LIFE IS FOR SHARING.

CONNECTED CITIES

How integrated infrastructures enable the digital transformation of urban space

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CONNECTED CITIES **CONTENTS**

Today's cities face tremendous challenges – from rising populations and shrinking budgets to the need to economize on the use of resources. In order to tackle these challenges and support the evolution of urban environments into more efficient ecosystems, information and communication technology are introducing into public services solutions such as traffic and urban mobility management. The deployment of these solutions establishes sustainable operational frameworks and offers new modes of participation for citizens, authorities, local companies, and other stakeholders. This transition to "Smart Cities" is actively pushed forward and funded by legislative institutions such as the European Commission, the European Investment Bank and local governments. Since European cities are complex, historically grown ecosystems, solutions very often require a high degree of flexibility and customization. In order to deploy them and integrate quite different types of solutions into a coherent, manageable and sustainable information architecture, cities have to design, deploy and operate a new breed of communication infrastructure. With this in mind, the European Commission has identified that, as a highly promising starting point for these transformation processes, the implementation of intelligent street lighting solutions could favor the establishment of communication infrastructures able to act as multifunctional networks (Humble Lamppost).

INTRODUCTION

Over 50,000 people crowd into an area of a few hectares. Space is limited but wellbeing is assured. There is fresh water and there are hot meals, chilled drinks and adequate sanitary facilities. What we are talking about here is not a city but a stadium. Facilities such as the Amsterdam Arena, one of the most up-to-date stadiums in Europe, concentrate in a small space many challenges that cities face on a larger scale. They form microcosms of their own, cities within cities, in which we can realize visions of the Smart City here and now.

By 2015, for example, the Amsterdam Arena is to be carbon dioxide neutral. Nearly 40 organizations are involved in the sustainability project. They include authorities, sponsors and business partners of the Arena. Initiatives range from programs to save resources such as water to more efficient garbage separation. Every Arena employee can submit ideas on sustainability strategies via a platform.

Similar to smart venues like the Amsterdam Arena, Connected Cities hold forth the promise of major benefits for a large number of players. For citizens the Connected City should be a place where the quality of life is high, daily tasks are made easier, and new opportunities to take part in community life are available. City administrators should be enabled to handle complex administrative tasks more efficiently and the target of a sustainable, safe and eco-friendly metropolis could thereby be achieved – even against a background of rising populations and shrinking public budgets.

Until now, most statements on the Connected City of the future have remained remote visions and utopias. The technologies were far too expensive, not always mature and ways to deploy them “smartly” were far too vague. Today we are experiencing a shift. Institutions such as the EU Commission and the European Investment Bank are investing heavily, facilitating the move to smarter cities and communities. Moreover, our world has entered into a new phase of global networking. The Internet is expanding to include the Internet of Things. Physical and virtual worlds begin to merge. The reasons are increasing network capacity and the maturity of basic technologies such as Machine-to-Machine Communication and Big Data Analytics.

Comprehensive solutions based on these technologies are already in use in nearly all areas of the economy – from fleet management systems to remote monitoring of production plants. They offer new insights into complex processes and optimize clearly outlined areas of responsibility such as public transportation. The most important point, however, is that they do not constitute isolated, standalone silos but are open for crosslinks between different official agencies. Right now, more and more solutions for cities are entering the market. As building blocks for sustainable and competitive structures they tackle the challenges that municipal administrations face. To realize the Smart City vision today’s building blocks must be capable of merging into a larger ecosystem of connected things and people. The fundamental prerequisite for this to happen is an open and multi-level, city-wide communication infrastructure.

Every city is different. Against the background of their respective history and starting points cities position themselves as a business location or as a cultural metropolis, for example. Smart City solutions must take into account each city’s different motivations, requirements, limitations, challenges and objectives very often generated and required by the dominant political and economic groups. They must support the performance indicators of the city’s strategy. Being “smart” means something different for each city.

This white paper provides an overview of the current state of communication infrastructures and solutions for Connected Cities. It is aimed at decision makers, municipal administrations and planners, and other experts and multipliers who would like to know more about the background and about the challenges and opportunities of the digital transformation of urban space. The starting points are, for one, the challenges and changes that cities are currently experiencing and, for another, the technical foundations of current solutions. Examples such as urban parking and mobility management and street lighting demonstrate what current solutions are already capable of achieving, how they fit into a city-wide network, and what they mean for citizens, municipal administrations, and manufacturers.

CONNECTED CITIES **INTRODUCTION**

DEUTSCHE TELEKOM AND SMART CITIES

Smart City solutions entail many different building blocks and challenges – from processes, hardware, software and communication layers to the design of new business models. They have to meet the interests, needs and political aspirations of citizens, authorities and businesses. Building on its expertise at operating, managing and advancing large communication infrastructures, its experience in the M2M sector and its IT integration capabilities, Deutsche Telekom aims to put the pieces of this complex ecosystem together. We believe that collaboration, open platforms and multi-layered urban networks are the key to take the digital transformation of cities forward. The move towards Connected Cities is an evolutionary process in which heterogeneous building blocks need to be integrated in a larger ecosystem of connected things and people. The step-by-step transformation of public infrastructures and services addresses the challenges of modern cities – from energy supplies and traffic planning to economic and ecological sustainability.

TOWARD THE SMART CITY

The digitalization of urban space is motivated by societal, economic, ecological and technological developments. They include superordinate current and future challenges such as increasing urbanization and demographic change, and also individual plans for the future and problems faced by individual communities. The road toward the Connected City must thus be understood as a complex interplay of different interests and objectives of cities, citizens and other stakeholders like local companies and institutions.

CITIES IN THE THROES OF CHANGE

The world's cities are growing faster than ever before. According to the United Nations, 3.88 billion people lived in cities in 2014; by 2050 their number is expected to increase to 6.33 billion – this will be 66.4 percent of the world population [1]. A historic threshold was crossed in 2008 when the number of city dwellers exceeded the rural population for the first time in world history. As a result of this trend more and more megacities with populations of more than ten million are taking shape. Forecasts have it that around 630 million people will live in megacities by 2025. This continued growth confronts cities with serious challenges. They must expand, adjust, and optimize traffic and administrative infrastructures and must at the same time develop sustainable structures and reduce their carbon dioxide emissions. Cities, after all, account for 70 percent of greenhouse gas emissions yet take up only two percent of the Earth's land mass [2].

In these booming environments, the central drivers suggesting the use of ICT-based solutions to deal with organizational and infrastructural challenges are falling budgets and rising public expectations in terms of quality of life. Cities are in competition with each other. They are in the paradoxical situation of facing major challenges due to massive population growth while at the same time depending on this very growth. They seek to attract people and businesses in order to strengthen their economic position, create jobs, and ensure prosperity.

One consequence of this competition is that cities are increasingly specializing and honing their profiles by means of different funding priorities – be it as a media city, a knowledge location, or a cultural metropolis. Demand for the digitalization of processes is triggered not least by these differences along with the city's individual starting points and objectives. Becoming a "Smart City" means something different for each city. Nonetheless, there are common challenges every city has to cope with one way or another. They range from mobility management and public transport to public safety, the management of resources, electricity, gas and water as well as support for local economy.

In the end, these diverse challenges do not only have to be solved separately – it is crucial for them to be integrated in a larger connected ecosystem and meet the interests of citizens, authorities and businesses. As a result of this linkup, additional use cases and services will emerge. Real time traffic information for example will redirect car drivers to other routes in case of an accident or suggest other means of transport by guiding them to the next Park and Ride station. Emergency services will arrive at the crash site faster due to an automated emergency call that sends the coordinates. By combining the emergency vehicle's current location, the target coordinates and real time traffic information, emergency management software is able to calculate the optimal route to the crash site and the nearest hospital and update it in real time.

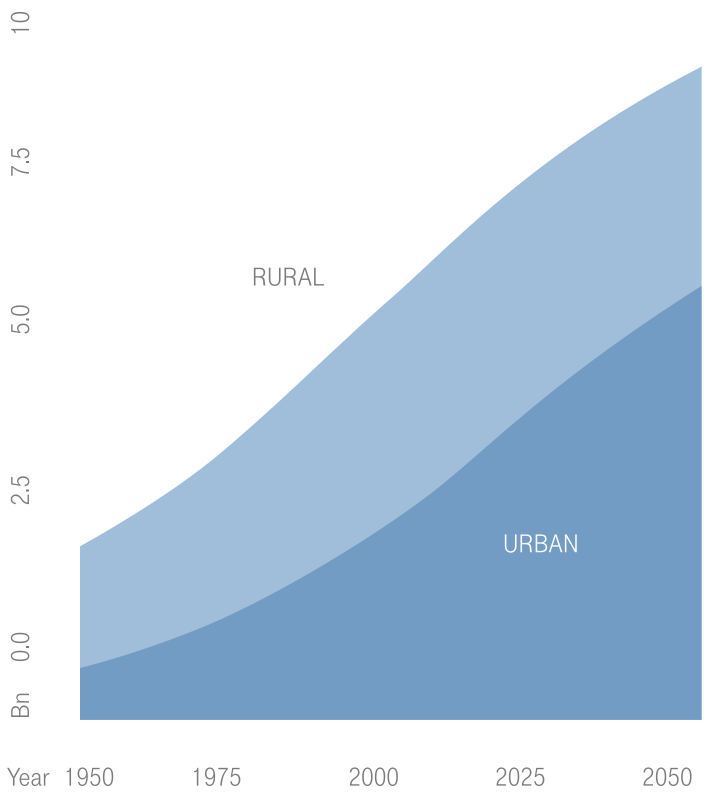


FIGURE 1: WORLD POPULATION FROM 1950 TO 2050

CONNECTED CITIES **TOWARD THE SMART CITY**

DIGITALIZED URBAN ENVIRONMENTS

Concepts around the digital transformation of urban space – which are today mostly covered by the term "Smart City" – emerged in the early 1990s and have accompanied the debate on urban change ever since against the background of technological changes [3]. To this day there is no generally recognized definition. In the course of two decades different focal points took shape, each with special emphasis on individual aspects, such as sustainability. Current approaches take care to view the role of municipal ICT infrastructure in the context of ecological, economic, and social aspects and, with regard to Web 2.0 and social media, to incorporate new forms of civil participation.

Andrea Caragliu, Chiara Del Bo and Peter Nijkamp summarize in their report "Smart Cities in Europe": "We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." [4]

A Smart City thus takes shape by means of the interplay of many factors. Just like the Intelligent City and Digital City concepts, the Smart City stands for the ideal of a city that deals skillfully and seminally with the resources at its disposal and the use of ICT. Social and ecological sustainability are strategic targets. They also include a high quality of life in urban areas. According to Hans Schaffers et al, "the stimulation of ICT-based applications enhancing citizens' quality of life is now becoming a key priority." [5]

Other than in drafts for cities with a promising future, the concept is also used as a collective designation for specific initiatives and modernization measures. At the beginning of 2013, for instance, Pike Research counted around 130 cities worldwide that are pursuing a Smart City concept. Half of them are in Europe, with Amsterdam, Copenhagen and Stockholm as showpiece examples. Depending on the extent and focus of the Smart City agenda totally different areas can be involved, ranging from traffic and utilities systems via housing concepts, public safety, education and administration to healthcare.

In many of these areas legislative institutions are taking the expansion of communication networks and the use of ICT-based solutions forward actively by means of directives and initiatives. The EU Commission's Directive EC 245/2009, for example, requires around 100 million streetlights to be replaced, to achieve CO_2 emission reduction and energy efficiency targets, only by more energy-efficient lighting technologies in the European Union member-states, banning obsolete technologies (polluting and inefficient) by 2016. That is an incentive for cities to introduce a connected solution for street lighting at the same time. It is the only way in which they can be prepared for upcoming directives and

DEUTSCHE TELEKOM'S DEFINITION OF SMART CITIES

A Connected City is an Ecosystem characterized by a partially digitized set of processes and striving to increase its self-awareness and efficiency, through ICT and a higher degree of participation from its Citizens, Authorities, Businesses.

THE EU COMMISSION'S DEFINITION AND OBJECTIVES OF SMART CITIES

A Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership. [16] "Smart cities" provide public services to their citizens in a more convenient way, are more responsive and citizen-centered, provide the right information in real-time to allow for better everyday and business decision-making and achieve all this in an economically viable way so as to improve environmental sustainability. [15]

EUROPEAN INNOVATION PARTNERSHIPS ON SMART CITIES AND COMMUNITIES (EIP-SCC)

The European Commission has initiated the European Innovation Partnership on Smart Cities and Communities in order to bring together citizens, cities and industry. Its Operational Implementation Plan contains eleven priority areas, ranging from "Sustainable Urban Mobility" to "Business Models, Finance and Procurement" [9]. For the purpose of implementing new technologies, the EU Research and Innovation program "Horizon 2020" is funding promising projects with nearly €80 billion between 2014 and 2020.

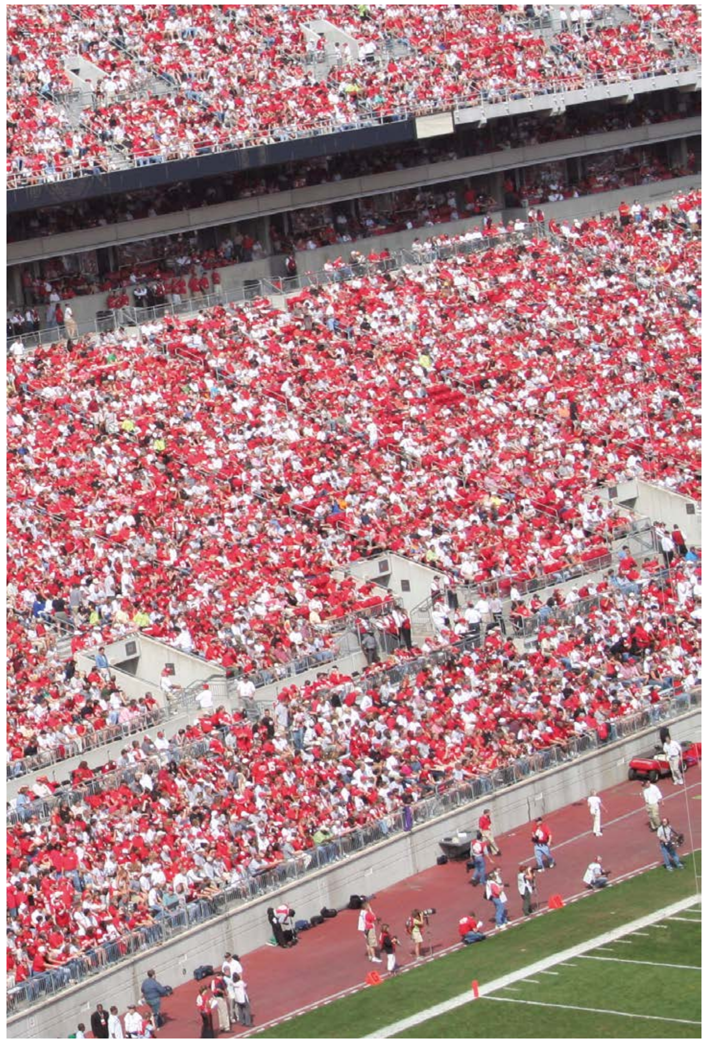
CONNECTED CITIES **TOWARD THE SMART CITY**

more ambitious climate targets. A remaining issue for cities, however, is the question of funding such projects on a large scale.

Apart from statutory guidelines, major events can tip the balance for setting Smart City solutions on the agenda. Rio de Janeiro pursued a Smart Mobility project with regard to the World Cup in 2014 for example. According to a transportation plan for the final match, the Rio Operations Center monitored the area around the Estádio do Maracanã in order to adjust traffic lights and guarantee a smooth traffic flow. Starting from 2016, Rio de Janeiro will invest further in the city's transport infrastructure for ten years according to its Sustainable Urban Mobility Plan. Despite the huge range of different Smart City solutions, they share commonalities, especially the fact of being connected. For figuring out the development of Connected Cities, the emerging Internet of Things plays a crucial part.

"FAN CITY" – MANAGING MAJOR EVENTS

Our palaces of sport accommodate tens of thousands of people in a very confined space, if only for a few hours. A little bit of chaos might be appealing sometimes. But it's certainly not if you are eager to watch your football team play and have to wait in incredibly long lines to get a beer. Efficient logistics is the key to a great experience here. T-Systems Multimedia Solutions GmbH has developed a proximity marketing solution for major events which improves logistics by directly addressing fans via mobile apps. It ensures that nobody goes hungry or thirsty and enables a regulated arrival and departure. The app guides fans to their seats in the stadium via beacons – small transmitters scattered throughout the stadium. During the game, fans can retrieve information such as team line-ups. Moreover, the app provides coupons and guides fans to beverage and snack stands. Fans can even pay directly per app which significantly accelerates the sales process and helps to reduce lines.



THE ROLE OF THE INTERNET OF THINGS

Within a few decades the Internet has embedded itself firmly in our everyday life, revolutionizing not only the media landscape but also large parts of the services sector. Alongside companies, cities use the Net to create more comfortable service offerings. Citizens can now apply for a residents' parking permit, reserve a place in a municipal kindergarten or check the status of a building permission application, and do it all online.

The Internet of Things (IoT) is currently ushering in a new phase of connectedness that will make an enormous impression on our future life and work. According to the European Research Cluster on the Internet of Things (IERC), the IoT " [..] is an integrated part of Future Internet including existing and evolving Internet and network developments[..] where physical and virtual "things" have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network." [14]

The Internet is spilling over into the world of objects with websites being joined by devices, machines and everyday items ranging from manufacturing plants and coffeemakers to watches, toothbrushes and razor blades. If the things around us are becoming smart, they will be a part of the digital information landscape and thereby usable in a new way. A connected car, for instance, can serve as a WiFi hotspot on wheels, while a connected trainer can measure the runner's speed and show it on his or her connected wristwatch. The watch could then relay the data to a Web portal for evaluating training results and comparing them with other runners. Or it could send the vital signs of the runner directly to a doctor for obtaining medical advice.

An essential enabling technology for the Internet of Things is Machine-to-Machine Communication, or M2M for short. It describes the automated data interchange between machines or between machines and a control center. The concept includes a number of networking practices like telemetry and telematics that have been in use for decades in some application areas such as remote monitoring and surveillance of industrial plants. The interplay of components in a networked application is also known as an M2M solution.

The basic structure of M2M solutions is always similar. Sensors, actuators, and IT components are integrated directly into objects as embedded systems or connected with them. By this means the objects can gather, send and receive data and control commands. Typical use cases are remote monitoring and remote control. The latter grants access to a diverse set of functionalities of connected objects from afar. Valves could be opened or closed and streetlights could be programmed to shine brighter on pre-defined occasions.

In case of remote monitoring, the objects record continuously data such as operating parameters, GPS coordinates, electricity consumption or incidence of light and share it or transmit it to a server where it is stored and evaluated. That is where data storage and management techniques as well as evaluation and forecasting methods such as Big Data Analytics come into the picture and are in some instances seen as implicit components of an M2M solution. If the sensor and machine data reach predetermined levels, further action is triggered automatically and the solution may send the operators a text message alert for example.

The pace at which the Internet of Things is progressing is indicated by the spate of computerized and connected objects and areas described as being "smart," "intelligent," and "connected." In the power supply context the Smart Grid is taking shape, while domestic networking is leading to the Smart Home and intelligent street lighting ensures that streets are better lit and safer at night.

The Internet of Things is no longer a distant vision; it is already in the realization phase. Every day, new devices, machines and objects are connected to it. Experts see the destination of this development in an overarching structure where the virtual and the physical world, objects and people, machine data and social media channels merge into a universal Net.

A challenge that cities face is to set the course for the networking of municipal infrastructure, including the power supply, traffic systems and municipal administration along with the healthcare and education systems. In much the same way as cities today use the Internet for administrative tasks and providing services for citizens, connected objects will have a key role to play in the future.

NETWORK INFRASTRUCTURES FOR URBAN SPACES

ICT-based applications for Connected Cities are complex technical architectural systems. Depending on the field of application they may require quite different communication services. Connected street lamps transfer very small amounts of data periodically while video-based traffic analysis systems have to relay huge amounts of data. Both network infrastructure and data storage have to be scalable and adaptable to a wide array of different applications.

MULTI-LAYERED URBAN NETWORKS

From private local networks to public telecommunication networks, ICT-based applications in Connected Cities utilize multiple infrastructures for data transport. Devices can be connected via fixed lines, but mobile networks become more and more important. If the connected devices change their location – take cars for instance – mobile connectivity is the only option. But even stationary objects such as traffic lights can be connected much more easily and at a lower cost using wireless technologies.

Since different applications bring along different communication requirements in terms of reach, speed and device density, cities should utilize several connectivity layers. Some of these such as broadband or cellular networks exist adequately in most European cities already. Others like narrowband or ultra-narrowband networks should be deployed additionally. Ultra-narrowband or Low Power Wide Area Networks (LPWA) for example aim at establishing a new, low-cost connectivity in the frequency range of less than one gigahertz. Current endeavors to set up LPWA networks envision modules that can run for ten years on a single AA battery and cost less than five dollars [17]. In contrast to classical mobile network connections with higher bandwidths, LPWA connections are intended only for simple messages with a low data volume. High coverage and low energy consumption are the key criteria – even if the connections are characterized by low bandwidth and high latency.

None of these layers should stand on its own. Both narrowband, ultra-narrowband and local area network technologies such as beacons have to be integrated into the existing communication infrastructure to establish an open, flexible and application-agnostic Multi-Layered Urban Network. The common denominator of data transport is the Internet Protocol (IP). All parts of telecommunication infrastructure are being updated to the next generation as part of the IP transformation as we speak. Additional protocols such as IPv6 over Low power Wireless Personal Area Network (6LoWPAN) enable even the smallest devices to communicate via IP and participate in the Internet of Things.

One of the first cities that is integrating several kinds of networks for Smart City technologies is Bristol. As part of the "Bristol is open" project (www.bristolisopen.com) – a joint venture between the University of Bristol and Bristol City Council – a fiber network in the city center is joined by a wireless network and a mesh network consisting of 54 fibered lamp post clusters. In terms of software, a city operating system is introduced. It can host various applications, which process captured data like air quality, traffic flow or energy use. According to the project's website, all generated data will be anonymized and made public in an open data portal. The project is funded by local, national and European governments as well as private and academic research funding.

Not every service enabled by Connected City application has to be evenly distributed throughout the municipal area. There are typically quite different demands in city centers compared with residential areas or outskirts. Downtown areas typically have to solve the biggest logistical challenges due to their complexity. They have the highest population, traffic density as well as workplaces, shops, and tourist attractions. Broadband is absolutely necessary here to support hotspots, streaming and traffic management services for example. In residential areas, however, standard services like intelligent street lighting play the major role. To keep the cost of connectivity and hardware low, narrowband networks are recommended for extended device networks. Using ultra-narrowband, even outskirts can be provided with basic services and sensor networks for monitoring river and stream flow for example.

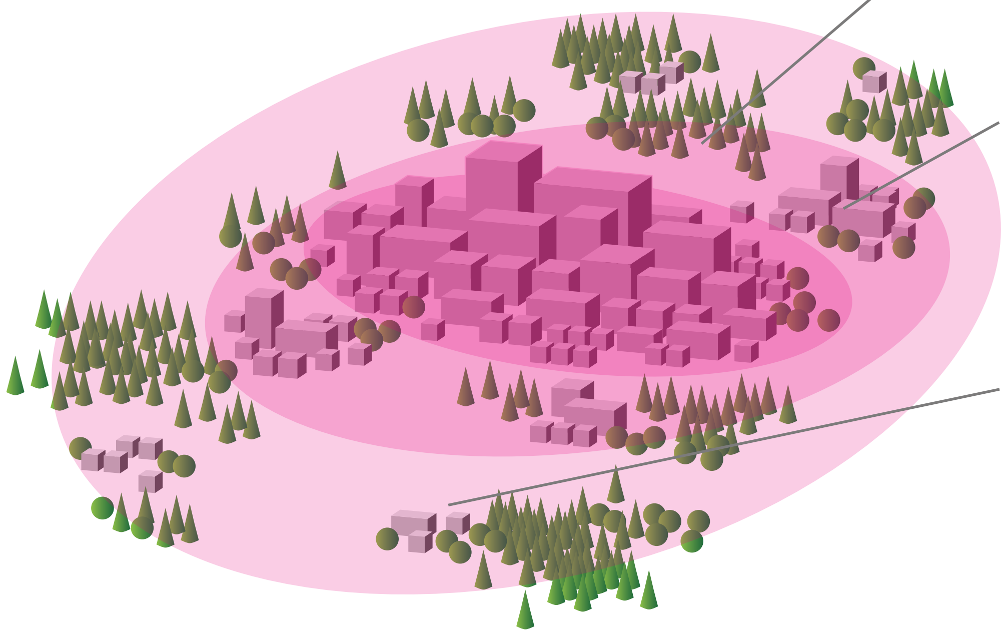
In the face of a growing number of applications which rely on data evaluation, connectivity layers are not the only constituents of a Connected City's communication infrastructure. Data storage and data management capabilities are becoming increasingly important, too.

CLOUD-BASED COMPUTING AND STORAGE

Connected objects generate data that needs to be stored for further processing. In many Smart City solutions, connected objects such as meters for water and gas store the measured data locally for a limited period and relay it to a server for storage in the long term. Cities usually operate some kind of server infrastructure that can be considered for this task. The trend is concentrating towards Cloud-based storage, however, or, in some instances, towards "edgeware computing" in order to keep relevant data and query results closer to the devices which will be consuming the data. A similar concept to "edgeware computing" is "fog computing" which

CONNECTED CITIES **NETWORK INFRASTRUCTURES FOR URBAN SPACES**

FIGURE 2: THE "IOT SOCIAL LAB" CONCEPT – TECHNOLOGICAL BACKGROUND



extends the cloud paradigm. In addition to data centers, computing and storage capacities are geographically distributed over several heterogeneous platforms at the network edge or even in devices such as access points [21].

Cloud computing ensures the demand-based provision of IT resources such as computing power and storage space along with platforms and software for application development and administration. Operating and maintaining a server infrastructure of one's own is no longer necessary. That cuts costs and accelerates the use of networked applications. In the United States the U.S. Chief Information Officer's 25-point plan to reform government information technology also led to the adoption of a Cloud First Policy [6]. Japan is working on a national cloud for the whole governmental IT infrastructure, too.

An important aspect of Cloud-based storage is the constant availability of data from any location. In much the same way as private users today can access their music collection, their photo album or even the state of play of computer games from different terminal devices while on the move, stored data can be used jointly by different agencies, employees, and citizens at different locations.

When using Cloud-based offerings cities must nevertheless consider the areas of the world where the provider's data centers are situated. Especially when sensitive information such as personal data is involved, they must ensure compliance with all statutory data protection regulations. Legal responsibility for the data lies with the entity responsible for Processing which is in many cases the city itself.

Along with sensor data that is stored in the cloud, most applications for Connected Cities provide Cloud-based Web portals and apps. All that is required to access them is an Internet-enabled device such as a PC, a smartphone or a tablet. Applications typically provide configurations for the system in question as well as services that build upon them such as maintenance planning.

Another pressing topic when it comes to urban data is data ownership. In case of raw data from devices the situation is clear. The device's owner owns the data. But as soon as data is aggregated and further processed in a platform, it gets more complicated. Processing of raw data results in new information and knowledge which is formed by sophisticated algorithms and the combination of several data sources. Without these processing capabilities new information wouldn't come into existence. But without raw data as source material, such processing capabilities alone would be useless as well. Therefore the question "Who owns the data?" is far from being trivial and has to be regulated across the value chain.

HARNESSING DATA FOR MUNICIPAL TASKS

Data has been described as the oil of the 21st century by many experts of the digital economy. In fact it shares many properties with the chemical substance figuratively. Similar to oil, data has to be refined before it can be of use. It has to be preprocessed, set in relation with other data and turned into information and knowledge eventually. In terms of urban data, specialized horizontal platforms for cities and analytics tools address this task.

HORIZONTAL PLATFORMS FOR CONNECTED CITIES

Handling the data of potentially thousands of connected devices is just one of the challenges Smart City solutions have to cope with. Another challenge is the management of all the devices themselves and their connections – especially in terms of their heterogeneity. Connected things range from traffic lights and signs to parking spaces and waste bins. For managing such a diverse set of objects, horizontal platforms are emerging. The ideal platform consists of the elements depicted in Figure 3. An agnostic object management layer provides functions for administering connected objects – independently of specific device properties. A layer for horizontal data transportation enables cross-connections between separate application areas. The applications enabling platform facilitates the development of Smart City apps by providing open Application Programming Interfaces (APIs), Software Development Kits (SDKs) and additional development tools.

Considering the development stage of horizontal platforms the situation is similar to the early stages of Enterprise Resource Planning (ERP) systems during the 90s. Just like ERP systems now integrate business processes and track resources across all domains of organizations, horizontal platforms for the Internet of Things need to provide an integrated view of connected objects.

Connectivity platforms constitute one of the lowest horizontal layers. They cope with the challenge of managing the connected devices and their connections regardless which devices are involved. Classic functions of connectivity platforms include controlling SIM cards. Customers can order and activate SIM cards, book data options or deactivate cards via a Web portal. But the latest platforms provide more than these basic functionalities. Deutsche Telekom's M2M Service Portal, for example, not only shows all connections and statuses, data volumes and card costs, but also provides card abuse and cost control functions. Enabling the portal to block unauthorized data traffic effectively curbs risks of malfunction and theft.

Further horizontal middleware layers may be superimposed: layers such as a data normalization layer that converts sensor data from different sources into a common format. Additional application layers operate on the normalized data. This is the domain of asset management platforms. They typically provide ready-made applications for standard tasks such as remote diagnostics, software and content distribution, reporting and analytics. Additionally, application platforms make development tools and APIs available for building and delivering custom applications. Another important aspect is their integration capabilities with other components of the IT landscape like CRM, ERP, billing or additional administrative software.

In order to connect devices throughout the city with an application platform, so-called agents are required. The agent is a piece of software that handles communication with the platform. It basically translates specific device information – be it the brightness sensor of a street lamp or a sensor that measures water pressure – into the platform's device-independent data model. Its drivers provide access to data sources, and core services for configuring business rules like alarms and the execution of scripts. Certification programs attest connected devices to be compatible with certain application platforms.

Even though today's application platforms provide basic functionalities for analyzing the data collected, more elaborate and powerful evaluation methods for continuously growing data sets are becoming more and more important.

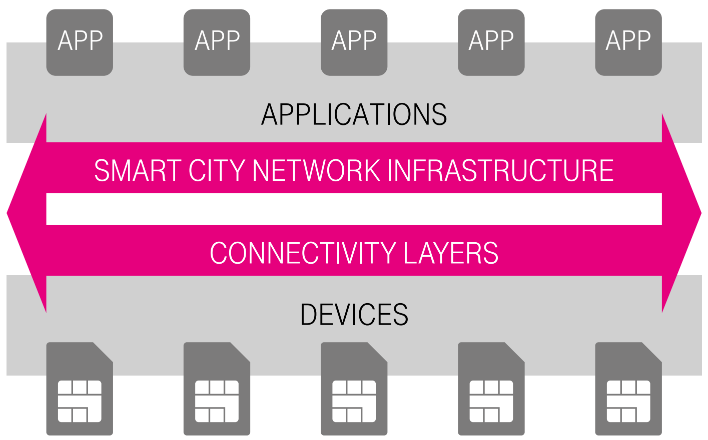
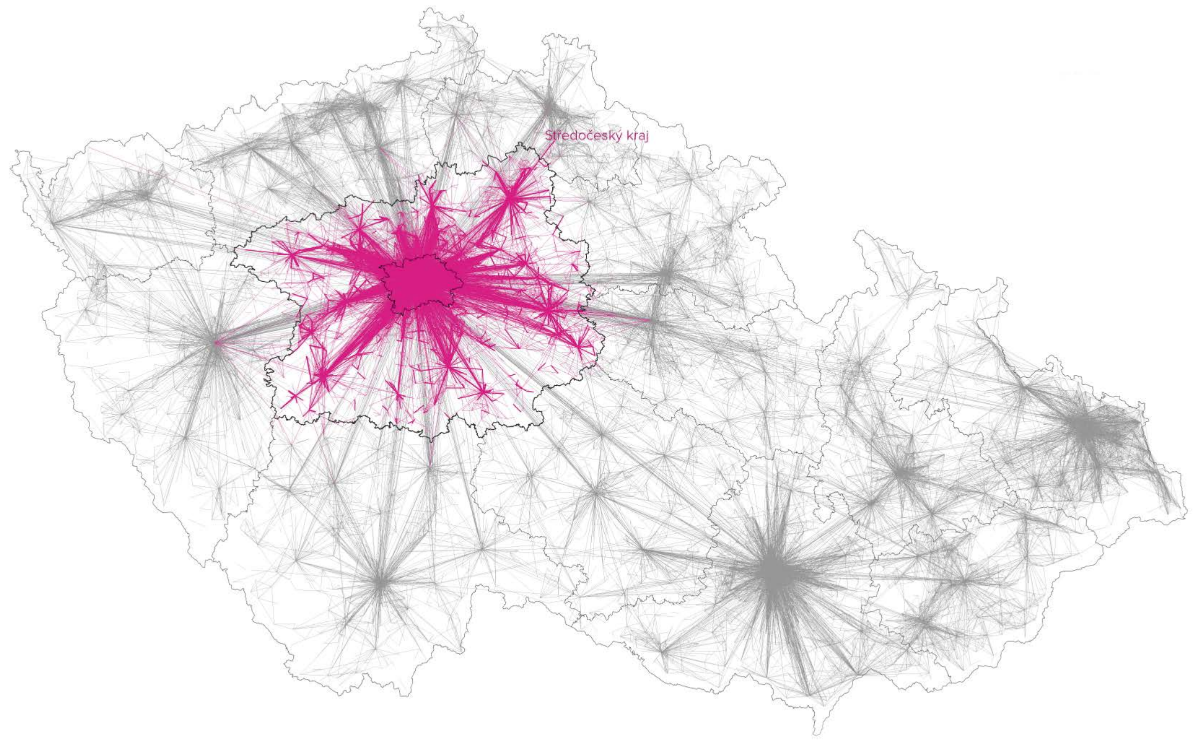


FIGURE 3: THE IDEAL-TYPICAL STRUCTURE OF A HORIZONTAL SMART CITY PLATFORM

CONNECTED CITIES **HARNESSING DATA FOR MUNICIPAL TASKS**



BIG DATA PROJECT: MOBILITY MONITORING

When it comes to detailed and extensive models based on huge amounts of data, cooperation is key. The Rodos Transport Systems Development Centre is a case in point. The initiative is led by the Czech national supercomputing center and assembles several Czech universities, industry players and public authorities. T-Mobile Czech Republic acts as a strategic partner. By combining data from mobile networks and traffic monitoring the participants have been able to build a complex mobility model. It has been used in several projects throughout the Czech Republic already. The Rodos team monitored 40 locations for Czech Tourism for example and provided the governmental agency with valuable insights about visitation patterns. During major events such as the World Ice Hockey Championships the model supports the police, fire brigades and ambulances in crisis management. By giving an overview of the actual distribution of people and detecting deviations in real time, the mobility model provides important information for decision making in critical situations. In Prague's metropolitan area, mobility information generated by the Rodos initiative is used for optimizing the city's integrated public transport system.

At the heart of the model lies anonymized signaling data from mobile networks. It enables the researchers to observe, with full respect of privacy regulations, the distribution of people in time and space and how they move around. This data is combined with several other data sources like floating cars, toll stations, census data, digital maps and sensors from traffic monitoring. The wide array of possible use cases ranges from urban planning and improving public transport to gaining tourism statistics and optimizing retail networks.

ANALYZING URBAN DATA

A crucial step to create actionable insights is the analysis and evaluation of urban data. If the amount of data is very large, takes different forms and varies in the velocity of data flow, we are talking about "Big Data Analytics." Its aim is to gain more precise insights into processes or courses of action by turning raw data into useful information such as patterns and predictions. Connecting different databases also promises to improve the opening up of complex systems and generation of added value. Techniques like machine learning algorithms, data mining and statistical modeling help to predict certain events, actions or conditions. Chicago, for example, is using predictive analytics in its Smartdata Platform to get rid of rodents [18]. Based on past data the platform predicts addresses where rats are most likely to make themselves at home. Streets and sanitation groups then visit these places, look for rodents, and lay out baits.

Cities are among the places where the most data is generated around the world. The data a city's administration has at its disposal ranges from sensor data of buildings and traffic infrastructure to feedback from citizens. Huge amounts of data are already collected automatically. Chicago's Windygrid for example – a geographic information system – gathers about seven million rows of data per day. Other types of data are on the verge of coming into the picture. Individual experiences that citizens share in social networks are seen as increasingly important for example. Targeted inclusion of this data is also known as crowdsourcing [7]. The more sensors there are in the objects around us, the greater the precision of the information that can be derived from the data they supply.

What benefit can be derived from the enormous data streams that Connected Cities generate daily is one of the crucial questions for every overriding Connected Cities concept. Pioneering cities such as New York pursue open data initiatives and include their citizens in them. The Open New York website (https://data.ny.gov/) not only contains a large amount of public data. It also gives citizens an opportunity to suggest other data that might be included. The city also provides developers with APIs to enable them to integrate certain data easily into applications of their own. One of these APIs, for instance, provides access to the number of vehicles that use each of the nine bridges and tunnels maintained by Metropolitan Transportation Authority daily.

ENGAGING CITIZENS

The purpose of a city lies in giving a livable home to its inhabitants. The most sophisticated and efficient infrastructures and solutions in Connected Cities don't make any sense at all if they can't be put to use by its citizens. When it comes to introducing ICT-based solutions in urban spaces one of the first questions is how citizens benefit from it. Regarding the Internet of Things and its impact on the mobile revolution, the question more often also includes how citizens can participate in it. While today's mass distribution of mobile devices like smartphones and tablets drastically transformed the way we communicate with each other, the dissemination of the very same technology in almost every aspect of urban infrastructure will introduce completely new modes of communicating with our surroundings.

Some of these modes of participation might come along in a rather passive way. London for example is trialing a new system for pedestrian crossings called the "Pedestrian Split Cycle Offset Optimisation Technique," or Pedestrian SCOOT. It uses video camera technology to detect how many pedestrians are waiting at crossings. Pedestrian SCOOT is able to adjust the timings of traffic signals automatically and extend the cross phase when many pedestrians are waiting. Citizens who cross the street don't have to do anything in particular. Nonetheless, they participate by influencing the counter in the algorithm which determines the length of the cross phase.

Other modes of participation feature active components. These include apps to find free parking places or access governmental services for example. Current efforts of fostering citizen engagement examine ways to promote beneficial behavior. An app for public transport might point citizens who are ready to help people who can't get onto a bus alone for example. Applications like these are in an early stage of development. Critics like Evgeny Morozov warn against simplification of this matter by stressing that the promotion of certain desired behaviors might bring along undesired behaviors as a side effect [20]. If personal waste disposal is strictly monitored and coupled with a "gamification" approach for example, citizens might reduce their waste output at home but there might be a rise of illegal waste disposal at the same time.

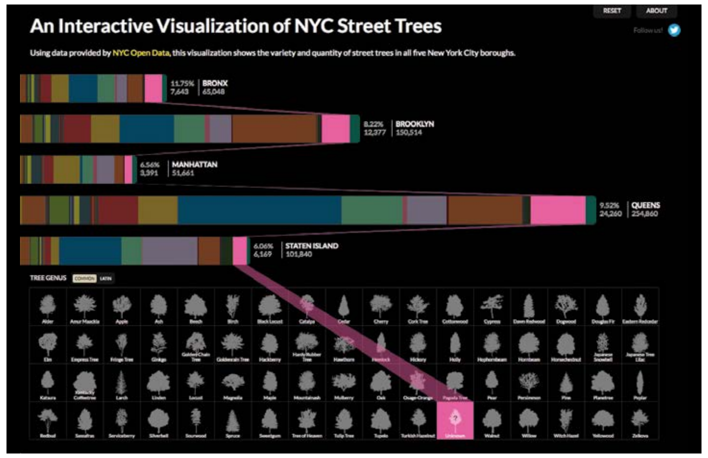


FIGURE 4: AN INTERACTIVE VISUALIZATION BASED ON OPEN DATA SHOWS THE VARIETY AND QUANTITY OF STREET TREES IN NEW YORK CITY

LOW CARBON MOBILITY MANAGEMENT

Car emissions have been identified as a major cause of global warming. According to a NASA study conducted in 2009, motor vehicles are the greatest contributor to tropospheric ozone, fine aerosols, aerosol-cloud interactions, methane, and long-lived greenhouse gases [19]. In theory every car driver can do his or her bit. In practice, however, it turns out to be pretty hard to stay conscious about one's own driving behavior and act accordingly. The amount of environmental pollution is not only determined by the vehicle and its technical parameters but also by the driving behavior after all.

In order to promote an ecologically compatible quality of driving, the Deutsche Gesellschaft für Internationale Zusammenarbeit (German Federal Enterprise for International Cooperation), GIZ for short, and Deutsche Telekom AG have implemented a Private Public Partnership (PPP) in the area of "Low Carbon Mobility Management." On behalf of the Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Economic Cooperation and Development) the PPP has developed an application and initiated projects for reducing greenhouse gases cooperatively in Chinese cities.

The basic idea behind the application is to analyze driving behaviors, calculate efficiency profiles, and give the drivers feedback about how they are doing. Up to now these functionalities have been available only in professional and expensive telematics solutions. The solution which has been developed in the context of the Low Carbon Mobility Management (LCMM) project, however, accomplishes the same without additional hardware. It simply uses smartphones with its integrated sensors and utilizes GPS speed profiles to measure fuel consumption. Positioning data is continuously relayed to a Cloud Computing and Big Data Computer Center of T-Systems which carries out the algorithm for calculating the driver's efficiency score. The score is visualized and presented on the driver's device in the colors of traffic lights from green to red.

In an Eco-drive field trial with DB Schenker in China from November 2010 to October 2013, 44 truck drivers, 10 delivery trucks within Beijing and 10 heavy duty trucks were equipped with smartphones. In July 2012 each group recorded GPS traces of all trips for six weeks. The data has been processed and represented in a Web portal – from start and end position to the average speed and the distance travelled. After receiving professional training the drivers recorded their daily trips again. Compared with the first test phase CO_2 emissions were 6.8 tons lower than in the second phase in which the drivers received feedback about their driving styles. The fleet consumed 2,575 liters less fuel and saved EUR 3,475.55. In order to motivate the drivers for ecofriendly driving an incentive scheme was set up where approximately half of the savings was handed over to the field participants with the best scores.

The app shows drivers in traffic-light colors how they are doing.

CONNECTED CITY APPLICATIONS

Very few infrastructures of Connected Cities are newly built from the ground up. There are exceptions, like the planned city of Masdar in the United Arab Emirates, a city under construction in the emirate of Abu Dhabi that is to be fully supplied by renewable energy. Most cities, however, face the challenge of incorporating new technologies into structures that have grown historically. Applications for Connected Cities therefore have to support a more evolutionary step-by-step transformation.

MARKET OVERVIEW

ICT solutions for cities are complex. They combine embedded systems with communication technologies and the software to enable different players, such as administration employees, city planners, and citizens, to interact. Furthermore, the areas of use encompass a wide range of different special areas from traffic guidance systems to water pumps and sewage treatment plants.

The market is thus strongly fragmented. Many small providers develop specialized solutions for specific areas. That is why collaboration by several partners and experts is needed to implement coherent Smart City concepts. At present, telecommunications providers and a number of globally active IT service providers have taken on the role of bundling all of the components and competences required. They aim to offer cities comprehensive, single-source turnkey solutions.

Industry experts agree that Smart City applications are on the increase. According to Pike Research, the market volume for smart technology solutions is set to rise from $6 billion in 2012 to $20 billion in 2020, with smart transportation alone accounting for $5.5 billion. ABI Research consultants using a wider-ranging concept of smart technology forecast for 2016 sales totaling $39.5 billion.

Machina Research predicts that the “Smart City & Public Transport” world market will generate more than 500 million M2M connections and a total revenue of €14 billion in 2020. Traffic management and environment and public safety are going to be the fastest growing application areas worldwide. Traffic management is expected to account for 446 million connections in 2020, generating a total revenue of €5.6 billion. With €7.5 billion, a share of 52 percent, environment and public safety contribute the biggest share of the Smart Cities and public transport market.

Apart from professional solutions with commercial interest in mind there is a growing number of initiatives by citizens, too. Many of these projects are motivated by issues individual cities and their citizens are facing on a regular basis. The Oxford Flood Network for example is striving to establish a citizen-built flood detection network (http://oxfloodnet.co.uk/). Web portals like https://smartcitizen.me/ aim at encouraging citizens’ participation in smarter cities using open source technologies and low cost hardware for environmental monitoring.

What can be said for sure is that the supply of applications for Connected Cities will increase and be expanded continuously in the years ahead. That not only confirms the cities’ commitment to deploying the technology but also provides opportunities for manufacturers and providers of connected solutions for sustainable city concepts.

AREAS OF USE

With regard to the expanding Internet of Things, nearly every connected solution can be seen as a part of the Smart City. In the narrower sense, however, Smart City solutions address specific municipal challenges. They include infrastructure areas, such as utilities, waste disposal and traffic, and public services for citizens like protection against threats. In practice, Smart City applications are not limited strictly to one area of use but influence several areas at the same time.

Smart utility grids are considered to be the precondition for sustainable handling of resources. In the energy supply sector the so-called Smart Grid leads to a local structure into which electricity from different sources such as solar panels and wind farms is fed. Smart meters replace conventional electricity meters. Similarly networked smart meters record not only electricity but also water and gas consumption.

The Smart Grid’s nodes include intelligent buildings that take into consideration aspects of climate protection and energy efficiency such as heating, light and ventilation management. The savings potential is significant. At present, building services still account for around 40 percent of net energy consumption. Intelligent buildings also provide impetus for further aspects of urban planning. In South Korea’s planned city Songdo City experiments are under way with a subterranean waste disposal system that transports waste straight from homes to a biogas power station.

Traffic is another important area, and one aspect of it is parking management, which is examined in greater detail in one of the following sections. This area also includes all transportation processes for goods and people. A comprehensive logistics solution has been deployed in the Port of Hamburg for example, Europe’s second-largest port. By the end of 2025, the port is expected to handle twenty million containers. The “smartPort logistics” system coordinates truck and container movements. It brings together traffic and infrastructure data like the location of containers, bridge opening times and available parking spaces. As a consequence, logjams and waiting times are reduced while cargo turnover increases. The system is based on an agreement between T-Systems and SAP for connected logistics, addressing the needs of logistics centers of seaports, airports and parcel distribution centers.

Houses that keep an eye on themselves or vehicles that call out the emergency services automatically in the event of a collision will very soon be a part of everyday life. Connected devices like smart smoke detectors or solutions such as video analytics offer great potential for public security. They ease the work burden of law enforcement or fire and rescue services, which can provide more extensive services with the same manpower. Due to the fact that about 57 percent of city expenditures can be attributed to public safety, the automation of processes in this area offers a huge potential for reducing operational costs.

Finally, smart public services influence administrative processes and hold forth the promise of better citizen services. Municipal authorities are currently undergoing an organizational transformation that finds expression in, say, the open data movement. The aim is to share data with citizens in order to promote opinion forming, cooperation, and participation and to make social interaction more open. These aspects too are strongly affected by the higher degree of networking. Citizens expect the authorities to provide the same services as other organizations. If they can follow the status of an order in an online shop, tracking its progress from door to door, they expect the same transparency when applying for a passport.

INTELLIGENT TRANSPORT IN BUDAPEST

Intelligent Transport Systems (ITS) rank among the most promising and beneficial infrastructures of Connected Cities. They include applications for traffic management and seamless information services for different transport modes. In Budapest, for example, public transport utilizes VECTOR – a modular traffic management system by T-Systems Hungary. The system supports the Budapesti Közlekedési Központ (Centre for Budapest Transport) in all aspects of community transport, from planning timetables and optimizing routes to analyzing past and current data. About 2,300 vehicles are directly connected to VECTOR. Based on the vehicle data, the system provides exact arrival times for passengers in real time. In addition to VECTOR, T-Systems Hungary provides public transport providers throughout Hungary with Ticket Vending Machines (TVM) and WiFi on board trains and long-distance buses.

Citizens and visitors in Budapest who prefer to go by bike can use the public bike-sharing system MOL Bubi. The system was developed by T-Systems Hungary and Csepel Zrt and celebrated its premiere in September 2014. MOL Bubi is comprised of 76 docking stations and 1,100 bikes so far. HUF 900 million of the project cost have been financed by the EU Regional Development Fund in the framework of Széchenyi 2020. The European Commission is actively driving the move to ITS forward. One of the incentives for meeting the EC’s objectives is the “Transport Challenge” of Horizon 2020. It provides more than €6 billion funding for smart, green and integrated transport.

The VECTOR system provides up-to-date arrival times. Thanks to a newly invented info terminal, it even works without external power sources. Travelers use a crank which generates electricity. The terminal then shows transport information on an e-ink display in real-time.

In recent years, the number of useful and creative applications for urban spaces has grown significantly. The Smart City category of the Internet of Things Award gives a good impression of the diversity. Among the 2014/2015 nominees is a solar-powered charging station for mobile devices and a wearable tracker which measures air pollution for example. One of the winning applications, the "Array of Things" (http://arrayofthings.github.io/) constitutes a network of sensors deployed in Chicago. It aims at gaining a better understanding of environmental factors, human activities and infrastructure in urban space and deriving useful information about the air quality in different blocks for example. In addition to the "Array of Things," Bigbelly and Kiunsys have won awards. Bigbelly has developed solar powered trash and compaction systems which allow a much more efficient waste disposal than conventional trash bins. Philadelphia has over 1,000 stations installed already. Kiunsys has won the award for its mobility management solutions which more than 25 cities in Europe rely on (see also "Parking in Pisa" on page 22).

USE CASE: STREET LIGHTING

Another use for which Smart City applications are already being extensively deployed is smart street lighting. It helps reduce cities' energy costs, light smog, and carbon dioxide emissions. Conventional street lighting accounts for more than 40 percent of cities' energy expenditure. By using an appropriate Smart City application (e.g., a combination of LED lights with intelligent management solutions) they can cut their electricity costs by between 30 and 70 percent and their maintenance costs by 10 percent. Citizens also derive direct benefit from smart lighting concepts. Street lighting that works is, after all, seen as an important security aspect. It prevents accidents and reveals sources of danger.

In Europe, the transition to more efficient lighting systems is currently underway. More than 90 million traditional streetlights are still in operation. Over 75 percent of them are older than 25 years. Some cities like Birmingham in the UK, Denmark's capital Copenhagen and Tilburg in the Netherlands have already deployed new LED lighting systems successfully. The combination of LED lights with intelligent management solutions promises even higher energy savings. Finland's capital city Helsinki started implementing a system in 2013. In Helsinki and its neighbor city to the north, Vantaa, approximately 130,000 luminaires can be managed by the new control solution.

For smart street lighting to work, streetlights have to be connected. In the most advanced solutions they are equipped with hardware devices that form a mesh network. In much the same way as in parking management they communicate with data collectors, also known as data gateways, that are in turn connected with a server infrastructure by mobile broadband. Once streetlights are connected in this way they can be controlled remotely by means of Cloud-based management software. They can be switched on and off, and lighting patterns and dimming behavior can be programmed.

In addition, more complicated arrangements using additional data sources can be set up. The brightness of lights can be regulated on the basis of weather data or ambient parameters. Motion sensors registering a pedestrian in the park at night could trigger a larger area around him or her to be illuminated more brightly.

Street lighting is a highly promising approach, and not only in respect of energy efficiency and safety. Streetlights are distributed around the entire city and thus provide ideal pillars for a citywide communication network infrastructure. Streetlights with embedded systems and gateways function as the nodes of a hardware and application-agnostic mesh network. This means that they can support any number and kind of Smart City applications – from parking management via diagnostic systems for gas and water supplies, to solutions for waste disposal.

USE CASE: PARKING MANAGEMENT

The structure of Smart City applications taking the interests of different players into consideration is well demonstrated by the example of parking management. Experts estimate that in the United States motorists looking for somewhere to park could account for between 10 and 30 percent of inner-city traffic. In New York the proportion is said to be as high as 45 percent. A 2007 study undertaken in Los Angeles found that in the course of a year motorists drove a total of 1.5 million kilometers in search of somewhere to park in a 15-block area, using nearly 180,000 liters of gasoline and emitting 730 tonnes of carbon dioxide.

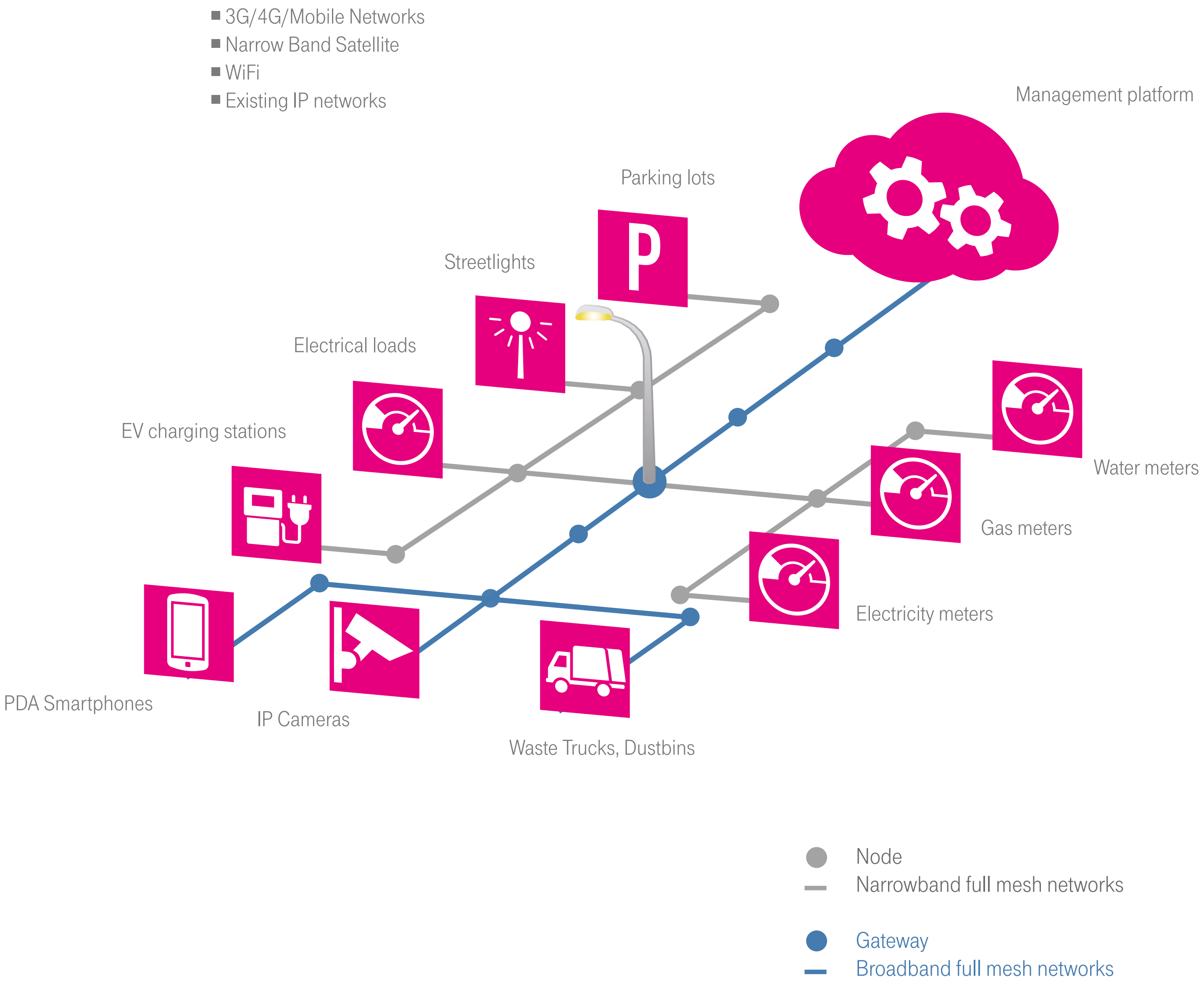
Smart parking systems are considered to be a mainstay of sustainable inner city mobility concepts. They lead to less atmospheric pollution and less fuel consumption, spare motorists the tiresome search for somewhere to park, free up more time for them and reduce their expenditure

LAMPS AND SENSORS: MORE THAN LIGHT

Due to their distribution throughout the city, streetlights represent the ideal pillars for a citywide communication network. More than that, they are also ideal for multifunctional sensor networks. The Croatian city of Dubrovnik is pursuing this path as one of the first cities in Europe. In May 2015 the first demo lamp with an integrated multi-functional sensor circuit was switched on in Lujo Šoletic park. The lamp can do much more than just give light. It can act as the eyes and ears of many different Connected City applications. The integrated movement sensors, air pollution sensors, temperature sensors and sound sensors provide a detailed view of the lamp's surroundings. Hrvatski Telekom and its partner Cisco have implemented the solution in Dubrovnik. It marks an important step towards an open infrastructure for Smart City solutions. While the city preserves its rich historical heritage on the outside – it is a shooting location of Game of Thrones for example, bringing its medieval fantasy setting to life – Dubrovnik relies on the most advanced technology under the hood to move into the digital era.

CONNECTED CITIES **CONNECTED CITY APPLICATIONS**

FIGURE 5: STREET LIGHTING SOLUTIONS CAN ESTABLISH MULTI-PURPOSE NETWORKS



THE HUMBLE LAMPPOST

The European Commission has already identified street lighting as a viable starting point for more comprehensive Smart City initiatives. The Operational Implementation Plan of the EIP displays the new role of "The Humble Lamppost" providing "additional services beyond the provision of light" [9]. It can provide public WiFi services or measure air quality and noise pollution for example.

CONNECTED CITIES **CONNECTED CITY APPLICATIONS**

on fuel. That is why directives that the EU issued as a result of the Kyoto Protocol include the provision of smart parking facilities [8]. Experiments are under way in other Smart Mobility projects and research areas to develop smart traffic light settings that adjust to the volume of traffic and public transport systems that show the timetables in real-time. Evaluation of the 2004 Urban Audit proved that the quality of urban traffic networks and the distribution of appropriate ICT technology are important factors for a city's prosperity [4].

Apart from mobility and traffic flow management, managing public parking presents a major challenge for cities. Different municipal departments are involved. A coherent pricing structure for parking in different areas of the city must be agreed. Residents' parking permits must be issued and special parking provisions approved for, for example, disabled drivers, taxi drivers, coaches, and delivery vehicles. Parking attendants check compliance and initiate further steps to penalize infringements. Smart City applications for parking management must ideally take into consideration, harmonize and support all of these areas of responsibility.

What shape do suitable solutions take and what do they accomplish? Smart City applications for parking management consist of hardware components for the urban infrastructure and software on which data from different sources runs. Key features are sensors for individual parking spaces, a network of data collectors and gateways, RFID cards, readers and gateways, and Web portals and smartphone apps. The sensors register which parking spaces are occupied and which are free. They transmit this information to a data collector that relays it by mobile broadband to a server infrastructure. Motorists can then access the current status of parking availability via a smartphone app and let themselves be guided automatically to an available space in the area where they need one. They can also pay the parking charges directly via the app and no longer need to fix parking tickets on the windscreen.

RFID cards take the place of printed parking permits for citizens and regional traders. Once issued, they can be used for several years. That saves printing and mailing costs and speeds up processing of permit applications. Parking attendants can check the validity of RFID cards by means of RFID readers. RFID gateways can also be used that read RFID cards automatically as vehicles drive past. Gateways provide access to restricted areas for certain road users such as taxis or delivery vehicles. A systematically distributed network of RFID gateways also recognizes how certain categories of road users anonymously move around the city. This data helps cities and traffic planners to optimize their mobility concepts.

On the software side all data recorded within the server infrastructure can be combined with other data sources and processed in different ways. A Web portal, for example, helps the city administration to manage permits, to analyze the parking situation, and to design its traffic policy more effectively. In return, a Web portal for citizens provides online services that make it easier for them to apply for or renew residents' parking permits comfortably.

SMART CITY PROJECT: PARKING IN PISA

Winding alleys run through the historic city's center southeast of the Piazza dei Miracoli and the Leaning Tower. Tourists flock to the world-famous landmark while students stroll around libraries, bars and cafés. Whoever shaped the development of the historic city prior to the 19th century certainly didn't have one thing in mind: cars and parking spaces. But right here in Pisa, the tradition-rich university city, the future of parking and mobility management is being put to the test. In cooperation with Deutsche Telekom, T-Systems and its partner Kiunsys, Pisa started a pilot project in 2014 that will bring about better traffic flows, lower CO_2 emissions and a more comfortable search for parking spaces. Core aspects of the project are a sensor-based guidance system and a Big Data Analytics service that examines the collected traffic data.

On the Piazza Carrara at the bank of the Arno, less than 700 meters away from the Leaning Tower, 75 parking spaces have been equipped with sensors. They check continuously which parking lots are free and which are occupied. Three mobile-based data collectors aggregate the sensors' information and relay them to the municipal IT infrastructure. From there, they get passed on to traffic information boards and an app for drivers. Due to the successful pilot, Pisa decided to equip additional 102 parking spaces with ultrasonic sensors on the Piazza Santa Caterina in 2015, in order to test the solution in a different environment.

Apart from the parking sensors, Pisa has been collecting traffic data for eight years. Residents' parking permits are equipped with RFID chips for example, and RFID gates measure the flow of traffic between different districts. Up to now, huge data sets have been collected but hardly evaluated. The introduction of a Big Data service was supposed to change that. During the first analysis however, the general data setup suggested a more comprehensive approach resulting in a "Smart City Enabler" project. It aims at establishing a flexible platform, which will be able to connect and combine past, current and future data in an open environment. Instead of analyzing mere snapshots, the new, future-proof approach facilitates a continuous reevaluation of all available data. Newly gained insights are intended to flow into planning process around the city's traffic. Local application developers, other authorities and institutions such as Pisa's university should be able to participate and access normalized data sets via APIs. In this way Pisa can establish even more efficient administrative structures, advance its Intelligent Transportation System (ITS), reducing the city's environmental pollution.

CHALLENGES

Connected Cities do not take shape from one day to the next. They are formed more like mosaics from the interplay of societal, economic, and technological developments. In this way new problems will constantly emerge. Right now the challenges that are most discussed are the integration of cross-departmental solutions, data security and financing.

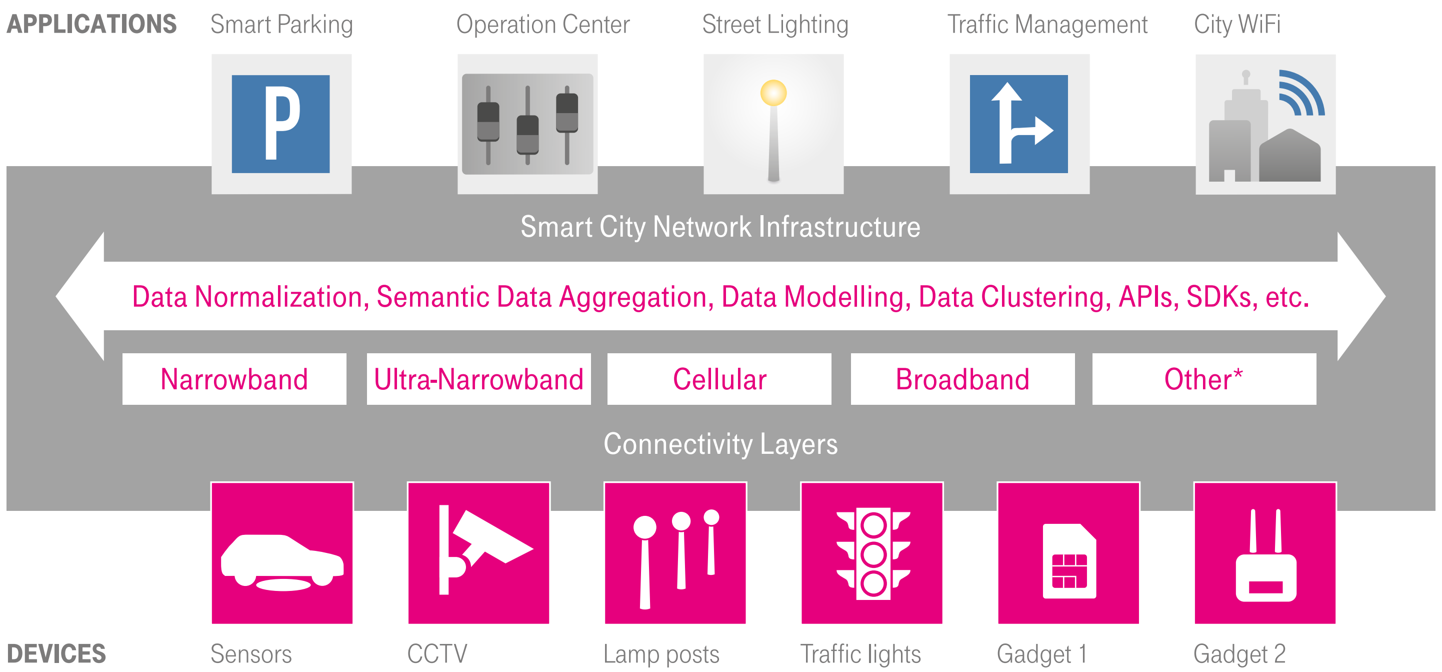
FITTING THE PIECES TOGETHER

A major challenge for the implementation of Smart City concepts is that the initiatives of individual departments cannot remain cut off from one another. They must be connected in order to realize the full potential of the Internet of Things and create synergies. These include not only cooperation between different departments but also participation of citizens in innovation processes. To build such bridges, open platforms and open standards must be used. That is the only way to ensure that people and city data remain combinable in the long term.

Cities are in a state of flux at all times. As they keep on changing, the requirements for ICT-based applications in urban spaces change as well. Flexibility, a large number of possible configurations and a future-proof architecture are indispensable features. Not least because of this constant change, identifying possible cross-connections between departments and organizing the use of Smart City solutions is no trivial task. Many city administrations have already appointed officials such as "Smart City managers."

In order to combine different solutions without complex integration efforts, standards are required. The standardization issue spans multiple dimensions. Which of the many emerging standards is considered to be the most favorable differs from country to country, application area to application area, and layer to layer. At present, global standardization work on the network layer is making good progress. In terms of embedded platforms, communication protocols and service layers, the market is still fragmented, but technology companies and standardization institutions have already teamed up to build a common ground.

Standards and internationally binding regulations are also regarded as security-relevant aspects. Cities must protect themselves specifically from cyber-attacks. Especially in view of their networked infrastructure it is important for them to retain their autonomy. If the network ever breaks down, systems must continue to function reliably. In this way an emergency will not lead to a collapse but merely to a brief outage of optional connected services.



DATA AND IT SECURITY LANDSCAPE

The more areas of a city's operations benefit and rely on ICT-based applications, the more important is the security of all systems involved. Guaranteeing uninterrupted services to citizens is an essential objective of city administrations after all. Being large and complex organizations, cities already operate huge IT landscapes which need to be extended with the advent of the Internet of Things. Every single component of Smart City solutions has to be safeguarded – from the applications running on smart devices and the communication network to the backend server. Potential risks have to be identified and assessed continually. This includes determining the probability of certain attacks and estimating the potential damage they could bring about. Appropriate mechanisms for the detection and prevention of attacks need to be put in place.

In addition to handling IT security in general, cities must develop new concepts for handling data. The Smart City involves enormous amounts of data the evaluation of which holds the key to creating sustainable and efficient structures. Data must be stored securely and legal issues must be clarified. Who owns which data and who is entitled to access it? Which data can be made accessible for the general public in the context of an open data initiative and which data must be kept under lock and key because it enables people to be identified or constitutes a security risk? To answer questions like these, new processes, tools, and mechanisms are needed to manage data and ensure its integrity.

Cities are subject to cyber-attacks in much the same way as companies are. San Francisco's intrusion protection system registered on average around 100,000 cases a day of malware intrusion in 2012 [9]. That is why data security should be taken into consideration at all stages of networking. Employees should be trained and sensitized and the Smart City applications used should always be chosen with due regard for the overall concept of data security.

When information from smart homes, networked traffic systems, and video surveillance solutions is merged, the privacy of citizens must not be breached. Experts call for the protection of personal data to be integrated into smart applications from the outset as a fundamental development principle: Privacy by Design [10]. To encourage acceptance of connected solutions they must provide the greatest possible degree of transparency about the data collected while maintaining the anonymity of users.

FINANCING AND FUNDING

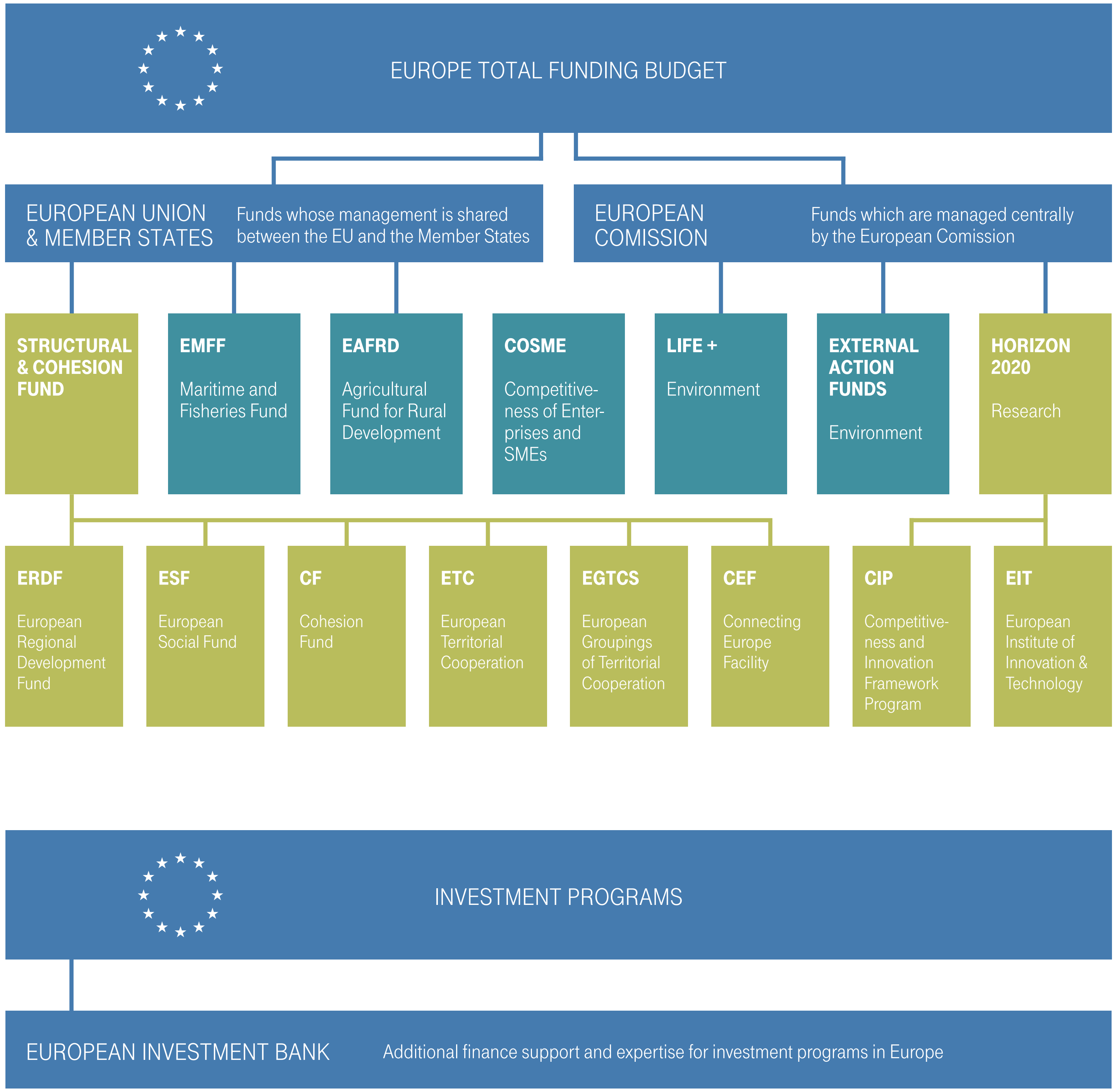
It is no secret that most cities have to cope with tight budgets. Even if Smart City solutions are about to handle a city's operations more efficiently and reduce costs in the long term, large upfront investments can be a serious stumbling block. Participating in development, testing and pilot projects for sustainable operations is an option to receive funding from institutions like the European Union, the European Investment Bank, the World Bank and the International Monetary Fund.

Another obstacle that may have dissuaded cities from deploying ICT-based applications for urban spaces in the past is the complexity of a fragmented market. In the worst case, they have had to rely on individual offers from hardware manufacturers, software providers, and mobile network operators and have also had to hire IT teams of their own. The result was high costs and uncertainty as to when and how the uncertain costs would be recouped.

This uncertainty is in the process of being eliminated. With the rise of the Internet of Things, providers are starting to put package deals together as turnkey solutions. What is special about them is that instead of needing to invest heavily up front, flexible, opex-based financing models emerge. In many cases, the operators of these solutions pay only a monthly fee per connected device. That makes it much easier for cities to weigh up the costs and benefits of a solution. New financing models enable a clear cost calculation and lower the threshold for important investments in infrastructure.

EUROPEAN FUNDING PROGRAMS

Smart City projects help driving the EU's Europe 2020 strategy. According to the EU Commission's Multiannual Financial Framework 2014–2020, the Structural & Cohesion Fund amounts to €376 billion while the Horizon 2020 program covers €80 billion. Additional funding is available for Smart City projects that are backed by the European Investment Bank.



CONNECTED CITIES **RECOMMENDATIONS**

RECOMMENDATIONS

With regard to pressing problems such as urbanization, the sustainable use of resources and tight budgets of public administrations, the move to Connected Cities is inevitable. But how should decision makers approach this complex transformation? The following recommendations provide points of reference that have their source from Deutsche Telekom's experience in consulting and deploying M2M projects in cities and vertical industries.

BRIDGE THE BOUNDARIES OF DEPARTMENTS

Considering the big picture is of capital importance. Smart City solutions that are being deployed within the boundaries of departments can't unlock their full potential. It is essential for cities to get a holistic view and identify possibilities for cross-departmental connections. In order to identify these opportunities, city administrations should commission internal Smart City managers for this task. Additionally, a broad analysis and assessment of external experts proves itself valuable.

RELY ON STANDARDS

From a technological perspective cities need an IP-based, open, scalable and extendable horizontal architecture that enables any authority, citizen and vendor to dock on to it. Proprietary protocols and data formats need to be avoided. A horizontal Smart City management platform will be able to integrate objects and applications citywide – similar to ERP systems that integrate all kinds of business processes and resources.

DEPLOY PILOTS

Identifying the best "solution" to address specific public needs requires both technical evaluations (proof of concepts, either in a lab or live, in "real" environmental conditions) and an in-depth review of the overall social, political, economical and environmental impacts on the community.

This second level of assessment, based on the concept of pilots in a homogeneous city area, is usually carried on for up to six months in order to evaluate and compare a set of KPIs indispensable to assess the full blown impact of the solution to the service/issue at hand.

Pilots, then, provide an opportunity to test ICT-based solutions for cities on a small scale and get a foretaste of their impact. Piloting may include the evaluation and comparison of different technologies and configurations in the same environment for the application in question. Due to the rapid development of the Internet of Things, most solutions for Connected Cities can be realized with a variety of different technology stacks – ranging from sensor and device types to different communication protocols and software architectures. But which technologies are best suited for specific issues and their individual requirements? Testing and comparing different technologies in the same area, defining a robust KPI framework to support the evaluation, contributes greatly to choosing the best options for the task at hand – both in terms of functionality and economic viability. In addition to different technologies several configurations could be tried out without running the risk of interrupting public services.

IDENTIFY INDIVIDUAL REQUIREMENTS

During the testing phase, individual requirements should be identified and transferred to a larger project. In some instances, pilot projects of Smart City solutions are funded and supported by national and supranational institutions like the European Union (Horizon 2020 is an example in the European Union). In line with these considerations, Deutsche Telekom strongly recommends focusing on deploying pilots to test new concepts of multifunctional sensor networks and advance steadily in the design of new architectures for the integration of city infrastructures. The "Humble Lamppost" scenario, which has been discussed in the EIP (European Innovation Partnership on Smart Cities and Communities), is a viable starting point for expanding a city's communication infrastructure with regard to a new generation of ICT-based applications for urban space. In this way cities establish an open infrastructure for testing a wide variety of applications.

HARNESS DATA FOR DECISION MAKING

Analyzing existing databases of cities' operations can reveal problem areas and determine the ways in which ICT-based applications should be brought into operation. Once more objects around the city get connected, more data will be available and entirely new opportunities for services will arise. Knowing in detail about the success factors and pitfalls of past activities provides city administrations with an entirely new basis for making decisions and issuing policies.

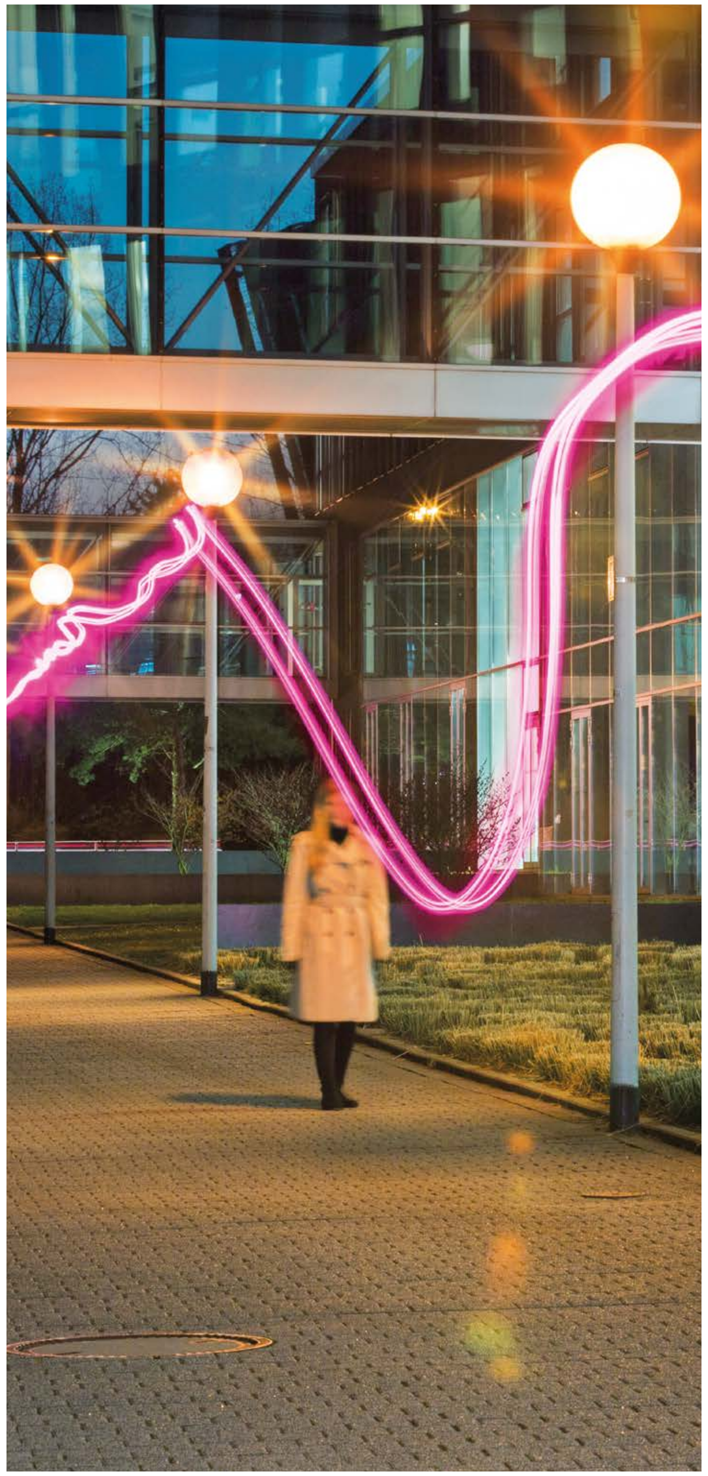
ENCOURAGE PARTICIPATION OF CITIZENS AND LOCAL BUSINESSES

Cities have a huge creative potential at their disposal. Creating incentives and new modes of participation for citizens and businesses is a key component for gathering ideas about how to improve communal life and stimulate the economy. The provision of open data, for example, can enable companies to refine existing business models or create new services. Participation in collaborative platforms and social media helps represent the citizens' perspective and take their interests into account.

COLLABORATE WITH RELIABLE PARTNERS

Implementing and deploying applications for Connected Cities places high demands on all stakeholders involved. Cities should look for partners that are experienced in large scale rollouts on both infrastructural and application levels. Partners should ideally cover a wide range of services from consulting city administrations to realizing projects. Since many application scenarios such as the restoration of historical street lamps require the expertise of small specialized companies, having a partner that can manage and orchestrate these niche suppliers is extremely helpful.

It will take time before cities harness connected infrastructures, applications and services in a similar way to modern stadiums. What already works in these microcosms of games and fandom is much harder to transfer to cities as a whole due to its larger scale and the sheer number of use cases, stakeholders and interests. But the connected stadium demonstrates that critical subsets of complex ecosystems can be both managed and opened up for participation with outstanding results. It realizes a carbon neutral venue, saves resources such as water and is based on new modes of participation. In order to tackle global challenges such as urbanization, the move to Connected Cities is inevitable in the long run. Since it concerns both citizens, visitors, authorities, businesses, and manufacturers, an open and collaborative approach is the only way to push the development of Connected Cities forward.



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Deutsche Telekom AG
Landgrabenweg 151
53227 Bonn

For further information please
contact us under smartcity@telekom.de

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