Evaluation and Enhancement of Ad Hoc Network Protocols for Industrial Implementations of Wireless Sensor Networks

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(Work-in-Progress Paper)

***Abstract*—Wireless Sensor Networks (WSN) poses a number of design challenges. Most WSN do not follow the same methodology even though the purpose is uniform. Mobile Ad Hoc Networks (MANETs) are a networks that are typified by being infrastructure-less and self-organizing. Using MANET protocols in WSN has become more common, but many changes need to be made to accommodate the low-power, low-cost and reliability needs of WSN.**

Re-examining the data link layer and the network layer of such networks render the best improvement on WSN needs, thus simulating and analyzing enhanced Medium Access Control (MAC) and routing strategies and adapting them to be consistent with realistic predictions and comparing strategies for the best end result.

I. Introduction

WIRELESS Sensor Networks (WSN) poses a number of design challenges. Most WSN do not follow the same methodology even though the purpose is uniform, to collect data and distribute it to the relevant point of collection. Nodes can be placed randomly and thus do not adhere to regular topologies, or nodes can be arranged in fixed topologies with dedicated routers and immovable structures. Some require human intervention and need to be maintained where other do not allow it and need to be self-maintainable.

Mobile Ad Hoc Networks (MANETs) are networks that are typified by being infrastructure-less and self-organizing. [1] Nodes in such networks can at any time join or leave the network, adding to the dynamic characteristics of these networks. Each of these nodes are connected to the base station via single- or multi-hop pathways and any node can act as a sensor and as a router. These attributes effect the overall performance and latencies of such networks.

It is becoming increasingly popular to apply MANET protocols to WSN, rendering low-cost, low-maintenance and minimum overall effort networks. There are, however, still many shortcomings with standard MANET protocols for this specific application. Based on the Open System Interconnection (OSI) model [2] the relevant layers are the data-link layer containing the Media Access Control (MAC) Layer and the network layer containing the routing protocol. These two layers will have the biggest effect on the throughput of such a network as well as the stability and reliability.

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The rest of this paper is organized as follows. Section II-A gives the background on the intended purpose of the WSN, and Section II-B gives the background on the problems facing this WSN. Section III-A states the proposed research in the media access control layer and relevant motivations, and Section III-B states the proposed research on routing methods and relevant motivations. The paper is concluded in Section IV.

II. Background

A. Physical Implementation

Many varieties of WSN are currently implemented in industrial applications. The current design is aimed at cold stores such as Commercial Cold Stores in Durban Harbor. These networks typically consist of anything from 20 to 800 sensor nodes. These nodes monitor the fruit core temperatures, ambient temperatures and humidity and need to log the data for exporting/importing and quality control standard reviews. Currently most of the networks have stationary, non-sleeping, wired repeaters. This infrastructure is time consuming and costly to deploy. Self-organizing, self-maintaining and infrastructure-less networks reduce network design time, deployment time and costs. [3]

Nodes in these WSN need to minimize costs, such that non-line-of-sight (NLOS) links can be avoided by deploying an additional node. These NLOS links are inevitable in the initial network deployment due to obstacles such as buildings and densely packed fruit pallets. The network must therefore operate in a low frequency for high signal penetration and must operate in a licence free band to minimize costs. The 433MHz band with 100mW transmission power restriction is sufficient for signal penetration and can optimistically transmit within a 1km radius [4], which is enough for average node density to secure acceptable line-of-site (LOS) links.

Popular solutions to WSN such as Zigbee (based on the IEEE802.15.4 Physical (PHY) and MAC Layer Standards) [5] implementations are not infrastructure-less and "neither quality-of-service (QoS) nor low-power modes are envisaged for routers," [6] rendering them unsuitable.

B. Implementation Challenges

Reliable quantifiable communication (such as QoS) is made difficult in MANETs and some WSN due to [3]:

- Wireless channels that are prone to errors.

- Wireless channels that are shared between all nodes within communication range.
- Wireless link failures due to moving nodes.

III. Proposed Research and Methodology

A. Media Access Control Layer

MAC can be divided into two approaches: deterministic and contention. Deterministic access, such as Round-Robin-Polling (RRP) strategies, is collision free, but can be slow when there is low traffic in the network. [4] Consequently RRP strategies are stable and efficient under heavy loading. Contention access such as basic Carrier Sense Multiple Access CSMA strategies combined with an automatic repeat-request (ARQ) or hybrid ARQ (HARQ) can also provide collision free transmission, but HARQ can become complicated to implement. [4] The focus of the research in the MAC layer is to predict the efficiency of each of these strategies through multiple approaches, and eventually compare them with measured results. The CSMA strategies will be modeled through transitional matrix and software based simulations (such as Simulink). The RRP strategies will be modeled based on existing base models in [7] and [8] through queueing theory and analytical models. The overall problem with the models are the lack of credibility due to:

- Assumptions of noise and sources of errors.
- Not compensating for retransmissions.
- Not compensating for rise times needed for synchronization.

These simulations and models need to take these factors into account to provide realistic transmission predictions.

B. Routing Methods

Routing protocols can be subdivided into three categories: pro-active routing protocols, reactive protocols and hybrid routing protocols. Pro-active routing protocols, also known as table-driven protocols, are networks in which each node maintains a table containing all the destinations in the network as well as each destination's path, which needs to be updated through the exchanging of tables throughout the network. Reactive protocols, also known as on-demand protocols, are networks in which paths are discovered when they are needed. Hybrid protocols are protocols that contain characteristics of both pro-active and reactive routing protocols. [1]

Commonly used pro-active routing protocols include Destination-Sequenced Distance-Vector routing (DSDV), Wireless Routing Protocol (WRP), Hierarchical State Routing (HSR) and Global State Routing (GSR). Commonly used reactive protocols include Ad hoc On-demand Distance-Vector routing (AODV), Optimized Link State Routing (OLSR) and Dynamic Source Routing protocol (DSR). [8] and [9]

Pro-active protocols are highly mobile since the tables frequently update to accommodate new topologies. Reactive protocols such as DSR protocols require the entire path to be added to the packet header. The following reasons can thus be stated in the development or enhancement of a hybrid routing protocol:

- The WSN in this application is not entirely mobile, but rather nomadic, thus it becomes unnecessary to frequently update tables which now becomes unwanted overhead.
- Payload sizes limited and cannot add long path lengths to package headers.

The focus of the research in the Network layer is to predict the throughput of the network with developed or enhanced protocols followed by the implementation of the best protocols and comparing the predicted and measured results. Protocols from the pro-active and reactive categories will be simulated as well as protocols from the hybrid category to evaluate if enhanced pro-active or reactive protocols surpass enhanced hybrid protocols.

IV. Conclusion

The improvements that need to be made have been presented in the preliminary research. Future work will contain the prediction models and prediction results of the MAC layer as as well as the evaluations and throughput predictions of enhanced routing protocols.

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