Prototypes of Opportunistic Wireless Sensor Networks Supporting Indoor Air Quality Monitoring

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Contribution

In this demonstration we describe a prototype of a Wireless Sensor Network (WSN) for monitoring the air quality of an arbitrary indoor infrastructure environment. Specifically, the proposed demonstration deals with an application of wireless mesh networks for monitoring the carbon dioxide (CO₂) levels of an indoor environment, supporting guaranteed real-time data acquisition and display. In the demonstration we will illustrate a number of advantages of opportunistic routing, including dynamic node deployment and dynamic routing path selection, opportunistic resource utilization, robustness to interference and guaranteed multi-hop QoS (Quality of Service) for an indoor gas concentration monitoring network.

System Modules

The system consists of the following three modules:

i) Sensor module: Indoor air quality sensor nodes, by Applied Sensor, are used for data collection. IAQ-2000 sensors can measure temperature, humidity and carbon dioxide (CO₂) levels. It is a sensitive, low-cost solution for detecting poor air quality in an indoor environment. Figure 1 shows an IAQ-2000 sensor node.

ii) Radio module: Radio nodes from OMESH networks are used for the wireless data transmission. RapidMesh OPM15 Development Platform is an open-source embedded platform that provides the tools for rapid wireless application development with the OPM15 radio module. At communication level, the radios have been implemented with multi-channel collision avoidance method. Figure 2 shows an OPM15 radio node. The node keeps monitoring the gas concentration (mol/m³) in the environment. The collected data are fed to the radio node, through a electronic circuit, shown in Figure 3, to properly form data packets and transmit them to the control room.

iii) Data aggregation interface: The graphical user interface (GUI) module runs at a workstation in the control room. The workstation is connected with a radio, through serial port, and receives the real-time data from the different nodes and feed them into the data tables and graphs. The interface will report the gas concentration in real time and can perform special actions, i.e. require more data from a node that report a gas concentration that over exceeds a predefined threshold.

Prototype

The development board of the prototype can be seen in Figure 4. The IAQ-2000 sensor requires a 5V power supply. Each prototype is powered by a 9V battery, which provides a 5V output to the RapidMesh board and IAQ-2000 sensor via the L7805CV voltage regulator. The radio at the control room which is connected to the workstation is powered via USB.

Technological Advantages

The demonstration shows that the technology of cognitive networking, along with opportunistic routing, and the potential of an easily deploying and inexpensive wireless sensor network can alleviate the problem. The technological advantages of the demonstration are summarized in the following:

i) Dynamic node deployment and dynamic routing path selection. The network topology is random while all the prototypes have a dynamic "drop-and-play" nature which is of high importance in cost-saving infrastructures. For instance in a large-scale indoor network, the installation or replacement of sensitive sensor nodes would not require to reconfigure the whole network.

ii) Opportunistic resource utilization. DATA packet transmission follows an opportunistic routing protocol. Opportunistic routing is an energy efficient and reliable dynamic routing protocol, especially for indoor environments.

iii) Robustness to interferences. The use of the opportunistic routing along with the opportunistic spectrum access, can provide the necessary robustness toward interference. Operation within unlicensed bands can result in large network capacity.

iv) Guaranteed multi-hop QoS. Cognitive networking can guarantee dataflow over multiple hops, in terms of throughput and end-to-end delay. These factors are crucial in a wireless sensor network for gas detection. It only requires sufficient network resources being deployed to cover the monitoring area. After testing the prototype, the error rate is less than 3% and the delay is minimized, less than 0.5s.

Operational Parameters

The prototype is based on the cognitive networking technology for WSNs, supporting real time data collection. It is implemented with Zigbee radio (IEEE 802.15.4)[1] while the operation parameters can be seen in the following Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Ranges</td>
<td>2405MHz to 2483MHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5MHz per channel</td>
</tr>
<tr>
<td>Peak Input Power to Antenna</td>
<td>3mW</td>
</tr>
<tr>
<td>Antenna Polarization and gain</td>
<td>2dBi Vertical Polarization</td>
</tr>
<tr>
<td>Waveforms</td>
<td>QPSK</td>
</tr>
</tbody>
</table>

References


