Wireless Multihop Networking for a Scalable Indoor Temperature Monitoring System

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***Abstract*—Wireless multihop networks have attracted much attention due to their flexibility and connectivity possibilities. In this demonstration proposal a novel network architecture of opportunistic routing is introduced, based upon the cognitive networking concept which opportunistically utilize the network resources, including both spectrum and station availability. The proof-of-concept prototypes are developed to show the enhanced real-time data transmission of an indoor temperature monitoring system. Packet transmission is over multiple wireless hops through opportunistic resource utilization and a drop-and-play networking model which can vastly save network deployment cost.**

I. Introduction

Wireless multihop network consists of spatially distributed autonomous nodes for data acquisition. In a complex indoor environment the deployment of such a network is relatively straightforward, and with low cost. Typical applications include monitoring of physical or environmental conditions. The non-line-of-sight (NLOS) problem is considered as one of the main challenges of these networks, especially in indoor environments, such as buildings. The line-of-sight (LOS) path can be blocked and the communications are conducted through reflections and diffractions.

In [1], a detailed cross-layer network architecture was proposed for cognitive networks, based on a new definition of wireless linkage. The new abstract wireless links are redefined as arbitrary mutual co-operations among a set of neighboring (proximity) wireless nodes. To support multihop wireless communications, a wireless unicast module is introduced under the cognitive networking architecture, which integrates opportunistic routing and opportunistic spectrum access in providing reliable and high performance end-to-end communications in large-scale wireless networks. In the proposed demonstration, cognitive networking [2] is used along with opportunistic routing [3], [4] in a wireless multihop network for temperature monitoring. The proof-of-concept is achieved via prototype where real-time data collection is supported. Moveover, a fluid drop-and-play network has been achieved.

II. Demonstration Modules

The proposed demonstration is a wireless indoor temperature monitoring system that consists of the following modules:

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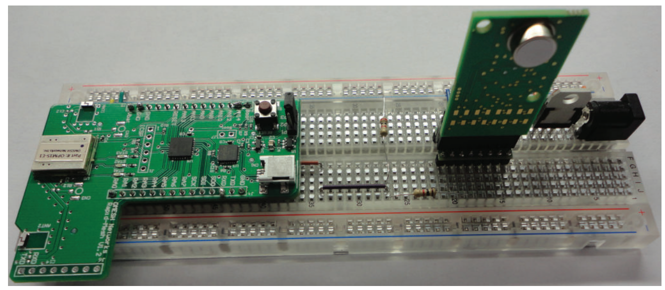

Fig. 1: Temperature Monitoring Board

A. Temperature Monitoring Board

Temperature monitoring board is a prototype [5] that has a *sensor module* connected to a *transmission module*, as shown in Figure 1. The *sensor module* monitors the temperature around the board and passes this information to the transmission module. iAQ-2000 sensors are used to monitor the temperature. The *transmission module* can be divided into communication and application level. Communication between different transmission modules is done at communication level while the data processing is done at the application level.

At communication level, the radios have been implemented with *Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)* method. In CSMA/CA, a carrier sensing scheme is used where a transmitter that detects another signal while transmitting a packet, stops transmitting that packet, transmits a jam signal, and then waits for a random period of time before trying to retransmit. At application level, there is a unicast transmission mode that transmits any data received from *Universal Asynchronous Receiver/Transmitter (UART)* to radio. In unicast mode, radios only establish point to point transmission where the transmitter sends to the destination.

Packets are created every second at the same rate as the sensor sends out data. A packet consists of three fields: identifier, timestamp, and data. Figure 2 shows the packet forming, transmitting and receiving process. The identifier stores the number of the transmitter which sends the packet in order to allow the receiver to identify the origin of the packet. Timestamp field stores the time the packet was created, so the receiver can prioritize the packets base on their timestamps. Data field contains all the crucial information from the monitoring area around the transmitter.

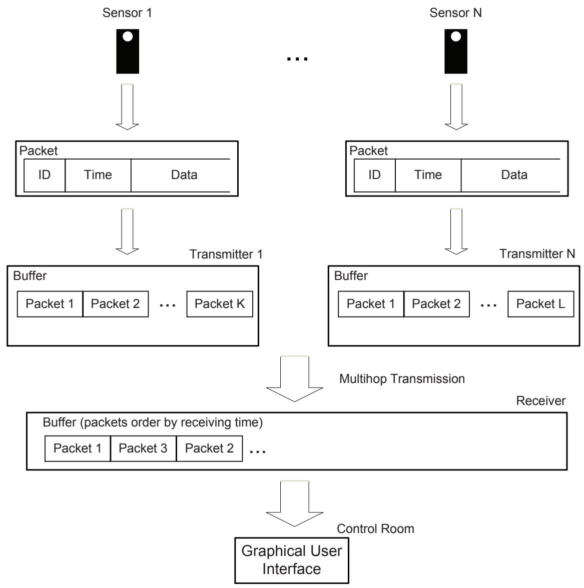

Fig. 2: Forming packets and transmitting

B. Drop-and-play radio module

RapidMesh OPM15 board is used as radio module, shown in Figure 3. OPM15 can be powered by the mini-USB port, or by external battery through the VBAT pin. The maximal air interface radio rate is $250kbps$, whereas the radio transmitting power is programmed to a lower level $-25dBm$, giving the radio range at about $15-20$ meters.

The modules are programmed to implement opportunistic utilization, hence, any module can join or leave the network at any time, without the need of special configuration. In an indoor complex infrastructure, the temperature monitoring of a room can be enhanced by adding a number of radio modules between the temperature monitoring board and the control room. On the other hand, modules can be moved to different locations without any special configuration procedure. Moreover, radio modules also implement opportunistic routing, hence efficient throughput and delay can be achieved.

C. Graphical User Interface

The graphical user interface runs in the control room of the monitoring system. It collects all the data packets that are transmitted and then it displays the temperature of each room. The data collection is done by a radio module connected to the computer while the reading of the packet is done via a developed application in $C\#$.

III. Demonstration Description

The proposed demonstration develops the idea of opportunistic multihop networking, along with wireless sensor and cognitive networks. A number of temperature monitoring boards are located in an indoor environment. The collected data are transmitted through OPM15 radio nodes to a control room, where the data are stored, processed and displayed in real-time with a developed graphical user interface.

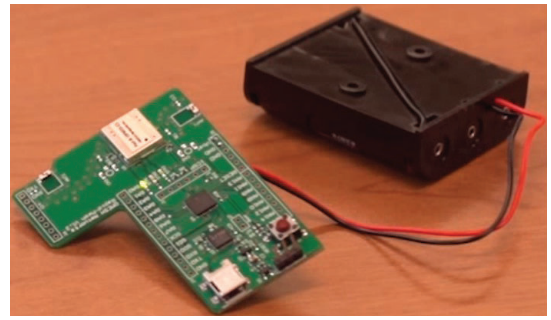

Fig. 3: OPM15 Radio

In this demonstration, we use one board to connect directly to a computer and act as the destination node, 4 temperature monitoring boards to monitor the temperature in different locations and a number of drop-and-play radio modules, between 3 to 6, to transmit the data. When more radio nodes join the network, the performance is improved in terms of throughput . Any new radio nodes can easily adapt to the network conditions without the need of any special configuration. Information about the relative location of the new nodes can be acquired by the neighboring nodes. When the temperature monitoring board is moved out of the range of the control room or the signal is blocked, the communication will be enhanced by adding a number of relay radio nodes in between. When a radio node leaves the network because of hardware failure or runs out of energy, the system will keep monitoring the area and the necessary packet transmission will be forwarded though other nodes. Since opportunistic routing is dynamic routing, again there is no need to reconfigure each node in the network.

IV. Conclusion

A demonstration of opportunistic multihop wireless communication is proposed. The enabling technology is of the large scale cognitive networking, with the use of opportunistic bandwidth and spectrum availability. A scalable indoor temperature monitoring system is developed to examine the performance of the proposed technology. Opportunistic routing along with cognitive networking can provide a scalable and reliable indoor monitoring system.

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