Energy Efficient Handover Management in Cluster Based Wireless Sensor Network

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***Abstract*— Wireless sensors are compact-size, low power, inexpensive devices which are capable to measure local environmental conditions or other parameters such as temperature, acceleration, and forward such information to a sink for proper processing. Wireless sensor networks (WSNs) have been under development by both academic and industrial societies for a while. By moving toward applications such as the area of medical care and disaster response mobility in wireless sensor networks has attracted a lot of attentions. In energy constraint sensor network, mobility handling introduces unique challenges in aspects like resource management, coverage, routing protocols, security, etc. This paper, proposes an energy-efficient mobility-aware MAC protocol to handle node handover among different clusters. The simulation-based experiments show that the proposed protocol has better performance compared to the existing S-MAC method.**

Keywords—wireless sensor network; MAC protocol; handover management; clustering; energy efficient

I. INTRODUCTION

Wireless sensors are compact-size, low power, inexpensive devices which are capable to measure local environmental conditions or other parameters such as temperature, acceleration, lighting level, humidity, pressure, movement, etc. and forward such information to a sink for proper processing. Wireless sensor networks (WSN) became popular in recent years, with big variety of applications from environmental monitoring to disaster recovery. Many areas of human activity such as healthcare applications are starting to see the benefits of utilizing sensor networks. Most of the contributions in the WSN have assumed static nodes because that assumption facilitates the simplification of the protocols, making them have a very low overhead and also avoids having to manage the mobility patterns of the sensors and allows saving more energy.

By moving toward applications such as the area of medical care [1-3] and disaster response [4, 5] mobility in wireless sensor networks has attracted a lot of attentions. In energy constraint sensor network, mobility handling introduces unique challenges in aspects like resource management, coverage, routing protocols, security, etc [6, 7].

Assuming that the transceiver is the most power-consuming component of a typical sensor node, then a large advantage can be achieved at the data link layer where the medium access control (MAC) protocol controls the usage of the radio unit.

Having critical applications increase the data rates and mobility of nodes in emerging wireless sensor networks, highlight the network reliability and its throughput as equally importance factors, in addition to power consumption. Most of the existing MAC technologies neglect the importance of one of these factors. An effective MAC needs a careful trade-off in energy-efficiency, throughput, and robustness under mobility.

S-MAC is one of the well-known energy-efficient MAC protocols that proposed in [8]. Several previous evaluations indicated that S-MAC can achieve a relatively energy-efficient communication in stationary WSNs. Although the performance of S-MAC has been evaluated in different situations, however, the performance of S-MAC yet to be evaluated in more dynamic environment, where mobile nodes exist along with stationary nodes. The existence of mobile nodes poses great challenges in clustering the network and can negatively influence the performance of protocol.

The rest of this paper is organized as follows: Section II discusses some related works. Section III proposes an enhanced mobility-aware MAC scheme, based on S-MAC. The simulation-based performance evaluation results and their discussion have been provided in Section IV and finally a brief discussion of the proposed idea and findings of this paper has been concluded in Section V.

II. RELATED WORK

In wireless networks, nodes share a single medium for communication. Network performance is largely affected by how efficient and fair nodes can use this shared medium. A common challenge in wireless networks is collision, resulting from two nodes sending data at the same time over the same transmission medium or channel.

Sensor MAC (S-MAC)

S-MAC [8] is a well-known energy-efficient contention-based protocol based on the IEEE 802.11 standard, that uses a periodic listen-sleep cycle to reduce idle listening time, thereby extending the battery lifetime of sensor nodes.

S-MAC divides nodes into different virtual clusters (VCs) to reduce the control overhead. Neighboring nodes from each VC set up a common sleep schedule. Bordering nodes follow the schedules of overlapping VCs so that they can bridge the communication among the different VCs. However, the drawback of this method is that these bordering nodes consume more energy since they have less time to sleep.

Since S-MAC uses a fixed pre-calculated size for active periods, it has no means to dynamically change the duty cycle to meet mobility or any non-uniform traffic load. When a network is facing mobility, a node moves from one VC to another, so its schedule is no longer valid. For example, if a mobile node wants to set up a new connection to a new node in different VCs, then the node has to wait for a new synchronization period (10 seconds every 5 minutes) to detect the SYNC message from the new node. During this long period (5 minutes) for the connection setup time, the mobile nodes become disconnected from the rest of network, possibly leading to high data loss.

III. PROPOSED PROTOCOL

The proposed scheme is based on S-MAC protocol and initiates the scheduling process similar to S-MAC with small modification as follows: A new identifier flag which shows the status/type of each node is introduced, which called Node-Type (NT). After accomplishing the initial scheduling process, nodes inside each VCs, will be divided into three different types: Cluster-Head (CH), Border-Node (BN), and Stationary-Node (SN). The workflow of scheduling process is shown in Fig 1.

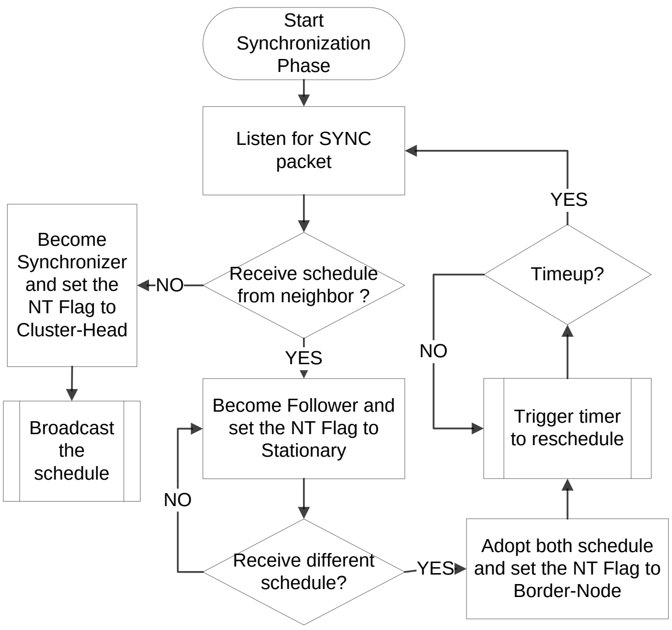

Fig 1: Scheduling phase of the proposed method

Then, the protocol activities begin by the following steps which is shown in Fig 2. The node listens to the medium and when the node detects any fluctuation in the RSSI and LQI value of the received SYNC packet, more than a predefined threshold, the node starts the mobility handling scheme. In case of the stationary node flag is changed to mobile-node (MN) and triggers a timer. After T units of time, if a node stays in same cluster the MN flag changes its NT flag value back to the stationary value. The amount of the timer can be pre-set depending on the application.

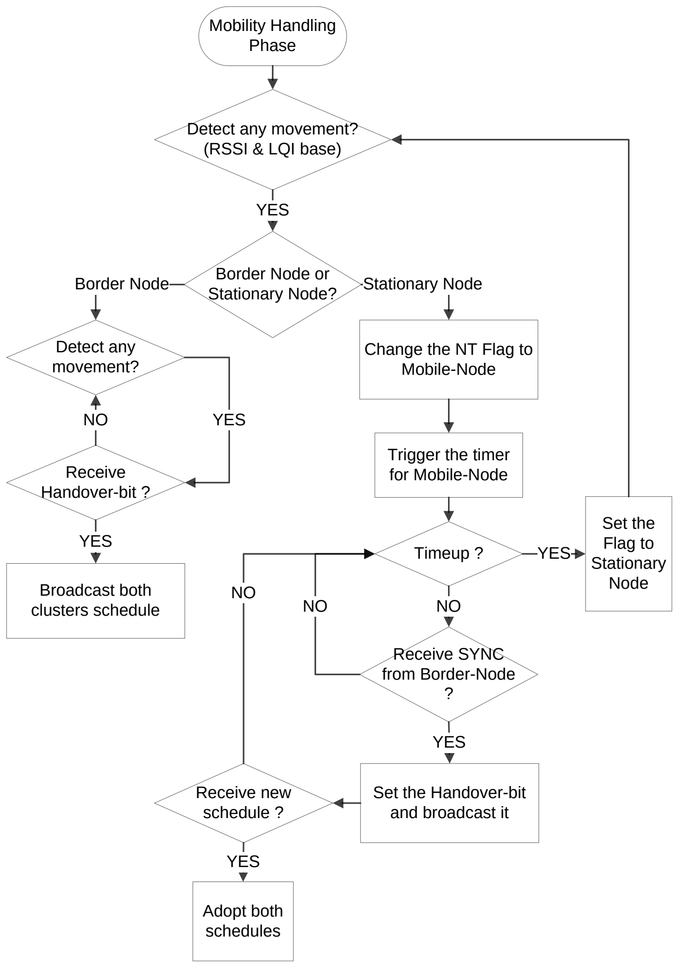

Fig 2: Mobility detection phase in stationary nodes

In the border node side, once the border-node (BN) detects the increasing change in the SYNC packet, it broadcasts its NT in the SYNC packet to inform the MN that it is approaching to the border. After the MN receives a SYNC packet from the BN, it activates the handover bit inside the SYNC packet and broadcasts the bit. On the other hand, the BN broadcasts the neighbor cluster schedule along the SYNC packet while the BN receives the handover packet. Thus, the MN can receive a copy of the neighbor cluster schedule and adopts its own schedule and the schedule of the neighbor VC as well. In this case, the MN works much like a wanderer BN, which helps it to have a smooth handover to another VC.

IV. SIMULATION AND DISSCUSSION

Due to stochastic nature of WSNs with mobile nodes, the simulation-based experiments have been conducted to evaluate the performance of proposed enhancement scheme comparing to original S-MAC as well as CSMA protocol. Castalia [9] as an open-source simulator tool, which is developed over OMNET++ [10] platform has been implemented to create a test-bed for the performance evaluation. Proposed MT-MAC codes developed the pon top of the existing module for S-MAC in Castalia.

The serving area has been considered as a square shape of 200×200 m^2 field consisting of uniformly distributed 50 nodes. Each experiment takes 1000 seconds, and the final results are the average of 10 simulation runs with different random seeds. The details of the simulation parameters are presented in Table 1.

Table 1: Simulation parameters

General	
Topology	Square (200×200 m^2), nodes distributed uniformly
Total number of nodes	50 nodes
Duration	1000 seconds
Message payload	64 bytes
Data length	Up to 512 bytes
Data sending period	1 packets per second
Mobility model	Random walk
Radio	
Effective data rate	250 kbps
Transmit	62 mW
Receive	62 mW
Sleep	1.4 mW
Modulation model	PSK
Tx power output	55.18 W

Beside the node's speed, the ratio of mobile nodes to the total number of nodes inside each VC has been changed to have better understanding of mobility effect on performance in both original and enhanced version of S-MAC. In each simulated scenario, average packet delivery ration (PDR) and average power consumption have been measured as main performance indicators. Figs 3 to Fig 6 illustrate the observed results of simulations with different network scenarios and dynamicity.

Fig 3 and Fig 4 respectively, illustrates the effects of mobility in the network while 10% of the nodes are mobile and the speed of the mobile nodes varies from 0.5 to 20 meters per second. The delivery ratio decreased when the speed of the node increased (Fig 3). It is noticeable that packets can get lost for different reasons, such as collisions in the contention part of the time slot or the nodes experiencing buffer overflow (due to memory limitations in real sensor nodes, as the nodes' buffer size was adjusted to 8 data messages in the experiment). The nodes broke their VC faster when speed of the nodes increased, resulting in further packet losses. The proposed MAC shows better packet delivery ratio than S-MAC almost in all cases, due to the use of mobility detection scheme which can help the protocol handle the movement of nodes from one VC to another VC more efficiently. By using random walk mobility model that does not have pause time, by increasing the speed the PDR of S-MAC falls sharply and the difference of S-MAC and the proposed MAC get larger.

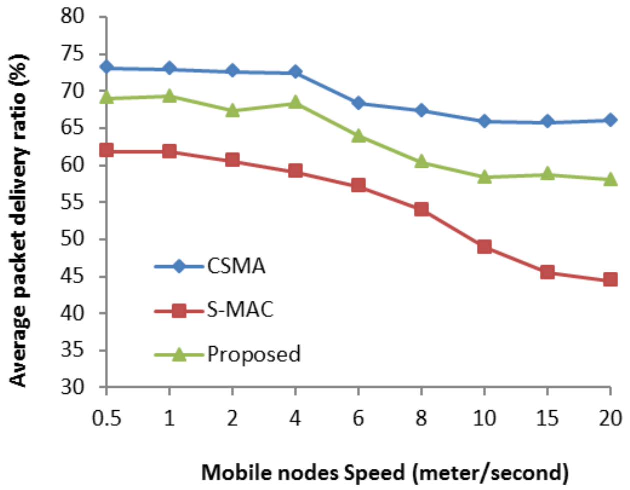

Fig 3: Impact of nodes speed on the average packet delivery ratio

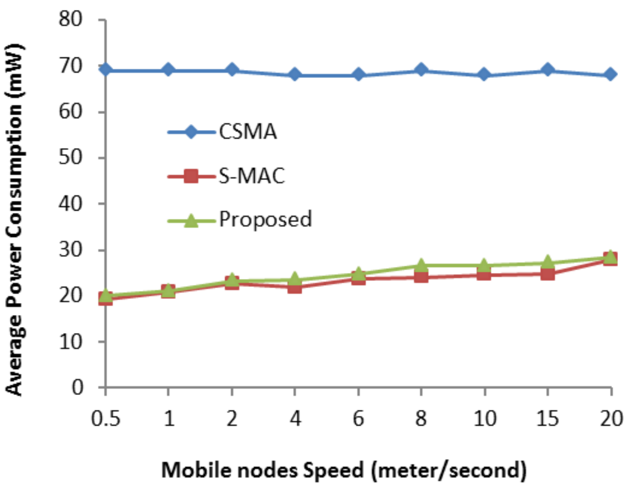

Fig 4: Impact of nodes speed on the average power consumption

Given that CSMA does not use a power conservation scheme, the mobility does not have any impact on the average power consumption. The results of CSMA have been used as a point of comparison for other protocols. As mobility increased, both S-MAC and the proposed MAC have to tolerate slightly higher power consumption, proportion to increasing speed of mobile nodes as illustrated in Fig 4. The reason is the extra synchronization and wasted energy by these nodes, once they enter to a new VC. T-MAC used an adaptive duty cycle that increases the duration of the active periods when an activation event occurred, which is expected to consume more power at a higher speed.

Although the proposed MAC shows slightly higher power consumption than S-MAC due to its light scheme for handover which in some cases force nodes to do extra synchronization to help them smoothly handover to new VC, however this is a reasonable trade off to get higher PDR (see Fig 3).

Fig 5 and Fig 6 illustrate the effect of network dynamics on the performance of the protocols. The network dynamics level has been varied by changing the number of mobile nodes in the network, while the speed was fixed at 4 m/sec.

In Fig 5, by increasing the number of mobile nodes in the network, the PDR of all the protocols falls whereas S-MAC shows the lowest PDR among other protocols. The proposed MAC protocol could improve the PDR of S-MAC to a good scale. Fig 6 shows the proposed MAC shows higher power consumption compare to S-MAC which is due to its increased frequency of synchronization.

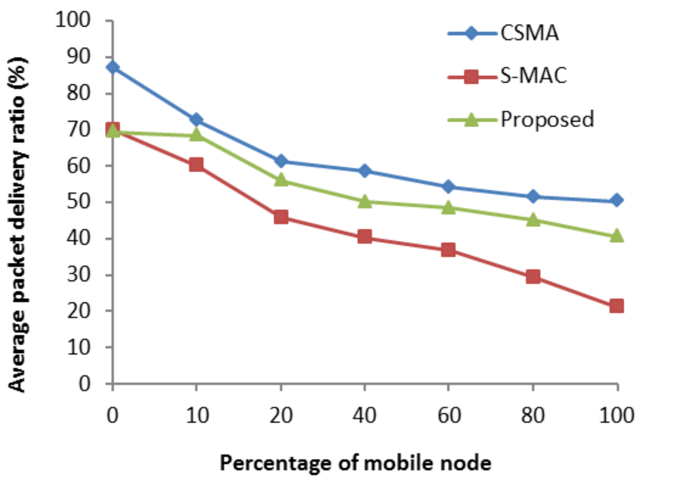

Fig 5: Impact of network dynamic changes on the average packet delivery ratio

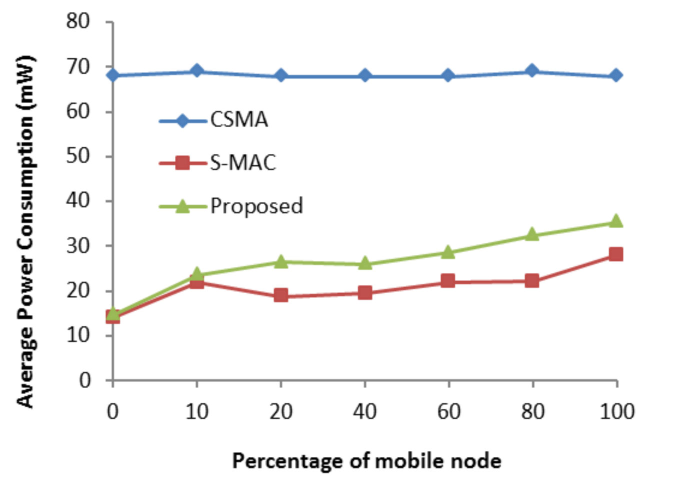

Fig 6: Impact of network dynamic changes on the average power consumption

V. CONCLUSION

This paper proposed an energy-efficient handover mechanism for cluster based MAC protocol for wireless sensor network. By using this mechanism which is based on RSSI & LQI mobility detection, a mobile node can move from its current cluster to a new cluster without getting disconnected from the network. Simulation based study shows that the proposed MAC protocol improves the packet delivery ratio of S-MAC protocol while achieve the good level of power consumption.

A comparison to other MAC protocols of sensor networks and considering other mobility models are parts of our future works

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