Integrated and Dynamically Adaptable Interest Dissemination and Convergecasting Algorithms for Wireless Sensor Networks

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I. Introduction

The demo presents IRIS, an Integrated Routing and Interest dissemination System for wireless sensor networks [1]. The strength of this solution consists of the integration of different algorithms in order to have a self-starting, self-adapting and easily reconfigurable sensing system. We implemented all schemes according to a cross-layer methodology, and paying attention to the MAC efficiency. The targeted application is a typical monitoring of physical phenomena such as temperature, humidity, vibrations, etc.

The sensor system works under very-low duty cycle operations. This is needed to provide high energy efficiency but leads to technical challenges related to, e.g., reliably disseminating the interests to all sensors and/or routing packets to the sink. The first scheme that we implemented is the Fireworks [2] data dissemination protocol. This is an efficient algorithm that, in order to work properly, needs to have some knowledge about the local node density at every sensing unit. To achieve density estimates, we used a further scheme based on a simple Bayesian recursive estimation technique, where each sensor iteratively counts the number of awake neighbors. Such an estimation is performed in rounds, where each additional round refines the quality of the estimates.

For data forwarding towards the sink we adopted the SARA protocol [3]. The next hop election is achieved online and is based on suitable cost metrics, which characterize the goodness of the node to be the relay. These may depend on several factors such as residual energy, queue occupancies, link quality, etc. The routing procedure dynamically adapts to these costs by trying to optimize the cumulative (sensors $\rightarrow$ sink) cost. The behavior of the data gathering protocol can be modified by means of new interest disseminations, whose aim is to change the cost function that is to be used at each node for the next hop election. MAC and routing are integrated together according to a cross-layer paradigm [1]. In addition, forwarding towards the sink, interest dissemination, density estimation and channel access consists of a single TinyOS module.

II. Demonstration

The demonstration shows some of the main features of the IRIS system. A number of EYES [4] sensor nodes are positioned in order to form a multi-hop network. A laptop acts as the data gathering point (sink). In addition, the state of the nodes in the network as well as the paths followed by both data packets and interests are shown by means of a visualization tool. The first aim of the demonstration is to show the effectiveness of the interest dissemination protocol. All nodes turn on and off their radio according to a given duty cycle during the whole demonstration (a led blink on each node to show its sleeping status). The sink node starts the interest dissemination whose result is tracked thanks to the visualization tool. Particular emphasis is given to the total number of nodes that are reached by the dissemination. In addition, the data dissemination is used to send specific commands to the sensors such as the traffic rate, the data gathering mode, and to specify the cost function that the nodes must use to propagate their readings towards the sink. Finally, self-adaptation is demonstrated by manually removing nodes from the network (so as to simulate failures) and showing that the data gathering towards the sink continues unaffected by exploiting the still available paths.

A. Demonstration Details

Next, we briefly outline some of the features/details of our demonstration.

Network and packets:

- **Sink node:** A sensor, randomly chosen among the nodes in the network, is connected to a laptop hosting the data gathering software.
- **Packet content:** Packets sent by the sensors to the sink contain information about the network topology: each transmitter includes in the packet a list of its neighbors. Additionally, the list of the hops traversed to reach the sink is also maintained. Finally, the payload carries information about temperature and/or light.
- **Data Collection:** Thanks to the data gathering software (running on the laptop) we collect information about light and/or temperature. Moreover, such information can be retrieved from any subset of the nodes in the network. Readings are reported either periodically or asynchronously (e.g., when a certain event occurs).

Data gathering software (see Fig. 1):

- **Description:** the software facilitates the control of the sensor system. Commands to the sensor networks are sent by means of interest disseminations. Interaction with the user is achieved through a graphical interface composed of four windows as detailed next.
- **Window1 – Dissemination:** from here the user can start the interest dissemination phase. The interest is described by means of an XML file, which can be modified by

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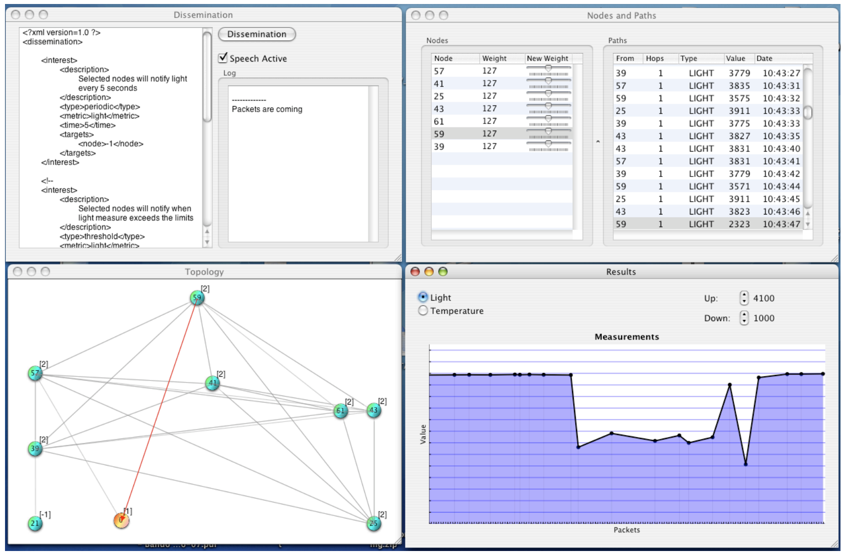

Fig. 1. Screenshot of the data gathering software.

the user. A *disseminate* button is provided to start the procedure.

- **Window2 – Nodes and Paths:** this window includes two tables. The table on the left keeps track of the sensors from which the sink has received at least one packet. The table on the right shows the packets received by the sink and their content. The user can select any node in the left table to visualize, in Window4, the complete list of data coming from this node.
- **Window3 – Topology:** this window is used to show the network topology. The topology is created online as the sink starts receiving data. The route of each packet is plotted by selecting the corresponding packet in the right table of Window2.
- **Window4 – Results:** the function of this window is to show the measurements collected by any given node appearing in Window2.

III. Sensor Network Platform

The EYESIFXv2 sensor device is featured with a Texas Instruments M430F1611 micro-controller equipped with an internal voltage and temperature sensor, fast wakeup from sleep modes ($\leq 6\,\mu s$) and integrated 12-bit ADC and DAC converter. It has a 16-bit RISC CPU, 10 KB RAM and 48 KB of flash memory. The sensor is designed in order to have a ultra low energy consumption. For instance, the M430F1611 works within a low power supply range ($1.8 \rightarrow 3.6$ V) and consumes about 330 μ A when in active mode at 1 MHz and 2.2 V, whereas in standby and off mode the energy consumption decreases to 1.1 and 0.2 μ A, respectively. The micro-controller is also equipped with a supply voltage monitor. In addition, there is a 512 KB on-board serial EPROM. The radio chip is a low power FSK/ASK transceiver, providing half-duplex low data rate communication in the 868 MHz band. The radio chip can operate using FSK modulation with a sensitivity lower than -109 dBm, which enables a data rate of 64 Kbps.

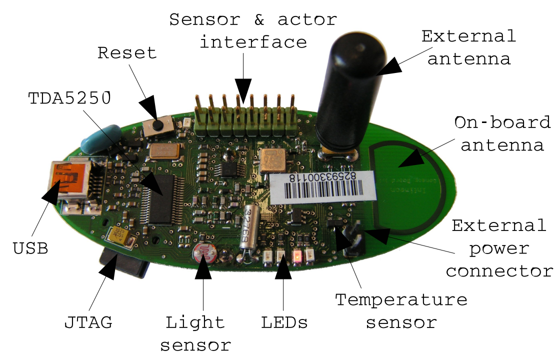

Fig. 2. Top view of the EYES sensor node.

Typical current consumption for the radio transceiver is $I_s = 9$ mA in receive mode, $I_s = 12$ mA in transmission mode. The transmission power can be modulated thanks to a digital potentiometer with 255 settings (even though only 180 to 255 produce useful transmission power level variations). Moreover, the nodes come with on-board temperature and light sensors as well as an SPI expansion port. Such a port can be used for additional sensing capabilities. Finally, the nodes can be powered by batteries with a capacity of 1000 mAh of through a power supply connected via an external polarized connector or a USB connection.

References

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