Demo Abstract: Radio-diversity Collection Tree Protocol

Wen Hu, Brano Kusy, Christian Richter, Michael Bruenig, Cong Huynh
CSIRO ICT Centre, Australia
{firstname.lastname}@csiro.au

ABSTRACT

We demonstrate how the communication reliability in a sensor network (end-to-end delivery ratio and network stability) can be improved by exploiting transceiver diversity. A new sensor platform, Opal, which features a dual radio configuration working in the 900 MHz and 2.4 GHz band, but driven by a single micro-controller is the basis of the demonstration. A new dual radio collection tree protocol network architecture is designed to provide a transparent communication stack to the upper layer users in TinyOS.

Categories and Subject Descriptors

C.2.1 [**Computer Communication Networks**]: [Network Architecture Design]

General Terms

Experimentation, Performance

Keywords

Sensor networks, collection tree protocol, radio diversity

1. INTRODUCTION

We demonstrate a dual radio system used to produce the results of our paper published in the Sensor Platforms, Tools and Design Methods (SPOTS) track [2][1].

The quality of radio links is highly coupled to unpredictable physical environments, leading to intermittent connectivity and frequent outages. Because link qualities are not predictable prior to deployment, current deterministic solutions to unreliable links, such as increasing network density or transmission power, do not adequately address this issue. We propose a new dual radio network architecture to improve communication reliability in wireless sensor networks. Specifically, we show that radio transceivers operating at dual widely-spaced radio frequencies and through spatially separated antennas offer robust communication, high link diversity, and better interference mitigation. The main advantage of the proposed system is its ability to select alternate routes when links become unreliable. As there are currently no devices that jointly use the selected radio bands, simultaneous interference on both of them is unlikely to occur.

[1]We used a prototype in [2], which featured two radio daughter boards with an Atmel Atmega1281 micro-controller. In this demo, we use a fully integrated mote platform called Opal (see Section 2 for details).

IPSN'11, April 12–14, 2011, Chicago, Illinois.

2. BACKGROUND

We use an in-house built sensor platform called Opal in this demo. Figure 1 shows a prototype Opal node, which features an Atmel AT86RF212 and an Atmel AT86RF231 low-power radio transceivers. Both transceivers are ZigBee (IEEE 802.15.4) compatible, but the Atmel AT86RF212 works in the ISM 900 MHz band and the AT86RF231 works in the ISM 2.4 GHz band. Both radios have similar energy consumption for transmitting and receiving, and they share a micro-controller, an Atmel Cortex SAM3U4E, via different SPI buses (see Figure 2). The Atmel Cortex SAM3U4E is a low-power 32-bit micro-controller which consumes approximately 28.8 mA when running at 48 MHz.

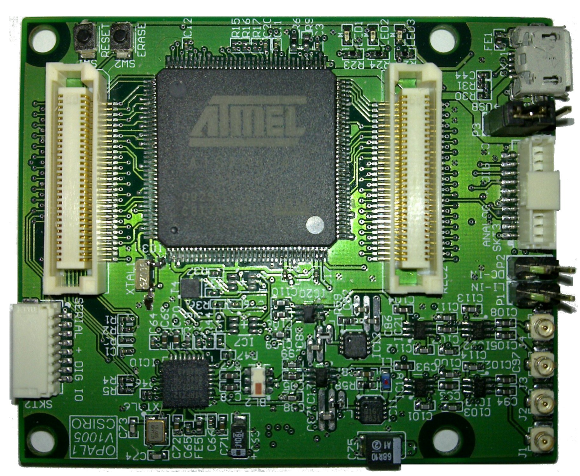

Figure 1: Opal (features two radio transceivers working at 900 MHz and 2.4 GHz respectively).

One of the key design criteria for our platform was to fully comply with standard TinyOS networks operating in a single radio band (either 900 MHz or 2.4 GHz). Therefore, we

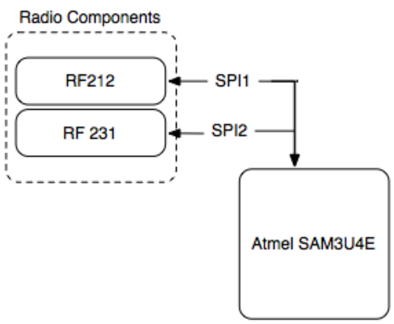

Figure 2: Opal system architecture.

integrated the support for multiple radios in the Collection Tree Protocol (CTP) communication stack [1] of TinyOS 2.1 (see Figure 3). This allows for TinyOS applications and services to be ported to our platform, and to allow them to utilise the dual radio functionality without modifications.

Although drivers for both AT86RF212 and AT86RF231 transceivers are supported by TinyOS, we choose to separate the two radio stacks completely and to execute the two drivers in parallel so that the two drivers can operate simultaneously, e.g., we can start and stop each radio independently to conserve energy consumption during Low Power Listening (LPL). We introduce a uniform link layer, which maintains a neighbour table each band to track radio link qualities of neighbouring nodes via the number of Expected Transmissions (ETX). Consequently, the original CTP implementation in TinyOS requires minimum modifications because it is completely agnostic to which radio band is used to calculate the ETX between a specific neighbour and itself. Therefore, the network layer can make routing decisions without explicitly considering radio diversity. Instead, it chooses a neighbour with the smallest end-to-end path ETX as its topology parent just like the original CTP does.

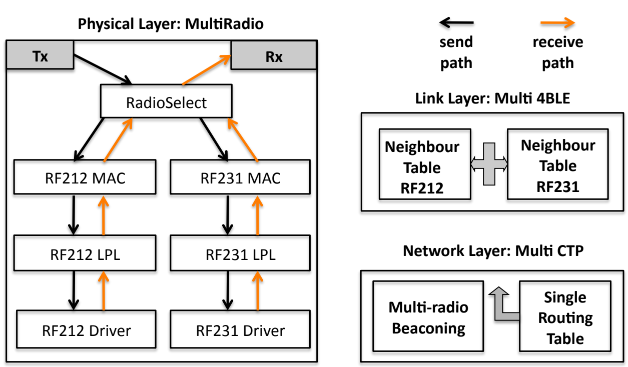

Figure 3: Multi-radio Collection Tree Protocol.

Our experimental results show that the proposed multi band CTP can choose the best quality end-to-end path to deliver packets to the base station that could consist of pure 900 MHz radio links, pure 2.4 GHz radio links, or the hybrid of 900 MHz and 2.4 GHz radio links and overcome the any single band radio interference completely, which provide significantly higher end-to-end packet delivery rates (e.g., 99.76%) compared to original single band CTP (e.g., 70.39% for 900 MHz and 87.27% for 2.4 GHz respectively). Moreover, the energy overhead of running dual band radio is insignificant. For example, compared to original single radio CTP, the proposed dual-band CTP consumes approximately 18% more energy only when the network packet generation rate is one packet per second and the LPL check interval is 1,024 ms. The readers are encouraged to refer to the main publication [2] in this proceeding for the detailed evaluation methodology, metrics and results.

3. DEMONSTRATION OVERVIEW

We will use 10 Opal nodes to form a multi-hop network in this demonstration. The nodes will be equipped with low gain antennas for each radio to enforce low link qualities at shorter distances in the demo hall. A few interference nodes with matching low gain antennas will be preprogrammed to intermittently jam different radio bands. Users will be asked to take the interference nodes with them and walk around the demo hall. We will display a Graphical User Interface (GUI), which shows the realtime network topology, on the base station (a notebook computer). The edges of the network topology graph will be drawn in different colours, e.g., red for 900 MHz and green for 2.4 GHz, to represent the specific band a node has chosen to communicate with its topology parent.

4. USER INTERACTION

Users will be asked to interfere with a part of the network using a radio jammer (either in 900 MHz or 2.4 GHz). Then, our GUI will show that the correspondent network topology changes under different interferences. Furthermore, we will use different colour LED to show the communication band a particular node chosen to use. Namely, if a node chooses 900 MHz transceiver to transmit a packet, the red LED in the node will toggle. On the other hand, if a node chooses 2.4 GHz transceiver to transmit a packet, the green LED in the node will toggle. This will enhance the user experience which shows how the Opal reacts to interference in real time.

5. CONCLUSION

We have presented the demonstration of our dual radio system on a new sensor node platform (Opal), which can provide high end-to-end delivery ratio and network stability in a hostile radio environment. The users interact with the demo by generating external interference to the network and observe how the system responds to interference in real time demonstrating the resilience of the system.

6. REFERENCES

[1] O. Gnawali, R. Fonseca, K. Jamieson, D. Moss, and P. Levis. Collection tree protocol. In *Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems*, SenSys '09, pages 1–14, New York, NY, USA, 2009. ACM.

[2] B. Kusy, C. Richer, W. Hu, M. Afanasyev, R. Jurdak, M. Bruenig, D. Abbott, C. Huynh, and D. Ostry. Radio diversity for reliable communication in wsns. In *IPSN '11: Proceedings of the 10th international conference on Information processing in sensor networks*, page To appear, 2011.