Robust Asynchronous Resource Estimation for Energy Efficiency in WSN with Transmit–Only Nodes

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Abstract---In Wireless Sensor Network systems could continuously provide reliable data-gathering service is another critical issue. In fact, system reliability is a top requirement in the industry applications. The radio frequency interference that could occur almost anytime and anywhere, network change that is either predictable as a result of planned adjustment or unpredictable due to the node failures and environmental effects (e.g., bad weather and blocking objects) that affect the wireless channel condition. It is desirable to have robust WSN systems that are able to cope with these negative effects. To realize the potential cost and energy saving benefits of transmit-only nodes. Robust Asynchronous Resource Estimation (RARE) that efficiently and reliably manages the densely deployed single-hop hybrid cluster in a self-organized fashion. Through analysis and extensive simulations, and it is used to improve the Quality of service.

Keywords: Wireless sensor networks, medium access control, transmit-only node, Internet of things, data communication

I. INTRODUCTION

A wireless sensor network (WSN) of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity.

A. Wireless Sensor Network

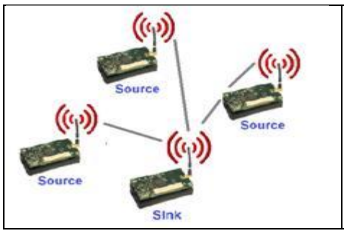
1) Source Node:

Source node is a node which provides required information to the network. Usually a source node could be a sensor node or actuator node that provides feedback about an operation.

2) Sink Node:

A sink is a node where information is required. Sink node could be a node in the sensor network it might be a sensor/actuator node or outside of the network and some time it might be a gateway to another larger network.

In a Single-hop network there is a multiple source or sensors nodes connected to the single sink node. In this scenario sink node could be a source node or gateway.



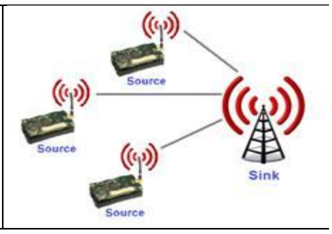


Fig. 1: Source node as a sink node
Fig .2: Sink node as a gateway

There are many advantages follows: The Single-hop Network was simple to implement, no need any routing considerations, lesser time delay to receive the data to sink node, time synchronization is much simplier, it is used for centralized applications and finally, if any source fails, network doesn't effect much.

II. MOTIVATION

We formulated the basic problem as follows: there are a large number of Low-Priority (LP) transmit-only nodes, a relatively small number of High-Priority (HP) transmitonly nodes and one data sink in a single-hop, single channel WSN. After every T time units, a new data packet is sensed on each node, and the packet needs be delivered to the sink before the next interval of T units of time begins. We designed a QoS-aware, optimal retransmission based MAC protocol, called QoMoR, where each node randomly transmits its packet an optimal number of times (i.e., the smallest number of transmissions to guarantee the statistical delivery probability requirement. Note that "transmission" and "retransmission" will be considered same in this work) within every T interval. We evaluated a range of settings through systematic analysis and extensive simulations, and provided formulas to guide the setup for different optimization problems.

III. RELATED WORKS

First, since the transmit-only nodes cannot perform carrier-sensing as in the Carrier Sense Multiple Access (CSMA) systems, data transmissions by these nodes are completely uncoordinated. This characteristic rules out the use of most existing MAC protocols such as IEEE 802.11 [10], B-Mac [11], S-Mac [12], and TSMP [13]. Second, although the cost and power savings due to the use of transmit-only nodes can be significant in a WSN with large number of nodes, when a greedy scheme is used by these nodes in an attempt to achieve a better data delivery performance, the transmissions will quickly saturate the shared channel, and collisions will deteriorate the overall performance. Third, our previous studies on WSNs with pure transmit-only nodes [14], [15] showed that one can achieve a satisfactory data delivery performance with up to a few hundred of such nodes within one-hop from the sink. In other words, in a denser deployment environment requiring more than a couple of hundreds of sensor nodes, having transmit-only nodes is not sufficient. In order to tackle the new challenges in such a hybrid WSN, we propose a robust MAC protocol framework based on our preliminary works in [16] and [17]. In addition to integrating pieces from our previous effort together, the framework design has been improved to achieve better efficiency and resiliency. We also present a more detailed performance analysis that takes into account channel characteristics, temporal and spatial diversity that were neglected earlier. The rest of the paper is organized as follows. Section 2 describes motivation of the work and related works. Section 4 elaborates the proposed protocol framework and supporting techniques. Sections 5 present analytic and simulation results respectively and Section 6 draws the conclusion.

IV. RARE FRAMEWORK

In this paper, we propose to use standard nodes with receivers as HP nodes and transmit-only nodes as LP nodes to form a hybrid WSN cluster. The core problem to be addressed is to: 1) find the optimal number of transmission x for LP category nodes, such that if each LP node retransmits its data packet x times in every T, it can achieve a data delivery probability of PLP sink at the sink, where PLP sink _ PLP ; 2) manage the data transmission of HP category nodes to maintain its data delivery probability such that PHP sink _ PHP . Moreover, we want to achieve the following improvements over the previous QoMoR work:

(1) Improved data delivery performance or lower energy consumption for LP nodes.
(2) Maximized data delivery performance and optimized energy consumption for HP nodes.
(3) Reliable data delivery performance against various interference and environmental effects for HP node.
(4) Dynamic network change support for node addition and node removal.

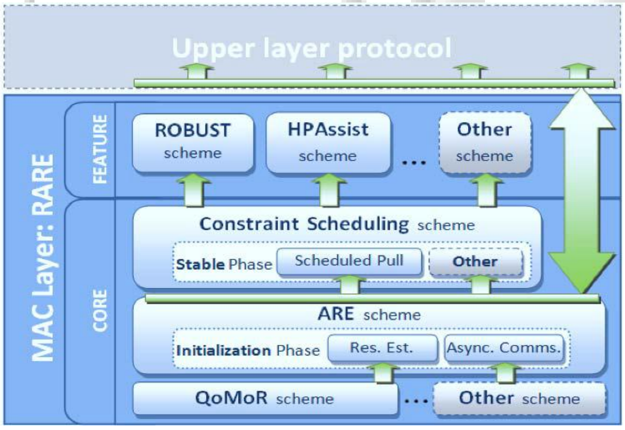


Fig. 3: Rare Framework

Robust Asynchronous Resource Estimation (RARE) is a MAC layer protocol framework designed to manage the operation of the low cost, low power and densely deployed hybrid WSN within a single-hop communication range. As shown in Fig. 3, the RARE framework consists of CORE stack and optional FEATURE stack. It manages the transmit-only nodes and standard nodes in different ways: transmit-only LP nodes access the channel randomly and will respond to no sink control as designed in underlying QoMoR, while channel access of the standard HP nodes is managed by the sink. From the perspective of operation phase, the RARE framework consists of two phases, the initialization phase and the stable phase.

A. Core Stack—The QoMoR Scheme

The QoMoR scheme is the fundamental component in the core stack and governs the random transmission. The optimal number of transmissions is precalculated based on the system requirement (e.g., data delivery probability, transmission rate, packet size, etc.) [14], [15] and programmed to the nodes before the deployment.

B. Core Stack—The Asynchronous Resource Estimation (ARE) Scheme

The ARE scheme is another fundamental component in the core stack and serves as an abstraction layer of the underlying components. It defines the asynchronous communication and supports resource estimation that is performed during the initialization phase and used by the scheduling scheme.

C. Core Stack—The Constrained Scheduling Scheme

The constrained scheduling scheme is the major component of the core stack, through which the sink manages all communications of the HP nodes. The enhancement components in the upper feature stack also rely on this scheme to schedule different operations within the vacant time slots during each interval. From the perspective of the operation phase, this scheme operates in the stable phase, and in this paper the sink works through the Scheduled Pull approach.

D. Feature Stack—The ROBUST Scheme

As mentioned in Section 1, external signal interference, environmental effects and scheduled network adjustment or unexpected node failure are the main causes that lead to the wireless communication failure. The ROBUST scheme is an enhancement component on the FEATURE stack to address these issues and to guarantee the nodes of highpriority category will still meet high-performance requirement. Basically, it utilizes the vacant time slot resource in each interval and redundancy in the packet structure to handle possible packet loss and support dynamic network change. Note that the basic supporting operations of the ROBUST scheme and necessary data redundancy in the packet structures have already been built into the CORE stack components, such as the second step in the initialization phase and the third step of scheduled pull approach in the stable phase. Below, we will focus on how the framework will handle the packet loss and network change.

E. Feature Stack—The HPAssist Scheme

The HPAssist scheme is another enhancement that works on the FEATURE stack. The goal of this scheme is to improve the data delivery capability of the LP nodes with the assistance of selected HP nodes. From the simulation results, we observed that the total energy consumption of the HP nodes over a certain period of operation time is far less than that of the LP nodes. This is essentially good because the constrained scheduling scheme lowers the HP energy consumption than the previous QoMoR does.

V. SIMULATION RESULTS

The simulation involves 500 nodes that are uniformly placed in a flat grid of size is 55m-55m.These nodes are divided into two priority categories, where 400 nodes are LP nodes, 100 nodes are HP nodes. One data sink is located in the center of the sensing area. Among the LP nodes, 390 nodes are initially deployed and another 10 nodes will be added to the network at the following time (Seconds): 0.5, 1, 1.5, 7, 9.5, 10, 11, 12, 15, and 20. Since both types of nodes will behave as LP nodes when added and these addition times cover all the stages of the framework, this configuration is valid to demonstrate the performance of the proposed RARE framework under a dense WSN setting. Every 300 ms (T interval), a new data packet is generated by the node and it is expected by the sink before the start of the next interval. Each data packet measures 72 bytes and will be transmitted Retran times every T interval. The size of the ACK and Confirm packet is 48 bytes. The Pull command is 48 bytes and at most 120 bytes when the HPAssist scheme is activated, while that of the NAKList packet could vary from case to case and can go up to 120 bytes. retransmission is set to 4. Hence only part (case 1 to 4 out of 10 cases) of the following graphs is more interesting to us.

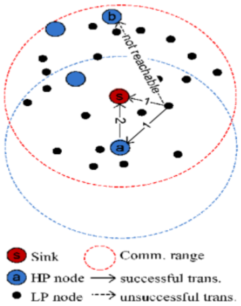


Fig. 4: Principal of HPAssist

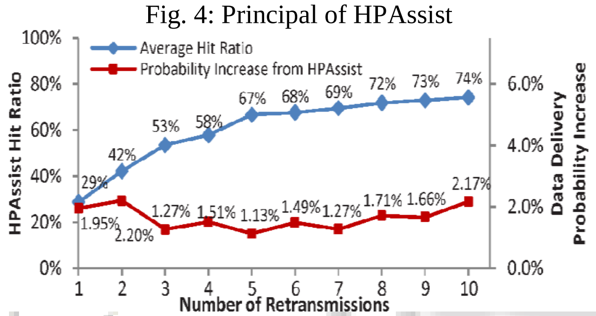


Fig. 5: HPAssist hit ratio versus probability increase.

In this paper, we have studied the hybrid WSN cluster that contains both standard nodes and transmit-only nodes within a single-hop of the sink. This hybrid WSN cluster architecture finds good operation tradeoffs between the traditional and transmit-only WSNs. It is more cost effective and energy efficient than traditional WSNs with only standard nodes. On the other hand, it is more flexible and better capable than the ones with just transmit-only nodes. To fully explore the potential of such hybrid WSN cluster architecture, we have proposed the RARE protocol framework to manage the hybrid system.

VI. CONCLUSION

The system has been shown to have significantly improved data delivery capability in both HP and LP priority categories as well as the optimized energy consumption compared to the transmit-only WSNs. Furthermore, the hybrid WSN cluster is able to provide a reliable performance guarantee for the high-priority category nodes through the strategic retransmissions even in the harsh deployment environment and always maintain a smooth operation when the system is facing either scheduled network adjustment or unexpected node failures. There are two major limitations imposed by the transmit-only nodes, however: 1) the precalculated optimal number of retransmissions needs to be programmed to the devices before their deployment; and 2) significant clock drifting on the nodes may degrade the performance over time. Our future work, besides addressing the above two issues, will further explore the potentials of this hybrid WSN cluster architecture in building a larger system with multicluster and multihop communications (based on sinks and/or HP standard nodes).

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