Integrating Agents and Services for Control and Monitoring: Managing Emergencies in Smart Buildings

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Abstract. The present work introduces a research perspective on developing *Smart Building* control and monitoring solutions using a service-centric conceptual framework in which agents and services are integrated in order to solve both the problem of comfort and the issue of safety. The proposed conceptual framework relies on the service oriented architecture approach and its related supporting technologies, tools, mechanisms that facilitate discovery, integration, processing and analysis of datasets collected from various ubiquitous appliances. At the same time, agents can take, based on environmental data, decision for control, monitoring, fault diagnosis and maintenance of more and more complex systems. In order to further develop the above mentioned service-centric conceptual framework, this paper proposes an extensive integration of emergency protection systems that take into account a varied range of hazards and disasters, from small fires to earthquakes, with *a priori* defined Intelligent Operations Centre for *Smart Cities*. In this respect, the CitySCAPE development framework is exploited, as being the architectural style of thinking in terms of *Smart Building* integration on different control levels, monitoring and safety intervention, meeting basic requirements of seismic protection at city level.

Keywords: agents, service orientation, smart buildings, Operations Centres for Smart Cities.

1 Introduction

Over the past two decades a major interest was dedicated to innovating building performance evaluation methods. In a larger perspective, “whole building” approaches to the operation of buildings were intended to be developed, where building components (construction materials) and systems (ambient components, like heating, lighting, ventilation etc.) are supposed to be integrated, not only to support the “green building” development, but also to educate users towards a sustainable use of planet resources.

There are many terms used today to describe different levels of device integration in a building, all of them enabling new “intelligent” building automation. *Home Automation* [1], *Smart Home* [2], *Smart Energy* [3] are only some few names to define

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current design of intelligent building management perspectives able to allow *real time monitoring* and *data collection* across different infrastructure components, centralization of real time events and data building in order to enable infrastructure-wide analytical and optimisation capability.

Smart Building is a term that defines a broader set of approaches, technologies, methods, tools and devices that crystallize European citizens and business increasing awareness towards *environmental*, *safety* and *comfort of living* issues [4]. It can be approached on different levels, through legislation, local initiatives of citizens and business organizations to better insulate and to install renewable energy sources, but also through better monitoring and control of building energy performance and *safety*. However, it was definitely recognized that none of these initiatives would be fully successful without the implication of the ICT.

Smart Building refers in fact to a new paradigm that has been developed in the last years, trying to define, develop and deliver intelligent building management solutions for energy optimization and facilities management. It offers real opportunities to innovate services based on the computational power of the Internet. Smart buildings are designed to run more efficiently and to communicate with and about their various systems assuring the *interoperability* of *functionalities exposed as services*.

In this respect, the research topic proposed in this paper defines CitySCAPE [5] as an *architectural style* of thinking in terms of *Smart Building* integration on different levels and control, monitoring and safety intervention meeting basic requirements of seismic protection at city level. An implementation of an inSCAPE type supervision system integrated in CitySCAPE has been tested, both in simulation and in hardware-in-the-loop configurations in [6]. As part of CitySCAPE, a building-level Critical Systems Emergency Protocol has been blended into the SOA based decision support system [7] of an integrated Intelligent Building Management solution.

The paper is organized as follows. Section 2 presents a novel perspective on the development of smart solutions for intelligent building management based on the CitySCAPE architecture. Section 3 presents the solution that integrates the two key aspects of CitySCAPE at building level, eSCAPE and inSCAPE, making use of *agents* and *services*, respectively. Section 4 includes two case studies, while section 5 offers final conclusions and further development perspectives.

2 Smart Buildings, Services and Agents – A Solution Development Framework

This section introduces a framework in which *agents* and *services* are *composed* to define a *smart product* – the *smart building* here. It is based on the following common observation. The most valuable features of a smart product aren't contained entirely within that product itself, but are delivered as a result of interactions with other products or services within an ecosystem that needs to collaborate and share information. In a smart building, system functionalities are distributed over the various *intelligent*, *interconnected*, *instrumented devices* in the building environment [8].

Today, a new generation of intelligent building applications are shifting from the centralized, local desktop computer application software towards the provision of distributed geo-spatial services and components that foster software modularity and reusability. On the perspective of the *smart* attribute, the next generation of IT development deals more with the integration of the existing software and infrastructures, than with creating new applications.

The smart building might contain a whole range of sophisticated software intensive systems, designed to make living comfortable while improving safety and optimizing energy consumption (Fig. 1).

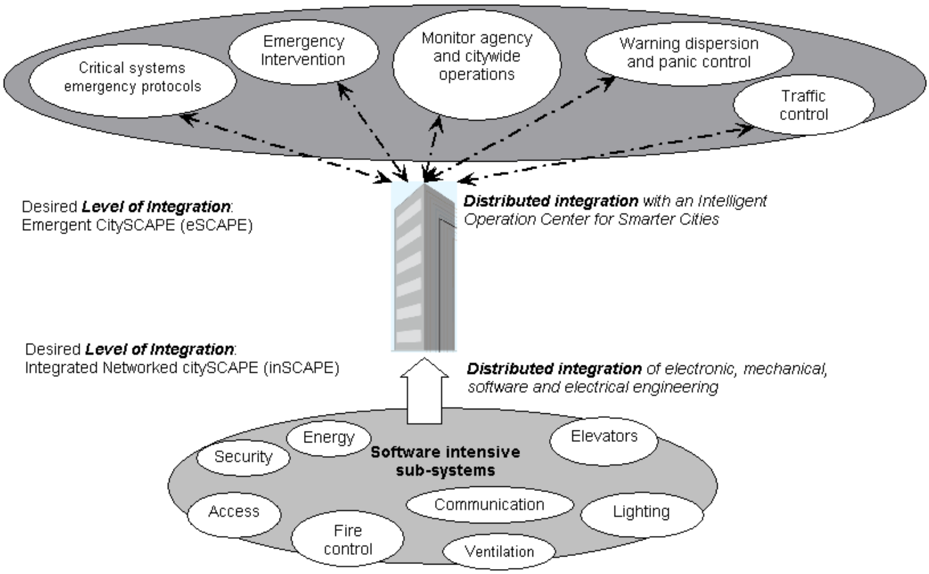

Fig. 1. Smart building – a system of systems in a larger ecosystem

At the same time, the smart building system might interact with other systems external to the building itself. For example, the building security systems might be engineered to interact with emergency response centres (such as the IOC – the Intelligent Operation Centre for Smart Cities) in order to deliver incident details to first responders based on data collected from sensors within the building.

CitySCAPE *(a Synergic Control Architecture for Protection against Earthquakes)* was proposed as an architecture dedicated to the control and monitoring of urban systems [5]. It has an hierarchical structure that implements a decentralized character at lower levels and centralized components at higher levels, that deal with the integration of its subsystems into the whole. CitySCAPE ensures structural integrity, implements and supervises social protection norms, and ensures emergency response in case of disasters.

This paper intends to propose o solution that integrates two key aspects of CitySCAPE at building level, eSCAPE and inSCAPE (Fig. 2), making use of *agents* and *services*, respectively. Each of these systems and their role in the protection of human life are described in the next paragraphs.

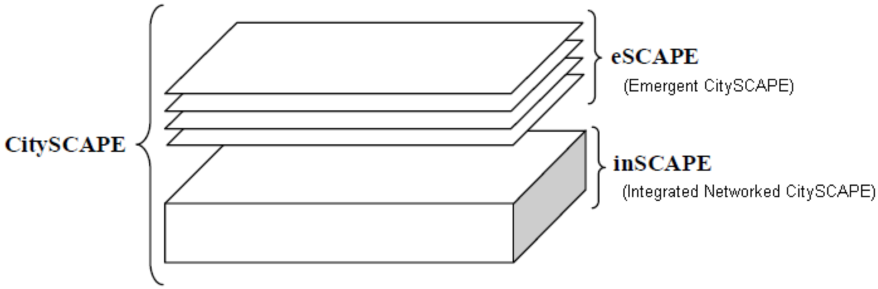

Fig. 2. CitySCAPE - a macroscopic level perspective

The two main aspects that are considered in the present solution are: *The Right To Life* (ensuring safety during an earthquake is a high interest, high complexity problem, that has attracted attention ever since the development of seismic structural design) and *The Right To Comfort* (in what concerns social protection and ensuring high living standards, one must take into account the requirements for energy consumption, evolution of social groups, view on living standards and, of course, green energy generation and Earth friendly living solutions).

Table 1 presents a comparison between different levels of integration in the Smart Building paradigm and the CitySCAPE architecture.

Table 1. Levels of integration – CitySCAPE vs. Smart Building perspective

	Smart Building	**CitySCAPE**	
		inSCAPE	eSCAPE
Building level integration	Distributed integration of electronic, mechanical, software and electrical engineering	Hierarchical integration of services, devices and their associated control systems for structural integrity	Emergent integration of intelligent control agents for human safety norms and protocols (during emergencies) and comfort (during normal operation)
IOC level integration	Distributed integration with underlying agency such as emergency management, public safety, social services, transportation or water	Hierarchical integration of services and associated control systems for city-wide seismic and disaster protection	Emergent integration of intelligent control agents for city-wide protection and comfort of social systems (for emergencies and normal operation)

2.1 The Service Side

Integrated Networked CitySCAPE (inSCAPE) is a CitySCAPE subsystem which integrates and interconnects a hierarchical system for structure integrity (including, for instance, seismic vibration control).

At city level, inSCAPE is wholly defined by two concepts: vertical interconnection and horizontal integration. In Fig. 3.a (**vertical interconnection**) the top-down decomposition is defined (for a city comprised of *q* clusters, there is a hierarchical structure *HS* that can perform the monitoring of the disaster protection systems). In Fig. 3.b (**horizontal integration**) the bottom-up composition is accepted (for a city comprised of *q* clusters, over which a hierarchical structure *HS* has been defined, on each layer of the *HS* there is a distributed structure through which structural control can be obtained).

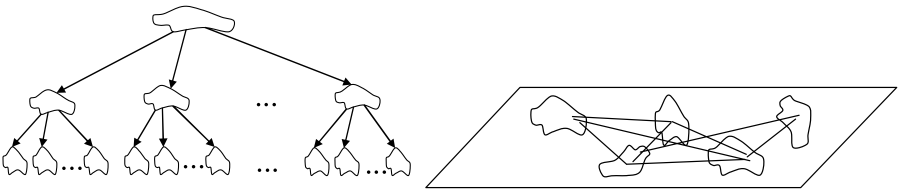

Fig. 3. a. Vertical interconnection (left). **b**. Horizontal integration (right).

Scaled down to the building level, this subsystem can be built as a supervision-type sub-architecture. Although the modules necessary to shape up inSCAPE at this level can be implemented in various ways and using various techniques (from heuristic supervisors to multivariable controllers integrated in intelligent control systems), this paper presents a service oriented solution. Past work for this approach includes an implementation of an inSCAPE type supervision system that has been tested, both in simulation and in hardware-in-the-loop configurations, in [6]. Moreover, a building-level Critical Systems Emergency Protocol has been blended into the SOA based decision support system [7] of an integrated Intelligent Building Management solution.

Let a structure *S* = {*f*(*struct*, *em*), *Ds*, *Css*, *Drs*, *Comm*} [5]. The structure *S* is comprised of a function that describes the structural behaviour during emergencies and normal operation *f*(*struct*, *em*), the set *Ds* of devices (both safety and comfort, as well as any transducers and actuators necessary for operation), the structure's control supervisor *Css*, a disaster response service *Drs* and a communication module *Comm*.

The function *f*(.) can be as complex as necessary, depending on structure, seismic zone, building materials, age and wear, installed devices and so on. From a systems engineering point of view, *f*(.) describes the controlled plant. From a service science point of view, the analysis of *f*(.) yields information necessary for the development of building specific services, be they safety or comfort oriented. For instance, the type of structure (number of floor, destination, use of space etc.) will generate specific evacuation paths.

The *Css* component is a supervisory-type service that manages the control and monitoring of all devices throughout the building, as well as all maintenance and fault diagnosis related tasks, while the *Drs* module is a service in charge of disaster response and protection of human life during such events. Both the *Css* and the *Drs* are high level services, operating on an elevated abstracting and containing building wide protocols and schedules. These two services access medium and low level agents and sub-services in order to ensure structure integrity during emergencies, optimal operation of its systems in normal conditions, and, of course, human safety. A detailed view of the connection between the aforementioned services and agents can be observed in section 3 of this paper.

2.2 The Agent Side

The emergent CitySCAPE (eSCAPE) subsystem models, controls and monitors the protection of living beings. This component manages the social system and human behaviour during disasters, with a flexible communication network. With a main role of protecting human life and critical systems, eSCAPE is the decision making entity that will decide, for example, what are the best evacuation paths, which are the high risk areas, which are the zones that need clearing for emergency intervention teams and so on. eSCAPE is defined as comprised of cells and tissues, the devices that form these components being implemented as agents in what follows, exploiting the natural reorganizing and emergent properties of multi-agent systems. The high diversity of the eSCAPE components can thus be properly implemented by making use of the properties and versatility of intelligent agents. Thus, a generic cell $< \cdot > = \{D_C, D_P, D_A, U_{comm}\}$ is a set of control modules D_C, perception modules D_P and actuating modules D_A, as well as a communication unit U_{comm}, while a generic tissue $« \cdot » = \{< \cdot >_i \mid i=1,n\}$ is a set of n cells of the same type.

Cell properties: *flexibility*: each cell can be dissolved and aggregated depending on the context in which it needs to operate; *modularity*: each cell is independent of other cells; *self-reorganizing*: each cell can reorganize around a nucleus represented by the communication agent U_{comm}, according to priority lists and/or proximity.

In order to build the eSCAPE components as multi-agent systems, two operations need to be defined, as follows: *Collaboration* - the operation of grouping cells, represented by their communication units as nuclei, into tissues: $« \cdot » = Co(< \cdot >_1, < \cdot >_2, ..., < \cdot >_n)$; and *Aggregation* - the operation of grouping modules into cells: $< \cdot > = Ag(module_1, module_2, ..., module_n \mid U_{comm})$ around a communication unit as nucleus. Each module of a cell can be an agent in itself, while cells as a whole function based on the generic intelligent agent architecture proposed in [9].

A series of tissue properties are to be noted: each cell of a tissue is interconnected with the others, giving the tissue a global emergent behaviour; cells of different tissues can occupy the same physical space; two or more cells of different type which occupy the same physical space are connected through their communication units.

At building level, eSCAPE is comprised of 4 tissue types (fig. 4). Each of these manages one aspect of the protection system: (a) emergency response; (b) evacuation protocols; (c) warning dispersion and panic control; (d) critical systems protocols.

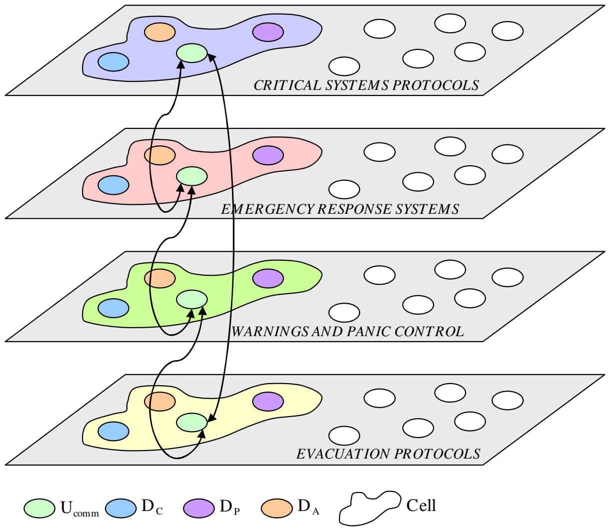

Fig. 4. eSCAPE tissues at building level

For example, an emergency response cell <ERC> = {D_C, D_P, D_A, U_{comm}} is formed of: D_C - agents for combined behaviour generation of intervention personnel (such as fire fighters, paramedics, police etc.) on a specific floor; D_P - agents for information processing from the building supervisor *Css* and emergency response service *Drs*; D_A - agents for intervention requests' transmitted to building clusters' supervisors and/or city-wide emergency response centres, like the IOC.

Thus, eSCAPE appears as a multi-agent system variation with emergent components specialized on specific problems, synergistically interconnected with the service oriented inSCAPE.

3 Services and Agents in Intelligent Building Control and Monitoring

A proposed further implementation of the Control and Monitoring solution discussed in this paper is depicted in Fig. 5. This holistic view of the architecture permits, on the one hand the integration of services and agents, and on the other, the coordination of safety and comfort specific subsystems.

Thus, the DRS^{HL} and CSS^{HL} services represent their counterparts from the inSCAPE side of CitySCAPE, as described in section 2.1 of this paper. These modules are high level (HL) components that access the Floor Agents (FA^{ML}) and the Control & Monitoring Agents (CMA^{LL}). In turn, they are coordinated by a general supervisor agent $SupA^{HL}$, whose role is to connect the building to the city-wide implementation of the architecture, through a communication unit *Comm*. This function allows structures to be integrated in the city level instances of eSCAPE and inSCAPE, and, ultimately, a complex large scale CitySCAPE.

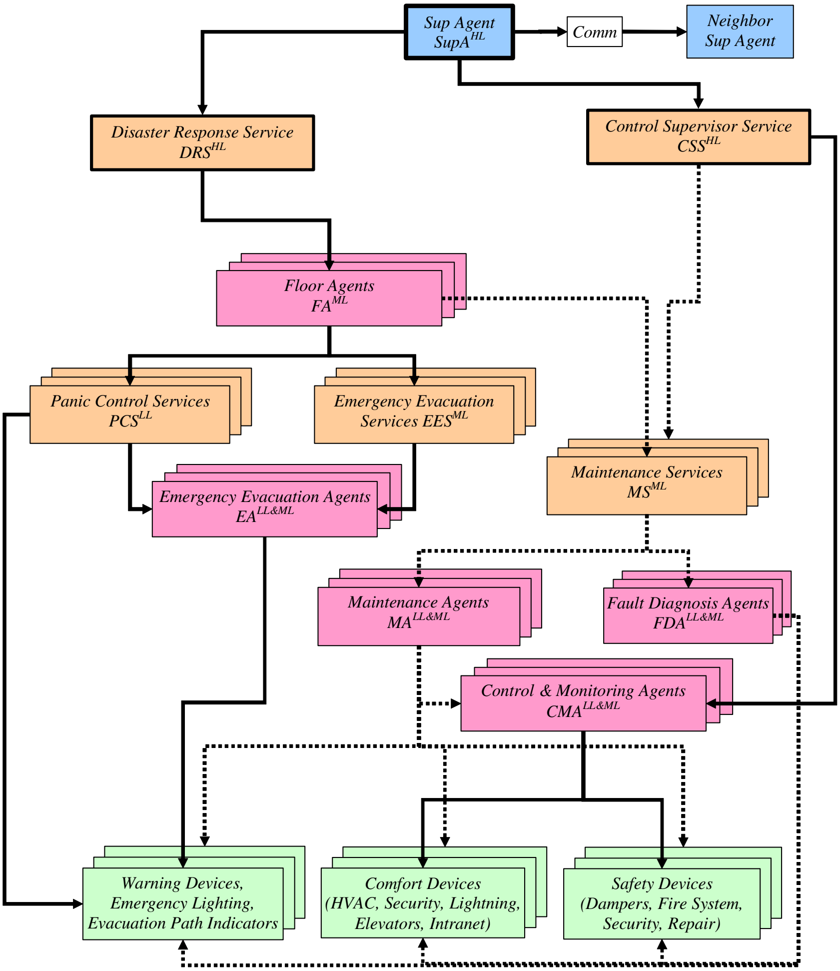

Fig. 5. Integrating agents and services for control and monitoring within intelligent buildings

The medium level (ML) agents and services deal, in turn, with disaster response on each floor (Floor Agents FA^{ML} and Emergency Evacuation Services EES^{ML}), and with optimal device operation throughout the building (Maintenance Services MS^{ML}) – these two aspects emphasize the horizontal interconnection and vertical integration of inSCAPE. For visualization purpose, in Fig. 5, the maintenance branch has dotted line connectors, while the flow of information for the control branches is represented using continuous connectors.

The low level (LL) agents and services, as well as some medium level (ML) agents are in charge of control and monitoring of physical devices ($CMA^{LL\&ML}$), specific maintenance tasks ($MA^{LL\&ML}$), fault diagnosis ($FDA^{LL\&ML}$), panic control ($PCS^{LL\&ML}$) and emergency evacuation ($EA^{LL\&ML}$).

The proposed solution includes three types of agents: low, medium and high level, each with its own level of intelligence. This perspective allows for the composition of heterogeneous groups of agents into several MAS, which, in turn, could group into a higher level MAS. Fig. 5 presents the three different types of agents according to their goal inside the building, taking into account their relation to the services considered for proper functioning, both from a structural point of view and a social/human perspective.

The LL agents (low level) are usually persistent software tools that perform basic tasks, such as the role of control algorithms. These agents are directly connected to the physical devices, either through their own network (on a seismic damper, for instance), or through basic web services (for example, to monitor and/or control the ventilation system). These agents are mostly reactive or are based on reflexive rules, sometimes incorporating very simple inference modules (for example, to allow various functioning points to be reached, such as night and day energy consumption levels or lighting services and so on).

The ML agents (medium level) can be either embodied entities or software tools that include higher reasoning than the LL agents. The ML layer performs like a heterogeneous agent society, in which several interactions types can be observed, goals are either defined or communicated, there can be cooperation, and different levels of autonomy can be identified. Considering these points, a more extensive classification is required for the medium layer [10]. Thus, ML agents are discussed based on:

- level of intelligence:
  - reactive agents: reflexive agents, either simple or with internal rules
  - deliberative agents: reasoning, intelligent inference systems, adaptive behaviours are only a few points that can describe such agents
  - composed reactive-deliberative agents
- composition:
  - singular: these agents exist on their own in the system and usually perform specific tasks; they receive directives from higher level agents;
  - emergent: these agents are usually the cell-type agents that are comprised of entities performing various roles (as described in section 2); the agents that group to form an emergent agent can be either reactive or deliberative, embodied or software etc.
- entity type:
  - embodied: these agents have a physical body
  - pure software: these agents exist only in the virtual world and interact only with each other through various communication systems
- human interaction
  - with strong social skills: these agents are required to interact with humans; their environment is highly non-deterministic and they require a high degree of autonomy to perform their goal
  - with weak social skills: these agents are only required to interact with other agents

- goal:
  - control & monitoring: these agents perform all the actions required for the control of the devices throughout the building
  - maintenance & fault diagnosis: these agents perform all actions required for maintenance & fault diagnosis; their goal is intrinsically different from the control & monitoring ones', due to the particularities of decisions and actions that these agents must take
  - protection: these agents are tasked with protection of human life, from hazard detection to hazard mitigation, including management of panic control devices and of the human component during emergency
- interaction protocols:
  - communicative agents: these agents are usually cell-type agents that have a communication component; the information transmitted between these agents has been described in section 2.
  - cooperative agents: these agents are usually the ones that perform the grouping into emergent agents; they have to cooperate to achieve a goal and are usually required to be of different types in order to compose a higher level emergent agent (as described in section 2)
- action type:
  - autonomous agents: these agents are usually the higher level ones, that are capable of making abstract decisions
  - dependent agents: these are usually the lower level agents that receive goals, directives or tasks from higher level entities

In this paper, the HL agent (high level) is only one software entity, with a high level of intelligence. This agent has a supervisory role, it interacts with human decision making entities, it communicates with adjacent building, integrating the structure in the more complex acceptation of CitySCAPE.

4 Case Studies

4.1 Fire Event Evacuation Scenario

A version of EES^{ML} has been implemented in [6], while several groups comprised of FA^{ML}, EES^{ML} and MS^{ML} are works in progress. As part of a more complex modelling and simulation of CitySCAPE, this case study illustrates a fire event scenario and subsequent evacuation on a floor of a smart building.

The first case study's interface included in this work can be observed in Fig. 6. An evacuation protocol cell is dynamically modelled, along with a emergency response cell for fire hazard, on a building story. The program includes a set of embodied evacuation agents that gather the floor occupants and guide them to safety, fire detection sensing elements, fire control systems for offices, a particular CO_2 fire control system for an archive space with an agent that dispenses oxygen masks for the human occupants. This simulation includes three different fire scenarios, with an interface that displays the transducers and actuators for the fire suppression system, the human entities, and the embodied agents.

Fig. 6. Fire event evacuation: floor view

The world model of this application is a floor map comprised of walls, elevators (with suspended activity due to fire hazard), stairway access and a hallway. Depending on space destination, the behaviour of the agents involved is particularized, described in what follows.

The fire suppression agent for offices is an emergent cell agent tasked with monitoring fire events and suppressing flames in office spaces. It is a cell agent that includes several instances of the same types of lower level agents:

- sensing agents: the fire detection transducers are reactive, singular, embodied, with control & monitoring goals, communicative and dependent agents
- control agents (not visible in interface): the control algorithms that analyse the information received from the sensing agents and transmit commands to the acting agents
- acting agents: the fire suppression actuators (sprinklers) are reactive, singular, embodied, with control & monitoring goals, communicative and dependent agents
- communication inside this cell has been provided by the AOP medium used for implementation of this application [11]

This agent controls & monitors the fire suppression system for the entire building.

The fire suppression agent for archive and/or server room is an emergent cell agent tasked with monitoring fire events and suppressing flames in special spaces, like archives and server rooms, which require particular fire suppression systems. In this example, the suppression agent is CO_2 (lethal to humans). It is a cell agent that includes:

- sensing agents: the fire detection transducers are reactive, singular, embodied, with control & monitoring goals, communicative and dependent agents
- control agents (not visible in interface): the control algorithms that analyse the information received from the sensing agents and transmit commands to the acting agents
- acting agents: the fire suppression actuators are reactive, singular, embodied, with control & monitoring goals, communicative and dependent agents
- communication inside this cell has been provided by the AOP medium used for implementation of this application [11]

This agent also transmits information to the evacuation system and deploys oxygen masks for humans caught inside the archive at the time of fire hazard event. Thus, an intrinsic connection between this fire emergency protocol cell and the evacuation cell (as viewed from the eSCAPE perspective) is built, the two cell-type agents ***working together to protect human life***. This is an illustration of the natural emergent properties of the eSCAPE system.

The evacuation agents are embodied agents tasked with gathering human entities and guiding them to the staircase doors. These agents' degree of intelligence is in the deliberative-reactive combined category. Apart from being embodied (for example a mobile robot type of embodiment), the evacuation agents of this simulation are singular, with strong social skills, have protection as a goal and are agents with a medium-to-high degree of autonomy.

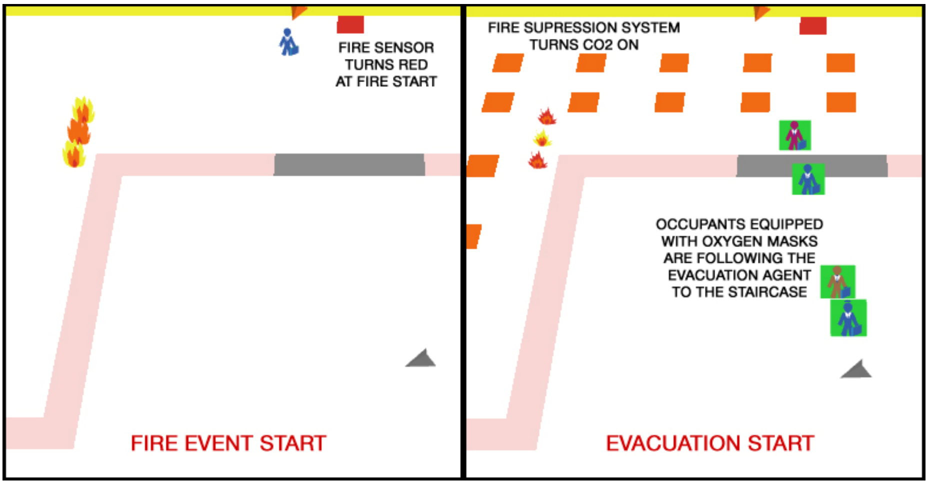

Fig. 7. Fire event evacuation: simulation

Fig. 7 presents a screenshot taken during simulation of a fire event inside the office, as well as inside the archive room.

Last, but not least, the fire hazard protection protocols and evacuation command are generated at the superior Emergency Evacuation Service EES^{ML}, that contains, for example, the entire set of evacuation protocols for that particular floor, as described by the authors in [6], and can commission, for instance, the evacuation agents with different goals in what concerns paths taken, staircases used and so on.

4.2 Chemical Spill in Laboratory Scenario

The second case study's interface included in this work can be observed in Fig. 8. An evacuation protocol cell is dynamically modelled, along with a emergency response cell for chemical spills [12], in a laboratory that spans on a building story. The world map includes nine lab spaces, an emergency shower room, one elevator and two stairwell access points.

The program includes a set of embodied evacuation agents that gather the floor occupants and guide them to safety, cell agents tasked with chemical spill control and with fire events in laboratory spaces. This simulation includes different chemical spill and fire scenarios, with an interface that displays the transducers and actuators, the human entities, and the embodied agents.

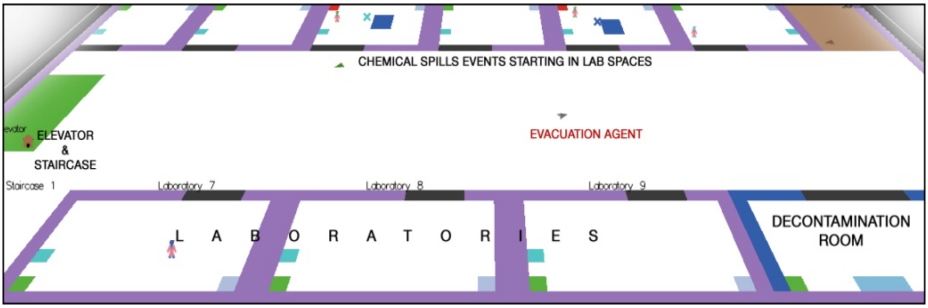

Fig. 8. Chemical spill in laboratory: floor view

The chemical spill control agent is an emergent cell agent tasked with monitoring chemical spills and containment in laboratory spaces. It is a cell agent that includes several instances of the same types of lower level agents:

- the sensing agents are air toxicity detection transducers (reactive, singular, embodied, with control & monitoring goals, communicative and dependent)
- the control agents (not visible in interface) include the control algorithms that analyse the information received from the sensing agents and transmit commands to the acting agents
- this particular cell includes three different types of acting agents that are used to implement the neutralization of toxic substances and protection of human life, as follows:

- o embodied agents, such as robots for chemical spill clean-up (deliberative-reactive, singular, with weak social skills, with protection as a goal and a medium-to-high degree of autonomy)
- o the shower decontamination agents (reactive, singular, embodied, with control & monitoring goals, communicative and dependent)
- o sealing doors for isolating non-exposed personnel in adjacent laboratory spaces, in absence of fire or when whole floor evacuation is not necessary (reactive, singular, embodied, with control & monitoring goals, communicative and dependent)

– the communication inside this cell has been provided by the AOP medium used for implementation of this application [11]

The fire suppression agent is an emergent cell agent tasked with monitoring fire events and suppressing flames in office spaces. It is a cell agent that includes several instances of the same types of lower level agents and is similar in nature with the fire suppression agent for archive and/or server room described in section 4.1 (CO2 fire suppression acting agents, control agents, fire sensing agents). The main difference is the protection protocol that implements a different behaviour:

- in the affected room: don't perform evacuation, but guide the lab technicians toward the emergency shower room
- for the rest of the floor: perform evacuation

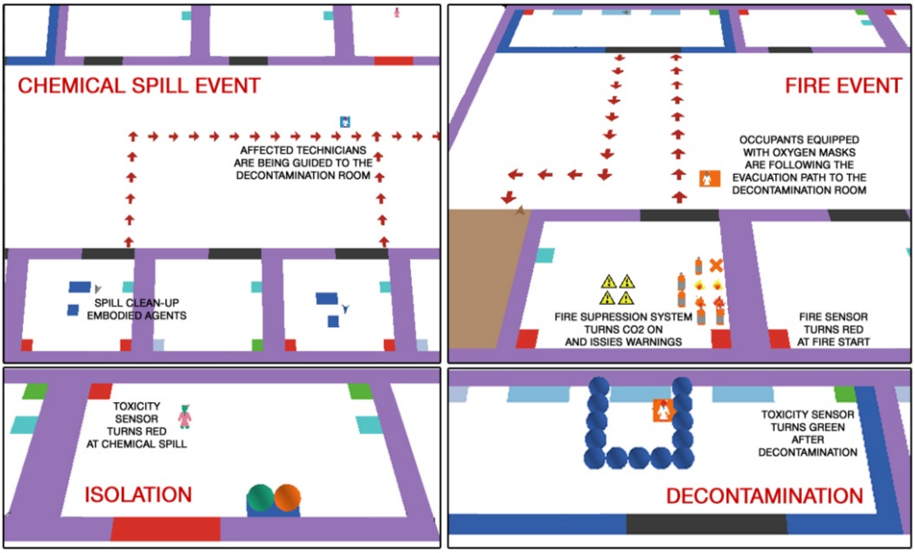

Fig. 9. Chemical spill simulation

These agents also transmit information to the evacuation agent and deploy oxygen masks for humans caught inside highly toxic spaces. Again, an intrinsic connection between the chemical spill control cell agent, the fire suppression cell agent and the evacuation agent is obtained. These agents are *working together to protect human life*, illustrating of the natural emergent properties of the eSCAPE system.

The evacuation agents are embodied agents similar to those presented in section 4.1. They are tasked with gathering human entities and guiding them to the staircase doors (in case of fire) or elevators (in case of spill). These agents' degree of intelligence is also in the deliberative-reactive combined category. They are embodied, singular, with strong social skills, have protection as a goal and a medium-to-high degree of autonomy.

Fig. 9 presents a screenshot taken during simulation of a fire event inside the office, as well as inside the archive room.

The chemical spill control protocols, the fire event protocols and evacuation command are generated at the superior Emergency Evacuation Service EES^{ML}, that contains for example the entire set of decontamination and evacuation protocols for that particular floor, as described by the authors in [6], and can commission different actions in what concerns paths taken, decontaminants used and so on.

5 Conclusions

It is in the perspective of the above mentioned paradigm – the *Smart Building* – that the solution presented in this paper is described. It is part of, CitySCAPE, a larger control and monitoring architecture. Primarily built to deal with earthquake protection and emergency response, this system can been expanded to encompass other life aspects and disasters, such as comfort and fire protection. Moreover, this framework can be applied to other fields, such as manufacturing, where service orientation and multi-agent system integration is a forthcoming direction with broad prospects.

CitySCAPE incorporates two subsystems, inSCAPE and eSCAPE, each with its own particularities and scopes of action. The two coordinate protecting the physical structures and the population, at both city-wide level, or, as it is the case of this work, at building level.

The case studies presented in this paper implement three evacuation agents, a chemical spill control agent and three fire suppression agents. Their architecture is the cell type proposed in this paper, that includes sensing elements, an inference system (reasoning), acting elements and an internal world model. Thus, the evacuation agents include the floor plan, position of offices/laboratories, staircase access etc., and they lead the human groups toward the evacuation points on the safest routes possible. The chemical spill control agents deal with neutralizing toxic substances and request the human occupants to move toward the decontamination chambers. The fire suppression systems sense the fire events, deploy oxygen masks when necessary and then activate the suppression systems. All protocols are included in the Emergency Evacuation Service, the can generate both low level and medium level requests, commands or behaviours, as much for evacuation, as for fire suppression and chemical spill protocols.

Future work will include implementation of the other services described in this paper and the particular communication between agents and services required by the

Smart Building. At the same time, communication with the outside world will be considered, taking into account emergency responders, outside environment before evacuation planning, neighboring buildings and their seismic structural stability and other such factors that can influence the operations of the Smart Building, be it in emergency management or in normal operation.

The proposed architecture integrates services and agents, making use of their advantages within the control and monitoring of intelligent buildings. In addition, this solution, as part of the CitySCAPE framework, allows further integration of structures as systems in the city level ecosystem, in a modular and visionary perspective over systems-of-systems and their role ensuring human safety and comfort.

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