RULE MANAGED REPORTING IN ENERGY CONTROLLED WIRELESS SENSOR NETWORKS

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Abstract: This paper proposes a technique to extend the network lifetime of a wireless sensor network, whereby each sensor node decides its network involvement, based on energy resources and the information in each message (ascertained through a system of rules). Results obtained from the simulation of an industrial monitoring scenario have shown that a considerable increase in the lifetime and connectivity can be obtained.

Keywords: wireless sensor networks, energy-aware, industrial monitoring

INTRODUCTION

A Wireless Sensor Network (WSN) typically consists of a number of small, inexpensive, locally powered sensor nodes that communicate detected events wirelessly via multi-hop routing [1]. WSNs are continuing to receive considerable research interest, partly due to the considerable range of applications to which they are suited. A key research area is concerned with overcoming the limited network lifetime inherent in the small, locally powered sensor nodes. Many of the WSN algorithms designed to extend the network lifetime are routing algorithms (deciding which route a message should take through the network). Of these, the majority of such algorithms rely on a distributed or negotiation based process when making decisions [2].

In Hull et al [3], an algorithm is proposed to prioritise outgoing data packets, depending on their derived importance. This is concerned only with controlling bandwidth, and does not consider energy management. Jain et al [4] uses a Dual Kalman Filter architecture to reduce the bandwidth by only transmitting data that cannot be predicted by the base station. This, however, requires nodes to perform complex matrix operations, and communicate with a base station. APTEEN [5] provides a technique to control reporting in clustered networks. A message is transmitted from the sensor node if the value being sensed a) exceeds the hard threshold, b) changes by more than the soft threshold, or c) has not been reported for a preset period of time. APTEEN is controlled by only these three parameters, which may not be sufficient for other applications (such as the industrial monitoring environment investigated in this paper).

In this paper, we propose IDEALS/RMR (Information manageD Energy aware ALgorithm for Sensor networks with Rule Managed Reporting) – a system that extends the lifetime of a WSN through making decisions about packet creation and routing. The extension in the network lifetime is achieved at the possible sacrifice of low importance messages, as a result of a union between:

- Information management – using an unlimited number of highly customisable rules to quantify the information content of sensor data, referred to as Rule Managed Reporting (RMR)
- Energy management, supplemented by energy harvesting

We believe that this union of information management and energy control has not been considered before.

THE PROPOSED SYSTEM

The basic principles of IDEALS were introduced in [6] as a system providing an increase in the lifetime of a network through the discrimination of certain messages. IDEALS was simulated under static conditions, and shown to provide a considerable increase in the network lifetime. The aim of this paper is to continue this work by:

- Extending IDEALS with the proposed RMR (Rule Managed Reporting) system to quantify the information content of sensed data
- Performing a detailed analysis through simulation of the IDEALS/RMR system in a realistic industrial scenario utilising intermittent energy harvesting

The concept of IDEALS/RMR is that a node with a high energy reserve acts for the good of the network by participating in routing all messages that come to it, and by generating its own messages from all locally detected events. However, a node with a near-depleted energy reserve acts selfishly, by only generating or forwarding messages that have a high information content. RMR determines the importance of packets using a system of rules. Any number of rules can be entered by the designer, and describe differing events that can be detected in the sensed environment, including (but not limited to) thresholds (the sensed parameter crosses a predefined limit), differentials (the sensed parameter changes by more than a predefined amount), or features (predefined patterns are observed in the sensed parameter).

IDEALS/RMR is able to extend the network lifetime for important data, through the possible loss of more trivial data. Under normal operating conditions, the network should harvest as much energy as it depletes. However, if an influx of messages occurs as a result of a significant event, IDEALS will manage the decline of the network to maintain its usefulness. The computational costs introduced by IDEALS/RMR are low, as the mathematical operations required are simple comparisons and increments.

This paper considers the simulated industrial scenario of a WSN used to monitor the temperature of 20 pumps in a water pumping station. The pumps are organised randomly as shown in figure 1. In this snapshot, the black dots represent sensor nodes, the lines between them represent possible communication links, the shaded grey circles represent the radio ranges of the sensor nodes, and the white circles represent areas of mechanical vibration (suitable for energy harvesting).

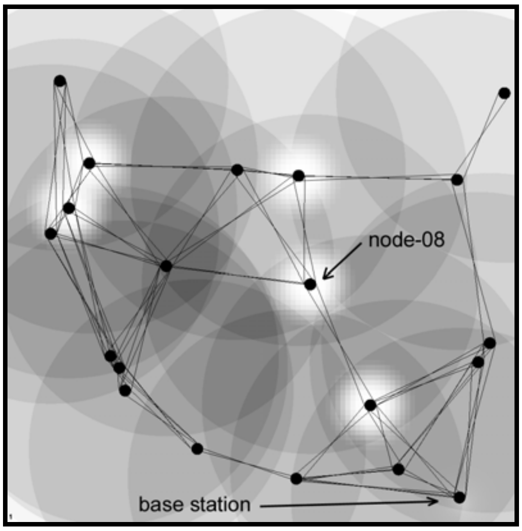

Figure 1 – A snapshot from the industrial monitoring scenario under simulation

The full paper provides a detailed description of RMR, and its integration into the operation of the IDEALS/RMR system. Additionally, extensive results from simulating the industrial network under normal conditions (representing the pumping station operating with no faults), and fault conditions (numerous faults occurring in the pumping station) are provided. For each set of conditions, the simulation is conducted with IDEALS/RMR and energy harvesting independently enabled. Results are presented for:

- **Node energy levels:** the residual energy in the node's battery for the duration of the simulation – shown in figure 2
- **Network connectivity:** the percentage of the nodes that can successfully propagate a packet to the base station
- **Message success:** the percentage of messages that are received by the base station having been transmitted by the node – shown in figure 3

We show that it is possible to sustain continued operation from a 1.2F super-capacitor harvesting around 100µW from intermittent mechanical vibrations.

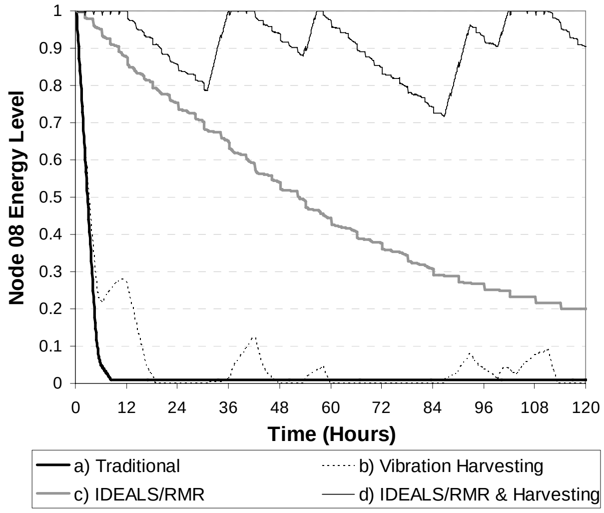

Figure 2 – Fraction of the energy remaining in node08's battery under normal conditions, for each of the four simulations.

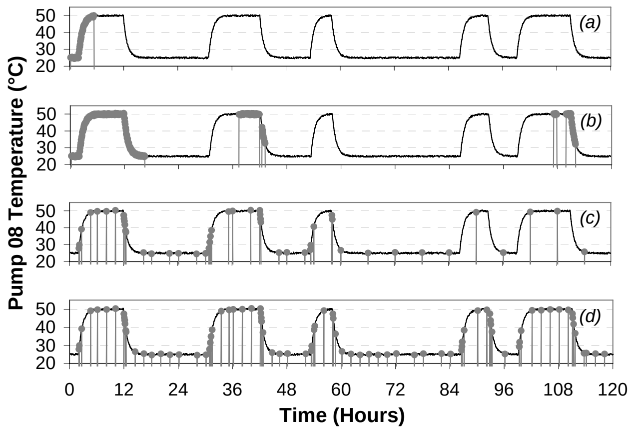

Figure 3 - Message success statistics for node08 under normal conditions for each simulation: a) traditional, b) vibration harvesting, c) IDEALS/RMR, and d) IDEALS/RMR with vibration harvesting. Gray dots represent packets successfully received by the base station.

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