Wireless Sensor Node Mobility and its Effect on Transmission Reliability

K.G. Ngandu[1], C.S. Nomatungulula[1], S. Rimer[1], B.S. Paul[2] and K. Ouahada[1]

[1]Department of Electrical and Electronic Engineering Science
[2]Department of Electrical and Electronic Engineering Technology
University of Johannesburg
South Africa

{gilbertnganduk@gmail.com, suvendic@uj.ac.za}

Abstract. Deploying a Wireless Sensor Network (WSN) poses certain challenges such as data reliability due to Electromagnetic Interference (EMI), multipath fading as well as faster energy depletion of nodes located near the base station creating communication holes in the network. Several energy efficient algorithms have been developed to improve the energy consumption of static nodes however the issue of battery depletion of nodes near the base station remains present. In this paper we attempt to model the relationship between the node mobility and the reliability of data transmission. Mobile nodes could move near static nodes experiencing high traffic in order to reduce the number of packets sent through the saturated nodes. This paper will investigate, using a real environment, the effect of speed and packet size on the reliability of the wireless link. This is a required prerequisite, prior to a detailed design of a Mobile relay node.

Keywords: Wireless Sensor Networks, mobile node, mobility and multi-hop routing.

1 Introduction

The use of WSN can greatly simplify the task of supervision control and data acquisition. Wireless sensor networks have allowed new developments due to their small size and the substantial reduction and simplification in wiring. The wireless sensor technology can have unrestricted configurations. A small device can incorporate the task of analog to digital conversion, digital-to-analog conversion, data processing and data transmission. These devices enable greater flexibility in factory design and layout. Using mesh networking, the wireless nodes have the capability to configure themselves and determine the best path to route data. Despite the apparent advantages of adopting WSNs in industrial control many challenges remain [1].

In this paper we propose the adoption of a combination of static and mobile nodes in order to optimize energy consumption and ensure reliable data collection. We also attempt to derive a model describing the effect of the mobile node speed and packet size on the reliability of the wireless signal. The rest of the paper is structured as follows. In Section 2, related work in the field is discussed. Section 3 describes the proposed algorithm and system overview. Section 4 is a summary of the experiments conducted and a discussion on the results obtained. In Section 6, we provide a conclusion.

2 Related Work

In this section we review some of the existing routing and mobility techniques. Luo and Hubaux show that nodes close to the base station experience accelerated battery depletion due to high traffic [2]. The authors established that by using an arbitrary mobility strategy the high traffic load experienced by certain nodes was reduced by a factor of 3. The mobility strategy used is based on sink mobility rather than relay mobility because the authors suggest that relay mobility has greater impact on latency compared to sink mobility. The base station mobility strategy used did not take into consideration the moving speed of the base station.

Berkeley MintRoute is a routing protocol that was designed for data transmission where all nodes directly transmit to a base node in a wireless sensor network (all-to-one transmission model) [3]. In order to achieve reliable communication the algorithm uses a distributed distance-vector based approach. The routing table data is intermittently transmitted between neighbor nodes and the next hop is determined by computing the costs of routing data through different neighbor nodes. One of the main objectives of the MintRoute is to minimize the total number of message transmissions hence increase the network life. Wu et al [4] have managed to distinguish packet losses due to attenuation as opposed to packet losses due to mobility of the transceivers. Three speeds were used namely static, walking and vehicular speed.

3 Proposed Solution

In robust environments, reliability of static WSNs can be compromised by interference and collisions. Furthermore, the probability of message loss will increase with the number of hops in the network [5]. A mobile sink or a mobile relay will have the advantage of using a single-hop transmission for data collection. Close range single-hop communication can increase the energy efficiency and reliability of the network [6] [7]. The real-time and reliability requirements of SCADA systems require the use of mobile relays instead of a mobile sink. The network load for mobile relays is smaller than the mobile sink case. Furthermore, a mobile gateway can be impossible to implement in certain applications [8]. In order to achieve reliable, real-time and energy efficient data collection in an industrial environment, we propose the usage of a mobile relay that will transmit data from the sink to the end point. The mobile relay (MR) will receive the data to be relayed from the base station and will move to a better location if the RSSI (Received Signal Strength Indicator) of one of the links weakens (base station-mobile relay link or mobile relay-end point link). We assume that the location of the static nodes is known by the mobile relay and the base station. The MR will make sure that both links are above the reliable Received Signal Strength (RSS) threshold. The RSS is a measurable quantity and can be readily obtained from several communication chipsets. The algorithm shown in Figure 1 will be applicable to a mobile relay with an XBee S1 running in API mode and a Microchip PIC16F917. The program comprises two parallel threads, namely:

- Communication Thread: This thread is responsible for the routine transmission and reception of packets.
- Relay Motion Thread: This thread decides if the relay should change its location.

When the mobile relay receives a packet, it extracts the destination address, the data, the sender identification and the signal strength. Depending on the sender, two signal strength variables namely rssi1 or rssi2 will be set. For example, if the static sink sends a command to machine 1 via the mobile relay, the packet received by the mobile relay from the sink will set the rssi1 variable(link 1: from sink to mobile relay). When the relay receives a packet from machine 1, rssi2 will be used (link 2: from machine1 to mobile relay). The set link RSS block will manage what variable needs to be set. Since the mobile relay has the intended destination address and the data to be sent, the checksum can be calculated in order to assemble the packet. Once the packet is assembled and transmitted to the destination, an acknowledgment must be received. The relay motion thread will continually compare both links to a reference RSS threshold in order to determine whether the mobile relay should move or not. The move relay function is a crucial part of the algorithm. Prior to its design, we need to understand how different factors affect its design. Mobility and packet size are two such factors that we aim to investigate in this paper.

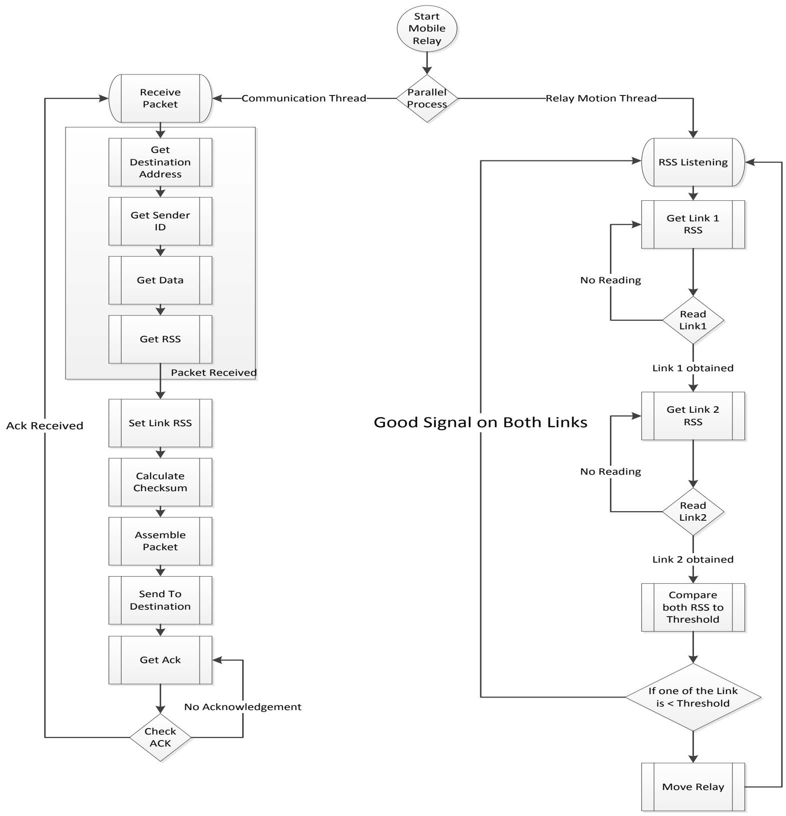

Fig. 1 Mobile Relay Algorithm

4 Results and Discussion

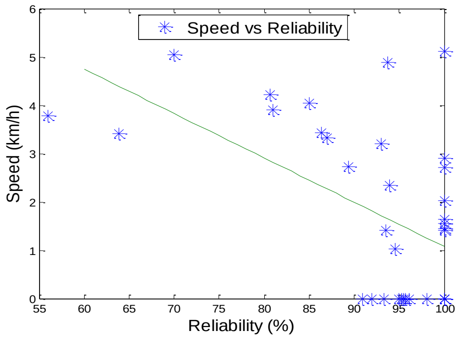

Fig. 2 **Speed vs. Reliability (8 bytes)**

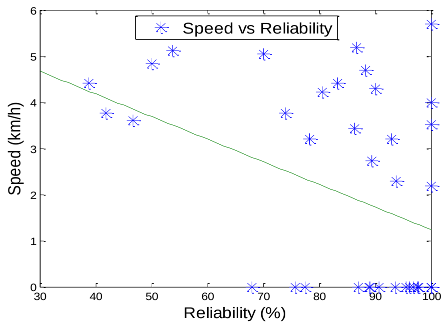

Fig. 3 **Speed vs. Reliability (16 bytes)**

Three nodes were placed in the corridor in the department of Electrical Engineering at UJ (simulation of an industrial environment). The endpoint and the base station were placed within line of sight. Since our aim was to determine the effect of the mobile relay motion speed on the communication link, the mobile relay was moved from the endpoint to the base station at various speeds while the endpoint was sending data. The computer connected to the base station node would determine the percentage of good packets received for the duration of the mobile relay motion. We conducted our experiments for two different packet sizes, 8 bytes and 16 bytes. We also took measurements of the link reliability from different distances when the mobile relay was stationary.

From Fig. 2 and Fig. 3, we have an indication that speed has an effect on the reliability of the transmission. As the speed increases there is a trend for the reliability to start deteriorating. We can see that the speed had greater effects on the reliability when the message size was increased. Since the message is larger, the packetization time has increased. Using the same data rate as the 8 bytes experiment will generate more errors. Decreasing the transmission rate while the mobile relay is moving could improve the reliability.

5 Conclusion

In this paper, the outline of a mobility and routing algorithms was presented. The objective is to move the relay to a better position if the RSS level recorded is below the reliability threshold set. In order to determine the viability of such an algorithm in a real life setup and before we embark on a detailed algorithm design, a series of experiments were conducted. The main purpose of these experiments was to determine the effect of speed and packet size on the reliability of transmission. From the experiments conducted, it was discovered that the speed and packet size have an effect on the reliability of transmission, to such an extent that we were unable to derive a suitable model to describe this effect. Further experimentation involving a larger dataset is thus required prior to the detailed design of a MR system.

6 Acknowledgements

This work is based on research supported in part by the Eskom Tertiary Education Support Program (TESP), reference number 264030.

7 References

[1] T. O'Donovan, J. Brown, F. Busching, A. Cardoso, J. Cecelio, J. d. O, P. Furtado, P. Gil, A. Jugel, W.-B. Pottner, U. Roedig, J. s. Silva, R. Silva, C. Sreenan, V. Vassiliou, T. Voigt, L. Wolf and Z. Zinonos, "The GINSENG System for Wireless Monitoring and Control: Design and Deployment Experiences," ACM Transactions on Sensor Networks (TOSN), vol. 10, pp. 111-154, 2012.

[2] J. Hubaux and J. Luo, "Joint Mobility and Routing for Lifetime Elongation in Wireless Sensor Networks," in 24th IEEE INFOCOM, 2005.

[3] A. Woo, T. Tong and D. Culler, "Taming the Underlying Challenges of Reliable Multihop Routing in Sensor Networks," in ACM SenSys, 2003.

[4] K. Wu, H. Tan, H.-L. Ngan, Y. Liu and L. Ni, "Measurement Study of Mobility-Induced Losses in IEEE 802.15.4," in IEEE ICC, 2010.

[5] D. F. Mario, S. K., D. Crewman and G. Anastasi, "Data Collection in Wireless Sensor Networks with Mobile Elements: A Survey," ACM Transactions on Sensor Networks (TOSN), vol. 8, no. 1, August 2011.

[6] J. Mohorko, K. Benkič, F. Žarko and M. Pešović, "Single-hop vs. Multi-hop – Energy efficiency analysis in wireless sensor networks,," in 18th Telecommunications forum TELFOR 2010, Belgrade, 2010.

[7] Z. Shelby, C. Pomalaza-Raez, P. Mahonen and J. Haapola, "Cross-layer Energy Analysis of Multi-hop Wireless Sensor Networks," in Proceeedings of the Second European Workshop, 2005.

[8] W. Wang, V. Srinivasan and K.-C. Chua, "IEEE/ACM TRANSACTIONS ON NETWORKING," Extending the Lifetime of Wireless Sensor Networks Through Mobile Relays, S vol. 16, no. 5, pp. 1118-1119, October 2008.