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Extended summary

Applying the Internet of Things and Internet of People paradigms to the urban context

Curriculum: Architecture, Buildings and Structures

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Abstract. Urban systems host a large amount of processes that are relevant to the everyday life of the citizens, to the economy, to the industry or to the administration of the city. Albeit the importance of these processes, currently we are not able to collect enough information about them or even to monitor them at all.
This work identifies the benefits of using Internet of Thing and People (IoTP) as the paradigm for the design of the information systems controlling the systems of the different urban domains (transportation, infrastructures, safety and security, ...). This would allow to improve our knowledge about and allow to increase the efficiency of urban processes, identify social issues and improve the effectiveness of urban planning.
An IoTP reference architecture for urban scenarios is currently missing and this work provides the key elements, such as: an approach to the design of urban systems from a systems engineering perspective and tools such as the domain model, the interaction model, the resource model and the functional model.

Keywords. Internet of People, Internet of Things, reference architecture, urban engineering

1 Problem statement and objectives

Cities and urban areas are facing a great challenge due to the global population increase, shift of population from rural to urban areas and consequent population density increase. The latter in particular threatens to bring the urban infrastructure (energy, transportation, waste, energy and supply distribution) to a collapse. Climate change, on the other hand, demands to take into account sustainability of urban processes. In order to address this issue, many municipalities are reviewing their approach to governance, focusing in first place on the opportunity provided by ICT to increase the efficiency and effectiveness of urban processes.

Internet of People (IoP) represents the ever-growing trend of social networks to pervade the life of people, recording and moving information about daily people's activities, events, moods in more or less automated ways. Currently there is no large consensus on the meaning and definition of the IoP in the scientific community. Building on the definition given in [1], we hereby define IoP a paradigm of interaction between people who envisages them as nodes of a global and pervasive communication network that transfers information using the Future Internet infrastructure and ICT technologies. The IoP projects in digital world some of the relationships and of the interactions that exist between people in a given context (social, occupational, communities of practice, etc.). In the future, however, the data transmitted through IoP could be used also by software agents employed for the monitoring and control of phenomena and urban processes of various kinds in physical reality.

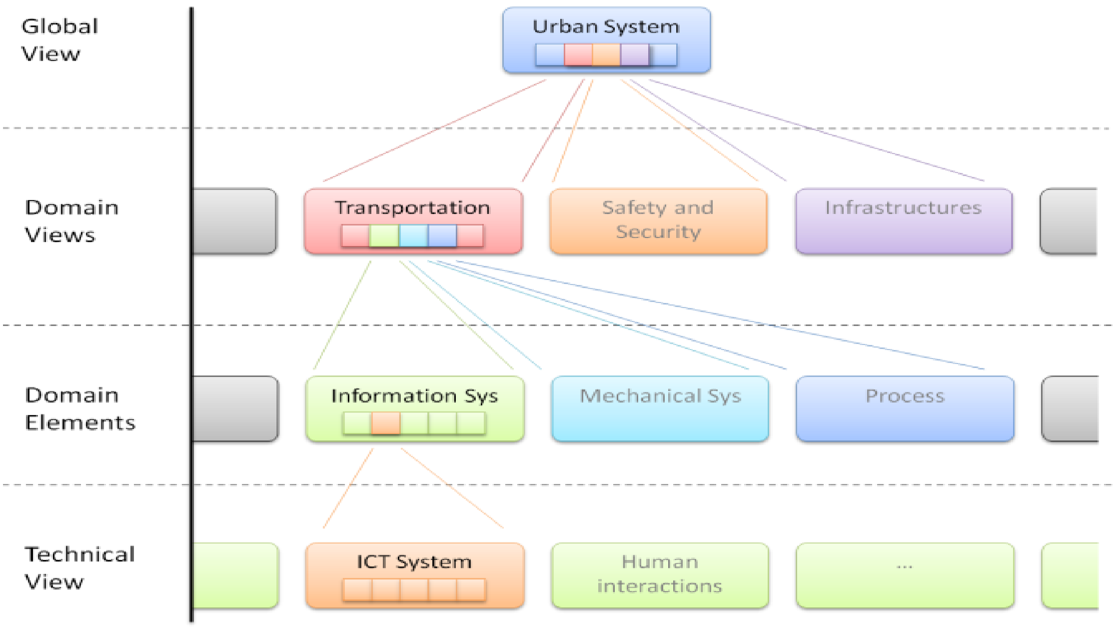
The Internet of Things (IoT) on the other hand is one of the greatest buzzwords of the last years. The term has a dual meaning in the academic community [2], referring to both a pervasive IPv6-based network resulting from the extension of the current internet to real-world objects and to a novel interaction paradigm that enables the physical and digital world to merge in one augmented world. One of the aims of IoT is also to enable machine-to-machine (M2M) communication among smart objects and between smart objects and existing applications and services [3][4] for the automation of processes.

1.1 The City System

Cities, as generally all artificial systems with a high degree of complexity, can be analysed from different domain views [6][6], each domain view, in turn, involving different containing elements (i.e. systems) belonging to different branches of engineering. The domain view is only one of the possible intermediate views introduced by the "concern separation" principle between the complex system and the atomic composing systems in order to a better control of the complexity and to allow a more accurate modelling of the system itself.

For instance, Transportation is an important urban domain that provides for the safe and efficient movement of people and goods in an environmentally responsible manner. It includes several subsystems according to the perspective we study transportation in the city: rail, water or road transport systems, passenger or freight transport systems, electrical- or fuel-based transport systems, public or private transport systems, etc.

Such a subsystem is in turn composed by elements that can themselves be more or less complex systems: road or railway network, stations, transportation users as cars, buses, trucks, pedestrians, tramways or trains, dispatchers, coordination centres, etc. Moreover, such a system is so complex that information systems are needed to monitor and coordinate transport processes in each subsystem.



In particular, emphasizing information aspects in nowadays artificial systems is particularly interesting in order to develop information systems that support the information flows in the systems.
Currently, Information Systems are very important because they are an efficient and effective tool for (at least partially) organizing, coordinating and managing complex systems. Generally speaking, all domains belonging to a complex system that should be organized should have an information system able to support internal information flows and exchange information with the information systems of other domains.

1.2 Information Systems

When developing information systems, the first and one of the most important steps is represented by the Information Model (IM) development, a documentation that models reality through information, capturing all the relevant information from a system in the real world about how information is measured/collected, transferred, stored, processed, and finally used in the system to be analysed or designed. IM consists of a (partial) description of the reality in which aspects concerning substance (mass, size, colour, position) and energy (energy loads and flows, light intensity, mechanical, magnetic, or electric forces) are transformed in information and represented only if they are relevant for the study of the reality.
IMs are used as a blueprint for information systems, essential components to almost all complex organized, artificial systems. Nowadays, considering a generic complex system, many Domain Views include information systems, which are also the way by which many composing (sub-)systems interact.
The development of an information system begins with the capture of user requirements from interviews with the system stakeholders. Requirements Engineering provides the appropriate knowledge and conceptual tools for understanding what the customer wants,

analyzing need, assessing feasibility, negotiating a reasonable solution, specifying the solution unambiguously, validating the specification, and managing the requirements as they are transformed into an operational system.
The analysis of these requirements has as result a high level model of the system. A model of a non-trivial system is usually composed of more sub-models closely related with each other and interdependent. Each sub-model emphasizes a certain aspect of the system: for example a sub-model should emphasize the system structure, other sub-models the system interactions with the environment or the system dynamics. The IM is used in the system design to first define an architecture for the future information system. In this architecture the system components and their interfaces are emphasized as information sources, processors, repeaters and sinks.
Mapping this logical architecture on technological solutions is the next step in development process in order to obtain the physical architecture of the future information system. One of these solutions is IoTP.
IoTP is a paradigm that can bridge the social and physical domains with the digital domain. The elements that allow this bridging are interface or boundary components called Adapters. They can be either information sources (sensors that generate data representing measurements) or information sinks (actuators that consume data representing commands). IoTP systems are characterized by the capability to interact (i.e. sense and, for only the physical domain, actuate on) the physical and social domains.

1.3 Project objectives

The aim of the project was to investigate the use Internet of Things and People for extending and improving the quality of the information which can be collected about cities and the processes they host. It was soon clear that IoTP could provide crucial information about the social and physical state of urban cities. This information is the knowledge of the context on which smart-city systems can reason in order to take decisions in an innovative and *smart* way.
The topic was thus changed to the development of a set of conceptual tools essential for the wide and easy adoption of the IoTP paradigm in urban systems.

2 Research planning and activities

The research activity started with the investigation of the state of the art for what concerns the IoT and IoP paradigms, and their possible application in the urban context (specifically the functionalities, architecture, features and interaction patterns of these systems). These were then analyzed in order to find commonalities and common abstractions that could fit into models. In parallel, the state of the art in systems engineering was studied in order to gain the necessary expertise in the analysis and design of complex systems.
Finally, the fundamental blocks of the reference architecture of IoTP in urban context have been developed.
During the whole process, the state of the art was monitored and integrations to the work already done were performed where needed.

2.1 IoTP State of the Art

While a shared definition of the Internet of Things (IoT) is still missing in the scientific community, it is clear that this concept is related to the trend of embedding communicating devices in and providing digitally-mediated interaction with physical objects and environments. The introduction of communication capabilities and the moving of processing capabilities to the peripheral part of the networks will also slowly move the use of Internet from human-oriented to scenarios where the main users will be machines (i.e. computing devices).
Due to its pervasiveness in the everyday environment and the impact on all fields of human activity, the advent of IoT will unavoidably also raise social, administration, privacy and security issues. In order to understand the potential of IoT the current state of the art in this domain is discussed. A general overview can be found in [7].
Taking into account [8][9][10][11], two different meanings (and thus definitions) of Internet of Things can identified: IoT as a network (of networks) and IoT as an ICT paradigm in which physical and digital entities interact in an augmented continuum where users could choose whether to interact physically or digitally with physical objects and things could have goals to achieve and can interact with other things in order to realize these goals. Description of the research program showing the details relating to activities, methodologies and theoretical and / or experimental tools used in order to achieve the intended goals.
The IoP instead is defined in this work as a paradigm of interaction between people which envisages them as nodes of a global and pervasive communication network that transfers information using the Internet infrastructure and ICT technologies. The IoP projects in digital world some of the relationships and of the interactions that exist between people in a given context (social, occupational, communities of practice, etc.). In the future, however, the data transmitted through IoP could be used also by software agents employed for the monitoring and control of social phenomena and urban processes of various kinds in physical reality.

3 Analysis and discussion of main results

This work builds upon the existing state of the art of IoT and IoP, providing a certain degree of integration of the two paradigms in the urban context. A basic model of Urban processes was introduced because no such model was found in literature, yet was needed as a basis for further reasoning.
Finally, the above key elements are used to provide a solid approach to the design of urban systems and, specifically, support the design of IoTP-based Information Systems of future (smart) cities. The innovation consists in both providing an integrated approach to urban design and in supporting state of the art paradigms such as IoT and IoP
This approach guides the system designer from the analysis and modelling of the urban context to the design of the information system that monitors and controls the system (or set of systems). The core concepts for this task are provided along with an explanation of the basic assumptions and the fundamental models that are the base for the urban IoTP reference architecture.
One of the main original contributions of this work is providing common models of IoTP interaction, domain, resource, functional and interaction that cover both IoT and IoP scenarios while providing a useful comprehensive model for urban system design.

The whole approach also takes into account as a requirement the support to Machine-to-Machine communication, which will be fundamental in future scenarios, enabling the autonomous discovery of the needed resources and thus the automation of many parts of urban processes.

4 Conclusions

Currently we have a very limited knowledge about our same cities. IoTP has the potential to provide urban actors with high quality (i.e. relevant, high spatial and temporal density) information about both the physical and the social dimension of urban processes and phenomena. This work sets the basis for the use of IoTP as the paradigm for ICT-based information systems in urban complex systems.

While this work is subject to refinement and improvement from the scientific community, it sets a clear path towards a common understanding of the IoTP paradigms and for enabling interoperability between IoTP-based applications pertaining to the same or to different domain views of the urban system. Such interoperability would unleash the true power of the IoT and IoP paradigms which resides in the synergies that can be achieved between different data collection applications.

As previously noted, this is only a starting point. The reference architecture is not complete. The security aspects should be addressed more deeply as this is one of the main barriers for the adoption of this paradigm. Interoperability should also be investigated and practically solutions and examples should be provided in a second version of this work.

Finally, a specific approach to semantics, specifically natural language processing in the frame of IoTP should be investigated. This would allow access to a huge quantity of highly valued information related to the social dimension of the urban processes generated by human beings *for* human users.

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