Smart Cities: An Overview of the Technology Trends Driving Smart Cities

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Technology trend papers aim to highlight key technologies that are shaping the world around us and impacting the daily working life of IEEE Members. They offer a high-level overview of a technology area and sufficient information for IEEE Members to be aware of upcoming technologies. This paper is a part of the series and focused on smart cities highlighting several key technology trends driving their growth.

Background

According to the United Nations Population Fund, in 2014, 54% of the world's population lived in urban areas, approximately 3.3 billion people. By 2030, roughly 66%, or 5 billion people will live in urban areas[1]. This not only represents a massive challenge in how we build and manage cities but a significant opportunity to improve the lives of billions of people. Rising to that challenge, engineers worldwide are turning to new technology - such as the Cyber Physical Systems, 5G and data analytics - searching for new approaches and solutions that will improve city transportation, water and waste management, energy usage, and a host of other infrastructure issues that underpin the operation of cities and the lifestyle of urban citizens.

There are many definitions for smart cities, ranging from those that focus exclusively on the infrastructure to those that focus more on enabling citizens and communities to act smarter. While no one definition suits all cities, a useful definition[2] we use in this series is from the ITU:

A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.

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[1] http://www.unfpa.org/urbanization

[2] http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

This definition, emphasizes that a smart city is not just a city that leverages new technologies, but is a complex ecosystem (Figure 1) made up of many stakeholders including citizens, city authorities, local companies and industry and community groups. It should be emphasized that the geographical boundaries of what is called a smart city may be wider than the city itself, gathering multiple governance bodies and municipalities to define services at the metropolitan or regional scale.

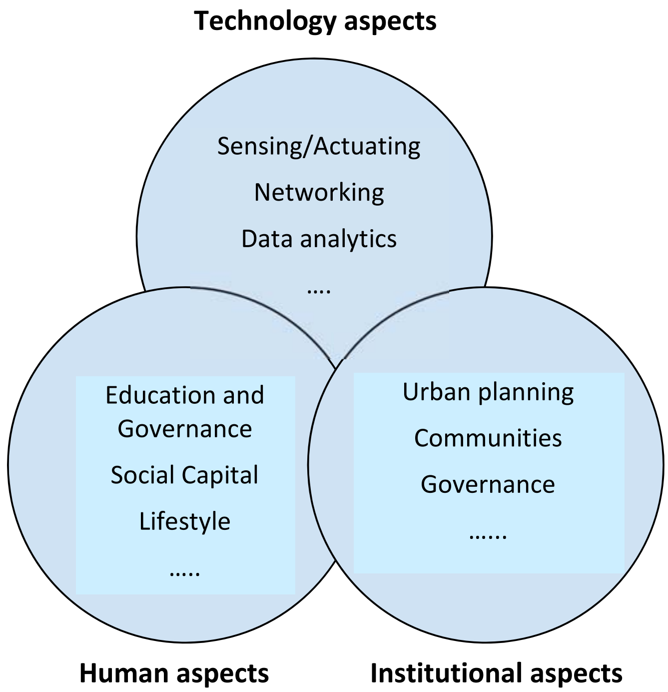

Figure 1. Smart cities as complex ecosystems.

In this report, we focus on technology trends that are shaping how smart cities are evolving. However, it is important to ensure that, when considering the application of technologies to solve problems, the human and institutional aspects are taken into consideration. In essence, a cardinal goal of the smart city is to create value for its entire ecosystem, whether this value is financial, quality of life, health, education, or time. The value created by a smart city can be assessed using both quantitative and qualitative metrics.

Smart City Technological Ecosystems

From a technological perspective, the smart city ecosystem is a complex one comprising many technology areas. Major players operate in several areas, providing solutions that complement (and sometimes overlap) other players. Those companies that are able, are working toward a convergence point where they can provide end-to-end solutions for city technology needs. However, most players lack the scale to achieve this and must work in collaboration with partners from other technology segments. To visualize the technology ecosystem, we can identify five key technology groupings (based loosely on a Frost and Sullivan report[3]) as shown in Figure 2.

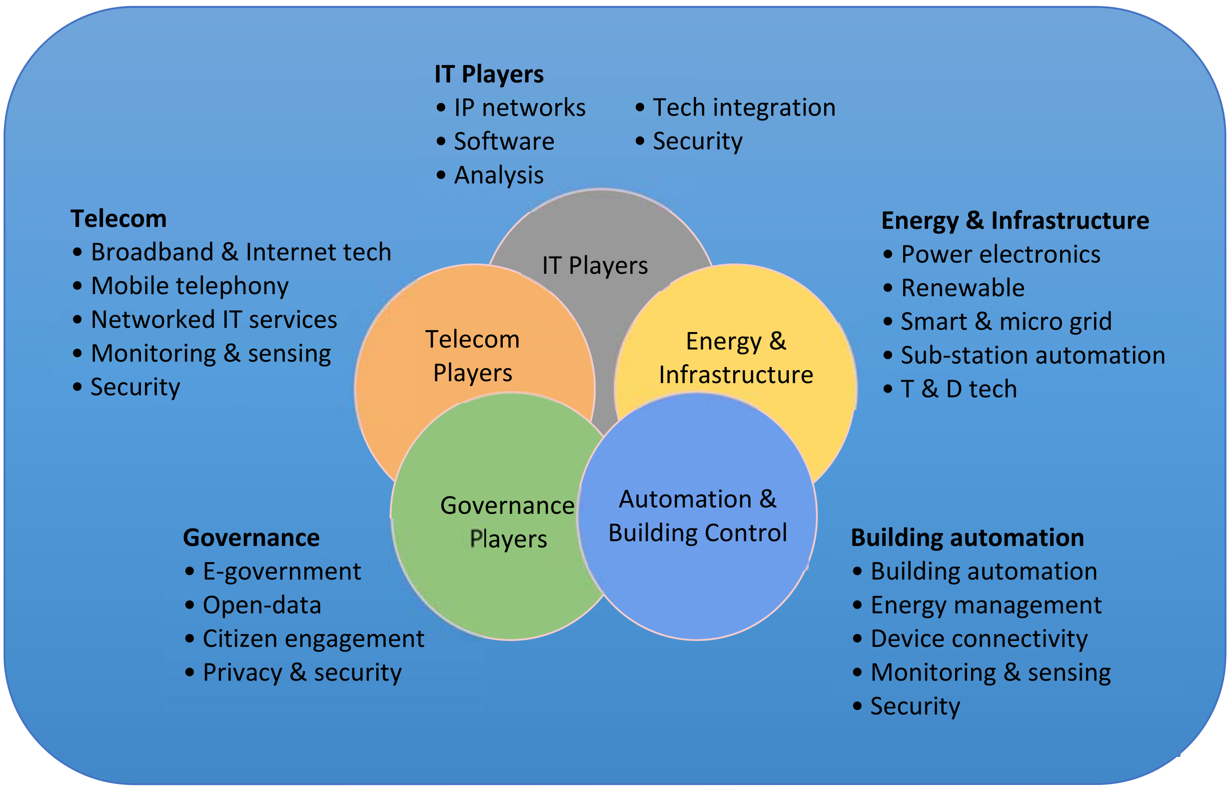

Figure 2. The technological ecosystem in smart cities.

[3] http://www.egr.msu.edu/~aesc310-web/resources/SmartCities/Smart%20City%20Market%20Report%202.pdf

In much the same way that smart cities are in fact complex ecosystems comprising a range of stakeholders, developing and deploying new services into smart cities generally require a holistic approach to technology deployment. Since the cities are built with a number of subsystems, for example transportation, health, and energy, a system-of-systems approach is needed to reason and address the needs of the city and its citizens.

While some large companies are able to develop and deploy effective smart city services by themselves, this is not the norm. Rather, it is more likely that successful smart city deployments require a number of companies to work together to combine solutions and technologies ranging from the low-level sensors/actuators, effective data communications, data gathering, and analysis, and domain specific applications such as health care, energy, and transportation.

Key Technology Challenges and Enablers

Underpinning the growing smart city market are a number of broad ICT trends that are enabling key segments, such as energy, transportation, and urban planning, to exploit new technologies to deliver smart solutions to cities and citizens. In the following section we highlight a number of these key trends and their impact on smart cities.

Networking and communications

Critical to many of the technology trends related to smart cities is the underlying communications infrastructure that enables smart cities to connect infrastructure, devices, and people, and gather data and deliver services to myriad endpoints. The complexity of smart city technological and service ecosystems requires a holistic approach to networking and communications that offers support for a range of needs, from infrastructure monitoring to backbones for digital media enterprises and from household security to citywide transportation monitoring. These diverse needs dictate that any smart city will encompass a range of technologies from low bandwidth wireless technologies such as Bluetooth LE and ZigBee, to dedicated fiber optics for backbone needs. Some critical technology trends that will affect future smart city developments include the following:

Low-Power WAN technologies

Fitting a niche in the technological landscape between personal/local area networking technologies such as Bluetooth LE, ZigBee and WiFi; licensed cellular networking such as existing 3/4G, and the evolution to 5G; sit technologies such as LoRaWAN and the evolving 802.11ah. These technologies use unlicensed spectrum and focus on low power and cost. While some argue they are a stopgap measure before the deployment of 5G networks, they are the subject of much interest and a number of trials including those by NTT in Japan, SigFox in France and Australia, and Comcast in the United States. One major appeal driving city adoption is the ability to offer a citywide service, for free, at a relatively low capital cost. An approach taken, for example, by the nonprofit organization ThingsNetwork[4].

[4] https://www.thethingsnetwork.org/

3/4G evolution

While there is significant activity around the development of 5G standards, they are not expected to have full deployment until 2020. In the meantime, a number of important initiatives are focused on the midterm evolution of existing cellular technologies. The 3GPP consortium is working on several activities including work on CAT-1 (and Cat-0) as well as the upcoming CAT-M1 and the narrow-band long-term evolution (NB-LTE). These standards focus on IoT scenarios and include better energy efficiencies, cost reductions, and better penetration/density, all critical for IoT situations in smart cities.

5G networking

Next-generation networking (5G) is the subject of intense technological (and business) activity with a number of major initiatives underway. 5G aims to address some of the key future needs of smart cities with higher bandwidth, delivery and performance guarantees, adaptability, energy efficiency, and real-time capabilities. 5G is still an evolving space, with considerable discussion on its long-term goals and technologies[5]. This complexity and rapid rate of change in the 5G space makes it difficult to provide more than a brief overview. For a fuller exploration of 5G please see the IEEE industry trend paper on 5G published as part of this series.

Regardless of the evolution of 4G and the eventual transition to 5G, two critical technology trends that address the need combine multiple evolving technologies are software-defined networking (SDN) and network function virtualization (NFV). Obviously, this complex networking landscape poses a challenge as operators and users grapple with needs that span multiple technologies. One solution to this is the adoption of SDN and NFV technologies that allow network operators to mix and match services using SDN and to push more intelligence into their networks (edge processing) using NFV[6,7].

Cyber-physical systems and the IoT

Cyber-physical systems and the IoT, defined generally as the connection and virtual representation of physical devices to the Internet, are critical to the growth of smart cities. While many parts of the traditional city infrastructure have been monitored for many years, such as for traffic, water, and electricity, this monitoring was often using proprietary technologies and maintained as individual silos. The IoT is changing that situation radically. City infrastructure, some of which may have been traditionally monitored, is now being connected using open standard protocols such as IP and HTTP, and made accessible through web technologies such as REST. Lower “hookup” costs are allowing the sensing to expand to more parts of the city infrastructure and enabling higher fidelity sensing. A good example is energy management. Though traditionally, many cities have been able to measure and monitor some city energy usage (via public or local utilities), increasingly private and commercial buildings are being hooked up, via smart meters that in turn, enables the adoption of microgrid technologies.

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[5] http://www.gsma.com/network2020/wp-content/uploads/2015/01/Understanding-5G-Perspectives-on-future-technological-advancements-in-mobile.pdf

[6] https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/wp-sdn-newnorm.pdf

[7] http://www.cio.com/article/2379216/business-analytics/understanding-how-sdn-and-nfv-can-work-together.html

This trend toward better sensing (and actuation) is not just about sensing city infrastructure such as roads and sewers. The costs and accessibility of IoT technologies is allowing private companies to instrument physical infrastructure and to use devices, including the smartphones that many citizens now carry. For example, auto manufacturers are increasingly sensing not only the car itself but its surroundings, traffic conditions, and even providing sensed data in the case of accidents. Civil engineering firms are deploying sensors to monitor stress in structures such as tunnels and bridges or the quality of road surfaces[8]. Citizens are getting involved by deploying low-cost sensors to track air pollution[9]and noise levels or just employing their smartphones as mobile sensor platforms.

Obviously, this growth in sensing is underpinned by wired and wireless communications, with low-power mesh networking and the eventual move to 5G as key technology trends.

While the IoT is driving a revolution in how we are able to sense and control the world around us, in the smart city environment there are several technology trends, and issues, that are driving the way we can harness the IoT.

The sheer volume of data being generated is driving its own needs both in the platforms needed to capture and store the data and in the tools and techniques needs to analyze the real-time data. We will explore cloud technologies in support of smart city platforms as well as trends in big data technologies next.

Cloud and edge computing

Cloud computing has had a significant influence on the development of smart cities, affecting the way cities manage and deliver services and enabling a broader set of players to enter the smart city market. Cloud computing, defined generally as the delivery of computing as a service, has offered organizations such as cities ways to reduce costs and increase efficiency. Due to legal and privacy concerns, cities have been reluctant to exploit the full benefits of public cloud services for core services, but many have used private cloud services and some have experimented with public/private or a hybrid cloud infrastructure[10]. When public cloud has been exploited, it has often been for noncore or newer services. For example, Barcelona, Spain, has used public cloud infrastructure to deliver identity services and device management for its field-based workforce[11], for data analytics, and to improve its customer records management (CRM) systems for managing citizen interactions.

A secondary factor driving the adoption of cloud solutions for smart cities is the massive increase in data being generated, captured, and analyzed by cities as they start to deploy and exploit IoT technologies. New infrastructure sensing, combined with private data sources and citizen data, means that cities now have access to a multitude of high-volume real-time data sources. While there

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[8] http://www-smartinfrastructure.eng.cam.ac.uk/news/future-cities-foresight-thought-piece-robert-mair

[9] https://www.fastcoexist.com/3026502/a-grassroots-environmental-sensor-network-so-you-dont-need-the-government-to-say-the-air-is-

[10] http://images.newsletters.lighting.philips.com/Web/PhilipsLighting/%7Bddcf75e7-1e51-40e6-9df2-88a2b59a902e%7D_Future-proofing_IT_for_Smart_City_services.pdf

[11] https://customers.microsoft.com/Pages/CustomerStory.aspx?recid=1939

are many examples of this use of cloud infrastructure in cities, intelligent transportation is a lead use-case. Taiwan has exploited cloud computing to handle the high data volume from its intelligent transportation systems (ITS)[12].

While cloud computing is an established part of smart city solutions, an emerging trend is the augmentation of cloud computing with edge (also known as fog) computing. Edge computing is a term used to describe the deployment and use of processing within and at the edge of the network[13]. This trend leverages the rollout of an IoT infrastructure, which often includes powerful processing and gateway devices to gather and communicate sensed data. The edge computing model offers cities ways to manage and monitor distributed infrastructure, for example, ITS, where processing is often best handled close to the infrastructure for performance and timeliness reasons or building management systems focused on energy efficiency[14].

Open data

Another significant trend in smart cities is the adoption and exploitation of open data. Open data in the context of smart cities refers to public policy that requires or encourages public agencies to release data sets and make them freely accessible. Typical examples are citywide crime statistics, city service levels, and infrastructure data. Many governments and leading cities now run open data portals, e.g., the UK and Canadian data portals, (data.gov.uk and open.canada.ca) and city portals such as San Francisco (dataSF.org) and London (data.london.gov.uk).

While open data is not a technology trend in itself, it leverages a number of the underlying technologies discussed here such as cloud computing and the IoT, and is a source of big city data. Open data is driving the use of these technologies as cities develop open data portals and other city stakeholders begin to exploit access to this open data. Some of the challenges associated with big data including data security and in particular issues of privacy.

The evolution of open data represents a broadening of the information available related to city operations. Its primary goal is transparency, but a significant subsidiary goal is to make information available to third parties that can be exploited to improve city services and foster innovation around new services. San Francisco and London have led efforts to exploit open data with local companies creating mobile applications based on park data[15], tourism, parking, and transportation[16]. Similar approaches are appearing in cities across the world. It is clear that, increasingly, cities will make more data available as open data. However, it is also likely that the ecosystem of open data providers and operators will evolve with cities taking on less of a role as open data operators and an

[12] http://www.intel.com/content/www/us/en/connected-transportation-logistics/taiwan-fetc-improves-traffic-modernizes-taiwans-transportation-industry.html

[13] https://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/computing-solutions.pdf

[14] http://blogs.cisco.com/perspectives/iot-from-cloud-to-fog-computing

[15] https://www.greenbiz.com/blog/2013/01/16/how-san-francisco-taps-open-data-city-apps

[16] http://data.london.gov.uk/case-studies/

increasing number of third parties taking city data and curating it for both citizen and business needs. An interesting early example of this is the city data exchange operated in Copenhagen[17].

Big data and data analytics

Smart cities, by their very nature, generate significant amounts of data in their daily operations. The trends identified earlier, for example, IoT and Open Data are driving cities to collect and make available additional significant amounts of data; some of it is static but increasingly large parts are real-time. This data exhibits the classic characteristics of big data; high volume, realtime (velocity); and extremely heterogeneous in its sources, formats, and characteristics (variability).

This big data can, if managed and analyzed well, offer insights and economic value that cities and city stakeholders can use to improve efficiency and lead to innovate new services that improve the lives of citizens.

The evolving technology that captures, manages, and analyses this big data leverages technology trends such as cloud computing. Cities are now able to access and use massive computing resources that were too expensive to own and manage only a few years ago. Coupled with technologies like Hadoop/HDFS, Spark, Hive, and a plethora of proprietary tools, it is now possible for cities to harness big data and analytical tools to improve the efficiency of city operations and services.

For example, Boston in the United States is using big data to better track city performance against a range of indicators but also to identify potholes in city streets and improve the efficiency of garbage collection by switching to a demand-driven approach[18]. New York has developed a system (FireCast) that analyzes data from six city departments to identify buildings with a high fire risk[19]. London uses a wide variety of city data and advanced analytics to map individual neighborhoods to better understand resource allocation and planning, which is made available through the Whereabouts service[20]. Singapore tracks real-time transportation and runs a demand-driven road pricing scheme to optimize road usage across the island[21].

Citizen engagement

Citizen engagement represents a complementary aspect of smart cities and although not strictly a technical consideration, relies on the data gathering and management discussed in the open data and big data sections. Essentially, it aims to harness technology in support of greater engagement with citizens, partly in an attempt to “tap into the collective intelligence” of cities, and partly to better understand what citizens do and need in their daily lives. In this context, engagement is not just with citizens but with the entire ecosystems, city workers, businesses, tourists, etc. While it may be obvious that cities need to engage and listen to their citizens, it is surprising how few channels exist for meaningful dialogue between cities and their citizens. To address this, a trend over the last

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[17] http://www.vinnova.se/PageFiles/751333230/Copenhagen%20smart%20city%20opl%C3%A6g%20i%20Stockholm2.pdf

[18] http://www.economist.com/news/special-report/21695194-better-use-data-could-make-cities-more-efficientand-more-democratic-how-cities-score

[19] http://www.govtech.com/public-safety/New-York-City-Fights-Fire-with-Data.html

[20] http://whereaboutslondon.org/#/

[21] https://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/managing-traffic-and-congestion/electronic-road-pricing-erp.html

five years in leading smart cities is the exploitation of technology to engage and communicate with citizens. This has taken a variety of forms including the following:

- Phone or web applications to allow citizens to report city issues such as graffiti or accidents or to directly engage with city services (often referred to as 311 services in North America). Originating from work in Washington, D.C., details of activities in cities such as Boston, Helsinki, London can be found on the open311 organization's website[22].
- Hackathons and other developer events to engage the technical community with open data and new service initiatives. Successful examples include the Code for America program[23] and other tech-focused routes adopted in Europe[24].
- Codesign and user-centric design processes to engage citizens in the ideation, design, and delivery of new services. This citizen-centric approach has be tried in a variety of forms in many cities, with early adopters such as Milton Keynes[25] in the United Kingdom and the European Union's citizen city project[26], developing best practices.
- Crowdsourcing city data from citizens to better understand the activities and actions of the urban population or use citizens to help gather data that otherwise are hard to obtain. Examples include crowdsourcing flood information in Jakarta using tweets[27] and using citizen input to create wheelchair accessibility maps in Böblingen, Germany[28].

Engagement, as described above, is actually an initial step towards empowerment. The ultimate goal of citizen engagement is the empowerment of citizens to take on and improve their daily lives through community leadership.

The six major trends identified here are critical to the rollout of smart cities and will shape the way technology is used to enrich the lives of citizens. Obviously, they are not the only factors and other areas such as security, privacy, environmental sustainability, and a host of others cut across these technology trends, shaping their evolution and deployment. However, these trends are critical and are shaping the future of our cities. In the next section, we explore standards activities that relate to these six areas and to the more general smart city landscape.

[22] http://www.open311.org/

[23] https://www.codeforamerica.org/

[24] http://www.nesta.org.uk/blog/power-people-how-cities-can-use-digital-technology-engage-and-empower-citizens

[25] http://www.mksmart.org/citizens/

[26] https://eu-smartcities.eu/content/citizen-city

[27] http://www.citymetric.com/horizons/making-smart-cities-work-people-no-1-crowdsourcing-flood-maps-jakarta-1228

[28] http://www.citymetric.com/horizons/making-smart-cities-work-people-no-5-b-blingen-s-crowdsourced-accessibility-maps-1519

Standards

Standards are critical to the evolution of smart cities to help smooth the adoption of new technologies and provide a trusted framework for city authorities and practitioners. All of the technological areas outlined previously are subject to intense standardization activities with significant ongoing activity in international organizations such as ISO, ETSI, and the ITU as well as national bodies and of course the IEEE. A useful overview of the main international activities is captured by the United Kingdom's national standards body in its smart city overview document[29].

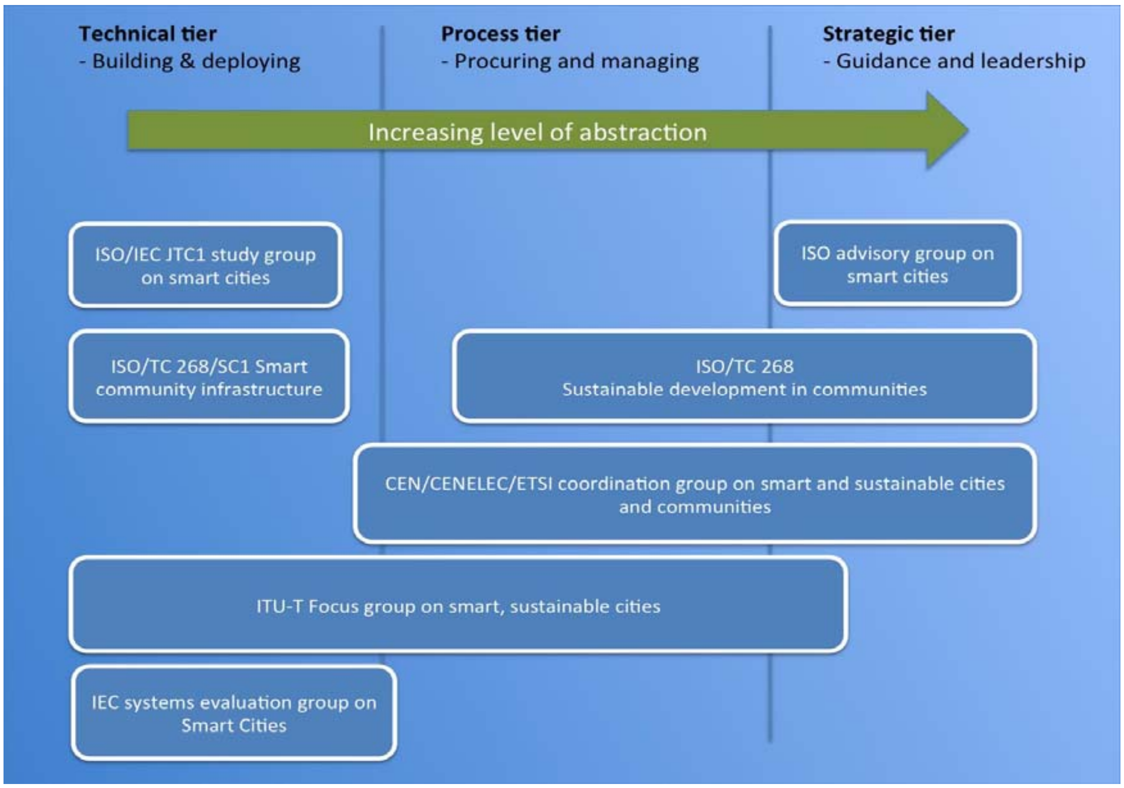

Figure 3. An overview of the major standards bodies activities in the smart city domain.

Figure 3, based loosely on the U.K. standards documents, shows standards body activities grouped into three levels, with *strategic* focusing on providing guidance to city leadership, *process* looking at procuring and managing smart city projects and activities, and *technical* looking at the lower-level details of the technologies used for smart city projects; IEEE standards tend to focus on the lower part of the diagram.

[29] http://www.bsigroup.com/en-GB/smart-cities/Smart-Cities-Standards-and-Publication/PD-8100-smart-cities-overview/

At the strategic level, an important standard is the ISO 37120 *Sustainable development of communities — Indicators for city services and quality of life*. This standard, part of a suite by ISO's Technical Committee 268, identifies one hundred indicators that cities should track to allow them to benchmark progress. There are a number of cities moving to adopt these standards and the World Council on City Data[30] has led efforts to promote these benchmarks and encourage cities to use them. The British Standards Institute has led some of the early thinking on a strategic approach to Smart Cities and has recently created the Smart City Institute in conjunction with the U.K. Future City Catapult[31].

At the more technical level, the ISO JTC1 committee has produced useful survey documents on smart city standards activities and is shepherding two technical standards that are still under development (from the ISO/IEC JTC1 group) but worth tracking. They are ISO/IEC AWI 30145 *Information technology – Smart city ICT reference framework* and the associated ISO/IEC AWI 30146 *Information technology – Smart city ICT indicators* which are both looking at the ICT infrastructure needed for smart cities.

The IEEE, recognizing that the IoT is a critical technology trend, has led efforts to create IEEE P2413, *Standard for an Architectural Framework for the Internet of Things (IoT)*. IEEE P2413 is in development to propose an architectural framework supporting cross-domain interaction, system interoperability, and functional compatibility, and to fuel the growth of the IoT market. Additionally, the ITU has an active standards group (Study Group 20) in the IoT area[32].

The IEEE Standards Association is known for taking a system-of-systems perspective in standardization. As an example, in the area of smart grids, IEEE 2030, *IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads*. A more comprehensive list of IEEE standards related to smart cities can be found in the "IEEE Standards Activities for Smart Cities" document[33].

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[30] http://www.dataforcities.org/wccd/

[31] https://www.bsigroup.com/en-GB/smart-cities/The-Cities-Standards-Institution/

[32] http://www.itu.int/en/ITU-T/studygroups/2013-2016/20/Pages/default.aspx

[33] http://standards.ieee.org/develop/msp/smartcities.pdf

Business Aspects

Although this trend paper focuses on technological trends, as outlined in the introduction, smart cities are complex ecosystems that cut across technological, social, organizational, and business domains. Understanding the rollout of technologies and their relative importance in the ecosystem requires understanding the business drivers that affect their deployment and uptake, and an overview of the smart city marketplace.

Increased urbanization, the development and growth of newer cities, and the natural renewal of infrastructure in established cities means that the smart city marketplace is both large and growing. While the scope and size of the market is difficult to accurately quantify and estimates vary, all place the size of the market in the US$300 to 700 billion range. For example, a market scoping report[34] by the United Kingdom's Department of Trade and Industry suggests that "We estimate the global market for smart city solutions and the additional services required to deploy them to be US$408 billion by 2020. Breaking this down by vertical, in transport for example, Pike Research estimates a global market for smart transport solutions based on digital infrastructure to be US$4.5 billion by 2018. These solutions are enabling solutions for a wider market of US$100 billion by 2018 which includes the physical and digital infrastructure for parking management and guidance, smart ticketing and traffic management. Also included in this US$100 billion are the traditional and new services such as heavy engineering, road design and big data analytics which are required as a result of investment in digital smart transport solutions."

Similarly, a report by Frost & Sullivan[35] breaks down the total spend into market segments, identifying governance and education, health care, and energy as three of the largest business opportunities.

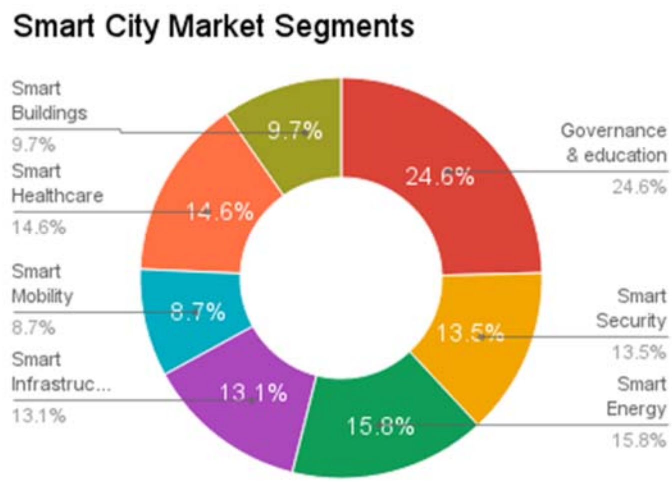

Figure 4. Smart city market segments (global, 2012-2020).

[34] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249423/bis-13-1217-smart-city-market-opportunties-uk.pdf

[35] http://www.egr.msu.edu/~aesc310-web/resources/SmartCities/Smart%20City%20Market%20Report%202.pdf

Trends and Recommendations

This report has highlighted a number of technologies whose evolution and deployment is contributing to the growth of smart cities. Some high-level observations include the following:

- Focus on point solutions: While many major cities are aware of, and to some extent pursuing, smart city strategies, it is clear that right now most smart city deployments are focused on specific infrastructure needs, for example, reducing water loss through aging pipe infrastructure, or improving transportation efficiency through monitoring. Companies need to focus on these types of projects and look for incremental ways to connect individual systems (silos) to provide aggregate efficiencies and support new services.
- Instrumentation and actuation from IoT: As sensors/actuators are being replaced in the system, an increasing percentage of city infrastructure is becoming IoT connected. Cities that recognize this and put in place middleware and cloud systems to capture and use this data will see significant advantages over time.
- Value from analytics: Today, few cities gather and analyze city data in a comprehensive way. Some lead examples do exist, but most cities are still developing these capabilities. Both government and industry need to adopt big data strategies as part of their core framework, building solutions from a cloud-centric perspective that incorporate data analytics as core capabilities. The growth of this area is likely to rapidly increase over the next decade with significant investment by cities in analytic capabilities.
- Different regions have different needs: It is clear that the needs of a smart city in India are different than those in Europe; different regions are grappling with different problems and will need different solutions. However, the underlying technology trends do not differ, and so the problem becomes the most appropriate application of a technology to meet a city's needs. Companies that are able to adopt a flexible approach to delivering solution will reap benefits.
- Collaboration is critical. Few, if any companies can deliver a full smart city solution. Therefore, companies need to identify their role in the smart city solution ecosystem and work to develop partnerships that allow them to collectively offer solutions to cities. Major players will be able to use mergers and acquisitions to plug capability gaps.
- Citizen engagement and activism are shaping the thinking of cities: Companies that can tap into this and can show how their approaches and solutions benefit from citizen engagement will accrue advantage through differentiation. Cities that develop comprehensive citizen engagement strategies will also benefit from citizens who are franchised as well as the collective wisdom of the community.

Resources

IEEE Smart Cities initiative:

http://smartcities.ieee.org/

There has been a significant activity by IEEE to promote smart cities and to engage cities in using technologies to develop new services. Examples are the core cities of Guadalajara in México, Trento in Italy, Wuxi in China, Casablanca in Morocco, and Kansas City in US. Additionally, this initiative organized the first two international conferences on smart cities successfully held in Guadalajara, México, in 2015 and Trento, Italy, in 2016; the third being planned for Wuxi China in 2017.

IEEE Industry activity:

http://industry.ieee.org

A portal of IEEE resources targeted at industry and practitioners including content on professional development, standards, and emerging technologies and trends.

British Standards Institute Smart Cities:

http://www.bsigroup.com/en-GB/smart-cities/

A set of standards-focused resources from the British Standards Institute that focuses on the smart city domain.

Biography

Dr. Rodger Lea - Currently CEO of Internet of Things startup, Sense Tecnic, Dr. Lea has over 25 years of experience spanning academic, large corporations and startups. For the last 10 years, he has started or helped start 4 new companies while managing an active research program (University of British Columbia, Canada and Lancaster University, UK) into distributed and ubiquitous computing.

Prior to his startups, Dr. Lea spent over 15 years in industrial research, most recently as Vice President and Director of Sony's US distributed system lab, located in Silicon Valley, CA. In this capacity, Dr. Lea aided in developing advanced technologies to support Sony's broadband media strategy including research and development in areas such as future media presentation formats, media delivery and caching, digital and interactive TV, home networking and peer to peer infrastructure technologies. This research generated over 100 international patents and delivered technology into a number of major products ranging from Sony's interactive set-top boxes, to the Sony PDAs and High Definition TV systems.

Before this, Dr. Lea was part of Sony's Tokyo based Computer Science Laboratory where he led developments in the area of adaptive operating systems, and networked virtual reality systems.

Before joining Sony, Dr. Lea spent time with Hewlett Packard's research labs where he led the definition and implementation of a distributed fault tolerant infrastructure for telecom systems. This work grew out of his previous role heading up the European research and development programs for Chorus Systems, a French start up company which spun out of the French national research labs.

Dr. Lea holds a Ph.D in computer science from Lancaster University in the UK and has numerous publications in the area of distributed systems, operating systems and home networking. He is the holder of several US patents and has published books on the Internet of Things (IoT) web graphics (WebGL), home networking and 3D graphics for virtual reality systems. He currently splits his time between BC, Silicon Valley and Europe