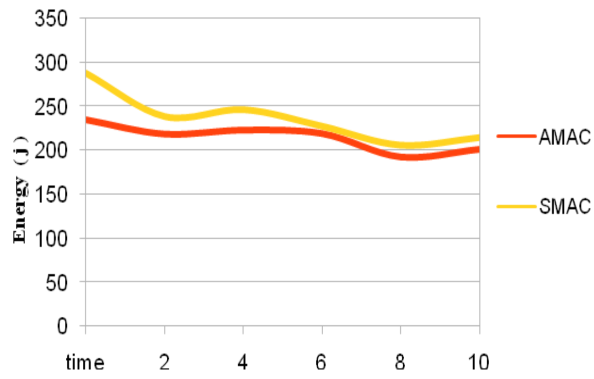

Figure 6: The average per-node energy consumption in terms of the packet inter-arrival time.

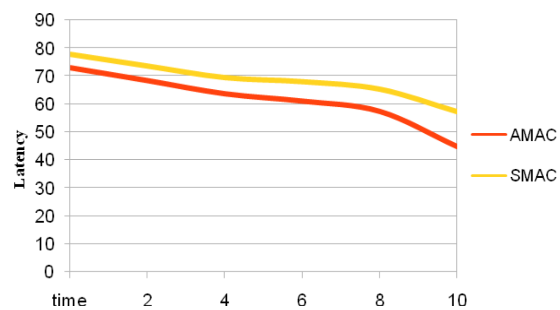

Figure 7: The average packet latency in terms of the packet inter-arrival time.

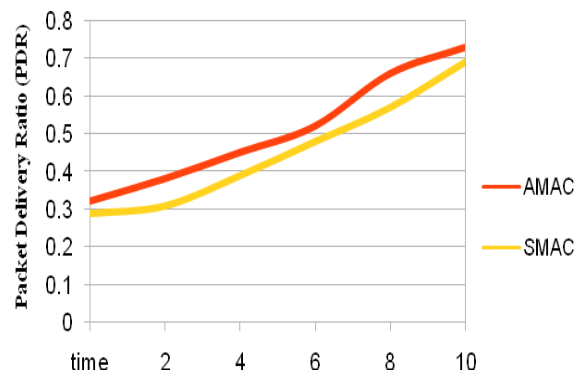

Figure 8: The average packet delivery ratio in terms of the packet inter-arrival time.

Before simulating any MAC protocol using NS-2.34 simulation tool, the various parameters needs to be set. The first step is to set the wireless parameters as below. The physical channel as Wireless Channel, radio propagation model as TwoRayGround , type of antenna as OminiAntena, MAC layer protocol as Adaptive MAC (A-MAC), routing protocol as AODV. The length of queue is set to 50, and number of sensor nodes are set to 100 and placement of nodes in terms of distance of 500m and 500m with respect to X and Y co-ordinates respectively. The ns-2.34 is an event-driven simulator, and therefore by default it takes calendar scheduler. The other types of schedulers are Heap and list. The next step is to open the trace and Network Animator (NAM) files to analyze and monitor the simulated network output. Further is to create number of nodes and assign the traffic for each node in terms of bytes (512) Packet Size _ 512. The traffic is assigned to each node depending on the Sink node and adjusts an adaptive duty-cycle dynamically depending on the traffic during simulation.

The final step is to set the simulation termination time. The termination time must be greater than scheduled events that occur in sensor network. Otherwise this leads to inappropriate output after simulation. In this paper the simulation start time is set to 1.0 sec and simulation stop time is set to 200 sec.

VI. CONCLUSION

The energy conservation is the most important concern in Wireless Sensor Network. The different MAC protocols are designed for energy reduction in relation to the different issues of a sensor network. In this paper design of media access control (MAC) protocol called AMAC is discussed for WSN, in that each node can adjust the duration of its active period interval depending on the variable traffic rate. This leads to a variable duty-cycle operation as compared to the fixed duty-cycle operations. Further this would allow us to achieve both high performance and low energy consumption. Since busy nodes can work with the highest duty-cycle while idle nodes can work with the lowest duty-cycle. It has been shown from the simulation results of AMAC protocol, an approximation energy reduction of 9.76 Joules is achieved compared to the conventional fixed duty cycle MAC protocol.

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