A Compact Device to Monitor and Report Firefighter Health, Location and Status

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Abstract

Wildland firefighters are exposed to a number of physiological stressors during the course of their duties, including smoke and carbon monoxide inhalation, physical exhaustion and dehydration. Since firefighters work in large geographic areas on the fire ground, in general their status (working, resting, eating, etc.) and physical positions are not easily established by fire managers further up the incident command chain. To correct this problem, we have constructed a lightweight, portable, unobtrusive device that reports on the health and status of wildland firefighters and monitors the physical environment in proximity to the firefighter. This device records and reports (via radio) temperature and carbon monoxide concentration near the firefighter, physiologic information such as heart rate and breathing rate, position and information on the movements of the firefighter, and firefighter status (as entered by the firefighter on a simple input device). We will show results from laboratory experiments and simulations prior to test deployments in the Northern Rockies and Eastern US.

Introduction

In both structural and wildland firefighting, determining the location and status of firefighters is crucial to the success of the firefighting operation and the safety of the firefighters. In structural firefighting, 15% of the fatalities on the fire ground come from firefighters being lost or trapped within the building.

In general, the sole means of communication between command and firefighters on the wildland or structural fire ground is a low-power voice walkie-talkie, which has limited range and requires a conscious effort to use. If the firefighter is busy or unable to respond or the area is noisy, communication may be impossible or the clarity of the transmission may not be sufficient. Additionally, communication can only take place between one sender and one receiver at a time. If multiple senders are transmitting, (e.g., multiple men in trouble) the strongest signal will dominate ('capture') what is typically an FM (frequency modulated) communication channel and repeats will be necessary or communications may be lost.

In structural firefighting, several systems are under development that use triangulation to determine the position of a firefighter within a building. These systems require the use of multiple antenna/receivers outside the firefighting perimeter. Short duration radio pulses are transmitted by an apparatus worn by the firefighter. The arrival time of this radio pulse at each antenna/receiver permits calculation of the firefighter's position (Time Domain Corporation 2005, Information Systems Laboratories, Inc. 2005). These systems are limited, however, since they cannot transmit the status or health condition of the firefighter. Moreover, they are unable to provide a complete picture of the fire ground to the command. Because a number of antennae are required outside the

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area where firefighters are deployed and transmitter range is relatively short, these systems are far from ideal for wildland fire use.

Systems in the form of an auxiliary attachment to the conventional voice walkie-talkie have become available. These use an external Global Positioning System (GPS) receiver attached to electronics mounted in a microphone handset to determine and transmit the position of the sender (Thales Communication, Inc. 2005). Sub-audible carrier tones are commonly used to encode position information on the voice channel. Special receivers at the command center must be used to decode these sub-audible tones. Although these systems do not require intervention on the part of the firefighter, they cannot be used to transmit health or fire safety information.

Still other systems monitor environmental conditions and report back to command via a radio link. (RAE Systems 2005) These systems are usually emplaced in fixed locations and while measuring a number of environmental conditions that may be of use to first responders or firefighters (hazardous materials airborne concentrations, radioactivity levels, etc.) do not provide information on personnel locations of condition.

In response to these issues, we have constructed a system that: (1) answers the need for unattended communication between a firefighter and command; (2) is not tied to the conventional voice communication channel; and (3) transmits firefighter position as well as status, health and environmental information in the vicinity of the firefighter.

Discussion

Using current technology, it is possible to construct a lightweight, portable system that can monitor local environmental conditions, the firefighter's physical condition and his or her location. This system can provide information in a number of fashions: automatically (e.g. environmental and firefighter health information); on command from the firefighter (status information e.g. 'out of service', 'resting', 'on duty'); or in response to a question from command. The units employ networked digital communication that can provide the command center with an immediate, continuous global view of the fire ground. We have built similar equipment for use as fire ground data recorders for research purposes. (Kremens 2003a, Kremens 2003b).

A schematic of the system carried by the firefighter is shown in Figure 1. The unit is small (12.5 X 17.5 X 5 cm) lightweight (~ 500 gm) and uses conventional 'AA' alkaline cells for power. The main unit is intended to be carried in the outside pocket of a firefighter's line gear, where the GPS receiver can have sufficient signal strength to locate the firefighter. Another small box ('dongle') with 3 LED lamps and input switches is used to signal various conditions to the firefighter and allows the firefighter to report back to command with status information. The dongle is attached to a cable that can be placed on the firefighter's line gear shoulder strap, where the lights are visible and the switches are easy to access. The location of this signal/input dongle is similar to that in equipment worn by structural firefighters on their SCBA (self-contained breathing apparatus) gear to signal "man down" and other hazards. A GPS receiver is attached to the main unit with hook-and-web tape, or may be detached to place the antenna in a better position on the line gear for receiving the signals from the GPS satellite system. A loud-sound signaling device is built into the unit to alert the firefighter of environmental dangers, to signal an emergency situation to nearby fellow firefighters, or to alert the firefighter about warnings received from command (e.g. rapid changes in the weather).

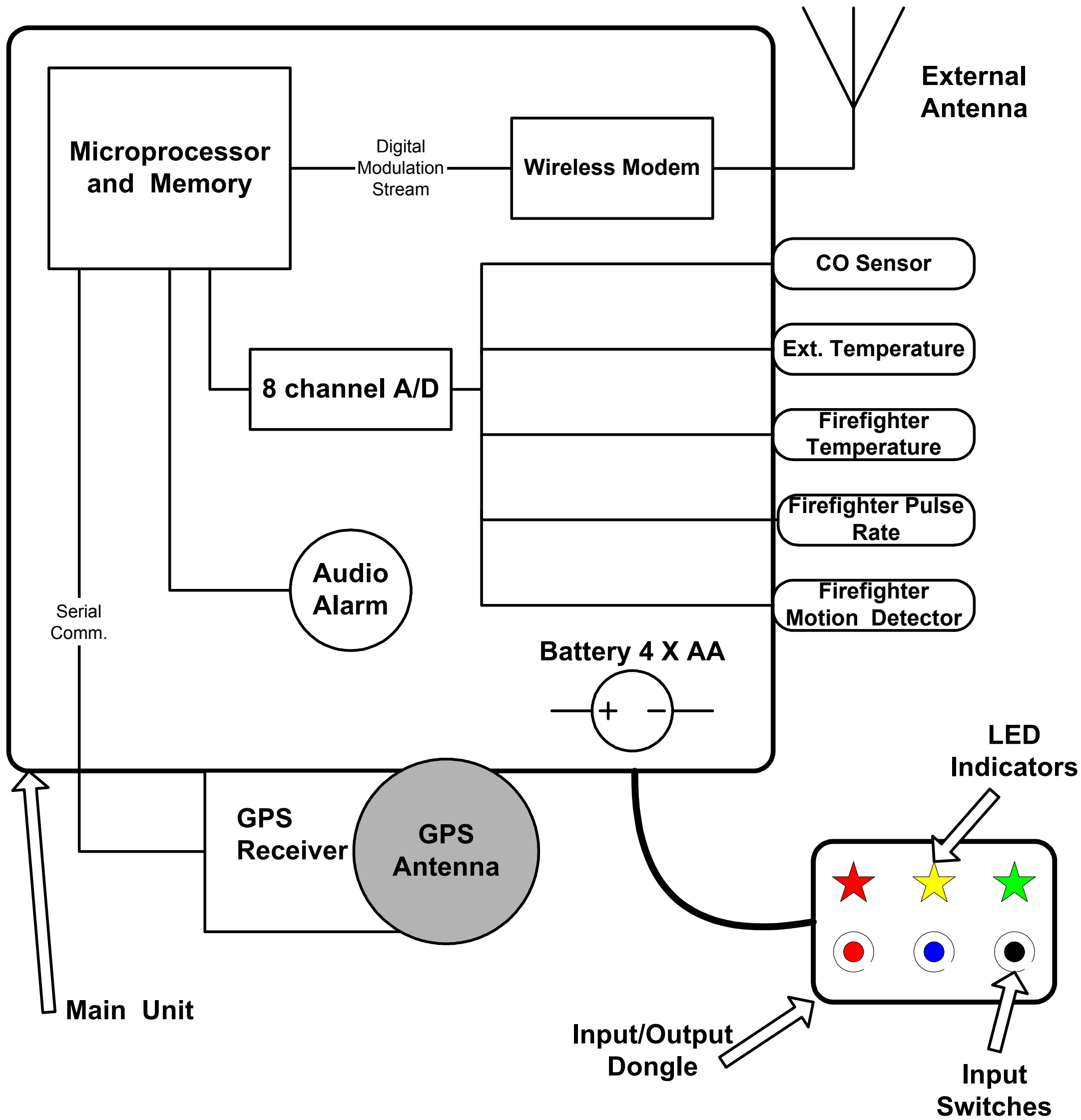


Figure 1 - A schematic of a system to monitor local environmental conditions, firefighter health and location.

Table 1 illustrates some of the possible input and output states for the firefighter signaling unit. Note that the communication is unattended and two-way. Proprietary (e.g. Maxstream Inc. 2005) or IEEE standard (e.g. 802.15.4 devices by Innovative Wireless Technologies, Inc. 2005) transparent wireless modem technology allows transmission of digital data between firefighter units or between units and a command post or posts without regard for the complexities of the underlying network commands or topologies. Another feature of the wireless modem used in this device is that it triggers the system to repeat transmissions in the event of missed data until a successful, accurate two-way message is obtained. Table 1 shows the messages sent to command and alarms received for operation of the switches on the dongle. Note in some cases that unless responses are received from the firefighter within a fixed time (e.g. the "In Service" query), an alert to command will be issued.

Sensor State	Red Led	Yellow LED	Green LED	Sound Alarm	Message Sent
No Hazards			X		Firefighter #, OK
CO Detected		X			Firefighter #,CO Alert
CO High Levels	X				Firefighter #,CO Hazard
No Motion for 20 seconds		X			Firefighter #,OK
No Motion for 60 seconds	X			X	Firefighter #,Potential Man Down
Outside Temperature > 35 C^o		X			Firefighter #,High Temp
Outside Temperature > 45 C^o	X			X	Firefighter #,Fire Alert
Body Temeperature Normal			X		Firefighter #,OK
Body Temperature High	X			X	Firefighter #,Body Temp Alert
Pulse Rate < 100			X		Firefighter #,OK
Pulse Rate > 150		X			Firefighter #,Active
Pulse Rate > 185	X			X	Firefighter #,Stress Alert
In Service Query		Flash		X	Firefighter #,In Service?

Table 1 - States of the sensor inputs, LED indicators, and messages sent to command.

Red Switch	Blue Switch	Black Switch	Sound Alarm	Message Output
X	N/C	N/C	X	Firefighter #,Man Down
	X	N/C		Firefighter #,Out of Service
		X		Firefighter #,In Service

Table 2 - Table of messages and sound alarms for various switch inputs. N/C means 'don't care'.

The receiving end ('command') of this system can be composed of a portable computer system (ruggedized laptop) or a Personal Data Assistant (PDA) and a wireless modem. (Figure 2) The wireless modem seamlessly transmits and receives data and monitors the integrity of the data link from each firefighter to command. The information can be displayed in a simple list format (a list of the number of firefighters and present status and alarms) or as an overlay on a GIS product where the information can be displayed in real time on a map. For this study we have limited investigation to crew level deployment, (star topology). It is possible, however, to relay the crew level information with distillations for higher command to upper command levels (branch topology) (Figure 3). Since the digital data stream addressing and message delivery is transparent to the user, 'dumb' repeaters are all that is necessary to relay information to higher command centers. The repeater system may also have data concentration and decision capability locally, reducing the amount of data flowing up to higher command levels.

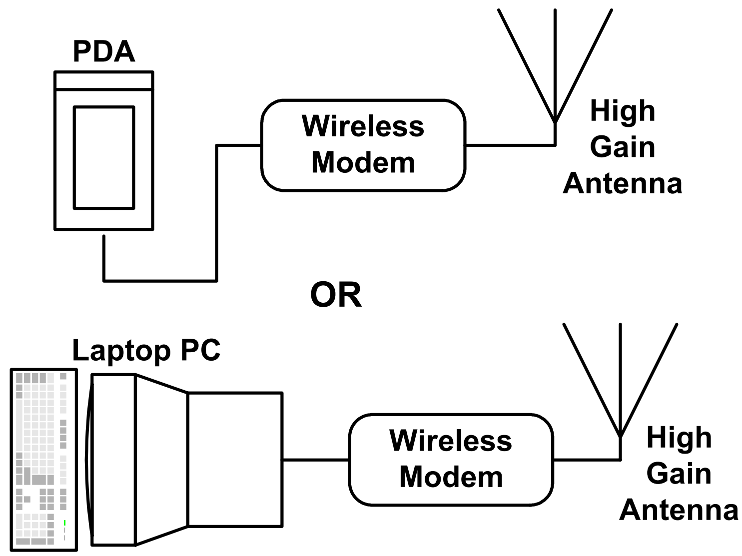


Figure 2 – Two possible data receivers for a crew-level implementation of the firefighter safety unit.

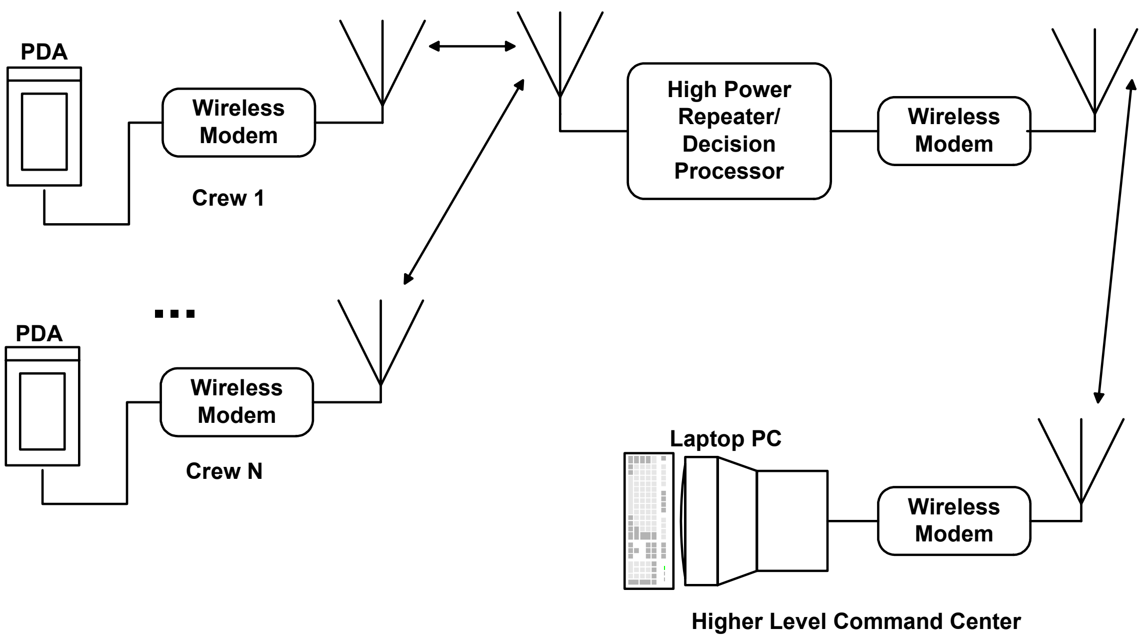
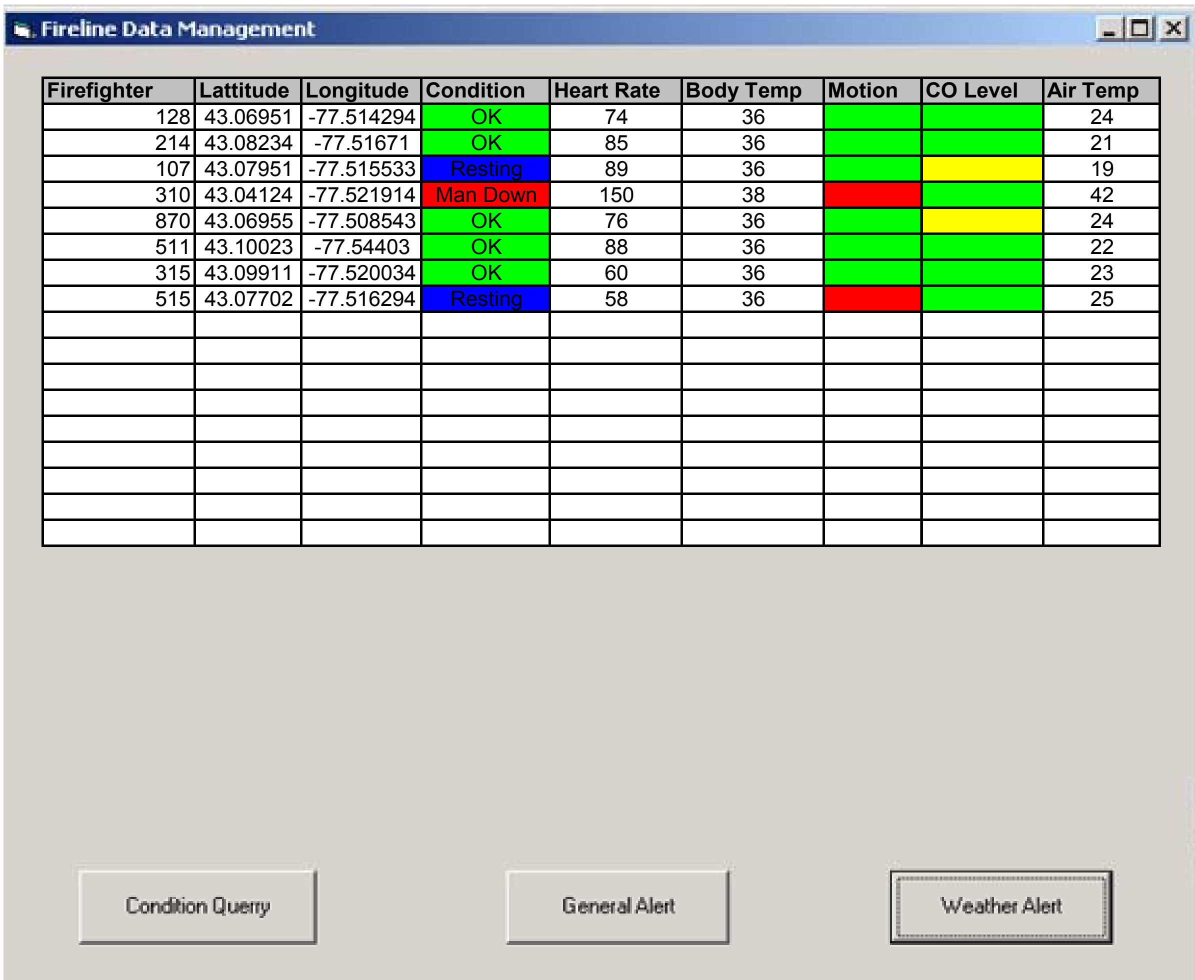


Figure 3 - Relay scheme for higher command level reporting. There may be a number of repeater/decision processors all reporting to a single command center.

Software is needed for the command receiver system to display and correlate input from the firefighters. Our first prototype system uses a simple list based text display to show the status of each firefighter, his location, and condition of the local environment. This software is written in a language common to both Microsoft Windows based personal computers and Personal Data Assistants using the Palm or Windows CE operating systems (Microsoft Visual Basic and Appforge VB). An example of the display from this monitoring software is given in Figure 4. This is the output from an actual screen of data using several (8) firefighter monitoring units and a laptop/modem combination. An obvious extension of this display software is to overlay the tabular information presented here on a map in real time using a GIS framework.



Firefighter	Lattitude	Longitude	Condition	Heart Rate	Body Temp	Motion	CO Level	Air Temp
128	43.06951	-77.514294	OK	74	36			24
214	43.08234	-77.51671	OK	85	36			21
107	43.07951	-77.515533	Resting	89	36			19
310	43.04124	-77.521914	Man Down	150	38			42
870	43.06955	-77.508543	OK	76	36			24
511	43.10023	-77.54403	OK	88	36			22
315	43.09911	-77.520034	OK	60	36			23
515	43.07702	-77.516294	Resting	58	36			25

Figure 4 - Display from the computer software used to monitor information from firefighters in the field. The 'Weather Alert' button issues a yellow watch out alert to all firefighters, the 'General Alert' button transmits a red alert, and the 'Condition Query' asks about the status of each firefighter. The 'Condition Query' must be answered within 60 seconds or a 'Man Down' status will be issued. *Firefighter 310* is in trouble in this screen, as indicated by his elevated heart rate, lack of motion and high air temperature.

Conclusions

Commercial technology in the form of wireless modems, smart sensors and low-power microprocessors permits construction of a highly efficient digital network to report firefighter health and status to command officers on the fire ground. This information delivery system can increase both firefighter safety and efficiency, while adding a minimal additional weight burden to the line firefighter. We have demonstrated a prototype system in the laboratory and in field experiments near our work site. The ability to track and log the condition and status of each firefighter, both during and after the fire, will be of great use to managers and crew supervisors.

We are continuing development of this system with the addition of better receiving (command end) software and the development of 'smart' repeaters to allow a wider coverage area and preprocessing of the data stream for use by upper levels of the command structure. We are also continuing development of software to be used on PDA devices, with lower cost, portability and long battery life a goal.

Acknowledgements

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Dr. Robert Kremens has been employed by the Rochester Institute of Technology at the Center for Imaging Science since 2000. At RIT he has specialized in physical measurements of wildland fires for remote sensing and fire behavior purposes and in constructing new airborne and ground based systems to monitor the environment and wildland fire. Dr. Kremens received his B.S. (1975) in physics form the Cooper Union, M.S. and Ph.D. in physics from New York University, (1981) and a M.S. in environmental studies from the University of Rochester (2000). Before RIT, Dr. Kremens worked at the University of Rochester on the world's largest pulsed laser, building and analyzing nuclear and laser diagnostics on an inertial fusion experiment, at the United States Army Ballistics Research Laboratory in Aberdeen MD, and at several industrial positions where he designed and constructed high speed data acquisition and imaging systems.