Redefining Interoperability: Understanding Police Communication Task Environments

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Abstract. The goal of this research is to understand the concept of police communication environments related to interoperable issues. Interoperability is critical to both inter- and intra- organizational communication. Especially in the emergency operations with multiple groups at the same place, the importance of interoperability has been much appreciated. This study used semi-structured interviews to examine the police communication issues and reconceptualize interoperability in the police communication domain. Based on the interview, we identified three important concepts to specify interoperable groups. First, highly distributed decision making processes are problematic for multiple communication needs. Second, a police team is self-organized at the scene. Finally, their operational boundaries are tentative based on contextual information. Based on these main concepts, we provided high-level suggestions to design a police communication system based on cognitive radio technology.

Keywords: Interoperability, Emergency Communication, Police, Cognitive Radio, Public Safety, Distributed decision making, Self organization, Contextual Information.

1 Introduction

Communication systems for public safety workers have very important roles in both daily and emergency operations. They can be a link among inter-team members at the same place as well as a bridge among remote teams or other agencies [1]. Although their communication needs have dramatically increased, the limitation of communication technology and the lack of understanding the design space have confined the intrinsic task performance of police, especially, when new technologies are introduced. Since the cognitive radio concept was first presented by Mitola and his colleague [2], with the advance of technologies, cognitive radio has been able to scan available networks and give appropriate feedback to agents. Ideally, the full cognitive radio technology can consider every possible observable parameter by means of a wireless node or network in order to address interoperability issues [1]. Interoperability is critical to ensure the cooperation within a team or between different agencies in

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large operations such as unexpected simultaneous incidents, a massive public event control, and a natural disaster. However, the current concept of interoperability underscores the technical communication possibility among devices. A previous ethnographic study identified the limitation of the current concept of interoperability [3]. Thus, there is a strong need to reconceptualize interoperability considering organizational and operational aspects to enhance cognitive radio capabilities in the public safety domain.

The main objective of this study is to specify the concept of interoperability in the context of police emergency communication. Based on this understanding we suggest a set of recommendations to design a public safety cognitive radio.

In order to address these issues further, we examined police communication and investigated the needs and definitions of interoperability, reviewing cognitive radio as enabling technology. We conducted a series of interviews with the Virginia Tech (VT) police force. Finally, we suggested the implications for designing police communication system with cognitive radio technology based on the result of the interviews.

1.1 Context of Police Communication

In general, the work categories of police are diverse, ranging from the simple patrol task to large-scale disaster management. Although there are some degrees of difference, all public safety work deals with emergency and life critical situations. Situations that are unknown and uncertain may include danger and may be considered risky and time-pressured [4]. Even though the public safety workers are doing their daily duty, their particular goals and tasks emerge from the situations they encounter [5].

Ron Westrum [6] has categorized three different kinds of threats according to their frequency. Regular threats are those that occur often enough to trigger certain standard response procedures. In these cases, public safety workers can respond according to their standard training. They can fully identify and understand the situation from the initial dispatcher, and thus can handle the situation. Most of the communication in this phase may be done in normal police communication procedure. Irregular threats, on the other hand, represent more challenging situations for which the police may not be fully prepared. This type of event needs more collaborative work among agencies to resolve the problem in question. The last type of situation is the totally unexpected event; the terrorism of 9/11 is a prime example of such an event. In this case, public safety workers require a megashift in their mental framework. In the case of Hurricane Katrina, most of the special agencies did multi-tasking with heavy collaboration in order to save many lives. Their tasks and work environments restricted their communication alternatives to achieve shared goals given the situation. From all the above, we conclude that understanding the context and situation surrounding a particular threat should be the first activity in designing a public safety communication system.

1.2 Interoperability and Cognitive Radio

From the Columbine High School massacre and Hurricane Katrina, to the recent April 16 VT massacre, many news media and official reports on those disasters indicated there were common needs for interoperability among agencies. The Congress of the United States also has stated their concern to resolve the interoperability issues that were exhibited during such national disasters as the tragedy of 9/11 attack [7]. Interoperability was originally defined as technological term [8]. Thus, related to technical issues that apply to specific types of hardware or systems. Alliance for Telecommunication Industry Solutions (ATIS) defines interoperability in five different ways that is also adopted by the American National Standard [9].

- The ability of systems, units or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.
- The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases.
- Allows applications executing on separate hardware platforms, or in multi-processing environments on the same platform, to share data and cooperate in processing it through communications mechanisms such as remote procedure calls, transparent file access, etc.
- The ability of a set of modeling and simulation to provide services to and accept services from other modeling and simulation, and to use the services for exchange enabling them to operate effectively together.
- The capability to provide useful and cost-effective interchange of electronic data among, e.g., different signal formats, transmission media, applications, industries, or performance levels.

These definitions deal with broad concepts of interoperability even though they do not include context-specific issues. Recently, in many conferences on technical interoperability among the various public safety entities, semantic interoperability (operational interoperability) has been emphasized.

Even though the technically dream of Mitola has not yet been achieved, his concept has greatly impacted many aspects of public safety communication. However, The Department of Homeland Security (DHS) listed cognitive radio technology as one of most important communication technologies needed to solve the interoperability problem in the first national emergency communication plan in July 2008 [10].

Virginia Tech's Center for Wireless Communications Team (CWT^2) has developed core cognitive radio technologies as part of a National Institute of Justice research project. This cognitive radio architecture can scan available spectra, automatically sort channels and connect them. It is also capable of bridging two networks. To maximize these capabilities in the public safety domain, it is necessary to understand the contexts of communication tasks and how we can assure the quality and usability of such a device.

To tackle these issues, the cognitive radio has knowledge domains including, user-, policy-, and security domains. The user domain should include organizational,

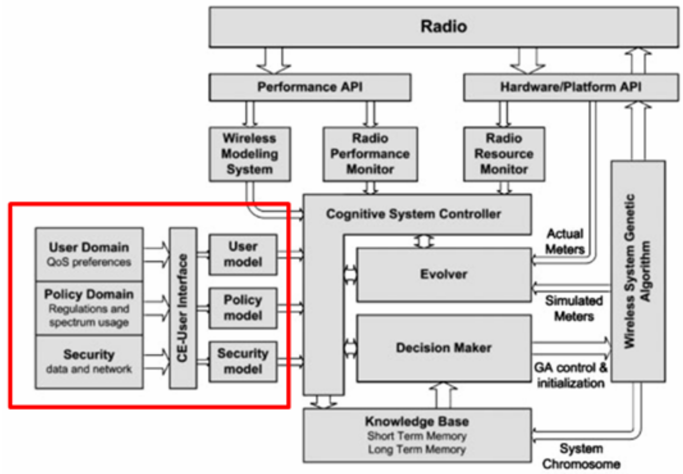

Fig. 1. A User Model in the VT Cognitive Architecture Model

operational, technological and environmental issues in the public safety domain. Figure 1 shows an architecture of a cognitive radio communication system that was proposed by Virginia Tech CWT[2].

For effective police communication, the user domain should be designed sophisticatedly considering the multiple aspects of police tasks. From this study, we can collect pertinent inputs for design requirements to develop a user domain in the part of public safety communication system.

2 Study

Semi-structured interviews were conducted as an existential-phenomenological study that examines the knowledge gained from the participants' experience [11, 12]. Since phenomenology as a branch of philosophy assumes that our perception is highly related with the objects perceived, and human epistemology is affected by the object of experience, this approach attempts to holistically understand the essence of human experience in context-specific settings [13]. In this study, we performed a series of interviews with a group of public safety workers with a view to focusing on the interoperability issues with the Virginia Tech Police Department (VTPD). Structured questions guided the outline of our discussion, followed by informal questions exploring in-depth points based on their specific experience, position and needs.

All procedures--from the recruiting to the interviews--were conducted under the approval of the Virginia Tech Institutional Review Board. Since the subject matter of these interviews was very sensitive, based on the recommendations of the IRB, the interviewers did not record any video or audio data. Instead, at least two interviewers were involved in a single interview and each took notes.

2.1 Participants

The members of the Virginia Tech Police Department (VTPD) participated in the interviews. Six participants volunteered for this study. Before the main study, we interviewed a public safety worker as a preliminary interview, which provided us with the basic knowledge about public safety work domains. Although they had different roles in their regular organization, they performed various roles in the incident organization based on the situation. Their roles varied from the captain to the dispatcher to the patrol officer. We carefully recruited participants through a combination of telephone and email screenings. We called the chief of the VT police. With his approval, we contacted participants. Involvement in a large number of incidents was not a pre-condition for participating in the study. However, the people we interviewed had more than two years of experience in emergency medical service as well as had experienced at least one large incident. Each had highly utilized the current communication devices. Nevertheless, they did not have enough knowledge to customize their portable communication devices.

2.2 Method

We developed three different types of representative task scenarios: daily work, massive public event control to highlight cooperative work, and supportive work for other agencies. They were generated based on the interview participants' past experiences and plausible events to ensure ecological richness. These participants had a variety of experience and performed various roles in police organizations, thereby making it easy to probe organizational issues and draw upon plentiful experiences.

Structured questions guided the boundaries of topics discussed, while open-ended questions were addressed to the participants based on their responses. Although our scenarios included administrative tasks, we focused on the core operational policing at the scene of the incident in question [4]. Each interview lasted about one and a half hours, during which time three prepared scenarios were described and the participants were asked 5- 10 questions per scenario, based on their operational task procedures. During an interview session, we explored four different perspectives of their main communication tasks: technology, information, organization, and operation.

3 Results

The analyses were done by a systematic procedure using Atlas.Ti (Version 5.4). We set the five a priori codes and additional 13 codes emerged during the analyses. We adopted grounded theory for our analysis [14]. Table 1 shows the codes used in this analysis and their description; note: the codes emerged from the interviews.

These codes came from the results of interviews and were related to overall communication problems. From two brainstorming sessions, we distilled three primary findings to define the concepts of interoperability: Distributed Decision Making, Self-organization, and Dynamic Operational Boundaries.

Table 1. Codes and Description

Codes	***Description***
Blind Spots	Any difficulty with service with the two way radios; for example, being in the basement of one of the dorms and not being able to use the radio because there is no signal
Button Usability	Difficulty with buttons being too easy to press or too difficult to use
Design Limitations	Aesthetic problems with radios or other equipment; e.g., radios being too heavy, too small, ear pieces being uncomfortable
Dispatching limitations	Any hindering of communication from calls made by those calling 911 to the dispatcher and troubles with dispatching emergency personnel
Environmental	Problems in particular environments or service problems in an entire area
Functional limitations	Problems with a radio not performing functions that it was designed to perform
Informational	Any problems related with sending and receiving any type of information
Need for texting	Any situation in which written information would help clarify the communication
Noise Problems	Subset of environmental problems with the same meaning; noise in the area hindering communication over the radio
Operational	Any problems with the radio not working from task procedural issues in operational situations
Organizational	Trouble receiving or giving information because of organizational reasons
Presentation of information	Trouble understanding information in the way that it is presented to the user
Technology	Trouble with the hand-held radios or other equipment due to hardware problems
Privacy	Any information that can be seen or heard by an outside party that it was not intended for

3.1 Distributed Decision Making

At the scene of an emergency, police officers' decision-making is critical to helping save lives or prevent big disasters. Like any other police force, the VT police attempt to make quick decisions based upon the local information they can obtain. They try to get as much information as possible from all available sources. Dispatchers, people in vehicles, or people at the headquarters collect the information from the entire police database system, including data from other people in relevant places. At the scene, they sometimes make locally optimized decisions to response the situation. However, due to the limitations of their current radio communication systems, the police can only transfer highly abstracted information by voice. Thus, they frequently use alternative ways to expand their communication capacity. In our scenario cases, the police officers interviewed stated they have had trouble in transferring the information that they collect and in making decisions based on incomplete information. The intrinsic characteristics of police tasks and communication capacity have rendered their decision-making distributed. In addition to communication capability, there are many barriers to hamper collaboration: environmental issues such as blind spots or noise, organizational issues such as individual and organizational culture, and privacy issues.

3.2 Self-organization

Public safety teams, especially, police teams, tend to self-organize at the scene. Their long-term and planned operations such as a football game day operation are performed by the formal organization. However, in some cases of emergency situations, their organizational structure emerges on the basis of physical and contingent constraints. For example, incident command teams consist of volunteers, firefighters and emergency medical service providers. It is not necessary that a decision maker should be the highest-ranked person in the situation. It depends on the situations. If the situation becomes more settled, the emergent organization reverts to the formal organization.

3.3 Dynamic Operational Boundaries

Their operational boundaries are tentative based on contextual information. For example, on a football game day, when some 65,000 people have gathered at the same place, the public safety team is in charge of allocated sections. As usual, their operational boundary is defined by geographical constraints. However, if a large incident would occur, the operational boundary would change dynamically. In case of multiple incidents at the same place, police officers could be overloaded with the communication they are receiving and giving. Most information might not be relevant at all or it might be less important. In this case, it is necessary to set different networks according to each incident to avoid information-overload. For emergency cases, these officers operate more than two tactical channels simultaneously. However, sharing the information of tactical channels with other relevant personnel becomes problematic.

4 Implications

Highly distributed decision-making processes are problematic for multiple communication needs. Decision-making in this context is geographically and organizationally distributed. It can be made by people at the scene, dispatcher centers, vehicles and other control centers at different levels of organization. In every decision-making task, the communication group shares situational knowledge. Thus, we characterize the concept of interoperability as a unit of decision-making in terms of the joint cognitive systems [15, 16, 17]. Each unit needs to have enough capability to collect and transfer the information in order to yield a seamless decision-making process. The cognitive radio communication system should support the transfer of multi-modal data including texts, images or videos. In addition, device usability is important when the situation becomes increasingly complex.

Second, the interoperability can be described in terms of self-organization characteristics: emergent, distributed and non-specific [18]. It is essential to present the organizational information in their communication devices in order to support effective communication. For example, people in the operation need to identify the person who is in charge of the case. It is critical, especially, in the case of multi-group operations. In addition, the functional unit also needs to be represented in their communication system to support direct communication between stakeholders [19].

Finally, the communication system should identify current operational boundaries. The police, for instance, use three or four communication networks for a single operation. In general, those communication networks support the communication within an organization. Yet, even though the police have tactical channels, they are not utilized much. The people at the operation need to know who is involved in this particular operation and how to contact them. Therefore, the communication system should present the boundaries of operation geographically as well as organizationally.

5 Conclusion

Understanding these characteristics of interoperability gives opportunities to improve police communication task performance. We can describe an interoperable group in terms of decision-, organizational- and operational groups. The results can be directly used to display and prioritize the networks that combine interoperable groups in cognitive radio devices. In addition, the results enable us to build richer decision-making process models in public safety domain from the perspective of joint cognitive systems. Cognitive radio system can include these results as a user model in their cognitive architecture. They can also suggest ways of integrating and allocating functions and other information within multiple device communication environments. Finally, this research on interoperability can be used to identify the contextual requirements of safety-critical systems that interact with their respective environments.

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