Network Architecture based on Virtualized Networks for Smart Cities

A.D. Guerrero-Pérez, A. Huerta, F. González and D. López

Abstract— Over the next three decades, seventy percent of the global population will live in cities; this fact implies the development of best practices to improving city resources management. The integration of information and communication systems into the various technical systems and infrastructures of a city are fundamental bases in smart cities. A smart city must combine legacy networks and new communication architectures; in order to configure existing communication networks to achieve compatibility and interoperability. The requirements toward a network often change impact direct and indirect costs of purchasing networking equipment and its rapid depreciation; in response to this fact, the network virtualization proposes decoupling of functionalities in a networking environment to develop new networking proposals, services and test platforms for smart cities.

Index Terms—Data communications, Emerging technologies, Network Communications, Optical Fiber.

1 Introduction

IN 2000, there were 6 billion humans living on Earth and 500 million devices connected to the Internet. During 2008, the prediction given by Europe Union presidency was *"the number of devices connected to the Internet exceed for the first time the number of people on Earth"* [1]. At the same time, the integration of the connectivity capabilities, information technologies and new mobile objects are the basis for a society of innovation and knowledge. When objects can sense the environment and communicate, they become powerful tools for gaining an understanding of the environment; while the nature of the objects connected have given meaning to information and are the symbol of the way a society watches and represents itself [1].

By 2050, 9 billion humans will be living on Earth of which 70 percent will be in cities [2], this fact implies the development of best practices to improving city resources management. The integration of information and communication systems into the various technical systems and infrastructures of a city are fundamental bases in this project. A smart city can be seen as a determined geographical space able to manage resources (natural, human, equipment, buildings and infrastructure), as well as wastes generated by life style; it should be sustainable and must not be harmful to the environment. In this context, there are several uses cases that represent opportunities areas, such as: urban waste, urban planning, sustainable urban environment, ageing population, continuous care, emergency response, intelligent commuter, building automatization, electricity consumption and smart renewable energy, as depicted in Figure 1; however, there is much work to do that will require the combined efforts of the public, academia and private sectors.

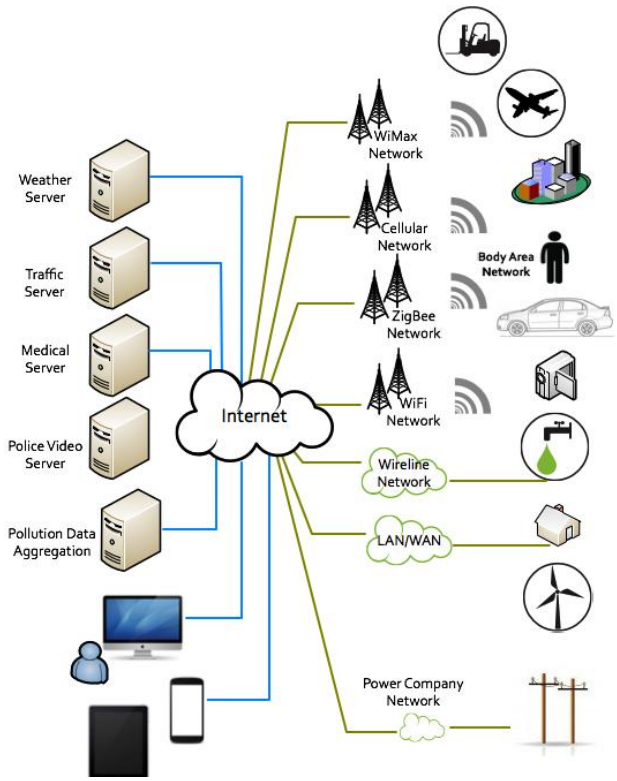

Fig. 1. An overview of smart city. Energy consumption, renewable energy, traffic solution, weather service, medical service, police video and connectivity in any place are examples of services that provide a smart city over a telecommunications infrastructure

Information and communication are key to the intelligent city of tomorrow [2]. A smart city must combine legacy networks and new communication architectures (sensor networks and mobile communication) while citi-

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zens play a key role, they have created their networks, obtain data and there is mutual feedback. The goal is configure existing communication networks, content management and the availability of information change to achieve compatibility and interoperability [2]. The telecommunications infrastructure is the basis for data generation, exchange data, flow data and their transport that provide intelligence to the city.

Under this perspective, CCD (Ciudad Creativa Digital) in its project of smart cities must be a reference model in Mexico and Latin America; as established in its principles, CCD aims to be a model for pushes the boundaries of sustainable integrated urban development. On the first stage, in accordance with the master plan will be fundamental an optical network and wireless access for all users based on open platforms; however, the network reference model from CCD goes beyond, since is not limited to provide services. CCD network will be a test platform and experimental laboratory to develop testbeds related to Next Generation Network (NGN), Future Internet, Internet of Things (IoT), Cloud Computing and Wireless Sensor Networks (WSN).

2 TECHNOLOGIES

The importance of digital infrastructure into a smart city can be defined based on metrics that define a city as a smart city, such as: smart economy, smart environment, smart mobility, smart people, smart living, smart governance [3]. Then based on a network infraestructure with a hierarchical model, which consists of an access network, backhaul network and core network; two fundamentals technologies are available to provide communication in each network layer, as WiFi technology to the access layer and optical fiber to the core layer.

2.1 WiFi

The WiFi (802.11 a/b/g/n) technology and WiMax (802.16) are applied to the access layer of the digital infrastructure, since is considered one of the major technologies to communicate in the smart city. This by providing wireless services to citizens, such as:

- Internet access, which can be supplied by a service provider.
- Access to information on the municipality or organizations using information panels and kiosks wireless connected.
- Citizen participation through web portals, also the possibility of performs online transactions offered by the municipality [3].

Besides, a wireless network offers a lot of opportunities for innovation for the municipality or organization, such as [4]:

- System Network-based video surveillance.
- Monitoring of traffic lights.
- Systems of georeferenced information.
- Data Collection environmental sensors.
- Monitoring parking spots.

Thus, the wireless network has great significance in the physical infrastructure of a smart city as through their different services and different opportunities for innovation allows fulfilling all aspects involved in a smart city.

2.2 Optical Fiber

With the growth of telecommunications, the interactive Internet trough televisions, laptops, smart phones, cloud computing and video streaming have become optical fiber as a fundamental part of any communication infrastructure [17].

The society demands more Gigabit/s and more bandwidth, as expressed in report of data mobility 2013A by Cisco. The practices and trends of this report have estimaded that between 2012 and 2017, the growth in demand for data services will be 80% from a variety of end user device, as depicted in Table 1 [18].

TABLE 1
Data Consumption

Device	Data Consumption Per Month (2012)	Data Consumption Per Month (2017)
No smartphone	6.8 Mb	31 Mb
M2M Module	64 Mb	330 Mb
Smartphone	342 Mb	2.660 Gb
Smartphone 4G	1.302 Gb	5.114Gb
Tablet	820 Mb	5.387 Gb
Laptop	2.053 Gb	5.731 Gb

Table 1 shows a projection of data consumtion with several end user devices. Optical fiber is modern telecommunications crucial, as for example in comparison to a copper pair is simply capable of carrying six simultaneous phone calls, while an optical fiber operating at a modest rate of 10 Gbps over 64 channels, you can carry more than 10 million simultaneous phone calls [15].

Given this need arises to transport larger information is so many other countries have realized the potential use of Fiber To The Home (FTTH), which enables features of several services and simultaneous data such as telephone, video, audio, television with more capacity at higher speeds file [14].

The structure of Smart Buildings Certification Institute (SBI), mentioned that the wiring is an important factor for intelligent building, the use of fiber optic cable provides an opportunity to reduce the number of contractors cable, reducing the necessary coordination project manager, cable routes and share results is a higher quality installation [16]. The optical fiber is a flexible technology for the future, so it is necessary for proper growth management bandwidth of various services that supports, which are necessary to maintain the type of activities to be undertaken in smart, and also a secure transmission of data spaces.

2.3 Technologies in CCD Guadalajara

In accordance with CCD master plan, the optical network must be deployed in the first stage of CCD project, while the users will access multimedia content over wireless network. In exceptional cases, projects or working teams can access to optical network, from their work space inside CCD; since research areas such as: big data, cloud computing or augmented reality and industries from TV or cinema, requiere a high speed data transmission. In these cases will be provided the optical access over FTTH.

3 Network Architecture Based on Software Defined Network

The use of the mobile Internet is playing a growing role and is involved with the creation and delivery of digital content; at the same time, the data volumen generated by users and mobile applications have caused new paradigms to existing networks; features such as bandwidth, symmetric communications, mobility, transfer rate and throughput have to provide an optimal performance able to handle the increasing data volumen. The flexible access to offers, information and services is provided through so called open service platforms in the city of tomorrow [2]. The open service platforms are supported by wireless and wired networks, Next Generation Networks (NGN) and Internet. This scenario empowers that acquired data from scenarios depicted in Section 1 and 2, are jointly managed by knowledge centers or data centers that give value and meaning to data. The requirements toward the network often change, some parameters are determined by unpredictable data grow, Internet quality (determines the impact to retention of users), Total Cost of Ownership (TCO) (it has shown direct and indirect costs of purchasing networking equipment and its rapid depreciation) and finally, technological developments from telecommunication industry compared with technological developments from software industry take months. In response to these needs, industry, research centers and academia have created a convergence point at three research divisions: Cloud Computing, Software Defined Networks (SDN) and Network Functions Virtualization, as depicted in Figure 2.

Cloud Computing automated platform for network functions in software, SDN give a network abstraction and flexible dynamic programmability and Network Functions Virtualization enabler for cost, energy consumption and space reduction by sharing, isolating and splitting of network functions [6]. In order to deploy architectures with decomposed functions between cloud and transport network.

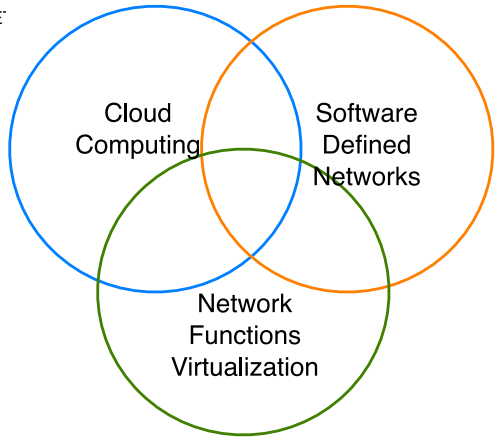

Fig. 2. Convergence point from three research divisions

3.1 Network Architecture able to innovate

We can speak about virtualization without speaking about SDN, but now if we try to imagine SDN without virtualization is practically impossible. At this time virtualization is playing a big deal and helps us to take advantage of one device to exhaust its resources without compromising performance. Now let´s take this idea to our beautiful network. Normally we have our substantial coreswitch, which handles most connections to other devices that we know as the distribution switches and finally we have our paper switches that provides access to end user. But let´s be honest, if we have redundancy on our devices and features like load balancing, port aggregation, multiple circuits, etc. the load & usage in our devices won´t exceed more than 30% in average. And let´s say our network is still growing every day and new branch offices are added to our network and the load of it requires a new device and this device will require more space. We will need to add a device to our Data Center, but what happen when we don´t have enough space? Thinking in growth is to think in more expenses, probably our site won´t have enough space and at the end the expenses about thinking in growth will be something that our finance department won´t allow.

Now we need to see what the market is preparing for us. New devices that can process ten times what we have in our actual devices and we are able to see that if we buy one of these devices it will use the same space than multiple devices that we have on our site. But this new devices have less ports because we will be able to virtualize what we have in our network.

But what about if I need another new device to be added in my network? Well, you won´t need to prepare too much the physical connections because at this point you will meet the controller. The controller will be the brain of our network. While our new device is being shipped, delivered and installed, we can prepare the configuration at the controller exactly the way that we want.

3.2 Virtual Networks for Next Generation Networks

Network virtualization has been propounded as a diversifying attribute of the future internetworking paradigm

[5]. The emergence of several heterogeneous networks with features specific is more frequently, since multiple stakeholders have conflicting with their goals and policies; in this way, alterations to the existing Internet architecture are now limited to simple incremental updates. Network virtualization proposes decoupling of functionalities in a networking environment by separating the role of the traditional Internet Service Providers (ISPs) into two: infrastructure providers (InPs) and service providers (SPs)[5]. The latter follows the design principle from ETSI (European Telecommunications Standards Institute) and ITU (International Telecommunication Union) in accordance with NGN reference model, decoupling layers from original architecture Internet to service stratum and transport stratum.

3.3 Projects and International experience

Research institutes have been seen in the task of developing and researching test beds to create technologies that give way to what you know as the Internet of the future, whit requirements such as security and availability, new networking technologies, new computing paradigms, application support, network management, economic concerns, planning for change. Some of the projects are listed below.

GENI o Global Environment for Network Innovations is an initiative of the US National Science Foundation (NSF) to build an open and large-scale experimental facility for the evaluation of new network architectures, carrying the real traffic on behalf of end users, and connecting to the existing internet to reach external sites [5]. The purpose of this initiative is to give to the researches the opportunity to create a customized virtual network to experiment unfettered by assumptions or requirements of the current internet [5].

GENI have its own dedicated backbone link through partnerships with the National LambdaRail and the Internet2 projects [7]. And also GENI have some key requirements for the infraestructure, such as [7], Slice ability, Programmability, Virtualization and resource sharing, Federation, Observability, and Security.

GENI proposes virtualization in the form of slices of resources, in two ways; partitions resources based on space and based on time [5].

VINI or Virtual Network Infraestructure Project is a distributed collection of network equipment coupled with software, this infraestructure allow network researchers to evaluate their protocols and services in a realistic environment with a high degree of control [5]. VINI project its considered an extension of PlanetLab through GENI project, because provide infraestructure with the support for virtual networks.

VINI is currently the project with the most advanced mechanism for testing the new structures of internet, implementing the most innovative transport network features [8].

PlanetLab is an overlay-based testbed that was developed to design, evaluate and deploy geographically distributed network services with the support for researches and users. PlanetLab is considered one of the origins of the current race of future Internet research [8]. Is the ancestor of VINI and GENI projects.

PlanetLab follows three principles: application-centric interfaces, distributed virtualization and unbundled management. This project is the most used public test bed for the future of internet [8].

FIND or Future Internet Design it's an initiative of the US National Science Foundation (NFS) NeTS research program [9]. The purpose of this project is to create the Future Internet in 10, 15, 20 years. The project consists of three phases; Elements of the new Future Internet architectures, Assemble architecture based on priori works and Produce integrated code and run on a research infraestructure [10].

JGN2 is the project has been promoting in collaboration with the industry, the academy, the government and regional organizations, launched on 2004 by The National Institute of Information and Communications Technology or NICT [11]. JGN2 is considered a high –speed open testbed network for research and development activities and field trials for many kind of applications [12].

Network based on the layers 2 and 3 of the OSI model, Ethernet and IP, the project has a super high speed backbone network up to 20 Gbps.

There are other network virtualization projects, which like the previous are based on an actual service of Internet communication and were summarized in Table 2.

TABLE 2

Project	Influences of existing concepts	Architectural domain	Networking Technology	Layer of virtualization	Granularity of virtualization
GENI	VPN, active and programmable networks, overlays	Creating customized virtual network testbeds.	Heterogeneous		
VINI	VPN, overlays	Evaluating protocols and services in a realistic environment		Link	
PlanetLab	Overlays	Deployment and management of overlay-based testbeds	IP	Application	Node
FEDERICA	SOA, IaaS, VPN	Experimental facility with reproducibility	Heterogeneous	Link	Node/Link
Tempest	Programmable Networks	Enabling alternate control architectures	ATM		Node/Link
NetScript	Active Networks	Dynamic composition of services	IP	Network	Node
X-Bone	L3VPN, Overlays	Automating deployment of IP overlays	IP	Network	Node/Link
UCLP	L1VPN, SOA	Dynamic provisioning and reconfiguration of lightpaths	SONET	Physical	Link
AGAVE	IntServ, DiffServ, VPN, Overlays	End-to-end QoS- aware service provisioning	IP	Network	

Data Consumption

Beside the projects mentioned above, there are a number of cities of the European Union that are known for their Innovation methodologies to the Public Sector in a scenario of Future Internet Services for Smart Cities [13] by leveraging existing tools, trials and platforms in

Crowdsourcing, Open Data, Fiber to the Home and Open Sensor Networks.

Amsterdam city has launched a crowdsourcing pilot in 2010 called Amsterdam Open Innovation. In this pilot 3 local policy issues were presented as challenge. Using crowdsourcing as a user-driven tool they enhance the interactions between the often anonymous civil servants and civilian to create engagement for public issues.

Amsterdam has now an own crowdsourcing tool, with this application everyone could submit an idea or start a discussion. The software tool has the functionality for the civil servants who published the challenges, to rank, select or reject ideas [13].

Barcelona nowadays has many smart assets in some areas such as energy, transport, urban planning or the use of ICT [13]. With the different key elements of the 22@ district such as infraestructure, the WiFi network, the Bicing, the Barcelona Urban Lab, or the Barcelona Open Data [13], Barcelona shows its commitment to the development of intelligent assets through the use of various technologies such as crowdsourcing, Open Data, Open Sensor Networks, Fiber Optic, WiFi.

Berlin is considered one of the most vibrant locations for creative industries, ICT and media technologies in Europe. Is the first city in Germany that has opened and published public data [13]. The Open Data project in Berlin is seen under two aspects:

1. Answer the citizens' demands for open governance and support civic participation.
2. Open Data is seen as a high potential impulse to foster the development of new innovative services and products whose improves the citizen's urban life, the economic power and competitiveness of local creative industries [13].

4 A FORMAL PROPOSAL (SDN) IN GUADALAJARA

A networking environment supports network virtualization if it allows coexistence of multiple virtual networks on the same physical substrate. Each virtual network (VN) in a network virtualization environment (NVE) is a collection of virtual nodes and virtual links. Essentially, a virtual network is a subset of the underlying physical network resources [5].

5 CONCLUDE REMARKS AND PERSPECTIVES

The CCD in its project of smart cities must be a reference model in Mexico and Latin America; as established in its principles, CCD aims to be a model for pushes the boundaries of sustainable integrated urban development. In this context, this proposal seeks to create a network laboratory with principles from NGN, IoT, Cloud Computing and M2M communications; however, there is much work to do that will require the combined efforts of the public, academia and private sectors. In this time will be offered platforms to develop first approach for data acquisition over M2M communication and data center with virtualized networks and servers.

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