BIG DATA: A CHALLENGING OPPORTUNITY FOR THE ENVIRONMENTAL SUSTAINABILITY

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Abstract: There is a general consensus that the Internet of things (IoT) is set to change how we work and interacts with the world in every possible manner. IoT will create opportunities for more direct integration of the physical world with computer-based systems, thus producing new and improved services.

The possibility to collect and analyze a large quantity of data, and communicate in various ways (such as Device-to-Device, Device-to-Cloud, Device-to-Gateway, and Back-End Data-Sharing) open up new challenging scenarios.
Smart cities are an example of how to exploit IoT and Big Data analysis coming from various sources, e.g. transportation, weather, building status, energy consumption, etc.
This paper illustrates how the Smart and Connected Communities (SCC) that are an emerging concept which aims to exploit state-of-the-art technologies, such as Big Data and IoT, can promote sustainable development of rural and urban communities.
The aim of this paper is to provide an exploratory analysis of the use, efficacy and contribution of SCC to an eco-compatible development. The major challenges in SCC are also discussed.
Keywords: Internet of Things, smart city, smart connected communities, Big Data, sustainable development.

1. INTRODUCTION

Since its creation by Tim Berners-Lee in late 1989, the internet has evolved through four main stages[8], namely the Web of documents (Web 1.0), the Web of people (Web 2.0), the Web of data (Web 3.0), and, now, the Web of things (Web 4.0).
The main comparative differences between Web 1.0, Web 2.0, Web 3.0, and Web 4.0 are detailed in table 1.

Web 1.0	**Web 2.0**	**Web 3.0**	**Web 4.0**
1996-2004	2002-2016	2006+	2014+
Read Only	Read and Write Web	Executable Web	Interoperating Web
Links	People participation and Interaction	Understanding contents	Full connections
Websites	Social networks	Semantic web	Internet of things
One Directional	Bi-Directional	Multi-user Virtual environment	Multi-layer real-virtual environment
Static content	Dynamic content	Intelligent analysis	Intelligent actions

Table 1.A few distinguishing characteristics of the Web stages

Nowadays, the internet continues to grow exponentially, and massive quantities of data are ever more accessible [16]. Recently, Artificial Intelligence solutions and Big Data tools are introducing new opportunities to overcome the limitations of the traditional web-based applications [9, 35].

However, to understand the potential of the latest stage of the internet, Web 4.0, we have to reckon thatmost of the new devices incorporate features that enable interaction with other devices or people. Several of them can auto-regulate themselves andexchange data with human beings, virtual agents, and physical smart objects. This new communication and interaction paradigmis known as*the Internet of Things* (IoT), or *Internet of Everything*[13, 19]. The IoT has been defined as "a worldwide network of uniquely addressable and interconnected objects, based on standard communication protocols"[18]. It enables applications whereby people caninteract with real-world objects, as well as applications based on network-assisted machine-to-machine interchanges (Figure 1).

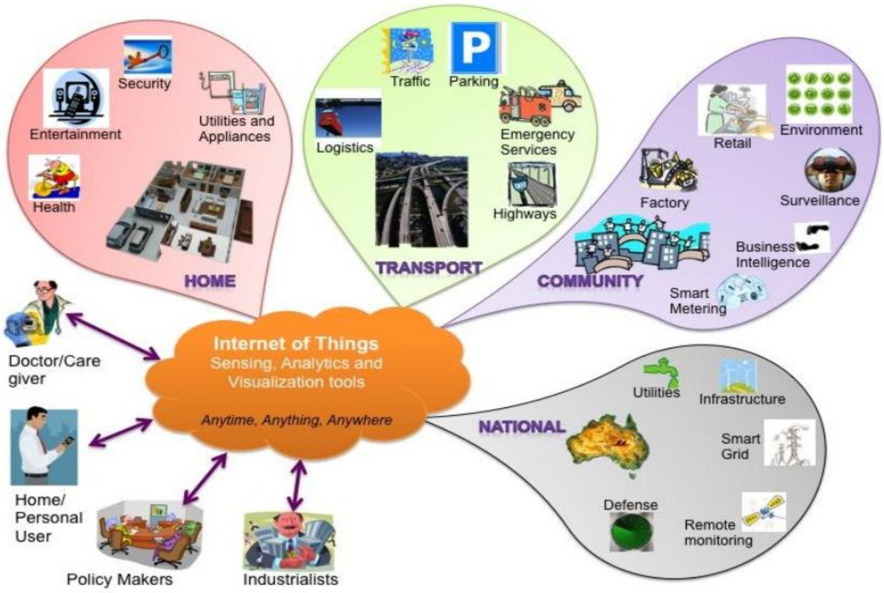

Figure 1. The Internet of Things schematic representation (source: from Gubbi, Buyya, Marusic,& Palaniswami, 2013)

The IoT is set to change how we work and interact with the world in every possible manner. Many applicationsbased on the integration of data gathered via smart sensors and deployed in the domestic environment are already operative [17]. Here are just a few of theavailable opportunities:

- Smart thermostats optimise energy usage by processing data from sensors, real-time weather forecasts, and the actual presence of people in the home.
- Sensors can measure electrical current on a line and calculate consumption levels, and send that data to a hosted application for analysis in order to cut cost and detect malfunctions on the basis of anomalous use.
- Smart sensors enable the switching on and off of any plugged-in device at home or from across the world, thus eliminating standby power use.
- Soil moisture sensors can turn on the garden irrigation system at a scheduled start time or shut it off.
- Smartphones equipped with sensors, such as Accelerometer, Gyro, Proximity, GPS, etc., can automatically monitor movements, location, and workouts.

- Sensors placed around rooms can check the movement of vulnerable persons and alert relatives when any serious risk is detected.

Today, the internet acts as a cost-effective channel for running services and for connecting citizens and institutions, as well as employees, customers, and suppliers. Unlike any other medium of communication, it facilitates the flow of information on a massivescaleat minimum cost. The opinion is also widely shared that the Internet can enhance innovation, creativity, economic opportunity, and social inclusion [4].

This paper aims to illustrate how an emerginginitiative developed to exploit state-of-the-art communication technologies, the so-called *Smart and Connected Communities* (SCC), can promote the sustainable development of rural and urban communities.

2. THE CONCEPT OF SMART AND CONNECTED COMMUNITIES

In 2009, IBM launched a program called *Smarter Cities* to investigate the integration and application of new sensors, networking, and analytics to urban centres [15]. Similarly, in 2012, Cisco created anew divisionnamed*Smart and Connected Communities*to commercialise its new products and services developed throughpilot projects conducted in 3 major world cities, namely Amsterdam, San Francisco, and Seoul [7].

These initiatives share the vision,matured at the beginning of the 2000s, that the ICT industry is able to provide cities with new and effective tools to help their sustainable development [1]. The notion of SCC embraces a collection ofinitiatives rather than a tightly defined discipline [12], andCisco,which coined the term SCC, usesit to indicate an orientation towards digital innovation in order to create new revenue and better serve citizens. The *Smart+Connected Digital Platform* promoted by Cisco isa pay-as-you-go cloud-hosted service for aggregating, analysing, and correlating data from wired or wireless sensors.

It has been argued that SCC can be represented as the synergetic interconnection of fourneeds[30], specifically: remembering the past (*preservation* and *revitalisation*); living in the present (*liveability*); and planning for the future (*sustainability*).In more detail, *liveability*comprises many aspects of life, from equitable and affordable housing to traffic flow management and the reduction of travel time and fuel consumption.*Preservation* concerns both cultural and natural heritage that are threatened by the increasing levels of pollution and the deteriorating quality of the environment, as well as by the changes in socio-economic conditions.*Revitalisation*addresses the challenge of the decline of rural territories and the rapid growth of metropolitan areas. Finally, *sustainability*refers to the ability ofthe development to meet the needs of the present without compromising thefuture of later generations [27].

We would suggest completingthe SCC framework by the adding oftwo further elements: *social innovation* and *harmony*.

Social innovation is any novel and useful solution to a social need or problem that is better than other existing approaches, and which creates benefits to social communities rather than to private individuals [26]. Indeed, there is a general consensus that innovation is *social* if it enhances social welfare [21]. We proposedto include social innovation in the SCC framework since it is crucial for anycommunity sustainable development. Social innovation appears to be a means to improve social capital in both the profit and non-profit sectors, and may referto ethical norms, such as fair business practices and respect for worker rights, or to values, such as justice, solidarity, and cooperation [23, 24]. Social innovation can also involve the artistic disciplines, since artistic creativity can be instrumental to social change [33]. Finally, it is related to the political sciences and bureaucratic organisation, since many social innovations are services, often public sector services, aimed at providing new and more effective benefits to citizens [25, 3, 31].

The multifaceted notion of social innovation motivated the introduction of *harmony* as a second additional essential factor that characteriseSCC. Harmonyis a human perception that can be associated with social and ecological situations. The concept of harmony includes the consonance and balance of diverse and even opposing elements as many in one. Indeed, the word *harmony* is of Greek origin, and carries the idea of the integral wholeness of all living things in the cosmos.Harmony is a concept that is studied in environmental sociology [22] as well as in ecology and architecture. Harmony qualifies relational processes and, accordingly, should regulate community interactions and interchanges.
Figure 2 synthesisesa five-element SCC framework.

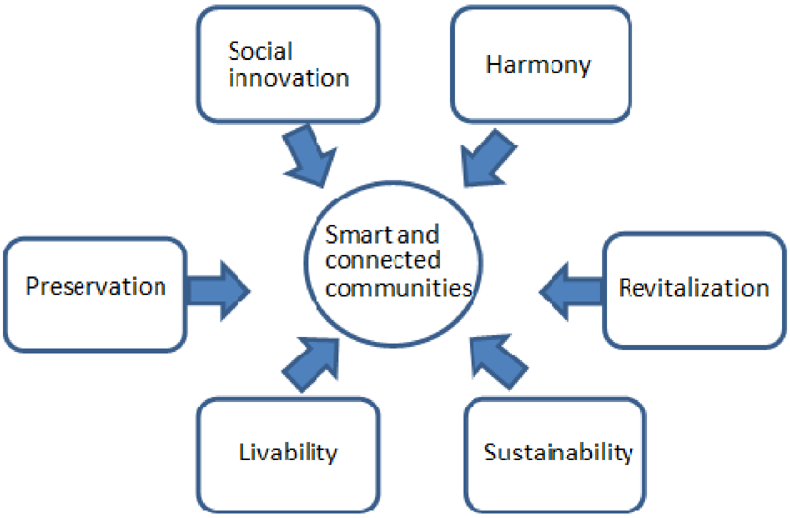

Figure 2. The SCC framework

The current literature reveals that the technical design of SCC consists offour distinct layers [2, 20, 30, 29]. These layers are: sensing layer, interconnecting layer, data layer, and services layer (Figure 3).

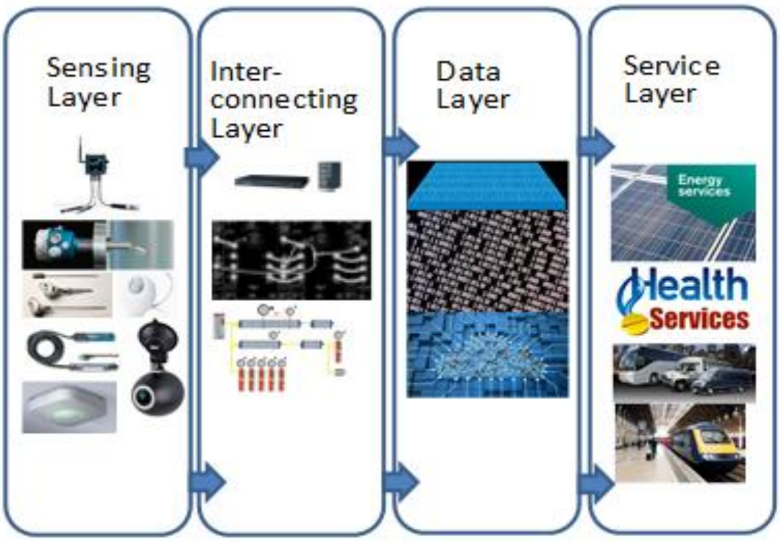

Figure 3. SCC four-layer architecture

The service layer, also called the application layer, is tasked with the primary objective of offering communities different administration capabilities.
The data layer is tasked with various objectives such as storing the big, inconsistent and variable data that are created by the diverse types of monitoring devices in the sensing layer; mining valuable data from the huge sensing data pools and identifying the significant information in a rational and productive manner; basic leadership and administrative support; and knowledge preservation and administration.

The interconnecting layer is tasked with the primary objective of the transmission of information and the interchange of data among various domains and devices.

The sensing layer is tasked with the primary objective of acknowledging global sensing. Besides RFID (Radio-Frequency Identification) sensing which is empowered by wireless sensor networks (WSN), individually driven urban sensing is gaining wider recognition. Individually-driven sensing can be classified into three different groups: social sensing, which concentrates on disseminating information in distinct and social interest communities; personal sensing, which focuses on individual observation and documentation; and public sensing, which concentrates on imparting information to everybody for the betterment of the populace (for example, recreational or group activities). Public sensing and social sensing can both be mutually referred to as community sensing, opportunistic sensing, or participatory sensing. Furthermore, thanks to the ubiquitousprevalence of smartphones with different sensors, for example, audio, GPS, camera, accelerometer, compass, gyroscope, ambient light, proximity, and much more, another community sensing model, known as mobile crowdsensing (MCS), is alsorapidly evolving.

3. OPPORTUNITIES FOR ENVIRONMENTAL SUSTAINABILITY

ICT-based participatory procedures and crowdsourcing processes, namely the “mechanism for leveraging the collective intelligence of online users toward productive ends” [5], can be used to increase community cohesion, or to influence and improve local government decision-making processes. There are several opportunities for developing new community services based on IoT and Big data analytics, for example:

- Emergency Monitoring and Response
- Municipal Traffic and Parking Management
- Citywide Building Monitoring
- Municipal Utilities Management
- Access Control
- Smart Card
- Energy Management

However, two application sectors, the smart grid (SG) and the unmanned aerial vehicle (UAV), have demonstrated how SCCs can stimulate innovative and environmentally sustainable initiatives.

SGs represent a new frontier in the way we produce, distribute, and consume energy. They are complex systems,since their development requires significant efforts in terms of technology, standards, and policies [10, 11]. AnSG is an electricity network that intelligently integrates the actions of all the users that are connected to it. The current power networksare based on centralised systemsin which electric power flows unidirectionally through transmission and distribution lines from power plant to customer.Conversely, anSG realises a flexible network that is based on higher and widely distributed intelligence embedded in local electricity production, bidirectional electricity, and information flows, thus achieving reliable, flexible, efficient, economic, and secure power delivery and use[36]. The Figure 4 shows an SG four-layer architecture.

The basic mechanisms of an SG [10]are:

- Energy feedback to home users to promote a more accurate energy consumption.
- Energy consumption information for building operators to optimise the energy requirements in buildings.
- The inclusion of distributed micro-generation based on locally distributed clean, renewable energy sources such as wind and solar.
- Real-time demand response and management strategies for lowering peak demand and overall load.

An experiment conducted in the city of Amsterdam by IBM and Cisco demonstrated that an SG application can reduce blackouts and faults, improve responsiveness, handle current and future demand, increase efficiency, and cut costs [6].

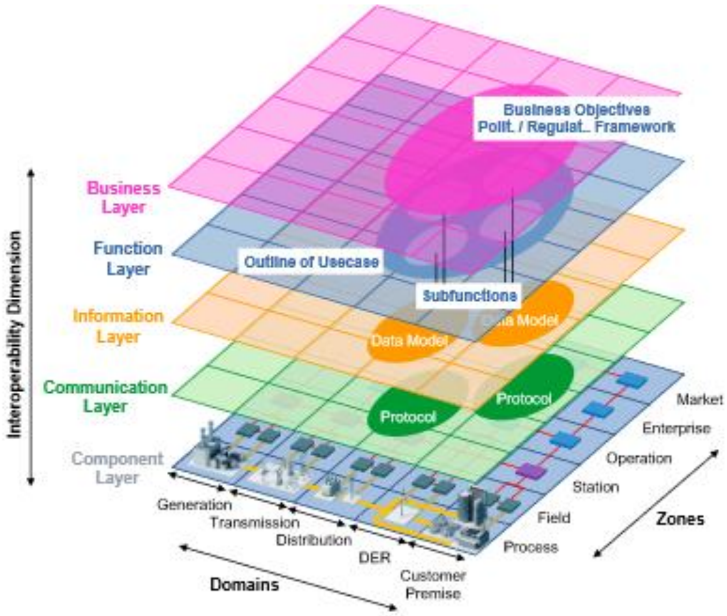

Figure 4. Smart Grid Architecture Model (source: Trefke et al., 2013)

Inregardsto UAVs, several opportunitiesexist forvery useful applications, such asmonitoring environmental hazards, traffic management,natural disaster control and monitoring, and pollution monitoring.A UAV is an aircraft without a human pilot or passengers, commonly known as a drone. It is essentially a remotely controlled flying robot that can fly autonomously by means of software-controlled flight plans and onboard sensors and GPS. Figure 5 shows a commercial multi rotor UAV especially designed for professional aerial photography and electric power line stringing and inspection.

Figure 5. A commercial unmanned aerial vehicle

UAVs are used for civil applications in geospatial surveying and environmental analysis.One use of UAVs can be security management, for example to manage big public events with huge numbers of participants. In the recent earthquake in central Italy, UAVs were used to evaluate the scale of thedamage (Figure 6).

Figure 6.Drone footage that shows the basilica of San Benedetto in Norcia

The development of UAV applications present many technical challenges:

- fail-safe systems in the case of aircraft failure
- very efficient solution to ensure low vibration
- flying precision during both day and night
- effective image data compression algorithms
- integration with smart sensors

In the last few years, applications inspired bythe SCC paradigm havemultiplied [29],also in new interesting sectors such as tourist information systems. This is the case of the TreSight, an initiative that provides an innovative tourist experience in Trento, Italy, by leveraging bracelet-based mobile crowd sensing and big data analytics.

However, technical issues aside, it must be noted that the implementation of SCC solutionsnecessarily introduces other issues such as privacy, since theIoT and Big data technologies gather and process masses of protected data. In this respect, the development of the SCC paradigm should include the harmonisationof both technology and legislation, since not everything that can technically be achieved or that an organisation would like to develop can actually legally be done.

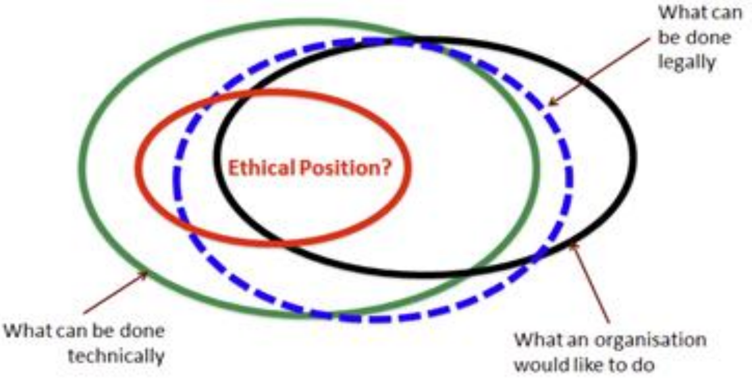

Figure 7. The ethical issue related to the use of the IoT and Big data

Figure 7illustrates how technology, legislative regulations, and organisational behaviours can generate ethical issues. In contemporary society, the protection of personal data is an ever-growing concern because the exponential increase in the use of online Big Data analytics necessarily requires a wide quantity of data, often of a personal nature, to create new predictive models, and this obviously raises the issue of personal data protection [28].Personal health information is the most at risk, especially that collected in low- and middle-income countries.

4. CONCLUSION

Profound changes will affect the world population in the next few decades. The*World Urbanization Prospects* published by the United Nations reports that half of the world's population (54 per cent) reside in urban areas [34]. By 2050,the forecast is that 66 per cent of theworld's population will live in urban areas, compared tojust 30 per cent in 1950. Consequently, thedevelopment of ICT-based community innovative services is fast becoming a necessity rather than an opportunity. Monitoring and managing energy consumption, green buildings, and green planning, as well as running healthcare services at a distance, and the intelligent management of waste and water resourcesareall essential for liveability, both for urban and rural contexts.

This article highlights the concept of SCC,including two new elements in its framework, namely social innovation and harmony, that are synergetic with the needs of remembering the past (preservation and revitalisation), the needs of living in the present (liveability), andthe needs of planning for the future (sustainability).

Although,so far,Big data analytics has mostly focused on marketing and business intelligence, the new technologies have the potential to enable innovative solutions for the development of SCC. The combination of IoT and cloud computing, in particular,could provide a ubiquitous networkof connected devices and smart sensors for SCC initiatives, and can contribute to the evolution of environmental sustainability.

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