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Redundant Transmission of Sensed data in Wireless Sensors and Actor Networks for Improved Reliability

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Abstract*— *In Wireless Sensor and Actor Network (WSAN), sensors and actors are linked through wireless channel. Sensor nodes are those which sense data and forward them to actors, which in turn process the data and perform a suitable action on the environment. An actor is a node that also acts as a data sink in the WSANs. The actor node, which can be a mobile, or a static node, may take actions on the environment either individually or collaboratively with other such nodes that may be present in the network. It is important that the sensed events are reported to the sink nodes with high reliability and in a timely manner in order to effect a real-time response behavior of the network. We consider a network in which sensors deliver the sensed events in the form of messages and data in a multi-hop manner. While forwarding data there is a possibility of data loss due to various reasons such as collision, noise interference, and congestion in the network. In such cases, the messages need to be re-transmitted to ensure reliability. Such re-transmissions would waste bandwidth and scarce energy of the sensor nodes and will lead to a shorter lifetime of the network. We propose redundant data transmission schemes in which, the messages are retransmitted by embedding the neighbor node's message as backup data along with the original message. So data even when lost, reaches the destination via neighbour nodes' messages. We evaluated the performance of the protocol using TOSSIM simulator and the embedding of data packets helps improving the lifetime of the network.

***Index Terms*—Medium Access, Reliability, Sensor Networks, Wireless.**

I. INTRODUCTION

Recent advances in pervasive computing, communication and sensing technologies are leading to the emergence of Wireless Sensor and Actor Networks (WSANs) [1, 2]. A WSAN is a distributed system of sensor nodes and actor nodes that are interconnected over wireless links. Sensors gather information about the physical world, e.g., the environment or physical systems, and transmit the collected data to controllers/actors through single-hop or multi-hop communications. From the received information, the controllers/actors perform actions to change the behavior of the environment or physical systems and in some cases also act as a data sink. Depending on the type of the target application, nodes in a WSAN can be either stationary or mobile. In many situations, however, sensor nodes are stationary whereas actor nodes, e.g., mobile robots and unmanned aerial vehicles, are mobile.

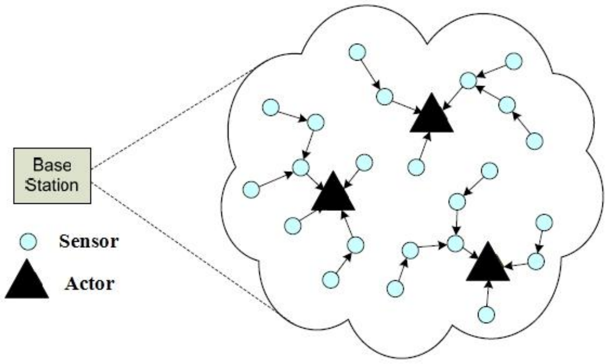

Figure 1. Architecture of Wireless Sensor and Actor Network.

As shown in Figure 1, a WSAN is a networked system of geographically distributed sensor and actor nodes that are interconnected via wireless links. Both sensor and actor nodes are normally equipped with certain data processing and wireless communication capabilities, as well as power supply. Sensor nodes are usually low-cost, low power, small devices equipped with limited sensing, data processing and wireless communication capabilities, while actor nodes typically have stronger computation and communication powers and more energy budget that allows longer battery life [3]. Resource constraints apply to both sensors and actors.

In WSANs, depending on the application there may be a need to rapidly respond to sensor input. For instance, in a fire application, actions should be initiated on the event area as soon as possible. Moreover, the collected and delivered sensor data must still be valid at the time of acting. For example, if sensors detect a malicious person in an area and transmit this information to the disposer of tranquilizing gas actors that person must then still be in the same area when actors carry out the task. Therefore, the issue of real-time communication is very important in WSANs.

The main requirement of WSANs is the coordination between actors and sensors. There are two kinds of coordination such as sensor-actor and actor-actor coordination. In particular, sensor-actor coordination provides the transmission of sensed data from sensors to actors. After receiving sensed data, actors need to coordinate with each other in order to make decisions on the most appropriate way to perform the action. It has to be decided whether the action requires exactly one actor or, on the contrary, it requires the combined effort of multiple actors.

On the other hand, depending on the application there may be a need to respond rapidly to sensor input.

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Moreover, the collected and delivered sensor data must still be valid at the time of acting. Therefore, the real-time issue is a very important requirement in WSANs.

The rest of the paper is organized as follows: Section 2 gives a brief overview of the motivation our work. Related works are summarized in the Section 3. The system model is depicted in Section 4. The details of our proposed scheme are discussed in Section 5. The simulation results and performance evaluation are discussed in Section 6. Section 7 summarizes our contributions.

II. MOTIVATION

The sensor nodes while transmitting the messages to the actor, there is a possibility of two or more nodes to send messages simultaneously. This results in collision, which leads to the retransmission of messages. Retransmission of messages results in wastage of the bandwidth and energy of the overall network life. But energy saving is an important factor in WSAN because the sensor nodes are static and are left energy constrained. Most of the energy is spent during the communication between the nodes. Thus our objective in this work is to (i) Reduce the communication overhead and design an energy efficient data delivery protocol for WSAN and (ii) To simulate and evaluate the performance of the proposed protocol.

III. RELATED WORKS

Data transmission in the wireless networks is more unreliable than it is in the wired network environment. This is caused by the characteristics of wireless communication such as high bit error ratio (BER) and the lack of collision detection same as wired IEEE 802.3 Ethernet. Although the virtual carrier sensing scheme (RTS/CTS/ACK) is used in the wireless unicast transmission, the multicast and broadcast still do not utilize the acknowledgement mechanism for reliable transmission [4]. This is due to the acknowledgement packets of broadcast transmission will cause higher communication traffic and overhead. This results in reduction of overall network lifetime and latency of the network.

Redundant data transmission protocol (RT) [5] improves the broadcast reliability by introducing redundant transmission and decreases the data loss ratio of every receiver node. It also avoids retransmission of messages which reduces the overall communication overhead associated with broadcast communication. Neighbor node's sensed values are embedded as the backup data along with the sensor's own sensed values and transmit. So, even if a message is lost it reaches the destination via neighbor node's message thus avoiding retransmission of messages. But there still exists probability of packet loss and extra communication cost due to redundant broadcast. On the other hand, since reliable data broadcast is critical and required in many applications, our study focuses on the extension of RT in which nodes follow (RTS/CTS/ACK) scheme. In our work, instead of broadcasting acknowledgement packets every time a negative acknowledgement (NCK) packet is sent to the sender if it does not receive the packet. By broadcasting NCK packets, the communication traffic overhead is further reduced.

Retransmission of messages should be avoided to conserve energy. Instead, redundant broadcast transmission of messages where the sensor node, send data by embedding data received at t, t-1… t-n to the actor node would conserve the energy. So data even lost in one transmission of message, it reaches the destination (actor) via other message transmission. By redundant transmission scheme, sensed data are more reliably delivered to an actor node in presence of message loss.

IV. SYSTEM MODEL

The following assumptions are made in sensor-sensor and sensor-actor communications.

As shown in Figure. 2, an actor node *a* and sensor nodes s_1… S_n $(n>=1)$ in an event area W are interconnected in one wireless broadcast channel. Every sensor node s_i can receive a message *m*, if an actor node a sends the message *m* and no message collision occurs and collision area of actor node a i.e. C(a)=W. A message sent by a sensor node s_i can be received by only a limited number of nodes, if there's no message collision. An actor node *a* sends a message *m* to every node with a strong radio channels. But a sensor node (s_i) can deliver only a message to nodes in the collision area $c\ (s_i)$ of the sensor node (s_i) due to its weaker radio.

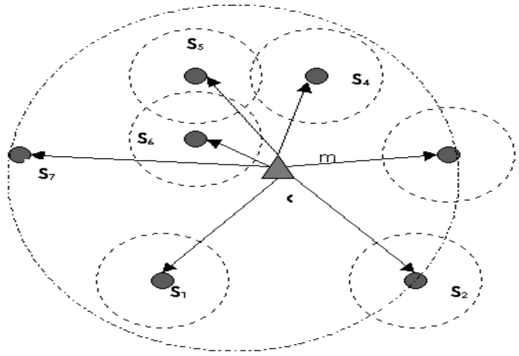

Figure 2. System model.

V. OUR WORK

Retransmission of messages can be replaced by redundant broadcast transmission of messages. In redundant broadcast transmission every sensor node (s_i) sends not only its own sensed values but also the previous sensed values of the sensor (s_i). It is possible because, in sensing applications, a sensor node sends a sensed value (e.g., temperature value of two bytes) in its message. But the message format of sensor node such as mica2dot [6] is 32 bytes long. So, after embedding the sensed value, the remaining bytes are left free as shown in figure 3. These free spaces can be filled by the sensor's previous sensed values as shown in figure 4. Our proposal in line with [5] is to utilize this free space by filling with the backup data. As mentioned in the previous section, the data transmission protocol in this work, avoids sending ACK for every message. Instead, NCKs are sent for the missing messages.

Source ID (2 bytes)	Sequence ID (2 bytes)	Destination ID (2 bytes)	Current Sensed value (2 bytes)	Free Space (24 bytes)

Figure 4. Utilization of unused bytes in Message format

Source ID (2 bytes)	Sequence ID (2 bytes)	Destination ID (2 bytes)	Current Sensed value (2 bytes)	Previous sensed values (24 bytes)

Figure 3. Message format of sensor node

VI. PERFORMANCE EVALUATION

We implemented our proposal in the MAC layer of the protocol stack. The performance evaluation of the protocol was studied using TOSSIM [7] by simulating a network with 30 sensor nodes and five actor nodes. The protocols behavior was studied with AODV as routing protocol and performance compared with conventional MAC schemes with RTS and CTS.

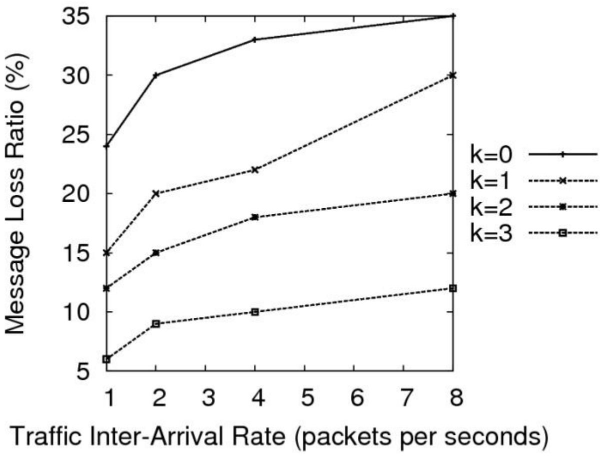

Figure 5. Comparison of Message loss Ratio by varying redundancy and traffic.

Figure 5 shows the Message Loss Ratio by varying the redundancy factor. When there is no redundancy (k=0), the MLR is as much as 35% when the traffic peaks. With our scheme, with more depth on the redundancy (k=3), it was observed that the MLR drops to 12%. It must be noted that the increase in the depth of redundancy does not contribute any additional overhead for the communication but with little overhead on the computation and buffering at the intermediate nodes.

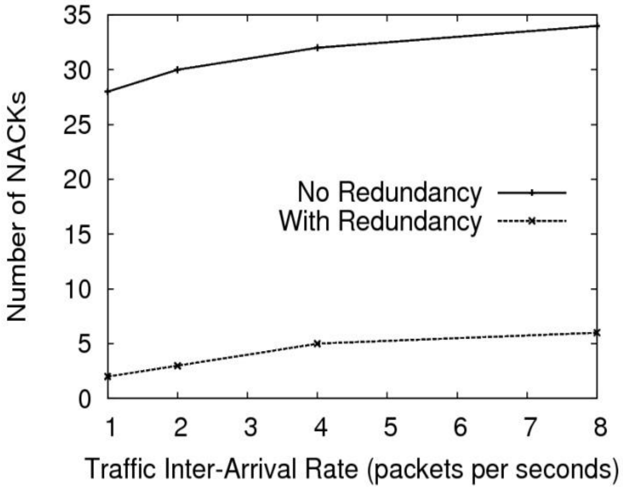

Figure 6: Comparison of Number of NACKs by varying traffic rate.

Figure 6 shows the performance of our scheme with respect to the number of Negative Acknowledgements are transmitted as a function of varying traffic inter arrival rate. It is evident from this result, that the introduction of redundancy in message transmission helps minimizing the number of NACKs to as low as 9. As mentioned earlier, the number of nodes in the experiment was fixed to 30.

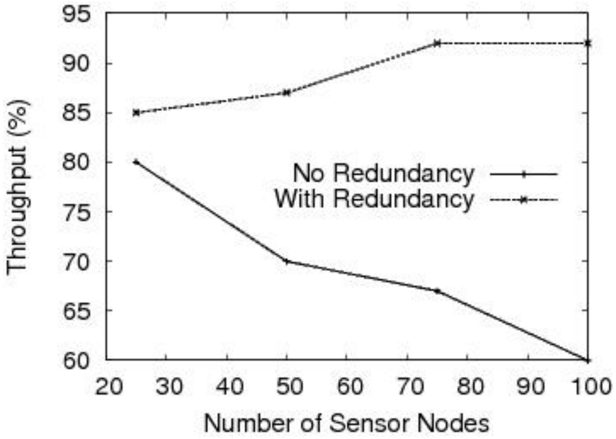

Figure 7: Comparison of Throughput performance by varying node density.

We have also measured the throughput performance by computing the ratio of successful delivered messages to the number of messages originated by varying the sensor node density. The results in Figure. 7 show that the use of redundant message transmission helps improving the throughput performance to a greater extent when compared to the conventional schemes.

VII. CONCLUSION

Energy efficiency is an important concern in Wireless Sensor Networks. The reliability of data transmission is important in WSANs. We, in this paper proposed a novel scheme in this work which efficiently utilizes the MAC level frame format to send the redundant messages without additional communication overhead. Through simulations we have shown that the use of redundancy in messages greatly improves the performance with respect to throughput and Message Loss Ratio. The work can further be enhanced such that the acknowledgments may be avoided for every reception of sensor messages.

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