A Dispatch-Mediated Communication Model for Emergency Response Systems

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The current state of emergency communication is dispatch-mediated (the messages from the scene are directed towards the responders and agencies through the dispatch agency). These messages are logged in electronic documents called incident reports, which are useful in monitoring the incident, off-site supervision, resource allocation, and post-incident analysis. However, these messages do not adhere to any particular structure, and there is no set format. The lack of standards creates a problem for sharing information among systems and responders and has a detrimental impact on systems interoperability. In this article, we develop a National Information Exchange Model (NIEM) and Universal Core (UCORE) compliant messaging model, considering message structures and formats, to foster message standardization.

Categories and Subject Descriptors: E.4 [**Coding and Information Theory**]: *Formal models of communication*

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1. INTRODUCTION

Emergency communication is an important aspect of emergency response [Bharosa et al. 2008; Chen et al. 2008; Seifert 2007]. According to Manoj and Hubenko [2007], communication is a primary challenge during an emergency. The US Department of Homeland Security [2007] has also identified the efficiency of communication as a long-standing issue of concern during emergencies.

The current state of emergency communication is dispatch-mediated, where messages from the scene are typically directed to the responders and agencies through a local dispatch agency. The emergency dispatch agency provides essential support to responders during emergencies. From a process perspective, the emergency dispatch

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agency generates an incident-related document (known as the Incident Report) to keep track of messages that are exchanged between the dispatch agency and the responders and/or agencies, and are useful in monitoring the incident, off-site supervision, resource allocation, and post-incident analysis. However, these messages do not adhere to any particular structure and there is no set format. The vocabulary in use also varies based on incident commander, geography, responding agency, and so on. Sense-making during the incident often requires responders to draw on their recollection and understanding of the context and sequence. The lack of proper standards makes information sharing among systems and responders cumbersome and has a detrimental impact on systems interoperability. The development of messaging systems fosters message standardization that allows communication in parsimonious, but unambiguous, ways. This requires the development of messaging systems to conform to the existing communication environment to avoid imposing major training requirements to use the system.

To develop a model that provides support for message standardization, this effort uses a design science approach [Hevner et al. 2004; Peffers et al. 2006]. In this, we draw on Maletzke's communication framework (adapted from Watson and Hill [2000]) to elicit requirements and use it for an analysis of 10,411 messages from 1,147 incidents dispatch reports. With the help of inputs from firefighters, we develop a semiautomatic message classifier to automate extraction of content from the message. We develop a message structure and message format to standardize the messages as part of the model. The structure informs the community of the required elements that form part of the message types. In addition, our approach is also compliant with existing standards such as the National Information Exchange Model (NIEM) and the Universal Core (UCORE), which provide XML-based data exchange.

The article is organized as follows. In Section 2, we provide a background of emergency response communication. In Section 3, we describe the emergency incidents. In Section 4, we describe message classification process. In Section 5, we describe our messaging model development process consisting of message structuring and message queuing. In Section 6, we highlight the output of our messaging model. In Section 7, we first validate the classifier part of the messaging model, and then apply the model to a real case scenario. In Section 8, we conclude with limitations and future work for this article.

2. BACKGROUND

In this section, we discuss the existing literature on message classification as well as the work in the area of standardization, including NIEM. Subsequently, for integration of our work with existing emergency systems, we provide a discussion on communication and interoperability.

2.1. Message Classification

The literature on message classification spreads across various domains in computer science and information science. There is one body of literature that deals with classification of messages based on the communicator's intentions [Habermas 1984]. This stream of literature is aimed at prescribing forms of social behavior in the language-action perspective of communication [Suchman 1994] and focuses on orientation and management of action dictated by messages [Winograd 1987]. Flores et al. [1988] discuss their ontology of action such as requests, promises, assertions, and declarations, derived from the messages (e.g., in the workplace [Flores and Ludlow 1980]). Medina-Mora et al. [1992] detail action workflows that provide design methodology focusing on communication activity deriving action.

A second stream of literature focuses on support for the diverse and changing ensemble of communicative practices [Suchman 1993] and classification based on a subset of features that are most informative from the entire vocabulary. Several studies have addressed classification of spam and nonspam short messages [Cormack et al. 2007; Healy et al. 2005; Hidalgo et al. 2006]. Munro and Manning [2010] classify medical text messages, and show how variations in messages could improve classification performance. In addition, recent literature in this area deals with techniques to classify short online dialogs by enriching the set of features using external data sources [Gupta and Ratinov 2008]. Munro's [2010] work deals with crowd-sourced translation of text messages written in Haitian Creole to English during the Haiti earthquake. Caragea et al. [2011] developed a technique to classify tweets and text messages automatically for better understanding of an emergency scenario, and consequently to develop a reusable information technology infrastructure, called Enhanced Messaging for the Emergency Response Sector (EMERSE).

2.2. Emergency Systems and Standards

Prior studies in development and improvement of emergency system have focused on various complex issues such as communication interoperability issues in fragmented emergency systems [Chen et al. 2008; Hancock and Hart 2002; Seifert 2007], coordination challenges during single- and multi-incident management [Chen et al. 2005, 2007; Comfort et al. 2004; Dawes et al. 2004; Petrescu-Prahova and Butts 2005], responder and resource accountability [Comfort et al. 2004; Jiang et al. 2004; Klein 1999], information and system quality [Bharosa et al. 2008, 2010], and information selection and processing [Comfort et al. 2004; Turoff et al. 2004]. However, research in the area of dispatch mediated emergency communication has received little attention.

There have been numerous systems that have been developed and improved significantly over the last decade for the purpose of mitigation of emergency events [Turoff 2002]. These systems range from expert-oriented [Valecha et al. 2010] to people-oriented [Chou et al. 2011]. To address the problem of information exchange across departments, the National Information Exchange Model (NIEM) was developed in partnership between the US Department of Justice, Homeland Security, and Health Services.

NIEM was designed to develop and support information exchange standards for sharing of information during an emergency situation. It uses XML data model to standardize content between agencies, thus providing efficient information management. NIEM consists of XML schemas for areas such as emergency response or criminal justice, and identifies various existing components, along with their type, element, and attribute. It also consists of definitions of these components. Finally, it provides rules for conforming to NIEM, and for adding nonexistent elements into NIEM. The standardization of content using NIEM improves communication and also leads to system interoperability [Chen et al. 2012].

The current practice in fire, EMS, and police departments across the United State of America is to ensure that communication systems deployed are NIEM compliant. Another framework that has been used by the US military is UCORE. It provides a framework that facilitates emergency communication for incidents such as forest fires, by providing a means for standardizing emergency messages. NIEM and UCORE compliance helps in system adoption especially when more agencies get involved in the system development process. Therefore, we have chosen to make our model NIEM and UCORE compliant in order to make the system more acceptable to the responder community.

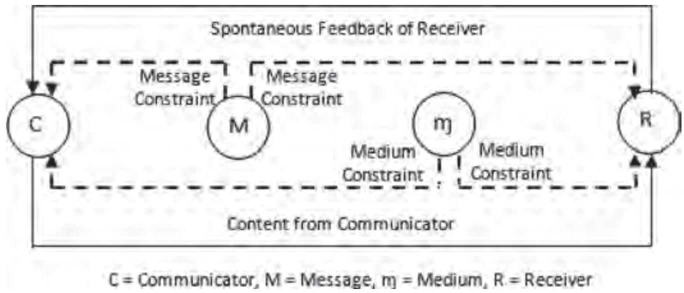

Fig. 1. Maletzke's framework for dispatch communication (Adapted from Watson and Hill [2000]).

2.3. Emergency Communications and Interoperability

Over the years, a number of data standards have been developed for effective coordination and communication. However, these standards are more general and are not targeted towards addressing the needs of emergency dispatch systems that deal with local day-to-day critical incidents. This has resulted in communicating critical information between different departments in a timely manner far more arduous.

Dispatch communication has been studied, for instance, with radio communication [Klappenbach et al. 2004; Meissner et al. 2006]. Some researchers have proposed design of better systems that facilitate effective and timely communication during emergencies [Jang et al. 2009; Lien et al. 2009], while others have proposed better communication strategies, communication architecture, and data models [Chen et al. 2012; Meissner et al. 2006; Ott 2003]. In this article, our focus is on the further development of local dispatch systems utilizing a framework that we explicate in the next section.

2.4. Maletzke's [1981] Communication Framework

As an information exchange process, communication involves exchanges of messages between a source and a receiver through a selected medium. There is now a vast literature that deals with the development of communication models [Berlo 1960; Riley and Riley 1965; Schramm 1961; Shannon and Weaver 1964]. These models consider elements of communication such as sender, receiver, message, medium, and effect. Maletzke's [1981] communication framework draws from these and adapts them to primarily focus on the constraints of message and medium on the participants. These are important considerations in an emergency context as there is limited bandwidth, urgency, and uncertainty. Further, messages must be short. They are transmitted over radio, as typically not all of the responders have computer access. Therefore we use Maletzke's [1981] communication framework (adapted from Watson and Hill [2000], to elicit requirements of our messaging model.

In Figure 1, we depict the three main components found in Maletzke's framework as follows: (a) basic communication elements (represented using circles), (b) information flow (represented using solid lines), and (c) factors operating on the participants (represented using dashed lines) during dispatch communication. There are four basic communication elements in the dispatch communication, namely communicator, message, medium, and receiver. Information flows from the communicator to the receiver. The receiver may provide a response to the communicator. Both the communicator and the receiver operate under the constraints imposed by the message and the medium.

In the emergency situation, the emergency agencies and the emergency responders exchange on-scene data with the dispatch agency. These messages are transmitted through the dispatch agency's radio channels, and are logged into the incident reports. The emergency responders act upon, and are influenced by the message, which is

Table I. Requirements of the Messaging Model

Pressure	Support	Example	Msg. Model Req.
Message -> Participant	Interpretation of message	The dispatch-mediated messages do not follow any set standard. These messages contain codes, short hand, numbers, keywords, updates, etc. Such a message is not compliant with any messaging standard.	Structure the message for extension to emergency standards.
Medium -> Participant	Prioritization through media	All the messages during an emergency are transmitted through the same channel. The high frequency of messages through a channel leads to channel overload.	Queue the message based on its frequency in the time period.

itself constrained by the dictates of the chosen medium, as enunciated in Maletzke's framework [Andal 1998].

2.4.1. Message Constraint. Message constraint is a restriction on the sender to be succinct, yet clear. The context (e.g., the extent of structural damage in case of a fire, or the impact that an additional water tanker might have on the structure in case of a fire) that the sender is aware of is not always communicated in the message. In addition, the dispatch-mediated messages contain codes, short hand, numbers, abbreviations, keywords, updates, and so on, that do not follow a set standard or sequence that is fixed in time. Following Maletzke, we suggest message structuring for relieving the message constraint on the participant. We utilize this guidance to structure the message by creating message formats after an understanding of the different classes of messages. We also attempt to ensure that the structure is close to the currently followed norms.

2.4.2. Medium Constraint. Medium constraint is a restriction on the receiver for handling the messages from the medium. The dispatch-mediated messages during an emergency are transmitted through the same channel. For multiple messages received simultaneously (e.g., one message with the extent of structural damage in case of a fire, and the second with the need for an additional water tanker in case of a fire), the currently available mechanism for message transmission only allows for first-in-first-out (FIFO) processing of the messages. Consequently, the receiver is constrained due to medium congestion. Following Maletzke, we suggest message queuing for relieving the medium constraint on the participant. We utilize this guidance to queue the message based on an analysis of message frequencies for different kinds of emergencies such as medical, fire, vehicle, and chemical emergencies.

The message and medium constraints operating on the communicators drive the requirements of our messaging model, as summarized in Table I. Maletzke's framework drives the top-level requirements of our messaging model. We build the development process in a bottom-up manner by mining real emergency data, which gives a solution that is much closer to the real emergency situation.

3. GENERAL OVERVIEW OF EMERGENCY INCIDENTS

3.1. Emergency Incident

Figure 2 depicts the communication that takes place in case of a general incident (such as fire, chemical spill, etc.) between various emergency agencies such as Fire, EMS, Police, and Dispatch. The interaction among responders from various agencies is mediated through dispatch. For example, if a fire agency requires police assistance for perimeter safety, they request it from dispatch, who further notifies the local area police about the request.

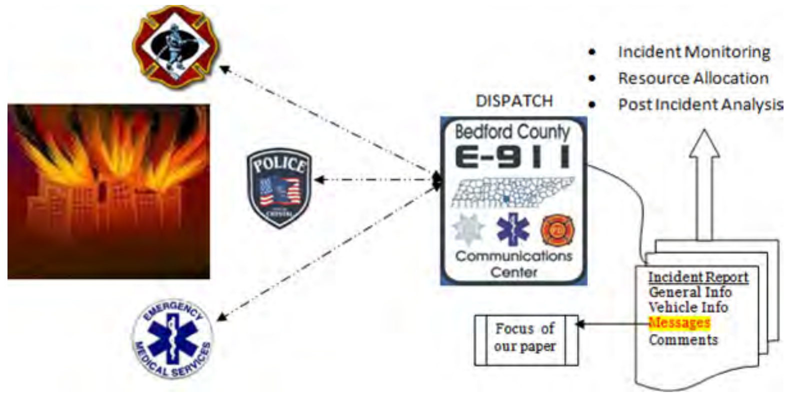

Fig. 2. Dispatch mediated emergency scenario.

3.2. Emergency Report

The initial notification of the incident is received by a dispatch agency that generates an incident-related document known as the "Incident Report." This notification is entered by the dispatch personnel in the incident report as "General Information." Upon receipt of this notification, dispatch alerts fire chiefs assigned to the locality of the incident. The fire chiefs respond to the notification with the status of their location. Upon arrival at the scene of the incident, the fire chief may request additional vehicles or resources from dispatch. The information about responding vehicles that arrive at the scene of incident is stored in the report as "Vehicle Information." The communication messages that are exchanged between dispatch and the responders/agencies are logged as "Messages." The report also includes comments by the responders on-scene. Figure 3 shows an excerpt from an incident report of a major fire emergency.

3.3. Data

The data used for model development was obtained from 1147 day-to-day local emergencies including fire, chemical, vehicle, and medical emergencies responded to by the North Bailey fire station from 2008 to 2010. The 1147 incidents provide a sample of 10,411 communication messages. Subsequently we built our evaluation dataset based on sample messages derived from 107 major randomly selected incidents from the period of 2009 to 2011 responded to by the North Bailey fire station. This dataset was not used in the development of the model. The 107 incidents contained a total of 769 messages that served as test data for our model's performance evaluation.

4. MESSAGE CLASSIFICATION

An important first step prior to developing the messaging model was to understand in-depth the 9-1-1 incident reports. To accomplish this, we contacted four first responders from different emergency agencies. Each of the contacted dispatch agency responders had more than five years experience in dealing with emergencies. These dispatch agency workers also worked as volunteer fire chiefs, EMTs, or other emergency occupations while they were not on duty. These experts provided us a detailed understanding of several reports, and worked with us through the development of the messaging model as described in the subsequent sections. At the outset, the experts identified two important attributes of an emergency message—keyword and objective. A keyword is an index word that serves as a key to the message. An objective is that toward which one's efforts are intended. Every message has both of these attributes.

```
Date: 4/01/2008                    Incident Response Report                    Page:  1  of 1
Time: 0:00:00 AM                                                               User:  USER

Incident/Exposure      0000000  000     Date  4/01/08     Day of Week  Tuesday
Fire District          0000

Incident Address       123 SOME STREET
                       WILLIAMSVILLE        NY 14221

Box#                   78      SOME FIRE DEPARTMENT

Alarm Time             00:14:39
Closed Time            00:50:26

Type of Call           TRC     -EMS-Transportation  Cold
Method of Alarm        B       123-4567
Incident Type          321     EMS Call
Type of Action Taken   34      Transport person
Fixed Property Use     419     1 or 2 family dwelling
Estimated $ Loss:      Property          0     Contents         0

Officer in Charge        99    NOT REPORTED
#Fire Service Injured   0
#Fire Service Fatal     0
#Civilian Injured       0
#Civilian Fatal         0

Vehicle Response Summary:

Vehicle:  ID Number    242   SOME CITY AMBULANCE     11111ET
          Dispatched   00:16:24
          Enroute      00:16:24
          At Scene     00:24:06
          Transport
          At Hospital
          Available    00:50:26

Dispatchers Comments
USER              00:14:43  Received: 04/01/08  00:14:39   Phone: 123-4567
USER              00:14:43  Caller:   SOME CALLER
USER              00:14:43  City/St:  WILLIAMSVILLE         NY   Type TRC
USER              00:14:43  Back Pain/F age 90's
EMS               00:16:43  Unit:242 From:MAPLE RD & N FOREST RD
EMS               00:16:43  Destination:<None> Mode:B Status:DS
EMS               00:16:43  Date/Time:2008-04-01 00:16:04
EMS               00:17:03  Unit:242 From:MAPLE RD & N FOREST RD
EMS               00:17:03  Destination:MAPLE RD & N FOREST RD Mode:B
EMS               00:17:03  Status:EN Date/Time:2008-04-01 00:16:28
EMS               00:20:50  Unit:242 Destination:MAPLE RD & N FOREST RD Mode:B
EMS               00:20:50  Status:AS Date/Time:2008-04-01 00:20:21
EMS               00:49:10  Unit:242 Destination:<None> Mode:B Status:TR
EMS               00:49:10  Date/Time:2008-04-01 00:48:35

Incident Comments
Caller reported elderly woman had fallen and had back pain. 242 to MIllard Gates
Circle.
```

Fig. 3. Excerpt from an incident report of a major fire emergency.

4.1. Clustering Messages into Message Types

Figure 4 depicts the process developed to determine the types of messages commonly found in dealing with day-to-day emergencies using the 9-1-1 reports and help from experts. The process involved two major steps: (a) keyword generation and (b) keyword synthesis.

4.1.1. Keyword Generation Process. In the first round, the experts provided us with 8 keywords along with their well-known abbreviations and synonyms (illustrated in Table II). The synonyms and abbreviations list was obtained from the experts who

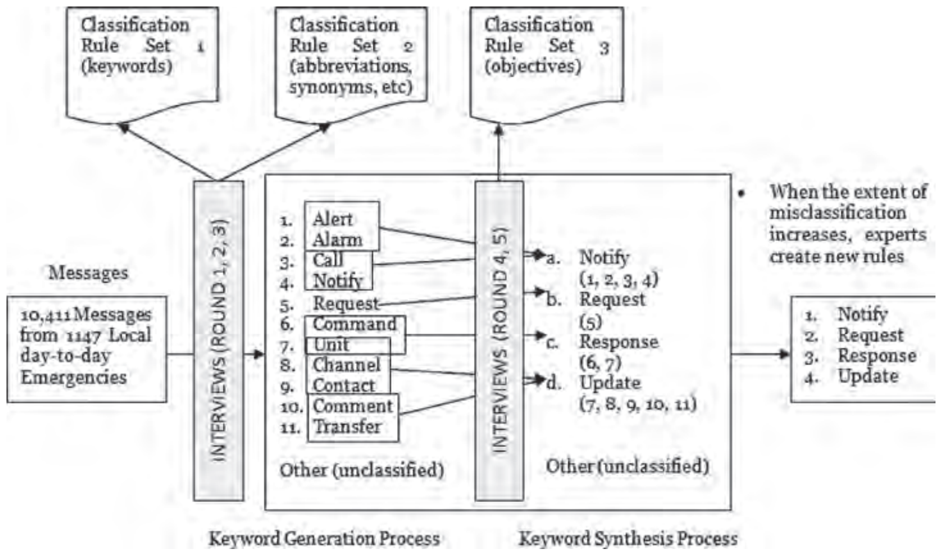

Fig. 4. Clustering messages into message types.

Table II. Emergency Message Types

Type	**Source**	**Target**	**Message**	**Scenario**	**Use**
Notification	ANY	Agency	"MERS NOTIFYING HAZMAT"	The emergency response service issues a notification to Erie County Hazmat team	To inform an agency about the incident
Request	Commander	Dispatch	"HARRIS HILL . . . – MAA REQ"	The incident commander requests dispatch center for additional ambulances from mutual aid plan	To request for additional resources
Response	Agency	Dispatch	"CD142 TO CLA OPS CTR"	The deputy chief responds to Clarence Operations center	To provide responding agency status
Update	ANY	Dispatch	"5800 LBS OF FUEL ON BOARD"	The airplane agency updates the dispatch center with the information on fuel level of the aircraft (5800 lbs)	To update the bits of information

also reviewed a thesaurus with us. This allowed them to combine local terminologies and borrow from the thesaurus. Next, we parsed the 10,411 messages based on this keyword set. This process resulted in partitioning the dataset into 9193 classified messages and 1218 unclassified messages. These unclassified messages were inspected by the experts in the second round of interviews. This round resulted in 3 additional keywords, with their abbreviations and synonyms. Next, using the expanded set of keywords (11) we parsed the 1218 previously unclassified messages, which yielded 42 unclassified messages. In the third round of interviews, these messages were reviewed in great detail by the experts and determined as being unrelated to the incident or unidentifiable messages (4.03%). The whole process produced the following 11 keywords: alert, alarm, call, notify, request, command, unit, channel, contact, comment, and transfer. After each round of interviews, the new keywords were included in the classifier leading to an improved version of the classifier.

4.1.2. Keyword Synthesis Process. The process of combining keywords to obtain a minimal orthogonal set was an iterative process as well, involving two additional rounds of interviews. The input to the fourth round was the 11 keywords. The experts identified objectives for each of the 11 keywords. A comparison of the objectives provided by the experts allowed us to combine the keywords into 6 message types. These include alerting agencies, informing about the incident, requesting additional resources, response status of agencies, informational update, and responder actions. There were two disagreements involving the four message types (call, notify, transfer, and comment). After a discussion (fifth round), "call" and "notify" message types were determined as alerting and/or informing an agency. Further, message types "transfer" and "comment" were determined as relating to informational update and/or responder action. This process finally yielded 4 basic message types: notification, request, response, and update. In the next section we describe in detail the functions of the message types.

4.2. Message Types

The onset of the incident is marked when the victim/observer calls 9-1-1 to inform the dispatch agency about the incident. This is the initial notification of the incident to the dispatcher. On receipt of this initial notification, the dispatcher directs the appropriate agency to investigate the incident. In the remainder of this section, we describe the four message types:

4.2.1. Notifications. Notifications are messages that inform of an event in a formal manner. They are the very first types of messages during an incident. The objective of these messages is to inform an agency (including dispatch agency) about the incident. It is a unidirectional message directed towards the agency. There are four different types of notifications: initial, internal, agency, and responder. The initial notification is the 9-1-1 call to dispatch center. The internal notification is an interdepartmental message that signals the end of the dispatch phase. The agency and responder notifications are the calls from dispatch in order to inform the appropriate agency and appropriate responder, respectively.

When a notification is received, the recipient acknowledges the receipt using the phrase "COPY," for communicating that the notification has been received. This COPY message is not logged in the incident report. This is a limitation of the current system. A better way of tracking acknowledgements is needed especially for post-incident analysis when memory has faded and one has to recollect such things in a court of law. Following the COPY message, the agency (or responder) provides the status of its arrival at the scene of the incident in the form of response to the notification.

4.2.2. Responses. Responses are messages that provide the status of the agency responding to the incident. Such messages may also include information about the status of the responder in charge, responding unit, arrival time, and so on. The responses can be characterized into three basic types—response by units about the status of the dispatched vehicle, response by agency about their arrival times, and response by team about the status of their resources. These messages are all logged in the incident report. On arrival at the scene of the incident, the commander-in-charge of the scene may decide that the available resources are insufficient to manage the mitigation of the incident, in which case he/she may request additional resources from the dispatcher. The dispatcher is responsible for directing other agencies that can make further resource commitments for that incident, and they generate appropriate requests. There is a preplan for local mutual-aid to guide dispatch agencies in this regard.

4.2.3. Requests. Requests formally ask for resources. They are unidirectional messages from the Incident Commander to the dispatch agency requesting additional resources upon determination of the requirement of those resources. The requests can be of two types: (a) request for resources that are a part of predetermined mutual agreement (as previously mentioned), and (b) request for supplementary resources. At any point of the mitigation effort, the dispatcher can also request information about the scene situation, for updating other neighboring agencies, the general public, or media, about the incident. On receipt of this request, the incident commander-in-charge provides the information (status) about the incident, and this generates the update messages.

4.2.4. Updates. Updates are messages that update the current status of the incident or resource. They are typically unidirectional messages from any sender (responder or agency) to the dispatch center. There is usually no reconfirmation, so update messages do not generate responses.

There are certain messages such as notification and response that are associated as a sequence. For example, a response may be produced after a request. Since the main focus of the article is message classification, we leave message sequence for future work.

Finally, there is only one incident log created for each incident even if several people call and report the incident. At times buildings may have frontage bordering several streets, which can cause the belief that there are several simultaneous emergencies in progress. However, since these are local incidents, dispatchers are usually familiar with the terrain and are able to sort this out. Further, the first responders clarify this issue with the status. In addition, notifications do not generate multiple responses. However, a second or third alarm may cause several responding units to report to the scene, as these are part of mutual-aid and preplan agreements.

4.3. Semiautomatic Classifier

It is necessary to discuss our classifier, which facilitates automatic classification of emergency messages based on the occurrence of keywords, their synonyms, and abbreviations and objectives within the message, as specified in the classification rule sets developed in the previous section. Let us consider some real emergency messages. “NOTIFY NAT FUEL,” consists of the keyword “NOTIFY,” and thus is classified by the classifier as a notification-type message. Similarly, “EA – MAA REQ” consists of an abbreviation “REQ” of the keyword “Request”, and thus is classified by the classifier as a request-type message. Finally “UNIT: 240 STATUS: DS” identifies the objectives of the message (to provide the status of unit # 240) as responding to the incident, and thus is classified by the classifier as a response-type message. The classifier is depicted in Table III.

5. MESSAGING MODEL DEVELOPMENT

With the help of Maletzke’s Communication Framework, we have identified two requirements of our messaging model, namely message structuring [Valecha et al. 2012b] and message queuing [Valecha et al. 2012a], for relieving the message constraint and the medium constraint respectively. In this section, we describe the process of messaging model development by describing in detail the process of message structuring and message queuing.

5.1. Message Structuring Process

Emergency response provides Universal Core (UCORE)—a framework that facilitates emergency communication for incidents such as forest fires, by providing a means for standardizing emergency messages. However UCORE, being a more general framework does not address itself to the management of local day-to-day emergencies such

Table III. Classification Rules for Semiautomatic Classifier

Type	**Comments**	**Classification Rule Set 1, 2, 3 (objective, keyword, and synonyms and abbreviations)**
Notification	9-1-1 call, Agency	— Foremost notification of the incident — Use of keyword “Notify” — Use of synonyms, abbreviations and codes (Notify, Alert, NOT, etc)
Request	Mutual Aid Type	— Inclusion of Mutual Aid Type — Use of keyword “Request” — Use of synonyms, abbreviations and other codes (Request, REQ, etc)
Response	Status of Response	— Inclusion of status of response — Use of keyword “Response” — Use of synonyms, abbreviations and other codes (Response, RESP, Dispatched, etc)
Update	Update Type	— Reference of information to be updated — Use of keyword “Update” — Use of synonyms, abbreviations and other codes (Update, Action, etc)

as medical, fire, chemical, or vehicular. Thus, in this article, we adopt the UCORE messaging framework to standardize our local emergency messages. We learn from UCORE that an emergency message is made up of one or many elements and associations among those elements. Message structuring is the process of arranging the elements and association of the message into one common structure.

The process of message clustering is similar to the process of message structuring. The former resulted in message types (as detailed in Section 4.1), and the latter results in message elements (as discussed here). We asked the four experts for message elements. At the outset, they provided 3 elements, namely responder, agency, and resource. We mined the elements of 10,411 messages based on this element set. The mining led to 3943 messages, where one or more of the elements were not identified. These messages and elements were inspected by the experts, who identified 2 additional elements in the second round of interviews, namely task and raw information. We mined the 3943 messages based on this element set. This mining accounted for all the elements in all the messages. The two rounds resulted in a total of the following 5 elements: responder, agency, resource, task, and information. These 5 elements form a mostly nonoverlapping, mutually exclusive message structure set consisting of message elements.

In the third round, we started off with the set of 5 element types obtained from the first round. We asked the experts to identify associations between the element types. We compared the associations provided by the experts. These associations were simple relations between the elements. For example, the experts iterated that a responder belongs to an agency. We revisited the UCORE framework to find the association depicting such a relation defined in the UCORE framework. This provided a structuring set of 4 association types as follows: controls, employed by, affiliated with, and involved in. There were no disagreements between the experts while specifying relations between the elements. The 4 association types form a message structure set consisting of element associations.

In the fourth round, the various elements of the messages and the association between them were mapped to the NIEM standard to check for their existence. If the definition of the element or the association did not exist in NIEM, it was added to NIEM. This process of message structuring based on elements and their associations resulted in a NIEM-compliant message structure.

5.1.1. Message Elements. The elements identified from emergency messages were classified into responder, resource, agency, task, and information category, based on setup

Table IV. Message Elements

Message Types	Elements: Responder	Resource	Task	Agency	Info
Notifications	X	X		X	X
Requests	X	X		X	
Responses	X			X	
Updates	X	X	X	X	X

codes provided by the responders from the dispatch database. These elements are discussed as follows.

Responder. As the incident grows in magnitude, the number of responders from local, state, and federal agencies who become a part of the response, also increases. The emergency responders have different levels of training and expertise. A responder element deals with responder characteristics, such as responder demographics, designation, training expertise, or accountable team and agency. A responder structure considers complex issues such as conflicts, training, interpersonal relationships, and dependencies with other structures [Chen et al. 2005].

Agency. During an emergency, different responding agencies including dispatch, fire, police, EMS, and other organizations, play a vital role in the mitigation of the incident. An agency element deals with agency characteristics such as status, specialized teams, or responder-in-charge. An agency structure becomes extremely complex when there are multiple agencies responding to the same incident, dealing with relationships, risk sharing, and goal conflicts in the organization, interagency mutual aid agreements, and dependencies with other structures.

Resource. During an emergency, there is a great extent of overlap of shared resources between tasks. The resource sharing for multiple tasks becomes very challenging, since the resource supply from a single location decreases owing to limited preplan arrangement [Mendonça 2007]. A resource element considers resource characteristics such as resource type, count, condition, accountable agency, or mutual aid plan, and deals with management of resources to ensure efficient allocation availability, functioning, and accountability.

Task. The involvement of inadequately trained volunteers [Turoff et al. 2004] alongside expert first responders is a norm during an emergency. Thus, allocation of responders to tasks becomes extremely challenging from a safety and execution point of view. A workflow element deals with task characteristics such as type, status, responder-in-charge, accountable agency, and allocated resources. A workflow structure deals with the response tasks ranging from simple tasks to extremely complex tasks, with multiple layers of hierarchy.

Information. Bharosa et al. [2008] state that emergency situations often encounter the problem of information quality. Incomplete and inconsistent information during an incident limits the efficiency of its response. An information element deals with bits and pieces of information that may be helpful during the mitigation of the incident. An information structure deals with information source, recipient, content, and quality [Yang et al. 2009]. The 5 element types help provide a more nuanced understanding of the message content. Table IV summarizes the messaging elements for different message types.

Table V. Association Scenario

Element	Association	Message	Scenario
Responder-Resource	Controls	"RELEASING SW ... – PER CC9"	The task of releasing Swornsville fire agency, as approved by the incident commander, discharges any associated resources from the scene.
Responder-Agency	Employed By	"C9 TO TOWN HALL"	The Clarence Chief C9 responds to staging at Town Hall
Resource-Agency	Affiliated With	"HARRIS HILL ... – MAA REQ"	Harris Hill agency is requested for mutual aid ambulance. This mutual aid is preplanned with a number of ambulances.
Responder-Workflow	Involved In	"C91 IN CHARGE OF THE SCENE"	The Clarence First Assistant Chief takes the charge of the scene that calls for evaluation of resources assigned to tasks, in terms of discharging or holding cold at the staging area
Resource-Workflow	Involved In	"LANCASTER TO COVER CLARENCE HALL"	The agency Lancaster is moved to cover Clarence Hall in order to provide support for active, cold tasks
Agency-Workflow	Controls	"LAW ENFORCEMENT SECURING AREA"	The law enforcement agency is securing the scene for crime scene investigation

5.1.2. Element Association. The elements of the message were closely associated with one another, as identified from the UCORE messaging framework and confirmed by experts. For example, a responder is associated to an agency in a "belongs to" relationship. In order to achieve a semantic structuring of the message, it was important to identify the type of relationship that existed between the elements. The responders helped us identify the associations as obtained from the incident reports. These element associations are summarized in Table V.

5.2. Message Queuing Process

The different emergency message types identified earlier depict varying characteristics. These characteristics prove useful in understanding how the responders process the messages for transmission through the medium. Using this understanding, we develop a mechanism for queuing of emergency messages in the medium. Message queuing is the process of holding the messages that are generated by multiple sources simultaneously into a queue for further processing. First, we interview the responders to learn about the medium (radio channels) used for communication, and second, we examine the frequency of each message type.

During our interviews the four experts identified the various radio channels available for transmission of the emergency messages. They also provided explanations pertaining to the use of these radio channels and identified how the messages can be switched to various other channels for efficient response. They all agreed on radio channels available for use. The findings from the interviews are summarized in the following.

5.2.1. Channel Types. The emergency dispatch agency utilizes 6 radio channels (numbered 1 through 6) for message exchange. These 6 radio channels are characterized into

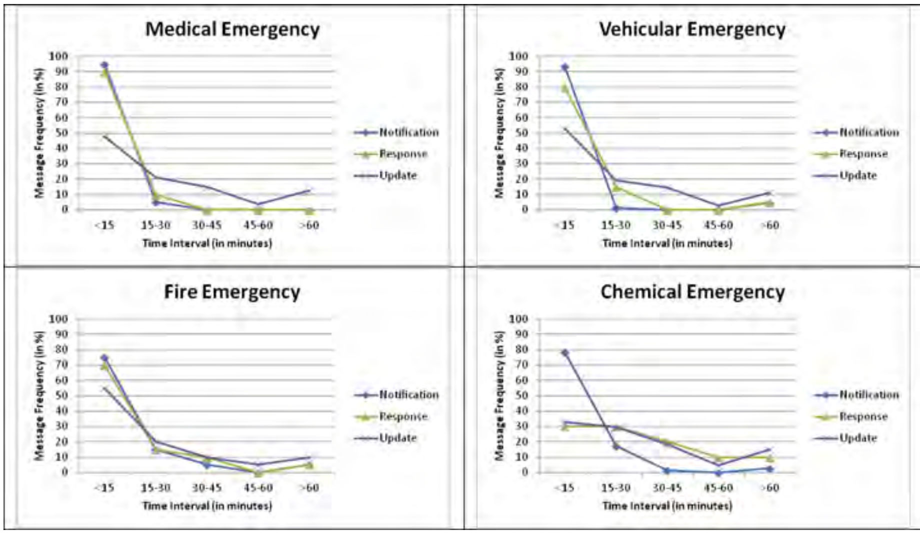

Fig. 5. Illustration of message frequency for emergency types.

three types: dispatch channel, fire ground operations channel and fire-police channel. These channels are discussed as follows.

Dispatch. In the current dispatch mediated communication system, the dispatch agency is notified on the dispatch channels. The dispatch channels (numbered 1, 6) are also used for receiving 9-1-1 calls. This channel is primarily used by the commander for quick dispatch-related notifications. The dispatch agency also uses this channel for communication, including notifying and requesting, with agencies when other lines are occupied/in-use.

Operations. Once the dispatch agency is notified about the incident, all communication with regard to that incident is transferred to a fire ground operations channel, freeing up the initial channel for receipt of information about new incidents. The operations channels (numbered 2 through 4) are also used for on-scene communication between responders. The dispatch agency allocates an operations channel to each incident. In case of major incidents, more than one operations channel is assigned, each for a major incident-related function, such as staging or clearing. This channel is primarily used for communicating update type messages.

Police. For the emergency wherein the incident commander identifies the causes of the incident as more than just "natural," the support of the police agency is requested for investigation and other related functions. The police channel (numbered 5) is primarily used for communicating with the police agency. For the major incidents where police support is constantly needed (e.g., securing the scene perimeter, providing scene safety), this channel is used as a part of operations channel so that the police agency hears all the communication taking place, and provides for fast response to the scene.

5.2.2. Message Frequency. In Figure 5, we illustrate the frequency distribution of message types over a timeline. As part of emergency management planning at the county, city, and area levels, there is a prearrangement of sharing resources to mitigate incidents from neighboring areas. This is referred to as "mutual-aid." Plans that are part of mutual aid also include what resources would be automatically provided for different types of incidents to neighboring areas or towns. During a normal incident, when a

Table VI. Descriptive Statistics

Emergency	Notification Mean(Std)	Response Mean(Std)	Update Mean(Std)
Medical	2.29(0.86)	0.86(0.49)	5.60(1.17)
Vehicle	2.33(0.88)	1.11(0.85)	8.85(3.03)
Chemical	3.75(1.21)	0.50(1.00)	4.20(3.00)
Fire	4.22(2.28)	1.35(1.15)	10.00(4.37)

second or a third alarm is sounded, neighboring counties automatically provide resources based on preplans. These preplans include sufficient resources to cater to normal day-to-day incidents such as single house fires or multitenant apartments. The request messages have lower frequency for most day-to-day incidents, as these are available through mutual aid (therefore they are not shown in Figure 5).

The three message types are analyzed for frequency of occurrence in intervals of 15 minutes (as suggested by the experts) over the "golden hour" of the incident. While incidents may last for more than one hour, Curra et al. [2009] and Samba [2010] suggest that the response in the first 60 minutes of the incident is the most critical. The most commonly occurring incidents identified from the incident reports can be characterized as Medical, Vehicle, Fire and Chemical. For each graph, the vertical axis depicts the "message frequency" in percentage of that total count of that message in that time period, and the horizontal axis depicts the timeline at 15-minute intervals.

We observe that for all types of incidents, the level of notifications is typically higher in the first 15 minutes, and gradually decreases. The level of updates follows a similar pattern except that it tends to marginally increase towards the end of the response action. The level of response messages follows a similar pattern as updates i.e. higher in the beginning, gradually decreasing, and higher towards the end of the incident. To better explicate the graph in Figure 5, we provide a short example here—a 95% notification in the first 15-minute interval during a medical emergency, implies that 95% of all notifications during the medical emergency are encountered in the first 15 minutes of the emergency. A declining graph indicates that the percentage of notifications decreases as the emergency progresses.

6. MESSAGING MODEL FOR DISPATCH COMMUNICATION

The process of analysis of the messages in the incident reports yields our messaging model, including the message format and message queues. These are summarized as follows.

6.1. Message Descriptive

Table VI depicts the descriptive statistics for the message types derived from the messaging model for medical, vehicle, chemical, and fire emergency. There is a higher number of notifications for fire emergency, since fire spreads quickly and more agencies may be required to provide the resource. There is a higher number of responses for fire and vehicle emergencies owing to the greater number of vehicles responding with their status. Finally, the number of updates is higher for vehicle and fire emergencies due to the number of activities undertaken at the scene of the emergency.

6.2. Message Format

The process of message structuring results in message formats, in that we structure the message by creating message formats compliant with NEIM and UCore after an understanding of the different classes of messages.

In this section, we first depict the structured messaging elements. For example, the entity "Fire Chief" is defined as "ResponderType" in the NIEM codespace. Second, we

Table VII. Messaging Elements for NIEM Extensions

Element	Existing NIEM Support UCORE Definition Extension to NIEM 2.0	Tag Definitions
Responder	niem:ResponderType	<xsd:extension base=”u:PersonType”> <xsd:sequence> <xsd:element name=”state” type=”StateType” /> <xsd:element name=”code” type=”codeType” /> <xsd:element name=”des” type=”desType” /> <xsd:element name=”team” type=”teamType” /> <xsd:element name=”train” type=”trainType” /> </xsd:sequence> </xsd:extension>
	ucore:Person	
	State: Physical or medical condition Training: Specialized experience Team: Special agent task force Code: Personal Identifier Designation: Hierarchical status	
Workflow	niem:ActivityType	<xsd:extension base=” nc:ActivityType ”> <xsd:sequence> <xsd:element name=”state” type=”StateType” /> <xsd:element name=”dur” type=”DurType” /> <xsd:element name=”charge” type=”RespType” /> </xsd:sequence> </xsd:extension>
	ucore:Event	
	State: Degree of on-scene execution Duration: Time to exhaustion Responder: Response task’s in-charge	

Table VIII. Association Scenario

Interaction	Message	UCORE AssociationType	Scenario
Responder-Resource	“RELEASING SW . . . – PER CC9”	<ucore:Controls> <ucore:PersonRef ref=”Responder” /> <ucore:EntityRef ref=”Resource” /> </ucore:Controls>	The Incident Commander controls the discharge of any associated resources from the scene.
Responder-Workflow	“C91 IN CHARGE OF THE SCENE”	<ucore:InvolvedIn> <ucore:PersonRef ref=”Responder” /> <ucore:EventRef ref=”Task” /> </ucore:Controls>	The Clarence First Assistant Chief is involved in the task of scene evaluation

depict the structured messaging element association. For example, the relationship between the entity “Fire Chief” and the entity “Fire Truck” is defined as “Controls.” In Tables VII and VIII, we show structuring of only responder and workflow elements, and structuring of only controls and involved association, because of space constraints. Finally, we depict the messaging format for each message type with the help of terminology, as summarized in Table IX. This messaging format identifies the communicators and the message objectives. As analyzed from the incident reports, a message typically contains a communicator (the sender and the receiver), a keyword, time stamp, criticality (assigned by the incident commander to the message), role-based security access (assigned to restrict access to the information) and message attributes such as interacting agency, resource, or status of response. In this article, we do not address the criticality element, since the data for such an analysis is not available.

6.3. Message Queues

Based on investments made by the community, each dispatch center across the country is provisioned to handle multiple simultaneous incidents. The dispatch agency we interviewed had the capacity to handle 4 simultaneous incidents without using any single channel for multiple incidents. The probability of more than four simultaneous events is rare and occurs only in cases of extreme events. The process of message queuing results in message queues, because we queue the messages with high frequencies on dedicated channels. In addition, the messages with low and medium frequencies are queued together on a single channel.

In this section, we first depict the message queues for the initial phase of the emergency (T1), where all the notifications (NOTF), responses (RESP), and updates (UPD),

Table IX. Message Format

DT: Date Time
NOTIFY: Keyword
REQUEST: Keyword
RESPONSE: Keyword
UPDATE: Keyword

AN: Agency Name
*: Any Agency or Responder
IC: Incident Commander
MT: Mutual Aid Type (aid agreement)
UT: Update Type
CT: Criticality

ST: Status
IN: Information
NT: Notification Type
DR: Dispatch Responder
AR: Agency Responder
AC: Access

Type	Source	Target	DT	Criticality	Access	Keyword	Attr1	Attr2
Notification	*	AR	DT1	CT1	DR	NOTIFY	NT	AN
Request	IC	DR	DT2	CT2	AR	REQUEST	AN	MT
Response	AR	DR	DT3	CT3	DR	RESPONSE	AN	ST
Update	*	DR	DT4	CT4	*	UPDATE	UT	IN

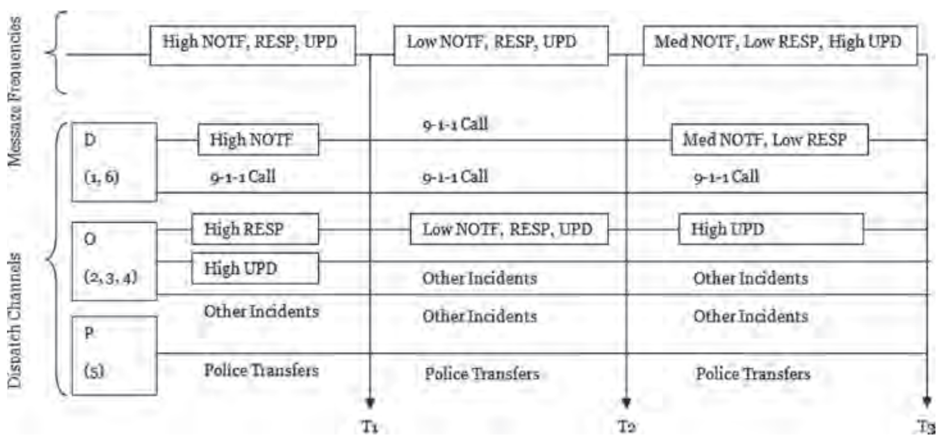

Fig. 6. Message queues.

are typically high. In order to avoid channel congestion, each high frequency message is queued on a dedicated channel (while also considering the objective of the message). Notifications are dedicated dispatch channel (D), while responses and updates are dedicated operations channel (O). Second, we depict the message queues in the second phase of emergency (T2), where all the notifications, responses, and updates are typically low. Since lower frequency messages do not congest the channel, we queue them together in the operations channel. Finally, we depict the message queues in the final phase of emergency (T3), where the updates are typically high. These updates are queued on a dedicated operations channel, while notifications and responses are queued together over the dispatch channel. The message queues are summarized in Figure 6. In case of multiple emergencies, the dedicated channel queuing may not be feasible, in which case there have to be efficient mechanisms for combining the varying frequency messages on appropriate dispatch channels. We leave this for future research.

Figure 7 summarizes our messaging model comprised of message formats and message queues generated in the process of message structuring and message queuing respectively.

7. VALIDATION AND APPLICATION OF MESSAGING MODEL

In this section, we first validate the classifier part of the messaging model, and then apply the model to a real case scenario. First, we carry out performance validation of

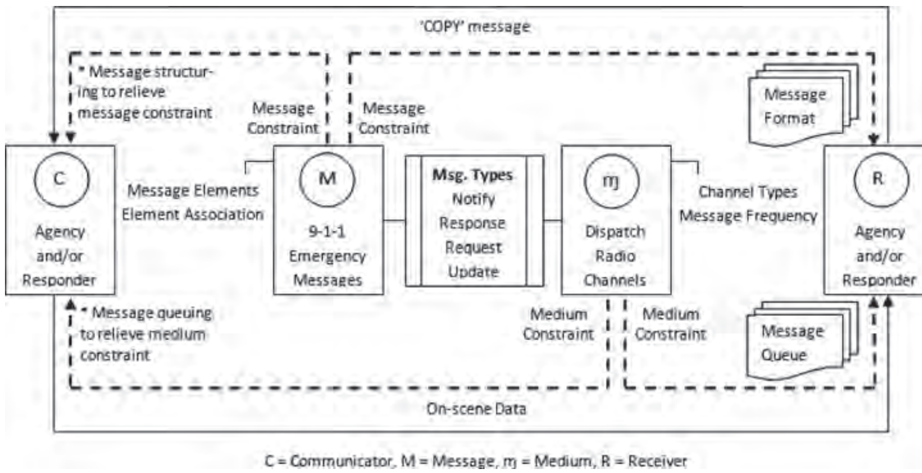

Fig. 7. Messaging model for dispatch communication.

Table X. Validation Dataset

Variables	Count
Total number of incidents	107
Total number of messages	769
Total number of Notifications	208
Total number of Responses	84
Total number of Updates	477

the classifier employing the confusion matrix (ground truth on correct classifications was obtained by asking experts to classify the same messages). Second, we show proof of concept of the model using a case study.

The confusion matrix is widely used in the literature to validate classifiers [Puniskis et al. 2006]. The lower the number of misclassifications, the better is the classifier. Typically, the extent of misclassification is assessed by the number of Type I and Type II errors. The confusion matrix provides a measure of not only the number of messages that were misclassified but also the category into which they were classified. This is therefore a very strong and relevant measure to use to evaluate a classifier. In this article, we have followed the process elucidated by Lau et al. [2011].

Proof of concept by applying it to a real case has been used in prior literature [Chen et al. 2008, 2012]. Albright et al. [1998] suggest that a case study is particularly useful for evaluating the model when the model is unique, when the model is implemented in a new setting, when a unique outcome warrants further investigation, or when the model appears in an unpredictable environment. In our context, the messaging model is developed for an emergency context that is outlined with unpredictability and time sensitivity. In the next section, we detail the application of these measures to our messaging model.

7.1. Performance Validation of the Classifier using Confusion Matrix

In this section, we detail our usage of the confusion matrix to establish the efficacy of our model. In Table X, we present the data that we use for testing the classifier.

We built our evaluation dataset based on sample messages derived from 107 randomly selected major incidents from the period of 2009 to 2011 responded to by the North Bailey fire station. This dataset was not used in the development of the model.

Table XI. Confusion Matrix for Performance Measures

	Notification	**Response**	**Update**
Notification	a	b	c
Response	d	e	f
Update	g	h	i

Table XII. Performance Measures

$$\mathrm{Nm} = \frac{d+g}{a+d+g}$$
$$\mathrm{Rm} = \frac{b+h}{b+e+h}$$
$$\mathrm{Um} = \frac{c+f}{c+f+i}$$
$$\mathrm{Cm} = \frac{a+e+i}{a+b+\cdots+h+i}$$

Table XIII. Classification Matrix

Messages	**Classification**	**Misclassification**
Notification	99.52%	0.48%
Response	96.43%	3.57%
Update	97.16%	2.94%
All	97.66%	2.34%

The 107 incidents contained a total of 769 messages that served as test data for our classifier. We used our classifier on the dataset previously described, and compared them to the classification done by expert emergency dispatchers. It should be noted that the emergency dispatchers used the same 769 messages used by our classifier, which we consider to be the ground truth. The results obtained by running the classifier were compared to a classification of the same 769 messages by the emergency dispatchers. Using the classification obtained from the dispatch responders (see Table X) as ground truth, we developed a confusion matrix, where columns represent the predicted message type and the rows represent the actual message type, to provide a visualization of the classification process. It details the percentage of correctly classified and misclassified messages (see Table XIII). With the help of the confusion matrix shown in Table XI, we define the various effectiveness measures in Table XII, where a, b, c, d, e, f, g, h, and i refer to the number of message types falling into each classification category.

The notification, response, and update misclassification (Nm, Rm, and Um) is the fraction of notifications, response, and updates, misclassified as other message types. As Nm, Rm, and Um are measures of failures, we measure true positive as Min(1 – Max(Nm, Rm, Um)). We also provide the common effectiveness measure (CM) for the case where the sample was more evenly distributed.

A summary of performance measures of classification of messages is depicted in Table XV. The misclassification rates are 0.48%, 3.57%, and 2.94% for notification, response, and update type messages, respectively. The common effectiveness measure (overall classification) is 97.66%. The true positive (lowest classification) is 96.43%. Both the measures are relatively higher than 90%.

7.2. Case Application of Messaging Model

The true test of a measure or a model is discovered in its usage and application [Chen et al. 2012]. In accordance with this belief, we apply our model to a real case to determine how well it fits a real scenario. Essentially, we asked a set of experts to compare

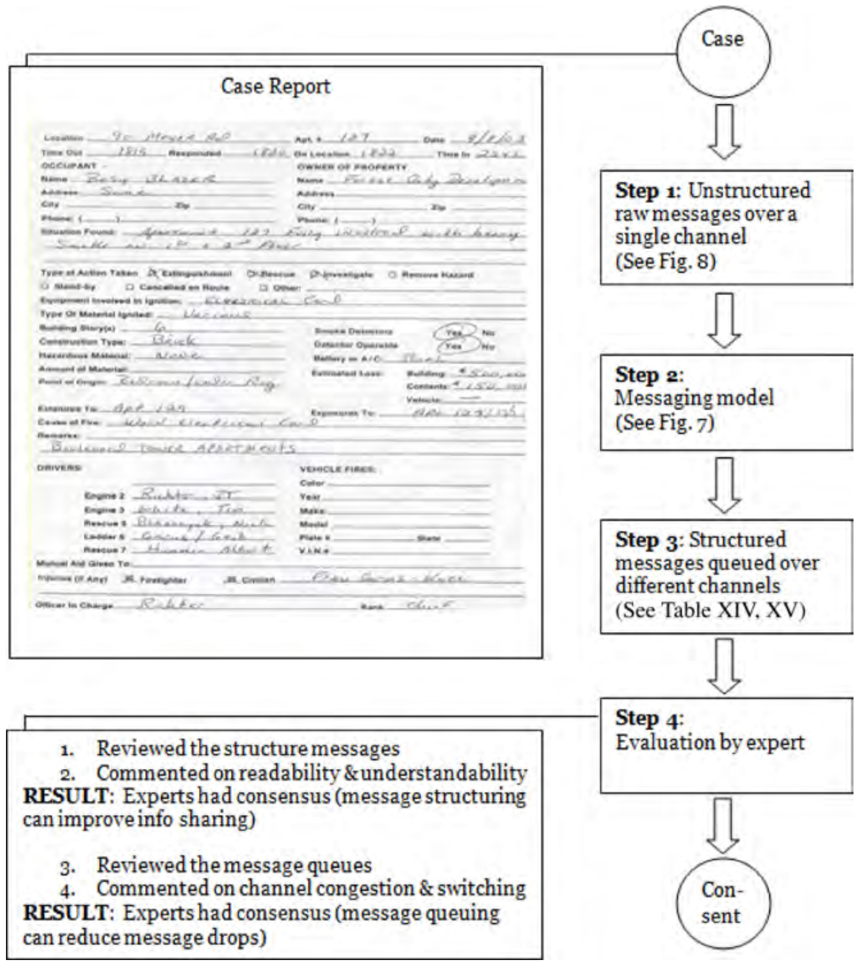

Fig. 8. Case application (adapted from Chen et al. [2012]).

messages obtained from a real incident to the output generated by the application of our messaging model. The goodness of fit derives from the assessments provided by the experts (see Figure 8 for details on the process). This provides a more comprehensive evaluation of our model. We detail this in the remainder of this section.

The case application of our model was accomplished in four steps. First, we presented the raw unstructured messages, transmitted over a single radio channel, from the incident report to the four different experts (these experts were not involved in the model development step). Second, we applied our messaging model to structure and queue the raw messages. Next, we presented the structured messages based on message formats, and queued messages based on frequency distributions to them. Finally, we conducted interviews to collect their feedback to understand their assessments about the way our messages were structured and the use of multiple channels. All four expert responders provided feedback that our model was a significant improvement over the current form that was employed. The experts concurred that our message format and message queues might be used to improve the communication by facilitating message standardization and channel switching respectively. The agreement was

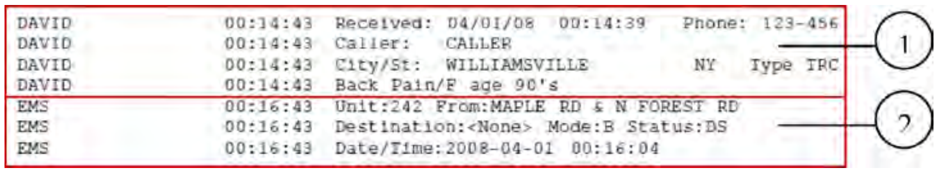

Fig. 9. Emergency communication message excerpt.

Table XIV. Message Format

Classification	**Sender**	**Receiver**	**Time**	**Criticality**	**Access**
Notification	CALLER	DAVID (Dispatch)	00:14:43	High	Dispatch
Response	Unit: 240	EMS Dispatch	22:19:48	Low	All

Attribute	**Event**	**Association**
Phone: XXX Caller: Caller	Informing about the incident	Sender Involved In Event
Unit:242 Mode: B Status: DS	Responding about its status	Resource Affiliated With Agency

Table XV. Message Queue

Channels	**#**	**<15 minutes**	**>15 minutes**
Dispatch	1	9-1-1 Call	9-1-1 Call
	6	Notification	.
Operations	2	Response	Notification, Response, Update
	3	Update	.
	4	.	.
Police	5	Police Transfer	Police Transfer

unanimous. They also let us know that the existing communication messages didn't have a structure that could hinder sharing and exchange of critical information during an incident response. In addition, they mentioned that higher frequency messages congested the channel, which could result in message drops. Figure 9 shows an excerpt from a log of communication messages, exchanged between the onscene responders and agencies. The incident pertains to an apartment fire that started in the living room of one of the apartment in a complex and quickly spread. Due to the extensive spread of the fire, tenants had to be evacuated within a short interval of time. This also included handicapped tenants who needed assistance. The total damage caused by the fire was estimated to be over $90,000.

Our message classifier automatically categorized messages into notification, request, response, and update. The first message is the initial notification to dispatch, and is thus classified as "Notification." The second message provides the status of the responding ambulance unit, and is thus classified as "Response." The message classifier worked as expected. The messaging format identified information relating to the communicator, the timestamp, entity, event, and association with other elements. This message format is shown in Table XIV.

From the illustration of message frequencies during the fire emergency, we identify that both notification and response messages have higher frequency in the first 15 minutes, so they are queued on different channels (dispatch channel # 6 and operations channel # 2). In addition, we also identify that both these messages have lower frequency for the rest of the incident. They are therefore queued on the same channel (operations channel # 2). This frees up additional channels (in the >15 minute time period) after the initial peak of messages (in the <15 minute time period). The message queue for the case application is shown in Table XV.

In summary, the results of (a) the performance validation shows that the measures for performance of the message classifier are acceptable (greater than 90%), and (b) the case application shows that the experts concurred that our message format and message queues might be used to improve the communication by facilitating message standardization and channel switching respectively.

8. CONCLUSIONS

This article helps improve existing knowledge and societal impact [Chen 2011] in the area of extreme events and the mitigation of local emergencies. The current state of emergency communication is dispatch-mediated (the messages from the scene are typically directed to the responders and agencies through a local dispatch agency). However, these messages do not adhere to any particular structure, and there is no set format. The lack of standards creates a problem for sharing information among systems and responders and has a detrimental impact on systems interoperability. In this article, we develop a messaging model that is compliant with National Information Exchange Model (NIEM) and Universal Core (UCORE), which provides for message structure and message format to foster message standardization.

Maletze's [1981] work provides broad guidelines on what needs to be done, instead of specific help. By doing so, it allows us to follow a bottom-up approach of mining the data and working with the extracts of that process with first responder experts to arrive at our solution. Such a bottom-up approach leads to a vocabulary that is closer to the currently used standards, and has a better opportunity for acceptance by first responders. In addition to this, Maletzke's work prompts us to consider message and medium constraints that act upon responders. The message constraint leads us to ensure that messages are structured, while the medium constraint leads us to ensure that there is queuing of certain types of messages (e.g., those high in frequencies in that time period) so that channel congestion is avoided.

Alternate works can be used in the development of message formats and message frequencies. One such stream highlighted in the literature is the work of Winograd and colleagues [Flores et al. 1988; Medina-Mora et al. 1992], using the language-action perspective. This provides more of a top-down theory-driven approach to prescribing the messages and their structures for dictating action based on the communicator's intention. We leave application of such work in emergency response for future research.

The limitation of our work derives from NIEM mapping. If a message element or association does not exist in NIEM, we have added its definition to NIEM. In addition, there are concerns about NIEM and how people use it, including a steep learning curve. NIEM standards are not exhaustive and are also not hazard-specific. The guidelines are broad and they do not pertain to specific incident types. There is a need to add vocabulary to extend the standard to specific incident types. Another limitation of our article is that it is based on 9-1-1 logs from some of the counties in the Northeastern part of the United States of America. Practices in other parts of the country may vary somewhat and future studies should generalize the model developed in this article to accommodate these variances.

Another limitation of the current system is that repeated messages are not logged. It may be noted that a unidirectional message may be multicast to several responding agencies to ascertain which agency has the resource to respond. In addition, a mechanism for dealing with missed messages in the system needs to be addressed in future research. The elements of the message could be further inspected to identify a relation between them and the objective of the message. Often during emergencies, the chaotic nature of emergency events results in a cognitive load for dispatchers and responders who have to search for problems. Instead, if the system can find the dispatchers by way of alerts on actions, the system becomes more intelligent. The data with regards to 911 calls also provides rich information on prank calls and aborted 911 calls. This data can perhaps be utilized to arrive at patterns that lead to more predictive analysis. Early detection of these aborted 911 calls and prank calls will allow dispatch responders to focus on actual emergencies. This is another area for future development.

Finally, this article strictly adheres to the design science research guidelines [Hevner et al. 2004; Peffers et al. 2006], which include a step-by-step approach in the development of an emergency dispatch system for dispatch communication. We have identified the issues with dispatch-mediated communication systems and developed a messaging model to support emergency dispatch communication.

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