Supporting Communication and Collaboration Practices in Safety-Critical Situations

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ABSTRACT
In this paper, we present the Firefighter Communication System — a system designed to enhance and improve firefighter communication during a crisis situation such as a structural fire. The system we present is a half-duplex communication system with an audio horizon for officers and a full-duplex system for standard firefighters. We also address the design for the company commander who simultaneously participates in both systems. These initial designs are the result of ethnographic-style investigations into firefighting practice combined with iterative design.

Keywords
Ubiquitous computing, CSCW, user-centered design, firefighting, audio, speech, ethnography

INTRODUCTION

In firefighting, when communication fails, firefighters die [3]. Failure can occur from two primary sources: hardware failures and communication failures. Our goal with the Firefighter Communication System is to provide a solution that reduces the communication failures while maintaining a robust and flexible system.

Firefighters refer to themselves as a "paramilitary organization." They follow a rigid tree-like communication hierarchy that must be followed in every crisis [2]. At the upper levels of the tree, the officers issue orders and receive system updates. These individuals do not enter the structure. At the bottom of this tree lie the companies, teams of four individuals who actually enter the structure on fire. Each company consists of a company commander (an officer) who possesses a radio and three other company members who are within voice-communication range. These individuals communicate with each other in a more discussion-oriented manner aimed at determining the appropriate implementation of an order.

There are many problems with the current communication system. The radios are those that can be found in standard catalogs. Therefore, they do not meet basic firefighting standards such as being waterproof and resistant to heat. Additionally, the design makes them difficult to use while in uniform. More importantly, the current communication equipment does not support the hierarchical organization of communication in a safety-critical situation.

In order to understand the domain of firefighting, we have undertaken an ethnographic-style investigation of firefighting practices through reading firefighting literature, talking with firefighters at Station 24A in Atlanta, GA, U.S.A., and listening to tapes of actual communications. In this process, we have begun to understand the formal, documented procedures of firefighting as well as the informal, undocumented, and vitally important practices that support the formal procedures.

FIRE COMMUNICATION SYSTEM DESIGN

When firefighters arrive at the scene of a structural fire, they assess the situation and establish the command and communication hierarchy before performing any other actions [2]. Our design focuses on supporting the communication practices as the firefighters proceed from this point. As such, we assume that our system can be initialized and controlled through a behind-the-scenes computer in an automated version of the current practice.

Officer-Level Design

Since officer-level communication consists of orders and updates, half-duplex equipment readily supports these tasks by affording shorter, directed communication and discouraging nonessential chatter. The drawback to traditional half-duplex systems stems from the fact that they easily become overloaded and frequently essential information goes unnoticed because an individual cannot gain control of the communication channel. In a famous incident in Hackensack, NJ, U.S.A., five firefighters died as a result of missed communication [3]. However, when evaluating one of our initial designs in which officers only heard communication directed specifically at them, firefighters informed us of the importance of hearing peripheral communication for maintaining situational awareness. Hence, our design must balance the need for peripheral awareness while managing audio clutter.

To support short, directed communication, our officer-level design gives officers half-duplex radios that allow them to

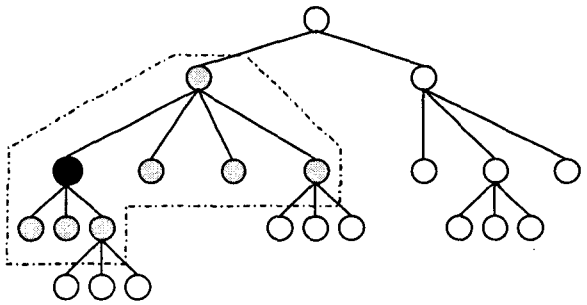

Figure 1: Illustration of the audio horizon for the officer in bold. The officer hears only the communication links between individuals in the audio horizon.

give orders and receive system updates in addition to an emergency function that allows the officer to override anyone speaking to gain control of the communication line. To further balance this tension between hearing peripheral information and avoiding audio clutter, we have introduced an audio horizon. Figure 1 illustrates the communication links from the command hierarchy included in the audio horizon of a given individual. This design reflects the division of duties at the fire scene. Since this configuration mirrors information sharing needs, interviews with firefighters suggest that it will enhance communication.

Company-Level Design

In one of our initial designs, we gave every firefighter a full-duplex radio. After reviewing that design, firefighters told us that officers working outside the building would not be well supported by this style of communication. On the other hand, they told us that this design made them realize how well full-duplex communication lends itself to the conversation-oriented communication style employed by companies working inside the building. Additionally, since the tasks performed by the companies – i.e., operating hoses or removing walls – are physically intensive, hands-free operation is vital.

Therefore, in our design, each member of the company has a full-duplex communication system with a directional throat microphone that dampens the ambient sound and open-ear headphones that allow for greater situational awareness. By default, these systems are always active, but can be turned off manually for situations such as after the crisis but before the firefighter has removed his[1] suit.

Company Commander-Level Design

The company commander, who resides at the intersection of our half- and full-duplex systems, warrants a more complicated design. Not only must the company commander actively engage in extinguishing the fire with the rest of the company, he must also actively listen for orders and other relevant communication from the officers. In order to give him the benefits of voice range communication with his company while maintaining communication with the command hierarchy, we have designed a system to support both of these tasks.

In one ear, the company commander receives full-duplex communication from the company; in the other ear, he receives half-duplex communication from the command hierarchy. Because communications are prefaced with the name of the target listener, the "Cocktail Party Effect" and our initial studies indicate that he will not have a problem distinguishing communications that are directed at him from the command hierarchy [1].

Since the company commander is actively fighting the fire, he is provided with a throat microphone with defaults to communication on the full-duplex channel. When he wishes to send a message to the command hierarchy, he simply depresses a button on the lapel to talk.

Emergency Distress Signals

Our interviews with firefighters revealed extensive problems with the current design – a small, recessed button on the radio – of the emergency distress signal. In order to make activation easier during a crisis, we have made this button into a larger protruding button. To avoid accidental activation, however, the button must be pressed repeatedly. Initial firefighter reactions are positive.

CONCLUSION AND FUTURE DIRECTIONS

In this paper, we presented the Fire Communication System, a system designed through ethnographic-style requirements gathering to understand practices of firefighters combined with an iterative design process. At this point, we are planning to continue work on the audio horizon in order to eliminate its recursive definition problem. Since this technique was a recent addition to our design, we are still attempting to fully understand its implications. Additional areas of pursuit are the addition of features (e.g., spatial location information) and extension to other types of firefighting crisis situations (e.g., hazardous materials accidents).

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[1] Males comprise over 97% of firefighters in the U.S.A. [4].