

Modeling and evaluating performances of complex edge computing based systems: a firefighting support system case study

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ABSTRACT

Edge computing extends cloud computing by providing a subset of computational resources that are close to the application site, lowering the need for bandwidth and augmenting responsiveness. This allows implementing cloud benefits in critical applications bound to a physical location, provided that a correct distribution between edge and cloud is applied. To achieve this purpose, a performance evaluation of the architecture is needed. In this paper we present a queuing networks based modeling approach for complex critical edge computing based systems, applied to a support system for accident management teams.

CCS CONCEPTS

• **Mathematics of computing** → **Queueing theory**; • **Information systems** → **Sensor networks**; *Mobile information processing systems*; • **Computer systems organization** → **Cloud computing**; • **Software and its engineering** → **Cloud computing**; **Software performance**; *Requirements analysis*; • **Networks** → *Network performance modeling*;

KEYWORDS

Performance evaluation, Edge, Firefighting, IoT, Cloud

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1 INTRODUCTION

Cloud infrastructures provide cost efficient, elastic access to large amount of computing and storage resources, but suffer from the need for fast and dependable long range network connections: this may create problems when implementing applications with high responsiveness requirements [8]. Edge computing [6][7] extends the paradigm by providing local resources that may compensate these problems (by performing data preprocessing and executing the highly responsive part of the system) but reduces the benefits offered by cloud elasticity and cost effectiveness. In this paper we propose a performance modeling approach to support the design and evaluation of a complex accident-response support system, applied to firefighting in large fire scenarios. At the best of our knowledge, *this is the first proposal of an edge based CBRN (Chemical, Biological, Radiological and Nuclear) management system*.

2 MODEL AND ANALYSIS

The architecture of the system is organized, according to the edge computing paradigm, into four main subsystems: *Cloud Backend* (CB: provides elastic computing and additional data sources for the management of mission strategy), *Edge Frontend(s)* (EF: provides on site reactive computing resources to support tactics, (e.g. characterized as in [1])), *Personal Support* (PS: personal sensors and augmented reality equipment for each fireman, similar to [5]), *Sensing Network* (SN: provides deployable and mobile sensors to provide additional field support, analogous to [2][4][3]). The configuration of the system is parametric and depends on the mission: a generic setup includes a CB supporting one or more EF, each controlling the PSs of a team and/or an SN.

The performance model for the system uses the multiclass queuing network in Fig. 1. Even with standard approach, that has been chosen aiming to provide a manageable modeling support to designers, interesting results were obtained about this architecture, a small sample of which are presented in this paper. The Mean Value Analysis technique (MVA) was used to solve the model. Three classes of jobs are considered: *SN* for networked sensors, *PS* for fire-fighter personal sensors, and *CC* for cloud servers accesses by the various

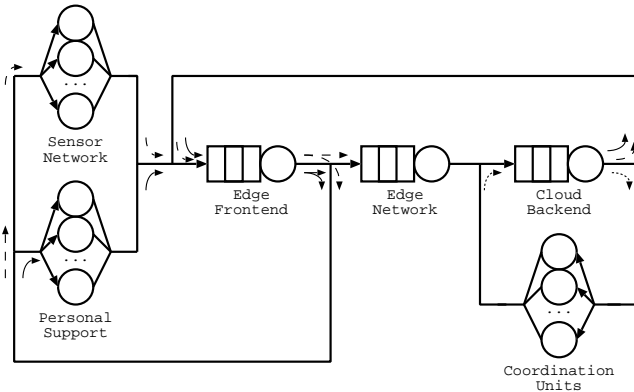


Figure 1: The multiclass queuing model of the considered scenario

actors on the field. The class populations are N_{SN} , N_{PS} and N_{CC} . Infinite servers stations *Sensor Network* and *Personal Support*, with average service time T_{SN} and T_{PS} , model the read, process, and send time of sensors. Analogously, *Coordination Units* models the average time T_{CC} needed to access the cloud and process data by the field actors. Queuing stations *Edge Frontend* (EF), *Edge Network* (Net) and *Cloud Backend* (CB) model the main system elements. All queues follow the **Processor Sharing** service discipline; *Edge Network* is single server (the communication channel is shared), while *Edge Frontend* and *Cloud Backend* are multiple servers, with C_{EF} modeling the number of edge servers on the field, and C_{CB} modeling the number of cloud-provisioned virtual machines. Each class may only use its corresponding infinite server station (e.g. SN uses *Sensor Network*); the CC class uses *Cloud Backend* servers. An edge server sends through the network data to be processed in the cloud: p_{SN} and p_{PS} are the probabilities that data from the environmental or wearable sensors generate a cloud request. Both classes have average network transfer time T_{Net} , and the other station has $T_{x@y}$ as average service time required by a class x job at station y .

Model parameters are reported in Table 1.

Table 1: Default model parameters

$N_{SN} = 15$	$N_{PS} = 5$	$N_{CC} = 12$
$C_{EF} = 1$	$C_{CB} = 4$	
$T_{SN} = 0.1$ s	$T_{PS} = 0.1$ s	$T_{CC} = 2$ s
$T_{SN@EF} = 40$ ms	$T_{PS@EF} = 80$ ms	$T_{Net} = 15$ ms
$T_{SN@CB} = 400$ ms	$T_{PS@CB} = 250$ ms	$T_{CC@CB} = 600$ ms
$p_{SN} = 0.3$	$p_{PS} = 0.3$	

To help deciding the number of Edge Frontend servers $C_{EF} = [1 \dots 3]$ needed varying the number of PS, in Figure 2 we studied the utilization and the throughput of the nodes. We assume $N_{SN} = 3 \cdot N_{PS}$ and vary $N_{PS} = [1 \dots 10]$. Cloud nodes are almost always fully utilized, because of the coordination traffic, without a significant effect on the edge node, as only a fraction of requests is routed to the VMs. Network is well dimensioned. The Edge Frontend becomes a bottleneck with $C_{EF} = 1$ with a number of firemen

greater than $N_{PS} > 5$: increasing the Edge Backend servers solves the problem.

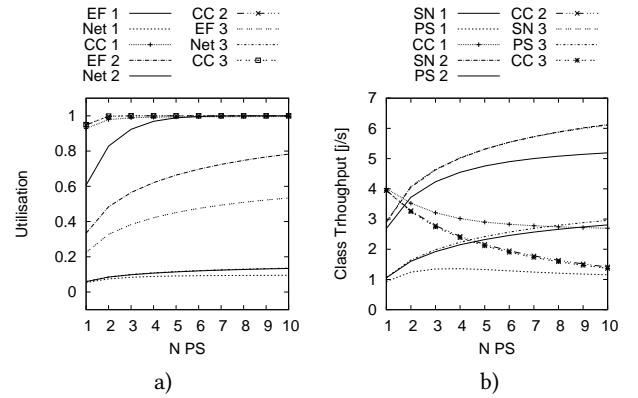


Figure 2: Utilization (a) and throughput (b) of the model varying the number of sensors (with $N_{SN} = 3 \cdot N_{PS}$), for different number of Edge Frontend servers

3 CONCLUSIONS

This paper briefly presented some results obtained in performance modeling of a novel edge computing based solution for critical CBRN applications. Even with standard modeling and evaluation techniques, the architecture exhibits interesting behaviors, confirming the paramount importance of using a performance modeling based design approach to understand in advance how to configure the architecture and how to scale it. Additional results obtained on the same model also show the relevance of the problem. Future work will be oriented to understand the impact of variety of data, unreliable communications on the field, and very large configurations (by using more scalable approaches).

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