Intelligent Medium Access Control Protocol for WSN

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INTRODUCTION

This article reports an ongoing research that proposes an approach to the expansion of sensor-MAC (S-MAC), a cluster-based contention protocol to intelligent medium access control (I-MAC) protocol. I-MAC protocol is designed especially for wireless sensor networks (WSNs). A sensor network uses battery-operated computing and sensing devices. A network of these devices are used in many applications, such as agriculture and environmental monitoring.

The S-MAC protocol is based on a unique feature: it conserves battery power by powering off nodes that are not actively transmitting or receiving packets. In doing so, nodes also turn off their radios. The manner in which nodes power themselves off does not influence any delay or throughput characteristics of the protocol. Inspired by the energy conservation mechanism of the S-MAC, we unmitigated our efforts to augment the node lifetime in a sensor network. In such a network, border nodes act as shared nodes between virtual clusters. Virtual clusters are formed on the basis of sleep and wake schedule of nodes. To prolong the lifetime of the network, nodes are allowed to intelligently switch to cluster where they experience minimum energy drain. Towards this end, we propose a multi-agent system at each node. This system includes two types of agents: stationary monitoring agent (SMA) and mobile mote agent (MMA). SMA is a static agent and has the functionality to monitor the node events. MMA is a mobile agent with the ability to roam in WSN. This article focuses on the architecture of the proposed system.

BACKGROUND

Recently, there has been development and adoption of many commercial and industry wireless communication standards. WSNs are a new class of wireless networks that have appeared in the last few years. Sensor networks consist of individual nodes that are able to interact with their environment by sensing or controlling physical parameters. They perform local computation based on the data gathered and transmit the results to their neighbors. Sensor nodes need to collaborate with each other to fulfill their tasks when a single node is incapable of doing so. The range of applications of WSN is rapidly growing. Some envisaged areas of applications include monitoring the environment, assisting healthcare professionals, military communication, and precision agriculture (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002; Stojmenovic, 2006).

WSNs differ from traditional wireless networks in several ways (Akyildiz et al., 2002). First, sensor networks consist of a number of nodes and have high network density that competes for the same channel. Second, most nodes in sensor networks are battery powered, and it is often very difficult to change batteries for those nodes. Third, nodes are often deployed in an ad-hoc fashion rather than with careful pre-planning; they must then organize themselves into a communication network. Fourth, sensor networks are prone to node, network failures and self-organization. Fifth, broadcasting is the main mode of communication in sensor networks and this may cause channel contentions. Finally, most traffic in the network is triggered by sensing events, and it can be extreme at times.

These characteristics of WSNs suggest that traditional MAC protocols are not suitable for wireless sensor networks without modifications. To this end, a number of MAC protocols have been proposed for WSNs (Frazer et al., 1999; Katayoun & Gregory, 1999; Heinzelman, Chandrakasan, & Balakrishnan, 2000).

These protocols are based on different design principles, including the number of physical channels used, the way a node is notified of an incoming message, and the degree of organization. Among these protocols, sensor MAC (S-MAC) uses in-channel signaling, slot structure, and a collective listening approach per slot to reduce idle-listening problem. We believe that the design principles of S-MAC enhance the energy performance for WSNs. This motivated us to propose

an intelligent medium access protocol, which is an extension to sensor-MAC (S-MAC) integrating a multi-agent approach. This approach allows the border nodes to intelligently select a cluster that will experience minimum energy drain.

Many research efforts are being made to propose MAC protocol in the area of WSN that is energy efficient with minimum collision and increase of throughput (Katayoun & Gregory, 1999; Heinzelman, Chandrakasan, & Balakrishnan, 2000). The MAC layer is considered as a sub-layer of the data link layer in the network protocol stack. MAC protocols have been extensively studied in traditional areas of wireless voice and data communications. Time division multiple access (TDMA), frequency division multiple access (FDMA), and code decision multiple access (CDMA) are MAC protocols that are widely used in modern cellular communication systems (Rappaport, 1996). The basic idea of these protocols is to avoid interference by scheduling nodes onto different sub-channels that are divided either by time, frequency, or orthogonal codes. Since these sub-channels do not interfere with each other, MAC protocols in this group are largely collision-free. These protocols are called scheduled MAC protocols. Other types of MAC protocols are based on channel contention. Rather than pre-allocating transmissions, nodes compete for a shared channel, resulting in probabilistic coordination. Collision happens during the contention procedure in such systems. Classical examples of contention-based MAC protocols include ALOHA (Leonard & Fouad, 1975) and carrier sensor multiple access (CSMA) (Norman, 1985). In pure ALOHA (Norman, 1985), a node transmits a packet when it is generated, while in slotted ALOHA a node transmits at the next available slot. Packets that collide are discarded and will retransmit again. In CSMA, a node listens to the channel before transmitting. If it detects a busy channel, it delays access and retries to transmit later. The CSMA protocol has been widely studied and extended. Today, it is the basis of several widely used standards, including IEEE 802.11 (LAN/MAN, 1999).

TDMA-based protocols are effective at avoiding collisions and have a built-in duty cycle extenuating idle listening. Contention-based protocols in contrast to TDMA simplify the activities and do not require any dedicated access point in a cluster. MACAW (Mark & Randy, 1997) is an example of contention-based protocol. It is widely used in wireless sensor networks and in ad-hoc networks, because of its simplicity and robustness to hidden terminal problems. The standardized IEEE 802.11 distributed coordination function (DCF) (LAN MAN, 1999) is also an example of the contention-based protocol and is mainly built on a MACAW protocol. Most of the research work (Wei & John, 2004) showed that energy consumption of the MAC protocol is very high when nodes are in idle mode. This is due to idle listening. PAMAS (Singh & Raghavendra, 1998) provided an improvement by avoiding the overhearing among neighboring nodes.

S-MAC (Wei & John, 2004) is a slot-based MAC protocol specifically designed for wireless sensor networks. Built on contention-based protocols like IEEE 802.11, S-MAC retains the flexibility of contention-based protocols while improving energy efficiency in multi-hop networks. S-MAC implements approaches to reduce energy consumption from all the major sources of energy as idle listening, collision, overhearing, and control overhead.

S-MAC: Highlights

The smooth operation of any wireless network depends, to a large extent, on the effectiveness of the low-level medium access control (MAC) sub-layer. MAC in WSN aims to ensure that no two nodes are interfering with each other's transmissions, and deals with the situation when they do. S-MAC contention-based MAC protocol not only addresses the transmission interfering issues, but also extends its efforts in minimizing the protocol-overhead, overhearing, and idle-listening. S-MAC principle is based on locally managed synchronizations and periodic sleep-listen schedules. Neighboring nodes form virtual clusters to set up common sleep schedules. If two neighboring nodes reside in two different virtual clusters, they should wakeup at listen periods of both clusters. Schedule exchange is accomplished by periodical SYNC packet broadcasts to immediate neighbors. The period for each node to send a SYNC packet is called the synchronization period.

Figure 1 shows an example scenario for sender-receiver communication. Collision avoidance is achieved by carrier sense (CS). Furthermore, Ready to send and clear to send (RTS/CTS) packet exchanges are used or unicast type data packets. An important feature of S-MAC is the concept of message-passing where long messages are divided into frames and sent in a burst. With this technique, one may achieve energy savings by minimizing communication overhead at the expense of unfairness in medium access. Periodic sleep may result in high latency, especially in multi-hop routing

Figure 1. Sender-receiver communication
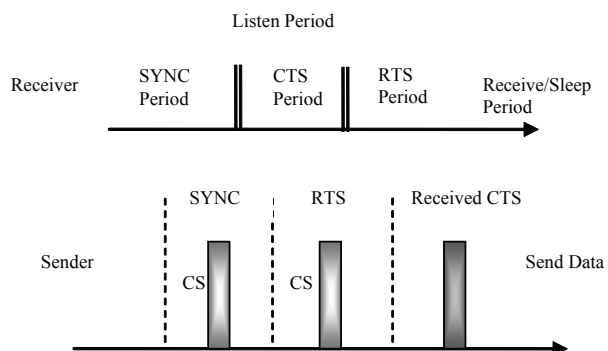
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