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How the internet of things technology enhances emergency response operations

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ABSTRACT

The Internet of Things (IoT) is a novel paradigm that connects the pervasive presence around us of a variety of things or objects to the Internet by using wireless/wired technologies to reach desired goals. Since the concept of the IoT was introduced in 2005, we see the deployment of a new generation of networked smart objects with communication, sensory and action capabilities for numerous applications, mainly in global supply chain management, environment monitoring and other non-stress environments. This paper introduces the IoT technology for use in the emergency management community. Considering the information required for supporting three sequential and distinct rhythms in emergency response operations: mobilization rhythm, preliminary situation assessment rhythm, and intervention rhythm, the paper proposes a modified task-technology fit approach that is used to investigate how the IoT technology can be incorporated into the three rhythms and enhance emergency response operations. The findings from our research support our two hypotheses: H1: IoT technology fits the identified information requirements; and H2: IoT technology provides added value to emergency response operations in terms of obtaining efficient cooperation, accurate situational awareness, and complete visibility of resources.

1. Introduction

1.1. Motivation

Disasters such as fires, floods, earthquakes, civil war, or terrorist attacks may cause crisis situations. Regardless of the origin, crisis situations are often accompanied by uncertainty of how the disaster will develop, a rapid pace of response operations, and the possibility of serious loss of human lives and property if not responded to properly. Good situational awareness and decision-making support are important factors for minimizing property damage and injury, and for saving people's lives. To provide adequate situational awareness and decision-making support to manage crisis situations, researchers and practitioners in disaster management have urged attention to the development of emergency response information systems (ERISs). Emergency response information systems should support first responders by enhancing their situational awareness which will lead to better decision-making [1]. It is argued that human decision-making failures during catastrophic incidents such as Bhopal [2], the firefighters' deaths during 9/11 [3] and the Three Mile Island nuclear crisis [4] were caused by situational awareness failures and the lack of support of decision-making. Several ERIS development efforts have addressed the importance of enhancing first responder situational awareness and improving their decision support capability [5–8]. Key studies [9–11] that recommended

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information system (IS) models and architectures suitable for emergency response (ER), have identified the ability of IS to provide support to decision-making and to understanding and recognizing the situation or context that responders face as key criteria for design of effective ERISs.

Different than IS for office use, an ERIS may work in an extreme and stress-filled environment, needing not only static information such as road maps and building floor plans, but also dynamic and real time information such as information about the latest disaster developments and the current locations of emergency personnel and resources. As an emergency evolves, requirements (both informational and logistical) may change resulting in necessary modifications of the response workflow [12,13]. An investigation of first responders' requirements in a Dutch emergency response case illustrated that much of the information first responders request during a crisis can be considered as dynamic information and needed almost instantaneously [14]. Furthermore, a desirable ERIS platform consists of a number of Mobile Data Terminals (MDT) [15], and many handheld devices such as mobile phones, iPads, personal digital devices (PDA), in cooperation with one or more large-scale computer server systems located in a fixed place. These features make it desirable for ERISs to be global and distributed information systems with the capability of real-time information acquisition, processing, sharing and understanding. To the knowledge of the authors, there are few such large-scale ERISs in use. Actually, many challenging issues involving technical, organizational and human factors and perspectives still need to be addressed before the desirable ERISs will be widely accepted. This paper addresses the information infrastructure issue of the desirable ERISs by introducing Internet of Things (IoT) technology into the emergency management domain, and investigates requirements-technology fit and the value added of using the IoT technology in ER operations.

1.2. Concept of the IoT

The concept of the Internet of Things (IoT) is to make every single 'network enabled' object in the world network connected, and represents a vision in which the Internet extends into the real world embracing everyday objects [16]. The term 'Internet of Things' was popularized by the work of the Auto-ID Center at the Massachusetts Institute of Technology (MIT), which in 1999 started to design and propagate across-company radio frequency identification (RFID) infrastructure [17]. One of the definitions of the IoT described it as 'a self-configured dynamic global network infrastructure with standards and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities, and are seamlessly integrated into the information infrastructure' [18]. The concept of 'things' in the network infrastructure refers to any real or virtual participating actors such as real world objects, human beings, virtual data and intelligent software agents. The purpose of the IoT is to create an environment in which the basic information from any one of the networked autonomous actors can be efficiently shared with others in real-time. With more powerful and efficient data collection and sharing ability, such a vision is possible and capable of supporting sophisticated decision support systems by providing services in a more accurate, detailed and intelligent manner. While workflows (descriptions of tasks to be performed, constraints on the tasks including resources needed, and relationships between the tasks) can be static in many applications (e.g. manufacturing), the constantly changing environment and requirements during an emergency requires an ability to dynamically alter the workflow in a rapid and correct way [13]. The IoT, with its potential for instantaneous updates of status, requirements, and other information, can enable dynamic workflow adaptations. For example, in [13] a formal approach for dynamic workflow management and analysis WIFA is proposed, and extended in [12] to incorporate awareness of changing resource (including people) needs and availability in dynamically creating and modifying workflows. The research of [12,13] developed an intuitive user interface to manage the dynamically changing workflow needs of an emergency. Incorporating the concept of IoT and the technologies that support it, in a system that uses the WIFA approach proposed by [12,13] will enable almost instantaneous changes in information and resources needed to update workflows and therefore enable decision-making about next steps (tasks) to be performed in a way that will make emergency response most effective during all phases of the event.

There are many definitions of the Internet of Things in the research and relevant industrial communities. The definitions may rise from the word 'Internet' and lead to an 'Internet oriented' vision, or 'things' and lead to a 'things oriented' vision. Putting the world 'Internet' and 'Things' together semantically means a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols. Atzori et al. [19] presented this third vision of IoT as 'semantic oriented' and the IoT paradigm as a result of the convergence of these three visions. The research roadmap from the European Commission [18] deemed the IoT as an integrated part of the future Internet. Some researchers tended to consider the IoT as a separate part of the Internet. Gershenfeld et al. [20] described the IoT as an extension of the Internet to reach out to the physical world of things and places that only can support low-end computers, while Fleisch [21] argued that the IOT is not on the same level as the Internet, but it is in fact an application of the Internet as are many existing Internet-enabled services. Since the concept of IoT was introduced in 2005, we see the deployment of smart 'network enabled' objects with communication, sensory and action capabilities for numerous applications such as in the areas of healthcare [22–24], smart buildings [25], social networks [26], environment monitoring [27], transportation and logistics [28], etc. All applications of the IoT rely on the data collected from distributed smart 'network enabled' objects and the IoT information infrastructure for data transmission.

The existing studies, however, have not explicitly dealt with the IoT as an entire technology for ER operations. Does the use of the IoT technology enhance ER operations? In which way does this enhancement occur? What is the strategic value of the IoT in ER operations? The main purpose of this paper is to provide insight into these questions by investigating the workflow ER operations follow, what information is required in the workflow, how the IoT fulfills the information requirements, and how the use of the IoT creates sustainable benefits. The focus of the paper is particularly on how the IoT technology enhances ER

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