Analysis of the Effect of Human Presence on a Wireless Sensor Network

Ben Graham, Letterkenny Institute of Technology, Ireland
Christos Tachtatzis, Letterkenny Institute of Technology, Ireland
Fabio Di Franco, Letterkenny Institute of Technology, Ireland
Marek Bykowski, Letterkenny Institute of Technology, Ireland
David C. Tracey, Letterkenny Institute of Technology, Ireland
Nick F. Timmons, Letterkenny Institute of Technology, Ireland
Jim Morrison, Letterkenny Institute of Technology, Ireland

ABSTRACT

Wireless Sensor Networks (WSNs) are gaining an increasing industry wide adoption. However, there remain major challenges such as network dimensioning and node placement especially in Built Environment Networks (BENs). Decisions on the node placement, orientation, and the number of nodes to cover the area of interest are usually ad-hoc. Ray tracing tools are traditionally employed to predict RF signal propagation; however, such tools are primarily intended for outdoor environments. RF signal propagation varies greatly indoors due to building materials and infrastructure, obstacles, node placement, antenna orientation and human presence. Because of the complexity of signal prediction, these factors are usually ignored or given little weight when such networks are analyzed. The paper's results show the effects of the building size and layout, building materials, human presence and mobility on the signal propagation of a BEN. Additionally, they show that antenna radiation pattern is a key factor in the RF propagation performance, and appropriate device orientation and placement can improve the network reliability. Further, the RSS facility in RF transceivers can be exploited to detect the presence and motion of humans in the environment.

Keywords: Built Environment Networks (BENs), Human Presence, Node Placement, Radiation Patterns, Wireless Sensor Networks (WSNs)

INTRODUCTION

Developments in wireless technology and sensors have resulted in a range of new applications for Wireless Sensor Networks (WSNs). One such type of WSNs is the Built Environment Networks (BENs) which can be deployed in a wide variety of applications such as environmental monitoring, surveillance and healthcare applications. WSNs are characterized by having...
a large number of devices (motes) with sensing capabilities, limited processing capability and wireless connectivity to other devices. The wireless capability allows the sensors to be deployed close to the phenomenon being observed while their limited memory and processing capabilities result in low cost; this allows the deployment of a large number of such devices. The motes used in WSNs usually contain a micro-controller, RF chip, sensors and often use low level operating systems such as TinyOS (Levis, Madden, Polastre, Szewczyk, Whitehouse, Woo, Gay, Hill, Welsh, Brewer, & Culler, 2005) or Contiki (Dunkels, Grönvall, & Voigt, 2004).

When deploying a wireless network within a building, it is vital to have an understanding of how the transmitted signals are affected through obstacles and with distance. The channel between transmitter and receiver may be a line of sight (LOS), but more likely the presence of objects such as office furniture, lab equipment and people will create obstructions and provide multiple paths (multipath) for the waves to reach the receiver. Diffraction, reflection and scattering are main causes of multipath and fading. Multipath and fading are the dominant effects on the channel as the transmitted signal propagates through the media to the receiver (Su & Alzagal, 2008). The ideal antenna radiation pattern for a mote is symmetric in all directions and would result in constant radio range and performance in a spherical radius of the mote (Su & Alzagal, 2008). In reality this uniform transmission pattern does not exist and failure to understand a mote antenna transmission pattern and how it can be affected by the environment can result in network reliability issues and/or inappropriate placement of motes. There are numerous papers that investigate the relationship between signal attenuation and building materials (Jang & Healy, 2009; Wilson, 2002; Masri, Chew, Wong, & Lia, 2005) and software packages that simulate the radio frequency (RF) attenuation within buildings using ray tracing techniques (Kim & Lee, 2009). Little attention has, however, been given to the effects that antenna pattern irregularity and human presence can have on the signal strength and reliability of even a small scale network when it has been deployed.

This paper provides measurements of Received Signal Strength (RSS) from within various locations of a typical office environment during a twenty four hour period and an understanding of how signal attenuation is affected by building materials, antenna selection, orientation and both human presence and movement.

The paper is divided into sections. First we describe the experimental setup and software used. The results of the experiments are provided and discussed following this. Finally, a conclusion is given by highlighting the main outcomes of the paper.

**Experimental Setup**

The experiment consisted of a large number of motes deployed within an office environment for a 24 hour period. The purpose of the experiment is to measure the RSS from a large number of locations within the office. This is achieved by having multiple motes within the lab transmitting data back to a basestation. Measurements of RSS were taken using the CC2420 Received Signal Strength Indicator (RSSI) and used to build a map of the signal attenuation from the centralized basestation. The CC2420 datasheet states that the RF chip has a very linear RSSI measurement with a dynamic range of about 100 dB (Texas Instruments, n.d.). To verify this linearity stated in the datasheet a calibration test was carried out; the results confirmed the linearity was within the +/-6 dB error allowed over the majority of the dynamic range. However non-linear behaviour was highlighted at transmission powers below -85 dBm.

The use of a twenty-four hour test period means that measurements are taken when the office is occupied during the day and unoccupied at night so that the changes in RSS due to human presence can be detected. The use of a large number of motes ensures that an accurate map of RSS can be obtained.
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