Enhanced Logistical Information in Fire Combat Post 9/11

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1. Introduction

Following the events of 9/11, it was necessary for the FDNY to analyze their current communication infrastructure. In a study done by McKinsey and Co. of FDNY’s response to 9/11, there were some startling finds about the communications breakdown and loss of information between firefighters and their command. The study showed that many of the issues faced were caused by deficiencies in the fire department’s present technology. Aside from the circumstances that caused pertinent information to be lost among the firefighting ranks, there was also a lack of adequate building emergency and escape management for the civilians inside which led civilians to get trampled in collapsed escape routes. With such widespread communications breakdown, many unnecessary casualties happened and a need for new communications technology became more prevalent.

In developing new technologies, Richard Nowakowski, the Coordinator of Special Projects, R&D, of the OECM in Chicago, approached Dr. Paul Wright and his students in the Integrated Manufacturing Laboratory (IML) at UC-Berkeley with a proposal to participate in a new project called F.I.R.E., or Fire Information Relay Equipment. The overall project, once implemented would allow firefighters to track their positions within a building, the location(s) of a fire, the ambient temperature, and their current state of health through a Heads Up Display (HUD), or small display screen that would be embedded with the firefighters mask.

In order to accomplish such a task, it was decided that a building would have to be equipped with a network of small wireless sensors that could track the firefighter, a fire, and possibly even civilians. As all this planning was occurring within the Mechanical Engineering Department, across the street at the UC-Berkeley campus, the Electrical Engineering and Computer Science department were developing their own wireless sensor network using motes, small wireless transmitters that had showed some promising results. It was concluded that these motes would be used to create the network necessary.

Using a stand alone mote would allow for a firefighter to track their location, their health and the ambient temperature, however, it would not have the ability to track the fire. In order to accomplish this task, it was determined that integrating a mote into a fire alarm would resolve this problem. Using the mote as a detection device, once an alarm would sound, a signal would be sent back to the base mote of the network, relaying the position of the fire. The incorporated mote would also still have all the previous abilities listed as well.

Although integrating a mote into a preexisting fire alarm seemed to be the most ideal case, the feasibility of such a task needed to be established. To do this, several different fire alarms needed to be analyzed, characteristic diagrams drawn up, possible locations to incorporate a mote determined, flaws of the new circuit examined, and the original fire alarm working properly.
2. Experimental Methodology

2.1 Integrating the mote into a preexisting circuit

In incorporating a mote into a fire alarm, the alarm itself had to first be analyzed and understood. To get a comprehension of the fire alarm circuit, a characteristic diagram of the circuit needed to be drawn up. In drawing such a diagram, this helped determine which sections of the circuit did what within the alarm both when the alarm was sound and active. To get the characteristics for when an alarm is going off, the test fire alarm button that every modern DC power alarm has was used. A table of the voltage, frequency and current was created of each component in the circuit for both states of the fire alarm.

Limited by the capabilities of the motes programming, it was determined that sensing a change in frequency or current would not be possible at the given time. Due to time constraints, it was decided that using the change in voltage to determine the state of the alarm was the most appropriate option. Referring back to the characteristics table, there were three locations within the circuit that experienced a voltage change when the alarm was active, see diagram. For each of those locations when the alarm was off, the voltage was at 0, thus 0 could be used as a threshold in determining the alarms state.

The first location, which is the location of the siren, seemed to be the most ideal. For one, the accessibility was the easy to find and wire a mote to. Second, its voltage change was so significant that it was easy to detect the voltage change at the same time it not affecting the original circuitry. However, although the voltage change was easy to detect, the power supplied to the siren came in pulses in order to give the alarm a pulsated beep. In detecting the state of the alarm, the pulses would cause the sensor to fluctuate between the two states the alarm could be in. A program based upon time delay vs a pulse could be used to determine a more stable state of the alarm but it was determined that either of the other two locations would suffice.

Although the second and third locations did not have the same voltage change, both had sufficient changes that the sensor detection would not be an issue. After determining that both locations could be used by the mote to determine the state of the alarm, it was then time to see the affect that the new circuitry in each location had on the original alarm. Table #, shows the affect that the new circuitry had on the alarm. In viewing the table and testing the circuit it can was concluded that the changes were nominal and had no notable impact on the system.

2.2 Working with TinyOS

In conjunction with integrating a mote into a fire alarm, researching on how to use the mote network system to detect the voltage change as well as ambient temperatures was also conducted. As stated earlier, the wireless network system determined to be used was created here at Berkeley. Dr. Kristofer Pister and Dr. David Culler, Professors of Electrical Engineering and Computer Sciences at UC Berkeley, helped in creating this
wireless system. The system itself is called TingOS, but each individual node, or transmitting device is called a Mica mote. A Mica mote consists of a printed circuit board with a low-power 6MHz microcontroller, RFM radio transceiver and flash memory. A sensor board, used in this case to detect the alarm state and ambient temperatures, is attached by way of a 51-pin connector.

The Mica mote transmits its data via the RFM radio transceiver at 916MHz. The motes communicate by way of packets. A packet consists of 36 bytes of information. It takes 1 byte each to transmit the mote ID, ambient temperature, and voltage detection. The mote transmits the signal to other motes, eventually relaying back to the base station, or central mote. The central mote is connected to a PC via the serial port in which it can relay the information received to the screen with a Java program used to display the information of each byte from the packet received.

To use TinyOS, at least two motes are required. One mote is used as a base station that transmits the packets of information it receives through the serial port to the computer. The other mote(s) using the sensor board attached to it collects and transmits the information back to the base station for data processing.

2.3 Working with TinyDB

TinyDB is a program similar to TinyOS. TinyDB is used to network the motes together allowing for packets transmitted from one mote to transfer to others motes in order to reach the base station. So like TinyOS, there is still one base mote that all motes transmit to, but instead of needing every mote connected to the base mote to transmit information, they can use other motes as a channel to connect them to the base mote. A topology chart is created, letting the user know what motes are connected together as well as the parent-child relationship relative to the base mote, i.e. if mote #2 needs mote #1 to reach the base mote, than mote #2 is a child of mote #1.

The range of each mote can transmit data depends on several different factors that are still under study. One is how new the batteries are, another just depends on the condition of the mote. Although motes peak efficiency is supposed to be around 20 feet, network connections between motes we being created at a distance closer to 80 feet.