Teamwork Behavior in Smart and Sustainable Cities Ecosystems

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***Abstract*— According to market research, the number of smart cities is increasing rapidly. Information and Communication Technologies provide the smart infrastructure that is the foundation for all of the key themes related to a smart city, such as smart economy, smart people, smart governance, smart mobility, smart health, smart buildings, smart water, etc. As such, a smart city is constituted of various infrastructure components that form a complex system of systems, which is essential to collaborate effectively. Services play a central role in this vision of smart cities, as they are used as building blocks for effective collaboration, i.e., to achieve interoperability between heterogeneous parties of a business process and independence from the underlying infrastructure. In order to cope with the problem of complexity and the scalability in smart cities' systems, a solution is to provide autonomous, collaborating services that have situation awareness and they are able to adapt dynamically to the changing needs of the environment. In this research, we propose to model smart cities' services collaboration by using the role modeling approach enhanced by the introduction of service teamwork roles. The teamwork roles definition is inspired both by human and agent team working models. We contribute by determining the dominant teamwork roles that prevail during service group cooperation where the main goal of each role is to intervene during collaboration and "act as a connector" in order to keep the team of component services together and consistent with the goal of the group–team. The teamwork functionality is applied through the introduction of a new layer in the architecture of smart cities and is exploited to overcome some of the aforementioned problems.**

Keywords- Services; Smart Cities; Service Choreography; Role Modeling; Teamworking.

I. INTRODUCTION

According to market research, the number of smart cities is increasing rapidly. This growth is expected to continue for the next years, since the market of cities with population over 150,000 people is already 5,000 [1].

While there is no universal definition for the smart city, an often used definition is that of International Telecommunication Union (ITU) report in 2014, which is the following: "A smart sustainable city is an innovative city that uses Information and Communication Technologies (ICT) and other means to improve quality of life, efficiency of urban operation and competitiveness of services, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects." [2].

ICT provides the smart infrastructure that is the foundation for all of the key themes related to a smart city, such as smart economy, smart people, smart governance, smart mobility, smart health, smart buildings, smart water, etc. As such, a city is constituted of various infrastructure components that form a system of systems [3].

According to Mayk and Madni [4], a System of Systems (SoS) is a collection of systems that were originally designed as separate systems for specific and different purposes but they have been brought together within the SoS umbrella, in our case a smart city umbrella, for creating new capabilities required for the mission of a smart city. A smart city as a system, is usually designed to accommodate various and diverse services, though not all services and their capabilities are defined precisely at least at the time of the initial deployment and, consequently, they are not included in the initial design. Further, since a smart city evolves dynamically, it could incorporate new enhanced and innovative services. This evolution includes continuous deployment of new services, reorganization of existing services and automatic development of novel more competitive services. Commonly, a smart city is characterized using terms, such as interoperable, synergistic, distributed, adaptable, inter-domain, reconfigurable, and heterogeneous. Actually, it is an ecosystem that evolves over its lifetime.

Furthermore, the key characteristics of SoS [5][6], which in our case are focused to a smart city should be a) operational independence of elements, b) managerial independence of elements c) evolutionary development, d) emergent behavior and geographic distribution. Although the above are quite important, however, another characteristic should be included, that of efficient collaboration, since the electronic habitants of smart cities are increasing rapidly with the massive introduction of Internet of Things (IoT) technologies.

Collaboration of smart infrastructure will provide the cognitive framework that smart cities subsystems need in order to have the ability to cooperate transparently and autonomously for offering composite, complex and more efficient services. However, developing this collaborative cognitive framework is not straightforward, since according to Vlacheas et al. [7], while a wide set of predefined services and applications is available for employment in smart cities, there are technological barriers among objects when they are used across application domains.

Services are commonly considered for performing complex tasks, thus research has focused on the problem of the automatic service composition. An automatic and dynamic web service composition is a highly complex process and the proposed standards of related technology do not answer holistically the problems of web services discovery and composition yet [8]-[10]. Further, service composition and collaboration is limited to approaches that groups of services follow a plan for the composition taking into account only their functional behavior, and this cannot be characterized as collaboration. In many cases, services need to work together as a group to achieve common objectives, implying teamwork abilities, which are commonly used in case of groups of humans, agents or autonomous vehicles. Developing autonomously collaborative services capable of exhibiting teamwork behavior that would have situation awareness and adapt in the environment of a smart city is a challenge for our research. A service capable of exhibiting teamwork behavior is one that can effectively cooperate with multiple potential teammates on a set of collaborative tasks and that is able to intervene and catch errors or prevent emergent behaviors that will put in danger the overall team goal, i.e., the overall execution of a composite service.

Teamwork has become an important research field and its contribution to organizational performance has attracted attention of various research groups from several disciplines. In recent years, many scientists studied why humans succeed or fail in joint activities and a variety of models have been developed that follow social - psychological approaches for human team formation. Apart from human team working, another area where similar problems have been studied and such theories have been applied, relevant with this research, is the area of autonomous software agents and robots. As with humans, a group of autonomous software agents must accomplish given tasks by organizing themselves according to their individual characteristics and their teamwork behavior within the overall system.

Towards this direction, the problem we address in this paper is to exploit the existing architectures and augment them with a teamwork layer that may introduce the notion of teamwork collaboration within a set of services, agents and other systems that "live" in a smart city. More analytically, we present (i) the teamwork behaviors needed, and (ii) a teamwork software layer.

In order to do so, we exploit the role modeling approach and the definition of behaviors to create roles that, except their functional behavior, will also have teamwork behavior. Services that exist in a smart city could be modeled using this approach that directs the team of services, which are called to cooperate to reach a goal. The focus is on architecting cooperative teams of services that form composite services, where cooperative teams is meant in a stronger sense than composite services where it usually simply implies a set of bound services. This teamwork hypostasis of cooperation in services makes the concept of collaboration stronger.

The rest of this paper is organized as follows. Section II describes the background and related work in teamworking, in Section III we present a layer in the reference architecture for smart and sustainable cities, in Section IV we describe the proposed teamwork software layer, while the last section presents conclusion and ongoing work.

II. TEAMWORK THEORY

In many cases, smart cities' environment is so complex that work is done in teams composed of members that are either humans, IoT devices, autonomous software agents where each of them is specialized in specific tasks. For example, teams of humans, vehicles and software services need to cooperate in various transportation scenarios [11], while humans, together with various smart cities cooperative agents offered by various providers implementing different protocols, need to collaborate. The success of a smart city use case depends on the team rather than the individual effort of each team member. In other words, a smart city is an ecosystem where, organization, businesses, human's operators, users, IoT services and Cyber Physical Systems (CPS) are effortlessly connected while exhibiting teaming behavioral attitudes. In order for these entities to be effectively connected and collaborate as a team, models based on human team working literature were investigated and exploited.

Team working has been thoroughly studied by psychologists and human resource experts over the last decades. In early studies, some researchers have proposed models focused on specific characteristics that team members should have such as personality, functional expertise, competencies, goal orientations, etc. [12][13]. As the team research matured, research moved firmly from dealing with single characteristics that members should have to a variety of behaviors that members should expose [14][15]. Ultimately, in current research, member's tasks and behaviors are often clustered into distinct roles within the system that are aligned with the expertise of each team member [16]. Increasingly, researchers propose that teammates, along with the operational tasks that they perform in a team, they have also to play some other teamwork role, such that of coordinator, contributor, idea generator, etc. Indeed, as it is witnessed by empirical studies, these approaches are effective in a variety of contexts, tasks and domains.

There were many attempts to classify roles and behaviors in the context of human team working. Among them, the most prominent models are: (i) Belbin's work in team roles [17], (ii) Parker' set of team player styles [18] and (iii) Margerison and McCann model, which defines eight different roles namely: (a) explorer–promoter, (b) assessor–developer, (c) thruster–organizer, (d) concluder–producer, (e) checker–inspector, (f) upholder–maintainer, (g) reporter–advisor, and (h) creator–innovator [19]. Each role is linked to predefined behavior and tasks. For example, "Creator–innovator" role is linked with forward thinking, new ideas and new ways of doing things. People playing this role in a team, come up with new strategies and different approaches to tasks, creating and experimenting with new ideas in order to handle various situations and challenges.

The various agent-based frameworks of team behavior proposed in the literature were also investigated to identify and analyze the different agent teamwork factors among various types of teams in related areas. Generally, agent based teamwork factors address different collaboration attributes, such as (i) how the team is organizing itself, e.g., by creating rules for collaboration and communication, (ii) how the team is forming its strategy for future direction, e.g., by planning and decision making and (iii) how the team work together to achieve synergy, e.g., by following rules of trust and engagement. Fifteen primary factors revealed from agent based models in the literature, which merit particular attention across different team tasks and group sizes. In the following, we present the three dimensions and how the teamwork factors are clustered [20]

a) Organizing factors, such as Collaboration (COL), Communication (COM) and Coordination (COO).

b) Strategy related factors, such as Planning (PLN), Learning (LRN), Decision making (DM), Evaluation (EVL), Teamwork policies (POL).

c) Synergy related factors, such as Ad hoc team setting (ADH), Autonomy (AUT), Delegation (DLG), Joint-intention (INT), Knowledge of teammates' capabilities (KCT), Knowledge sharing (KNL) and Trust (TRS).

The framework for the goals of this research paper is partially based on existing approaches in service modeling and teamwork behavior. However, according to our point of view, the primary objective for smart cities is to not only provide services coming from different smart systems and combine them through basic communication and collaboration. According to our opinion, the benefit comes through the ability to bind them in novel services that include the abilities of the composed services or systems and could implement the collective intelligence they have gained from the domain during their execution.

III. SMART AND SUSTAINABLE CITIES ARCHITECTURES

Smart cities are distributed-computing environments composed of a large number of software services. This architecture enables the continuous evolution of smart cities ecosystems. Therefore, a key quality of a smart city architecture is its ability to accommodate new services by automatically composing and executing as novel software services. This service composition process is critical, since in many cases there are interrelationship between city's core systems, given that these systems cannot work in isolation. On the contrary, it is quite common to operate in close collaboration, e.g., smart transport network relies on traffic management. Interconnecting these systems obviously improve their efficiency and intelligence. Numerous examples of such synergies exist e.g., smart water - smart energy, smart energy – smart buildings, etc.

Service composition in most cases is based on service orchestration, which is a basic concept of Service Oriented Architectures (SOA). Service orchestration is a centralized approach for composing services out of existing atomic software services. However, service orchestration is better suited on static environments, when there exists a coordinator, and plans are known in advance while minimal changes happen during the execution. Nevertheless, this is not the case in smart cities ecosystems, where changes are introduced frequently and the number and the type of offered services are not upfront defined. For such cases, service choreography is a preferred solution, since composition of services is done on a peer-to-peer fashion, leading to autonomously operating services. This need was early identified, thus choreographies were included in Business Process Model and Notation (BPMN 2.0) specifications [21].

As already mentioned, in the smart city case myriads of heterogeneous services operate independently. This trend will grow even more in the near future since smart services are transformed to sustainable cities that need to exhibit even richer behavior and functionality. According to ITU Telecommunication Standardization Sector (ITU-T) [22], the overall smart city architecture should provide support for Transportation services, E-government services, E-business services, Safety and emergency services, Smart health services, Tourism services, Education services, Smart buildings, Waste management services, Smart energy services, and Smart water services.

The only way to keep control of such complex systems is by developing services that are able to act and interact independently and on a demand basis. The development of smart cities' systems and applications demands software development environments that are able to support a number of functional and non-functional requirements. The functional requirements that need to be satisfied by a development environment, as they described in [23], are:

- Data management, which includes collection, storage, analysis, and visualization of city data.
- Applications Run-time support for facilitating deployment and integration of smart cities' applications.
- Sensor network data management and control.
- Data analytics functionality for analyzing massive volumes of data produces by a smart city.
- Service management according to SOA or other service management standards.

- Tools for conceptually defining smart cities models, organizations, etc.

Furthermore, a number of non-functional requirements need to be introduced to enrich the existing list, related mainly but not exclusively to the quality characteristics of the provided services. More specifically, some of the existing non-functional requirements are: interoperability, scalability, security, privacy, configurability, etc.

According to ITU-T [22], as shown in Figure 1, the Smart and Sustainable City (SSC) architecture should be layered and it consists of a) the sensing layer b) the network layer, c) the application layer and d) the Operation, Administration, Maintenance and Provisioning, and Security (OAM & P & Security). Many such frameworks have been presented in the literature, focusing on different architectural aspects. For example, in the work of Gaur, Scotney, Parr, and McClean a software framework is presented that includes a semantic layer, which enables exploitation of domain specific data based on the concepts and relationships between these concepts [24].

Anthopoulos and Fitsilis [25] explored various smart cities around the world and concluded that the architecture that is preferred by well-managed cases is the multi-tier architecture, which is applied in new, existing and smart planting cases, while it addresses both soft and hard infrastructure, and it considers natural environment and the evolving Internet-of-Things (IoT) in terms of sensor installation.

Obviously, architectures that in many cases were operational in the near past seem to be inadequate for the future and have deficiencies. For example, they are tuned for static service provisioning but not for dynamic service composition, they are controlled in most cases centrally and they do not allow ad-hoc collaboration between services (service choreographies) while smart city subsystems are interconnected and integrated but they do not exhibit intelligent behavior (situation awareness, adaptive behavior), etc. In order to overcome these deficiencies, in the sequel, we present the introduction of a new layer, which will provide teamwork functionality and could be utilized to solve some of the above-mentioned problems.

IV. TEAMWORK LAYER

In this paper, we do not present a complete architecture since specific functional requirements do not exist; they are generic and not analytical for a particular smart city implementation. What we discuss here, is best described as a conceptual application architecture layer, capturing the most prominent requirements for exhibiting an intelligent teamwork-collaborative behavior to smart cities' applications. However, this conceptual teamwork layer could be modified and transformed as necessary, to address all specific functional and quality requirements for specific smart city frameworks or projects. This teamwork layer, ideally, could be used with the role based modelling approach, for presenting the services/components that cooperates within the smart city ecosystem. According to this approach, for each smart city/domain a set of roles is defined. Each role is a set of behaviors. A role model of the domain contains all roles and their defined behaviors. The set of roles that each service acquires implies paths for the collaboration of the service with other services of the domain. By defining services as set of roles, it allows an abstraction and helps to capture other entities that might exist and cooperate in the domain to form heterogeneous teams, e.g., teams of services, agents and robots. This is also necessary since, although some services may have the same functional requirements, not all services can exhibit the same behavior concerning nonfunctional requirements. The role model and its application to model composite services is defined in [26].

Even though the role model is an abstraction that describes the patterns of interactions among a set of entities, our intention is to introduce in this paper specialized team work roles that intervene when particular behaviors extracted, for infusing team working behavior within smart and sustainable city services. By researching the related bibliography in human and agent team working, the

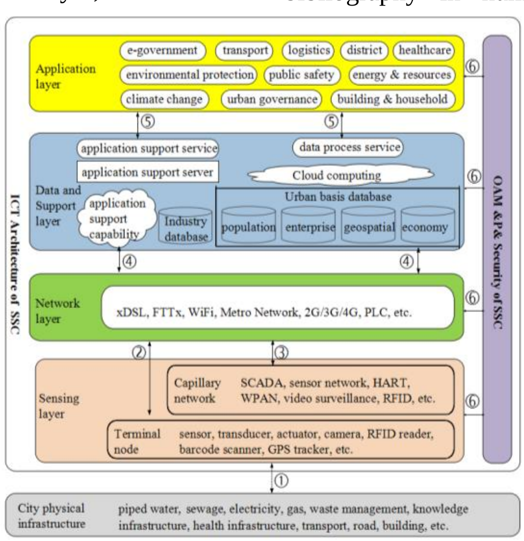

Figure 1. Smart and Sustainable City Architecture ITU-T [22]

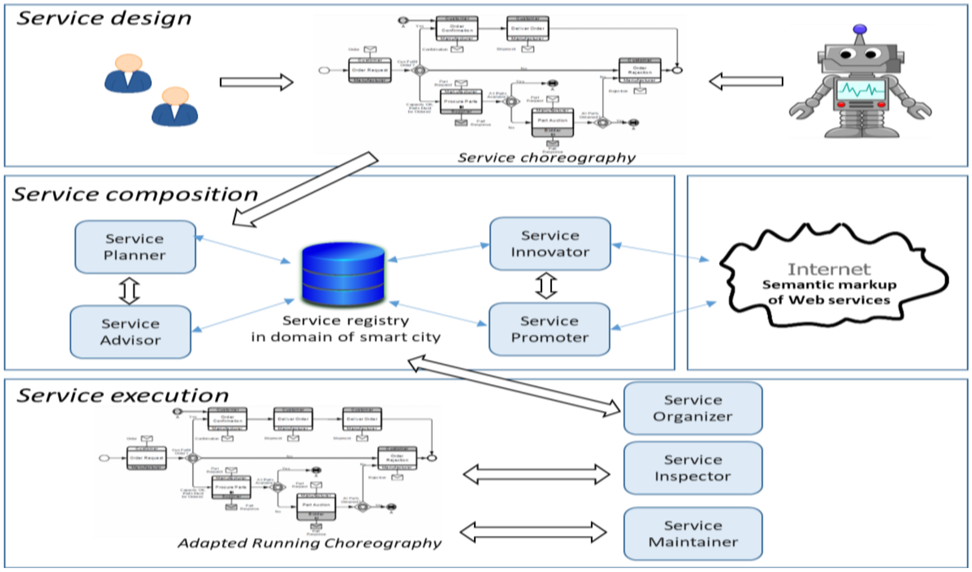

Figure 2. Smart and sustainable city service teamworking

following fundamental roles have emerged. The description of each role is minimal in the sense of reflecting solely the most substantial aspects of teamwork during the collaboration. Additional aspects occur in specific cases; these may be addressed by modifying the role and adapt it to the detailed behaviors.

Planner role. Complex smart city services need to be executed according to an overall plan. This role should be assigned to services having central function within different smart cities subsystems. For example, we should have one planner role for each different type of transportation service.

Organizer role is a role needed for organizing and monitoring the execution of different plans. It is possible that different services are assigned both the roles of planner and organizer, however these services should be strongly coupled (planners and organizers).

Similarly, the **inspector role** is the role that monitors the execution of the plan within the domain of a smart city. It is responsible to keep track of the progress, to inform organizer for possible delays and to trigger the planner when a new plan re-scheduling is required.

The **promoter role** is a role that enables interacting with different domains, e.g., by promoting services offered outside the domain of specific smart cities. A service having this role should be aware of the capabilities of all services of the domain. This is done with the aim to expand the offered services of a smart city or for looking about potential new services that are in demand.

Producer is a generic role that is assigned to all software services offering added value services to the citizens within the domain of a smart city.

Advisor role is needed for exploring new alternatives to develop the offered services within the domain of a smart city. Through history execution of services in the domain, it can reason and evaluate a set of services that will make the team formation. In a more advanced form, the advisor is based on semantic constructs such as domain ontologies in order to offer better reasoning using knowledge retrieval algorithms and provide recommendations of better quality.

Maintainer role. The main goal of the maintainer is to ensure that standards and processes of the domain are upheld and to maintain team functionality. It check for new updates for the system and keeps the configuration of the system.

Innovator role could be assigned to all experimental services of the domain, or to services running at a test system e.g., a landscape that have not been deployed yet.

As it is already mentioned, this team working model could be executed within a smart city domain to improve the collaboration of the composed systems. Services executed within the same domain will be aware of this fact, and will be able to share knowledge artifacts of the domain existing in various forms and formats. Further, through the role of the *advisor*, services are informed about other services that have similar behavior, their capacity, which of them are trusted, their functioning within the system in relation to the smart city's semantic model (e.g., smart city ontology) and the geospatial information of each service (e.g., which smart building is in the proximity of a smart vehicle). The satisfaction of these requirements would lead to the implementation of important operations within a team such as *delegation*, *common intention and knowledge sharing behavior*.

The implementation of team working services essentially follows the three-step implementation, which are: a) Service design phase, b) Service composition phase and c) Service execution phase. During the service design phase, a choreography could be designed using a business process modelling language, such as BPMN 2.0. The design is done after capturing the service requirements in collaboration with domain experts and users. Service composition could be done using BPMN 2.0 and after discovering the appropriate service instances needed. At this phase, after the *planer* provides a plan for the composition, the *advisor* role is needed in order to identify and evaluate the services published by providers within the domain. For describing the service plan, the behavior, the interactions, and messages exchanges need to be specified. This is implemented in the context of the *planner* role. The result of service composition is the description of services to be executed and in this context the *inspector* role need to be activated. Meanwhile, service *innovator* is in collaboration with service *promoter* and according to the availability of services in service registry, they either promote existing services to be used or search for new available services that could be found from other providers through the internet. The *inspector* role in collaboration with the *organizer* role are the necessary components for running and monitoring the final choreography. This scenario is presented in Figure 2.

V. CONCLUSION AND FUTURE WORK

Collaborative processes performed by teams of services in a smart city environment require teamwork abilities. In this paper, we outline the principles for service teamwork roles, which are a fundamental building block for our proposed model of service teamworking in the context of a smart city. More analytically, we habilitate these roles with indicative teamwork behavior that services need as participants of an optimal team in order to underlie the required teamwork abilities and go beyond other approaches, by providing teamwork grounded service abstractions. Clearly, this is not sufficient and the analytical primitive behaviors should be designed that would be extracted from each team role according to the proposed role descriptions and the application domain. This is a step towards the definition of the architectural design and for creating a sophisticated smart city scenario where all defined roles will intervene and contribute, using real data from a smart city ecosystem. The benefits of applying this approach is that as smart cities are becoming even more complex systems we need to introduce concepts of intelligent collaboration and autonomous behavior that will allow such systems to evolve and to be managed easier.

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