Towards Context Aware Sustainable Cities

Guadalupe Ortiz, Alfonso Garcia-de-Prado

***Abstract*—**The breathtaking advance of technologies and communications and 24/7 universal access to Internet has transformed the cities in which we live into interconnected spaces where we are constantly sending and receiving data. Thanks to this amount of information, the services offered to us by cities can be much better tailored to the needs of citizens and particularized according to their context. However, this has its difficulties: obtaining context in time and being able to properly correlate data from different domains that could provide contextual information for others. In this paper we outline a proposal to address these challenges and illustrate it through a case study.

***Index Terms*—**Event-driven service-oriented architectures, context awareness, collaborative IoT, smart cities.

I. Introduction

The great advance of technologies and communications in recent years, the reduction in the cost of any electronic device and universal access to the Internet in general and mobile Internet in particular has transformed the spaces in which we live, work or spend our leisure time, in short, they have transformed our cities. Cities that until now we could only access to a limited amount of information and also mostly static, now offer an amount of information and services that evolve dynamically and adapt to the situations or specific needs of the citizen.

In this scenario, a concept that favors the transformation of cities in the interests of the citizen, the awareness of the context, takes on a stronger role. Dey defined context in 2001 as all the information that can be used to characterize or particularize an entity and that can be used to improve the interaction between various entities [1]. These entities, in the particular case we are dealing with, may well be the citizen and the city, more specifically the relationship between the citizen and the applications or services offered by the city. The context, the information describing this context, may be very variable as it will depend on the service application domain, as well as on the specific needs of the citizen, so it is difficult to provide a generic collection of contexts applicable to any domain and we will have to define an ad hoc one for the case study at hand.

On the other hand, context awareness refers exactly to the ability of applications or services to use the knowledge of that context to provide a better service to the end user; in cities, the citizen. The service or application should be able to obtain context from various sources in the environment of the application or the citizen, such as, in general terms, their location, their activity, their tastes or personal features or any other information that can be used to personalize the service and therefore improve their satisfaction with it. Thus, a service is context aware when it uses the user's context to offer a more personalized and therefore more effective and satisfactory service [2].

The development of context-aware services and applications is not without a number of challenges to be faced that hinder their early implementation. First, the initial and most obvious challenge is the ability to obtain such context information. Secondly, being able to obtain it in real time in order to perform service personalization also in real time, so that it really benefits the use of the service. Finally, to be able to correlate contextual information coming from different application domains to improve the knowledge and services offered in any of them or in any other domain.

In this paper we explain how the use of service-oriented and event-driven architectures, enhanced with a context-aware module, can obtain and process context in real time and provide context-aware services in the domain of smart cities. The approach is illustrated through a case study of smart cities where contextual information is obtained from various application domains, such as water supply networks, electric power, social relations, etc. Thanks to the correlation of contextual data from various data domains and the sharing of data by the various entities of the smart city, including citizens, a great enrichment of the knowledge of the events occurring in the city will be achieved and much better and more contextualized, and therefore particularized, services can be offered to citizens.

The rest of the paper is organized as follows. Section II introduces the background related to event-driven service-oriented architectures for smart cities. Section III depicts the proposal for context-aware smart cities. Section IV illustrates the proposal through a case study. Section V

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Guadalupe Ortiz is with the Department of Computer Science and Engineering, University of Cadiz, 11519 Puerto Real, Cádiz, Spain

Alfonso García de Prado is with the Computer Architecture and Technology Department, University of Cadiz, 11519 Puerto Real, Cádiz, Spain

analyzes other existing works in the literature and finally Section VII ends with conclusions and future work.

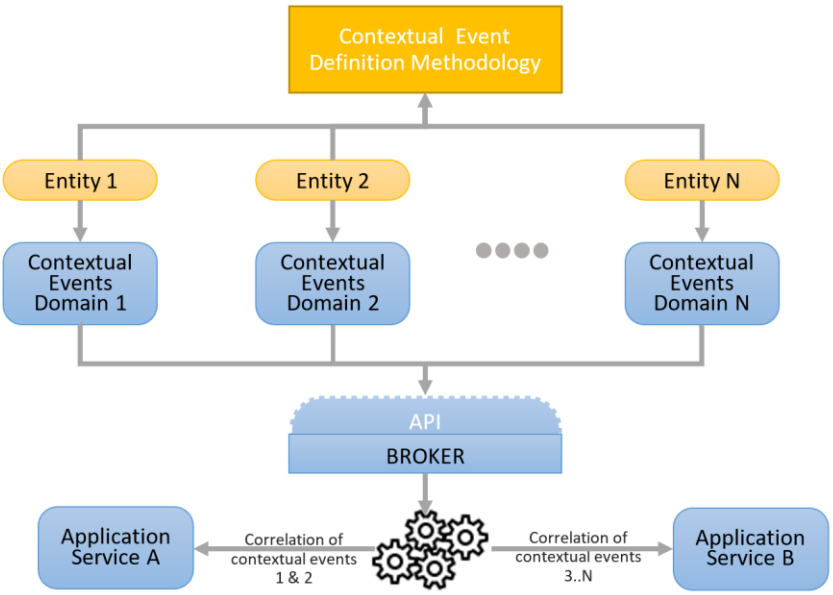

Fig. 1. Context-aware proposal for Smart Cities

II. Background: Architecture for Context Aware Smart Cities

As previously mentioned in this paper we propose the use of service-oriented and event-driven architectures. Service-oriented architectures (SOA) propose an implementation where the client and the service communicate in a loosely coupled manner. This feature together with the use of standards for communications independent of the development language and the deployment system, position it as a suitable option to facilitate interoperability between third parties [3]. These architectures are complemented by the use of events, giving rise to service-oriented and event-driven architectures or SOA 2.0; so that in a completely decoupled way third parties can send events of interest to the system or subscribe to them [4]. It is precisely the ability to receive and process events that leads to the introduction of another technology in the application, complex event processing, which allows processing and correlating large amounts of data and, moreover, allows doing so in real time.

In the past we have seen how these architectures can indeed be successfully used to process large amounts of Internet of Things data, and thanks to the integration of a context module, infuse context awareness into the architecture and thus provide the ability to offer context-aware services[5], [6]. We have illustrated the use of this architecture in domains where the application context was intimately related to that domain, but how can we correlate totally heterogeneous application domains? How can we manage to integrate contextual data from the various domains into the architecture?

III. The Proposal in a Nutshell

Our proposal is to treat the domain-specific data of any domain within the scope of the application as contextual events for the rest of the domains. Thus, let's suppose that the city council of a city offers a comprehensive application for querying household water consumption, electricity consumption, the location of the nearest garbage containers, and public transportation. On the surface, these are very disparate domains, but if we think more carefully, we will see that we can establish relationships of interest between many of them. For example, if public transport data show that more citizens than usual are going to a certain area of a city; possibly the garbage containers in that area are fuller than usual and need to be collected more frequently. Another example could be to detect that in a house where a single person lives there is no water or electricity consumption, this could be an indication that something may have happened to that person.

Obviously, the correlation of events from such disparate domains also poses a number of additional challenges:

1. First of all, we need to convince multiple people and entities to share their data. Not only public entities such as the city council, or the private company that has the concession for garbage collection or public transport, but also citizens who share their data to obtain a better service. Although the democratization of data and the publication of open data are gradually gaining more and more followers, there is still a long way to go.
2. Secondly, when we talk about data sharing, it is unavoidable to talk about data security and privacy. We must ensure that no data reaches third parties who can make unlawful use of it; and we must also ensure that sensitive data is anonymized and does not leave the individual's control.

We suggest, as shown in Fig. 1, a methodology that provides a method to share the different contextual events to the different entities participating in the city. All this data would be routed through a series of smart city brokers and each application subscribes to various brokers corresponding to the various domain data that will serve as context data for a

particular application. For instance, as shown in Fig. 1, Application Service A might be interested in the correlation of the context events from domains 1 and 2, and Application Service B might be interested in the correlation of the context events from domains 3 to *n*. It will be the complex event processing engine that correlates the domain data with the various context data and can provide a more particularized service. In addition, the various context data could also be made available through a REST API to be used by third parties.

IV. Case Study

Let us assume the case study of the care of the elderly living alone or the discipline that has come to be known as Ambient Assisted Living (AAL). As we know, the world's population in general and that of developed countries in particular is becoming increasingly older as it reaches higher and higher age rates. This means that there are many elderly people living alone who, although they have the capacity to take care of themselves, are susceptible to accidents at home or from other causes and no one realizes what has happened until it is too late; for example, people who fall at home and due to some fracture cannot move or warn anyone, people who become depressed and no one notices because they do not receive guests, people who become confused or get lost, etc.

In this case study, the more information we can have about the person's environment, the more likely it is that we can offer a reliable service for incident detection and notification to the caregiver or the appropriate entity. However, if we correlate water and electricity consumption and see that water consumption is very low, but there is an average consumption of electricity, perhaps the person is simply drinking bottled water and has decided not to take a shower today; in this case there is no reason for alarm, although perhaps a caregiver should do some checking by a phone call; but if no water and no electricity is consumed for several hours maybe the person has fallen downs and suffered any damage and then the caregiver should be immediately alerted. Such scenarios have been represented at the top of Fig.2.

On the other hand, if the person usually goes out to throw the garbage and by means of the communication of his cell phone with the sensor of the container, we see that he has gone to a container that is not the one closest to his home, perhaps he has become disoriented or perhaps it is not his fault, but that the other container was full and then the garbage collection company should be notified. Such scenarios have been represented at the bottom of Fig.2.

Also, the most involved citizen can also collaborate by sending context to the application, simply by means of simple data inputs to the application by pressing a button (for example, "I have taken my medication", "I have eaten", "I have taken a walk", "I feel good/bad", etc.). Such contextual information is of great relevance although it requires direct action by the user.

V. Related Work

There are multiple works which deal with context awareness in general; and, among them, a few which deals with context awareness in the Internet of Things and smart cities, and those

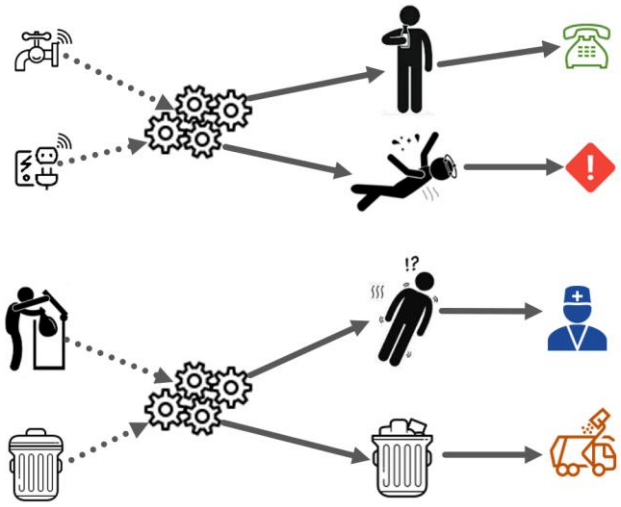

Fig. 2. Context correlation in a smart city scenario

are in which we are mostly interested. Among them, we can mention ACAIOT [7], a framework for adaptable context-aware IoT applications. This paper proposes a framework for context aware adaptive IoT applications to encapsulate and manage data in a separate context management layer that is responsible for generating the relevant context information. It also proposes an ontology to achieve domain-independent context management and incorporates a rule structure to facilitate activity recognition. However, it is not clear from the paper how they can obtain information about different contexts and correlate them, nor if they use any recognized technology for real-time data processing, which is essential in the IoT domain. On the other hand, Pradeep et al [8] have developed a generic, ontology-based, extensible approach to modeling and organizing Context for IoT. The ontology follows a hierarchical approach that provides an abstract and global vocabulary and thus favors reusability. However, it is not clear how, in a real scenario, the retrieved context will be adapted to the ontology and how a real-time processing system could make use of these contextual data to correlate them. When we focus on smart city scenarios we find many proposals that provide ontologies for various application domains, but do not give clear how the processing of the structural data of the ontology could be done in a particular scenario in real time, such as [9]–[11].

VI. Conclusion

Thus, if we can better manage and correlate the contexts in cities, we will be able to provide them with more effective applications and services, adapted to the needs of each individual. The ability to correlate heterogeneous contexts will give us a greater richness and knowledge of the environment and therefore will facilitate the improvement of the cities in which we live, making them safer and more sustainable.

In the future we will specify the methodology for the definition of contextual events, as well as how the communication should be done and how to correlate them, so that developers of applications and services for smart cities have the appropriate tools and means to make them fully

context aware with certain facilities and guarantees of success.

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Guadalupe Ortiz was born in Madrid, Spain in 1977. She obtained a Ph.D. degree in Computer Science from the University of Extremadura, Cáceres, Spain, in 2007.

She was as Assistant Professor at the University of Extremadura, Spain, since 2001. In 2009, she joined the University of Cadiz, Spain, as Professor in Computer Science and Engineering. She has published over 100 peer-reviewed papers in international journals, workshops and conferences. Her research interests embrace service context-awareness and their adaptation to mobile devices, as well as the integration of CEP in service-oriented architectures in the scope of the IoT and smart cities.

Alfonso García-de-Prado was born in Madrid, Spain in 1972. He received a Ph.D. degree in Computer Science and Engineering from the University of Cadiz, Puerto Real, Spain, in 2017.

For several years, he has been a Programmer, an Analyst and a Consultant for various international industry partners. Since 2011, he has been an assistant professor at the University of Cadiz, Spain. His research focuses on trending topics, such as the CEP integration in service-oriented architectures and context awareness in the IoT.