Delay Sensitive and Longevity of Wireless Sensor Network Using S-MAC Protocol

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Abstract: ***In WSN, delay sensitive means minimizing the delay of event driven wireless sensor network for which events occur occasionally by using asynchronous sleep wake scheduling protocol (SWSP). SWSP can be significantly reduced the energy consumption without incurring the communication overhead the clock synchronization needed for synchronous SWSP. In WSN most of the energy consumed through when the sensor nodes are on waiting for an event to occur. SWSP is an effective mechanism to increase the lifetime of WSN. This article presents the energy consumption by the mobile sensor nodes using 802.11 media access control (MAC) and sensor media access control (SMAC) protocols and calculates total energy consumption in the network which helps to make a good balance between energy efficiency and delay. Also the investigation report is presented which explains the throughput and end to end delay of nodes and estimate the life time of sensor networks based on delay (latency). Network Simulator-2 is used for experimentation.***

Keywords: Delay, Energy efficiency, SMAC protocol, Throughput, WSN.

1. Introduction

A WSN is a collection of nodes organized into a cooperative network. Each node consists of processing capability, may contain multiple types of memory have a RF transceiver, have a power source, and accommodate various sensors and actuators. [4] Sensors consume energy in sensing the object, processing and transmitting data. Energy consumed in processing is negligible [14]. There are four main sources of energy consumption: energy required keeping the communication radios on; energy required for the transmission and reception of control packets; energy required to keep sensors on; and energy required for actual data transmission and reception. The fraction of total energy consumption for actual data transmission and reception is relatively small in these systems, because events occur so rarely. The energy required to sense events is usually a constant and cannot be controlled. Hence, the energy expended to keep the communication system on (for listening to the medium and for control packets) is the dominant component of energy consumption, which can be controlled to extend the network lifetime. Thus, sleep-wake scheduling becomes an effective mechanism to prolong the lifetime of energy constrained event-driven sensor networks. By putting nodes to sleep when there are no events, the energy consumption of the sensor nodes can be significantly reduced. However, it is well known that sleep-wake scheduling can significantly increase the packet-delivery delay because, at each hop, an event-reporting packet has to wait for its next-hop node to wake-up. Such additional delays can be detrimental to delay-sensitive applications.

MAC is an important technique that enables the successful operation of the network. MAC for WSN has been a very active research area in recent years. The traditional wireless MAC protocol such as IEEE 802.11 is not suitable for the sensor network application because these are battery powered. The recharging of these sensors nodes is expensive and also not normally possible. The classical IEEE802.11 MAC [3] protocol for wireless local area network wastes a lot of energy because of idle listening problem in wireless networks can be minimized by putting the radio into sleep mode.

This paper presents the suitability of current network simulators to evaluate the total energy consumption by using 802.11 MAC protocol. It is also estimate the lifetime of WSNs. In order to understand the requirements of a simulator, section II provides an overview of energy efficient WSNs. Section III present the related work of S-MAC protocol design and problem with S-MAC protocol. In section IV we study the delay analysis of S-MAC protocol for WSN. In section V we provide the simulation & results that illustrate the superior performance of our proposed solution.

The energy components of a typical wireless sensor node are shown in Figure. 1.

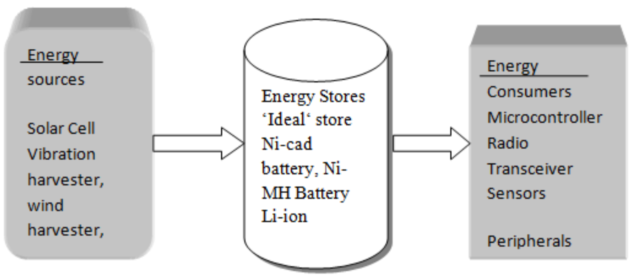

Figure 1: Energy components of a typical wireless sensor node

Energy is provided to the node from an energy source, whether this is a form of energy harvesting from sources such as solar, vibration or wind, or a resource such as the mains supply or the manual provision and replacement of primary batteries. Energy obtained from the energy source is buffered in an energy store; this is usually a battery or super capacitor. Finally, energy is used by the node's energy consumers; these are hardware components such as the microcontroller, radio transceiver, sensors and peripherals.

2. Related Work

The most known MAC protocol for wireless networks is IEEE 802.11 which is the standard now for WLAN applications [13]. The performance of IEEE 802.11MAC is good in terms of End-to-end delay and throughput but it is very undesired in terms of energy consumption because of the (idle listening) problem issued with it. When the node is in idle listening state it is been proved that the node consumes energy equivalent to the receiving energy that is why this protocol is not preferred for WSNs applications. Wei et al, presented sensor-MAC (S-MAC), a contention based MAC protocol designed explicitly for wireless sensor networks [13]. The primary goal of design MAC protocol is minimizing energy consumption and has good collision avoidance capability. It achieves efficient energy consumption by using a scheme of periodic listen and sleep reduces energy consumption by avoiding idle listening. It uses synchronization to form virtual clusters of nodes on the same sleep schedule. These schedules coordinate nodes to minimize additional latency. The protocol uses the same mechanism to avoid the overhearing problem and hidden channel problem that is used in IEEE 802.11 MAC protocol. S-MAC has a problem of latency because of periodic listen and sleep scheme which is fixed depending on the duty cycle [9].

1. S-MAC protocol Design

This paper proposes, a medium-access control (MAC) protocol designed for WSNs. One mechanism used to reduce energy consumption is to periodically turn off the radio receivers of the sensor nodes in a coordinated manner. S-MAC may require nodes to follow sleep wake schedules [2]. A modification of the protocol is then proposed to eliminate the energy consumption by using sleep-wake scheduling policy. The new version S-MAC of 802.11 MAC improves the energy efficiency, Delay and the throughput and hence increases the lifetime of a WSN.

WSNs use battery-operated computing and sensing devices [2]. We expect sensor networks to be deployed in an ad hoc fashion, with nodes remaining largely inactive for long time, but becoming suddenly active when something is detected. These characteristics of sensor networks and applications motivate S-MAC that is different from traditional wireless MACs such as IEEE 802.11. S-MAC uses a few novel techniques to reduce energy consumption and support self-configuration. It enables low-duty-cycle operation in a multi-hop network. Nodes form virtual clusters based on common sleep schedules to reduce control overhead and enable traffic-adaptive wake-up. S-MAC uses in-channel signaling to cancel overhearing unnecessary traffic. Finally, S-MAC applies message passing to reduce contention latency for applications that require in-network data processing.

2. S-MAC Protocol

The Sensor MAC (S-MAC) protocol was present in [5] to solve the energy consumption related problems of idle listening, collisions, and overhearing in WSNs using only one transceiver. S-MAC [2] reduces the idle listening problem by using periodically sleep-wake scheduling policy. Nodes are synchronized to go to sleep and wake up at the same time. In order to address the issue of synchronization over multi-hop networks, nodes broadcast their schedules to all its neighbors. This is performed sending a small SYNC frame with the node schedule periodically. S-MAC divides time in two parts: the active (listening) part and the inactive (sleeping) part. The active part is divided at the same time in two time slots. During the first time slot, nodes are expected to send their SYNC frames to synchronize their schedules. The second time slot is for data transmission in which the S-MAC protocol transmits all frames that were queued up during the inactive part. In order to send SYNC frames over the first time slot or RTS–CTS–DATA–ACK frames over the second time slot, nodes obtain access to the media utilizing the same contention mechanism included in IEEE 802.11, which avoids the hidden terminal problem and does a very good job avoiding collisions too. However, nodes using the IEEE 802.11 protocol waste a considerable amount of energy listening and decoding frames not intended for them. In order to address this problem, S-MAC allows nodes to go to sleep after they hear RTS or CTS frames. During the sleeping time, a node turns off its radio to preserve energy [7].

3. Problem with S-MAC

The following two problems have been identified in S-MAC [2] protocol.

Longer listen period: - While choosing and maintaining the listen and sleep schedule some nodes may have to keep wake during the listen time of more than one schedule [2].

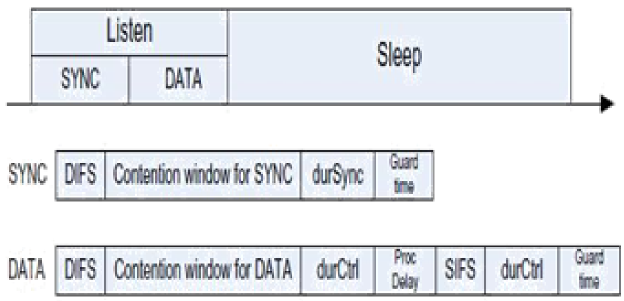

Figure2: S-MAC frame format

Sleep delay: Sleep delay introduces extra end to end delay called sleep delay [2]. Sleep delay increases communication latency in multihop networks, as intermediate nodes on a route do not necessarily share a common schedule. In a nutshell, the difficulty is to make a tradeoff between sleep delay and optimal active periods.

3. Delay Analysis

We define the end-to-end delay as the delay from the time when an event occurs, to the time when the first packet due to this event is received at the sink. We motivate this performance objective as follows:

For those applications where each event may generate multiple packets, we argue that the event reporting delay is still dominated by the delay of the first packet. This is the case because once the first packet goes through; the sensor nodes along the path can stay idle for a while. Hence, subsequent packets do not need to incur the idle delay at each hop, and thus the end-to-end delay for the subsequent packets is much smaller than that of the first packet [11].

1. Delay of SMAC over H hops

Suppose there are N hops from the source to destination. For node n, denote carrier sensing delay as tcs , transmission delay ttx , sleep delay ts , and a frame of listening and sleep cycle as Tf the average latency of S-MAC over N hops[1] is shown as:

$$E[D(N)] = NT_f - \frac{T_f}{2} + t_{cs} + t_{tx} \quad (1)$$

Now T_f is in general, much larger than (t_{cs}+t_{tx}). So the delay over h hopes is almost proportional to T_f.

T_f, is inversely proportional to the duty cycle. Then we have

$$E[D(h)] \propto T_f \propto \frac{1}{dutyCycle} \quad (2)$$

Let H denote the maximum possible number of hops of the network. Let ρ be the node density of the sensor network, the number of nodes h hops apart from the sink, N(h), is expressed by

$$N(h) = \rho(h^2 - (h-1)^2)\pi - \rho(2h-1)\pi \quad (3)$$

The main source of energy consumption is transmission and reception of packets, as well as idle listening. If the duty cycle is ideally configured with the finest granularity, the wakeup period is spent only for transmission and receptions. Then the energy consumption rate for each node h hops from the sink, E(h), is calculated as:

$$E(h) = \frac{E_{tot}(h)}{N(h)} =$$

$$\frac{\rho\lambda\pi((H^2 - h^2)E_{rx} + (H^2 - (h-1)^2)E_{tx})}{\rho(2h-1)\pi}$$

$$= \frac{\lambda((H^2 - h^2)E_{rx} + (H^2 - (h-1)^2)E_{tx})}{2h-1} \quad (4)$$

E_{tot} , E_{tx} and E_{rx} denote total energy consumption, energy consumption due to transmission and reception.

By defining ε as the ratio of E_{rx} to E_{tx}, we express the delay of S-MAC over H hops as:

4. Simulation and Results

The simulation work is conducted by using ns-2.34 [8]. By default we use 20 mobile node topology forming a 5 X 5 grid. The other simulation parameter is shown in table 1.

Table 1: Simulation Parameters

Initial Energy	1000 J
Max. packet in interface queue	250 bytes
Radio Transmission Range	30 m
Data Rate(Radio Bandwidth)	2Mbps
Idle Power	0.2 w
Receiver Power	0.5 w
Transmit power	1.0 w

Simulation topology: The following diagram shows the topology used to simulate the procedure described in the paper.

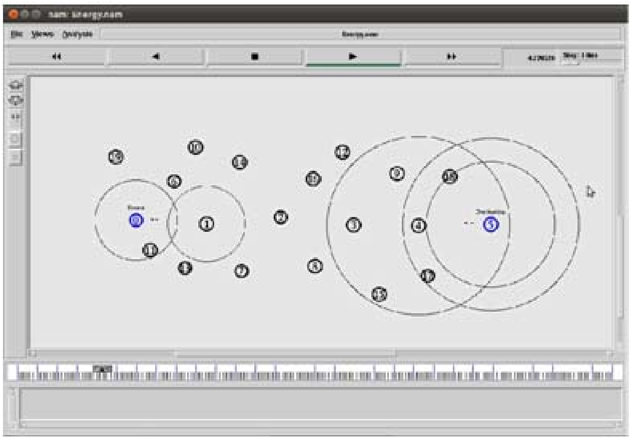

Figure 3: Simulation Topology

5. Simulation Results

The following graph figure 4 (a) shows the summation of energy consumed of all the nodes involved in process by using 802.11 MAC protocol and figure 4(b) shows energy consumed of the individual nodes involved in the communication while transferring data from source node to destination node.

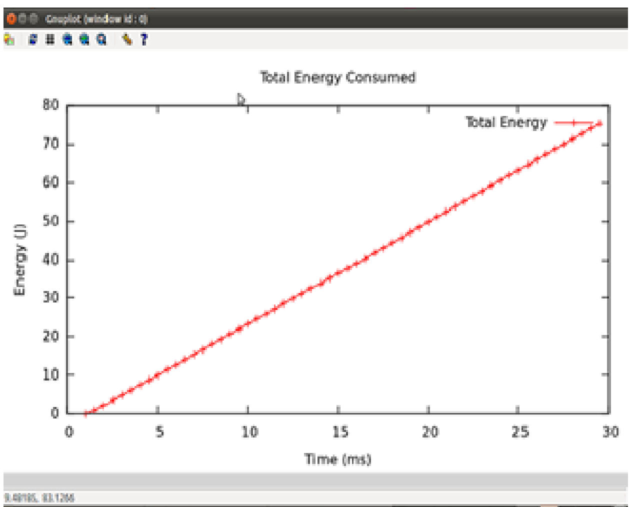

Figure 4(a): Total energy consumed

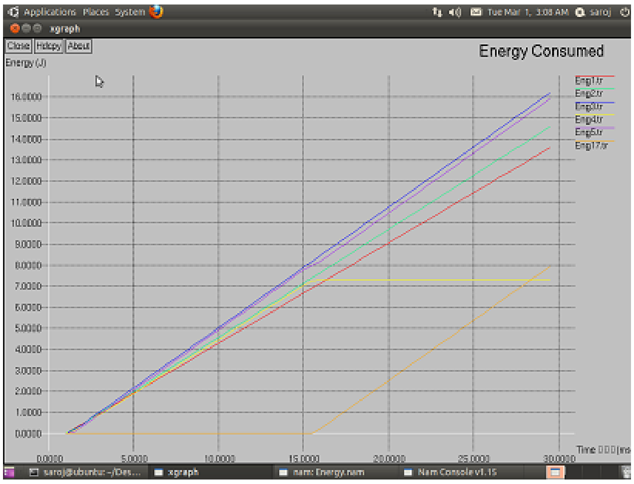

Figure 4(b): Energy consumed by used nodes

The following graph figure 5 shows the end-to-end delay of individual nodes involved in the communication process while transferring data from source node to destination node and figure 6 shows that the lifetime of sensor network based on delay while simulation time is 30 ms.

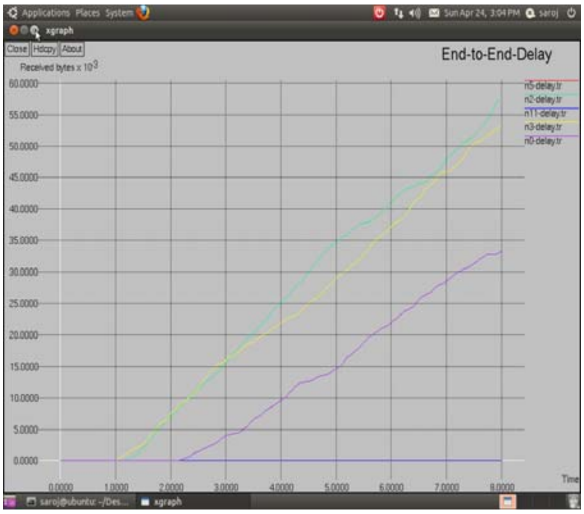

Figure 5: End-to-end delay by nodes

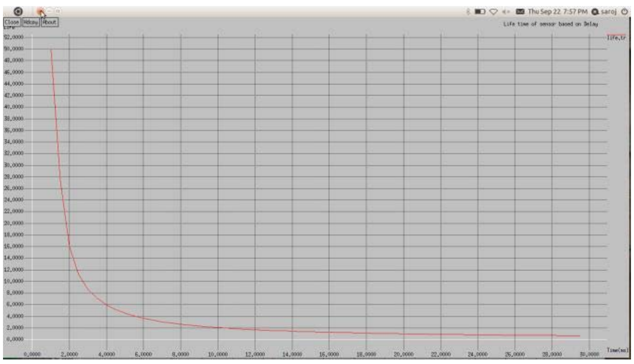

Figure 6: Lifetime of sensor based on delay

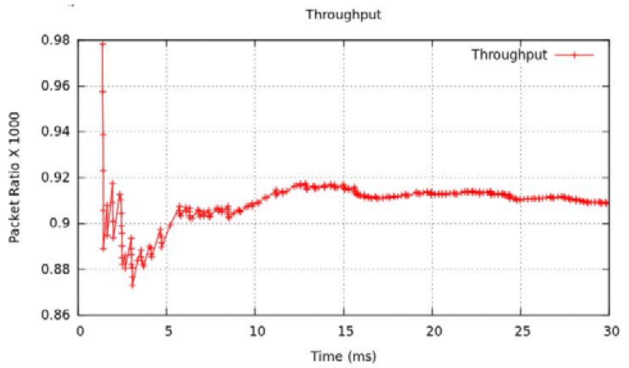

Figure 7: Throughput of the WSN

6. Conclusion

The minimization of the energy consumption is aimed to WSNs because the capacity of the power supply is limited of the sensor nodes. There is no single MAC protocol as universally minimized energy consumption for WSN, the need of protocols may vary depending on the network applications. The above paper shows the various results of energy consumption and their lifetime behavior of the various nodes of sensor networks the method applied in this paper can be extended to a bit more level to optimize the energy expenditure of the sensor network during the transmission of the data, implementation of this methodology to a more complex topology would be the future recommended work.

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