The Internet of Everything for Cities

Connecting People, Process, Data, and Things To Improve the 'Livability' of Cities and Communities

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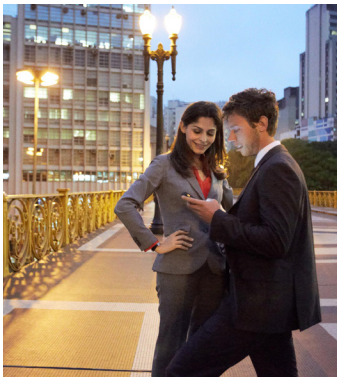
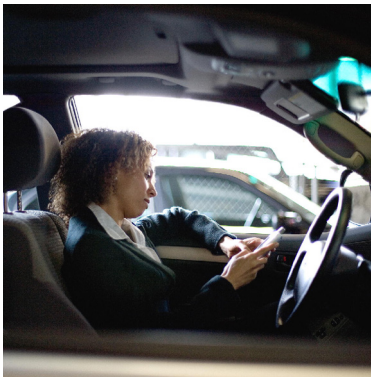



Given these trends, understanding where we are in the evolution of the Internet is critical to future city-planning processes.

Introduction

As microcosms of the Internet of Everything (IoE), cities stand to benefit the most from connecting people, process, data, and things. Working with Cisco, in partnership with global and local innovators, cities are developing IoE-related projects, platforms, and implementations. Importantly, the IoE ambitions and scope are designed to respond to the need for real-time, context-specific information intelligence and analytics to address specific local imperatives. The lessons and framework from many pilots can provide other cities with a pattern language for progressing strategies, and for developing their own city initiatives.

Cities: Fertile Ground for Realizing IoE Value

Over the past few years, the definition of "Smart Cities" has evolved to mean many things to many people. Yet, one thing remains constant: part of being "smart" is utilizing information and communications technology (ICT) and the Internet to address urban challenges.

The number of urban residents is growing by nearly 60 million every year. In addition, more than 60 percent of the world's population will be living in cities by 2050. As a result, people occupying just 2 percent of the world's land will consume about three-quarters of its resources. Moreover, more than 100 cities of 1 million people will be built in the next 10 years.[1]

Today's cities face a variety of challenges, including job creation, economic growth, environmental sustainability, and social resilience. Given these trends, understanding where we are in the evolution of the Internet is critical to future city-planning processes.

In terms of phases or eras, Cisco believes that many organizations are currently experiencing the Internet of Things (IoT), the networked connection of physical objects. As things add capabilities like context awareness, increased processing

City leadership must understand how the components of IoE — people, process, data, and things — play specific roles, and work together, to enable our future cities and communities.

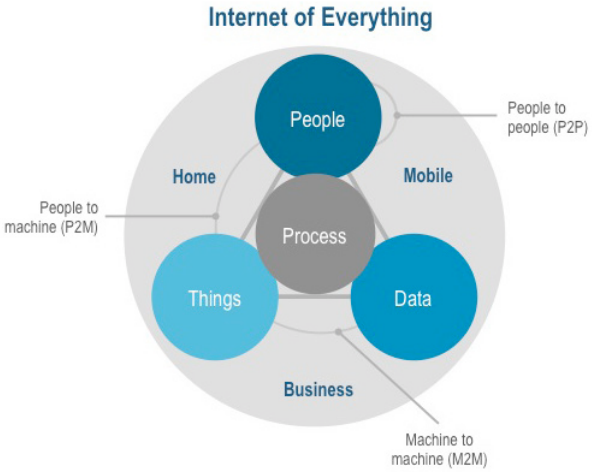
power, and energy independence, and as more people and new types of information are connected, IoT becomes an Internet of Everything — a network of networks where billions or even trillions of connections create unprecedented opportunities as well as new risks.

In fact, we are seeing the emergence of a new imperative from public leaders and industries. "Digital urbanism"[2] is rapidly becoming a central pillar for urban planners, architects, developers, and transportation providers, as well as in public service provision.

From a public sector leadership perspective, cities can be viewed as microcosms of the interconnected networks that make up IoE. In fact, cities serve as "fertile ground" for realizing IoE value.

For this to happen, however, city leadership must understand how the components of IoE — people, process, data, and things — play specific roles, and work together, to enable our future cities and communities (see Figure 1).

Figure 1. IoE Brings Together People, Process, Data, and Things To Make Networked Connections More Relevant and Valuable.



Source: Cisco, 2012

- **People.** In IoE, people will be able to connect to the Internet in innumerable ways. Today, most people connect to the Internet through their use of devices (such as PCs, tablets, TVs, and smartphones) and social networks (such as Facebook, Twitter, LinkedIn, and Pinterest). As the Internet evolves toward IoE, we will be connected in more relevant and valuable ways. For example, in the future, people will be able to swallow a pill that senses and reports the health of their digestive tract to a doctor over a secure Internet connection. In addition, sensors placed on the skin or sewn into clothing will provide information about a person's vital signs. According to Gartner, people themselves will become nodes on the Internet, with both static information and a constantly emitting activity system.[3]

The key is creative use of new technologies that are emerging in the Internet of Everything economy, over and above the growth of current data sources.

- **Data.** With IoT, devices typically gather data and stream it over the Internet to a central source, where it is analyzed and processed. As the capabilities of things connected to the Internet continue to advance, they will become more intelligent by combining data into more useful information. Rather than just reporting raw data, connected things will soon send higher-level information back to machines, computers, and people for further evaluation and decision making. This transformation from data to information in IoE is important because it will allow us to make faster, more intelligent decisions, as well as control our environment more effectively.
- **Things.** This group is made up of physical items such as sensors, consumer devices, and enterprise assets that are connected to both the Internet and each other. In IoE, these things will sense more data, become context-aware, and provide more experiential information to help people and machines make more relevant and valuable decisions. Examples of "things" in IoE include smart sensors built into structures like bridges, and disposable sensors that will be placed on everyday items such as milk cartons.
- **Process.** Process plays an important role in how each of these entities — people, data, and things — works with the others to deliver value in the connected world of IoE. With the correct process, connections become relevant and add value because the right information is delivered to the right person at the right time in the most appropriate way.

In a recent study, Cisco calculated that the Internet of Everything,[4] applied in 21 core "use cases" in five areas of business (asset utilization, employee productivity, supply chain and logistics, customer experience, and innovation), has the potential to deliver $14.4 trillion of value (net profits) for private-sector companies globally between now and 2022. This "Value at Stake" is based on the ability to secure lower costs and higher revenues from IoE strategies and applications. The use cases cover areas such as smart grid, smart buildings, connected healthcare and patient monitoring, smart factories, connected private education, connected (commercial) ground vehicles, connected marketing and advertising, and connected gaming and entertainment.

In a follow-up study,[5] Cisco estimated that in 2013 alone, IoE will drive $613 billion of value for private-sector companies in 12 of the world's largest economies. The key is creative use of new technologies that are emerging in the Internet of Everything economy, over and above the growth of current data sources. The value is unlocked when data is combined with changes to the "people" dimension (skills, attitudes, culture, work style, and work practices) and to business processes (especially the more pervasive use of collaboration).

The Cisco study calls out three capabilities that have the potential to enable businesses to realize IoE's benefits as quickly as possible:

- The ability to handle "big data" and what we might call "big analytics" (making sense of the data for better judgment)

The Internet of Things is reaching a tipping point that will make it a sustainable paradigm for practical applications that can change the future of individuals, enterprises, and the public sector."

IDC, 2013

- The capacity to connect things through sensor networks (assets and physical objects that can start "talking" and sharing information)
- Collaboration

Internet of Everything and the Public Sector

In more recent work, which is still underway, the Cisco Consulting Services public sector and economics teams are beginning to measure the potential impact of IoE on government and the public sector.

That work starts with the premise that public-sector bodies will find opportunities similar to those already being exploited in the commercial world to create new services and capabilities, or to improve existing ones. This is an outcome that other market analysts are also identifying:

"The Internet of Things is reaching a tipping point that will make it a sustainable paradigm for practical applications that can change the future of individuals, enterprises, and the public sector."[6]

At the regional or city level, opportunities are likely to cover things such as improved building management, more efficient traffic flow, clever ways to provision basic services (for example, "street lighting as a service," which can be managed and consumed to reflect more accurately changing patterns of need and demand), water or waste management, and policing.

At a state level, the Internet of Everything holds particular promise in areas like road infrastructure (better monitoring of pavement and bridge conditions by using intelligent sensors and new "big data" computing capabilities), highway traffic management, healthcare,[7] education, and agriculture.[8]

The following examples show how Cisco has been working with cities over the last decade or more to address key public and private priorities; develop new business/governance models and public-private partnerships; and engage citizens in the development of enhanced experiences and utility for individuals, organizations, and society.

Amsterdam: Connected Public Lighting Within Smart Cities

Over the past decade, the city of Amsterdam, the Netherlands, has developed a vision for collaborating, envisioning, developing, and testing numerous connected solutions that could pave the way to a smarter, greener urban environment.[9] A number of projects were launched, beginning in 2006, as Amsterdam identified ways to improve sustainable living/working, public spaces, and mobility. Most recently, the city has been exploring the potential for a connected public lighting infrastructure.

With a mutual market focus around "livable" connected cities, Cisco and Philips are developing new concepts and innovations around network-enabled LED street lighting,[10] including widespread education of elected officials, city managers,

A joint effort is required to realize the vision of smart connected cities, enabling meaningful innovation for years to come.

investors, and industry peers; development of new and powerful business ecosystems; and proofs of concept with leading cities.

One engagement focused on the development of networked lighting and media content is in the Westergasfabriek zone of Amsterdam, in partnership with Philips, a real estate owner, and the city. This has resulted in a pilot that aims to provide an enhanced citizen experience by applying "design thinking" to enhance citizen experiences, and by developing the potential for on-demand, usage-based service provision; revenue-generation opportunities; and public-private partnership business models for networked civic services.

There is a huge impact from developing a connected lighting solution across this city and globally. Artificial light is an essential element of urban environments – not only after dark, but also as part of a city's identity. It affects residents' sense of safety and social inclusion, and also influences the degree to which cities can create an inviting environment for business and tourism.

- Lighting accounts for 19 percent of all electricity consumed.
- One-third of the world's roads are still lighted by technology dating back to the 1960s.
- The installation of new street lighting solutions can save up to €10 billion (U.S. $13.1 billion) in energy per year.[11]

Philips estimates that a complete switch to LED technology alone can generate savings of approximately €130 billion (U.S. $170.5 billion) – an enormous sum equivalent to the elimination of 640 medium-sized power stations globally.

Furthermore, an independent, global trial of LED technology in 12 of the world's largest cities found that LEDs can generate energy savings of 50 to 70 percent – with savings reaching 80 percent when LED lighting is coupled with smart controls. The program also indicated that citizens of pilot cities prefer LED lighting, citing the social and environmental benefits, such as a greater sense of safety and improved visibility.

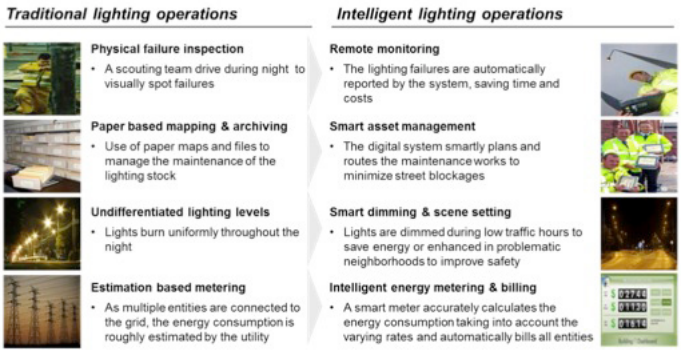
The LED lighting revolution is gaining traction: worldwide, 10 percent of new public streetlights installed are currently LED-based – a figure expected to rise to 80 percent by 2020.[12]

Switching to LED lighting alone, however, will not be enough to meet cities' energy consumption and cost reduction targets. Adaptive, interoperable lighting solutions are needed to bring savings to a next level. Urban leaders now face a dilemma: cities are complex entities where inefficiencies arise because systems are not interconnected and have no way to "talk" to one another. A joint effort is required to realize the vision of smart connected cities, enabling meaningful innovation for years to come.

We view the future of public lighting as a transition from analog to digital, from fluorescent lightbulbs to solid-state lighting – all connected to an energy grid through a variety of last-mile access technologies (see Figure 2).

Ubiquitous wireless connectivity, symmetrical broadband, and IP-based utility networks are recognized by city authorities as enablers of these improvements.

Figure 2. Moving from "Traditional" to "Intelligent" Lighting Networks.



Source: Cisco Consulting Services and Philips, 2012

Additional savings can be achieved by incorporating connected controls to the Internet. And even greater value can be derived by using the lighting network for other connected services. Ubiquitous wireless connectivity, symmetrical broadband, and IP-based utility networks are recognized by city authorities as enablers of these improvements.

The city of Amsterdam's broader objective is to connect all of its citizens by 2018. Once connected, residents and businesses will be able to access rich information and media resources, friends and colleagues, and a wealth of innovative services that improve life across the city.

Chicago: Developing Digital Planning and Neighborhood Services

Cisco and a wide range of public and private stakeholders in the city of Chicago are advancing a series of Smart+Connected Community initiatives.[13] Objectives include fostering smarter working practices, incubating technology innovation, and promoting multi-stakeholder collaboration to investigate and enhance the social life of the city.

As part of the Chicago STEM Education Initiative,[14] a new Cisco STEM Lab at one of the City's five Early College Science Technology Engineering and Mathematics (STEM) Schools was announced by Chicago Mayor Rahm Emanuel. Cisco is developing this new STEM Lab and a Cisco Network Academy, which teaches students the skills needed to build, design, and maintain, networks – improving their career prospects while filling the global demand for networking professionals.

Another agreement with the city, Cisco announced a partnership with Chicagoland Entrepreneurial Center to build a new smart working center named "1871" that promotes entrepreneurship and collaboration throughout the city.

Team Approach to Violence is yet another project in Chicago that is exploring the use of everyday digital technologies to boost community resilience – in this case, in Chicago's South Side neighborhoods. The aim of the project is to use digital tools – web, mobile, SMS – to enable residents, community organizations, police, and

The aim of the Collaborative is to work with a small number of cities to develop and prototype innovation projects that support city leaders, urban planners, and community organizations to think differently about creating and shaping thriving and sustainable places.

public agencies to share information and start conversations about community safety and tackling violent crime. In the process, the city hopes to support communities by building trust between neighbors and local agencies, and by creating a space for a public dialogue about crime and safety. The work is being funded by the University of Chicago's Office of Civic Engagement, McCaffery Interests, and Cisco.

The idea for Team Approach to Violence came from a workshop about digital technologies and community resilience that was hosted by the University of Chicago and Cisco in 2012.[15] The project is part of The Social Life of Cities Collaborative, a wider program of work about urban social innovation and socially sustainable communities that is run by Cisco, Social Life, and the Young Foundation. The aim of the Collaborative is to work with a small number of cities to develop and prototype innovation projects that support city leaders, urban planners, and community organizations to think differently about creating and shaping thriving and sustainable places. Cisco is currently working in Chicago and Malmö (Sweden), and developing partnerships in Asia, Australia and the United Kingdom.

In Chicago, the consortium has proposed three application concepts: Stay Safe, Community Report, and Safe Passage. Two of these — Stay Safe and Community Report — focus on synthesizing different sources of data (both user-generated reports and data collected by police, public agencies, or community organizations) and making this information available in a smartphone application that uses a simple mapping interface and GPS.

Over coming months, the Team Approach to Violence team will investigate the availability of different data sources, develop a demonstrator version of one of these concepts, and test the demonstrator app with community-based organizations in one or two South Side neighborhoods. The overall aim is to develop a demonstrator that can be tested and rolled out to other South Side neighborhoods.

New York: City24/7 Platform Informs, Protects, Revitalizes

To revitalize the world's largest cities, City24/7 — a company committed to making public communications more accessible to everyone, everywhere — in collaboration with Cisco and the City of New York has launched an interactive platform that integrates information from open government programs, local businesses, and citizens to provide meaningful and powerful knowledge anytime, anywhere, on any device. In short, City24/7 delivers the information people need to know, where and when it helps them most.

Located at bus stops, train stations, major entryways, shopping malls, and sports facilities, City24/7 Smart Screens incorporate touch, voice, and audio technology to deliver a wide array of hyper-local (about two square city blocks) information, services, and offerings in real time. The Smart Screens can also be accessed via Wi-Fi on nearby smartphones, tablets, and laptop computers.

In effect, City24/7 becomes a virtuous cycle – as more citizens use and gain value from the system, cities and businesses can offer even better services, which, in turn, increase people's involvement.

The overarching goals of the City24/7 Smart Screens are to:

- Inform by instantly connecting people with information that is relevant to their immediate proximity
- Protect by giving local police and fire departments a citywide sensing, communications, and response network that can direct needed personnel and resources exactly where and when they are needed
- Revitalize by increasing levels of commerce, investment, and tourism

Figure 3. City24/7 Smart Screen Locations.

Source: Cisco Consulting Services and City24/7, 2012

To develop a solution that works for the public and private sectors, as well as for citizens, City24/7 needed to overcome the obstacle of monetization – a key barrier that has prevented the success of other public-private partnerships with similar goals. City24/7 worked with numerous organizations during the development and testing phases, including the New York City Department of Information Technology & Telecommunications, Amtrak, New Jersey Transit, New York City Health and Hospitals Corporation, the New York Mets, the United States Postal Service, the Javits Center, the New York City Department of Parks & Recreation, the New York City Department of Transportation, and New York University. It became clear to City24/7 and its main development partners, Cisco and the City of New York, that it was critical to leverage the network – in combination with ubiquitous platform support and powerful analytics – to gather and distribute valuable insights and data to all of the program's participants.

As the network grows by deploying more Smart Screens, the amount of insights and data also grows, delivering even more value to cities, businesses, and citizens. In effect, City24/7 becomes a virtuous cycle – as more citizens use and gain value from the system, cities and businesses can offer even better services, which, in turn, increase people's involvement.

Once the Smart Screens have reached critical mass in New York City, City24/7 will start the second phase, which includes expansion to several major cities in the United States and around the world.

"When the implementation of the Busan u-City is complete, it will usher in a new era in urban mobility around the city, with education, medical service, and public welfare all benefiting from the creation of a smart community environment. This is Busan's chance to cement its reputation as a world-class city that the whole world can learn from, in its simultaneous achievements of local economic growth and green growth."

Young-Sik Kim

Director General, Planning and Financing

Busan Metropolitan City

Busan: Transforming Economic Sustainability with Public Cloud

Busan, South Korea, faces challenges similar to those of other large, industrial cities. A primary imperative for Busan is creating job opportunities for its 60,000 annual university graduates and retaining a high-quality workforce.

The Busan Metropolitan Government recognized the potential for growing its economic base through the use of ICT. By connecting citizens, educational institutions, government agencies, and industry, the city could drive sustainable urban development while providing citizens with easy access to city services.

A 10GB broadband infrastructure, the Busan Information Highway, was already deployed and linked 319 public institutions. This infrastructure gave the Busan government a strong foundation for expansion. For assistance, Busan turned to Cisco and the Cisco Smart+Connected Communities solutions to develop a cloud infrastructure strategy.[16]

Today the cloud connects the Busan Metropolitan Government, the Busan Mobile Application Center (BMAC), and five local universities. BMAC offers physical workspaces, such as project and meeting rooms, shared application development, cloud platforms for Windows and Mac OS operating systems, an applications library, a consulting center for start-ups and small-office/home-office professionals, testing tools, smart devices, application programming interfaces for access to municipal data, an application developer's forum, and marketing resources.

The shared platform as a service (PaaS) provides developers with convenient access to municipal data from the city's geographic information and intelligent transportation systems. Using this data, developers can create innovative applications that help improve city operations, quality of life, and citizen access to services.

Since the BMAC's opening, cloud development community membership has grown from 500 to 1,500, with 100-220 simultaneous users of the platform. The Center held its first Mobile App Contest and received 115 apps or application development ideas. Prizes totaling 26 million KRW (U.S. $23,686) were awarded for 14 new apps. In the first year of operation, 840 people registered for professional development courses and seven new businesses registered as start-ups. As of February 2012, BMAC has trained 2,350 people, and 3,150 individuals registered as professional mobile application developers in the BMAC talent pool.

Eventually, the cloud platform is intended to deliver services to citizens through kiosks, citywide digital interactive displays, home-based access, and mobile access.

With a shared development platform, developers can work with the city to co-create Smart City services. The Busan Metropolitan Government plans to establish a public-private collaboration company to create, deliver, and manage innovative urban services. In addition, the city is encouraging a greener city environment through increased citizen engagement.

As these solutions are implemented, Cisco and the city of Nice are assessing how captured data can be treated to make information context-specific and useful across different services.

Nice, France: IoE Smart City Pilot

Cisco is partnering with the city of Nice, France and several local and other industry partners to build a Smart City solution to further advance the potential impacts of IoE for cities. The project's main objectives are to test and validate an IP-enabled technology architecture and economic model, as well as to determine the social benefits of IoE. The project is based on a shared platform designed to be more flexible, granular, and scalable than early attempts at developing urban operating systems. The shared platform is intended to make it easier to establish the new connections that are critical for Nice to become a Smart City.

In addition, the project will serve as a catalyst for combining key discoveries from this and other Smart City initiatives. The intent is to share what Nice has learned with other aspiring cities so they can create their own Smart City framework.

The project includes four city services that can rapidly demonstrate the benefits and value of IoE for both residents and city leadership. These services include: 1) smart circulation, 2) smart lighting, 3) smart waste management, and 4) smart environment monitoring.

As these solutions are implemented, Cisco and the city of Nice are assessing how captured data can be treated to make information context-specific and useful across different services. For instance, can data captured by sensors for traffic patterns serve purposes beyond smart parking? How can this information also help optimize waste collection and environmental monitoring? The implications of data "cross-fertilization" and cross-collaboration go beyond technological feasibility because they also impact the decisions of city managers, cross-departmental collaboration, and back-office operations.

Key Considerations for the IoE-enabled City

City Operating Models for IoE

City leaders face several challenges that impact their operating models for the Internet of Everything.

- **New operating models.** Faced with unprecedented budget issues, city leaders are creating more effective and efficient operating models by moving away from top-down, centralized management systems and breaking down "siloed" service functions and departments. To be helpful, Smart City solutions must not only deliver the promised benefits, but also enable leaders to mange city expenses more effectively. Given this backdrop, many Smart City schemes are focused on offering "pay per use" as opposed to "pay to see" solutions. These can also involve software-as-a-service (SaaS) models and step-by-step build-outs that allow for an incremental return on investment (ROI).

  From a procurement side, city governments are starting to move from a centralized, products-and-services procurement model to a "decision as a service" model. For example, the city of Barcelona, Cisco, and a number of partners are embarking on a program intended to develop a "light as a

By combining public and private data, city governments can carve actionable insights that generate value – for the city government, or directly for citizens.

service" operating model utilizing public lighting infrastructures. In this model, development of the technology infrastructure and management of the data are out-tasked to a public-private partnership whose objective is to leverage the data and provide actionable insights related not only to the performance of the networks, but also to the level of interactions between the networks and the environment around them. Lighting is activated only when an event occurs in the area, with the decision taken locally at the network level, rather than at the data center. This represents a distributed operating model, as opposed to a centralized, command-and-control approach.

- **IoE deployment plans.** City leaders are exploring new strategies that will allow them to anticipate and adapt more quickly to changes that impact their cities. With this in mind, cities should provide a coherent deployment plan to ensure synergies and cross-functionalities that optimize the number of sensors and services provided. This will allow them to prevent redundancies, rationalize security and privacy concerns, and manage undue sensor proliferation. Of critical importance will be the development of smart regulations, stimulating deployment of connected devices at the public and private levels, as well as integration among disparate data sets coming from them.
- **Data ownership by the city.** While infrastructure integration of different organizations at the network and infrastructure levels (within the public sector and between the public and private sectors) has proven to be virtually impossible, integration at the data level is happening. By combining public and private data, city governments can carve actionable insights that generate value – for the city government, or directly for citizens. As the debate over governance and ethical exploitation of data receives increasing public attention, city leaders are looking for ways to preserve their cities' assets (data), as well as those of their constituents, while also integrating these data sources with others coming from the private sector. Cities are addressing aspects of data management, including intellectual property rights, proper data handling, and physical storage and distribution requirements.
- **New governance models.** Smart Cities create an environment that disturbs traditional decision-making processes and project ownership. It creates urgency for leaders to establish new rules of the game. Collaborative design of multi-stakeholder ownership and processes calls for new governance and business models, which are essential to aligning all city services. This cross-functional and inter-organizational collaboration is necessary to unify the increasingly complex ecosystem required to provision end-to-end solutions for Smart Cities. Leading cities have set up dedicated business-relation functions and special-purpose organizations to act in an orchestration role, to look into the various interests of different service sections, and to facilitate dialogue and cross-fertilization of ideas.
- **Societal challenges.** Concerns over societal challenges (pollution, CO2 footprint, well-being) are just as important as economic and social impact. The project design, therefore, is supported by a strong, multidimensional economic hypothesis aimed at validating quantitative and qualitative gains by project partners.

More important, the infrastructure needs to process the data, capture the insights, and take a decision at the edge of the network — without the need to transport a large amount of data to a data center and then bring the decision back to the edge.

IoE Technology Architecture for Cities

IoE technical architectures for cities require seamless integration of sensors in a mutualized communication environment. Traditionally, a specific network is deployed around a given application, such as streetlight management, video surveillance, or environmental monitoring. While separate networks provide a natural separation of domains, typically they are not optimized (costs, security, availability), bringing about information silos. In addition, interaction between the sensor and devices in each network requires specific integration.

Cities are exploring the deployment of horizontal multiservice infrastructures that will host all of the city's systems. Such approaches are designed to facilitate easy, seamless integration of new applications that typically require installation of end devices and relevant software stacks. The objectives are to ensure that future services can be added at minimal cost and disruption to the existing network architecture. The efficacy of the technical architecture will be determined by how well it:

- **Interconnects** people, machines, and sensors throughout the city (indoor and outdoor)
- **Securely collects** real-time and context-aware data from multiple sources
- **Stores** data from devices, people, and applications so that it can scale to accommodate growing volume
- **Organizes** data by using semantic links to identify and send it to relevant users according to individual access rights
- **Analyzes** data by interpreting and correlating patterns of use, such as sales trends, that may allow for monetization opportunities in the future. More important, the technical architecture should improve predictive modeling by allowing the city to analyze historical data.
- **Shares** information with end users and publishes linked data based on semantics. End users include both city agents who will use specific monitoring applications, and city residents who will receive access to the information either on their smartphones or on multimedia kiosks.
- **Enables** an open ecosystem for innovation to develop new services that appeal to both citizens and city leaders. Platforms need to be open to local start-ups and businesses (either for free or for a fee), and local businesses can develop their own offer in agreement with the city charter of good behavior.

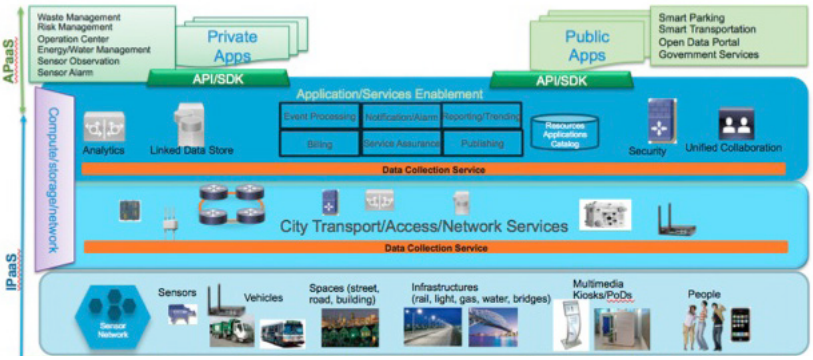
To achieve these goals, the technology architecture must be capable of handling millions of devices and sensors; thousands of servers; multidimensional transmission, processing, and streaming of Big Data; and more. More important, the infrastructure needs to process the data, capture the insights, and take a decision at the edge of the network — without the need to transport a large amount of data to a data center and then bring the decision back to the edge. The sheer scale and complexity of the architecture will make it difficult to predict the speed, reliability, quality, and security of service delivery.

The IoE-friendly architecture encapsulates several unique characteristics that make it much more extensible, resilient, and robust than operating systems typically used by cities over the past five years or so.

The first response to addressing these challenges could simply be to add more processing power to the city's existing technology infrastructure. To achieve the desired attributes described earlier, however, an entirely new architecture is required. For example, the city of Nice's smart parking pilot proposes an architecture with four distinct layers (see Figure 4):

- **Layer 1:** Sensors and networked devices with mesh technologies, which promote more efficient integration of emerging context-aware sensors and devices, ultimately improving the city's resilience.
- **Layer 2:** Data capture, processing, storage, and analytics at distributed points across the city. This reduces architectural complexity and ensures extensibility. In addition, a distributed architecture boosts scalability. Most important, it increases responsiveness to real-time and context-critical data, which, when processed and analyzed, enables information intelligence.
- **Layer 3:** Central data collection, including computing, storage, and analytics, combined with integrated and open-standard application programming interfaces (APIs) for building on open-data readiness (as determined by the city).
- **Layer 4:** New and innovative applications and services for both city managers and residents.

Figure 4. Technology Architecture for the City of Nice Includes Four Layers.



Source: Cisco Consulting Services, 2013

The IoE-friendly architecture encapsulates several unique characteristics that make it much more extensible, resilient, and robust than operating systems typically used by cities over the past five years or so. The technology architecture is designed to deliver the following benefits:

- **Simplicity and availability.** End-to-end IP, bandwidth, and frequency optimization, combined with mesh technologies and resiliency, guarantee high service quality and relatively low maintenance.

"The power of public-private partnerships cannot be overstated. With the vast range of companies and nonprofit organizations whose expertise lies in connectivity, intelligence, and technology, we have a rich pool of resources for identifying and deploying the best solutions. We are successfully working together to deliver superior services with far greater efficiency."

Ger Baron

Program and Cluster Manager

Amsterdam Innovation Motor

- **Security.** IP security mechanisms ensure a highly robust and resilient system. In addition, the peer-to-peer model separates each component from the others and prevents isolated failures from jeopardizing the entire system.
- **Interoperability.** Standards-based solutions make it easy for the city to involve new partners and add services not necessarily envisioned at the beginning of the proof of concept.
- **Multiservice.** The solution places equal importance on data, voice, video, and sensors. In addition, the architecture is service- and end-usage-agnostic in the sense that diverse business applications can be hosted and treated in the same environment, regardless of the source and nature of the data.
- **Technological scalability.** By using IPv6 and distributed data processing, the architecture is designed to handle the large number of connected "things" that a Smart City requires.
- **Business scalability.** The solution offers "pay-per-use" opportunities to enhance granularity so that it can be scaled as budgets allow.
- **Manageability.** The end-to-end nature of the solution makes maintenance easier by enabling greater visibility into the infrastructure.
- **Extensibility.** New applications require only endpoints and application programming interfaces (APIs) to integrate with the existing infrastructure.
- **Flexibility.** The architecture allows city managers and citizens to utilize the same services and information for their specific needs.

Collaborative and Dynamic Ecosystem for IoE

No single company or public agency is capable of delivering an end-to-end, plug-and-play Smart City solution. To address the complexity involved, city programs are enabled by a collaborative and dynamic multi-stakeholder ecosystem.

This perspective is explored in the Smart City Framework[17] thought leadership previously published by Cisco (see Figure 5).

Typically, these ecosystems consist of a core group of partners that can be extended to include other relevant expertise providers, enabling the architecture to address a broad range of demands for city services. Further, the ecosystems are then driven by a common purpose that unites the various stakeholders.

As new services are added, sub-networks of other alliances and collaborators could potentially come together to develop or achieve a context-specific Smart City application and evolve into other partnership organizations, as needed.

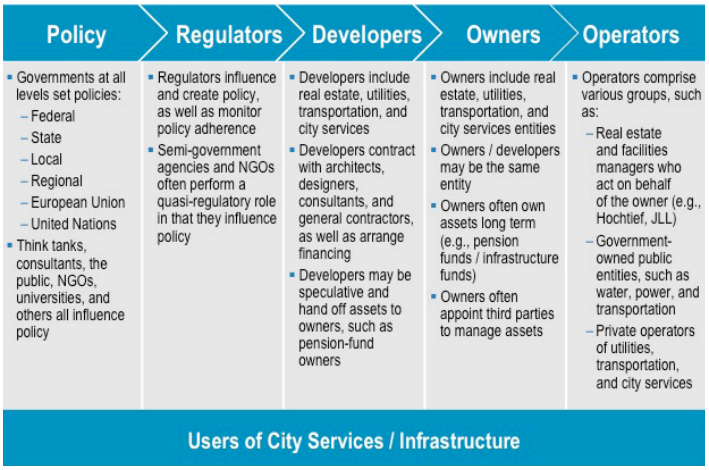
The advantages of a collaborative and dynamic ecosystem include:

- Ability to provide end-to-end solutions to city decision makers
- Mutual and recurring solution improvement to optimize city operations and spending

Within a Smart City context, however, infrastructure will become a dynamic platform enabling continuous innovation. It thus needs to be looked at from a different point of view: total value of ownership (TVO).

- Mutual and recurring solution improvement to optimize city operations and spending
- Improved management and roadmap planning, as well as seamless technology integration among partners
- Ability for cities to respond flexibly to new needs and service complexities with a business model that focuses on OpEx rather than CapEx

Figure 5. Stakeholder Roles and Responsibilities.



Source: Cisco Consulting Services, 2012

Some of the most successful ecosystem thinking by cities has been enabled by "Special Purpose Vehicle" agencies, which fulfill the broad purpose of being mediating entities between private companies and public agencies. Groups such as Amsterdam Innovation Motor[18] in Amsterdam, and Forum Virium[19] in Helsinki, Finland, have been at the forefront of new business models, living lab pilots, and innovative projects and thinking toward delivering the vision for the Smart City.

Consumption Economics Trends in Public Tendering

In order to move away from traditional tendering, which has focused on initial cost (and, as a result, on inexpensive but not necessarily sustainable solutions), cities are now considering the entire lifetime cost of infrastructure, or total cost of ownership (TCO). The notion of TCO takes into account all costs linked to new infrastructure: from the initial investment (CapEx) to the operating costs (OpEx), such as costs of maintenance, energy, disposal, and so forth.

Within a Smart City context, however, infrastructure will become a dynamic platform enabling continuous innovation. It thus needs to be looked at from a different point of view: total value of ownership (TVO). Only then does the case in favor of sustainable, livable infrastructure become clear. Developing infrastructure with a TVO-based approach includes:

Cities across the world are starting to explore the utility of latent data that is emerging from a connected society.

- Linking the project to the city's vision in terms of livability, economic growth, and sustainability
- Defining the connected public infrastructure as a "network of networks" and a platform for service innovation
- Working actively with stakeholders such as city officials, retailers, shop owners, police, telephone operators, ISPs, and, of course, citizens to create meaningful use cases
- Investing operational cost savings in the platform to enable new functionalities
- Measuring the total value generated year-over-year in terms of savings and revenues, jobs created, and livability improvements

Big Data and Analytics

Cities' explorations on becoming Smart Cities, and most recently the focus on the Internet of Things (IoT) and the wider IoE framing, have gone through an evolutionary discovery process. The city initiatives highlighted in this paper show how the discussion progressed in a number of stages:

- **Stage 1:** Networking infrastructures
- **Stage 2:** Transforming public services
- **Stage 3:** Mobility and personal interconnections
- **Stage 4:** Growth in data: from opening up public information (open data) to real-time data flows from sensors, connected devices, and applications
- **Stage 5:** Making use of data and analytics

Today, Big Data is characterized by high volume, high variety, velocity, and value. This evolving landscape makes one thing clear: the rules of networking have changed:

- Networking is no longer about "data transport"; it is about "intelligence" derived from network data to achieve better business and policy outcomes.
- A distributed architecture is emerging, where data can be analyzed in real time at the edge of the network, as well as in batch-mode in the cloud.
- High-performance computing capability is increasingly embedded in the network to filter, screen, and analyze "data in motion."
- An increasing range of new business insights, operational and policy decision making, revenue services for the public and private sectors, and city management solutions is based on data analytics derived from the network.

Cities across the world are starting to explore the utility of latent data that is emerging from a connected society. Open public information policies and the instrumentation of objects are providing an exponentially growing repository of data, at micro and meta levels.

Developing ways to access the latent intelligence being created in the network, directly at its edges, brings information closer to communities, and promotes better citizen engagement and participation.

The task is to find the effective applications of data analytics, with the potential to transform business, government, and society. For example, city governments have relied on static demographic data or expensive, custom on-site surveys to visualize data for patterns in vehicle and pedestrian traffic. Advanced analytics, computing, and networking technology, however, transform this capability by automating pattern visualization to derive insights from Wi-Fi and/or cellular network data in real time to help local governments improve services and manage cities better. City managers can view a near-real-time profile of car and foot traffic of a relevant population to make better and dynamic decisions on highway toll pricing and parking space management.

Cisco has a long track record in working with cities on their journey across the stages outlined here. At an analytical level, geo-mapping data analysis platforms, including applications of data for the retail, financial services, and real estate industries, are contributing to a rich understanding and expertise, which is being applied and developed further with some of the leading innovative city projects. Developing ways to access the latent intelligence being created in the network, directly at its edges, brings information closer to communities, and promotes better citizen engagement and participation.

Social Engagement

As more collaborative and distributed dynamics take shape at every level of a city's journey[20] to become "smarter," engagement with citizens using tested services becomes critical. A Smart City cannot be founded solely on the vision of technology companies or the ambitious aspirations of the city's elected officials, no matter how well-intentioned they may be. A true partnership with different constituents and community groups gets people involved, engaged, and excited to contribute over the long term.[21] A new report, "We the City," by Cisco Consulting Services and the city of Sydney,[22] highlights how "crowd-sourced" and diverse ideas and experiences are the best ways to shape and prioritize where smart ideas will gain most traction. The Sydney report provides initial thinking and makes recommendations from the committee, with input from colleagues in government and the private sector.

In essence the report recommends the promotion of competitions, active communities of interest, fellowships of leading thinkers to work across the city, support of cross-city knowledge networks, and a dedicated function in the city that facilitates cross-community and cross-industry engagements.

These recommendations are universal to cities globally, and are familiar characteristics of the most successful, dynamic, and innovative cities with which Cisco has worked around the world. While this paper highlights merely a few of these cities, there is a dynamic local and global city exchange network connecting cities across the world.

Cities investing in the long-term efficiency of their infrastructure aim to make their infrastructure intelligent, with shared operations.

Design Is Central

Much has been written and debated about the rise of the "design thinking" ethic in public policy and service design. It's possible the idea is suffering from a certain amount of over-hype and has even become something of a cliché. That's a shame because some of the core instincts of design, which futurist and organizational writer Ross Dawson[23] has described as combining function and aesthetics within constraints, will be critical to the work and impact of the Internet of Everything, particularly in public service provision locally and nationally.

Being comfortable with "launch to learn" — basically getting an idea to a rough prototypical stage and then releasing it for public comment and feedback — and the need to ground policy and service design in the needs and circumstances of users, not of policymakers, can be difficult. But these kinds of radical but pragmatic instincts of designers, whose overriding ambition is to create solutions that work for people in context, are going to feature more strongly in the emerging shape of the Internet of Everything economy.

Design considerations include the operating model, technology architecture, collaborative and dynamic ecosystem, and social engagement. Cisco's engagement with the cities of Amsterdam and Chicago are examples of how design thinking is helping inform the development of Smart City projects. This includes usability studies, community engagement, and bringing many perspectives to determine how technology can be applied to the demands and requirements of all who are sought to engage.

Such a two-way process of participation is fundamental to realizing the potentials of urban smart solutions. As Usman Haque, architect and designer of urban sensor applications, states, enabling the "granularity of participation"[24] is vital.

Next Steps for the IoE-enabled City

Efficient IoE infrastructures for cities require two elements:

1. Smart, innovative solutions that break away from traditional, energy-intensive, waste-generating approaches
2. Solutions that eliminate silos of information within a city, allowing for more efficient and open sharing and utilization of information and resources

Cities investing in the long-term efficiency of their infrastructure aim to make their infrastructure intelligent, with shared operations. These cities not only see their energy usage and carbon footprint diminish — they also enhance their livability as safe, vibrant cities, thus attracting both citizens and tourists. How is this achieved? By providing a mix of enabling devices and intelligent data-treatment tools, which, in turn, trigger smarter decisions in infrastructure operation and management:

- **Data-collection devices.** Sensors and metering systems enable the city to generate information about its own infrastructure usage and condition.

In order to realize the full potential of Smart+Connected Communities in the era of the Internet of Everything, a strong public-private partnership approach is necessary, beyond silos of existing city infrastructure providers.

- **Networks.** Different types of networks connect these devices with a central data-collection unit. Once the information is generated, the network allows it to be transported to a server. The communication media itself can be fairly diverse (wireless Internet connection, radio frequency, GPRS, 4G/LTE, power line communication, and IP).
- **Intelligence and analytics.** When information from different places on the network has been collected at a central location, it needs to be processed to define whether there's a need for optimization of the way the network is operated. That definition is increasingly being created at the edge of the network, where it is needed, in real time, through a distributed, intelligent network approach.
- **Intervention.** The infrastructure will require an intervention, such as dynamic adjustments in, for example, zonal street lighting, traffic signaling, or parking controls, communicating critical and location-specific information. All this data will be integrated in open networks so it can be combined in intelligent ways to provide new services and benefits for cities and their citizens.
- **Platforms for interaction.** This infrastructure platform could be used by local SMEs and software developers worldwide, who are constant creators of new, interesting, and relevant applications.

Their innovations can be based on the data generated by the network of inter-connected sensors, cameras, and other intelligent assets in the public space, enabling new ways of generating revenue by associating data from businesses and infrastructure. The opportunities become endless.

Clearly, as systems become more connected and interoperable, the public sector will have to take an "asset bundling approach" with partners, eliminating previously proprietary silos. City governments will need to approach the "Smart Connected City" differently, with an understanding of what is "core" and what is "context," while maintaining centralized control and visibility of critical functions.

In order to realize the full potential of Smart+Connected Communities in the era of the Internet of Everything, a strong public-private partnership approach is necessary, beyond the silos of existing city infrastructure providers. Asset-bundling and new partnership models will enable the creation of a connected public infrastructure that delivers value to both city administrators and citizens, enhancing the livability of a city.

We invite cities, innovators, and business leaders in public services and infra-structure (such as utilities, transportation, traffic, and safety) to join our mission to improve livability in cities and communities by utilizing connected infrastructure platforms, applications, and processes.

Endnotes

1. UN State of World Cities report, 2012/13, http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3387
2. http://timstonor.wordpress.com/2013/06/06/smart-cities-why-what-how-how/
3. Source: Ray Kurzweil, May 2, 2003.
4. http://www.cisco.com/web/about/ac79/innov/IoE.html
5. http://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1209280
6. IDC, 2013, http://www.idc-gi.com/getdoc.jsp?containerId=prUS24087613
7. http://www.wired.com/wiredscience/2012/10/big-data-is-transforming-healthcare/
8. http://www.theaustralian.com.au/australian-it/tracking-technology-is-helping-farmers-take-stock/story-e6frgakx-1226656458095
9. http://www.cisco.com/web/strategy/docs/scc/cisco_amsterdam_cs.pdf
10. "The Time Is Right for Connected Public Lighting Within Cities," Cisco Consulting Services and Philips, 2012, http://www.cisco.com/web/about/ac79/docs/ps/motm/Connected-Public-Lighting_Philips_Cisco.pdf
11. "The LED Lighting Revolution," Philips, May 2012.
12. Source: Philips Lighting, 2012.
13. http://newsroom.cisco.com/press-release-content?articleId=678356
14. http://www.cityofchicago.org/city/en/depts/mayor/press_room/press_releases/2013/september_2013/mayor_rahm_emanuelattendslaunchofnewciscostemlabatmicheleclarkhi.html
15. http://www.social-life.co/media/uploads/tatv_workshop_july_2013_summary.pdf
16. "Smart+Connected City Services," Cisco Consulting Services, 2011, http://www.cisco.com/web/about/ac79/docs/ps/Busan-Green-u-City_IBSG.pdf
17. "Smart City Framework," Cisco Consulting Services, 2012, http://www.cisco.com/web/about/ac79/docs/ps/motm/Smart-City-Framework.pdf
18. http://www.aimsterdam.nl/english
19. http://www.forumvirium.fi/en
20. "Participation, Collaboration, and Community," Cisco Consutling Services, 2011, http://www.cisco.com/web/about/ac79/docs/ps/Participation-Collaboration-and-Community.pdf
21. http://urbantimes.co/section/social-life-of-cities/
22. http://www.sydney.org.au/think-sydney-blog&post=cfs-issues-paper-2--wethecity-collaborating-to-compete-in-the-digital-era&id=A6CCDA37F66FF1D8A79F058508AB4E57
23. http://rossdawsonblog.com/weblog/archives/2013/07/how-soaring-expectations-of-beauty-are-shaping-technology-and-society.html
24. http://www.haque.co.uk/papers/notesonthedesignofparticipatorysystems_eng.pdf; http://vimeo.com/42748883

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