Innovating Multi-agent Systems Applied to Smart City

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INTRODUCTION

When discussing smart city, you must think about a developed urban area that creates sustainable economic development and high quality of life by excelling in multiple key areas, economy, mobility, environment, people, living and government (Karnouskos and De Holanda, 2009; Lazaroiu and Roscia, 2012; Albouy *et al*., 2013). Excelling these key areas can be done so through strong human capital, social capital and/or Information and Communication Technology (ICT) infrastructure (Moslehi, 2010).

The current economic crisis, combined with growing citizen expectations, is placing increasing pressure on European cities to provide better and more efficient infrastructures and services, often for less cost. This trend has contributed to the growing popularity and use of the term 'Smart City (Dijkstra *et al*., 2013).

Smart City represents a new way of thinking about urban space by shaping a model that integrates Green Energy Sources and Systems (GESSs), energy efficiency, sustainable mobility, protection of the environment and economic sustainability that represent the goals for future developments (Schoenherr, 2013; Viitanen and Kingston, 2013).

The politics of research and innovation to which the European Union is shifting provides strategic direction quite clear. Of this orientation, the Smart City initiative is perhaps the richest opportunities for its potential ability to combine the three fundamental values of the Horizon 2020: intelligence, environmental sustainability and social inclusion (Clayton *et al*., 2013).

Smart Cities transport systems are sustainable, smart grids are enhanced to ensure greater integration capabilities of production plants from renewable sources, public lighting is efficient (Roscia *et al*., 2011). However, the buildings are equipped with sensors and devices aimed at rationalizing consumption energy and create greater awareness on the part of citizens with the aim of improving the quality of life of people through a new government of public administration capable of managing this innovation and cultural change. And finally, while wishing the transformation of cities in smart systems, have not defined models infrastructure, that allow different subsets to communicate and interact, in order to make the concrete realization of a smart city.

The Smart City (SC) refers to that place and territorial context, where use of planned and wise of the human and natural resources, properly managed and integrated through the various ICT technologies already available, allows for the creation of an ecosystem that can be used of resources and to provide integrated and more intelligent systems (Lazaroiu *et al*., 2012).

The SC through ICT appropriately integrated with a network of fixed and mobile telecommunications, it can guarantee a real improvement in the quality of life, job creation and urbanization understood as the sum of the environmental and social sustainability, development and cost savings. The SC must take into account the fundamental dimension of information management in an environment of inclusiveness and territorial cohesion of open government, sustainability and opportunities for cooperation and development between public administrations, business, finance and citizens. Among the main players who can take concrete steps in the development of this system, are over the government, those responsible for the supply, distribution and energy management, cultural

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associations, citizens, organizations operating in the context of health, voluntary associations, universities and schools, cultural institutions, local facilities, the public security forces.

Different aspects applied to smart city: In order to build intelligent places it is necessary a multidisciplinary and integrated approach that starts from the needs of the city and the objectives to be pursued, identifying digital innovation as a tool and not as a purpose of change, involving a variety of systems (remote monitoring systems, decision support and planning systems, communication systems, etc.). It already available on the market and involving the various subnets of a SC as:

Mobility, transport and logistics: Advanced solutions for mobility management can return to the people in real time. Useful data traffic on routes to take to reach destinations of interest and trade with neighbouring areas and that they can manage and make the most of the infrastructure (parking, roads, etc.), equipment and means (public vehicles, bicycles, car sharing, electric charging points, etc.), including through user friendly app mobile (smart phone and tablet).

Energy and smart building: The context of this area includes different smart systems for cities, as well as the implementation of smart grid, for example Smart Street, Smart Home, Smart Building and Micro-Smart Grid.

Public safety urban: It is a key element: urban crime, disasters and emergencies, terrorism to the infrastructure, to the people and to the safety of transport, require systems of ‘Urban Safety’, this all-time control of these events, to achieve the improvement to entire city districts.

Environment and natural resources: It is necessary to optimize the management of natural resources according to principles of equity and sustainability through the development of technologies and business models for the management, treatment and upgrading of natural resources and the protection of biodiversity.

Tourism and culture: This aspect can be innovative through the development of solutions for diagnostics, restoration, preservation and digitization of cultural heritage materials and or intangible, defining useful models to digitize and make more competitive tourist sector, with an adequate information and communication that use specific applications and adopt the telecommunications network as a vector.

Health and assistance: It may be partially managed ‘at a distance’; it will be necessary able to innovate the health care system, allowing to increase the level of service felt by the user and at the same time to decrease costs.

E-education: This field will allow the school innovation through educational technologies learning.

Public spaces and social aggregation: This context includes the set of services and technologies that will be able, for example, to identify such barriers, possibly by proposing alternative routes for people with disabilities or the elderly.

E-government: A new innovation in public services through the digitization of back end processes of Public Administration (PA), through the development of ‘cloud computing’ and the spread of new tools, including open source, to the use and sharing of data (open data) in digital format, input and output with the PA.

Smart economy: Invest for the future in an intelligent way developing a new ‘ideology’ commercial, the ethics of environmental sustainability and inclusion civil. Indeed the white-green economists driving the job market in environmental spheres, going against the trends in the current economic context.

The definition of SC has open new indicators with several definitions and debates. There is not still a model, a physical structure that identifies what could be the type of system to be used to operate a SC. Currently data and information flows of the different sectors of society are stored and used in systems typically ‘vertical’ heterogeneous, not associated with each other, making it very difficult for city administrators to coordinate fully and effectively all the forces and activities. The aim of this study is to analyze, to design, to implement and to evaluate a new approach that it can permit to use the aspects above cited simulating a dynamic infrastructure within the wider context of Smart City. It is important to integrate these aspects in a model of type horizontal. With this typology, the scope is to optimize energy resources, the reduce emissions, the improve of quality of life. Furthermore it must be replicable and it must be able to communicate with different users. A key goal is that to have this infrastructure as close as possible to a real-world view, in order to evaluate different ways to see and to live.

METHODOLOGY

Smart grid technology: The Smart City can permit to increase the connectivity; the automation and the coordination between providers, consumers and network for make the best the work of transmission and distribution data. The whole system connects with equipment and devices, but it is more correct to refer to networks of processing and consumption on a large scale, as it is not identifiable as a single entity, but consists of an interconnection of subsystems. The smart

Table 1: Characteristics of a smart city grid

Information and Communication Technology (ICT)	Models of decision support
Communications infrastructure	Sensors and actuators
Analysis of 'big data'	Systems reduction of energy consumption
Technology services	Systems of energy production and distribution
New hybrid and electric vehicles	New material sand solutions for sustainable construction
Models of urban planning and decision support	Sustainable organizational models
Models for social inclusion	Management of the waste cycle: models of collection, treatment and recovery
SCADA (Supervisory Control and Data Acquisition)	

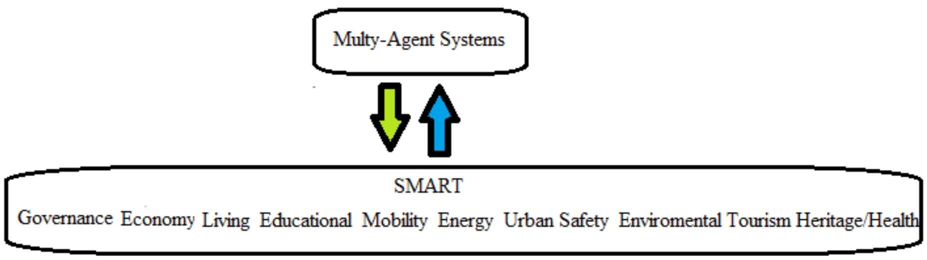

Fig. 1: Conceptual model of smart city

city is also aimed at making integration that is more balanced a number of subnets. The traditional control and communication system needs to be improved to accommodate a high penetration of data. To perform demand response in a most efficient way, the system operation conditions need to be known. For example, smart meters and two-way communication technologies are can provide consumers and operators the information for decision-making.

The smart city grid infrastructure is highly dynamic and by being able to tap to the information generated by its discrete items, i.e., generating and consuming devices in real-time, new possibilities are emerging towards real-time adaptation, optimization and prediction. Advances in the areas of embedded systems, computing and networking are leading us to an infrastructure composed of millions of devices. These devices will not convey only information but compute on it, network and form advanced collaborations. In Table 1 have been identified different categories of technologies and management to provide characteristics of a Smart City Grid.

Other aspects are the distributed intelligent agents, which are designed to act on the system performing the task assigned for a common goal, which is to always keep the network operational and quality standards of the highest possible service. A grid must be intelligent. For finally, infrastructure of internet will be strongly integrated with the surrounding environment and additionally it will closely connected with the enterprise systems. The last will lead not only to further blur the line between the business and real world, but will change the way we design, deploy and use services. New opportunities will emerge for businesses, which can now closely collaborate with the real world (Yang *et al*., 2010; Zaslasky *et al*., 2012).

The conceptual model proposal of the Smart City consists of several domains, each of which contains many applications and actors are shown in Fig. 1. The bidirectional lines represent the secure communication interface. In this infrastructure the devices, of all domains, will be no more considered as black-boxes, but will also get interconnected and will be represented by its own intelligent software agent that communicates information on operating status and needs, collects information and responds in ways that most benefit its owners and the grid.

Constant interactions and transactions of millions of smart agents will move the grid beyond central control to a collaborative network of almost biological complexity. It also expected that they would provide their functionality a service and be able to consume online services (Internet of things) in order to better address their internal goals. This does not represent the final architecture of the Smart City Grid; rather it is only a tool for describing, discussing developing that architecture. The conceptual model provides a context for analysis of interoperation and standards, both for the rest of this document and for the development of the architectures of the Smart City Grid.

Distributed intelligence for smart city: In recent years, more and more often we hear about Smart City in government circles. The focus seems to be on the strategic role played by ICT infrastructure for the development of cities, but in fact, many studies identify the enablers of urban growth, meaning the ability to progress, with increasing attention to the environment, improving the levels of education and the centrality of human resources, as well as the social and relationship capital. SC is no single definition where the term is used with different meanings and especially highlighting specific aspects of a city in different modes.

Often the term refers to the use by the public administration of the new communication channels to interact with citizens, focusing on e-Governance and e-democracy. Very often indicates a strong appeal to the use of computer technology in everyday life of a city in terms of transport systems, infrastructure, logistics and systems for energy efficiency. In other cases, the term Smart City emphasizes the softer factors such as urban development best practices of participation, high levels of security and enhancement of cultural heritage.

The concept of SC is the meeting point of an ideal path that joins the new economy of the century with the green economy of the present day, in which the connector thread is represented by the uninterrupted development of ICT, as a tool to revive the economy of knowledge that becomes engine of sustainable development of cities. This process is achieved through the implementation of a variety of policies and strategies to ensure a smoother transition by a dissipative system of natural resources to a more efficient, dynamic, circular, can pursue growth and well-being of citizens, focusing on capacity and relationship social.

The smart approach is also able to equip the cities with tools that they can track and manage their emissions in advance, reducing the cost of energy supply. A better availability of information on the infrastructure and the activities of a city also facilitate the identification and management of risks. For example, real-time data related to flows of commuters provided by the transport systems and mobile devices, you can help to optimize the allocation of the security services during emergencies.

In the middle of a SC are the people who live in environments, real and virtual and can obtain and exchange information at any place and time, as well as by any means, thanks to the spread of broadband, mobile technologies and opportunities offered by the Internet of things.

To obtain a SC is necessary to establish a telematics platform that is able to use existing systems (e.g., smart grid, smart mobility), to collect and normalize information sourced from these systems and make them available to the application layer, where to create value-added services oriented business operators, the government and citizens.

The project objectives and scenarios presuppose the following technological issues:

- Use new technologies, integrated or supporting existing ones give value to the services to the community.
- Integrating existing technologies to acquisition, normalize and correlate heterogeneous data.
- Create functionality, algorithms and shared services with the end user.

MULTI-AGENT SYSTEM: A NEW POSSIBLE MODEL FOR SMART CITY

Virtually all new energy technologies come with embedded electronic intelligence that controls their operations and enables them to link with other devices, buildings and the overall grid where Information and Communication Technology (ICT) represents the 'backbone'.

Realization of the Intelligent Distributed Autonomous Smart City (IDASC) requires meeting the ever-increasing reliability challenges by harnessing modern communication and information technologies to enable an ICT infrastructure that provides grid-wide coordinated monitoring and control capabilities. Such ICT infrastructure should be capable of providing fail proof and nearly instantaneous bidirectional communications among all devices ranging to the grid-wide control centres including all-important equipment at the distribution and transmission levels. This involves processing vast number of data transactions for analysis and automation. This requires a high performance infrastructure capable of providing fast intelligent local sub-second responses coordinated with a higher-level global analysis in order to prevent or contain rapidly evolving adverse events. Centralized systems are too slow for this purpose. A distributed architectural framework can enable the high performance infrastructure with local intelligent sub-second response using modern technologies (Fig. 2).

The Agents facilitate common use of local controls coordinated by global analysis, real-time tuning of control parameters, automatic arming and disarming of control actions in real time, as well as functional coordination in the hierarchy and in multiple timescales. The virtual architecture allows seamless integration of intelligence at all levels so that the locations of specific services and data are virtualized and transparent throughout the infrastructure subject to cyber security. Such modular, flexible and scalable infrastructure meets the global operational needs and allows for evolutionary implementation on a continental scale. It can respond to actual steady state and transient operating conditions in real-time more effectively than conventional solutions that depend on off-line analyses.

The Agents operate at different timescales ranging from milliseconds to hours. Their actions are organized by execution cycles. That is referred to a set of related functional tasks performed in a temporally coordinated manner. The specific periods and activities of the cycles are configurable according to the operating concerns, physical phenomena, control response times, computational burden and engineering practices. In each cycle, at each hierarchical level, an agent is responsible for a specific function and for a specific portion of the grid. Autonomous agents intelligent are deployed, as needed, on a grid-wide computing network

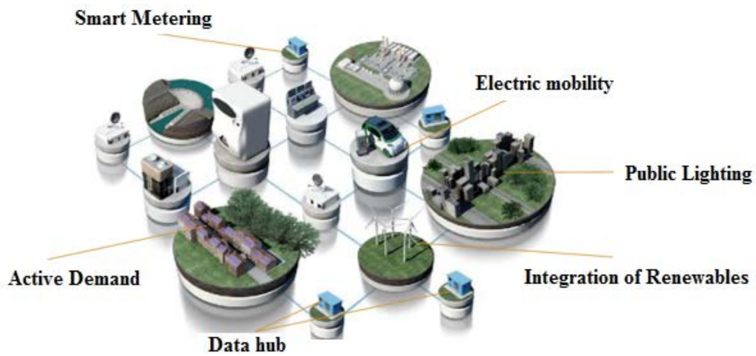

Fig. 2: The new strategic role of the infrastructure

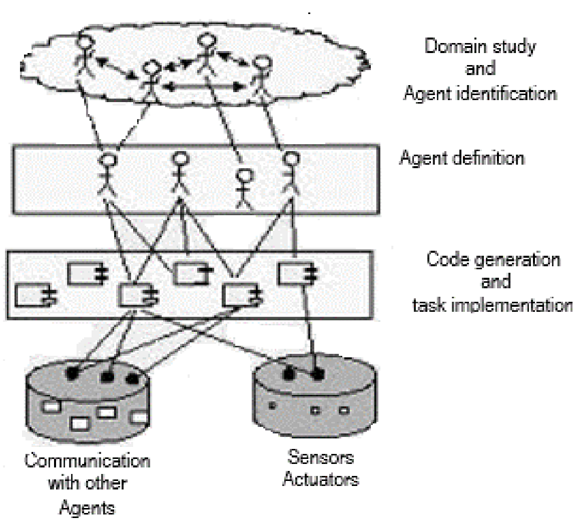

Fig. 3: Step of development of agent ZEUS

throughout the infrastructure to provide services necessary for the execution of functional tasks in the areas of data acquisition and model management, system monitoring and enhancement and performance control.

The IDASC will have to use a two-way communication, able to make the SC infrastructure dynamic and interactive, capable of exploiting architecture plug-and-play open, such as to create a secure environment to allow the passage of resources between the various networks and allows both real and virtual operators to communicate and interact with each other.

Analogies between distributed networks and telecommunications networks peer-to-peer protocols suggest to inherit already studied in the field of ICT and design them so as to make up for the new challenges related to the creation of a distributed network for the control of smart subsystems that will be among their integrated and interacting. For the implementation of the chosen architecture, among numerous open source platforms to existing agents, the most valuable is ZEUS. It is a framework that uses communication Java and it is based on Agent Communication Language (ACL) and Knowledge Query and Manipulation Language (KQML). However, it has some features oriented on security and a Graphic User Interface (GUI) advanced and compatible with the standard Foundation for Intelligent Physical Agents (FIPA), to ensure interoperability between systems to heterogeneous agents. ZEUS reflects the need to have methodologies and toolkits to solve problems, rather than specific solutions to specific problems. To do this, it provides a library of components based on agents and an environment that supports them. It can be considered as a synthesis of ZEUS agents already established technologies, combined with some innovative solutions to develop applications quickly and integrated. It offers implementations, software, already functioning for communication, reasoning and cooperation, leaving only the definition of the Agents necessary for the application, which is accomplished by writing the code necessary to give the agent the specific capabilities of the application domain. Figure 3 shows the stage of development of Agent ZEUS.

Each agent is divided into three levels:

- Definition, to determine which agent has the ability to reason, its goals, resources, skills, beliefs, preferences.
- Organizational, specifies relationships with his fellow agent.
- Coordination, modelling the agent so that it can negotiate and coordinate with other agents.

The agents provide the functions of the Name Server, which maps agent names to network addresses and Facilitator, which provides the names of possible agents capable of a certain capacity, utilities.

The implementation of agent system consists in:

- Specification of the Agents
- Analysis of the application, which is achieved through a Collaborative Agent diagram. This description is shown in Fig. 4, where the control agent puts forth responsibilities that include monitoring system to detect contingency situations

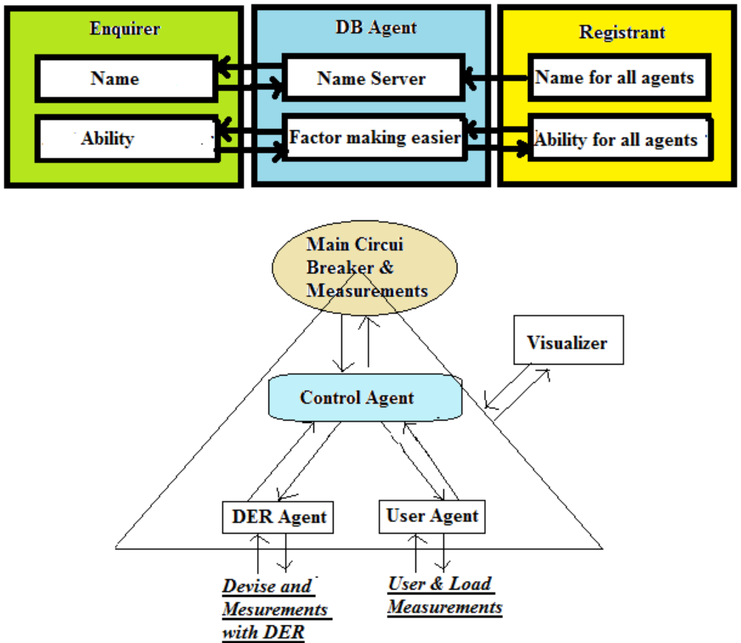

Fig. 4: The multi-agent systems collaborative diagram

or grid failures and sending signals to the main circuit breaker to isolate the IDASC from the utility when an upstream outage is detected

Distributed Energy Resources (DER) agent is responsible for storing associated information, as monitoring and controlling power levels and it connect/disconnect status. DER information to be stored may include identification number, type (solar cells, micro turbines, fuel cells, etc.), power rating (kW), local fuel availability, cost function or price at which users agree to sell, as well as availability, i.e., planned maintenance schedule.

User agent acts as a customer gateway that makes features of an IDASC accessible to users. It includes responsibility of providing users with real-time information of entities residing in the IDASC system. A user agent also allows users to control the status of loads based on priority predefined by a user:

- Application design, through modelling of the knowledge of each agent.
- Realization of the application, create, trough a graphical interface of the framework, the agents.

Finally once generated codes agent, the application process is completed. All messaging exchanges among agents are established for the Transmission Control Protocol/Internet Protocol or TCP/IP. The idea behind any multi-agent system is to break down a complex problem handled by a single entity (centralized system) into smaller simpler problems handled by several entities (distributed system).

The multi-agent system has become an increasingly powerful tool in developing complex systems that take advantages of agent properties: autonomy, sociality, reactivity and pro-activity. It is autonomous in that they operate without human interventions and it is social-able in that they interact with other agents via some kind of agent communication language. The agents also perceive and react to their environment. Lastly, it is proactive in that they are able to exhibit goal oriented behaviour by taking initiatives. The proposed architecture of IDASC provides a generalized framework that facilitates the design and development of various components of the ICT infrastructure and emergence of necessary standards and protocols needed for the SC. The technical feasibility of the architecture relies on recent advances in the areas of sensors, telecommunications, computing, internet technology, power equipment and power system analysis.

CONCEPTUAL MODEL OF SMART CITY

The IDASC is a system that considers different technologies, operators and connections. The composition of these systems will change depending on how the will evolve technology, generating new businesses and new interactions. To support this quality, the smart city systems must not have great relations with each other they must interact with each other using minimum amounts of mutual information. The conceptual model of a Smart City is a set of views and descriptions (Fig. 5) that are the basis for discussing the characteristics, uses, behaviour, interfaces, requirements and standards of the Smart City.

The model provides a context for analysis of interoperation and standards, for the development of the

Fig. 5: The diagram of domain of smart city grid

architectures of the Smart City. It is important to note that the conceptual model of the Smart City is not limited to a single domain or a single application or case use. The scope also includes cross cutting requirements including cyber security, network management, data management and application integration. For each domain model and for each individual device of SC, it wills importance to associate an Agent, with the characteristics illustrated above and to obtain IDASC previously described.

The key is the algorithm. It is the heart of the operation of IDASC and that will be determined by following the guidelines provided by the governance, in according to environmental, social, economic aspects.

Smart software agents can be programmed to seek the power it from the green source. Agents representing each generation source can report current air emissions. The power customers interested in reducing their environmental impacts can order to their agents to buy the cleanest power available within their budgets. Smart networks respond collaboratively during the alerts smog.

CONCLUSION

This study has discussed the design and implementation of a multi-agent systems in the context of Intelligent Distributed Autonomous Smart City (IDASC), a model outlining the subsystems, manufacturing technologies, operating systems, application of Multi-agents systems making concrete that the project of a smart city, so as to give a clear overview and user-friendly to policy makers. Several positive aspects are able to generate a Smart City. For example, stimulus to the economy; service innovation; involvement of citizens; reduction of carbon dioxide emissions; increased public safety; protection of health.

The concept of Smart City appears to be fundamental in the redefinition of urban systems, where for the first time also takes into account the human and social aspects for the establishment of an urban structure. Essential to enabling the realization of a model give clear and objective to define the key elements constituting and implemented by SC in order to make it replicable. The originator of the first great electrical revolution knew that innovative devices were important, but the key is creating systems that make them useful. By distributing decision making to virtually everyone systems, it will create a smart network that supplies clean, secure, reliable and economical energy to meet the emerging needs of economy. The more comprehensively the potentials of SC are addressed and are developed, more quickly and fully we will realize its many opportunities and benefits.

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