Toward providing some new technologies in Smart cities

Dragorad A. Milovanovic, Zoran S. Bojkovic

***Abstract*—**When dealing with new technology infrastructure of cities there are special demands concerning objects connection, people and sensors. To realize vision of smart cities different issues such as wireless technologies and mobile computing have to be taken into account and explored. First of all, the backbone are self-sustaining buildings with their energy requirements. Next, the introduction of mobile cloud computing is necessary. In order to improve the quality of service (energy, mobility, healthcare, disaster recovering) integration of mobile edge computing, and the 5G mobile networks is one practical solution. Cell-less communication is proposed to support mobile terminals in ultra-dense networks. The presentation is concluded with an outline of smart city applications types and corresponding requirements.

***Keywords*—**Cloud computing, mobile edge computing, cell-less communication.

I. Introduction

Due to the rapid growth and innovation in communications as well as computer technologies, *smart cities* are the subject of permanent research in industry and academia. The final goal is to provide numerous services such as real-time traffic monitoring, healthcare assistance, security, safety. It should be noted that the concept of smart buildings with many Internet-enabled devices can be controlled from the remote locations and communicate each other, thus becoming parts of smart cities. Internet of Things (IoT), as the collection of smart appliances for data sharing across the globe, introduces a vision of the future smart cities where users, computing systems and everyday objects cooperate with economical benefits [1].

One of the best options for processing a large collection of data from different buildings is cloud-computing. The ability to share resources, services, responsibility and management among cloud providers is the fundamental assumption from the view point of cloud interoperability. Providing sustainable solutions to jointly optimize the data transfer exploiting heterogeneous networks and the data processing, is one of the main challenges. For handling video services, *mobile edge computing* (MEC) originating from the cloudlet concept is one of the vital solution. MEC and the 5G mobile networks when integrated are going to improve the quality of service in smart cities [2]. In connection with demands for mobile communication, current heterogeneous networks meet face to face with issues for the information services in smart cities such as: network convergence, balancing in cell networks [3], handover, interference [4,5]. Cellular networks cannot accept these issues in order to satisfy the demands. Thus, considering the deployment of 5G ultra-dense wireless networks, 5G converged *cell-less communication* networks are proposed to support mobile terminals in smart cities [2].

This paper is structured as follows. In the first part, smart buildings in smart cities are introduced, together with urban mobile cloud computing. Next, we continue with role of mobile edge computing in smart cities. Then cell-less communications in smart cities are presented together with the corresponding characteristics. Applications challenges through the services provided to citizens are outlined in the finale part.

D.A.Milovanovic is with the University of Belgrade, Studentski Trg 1, 111000 Belgrade, Republic of Serbia (e-mail: dragoam@gmail.com)

Z.S.Bojkovic is with the University of Belgrade, Studentski Trg 1, 111000 Belgrade, Republic of Serbia (e-mail: z.bojkovic@yahoo.com)

II. Integration of Buildings in Smart Cities

Smart buildings along with other components such as transportation systems, governance, healthcare, etc. constitute smart cities. With the popularity of low-voltage DC appliances such as-LEDs, computers, and laptops, there arises a need to design new solutions for self-sustainable smart energy buildings containing these appliances. As sources generating DC voltage, Photovoltaic (PV) panels and fuel cells are used, together with energy-sources as well as AC-DC convertors. In order to maintain the balance between demand and supply, generated energy can be stored in the battery energy storage system.

As one option for processing a large collection of data produced from smart buildings, cloud computing solution is offered. For example in [1], it is assumed that there is one data center for each smart city located in a geographical region. All data centers are interconnected, with each other and to the central cloud using the Internet for data sharing and local balancing. To achieve energy saving, one of the data centers may be shutdown. Then, its load may be shifted to another data center that is underutilized. This type of decision needs to be made by a central controller, which is located on the central cloud (Fig. 1). As it can be seen, various data centers are connected to the centralized cloud using the grid as interconnection. *Smart Grid* can be defined as en electrical system that uses information, two-way secure communication technologies and computational intelligence in an integrated fashion across the entire spectrum of the energy system from the generation to the end point of power consumption.

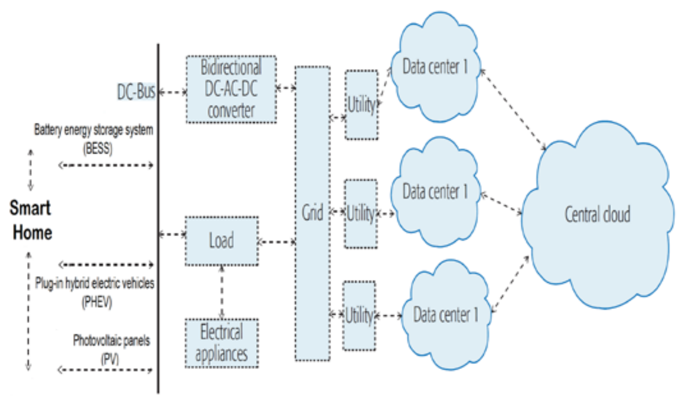

Fig. 1 Integration of nano-grid and cloud with smart buildings [1].

Here, BESS is battery energy storage system and PHEV is plug-in hybrid electric vehicles in the system smart home to central cloud. The smart home has got battery energy storage system, plug-in hybrid electric vehicles, photovoltaic array as well as various charging points. The power sources generate DC voltage being connected to the common DC bus, where bidirectional DC-AC-DC converter is attached, to. Different loads are considered as various electrical devices. Information transmission from different localities through data centers is carried out to the central cloud and to be processed with as less delay as possible. Smart grid and smart buildings can be integrated with a centralized cloud-based infrastructure.

III. Urban Mobile Cloud Computing in Smart Cities

Urban mobile cloud computing (**UMCC**) exploits both cloud computing and mobile devices with the ultimate goal to enable a distributed cloud infrastructure [6]. Cloud computing serves as a means for providing remote computation storage and management of information. On the other hand, mobility allows broadband connections to create a distributed and flexible virtual environment. Cloud topologies in urban mobile cloud computing framework is shown in Fig. 2.

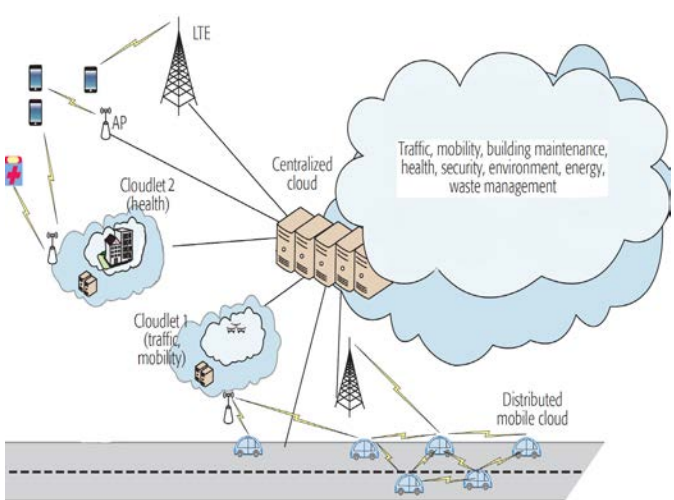

Fig. 2 Cloud topologies in a unified urban mobile computing offloading mechanism [7].

UMCC consists of centralized cloud, cloudlet, and distributed mobile cloud as the main part of this framework. *Centralized cloud* provides citizens the ability to interact remotely. It refers to the presence of a remote cloud computing infrastructure having a huge amount of storage space and computing power. *Cloudlets* are installed between mobile devices and the centralized cloud. The introduction of this small cloud infrastructure permits decrease in the latency of the access to cloud services. Also, the transfer distances is reduced because of the use of smaller and less powerful cloud devices. Finally, *distributed mobile cloud* addresses the issue of non-persistent connectivity. The neighboring mobile devices are pooled for resource sharing [8].

Smart mobile devices become part of smart city infrastructure based on different cloud topologies and exploit heterogeneous wireless link technologies:

Sensors. They can acquire different types of data regarding the users and the environment, transmitting a large amount of information to the cloud in real time by means of wireless communication systems.

Nodes. They can form distributed mobile clouds where the neighboring mobile devices are merged for resource sharing, becoming an integral part of the network.

Outputs. They can make the citizens aware of results and consequently able to make decisions, or become actuators without need of human intervention.

IV. Role of Mobile Edge Computing in Smart Cities

Originating from the cloudlet concept, mobile edge computing (**MEC**) transforms the cloud hierarchy in the way to move more computing resources in the proximity of mobile users – at the mobile network edge. Integration of MEC and 5G achieves the improvement quality of service in smart cities. The main idea is to push storage and computation resources at the network edge, i.e., in the proximity of users. In that way, data processing is displaced from the remote cloud to the edge. At the same time, the traffic bottleneck toward the core network is reduced [9]. The application of mobile edge computing architecture for smart cities is shown in Fig. 3.

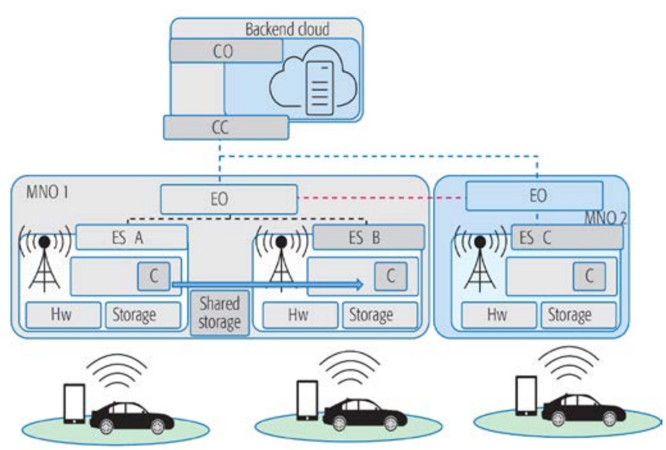

Fig. 3 Inter/intra mobile edge computing network [10].

The proposed architecture is based on the two-tier principle. Cloud service provider gives access, through an appropriate application programming interface (API), to a content provider or a third party over-the-top (OTT) service to use the cloud resource to deploy its application. The cloud has its own orchestrator (CO) to manage the cloud infrastructure and its resources. Cloud controller (CC) is invoked in order to maintain the service level agreement with content providers as well as mobile network operators (MNOs). The edge server (ES) is the part of the MNO's network and is managed and controlled by the edge orchestrator (EO). Each MNO has its own EO and is managing set of ES clusters. The level connection between cloud service provider, mobile network operator, edge orchestrator and edge server is presented by dotted lines. The edge server ES is hosted on virtual machines on top of the existing server hardware residing in the MNO's edge network node. The ES has its own compute and storage. The compute node (C) is responsible for hosting container-based applications on the edge. The storage is used to keep images of the application containers. For an intra edge network, additional shared storage is needed to ensure live migration of containers between edge compute nodes.

V. Cell-less communications in ultra-dense smart cities

Smart cities employ various wireless communication technologies and networks. Along with fiber and cellular networks, different type of heterogeneous wireless networks are expected to support mobile Internet, IoT, cloud computing and big data in smart cities. Different types of information need to be transmitted with high data rate and low energy consumption.

It is evident that compared to the existing interconnection network, a new architecture is headed in smart cities. Thus, converged *cell-less* communication networks instead of *cellular* networks to support the mobile users is proposed [2]. In cellular network, a mobile terminal associates with one and *only one* base station / access point (AP/BS). On the other hand, in a cell-less network, a terminal does not associate with any BS/AP (Fig.4).

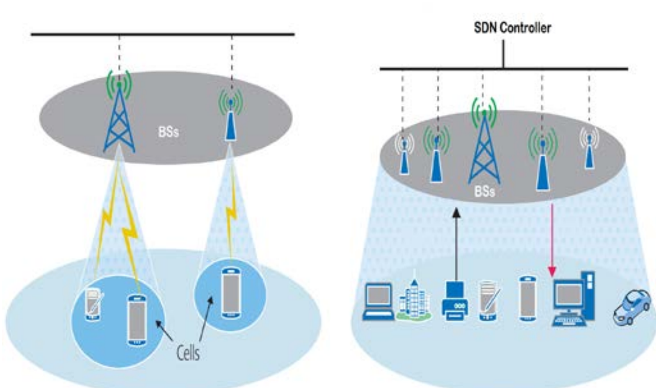

Fig. 4 Conventional cellular network and cell-less network [2].

In the cell-less block scheme, a mobile terminal can access *one or more* base stations/access points using different uplinks and downlinks. A mobile terminal does *not* associate with any BSs/APs before it starts to transmit data. Software defined networking (**SDN**) controller makes a decision which one or more of BSs/APs will perform the data for the mobile terminal using control link. With backhall links as well as downlinks/uplinks, the joint transmission or reception group of BSs/APs can cooperate with other members of the same group in order to support joint transmission and reception for a specified mobile terminal. Software defined networking (SDN) controller and core routers form the *SDN cloud*, while the *control plane* is driven by cloud computing. *Data plane* in the cloud is formed by routers and backhall links.

To implement the unassociated transmission between BSs/APs and mobile terminals in cell-less wireless communications, it is necessary to change the access method. Mobile terminals update their locations and channel status around them to the SDN cloud in case the communication to BSs/APs is necessary. As shown in Fig.5, a mobile terminal transmits the data by broadcasting when it wants to send the uplink data. Nearby BSs/APs receive the data, then forward the data to the joint reception controller in the cloud where the data transmitted from the mobile terminal are jointly decoded. When there are data to be sent to a specified mobile terminal, the SDN controller in the cloud decides which one or more of the BSs are chosen to form a *cooperative group* to perform downlink joint transmission, considering the location and channel status around the terminal. The basic criteria of cooperative BSs/APs grouping are simplicity, economy, uniformity between grouping for uplinks and downlinks, employing backhaul multicast capability if possible, mobility prediction for adjacent mobile terminals, and pre-grouping of BSs/APs.

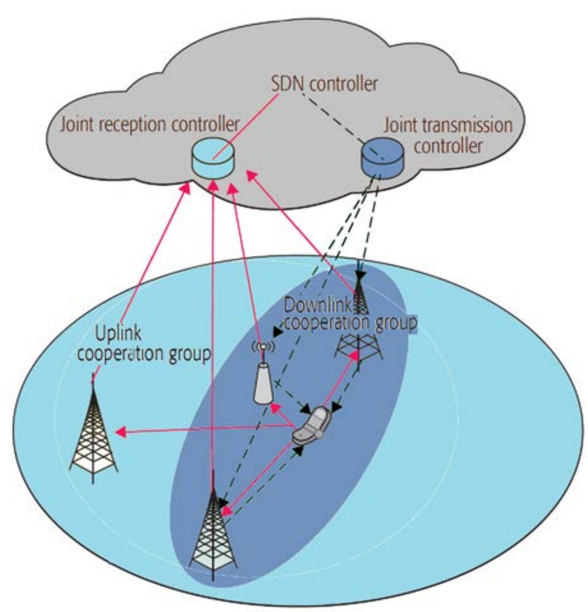

Fig. 5 Transmission model of a cell-less network [2].

VI. Smart City Applications Through the Services Provided to Citizens

Each of the considered smart city applications (energy, mobility, healthcare, disaster recovering) can be defined through the services provided to citizens, concerning the requirements in terms:

Latency. The amount of time required by a certain application between the event happening and the event being acquired by the system.

Energy consumption. The energy consumed for executing a certain application locally or remotely

Throughput. The amount of bandwidth required by a specific application to be reliably executed in the smart city environment.

Computing. The amount of computing processes requested by a certain application.

Exchanged data. The amount of input, output, and code information to be transferred by means of the wireless network.

Storage. The amount of storage space required for storing the sensed data and/or the processing application.

Users. The number of users needed to achieve reliable service.

Table 1. Some of the smart city application types and corresponding requirements.

	Energy	**Mobility**	**Healthcare**	**Disaster recovery**
Latency	Non-restrictive	Restrictive	Restrictive	Restrictive
Energy	Non-restrictive	Variable	Non-restrictive	Restrictive
Throughput	Non-restrictive	Restrictive	Non-restrictive	Non-restrictive
Computing	High	High	High	High
Exchanged data	High	High	High	High
Storage	High	Variable	High	High
Users	High	High	High	High

The quality of service (QoS) of a certain application can be seen as a function where each requirement plays a role less or more important depending on the application type [7]. Some of the most influential smart city applications by highlighting their technological requirements and characteristics are following (Table 1).

Energy. Energy saving can take advantage of the cloud basically thanks to smart grid systems, aimed at transforming the behavior of individuals and communities toward more efficient and greener use of electric power.

Mobility. All the components in an intelligent transportation system could be connected to improve transportation safety, relieve traffic congestion, reduce air pollution, and enhance driving comfort. The necessary throughput, the computational load, and the amount of data to exchange are high, whereas we can think of storage as a secondary requirement, unless for security recording.

Healthcare. Intelligent and connected medical devices, monitoring physical activity and providing efficient therapy management by using patients' personal devices, could be connected to medical archives and provide information for medical diagnosis. In this case, there are relatively low requirements regarding energy consumption, throughput, and number of users, whereas the requirements in terms of latency, computation, exchanged data, and storage are high.

Disaster Recovery. In a disaster relief scenario people are faced with the destruction of infrastructures, and local citizens are asked to use their mobile phones to photograph the site. In this case there are relatively low requirements regarding throughput, whereas it is important to have a quick response and to save the energy of the devices.

VII. Concluding Remarks

Taking into account the importance of mobile and wireless technologies for realizing the vision of smart cities, there is an obvious task to continue the research in the field of further investigation concerning new technologies. In this context, urban mobile cloud computing concept supports the smart city vision for various types of smart city applications. Next, mobile edge computing is supposed to be a promising solution for exploiting video services. Its limitations in terms of resource control and orchestration is an important challenge. As for smart city scenarios, user's mobility and the need for dynamic service migration can be considered, especially when determining solutions for service applications. A lot of works have to be done to facilitate the introduction of smart cities worldwide with interoperable and secure devices. Also, as an important issue, harmonization of standards and effective frameworks for large-scale deployment is expected to facilitate a basis for future research.

References

[1] N.Kumar, A.V.Vasilakos, P.C.Rodrigues, "A multi-tenant cloud-based DC nano grid for self-sustained smart buildings in smart cities", *IEEE Communication Magazine*, vol.55, no.3, pp.14-21, March 2017.

[2] T.Han et al., "5G converged cell-loss communications in smart cities", *IEEE Communication Magazine*, vol.55, no.3, pp.44-50, March 2017.

[3] X.Ge et al., "User mobility evaluation for 5G small cell networks based on individual mobility model", *IEEE JSAC*, vol.34, no.3, pp.528-541, March 2016.

[4] H.S.Dhillon et al., "Modeling and analysis of K-lier downlink heterogeneous cellular networks", *IEEE JSAC*, vol.30, no.3, pp.550-560, April 2012.

[5] T.Han et al., "Interference minimization in 5G heterogeneous networks", *ACM/Springer Mobile networks and applications*, vol.20, pp.756-762, 2015.

[6] K.T.Dinh et al., "A survey of mobile cloud computing architecture, applications and approaches", *Wireless communications, mobile computing*, vol.13, no.18, pp.1587-1611, Dec. 2013.

[7] D.Mazza, D.Tarchi, G.E.Carazza, "A unified urban mobile cloud computing offloading mechanism for smart cities", *IEEE Communication magazine*, vol.55, no.3, pp.30-37, March 2017.

[8] D.Huang, T.King, H.Wu, "Mobile cloud computing service models: A user-centric approach", *IEEE Network*, vol.27, no.5, pp.6-11, September 2013.

[9] W.Zhu et al., "Multimedia cloud computing", *IEEE Signal processing magazine*, vol.28, no.3, pp.59-69, May 2011.

[10] T.Taleb et al., "Mobile edge computing potential in making cities smarter", *IEEE Communication magazine*, vol.55, no.3, pp.38-43, March 2017.