Cyber-Physical Objects as Key Elements for a Smart Cyber-City

Riccardo Petrolo, Valeria Loscri and Nathalie Mitton

Abstract The continuous growth of the urban population has generated a drastic expansion of our cities. Nowadays, indeed, more than 50 % of the world's population is urban, and they forecast that it will reach 70 % by 2050. Therefore, cities need to be ready to accommodate this huge amount of citizens and to face new challenges (e.g., traffic congestion, air pollution, waste management, etc.). The concept of cyber-physical systems, as integration of computation and physical processes, can help toward the realization of real smart cities capable to ensure sustainability and efficiency. To this purpose, this chapter investigates the cyber-physical system (CPS) and their cyber-physical object (CPO) as key units, in the context of a smart city concept. We survey the smart city vision, providing information on the main requirements, the open challenges, and highlighting the benefits; we also browse the European Commission initiatives for smart cities and some pilot projects that are in development.

Keywords Smart city · Cyber-physical systems · Cyber-physical objects

1 Introduction

The continuous growth of cities started with the urbanization phenomena in the late eighteenth century. Since that time, more and more people moved from rural to urban areas in order to access major opportunities for jobs, education, housing, and transportation.

R. Petrolo (✉) · V. Loscri · N. Mitton
Parc scientifique de la Haute Borne, Inria Lille-Nord Europe,
Villeneuve d'Ascq, France
e-mail: riccardo.petrolo@inria.fr

V. Loscri
e-mail: valeria.loscri@inria.fr

N. Mitton
e-mail: nathalie.mitton@inria.fr

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Following this trend, in 2010, 50 % of the world's population was living in cities [1]; as shown in Fig. 1, in the developed world the proportion of people living in cities is higher than 75 %. In China, even though the proportion of people living in cities is under 50 %, the total number of urban dwellers is greatest (559 million).

Fast Co. Design [2] forecasts that in 2050, 70 % of the world's population will be urban; therefore, it is crucial, for cities, to be ready to accommodate this huge amount of citizens and to face new challenges (e.g., traffic congestion, air pollution, waste management, water monitoring, and so on).

In this context, information and communication technologies (ICT), together with local governments and private companies, play a key role for implementing innovative solutions, services, and applications to make the *smart city* a reality [3].

Hancke et al. [4] define a smart city as a *city which functions in a sustainable and intelligent way, by integrating all its infrastructures and services into a cohesive whole and using intelligent devices for monitoring and control, to ensure sustainability and efficiency.*

This definition makes evident that the smart city concept (Fig. 2) needs interoperability between the different application domains, that are, nowadays, mainly closed and vertically integrated (e.g., smart mobility, smart living, etc.).

Aloi et al. [5] outlined the requirements for a smart city can be classified into two different types:

1. *Service/application*, considered from the point of view of the citizens.
2. *Operational*, seen from the city authorities and network administrators viewpoint.

Concerning the *service/application* aspects, the end-user devices equipped with multiple radio technologies and several sensors and actuators deployed all over the cities, make possible the individuation of novel services and applications for the

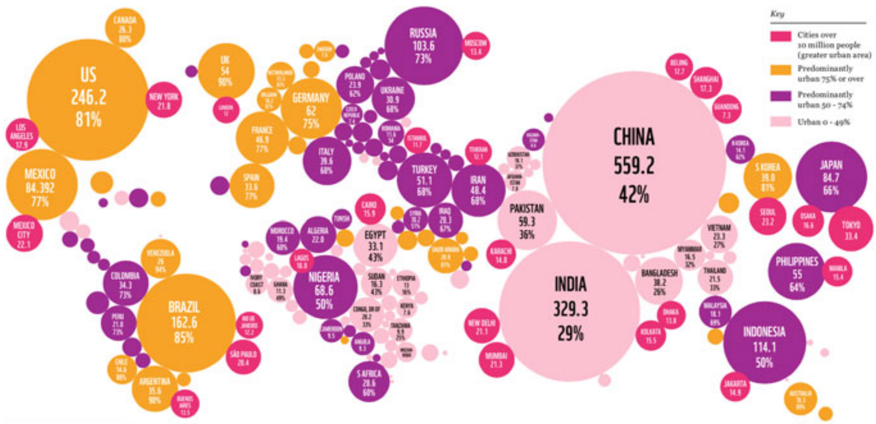
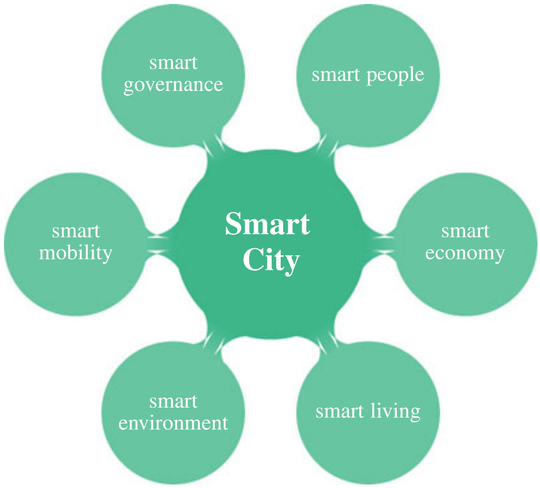


Fig. 1 Number of people together with percentage of population living in cities in each country in 2010 [41]

Fig. 2 Smart city concept



citizens. These services will have specific features, like: (a) *user-centric*: based on the specific context and the preferences of the users, (b) *ubiquitous*: reachable everywhere and from any devices, and (c) *highly integrated*: based on the integration of services and data from several and different applications or on the social cooperation of multiple users. Of course, beyond the citizens, also the stakeholders of a city, like educational institutions, health-care and public safety providers, governmental organizations, etc., will be in conditions to exploit the key features of these new services that make the city more sustainable.

On the other hand, the smart city concept considered from the point of view of the administrations and the network providers are translated into a network infrastructure, i.e.,: (a) *highly interconnected*: by overcoming the heterogeneity of the devices and the Internet of Things (IoT) platforms, it is possible to provide ubiquitous connectivity, (b) *cost-efficient*: the deployment and organization of the network should be as much automatic as possible and independent from the human intervention, (c) *energy-efficient*, able to realize an efficient resource utilization, in order to meet the main requirements of *green* applications, and (d) *reliable*: that connectivity, the ubiquity of the network should be guaranteed above all in the case of exceptional and adverse conditions. The real scenario we can observe at the moment is characterized with a high level of *fragmentation* of technologies, lack of ubiquity in terms of both connectivity and coverage, due to the plethora of technologies and devices present in a city. This *fragmentation* is mainly due to the presence of many access networks usually managed by different operators (i.e., Universal Mobile Telecommunications System—UMTS, Worldwide Interoperability for Microwave Access—WiMAX, WiFi, etc.).

The requirements aforestated trace the need of systems highly interconnected, able to communicate with the surrounded environment in order to learn, self-organize and react. To the follow, we will introduce what we envisioned as a potential "horizontal-integrator" enabler that can play a crucial role for the realization of the smart city: the *cyber-physical system (CPS)* concept and their key-elements, the *cyber-physical object (CPO)*. We will analyze as the key features of *CPS* and *CPO*, can play a primary role in the fulfillment of the smart city requirements.

2 Cyber-Physical Systems

Cyber-physical systems (CPSs) are defined by Lee [6] as the integration of computation and physical processes. The potential of such systems is enormous considering both economical and social points of view; just thinking, for example, the disparate applications achievable thanks to CPSs, to name a few, high confidence medical devices and systems, assisted living, traffic control and safety, process control, energy conservation, environmental control, and critical infrastructure control (e.g., electric power, water resources, and communication systems).

Wu et al. [7] discuss the unique features of CPS introducing also some technical challenges:

- *Cross-domain and cross-network*. Multiple types of sensors will be adopted at the same time; these cross-domain data will be exchanged over heterogeneous networks.
- *Embedded and mobile sensing*. Sensors are no longer static and may have high-degree mobility through carriers such as smartphones and vehicles, introducing then uncertainty due to the variability of the sensing coverage. Intelligent discovery mechanisms are required to analyze these mobile data.
- *Elastic load*. With the maturity of cloud computing, the *pay-as-you-go* concept, introduced by Banerjee et al. [8], is likely to be adopted in CPS to serve storage, computing, and communication needs. This allows CPS developers to focus on their own work and users to choose the part of CPS applications that they really want.
- *Accumulated intelligence*. Data in CPS may have high dynamics and uncertainty, therefore learning and data mining technologies can be useful to retrieve *knowledge*.
- *Interactions among many objects*. A lot of sensor–sensor, sensor–user, sensor–actuator, user–user, and user–actuator interactions may occur in CPS applications, therefore a flexible communication channel, like the Internet, is required.

Figure 3 shows the differences between two different approaches, middleware and CPS. The first solutions (Fig. 3a) follow a vertical architecture, indeed servers, at the virtual layer, use the network to analyze data gathered from the sensors, and then send command to the actuators. On the other hand, the CPS solution (Fig. 3b), is more independent, devices are all the same level horizontally integrated around different networks.

The above features manifest the differences between CPSs and traditional systems (e.g., desktop computer, wireless sensor networks (WSNs), etc.) and they also open

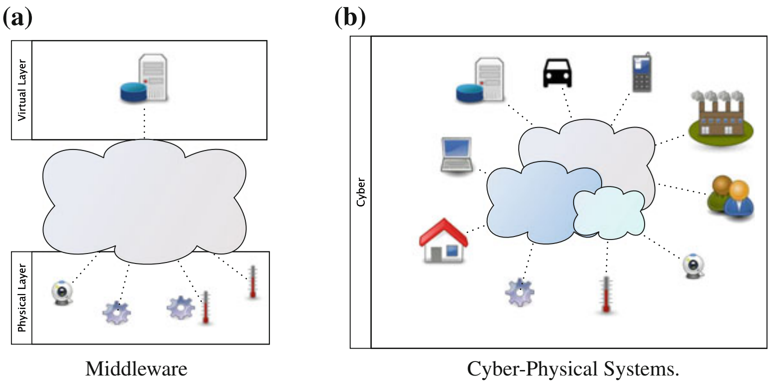


Fig. 3 Middleware versus CPS approach

new research directions on the field. It is reasonable that *networking* and *computing* aspects play a key role within the CPSs evolution; below we review the technical challenges and progresses that have been made with regards to these issues.

2.1 Networking

As own enabler of the communication between the different actors of the CPSs, the network aspect plays a key role. In the past years, researchers have focused on wireless communication and network, making significant progress in the fields of *mobile ad hoc network* (MANET) and *wireless sensor network* (WSN). CPS would take advantage from expertise in the areas of MANET and WSN since they are quite similar in many networking aspects even if there are some major differences. Roughly, while MANET is for ad hoc communications [9] and WSN is designed for delivering sensor data [10], CPS aims to construct intelligence across different domains like sensing data, crosses multiple sensor network and the Internet.

Therefore a CPS has to combine WSNs with the Internet, and a lot of inter-working issues have to be resolved. Indeed, ubiquitously deployed Internet protocols such as HTTP, TCP, or even IP are too complex and resource-demanding [11]. The *μIP* [12] includes a low-power link built on IEEE 802.15.4 for small embedded devices. IETF introduces 6LoWPAN [13] which defines mechanisms capable to fragment and to compress the header of IPv6 datagrams. In [14] authors consider multiple WSNs connected by IPv6-based *border routers* through IP link, including Ethernet, WIFi, GPRS, and satellites. COAP [15] is an application layer protocol designed for energy constrained devices. It deals with constrained RESTful environments, providing a lightweight alternative to HTTP.

All the technologies above presented, open an opportunity for future CPSs, since cross-domain end-to-end communication among *objects* is possible.

2.2 Computing

We believe that cloud computing techniques can play a primary role toward the CPS's development. In the past years, cloud computing has attracted the attention across the world, thanks to its ability of transforming service provision models over the entirely current IT industry with reduced upfront investment, expected performance, high availability, tremendous fault tolerance, infinite scalability, and so on [16]. The services offered by the cloud computing can be divided into three layers: [17]:

- *Infrastructure as a Service* (IaaS) that offers computing resources such as processing or storage.
- *Platform as a Service* (PaaS) that offers particular platform to software developers according to their specification.
- *Software as a Service* (SaaS) that offers software applications to be accessed and used by end-users.

This service *isolation* enables autoscaling and automanaging capabilities that are crucial for the future CPSs.

In addition to the above main layers, some others are also introduced and discussed in the literature such as *Data as a Service* (DaaS) [18], *Network as a Service* (NaaS) [19], and *Identity and Policy Management as a Service* (IPMaaS). The *Everything as a Service* model (XaaS) [8] promotes the "*pay-as-you-go*" method, allowing the consumption of a service by paying only for the amount of resources used. This concept is also at the base of the *Sensing as a Service* model, introduced by Perera et al. [20], in which authors delineate four conceptual layers:

- *Sensor and Sensor Owners Layer*: to manage sensors and their possible publication into the cloud.
- *Sensor Publishers* to detect available sensors and get permission to publish them into the cloud.
- *Extended Service Providers* to select sensors from multiple publishers based on customer's requirements.
- *Sensor Data Consumers Service Providers* that need to register to consume sensors data.

The advantages and benefits promised by the *SeaS* model are numerous, to name a few: *sharing and reusing sensor data* (no need to deploy other sensors, it is possible to access sensors already deployed by paying a fee to the owner), *reduction of data acquisition cost* due to the shared nature, *collect data previously unavailable* (companies are stimulated to "sell" data).

The inherent features that the SeaS paradigm is able to offer, perfectly match with the smart city requirements. First, the possibility to reuse devices and resources already available; cities are currently disseminated with many sensors and "communicating" devices that may be effectively and properly "re-used." This will embrace the philosophy expressed very well by Jochen Kreusel "Many of the building blocks for creating smart cities are already available. It is an ongoing evolution rather than a disruptive change."[1] Second, the "data shared" nature, intrinsic in SeaS, that would face in some way the problem of the big data intrinsically correlated with an ICT City.

The SeaS together with the other models of cloud computing, represent a good approach to be adopted in CPSs to serve storage, computing, and communication needs.

2.3 Actors of CPSs: Cyber-Physical Objects

In this section, we will try to "dissect" the CPS in order to individuate the atomic units of the CPS. In the following, we will refer to these elementary units/objects that constitute an important block of the CPSs as *cyber-physical object (CPO)*. In order to be integrated in sophisticated and ubiquitous CPSs, *objects* have to self-organize, learn, and react; they will be accessible via the network and queried in order to facilitate everyday life, at home, in the office, and in leisure. Examples of objects, to name some, can range from monitoring devices and sensors, home appliances, lifts, cars, buses, traffic light, parking meters, containers, security cameras, locks, alarms, water valves, wind turbines, drills, retail objects, and retail selves [21].

In [22], Kortuem et al. differentiate smart objects following three design dimensions:

- *awareness* smart object's ability to understand events and human activities occurring in the physical world.
- *representation* refers to a smart object's application and programming model.
- *interaction* denotes the object's ability to converse with the user in terms of input, output, control, and feedback.

The combination of the Internet and emerging technologies as near-field communications, real-time localization, and embedded sensors let us transform everyday objects into *smart objects* that can understand, communicate, interact, and react to their environment. Such objects are building blocks for the CPSs and enable novel computing applications.

In contrast to RFID technology—main actors of the *Internet of Things* [23] success—smart objects carry chunk of application logic that let them make sense of their local situation and interact with human users. They sense, log, and interpret what is occurring within themselves and the world, act on their own, intercommunicate with each other, and exchange information with people.

[1] http://www.abb-conversations.com/2014/10/smart-cities-intelligent-solutions-for-future-generations.

The goal of the Internet of Things is to enable things to be connected *anytime*, *anyplace*, with *anything* and *anyone* ideally using any path/network and any service.

As stated [24] the Internet of Things is a new revolution of the Internet. Objects make themselves recognizable and they obtain intelligence by making or enabling context-related decisions thanks to the fact that they can communicate information about themselves. They can access information that has been aggregated by other things, or they can be components of complex services.

Different technologies are available to connect an object, already well spread in our everyday life environment like RFID in subway, 3G with our phone, WiFi for Internet at home, etc. However, due to the very heterogeneous landscape in terms of hardware capabilities/constrains and network protocols, IP-based access is required as unifying network layer in order to turn smart objects into *Internet-connected objects* (ICOs).

Hauswirth et al. [25] point out on the need of a *semantic representation* in order to understand the data which comes out and goes into the ICO interfaces. This "*data exchange layer*" may influence discovery and routing approaches and it will be crucial to enable scalability from an application's point of view as nobody will be able to deal with the number of ICOs efficiently and scalable without such layer. The necessary technologies are already being developed and deployed: Linked Data [26] and the Resource Description Format (RDF) [27] are accepted standards in the web and provide a general model. However, these technologies need to be condensed into lighter forms in order to be used on resource-constrained devices, very much in the same spirit as CoAP was done for the service side. With light-weight semantics, ICOs will be the first-class citizens of an interned-wide semantic database that can easily be indexed, searched, and used using standard web technologies.

In order to manage those ICOs, several IoT platforms have been introduced in the literature; we review some of the most representative without pretending to be exhaustive:

- *GSN*[2] (Global Sensor Networks), provides a flexible java middleware to address the challenges of sensor data integration and distributed query processing. It lists all the available sensors in a combo box, which users need to select. GSN's purpose is to make applications hardware-independent and the changes and variations invisible to the application. Its main limitation is a lack in metadata semantics.
- *LSM*[3] (Linked Sensor Middleware) is a platform that bridges the live real-world sensed data and the semantic web thanks to many functionalities such as, wrappers for real-time data collection and publishing; data annotation and visualization; and a SPARQL endpoint for querying unified linked stream data and linked data. However, it does not offer tools for manipulating data.

[2]https://github.com/LSIR/gsn.

[3]http://lsm.deri.ie.

- Fortino et al. [28] propose a multilayered agent-based architecture for the development of proactive, cooperating, and context-aware smart objects. This architecture takes into account a wide variety of smart objects, from reactive to proactive, from small to very large, from stand-alone to social.
- *Sensor-Cloud* [29] aims at managing physical sensors by connecting them to the cloud, providing the service instances (virtual sensors) in an automatic way in the same fashion as these virtual sensors are effectively part of the IT resources. The generation of the services implies that the sensor devices and service templates (used to create the virtual sensors) and metadata should be first described by using SensorML.
- *OpenIoT,*[4] a joint effort of several contributors to IoT-based applications according to a cloud computing delivery model, provides a cloud-based middleware infrastructure to deliver on-demand access to IoT services issued from multiple platforms. It can opportunely collect and filter data from the Internet-connected objects. Its main limitation is the lack of an ontology to describe smart city concepts.
- *Xively*[5] (formerly Cosm and Pachube) offers a public cloud that simplifies and accelerates the creation, deployment, and management of sensor in scalable way. Its main constraint is due to the limitation to manage and to retrieve data just from own devices.

These approaches strengthen the importance of the cloud solutions, but a lot of new enhancements are still needed to realize platforms ready to manage a smart city. To fill this gap, in the last years the European Commission, funded several projects; some of the most representative are described in the section below.

2.4 European Commission Initiatives for Smart Cities

The enormous interest that the smart city concept has acquired is witnessed from the several initiatives that also the European Commission has activated.

The European Innovation Partnership on *Smart Cities and Communities—(EIP-SCC)* focuses on the integration of industry, citizen, and cities to try to improve the sustainability of the urban life through integrated solutions. The Seventh Framework Programme for Research and Technological Development of the European Commission funded different projects under the call smart city, in order to correctly identify and address smart city issues and challenges. Without pretending to be exhaustive, we will present some of the most representative projects that have been proposed in the European FP7 calls. *ClouT*[6] uses cloud computing as

[4]http://openiot.eu.

[5]http://xively.com.

[6]http://clout-project.eu.

an enabler to bridge the Internet of Things with the **Internet of People** via the *Internet of Services*, to establish an efficient communication and collaboration platform exploiting all possible information sources to make the cities smarter and to help them facing the emerging challenges such as efficient energy management, economic growth, and development. ClouT will provide infrastructures, services, tools, and applications that will be reused by different city stakeholders such as municipalities, citizens, service developers, and application integrator, in order to create, deploy, and manage user-centric applications taking benefit of the latest advances in internet of things and cloud domains.

SOCIOTAL[7] aims to design and provide key enablers for a reliable, secure, and trusted IoT environment that will enable creation of a socially aware citizen-centric Internet of Things by encouraging people to contribute their IoT devices and information flows. It will provide the technosocial foundations to unlock billions of new IoT information streams taking a citizen-centric IoT approach toward creation of large-scale IoT solutions of interest to the society. By equipping communities with secure and trusted tools that increase user confidence in IoT environment, SOCIOTAL will enable their transition to smart neighborhood communities and cities.

CityPulse[8] provides innovative smart city applications by adopting an integrated approach to the Internet of Things and the Internet of People. The project will facilitate the creation and provision of reliable real-time smart city applications by bringing together the two disciplines of knowledge-based computing and reliability testing.

SMART-ACTION.[9] Due to the high level of interdisciplinary work in the research produced in the areas of smart cities and the Internet of Things, it will be necessary to understand, coordinate, support, and engage not only the technological elements, but also other areas such as biotechnology, social sciences, and nanotechnologies, just to name a few, that provide the right context in which Internet of Things concepts can be embedded and will be used to provide solutions that can benefit society at large.

SMARTIE[10] aims to create a distributed framework to share large volumes of heterogeneous information for the use in smart city applications, enabling end-to-end security and trust in information delivery for decision-making purposes following data owner's privacy requirements.

VITAL[11] [30] objective is the integration of ICOs among multiple IoT platforms and ecosystems. The project explores the convergence and federation of multiple IoT platforms by taking account of the cost efficiency of the deployments. In the context of VITAL, an important key factor is represented by the *virtualization* of

[7]http://sociotal.eu.

[8]http://www.ict-citypulse.eu.

[9]http://www.smart-action.eu.

[10]http://www.smartie-project.eu.

[11]http://vital-iot.eu.

interfaces that in combination with cross-context tools that enable the access and management of heterogeneous objects supported by different platforms and managed by different administrative stakeholders [31, 32].

As we shown in Fig. 4, the data and services' access of the heterogeneous objects involved in VITAL is based on the implementation of the VUAIs (Virtualized Universal Access Interfaces) that makes possible to consider a single virtual access by making the architecture platform-agnostic. The VUAI layer is built upon a so-called meta-architecture and migration layer and includes several connectors to communicate and interconnect different IoT platforms and clouds. In practice, this module deals with issues related to the management of the overall VITAL infrastructure built on the top of existing IoT architectures and cloud platforms and enables heterogeneous mashup. The VUAIs allow the implementation of a kind of abstraction, where "objects" handle that point to physical items, can be discovered, selected and filtered and also allocated.

VITAL also includes a data store for data like geographical information and smart city stakeholders. Of course, it is expected that the management of this kind of information giving location awareness and other context-related information can be effectively exploited in the optimization of computing and sensing of the management of the various clouds.

It is worth outlining that VITAL is based on W3C SSN ontology [33] that is considered ideal as a basis for unifying the semantics of different IoT platforms, since it is domain independent and extensible. Several additional concepts have to be considered to enhance the ontology starting from information about city-wide, stakeholders, IoT system, etc. The ontology update with additional functionality will allow the migration of smart city application across different urban environments.

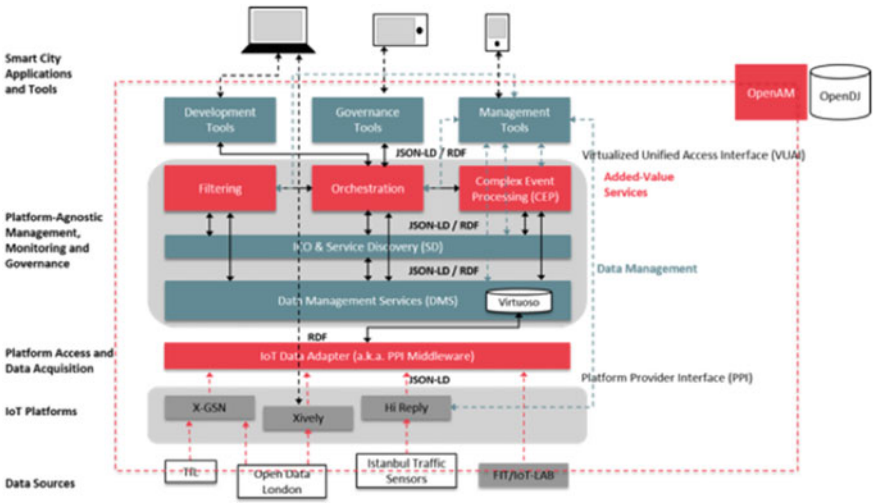


Fig. 4 VITAL platform

3 Smart Cyber-City

A *smart cyber-city* is a city where the urban environment is an integration between people, processes, places, and technologies. This ecosystem is able to self-organize and to react in order to adapt itself to the surrounding situations.

Different can be the scenarios within this context; Libelium, [34], lists 50 sensors-based applications for a smarter world (Fig. 5), to name a few, air pollution, quality of shipment conditions, smartphones detection, radiation levels, traffic congestion, water quality, waste management, smart parking, electromagnet levels, smart roads, smart lighting, noise urban maps, vehicle auto-diagnosis, and intelligent shopping.

In most urban settings, the *town center* can be considered as the core of major socioeconomic activities including tourism, social, business, shopping, work, traveling hubs (bus or train stations), education (colleges/universities). Typically, a number of people commute to the town center at different times on weekdays (mostly for work) and over weekends (shopping, work, leisure, etc.) and act as a stimulus to the socioeconomic development. These activities create an environmental track that requires to be managed in a smart way in order to migrate any negative effects on these town centers. For such purpose, the *smart city* needs a core requirement of pervasive, interconnected communication infrastructure, and access to contextual information of its citizens and physical spaces by data sensing,

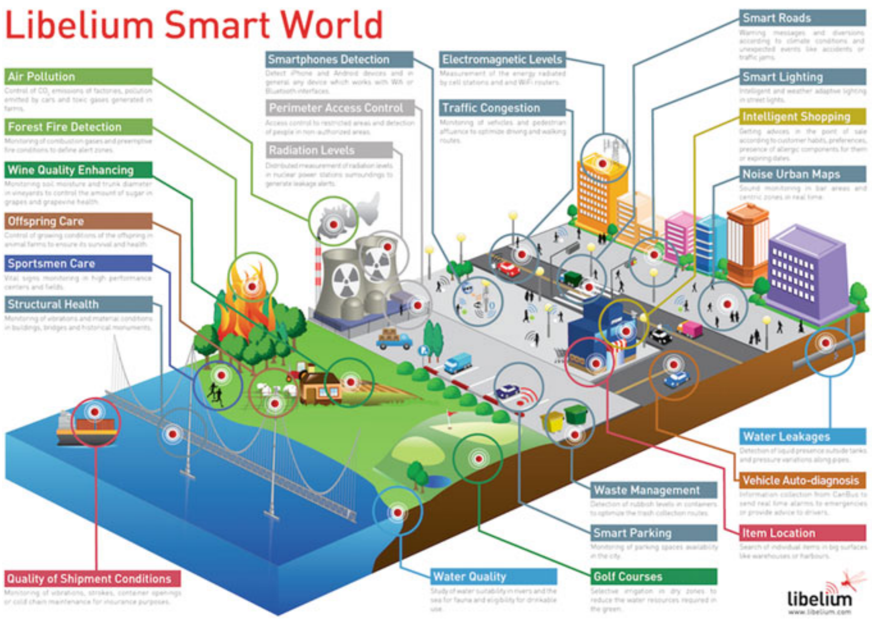


Fig. 5 Libelium Smart World vision [34]

processing and useful information for different stakeholders for consumption and decision-making [35].

For instance, a common scenario can be location of empty parking spaces during peak hours using smartphones. Another scenario relies on the information about number of vehicles available on specific roads of town center which can be detected by specific counting sensors and/or vehicle fitted with GPS devices. This information helps in route optimization by providing a traffic congestion map in real-time to the citizens who are planning to visit/leave the city and assist their decision-making toward their mode of transport (private, public) and route planning. Other scenarios concern security applications, road management, waste management etc.

Interesting technologies and solutions are introduced and discussed in the literature.

Dimitrakopoulos [36] envisions the *Internet-Connected Vehicles* concept, in which vehicles and objects of the transportation infrastructure are connected through an all IP-based infrastructure capable of exchanging information directly or indirectly and appropriate for resolving several kinds of issues, so as to result in a more efficient, safe, and green world of transportation.

In [37] Dagher et al. propose *Ubiquitous Navigation System* (UNS), a WSN-based navigation system which takes benefit from the smart street lightning system to provide a local navigation service. The idea of the authors is to make use of the already deployed WSN infrastructure for smart street lightning to provide a GPS-like service to the vehicles in the city. This WSN-aided navigation becomes important especially in cluttered and urban environments or undergrounds where GPS reception fails, thus providing a continuous smart navigation service to the user.

Crowd sourcing consists of outsourcing tasks to a "*crowd*" in an attempt to collaboratively completing tasks quickly. With smartphones becoming increasingly more powerful in terms of resources, and fitted with a variety of sensors such as GPS, gyroscopes, accelerometers, and compasses, it is possible to enable a variety of crowd sourcing applications [4]. MobSens [38], for instance, is a crowd sourcing application that can monitor air pollution and the noise levels.

The above solutions strengthen the vision toward the development of a smarter city. However, we believe that in order to realize the smart cyber city concept, those applications need to communicate and interact; CPS can play a key role as enabler of this synergy between the different actors.

3.1 Smart City Pilots

The smart city concept is still far from being realized, due to its highly autonomous and intelligent features. Indeed, the available technology is not yet sufficiently mature for smart cities to be truly autonomous, despite the recent breakthroughs in technology. However, there are currently pilot projects of smart cities in development worth mentioning.

SmartSantander [39] is a pilot project which has recently received significant attention. This is unique in the world city-scale experimental research facility in support of typical applications and services for a smart city. The test-bed deployed has dual purpose; one allows real-world experimentation on IoT-related technologies (protocols, applications, etc.), the second is supporting the provision of smart city services aimed at enhancing the quality of life in the city of Santander. Different devices have been installed: *fixed sensor nodes* attached to public lampposts or to building façades, which can observe a wide range of physical magnitudes (e.g., light intensity, noise, carbon monoxide, air temperature, relative humidity, solar radiation, atmospheric pressure, soil temperature, wind direction, etc.); *mobile sensor nodes* installed on the top of public transport buses, taxis, and other municipal services vehicles; *parking monitoring sensor nodes* buried under the asphalt on outdoor parking places; *traffic monitoring sensor nodes* buried under the asphalt on the main entrances to the city; *QR and NFC tags* located at city Points of Interest (POI) (e.g., monuments, bus stops, local administration premises, shops, etc.) which represent a key asset for the augmented reality service.

The development of Songdo [40] in South Korea, started from the scratch in 2001 and is predicted to be complete by 2018. Smart systems in every building are used to monitor the water and electricity, which also allow residents to connect remotely using their smartphones. Sensing technologies include RFID tags on vehicles which send signals to sensors on the road to monitor traffic flow, surveillance systems as well as smart street lights, which can be adjusted to pedestrian traffic.

Amsterdam has seen some recent developments en route to make it a smart city. The main operator of this development is Amsterdam smart city project,[12] started in 2009 with the main goal of increasing green growth using technology. Different initiatives started in specific city locations, like for example an intelligent electricity network (Smart Grid) developed in the New West district, which promises to reduce the number and duration of power outages; to improve the opportunity to feed consumer-produced electricity back to the grid; to increase capability to support the integration of electric-powered vehicles, etc.

Other important initiatives involve Barcelona.[13] Sensors have been deployed in garbage bins, allowing remote monitoring of the content of bins and optimizing garbage collection service. Additionally, the city council installed smart water system for telemanaging the irrigation of the city's green spaces, an initiative that is as good for the environment as it is for the economical aspect, with its use of latest generation technology for better resource management. Sensors on street lights detect presence and adjust the light intensity accordingly as well.

[12] http://amsterdamsmartcity.com.

[13] http://smartcity.bcn.cat/en.

London and in particular Camden Town, is one of the two cities involved in the VITAL project. Different sensors and data feeds are already available in Camden, like *cameras* used for monitoring traffic, public transport, and safe shopping; *GPS and location sensors* used for deriving information about the positioning and the status of waste collection vehicles; *meteorological data feeds* used to provide relevant information to tourists; *traffic data streams* used to balance load on public and private transport; *security data streams* used for monitoring as per national policy directives; *disaster prevention data streams* used for monitoring as per disaster plans and simulations. The aims of Camden is to boost targets of its business strategy like reducing the cost of business operations, with a view to make it an attractive destination of commercial, retail, and leisure activities; strengthen Camden's links to neighboring areas/districts (such as Euston and Kings Cross), and so on.

The other city partner of VITAL is Istanbul. As one of the largest cities in the world, Istanbul has a population of 13.9 million on a surface area of 5313 km^2. This cosmopolitan and historic city needs to meet the challenge of maintaining transportation safety and accessibility since it continues to become an important international metropolis with increasing traffic numbers. To ensure effective and efficient use of the current main arterial road network, traffic management in Istanbul is a critical issue. To deal with those issues, the idea is to develop, install, maintain, and operate intelligent transportation systems and their infrastructure including traffic monitoring and supervision cameras, radar detectors, sensors, and so on.

The Expo Milano 2015[14] is announced to be full of digital technologies that will make the overall experience easier. The visitor can use dedicated services through the multimedia Totem or smartphones that will guide them during the visit and that can be personalized according to the person's interests or available time. The smart city experience is not just limited to the exposition site but can also be used when visiting the city of Milan.

The Sunrise Lille project aims to transform the Lille1 University[15] environment into a semi-scale pilot testbed for the research, development, field assessment, and large-scale demonstration of innovative smart urban networks (SUN) for upgrading strategic and operational management capabilities of metropolitan infrasystems as water, energy, and heating supply. The major advantage of Lille1 project is to bring together governmental agencies, industry and academia, and customers.

Starting in 2012, the Sense-City project[16] will offer a suite of high-quality facilities for the design, prototyping and performance assessment of innovative, micro- and nanotechnology-based sensors devoted to urban instrumentation. Acknowledging the shortcomings of evaluating sensors performances in laboratory conditions only or in the ever-changing environment of our cities, Sense-City will provide a realistic urban test space in climatic conditions, far more complex than

[14]http://www.expo2015.org.

[15]http://www.univ-lille1.fr.

[16]http://www.sense-city.univ-paris-est.fr.

Table 1 Smart city projects

City/project	Purpose
Santander, Spain	Testbed platform; smart parking systems; environmental monitoring; traffic monitoring
Songdo, Korea	Smart buildings; tags on vehicles; sensors on the road; smart lighting
Amsterdam, the Netherlands	Smart grid; smart energy management
Barcelona, Spain	Smart garbage bins; smart water systems; smart parking; smart lighting
Camden Town, England	Traffic data; meteorological data; disaster prevention
Istanbul, Turkey	Smart traffic management
Milan, Italy	Augmented reality service; smart services
Lille, France	Testbed platform; upgrade strategic and operational management capabilities of metropolitan infra-systems
Sense-City Project	Testbed around mini-city concept; urban sustainability (quality of air, water, etc.)

clean rooms and far less complex than actual cities. Sense-City revolves around the mini-city concept, a large, fully customizable climatic hall able to host full- and reduced-scale models of essential urban components. The design of the models will allow for the simulation in climatic conditions of numerous scenarios of sustainable cities. The scenarios to be implemented will correspond to different research topics related to urban sustainability: energy performances in buildings, quality of air, water, and soils, quality of fluid distribution networks (gas, sewage, drink water), control of waste disposal areas, durability, and safety of infrastructures.

Table 1 summarizes the goals of the cities/projects discussed above.

4 Conclusion

This chapter focuses on the concept of cyber-physical objects and how they can help toward the realization of real smart cities capable to ensure sustainability and efficiency. Specifically, we survey the requirements and challenges in terms of *networking* and *computing* for cyber-physical system, highlighting that lightweight technologies, which enable cross-domain end-to-end communication among objects, together with cloud computing techniques can play a primary role in the field. We presented some of the most representative solutions capable to manage CPO, underlining that a lot of new enhancements are still needed in order to realize platforms ready to manage complex systems such as a smart city. In order to fill this gap, the European Commission has funded different projects under the call smart city of the Seventh Framework Programme for Research and Technological Development. We browsed the most interesting proposal, together with some of the smart city pilots already developed across the world.

The above solutions represent the first step toward the realization of the smart-cyber city concept, but still more integration is required between people, processes, places, and technologies. Only then, this ecosystem will be able to self-organize and to react in order to adapt itself to the surrounding situations.

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