A Fully Reconfigurable Approach to Emergency Management

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ABSTRACT

Emergency management is one of the most important areas where technology innovation has direct impact on social well-being and sustainability. In the past few years, Information and Communication Technology (ICT) has proved to be instrumental to improve emergency management with particular focus on resilience, rapidity of response, adaptability to situations. To these ends, joint optimization of communication and computing is a promising cross-layer approach. Indeed, this paper is focused on the consideration of both cognitive and autonomic networking approaches when deploying an emergency management system. The cognitive approach was initially considered specifically for wireless communications, while the autonomic approach was initially introduced for managing complex computing systems; however, they share several similarities in dealing with fully reconfigurable systems. The future trend is to expand their influence toward the global optimization of the ICT infrastructure, as the authors show in this paper for the specific case of emergency management systems.

Keywords: *Autonomic Networking, Cognitive Networking, Emergency Management, Pervasive Grid Computing, Reconfigurable Networks*

INTRODUCTION

Emergency management and disaster recovery schemes have great importance in communities throughout the world: the earthquake in March 2011 in Japan with the following Tsunami and nuclear plant emergency have dramatically highlighted the need to pay close attention to all those instruments aiming at preventing or, at least, reducing the negative effects of disasters (Haddow, Bullock, & Coppola, 2008).

The main target of emergency management is to design a system having a good grade of resilience and autonomicity (Boin & McConnell, 2007). Resilience is intended here as the ability of the system of reacting to disastrous effects in the presence of infrastructural deficiencies. This is particularly important in all situations whereby the disaster seriously damages any

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critical infrastructure (e.g., electrical energy network, communication infrastructure). In fact, several studies show that damaging any critical infrastructure can create a cascade effect on other ones, generating a critical scenario that takes a long time to be resolved (Rinaldi, Peerenboom, & Kelly, 2001). Autonomicity stands for the ability of the system to react in a human-free way by following self-managing rules. As such, it is one of the most important characteristics to be taken into consideration when designing any emergency management system, so that the system can rapidly self-manage itself without requiring human intervention as, especially in these cases, the latter should be limited. Both characteristics require a high level of reconfigurability of the system, to circumvent obstacles and to react promptly to the disaster.

An emergency scenario is characterized by the presence of several users and devices that must collaborate in order to have a ready response to the emergency situation, or to be able to forecast the upcoming emergency situation in time (Chiti, Fantacci, Maccari, Marabissi, & Tarchi, 2008). The coordination among different actors working on emergency management (institutions, local administrators, volunteers, police, etc) is fundamental in order to optimize emergency responses and to reduce disaster consequences on people and things.

Our focus within this context is toward the optimization of the communication infrastructure (Gucenc, Kozat, Jeong, Watanabe, & Chong, 2008; Habib & Mazzenga, 2010; Manoj & Baker, 2007) with the aim of supporting emergency prevention and management operations. This requires reliable access to all heterogeneous networks and services in a ubiquitous manner, granted to all to people operating in the disaster area with different mobile devices and terminals (cellular phones, notebooks, smartphones, etc.). The emergency telecommunication infrastructure must be deployed in a simple and effective way in case of disaster and allow functional integration with the survived systems to provide a flexible platform able to satisfy the resilience and autonomicity requirements. One should notice that, nowadays, it is possible to consider an environment where multiple means of communication coexist. This heterogeneity can be seen as a source of network diversity to be exploited in order to respect the different user requirements typical of an emergency scenario, whenever a disruptive event causes the unavailability of certain network portions.

It is worth noticing that emergency management is also strictly related to modeling the physical/artificial causes and consequences of disastrous situations. Emergency forecasting and management activities are both based on very complex mathematical models, which require high-performance computing to provide clients with prompt and best-effort services (Thompson, Refstrup Sørensonb, Gavina, & Refsgaard, 2004). The most up to date trend within this context is to develop a system able to interconnect all operators and citizens within a given emergency area with high-performance computing platforms able to forecast the disaster and/or to monitor its evolution (Fantacci, Vanneschi, Bertolli, Mencagli, & Tarchi, 2009). It is worth noticing that the classical solution of high performance computing is to map the complex models to central processing centers supporting high performance architectures (e.g., clusters), but which are geographically far from the emergency area. An alternative solution is to exploit all locally available processing and communication resources, albeit heterogeneous and with limited computational capabilities (Bertolli, Menacagli, & Vanneschi, 2009). This concept allows a more resilient approach to disaster management, due to the presence of multiple devices near the emergency area, to solve these complex models by exploiting the parallel and distributed computing features. However, this approach requires the development of suitable techniques to manage interconnections among users and computing devices with the timing constraint typical of such applications. The pervasive grid computing paradigm (Parashar & Pierson, 2010) is particularly suited for these applications by allowing the development of distributed applications that can perform parallel computations using heterogeneous

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