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ABSTRACT

During an emergency, the on-scene communication takes place in the form of dispatch-mediated emergency messages. These messages, identified from the emergency communication reports, follow no standardized format, which render them useless for several other departments. This paper develops a messaging model, compliant with UCORE messaging framework, as follows: First, it determines the structure of the emergency messages. Second, it translates the emergency messages to a standardized format.

Keywords

Messaging Model, Emergency Communication, Design Science, Dispatch Mediated Message, Schramm's Communication Model

INTRODUCTION

Emergency communication is extremely complex and challenging because it is constraint by uncertainty, time sensitivity and unpredictability (Bharosa et al. 2008; Chen et al. 2008). (Manoj and Baker 2007) have clarified that communication is a primary challenge during an emergency. Department of Homeland Security (2007) has identified that the efficiency of communication has been a long standing issue of concern during emergencies. During 9/11 terrorist attacks, ineffective communication, affected the performance and damaged the capacity of organizations in emergency response. Thus, one of the most important features of an emergency response system is to ensure effective communication (Seifert 2007).

During an emergency, the on-scene communication takes place in the form of dispatch-mediated emergency messages. These messages, identified from the emergency communication reports, follow no standardized format, which render them useless for several other departments. A standardized message is very important for encoding and decoding purposes. It also allows for providing interoperable solutions for communication systems. Universal Core (UCORE) provides such 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 cater to the management of day-to-day emergencies such as medical, fire, chemical, vehicular, etc. In this paper, we adopt the UCORE messaging framework to standardize on-scene local emergency messages.

This paper develops a messaging model, compliant with UCORE messaging framework, as follows: First, it determines the structure of the emergency messages. Second, it translates the emergency messages to a standardized format. The paper is driven by existing literature in the field of emergency communications, data in form of incident reports, and inputs from first responders. The paper adheres to the design science (Hevner et al. 2004; Peffers et al. 2006) research guidelines, which include step-by-step approach in attaining the ultimate goal of IT innovation. These steps include identifying a problem, generating the objectives of a solution, extracting the design from the objectives, facilitating demonstration of the artifact to professionals, evaluating the design and artifact, and communicating its effectiveness to appropriate audience. The paper is organized as follows. In section 2, we provide background of emergency response communication. In section 3, we develop the messaging model. In section 4, we provide a case application. In section 5, we conclude with limitations and future work.

BACKGROUND AND THEORETICAL FRAMEWORK

Emergency Systems & Standards

The prior studies in emergency systems have focused on various aspects of emergency response, such as single- and multi-incident management, information management, onsite management, etc as discussed: (Chen et al. 2007) proposed a framework for multi incident management including information exchange, coordination, and response escalation/de-escalation. (Kim et al. 2007) developed a conceptual model for critical incident management system (CIMS) for efficient decision making, evaluating the effect of technology for communication and information processing. (Almazan et al. 2007) discussed the integration and fusion of the enormous pool of information on-scene for the purpose of information reusability. (Valecha et al. 2010) discussed interoperability for isolated nature emergency systems, by highlighting problems associated with such information systems.

A number of data standards have been developed for effective communication, such as National Information Exchange Model (NIEM), Universal CORE (UCORE), Global Justice XML Data Model (GJXML), Common Alerting Protocol (CAP), and Emergency Data Exchange Language (EDXL), IEEE 1500 and more. These standards provide XML model to standardize content between agencies, thus providing efficient information management through the means of information sharing, exchange and standardization. However, these data standards do not cater to local incidents such as Medical Assists, fire, chemical incidents, etc.

Emergency Communication &Interoperability

During an emergency event, emergency responders and agencies are unaware of the policies and structures that define roles and responsibilities for emergency communications. One reason for this lack of awareness is the absence of standardized models to identify communication capabilities. Emergency Systems utilizing communication standards are fragmented and disintegrated. The non-interoperable systems have made it difficult to communicate critical information between different departments in a timely manner. An interoperable emergency communications system is one of the important steps to respond to national disasters. Center for American Progress' National Security issue of 2005 states that, currently, the US has no system in place to allow emergency response personnel communicate reliably and effectively in a crisis. Thus, more efforts are required in designing emergency response systems using theoretical models to address communication problems.

Onsite Communication

While there have been numerous systems that have been developed and improved significantly over the last decade with a number of these systems being deployed at different levels including local, state, and federal for the purpose of mitigation of fire related extreme events (Turoff et al. 2004), there have been very few information systems that have facilitated the onsite communication (Valecha et al. 2010). The current systems in place include radio communicators, cues on paper, and mental notes. Without communication systems present to handle detection, mitigation and control, emergencies can cause immense damage (Stula et al.).

Thus in order to motivate development of prototype systems for on-scene communication, in this paper, we develop a messaging model by determining the structure of on-scene emergency messages as follows: First, we identify the various elements that are a part of on-site emergency message. Second, we examine the interaction between the various elements of the message. Third, we determine the element states and their transitions.

Schramm's Communication Model

The development of a messaging model for standardizing on-site emergency messages requires a systematic approach to identify the basic communication elements involved. In this paper, we use Schramm's Communication Model (Schramm 1954) to guide this process of development. The sender uses a system to encode the information into a message for transmission, and sends it to the receiver. The receiver uses a system to decode the message for information. The receiver interprets the information to be used to guide his actions. Finally, the receiver sends a feedback, thereby acting as a sender. The communication elements have significant implications for our study. Response to an emergency is complex, and dynamically develops over the period of time. It is dynamic and undergoes frequent restructuration. By advocating the model, we investigate communication during the response stage along the lines of the elements of communication, namely the communicator, the message, the interpretation and the feedback.

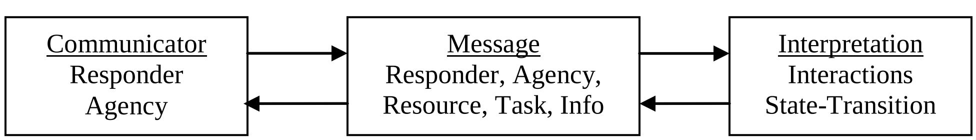

Figure 1. Emergency Communication (Adapted from Schramm 1954)

DEVELOPMENT OF MESSAGING MODEL

Development Process

We inspected raw data from 1147 major incidents responded to by North Bailey fire station from the period 2008 to 2010. The 1147 incidents provided a sample of 10411 communication messages. We then contacted first responders (two dispatchers and two fire chiefs) from dispatch and fire department with an average of more than five years of experience in dealing with emergencies. They were provided with various emergency messages. Their responses included identification of key elements in the message. They also provided rules that facilitate the process of message classification into four main categories based on their objectives, namely notification (informs about the incident), request (requests for additional resources), response (acknowledges notification) and update (updates information). The message classification is not detailed here, since it is not the focus of this paper.

Message Structure

An emergency message is made up of one or many elements that are related to each other, and exhibit temporal progression. In order to standardize the message, first, we identify the various elements that are a part of emergency message, second, we examine the interaction between the various elements, and third, we determine the element states and their transitions. The messaging structure was determined as a result of the analysis of 10411 emergency communication messages stemming from 1147 emergency incidents.

Messaging Elements

The elements identified from emergency messages are classified into responder, resource, agency, task, and information category. In order to maintain consistency with existing communication standards, we adopt a UCORE taxonomy that classifies these elements into two subclasses – Entity and Event. The “Entity” subclass corresponds to elements that are deployed, such as responder, resource, agency, and information. The “Event” subclass corresponds to elements that are executed, such as task.

Responder: As the incident grows in magnitude, the number of responders from local, state and federal agencies, that 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, accountable team and agency, etc. 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, dispatch, 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, responder-in-charge, etc. 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 agreement, 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 pre-plan arrangement (Mendonça 2007). A resource element considers resource characteristics such as resource type, count, condition, accountable agency, mutual aid plan, etc. A resource structure deals with management of resources to ensure efficient allocation availability, functioning, and accountability.

Task: The involvement of inadequately trained volunteers (Turoff et al. 2004) with that of 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 tasks 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. The 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 and recipient, information content and information quality. The Figure 2 below summarizes the messaging elements for different message types.

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

Figure 2. Message Elements

Element Interactions

The elements highlighted above are closely associated with one another. For example, a responder is associated with an agency. However, it is difficult to identify how the two – responder and agency – are associated. Such information about the relationship between the entities plays an important role in machine learning or intelligence building. In order to achieve a semantic interpretation of the message, it is important to identify the type of relationship that exists between them. While the analysis of emergency messages confirms that the elements are associated together, it fails to identify the type of the relationship. In order to determine the type of relationship between the messaging elements, we map the messaging elements to UCORE's entities and events. The element interactions are summarized in the Table 1 below.

Interaction	**Message**	**Scenario**
Entity-Entity Interaction		
Responder-Resource	"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	"C9 TO TOWN HALL"	The Clarence Chief C9 responds to staging at Town Hall
Resource-Agency	"HARRIS HILL … – MAA REQ"	Harris Hill agency is requested for mutual aid ambulance. This mutual aid is preplanned with number of ambulances.
Entity-Event Interaction		
Responder-Workflow	"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	"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	"LAW ENFORCEMENT SECURING AREA"	The law enforcement agency is securing the scene for crime scene investigation

Table 1. Interaction Scenario

Element States & Transitions

The emergency message demonstrates a temporal component i.e. the elements and their structures are not static. They are dynamic, and have a life cycle associated with them. In order to interpret the temporality of elements in a message, it is important to consider various states that the elements go through during their life cycle. A simple view of element life cycle could be studied though the process flows of the element. The "Entity" subclass of elements go through four stages, namely dormant, dispatched, cold and active as shown in Figure 3 below, and the "Event" subclass of elements go through six stages, namely dormant, queued, approved, active, suspended and completed as shown in Figure 4 below.

An "Entity" is in a dormant state when it is not dispatched for the incident. Once it is dispatched, it comes into action and can be deployed. When it arrives on the scene, it can be in the cold state, i.e. not utilized, or in the active state. The "Entity" in cold state can transition to active state and vice-versa when it is assigned to an "Event" or withdrawn from the "Event". An "Event" is in a dormant state before it is considered for approval. It can transition to a queued state in case of a lower priority. Once it is approved, it comes into action and can be implemented. During its execution phase, it is in the active state. An active "Event" can be put to halt for any reason, which transitions it into the suspended state. A suspended "Event" can be released to an active state, and consequently to completed state.

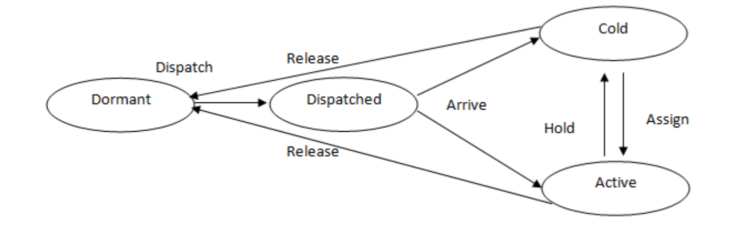

Figure 3. Entity Process Diagram

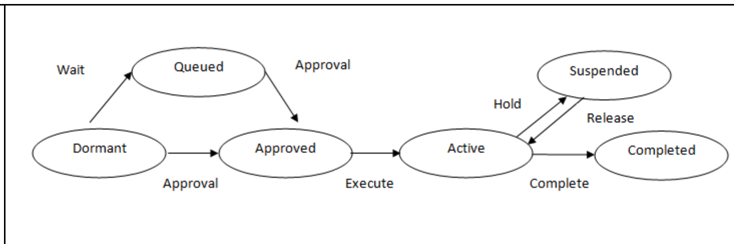

Figure 4. Event Process Diagram

Message Standardization

The discussion of messaging elements, their interactions and their state-transitions is useless unless they are implemented in practice. The message standardization is such an implementation that allows for providing interoperable solutions for communication systems. UCORE provides such a framework that facilitates emergency communication by providing a means for standardizing emergency messages. In this section, we use the UCORE framework to standardize each module of our messaging structure as follows: First, we derive broader, more loosely coupled definition of the element from UCORE framework and more specific, tightly coupled definition of the element from NIEM standard. Second, we derive the relationship with other elements with the help of UCORE associations. Third, we wrap the definitions and associations into a standard messaging format. Role-based security is applied to the message to restrict access to the information. These three steps are discussed with an example:

Element Standardization

In this section, we explain the process of standardizing the messaging elements with an example. The entity "Fire Chief" is defined as "Person" in the UCORE codespace and as "ResponderType in the NIEM codespace.

Element	Existing NIEM Support	Tag Definitions
	UCORE Definition	
	Extension to NIEM 2.0	
Responder	niem:ResponderType	<xsd:extension base="u:PersonType"> <xsd:sequence> <xsd:element name="state" type="StateType" /> <xsd:element name="des" type="designationType" /> <xsd:element name="training" type="trainingType" /> </xsd:sequence> </xsd:extension>
	ucore:Person	
	State: Physical or medical condition Training: Specialized experience Designation: Rank within the organization	
Workflow	niem:ActivityType	<xsd:extension base=" nc:ActivityType "> <xsd:sequence> <xsd:element name="state" type="StateType" /> <xsd:element name="dur" type="DurationType" /> <xsd:element name="charg" type="ResponderType" /> </xsd:sequence> </xsd:extension>
	ucore:Event	
	State: Degree of on-scene execution Duration: Time to exhaustion Responder: Response task's in-charge	

Table 2. Messaging Elements for NIEM extensions

During such a process of mapping the element to NIEM codespace, if the NIEM definition does not exist, we provide extensions into NIEM. This provides a strong base for developing extension to NIEM, from the communication perspective, which is a contribution to practical standards. In Table 2 above we show standardization of only one entity and one event because of space constraint.

Interaction Standardization

The analysis of emergency messages confirms that the elements are associated together; however, it is difficult to identify the type of the relationship that exists. This relationship is derived from the UCORE association types, by mapping the messaging elements in the form of entities and events to UCORE's elements, namely EventType, EntityType, PersonType, OrganizationType and CollectionType. Since UCORE specifies relationship among its elements, we were able to determine the exact type of relationship that exists among the messaging elements. For example, in order to determine the relationship between the the element "Fire Chief" and the element "Fire Truck", we map the elements to UCORE's "Responder" and "Resource" definition to obtain relationship as "Controls". In the following Table 3 below, we show standardization of only one entity-entity interaction and one entity-event interaction because of space constraint.

Interaction	**Message**	**UCORE AssociationType**	**Scenario**
Entity-Entity Interaction			
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.
Entity-Event Interaction			
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

Table 3. Interaction Scenario

CASE APPLICATION

The development of a messaging model contributes to emergency response communication in that it supports information exchange between responders and agencies on the scene of the incident, and provides a mechanism for automating this communication process through the end-user processing devices. For this case application, we apply the messaging vocabulary to the February 2009 plane crash incident, to standardize the communication messages. The Figure 5 below shows an excerpt from its communication report. A communication report is a log of messages that are exchanged between the responders and agencies, and is extremely useful in strategic planning and incident management. To standardize the communication messages, we follow a three phase process, namely, message classification, standard mapping and XML building. This process helps in development of structured semantic and syntactic XML messages standardized for emergency communication.

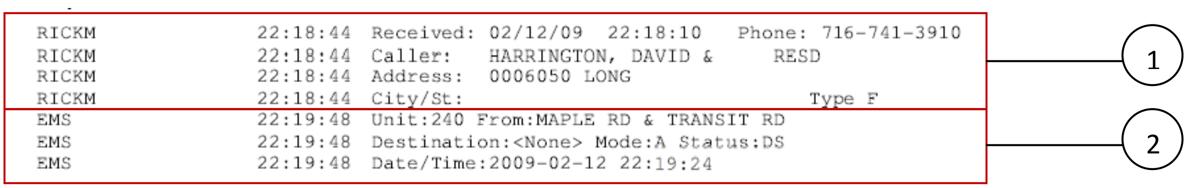
RICKM 22:18:44 Received: 02/12/09 22:18:10 Phone: 716-741-3910
RICKM 22:18:44 Caller: HARRINGTON, DAVID & RESD
RICKM 22:18:44 Address: 0006050 LONG
RICKM 22:18:44 City/St: Type F
EMS 22:19:48 Unit:240 From:MAPLE RD & TRANSIT RD
EMS 22:19:48 Destination:<None> Mode:A Status:DS
EMS 22:19:48 Date/Time:2009-02-12 22:19:24

Figure 5. Emergency Communication Excerpt

The message classification phase classifies each message into notification, request, response and update based on its objectives. The classification algorithm automates this classification process based on keyword and other criteria. In the standard mapping phase, the elements of the messages are, first, mapped to NIEM for specific definition, and then, incorporated into broad UCORE taxonomy. The relationship, if any, between the elements, is captured in the UCORE association. The mapping phase is followed by XML building, where the message is translated into XML. For example, the first message is the initial notification to dispatch, and thus classified as "Notification". The individual element, sender, is mapped to niem:PersonType, and categorized under ucore:Person. The relation between the sender and the event is mapped to ucore:InvolvedIn association type. This classification and mapping is shown in Table 5 below. Due to the space constraint, the XML code is not included in the paper.

Classification	Sender	Receiver	Date/Time	Entity	Event	Association
Notification	Harrington, David	RICKM (Dispatch)	22:18:44	Received: 02/12/09 22:18:10 Phone: 716-741-3910 Caller: Harrington, David & Resd Address: 0006050 Long City/St: Type F	Informing about the incident	Sender InvolvedIn Event
Response	Unit: 240	EMS Dispatch	22:19:48	Unit: 240 From: Maple Rd & Transit Rd Destination:<None> Mode: A Status: DS Date/Time: 2009-02-12 22:19:24	Responding about its status	Resource AffiliatedWith Agency

Table 5. Classification and Mapping

CONCLUSION

During an emergency, the on-scene communication takes place in the form of dispatch-mediated emergency messages. These messages, as identified from the emergency communication reports, follow no standardized format, which make them difficult to use for several other departments. This paper develops a messaging model, compliant with UCORE to standardize the emergency messages by employing Schramm's Communication Model to identify key elements, their interactions and their state-transitions during emergency communications. The paper evaluates the messaging model with the help of Buffalo Plane Crash case application. The paper has certain limitations: It considers data for single incidents and from dispatch agencies only. For future work, the paper can be extended to incorporate complex management issues such as information management, coordination, accountability, etc.

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