Network Technology Trend for Next-Generation Wireless Communication

Subrat Kumar Sethi and Saswati Paramita***

The high-rise demand for wireless communication and its customized services has experienced tremendous growth over the last decades. This growth is expected to continue relentlessly with addition of more traffic load as signaling storms. This consumes a significant amount of network resources, compromising network throughput and efficiency, and even in some cases, it may collapse the whole network for a particular period. Nowadays, even new necessities are coming up, besides impending new challenges like lower burden of operation and management pertaining to Device-to-Device (D2D) communications and new social network dynamics. In this scenario, huge investment is required to change/upgrade the existing wireless communication networks. Taking into account the new priority of requisites, it is pertinent to expect that some network demands can be realized by new network technology based on the current research activities which are continuously enhanced in parallel with user trends and technology developments, and it is also anticipated that such new architecture could be the foundation of networks of the future. Therefore, this paper highlights the requirement and expectations of next-generation network technology.

Keywords: Device-to-Device (D2D), Signaling storms, Social network dynamics, Throughput

Introduction

Nowadays, new necessities are coming up, besides impending new challenges like lower burden of operation and management pertaining to Device-to-Device (D2D) communications and new social network dynamics. In this scenario, huge investment is required to change/upgrade the existing wireless communication networks. Taking into account the new priority of requisites, it is pertinent to expect that some network demands can be realized by new network technology based on the current research activities which are continuously enhanced in parallel with user trends and technology developments, and it is also anticipated that such new architecture could be the foundation of networks of the future. So, this paper inquisitively reflects the different concepts of future networks that arise from new social and global requirements.

* Assistant Professor, Member, IEEE, Department of Electronics & Communication Engineering, National Institute of Technology Jamshedpur, Jamshedpur, Jharkhand, India; and is the corresponding author. E-mail: subrat.ece@nitjsr.ac.in

** Assistant Professor, Department of Electronics & Communication Engineering, Faculty of Science and Technology, ICFAI Foundation for Higher Education, Hyderabad, India. E-mail: Sparamita2007@gmail.com

Why Future Network Technology?

The remarkable advances in network technology in recent years have brought about a new information revolution that ranks alongside the industrial revolution. Today, network is an integral part of social infrastructure not only in the commercial world, but also in our daily life. The current networks (e.g., Internet), however, are facing a critical crisis. The thin veneer of expansion of the network has come off, and the networks find it difficult to respond to newly emerging social demands. And the current networks show a level of inflexibility at the network layer and a lack of built-in facilities to support any non-basic functionality.

The future network technologies should be able to align with new functionality, including capability for activating a new service on-demand, even with serious bottleneck issues, new network functionality, or protocol with self-management ability with low cost-effective solution in order to maintain the network lifecycle under intelligent energy awareness scheme for mobility of network, services and devices with a guaranteed Quality of Service (QoS) and facilitating appropriate service level agreements.

In addition to the above problem-solving aspects, it is also expected from future network support for mobility, context awareness, service support, security, reliability, robustness and management for both communication resources and services resources. It should also support socioeconomic aspects, diverse business models, and legal, regulative and governance issues. It must demonstrate appropriate trust management and security of the individual privacy and data protection. Apart from this, the future network should fulfill diverse participants of the Internet whether individual users, intellectual property right holders, commercial ISPs or governments.

Distribution of Networks

In order to make the future network technology a part of essential social infrastructure, it should be researched and developed with, taking the following points into account: network for the individual, network for the society and network for a global prospective.

Network for the Individual

The future network technology should be capable enough to facilitate customized service to the individual user with an easy to access method so as to enhance and empower human ability and potential for the betterment of society.

Network for the Society

The future networks should become the common and global information exchange of human knowledge and should be scalable to provide cultural, scientific and technological exchanges among different regions and cultures. At the same time, the future network must be secure, accountable and reliable without impeding user privacy, dignity and self-arbitration.

Network for a Global Prospective

The future network technology should bridge the gap by facilitating the hybrid satellite terrestrial network with less delay or jitter. It should also make a road map for GMR (GEO-Mobile Radio). It should help to solve global climate change and energy conservation, and at the same time, the network itself must be environment-friendly and energy-savvy.

Factors Affecting Network Technologies

Effectively assessing and configuring the future network design, the following factors can be discussed: customized service factors, social factors, commercial factors, and operation and management factors.

Service Factors

In order to catapult the extremely wide range of service demands of diverse users, the future network forms a network of networks, i.e., meta-network architecture supported by bandwidths ranging from narrow ones to ultra-wide ones with a wide dynamic range of latency for adapting applications and service characteristics by accommodating a huge number and wide variety of terminal devices, which provide the network services with high reliability and advanced security mechanisms against any tapping or denial of service attacks and with an architecture of flexible mobility to achieve pervasive communication and computing environment along with massive backhaul of storing facility.

Social Factors

The future network technology should facilitate the inclusive growth of society and environment by supporting public and private social environment-friendly applications such as education, transportation, healthcare and energy awareness, among the individual members of the society and making a road map for envisioning and provisioning the entire operation and management aspects.

Commercial Factors

Since an entrepreneur with a new idea is the driver of technology-driven society, they must be encouraged with appropriate and guaranteed economic incentives according to their individual contribution, so as to maintain healthy competition and sustainability of the entire operation in the long run.

Operation and Management Factors

From the perspective of operation and management, the future network technology should solve the complexity of operation and management by supporting selfstabilization and self-management functions of the network with effective utilization of ICT resources and enabling smooth migration between different network services with customized services as on demand and taking customer Quality of Experience (QoE) as means of feedback to making QoS better.

It should be flexibly deployed and have the capacity to support and sustain new technologies, which facilitates new entrepreneur by allowing user-oriented service platforms. The network technology should also be able to acquire accurate, unambiguous and real-time information of the whole network and service resource by supporting not only network and service resource control, but also have a capacity to process massive data and information as Big Data Analytics.

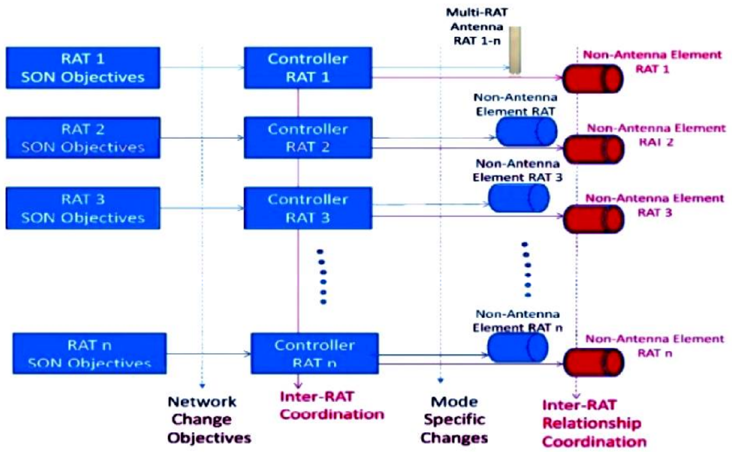
Network Technologies

Technologies to Simplify Management and Improve Network Reliability

Mobile technology, in the form of phones, tablets and notebooks, is making our lives better than ever before, increasing the mobile data traffic to a larger extent.

The increase in user-traffic, especially for Over-The-Top content (OTT) application traffic, makes a new network architecture and dense deployment necessary to reduce the Capital Expenditure (CPEX) and Operational Expenditure (OPEX) of operators and overcome revenue deficit, as operators introduce more multi-Radio Access Technology (RAT), as shown in Figure 1, and multilayer networks leading to increased network complexity. In order to overcome this shortfall, there is a need for solutions to meet those challenges.

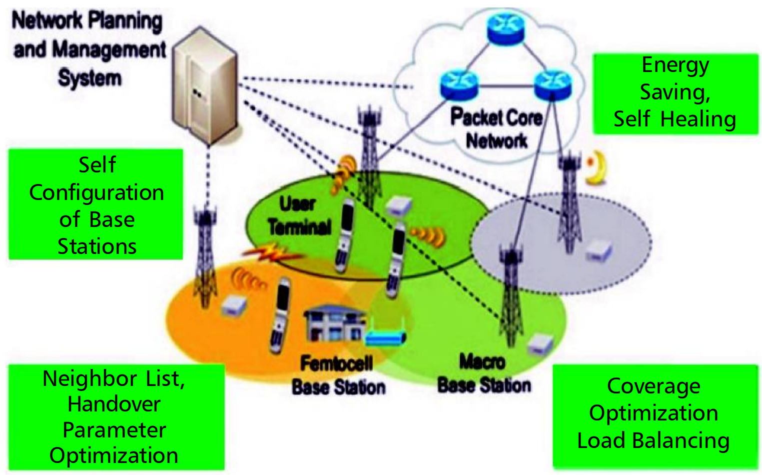
Figure 1: Multi-RAT SON Objectives over Shared Antennas



Source: Reverb Networks (2012)

The advanced Self-Organized Network (SON) (NEC, 2009; and Reverb Networks, 2012) technology, as shown in Figure 2, is one promising technical solution to enable the operators to improve the OPEX efficiency of the multi-RAT and multilayer network, while satisfying the increasing throughput requirements of subscribers.

Figure 2: SON Architecture



But in future, we may need cognitive approach for the entire network so that it will allow optimization of networks, which may take intelligent decision for the evolving network within a short time period.

Technologies to Support Ease of Deployment and Increase Network Reach

The future network deployment strategies should be based on the instant traffic variation, taking into consideration different dimensions of logical architecture or deployment architecture, i.e., network deployment, cost reduction, better QoE and energy awareness. The highlighted features of future network architecture should consider the following aspects:

Network Densification

To meet the increasing demand of traffic density, the cell miniaturization and densification (Ge *et al.,* 2015) is taken as the most favorable option where complexities of site acquisition is a pragmatic issue to deploy a large number of small cells and the criticality increases even further with heterogeneity of network. The transfer of information between small cells with low cost is very critical when a huge number of low cost cells are deployed in the network. Therefore, it is vital to ensure the backhaul link (FlexiHaul, 2012) between the small cells taking into account the cost of the entire network programming and network optimization with high capacity, low latency and high reliability. The advanced SON technology enables the adjustment and optimization of the parameters such as low power, inclination angle, boundary of cell/cell group, and Radio Resource Management (RRM) algorithm by plug and play deployment of small cells in a very dense network without manual intervention.

Small Cells

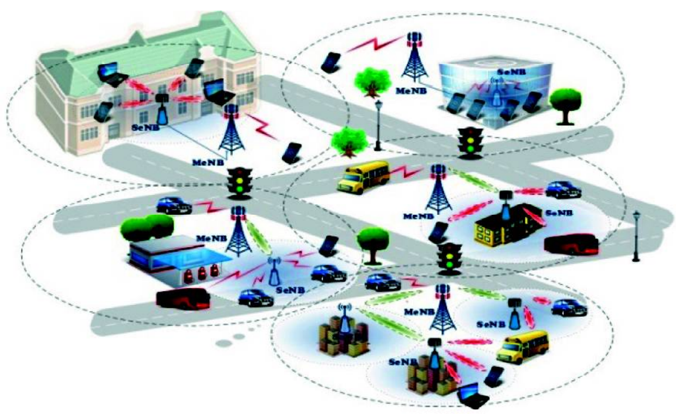
The small cells provide seamless integration with the existing network deployment with increased system spectral efficiency, scalability and capacity without causing (Hoydis *et al.,* 2013; and Zhang *et al.,* 2013) undue interference which can be handled by self-organizing, self-optimizing and self-healing capabilities within the small cell network as an intelligent network, which in turn, reduce the operational expense required to maintain and operate dense deployments. With the proliferation and prominence of the dynamic virtual cell in conjunction with the current small cell, higher link reliability and uniform QoE can be provided to the end user and particularly it offers improvement of capacity in dense urban environments.

Apart from this, the flatter network architecture is also a promising technology as it offers significant volume of traffic from small cells by distributed Internet access at local nodes while providing better features as content cache and edge cloud for the small cells. But the system complexity increased particularly in terms of Radio Frequency (RF) and antenna design for small cells, which can be nullified by further application of new network technology.

Ultra Dense Network

With the proliferation of ultra dense wireless networks (Ge *et al.,* 2015), as shown in Figure 3, it is expected that the Base Station (BS) density may come up to 40-50

Figure 3: Ultra Dense Network for Next-Generation Communication



BS/km^2. These are usually used in hotspot, dense urban areas and indoor scenarios or stadiums. The most important design goals of ultra dense network are to provide extremely high traffic capacity and multi-Gbps data rates in those specific scenarios. A comparison has been made between conventional cellular network and ultra dense network in Table 1.

Table 1: Comparison Between Conventional Cellular Networks and Ultra Dense Networks

Network Types	Conventional Cellular Networks	Ultra Dense Networks
Network architecture	Centralized architecture	Distributed architecture
Densification deployment target	Macro cells	Small cells
Densification reason	Heavy crowded zone in urban area	Massive MIMO communication
Coverage between macro cell and micro cell	Overlap	No overlap
Function of macro cell and micro cell	Same	Macro cells transmit management data, micro cells transmit user data
Micro cell and small cell deployment	Deploy in partial areas	Deploy in all cellular scenarios
Backhaul method	Backhaul traffic is directly forwarded into the core network by the gateway	Backhaul traffic is relayed to the gateway by multi-hop wireless links
Number of backhaul gateway in micro cell	One	Multiple
Merit	Flexible gateway and low cost	Ubiquitous and high-bit rate
Demerit	Small cell partial deployment, low network capacity, uneven distribution of the achievable data	Low mobility and high cost

Moreover, nowadays, in all the above cases, BSs are directly connected by gateways and all backhaul traffic is forwarded by fiber links or broadband Internet. But, in the next-generation cellular networks, distributed architecture of ultra dense cellular network with single and multiple gateways can be deployed. In the distribution network architecture, not only backhaul traffic, but also fronthaul traffic needs to be relayed into the destination. The selection of relaying small cell BS should be carefully taken into account in ultra dense cellular networks, which leads to a key challenge to designing wireless multi-hop routing algorithm for the ultra dense cellular networks.

Apart from supporting ultra high data rates and capacity, ultra dense networks should address network architecture with flexible deployment strategies and protocol procedure enhancements, energy efficiency of the network, interference awareness and its subsequent minimization.

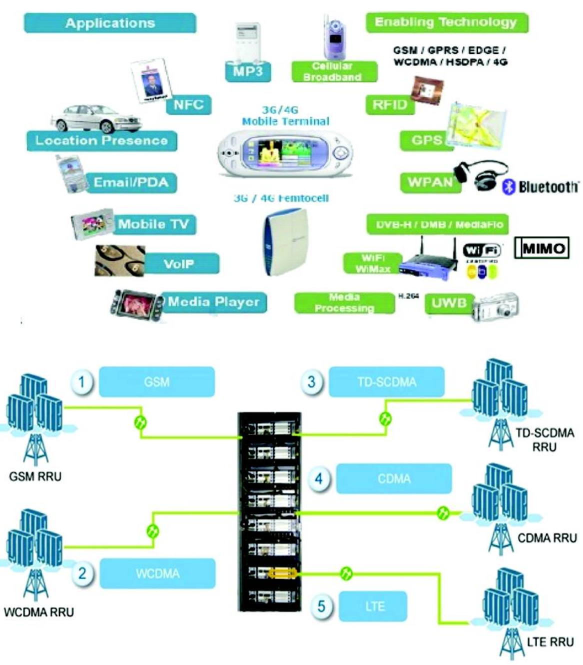
Multi-Radio Access and Multi-Mode

The trend to integrate multiple radio access technologies seamlessly will accelerate due to the need for integrating new spectrum bands, whether licensed or unlicensed, to meet the capacity demands and to support usages such as IoT wherein through a multi-radio gateway noncellular radio may connect to cellular network (Ge *et al.,* 2014; and Wang *et al.,* 2014).

The coexistence of multi-RAT introduces many challenges for operators, such as operation and maintenance with multiple management system, delay and power consumption, imbalanced and low resources utilization, and inflexible and inefficient traffic steering with a degraded QoE.

So, multi-radio access and multimode network architecture, as shown in Figure 4, will be a typical solution for the next-generation communication. Therefore, it is required to have a better coordination among multi-radio access and multimode network.

Figure 4: Multi-Radio Access and Multi-Mode Network Architecture



So, it is important to consider a new architecture and solution to optimize the multi-RAT coordination (Reverb Networks, 2012) and interworking from advance RAN perspective to meet the above requirements, in addition to load balancing and seamless mobility management, such as on demand traffic steering, improved QoE with reduced maintenance and optimization complexity.

Mobile Relay

Generally, a mobile relay indicates a BS/access point mounted in high-speed transportation such as bus, train or airplane. It may provide several services of good quality like seamless wireless connectivity (Zhang *et al.*, 2013) to the last-mile users inside the moving vehicle, capability to perform group mobility and the integration of different air interface technologies on the backhaul, so as to increase handover success rate and penetration loss through the vehicle and increased spectrum efficiency. Eventually, with the use of mobile relay, the frequent handover drastically reduces, which in turn reduces heavy load on the entire network.

Technologies to Enhance Architecture

The next-generation wireless network systems can accommodate voluminous data traffic, and the increased surge in data traffic leads to several challenges such as increased number of intelligent and flexible nodes at the network edge, expansion of storage capabilities, the leverage of pre-caching of content based on estimated popularity, aggregation of raw information coming from the multitude of sensors, etc. Along with this, the introduction of Software Defined Radio (SDN), Digital Monadile Radio (DMR) or other high rate web browsing services through OTT leads to designing a more challenging network under circumspect of feeble spectrum allocation.

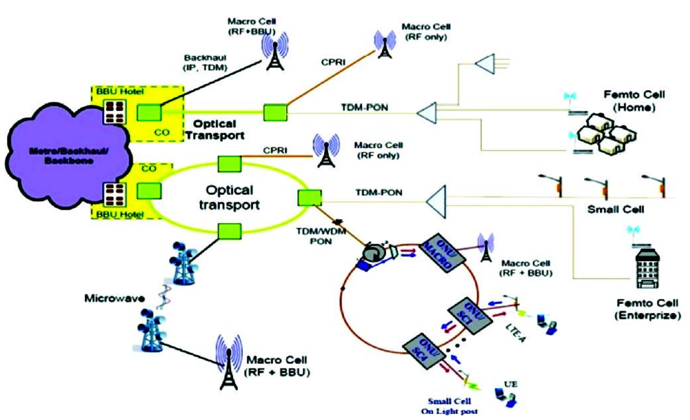
Therefore, these emerging trends have the potential to drive dramatic changes in the network architecture for service delivery. So, by providing customized service on demand basis, the operators can overcome their financial liabilities in a healthy, competitive and transparent way. Some of the recent architectures that support the enhanced features are as follows:

Novel RAN Architecture

The Radio Access Network (RAN) architecture (Shahab, 2014), as shown in Figure 5, can support simple network-centric interference coordination options to more advanced Coordinated Multi-Point (CoMP) schemes with autonomously organizing capability by providing high-speed low-latency switching networks to enable timely exchange of information among Base Band Units (BBU) within the pool of units.

It is not only helpful for small cell indoor BS, but also for ultra dense clusters of small cells with a simultaneous or separate control activity having potential of multicell RRM among different architectural layers which leverage the CPEX and OPEX of service providers.

Figure 5: A Typical RAN Architecture



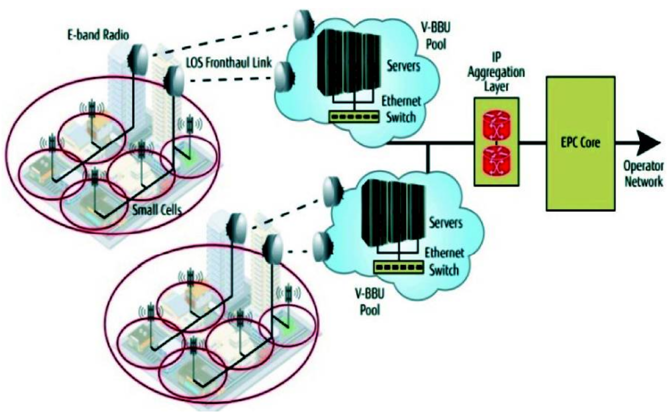
Source: Hussain (2014)

Cloud RAN Architecture

The Cloud RAN architecture (C-RAN) (Ericsson, 2015) can support fully distributed and centralized networks or the combination of both centralized and distributed networks in collaborative fashion which can deploy dense heterogeneous networks with intelligent and flexible nodes.

By centralizing the baseband and higher layer processing resources, a pool can be formed so that on demand basis, the C-RAN network, as shown in Figure 6, will dynamically handle the processing resources and can deploy the radio units and antenna in a distributed manner. Here, the control signaling can be delivered by the macro cells and user data transmission can be delivered by small cells, with automated

Figure 6: Cloud RAN Architecture



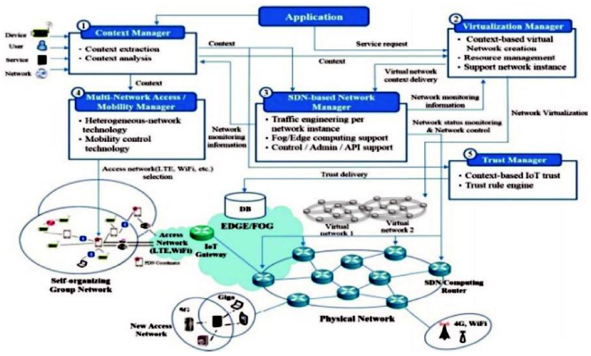
traffic steering, enabling virtual transceiver approach to mobile access which can select a suitable transmitter and receiver out of the pooled transmitters/receivers facilities.

This type of architecture leads to uniform performance and quality everywhere over a cell, even at cell edge with joint transmission and processing, coordinated scheduling, load balance management and interference coordination among individual small flexible cells from centralized site office which can accommodate several dozens of BSs with an ability to dynamically allocate the processing resources to busy cells on demand basis by reducing Total Cost of Ownership (TCO).

Future Network Infrastructure for IoT Services

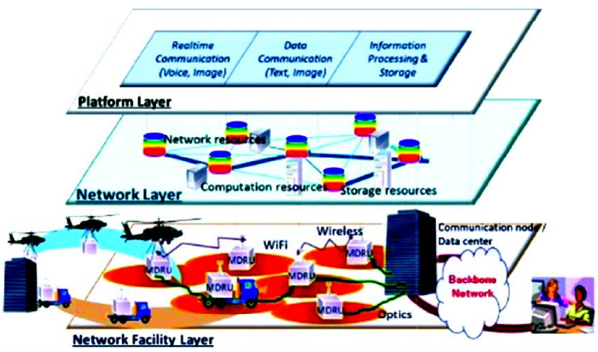
The emerging IoT has huge potential, but simultaneously it poses serious challenges as to how to integrate these enormous streams of physical world IoT devices with all the existing network structure, as this will lead to heavy surge in traffic density. So here it may be considered to infuse context-aware user-centric IoT-based network (Chin *et al*., 2015), as shown in Figure 7.

Figure 7: Architecture Supporting IoT Services



Source: Chin et al. (2015)

Figure 8: Disaster-Resilient Communication Network Flat Form



Source: Sakano et al. (2012)

So, the IoT-based network may be characterized by context-aware infrastructure, where contexts are extracted from the corresponding IoT devices and analyzed in order to create and utilize virtual networks by virtualizing the physical network, bandwidth optimization and reservation, QoE and QoS support, flow control and load balancing in the entire network. It may also support edge diversity, i.e., interconnectivity of various IoT services and end devices with different network technologies such as WiFi, WiMAX, LTE, ZigBee and Bluetooth, along with a backhaul support of D2D communication services.

This will attract many implementation challenges such as trusted computing in a trusted environment with privacy issues caused by some sensitive services and universal security evaluation standards for ubiquitous computing and uninterrupted connection among devices.

Disaster-Resilient Communication Network Architecture

During the disasters or warfare-like situations, a lot of Information and Communications Technology (ICT) resources such as optical fiber communication link, microwave communication link, telecom-switching offices and satellite communication network platforms were completely or partially damaged. As a consequence, the demand for ICT services explosively increased, mainly because the people of the affected areas were trying desperately to communicate with the outside world, which led to a phenomenal rise in the network traffic. The demand for fixed line and mobile telephone services proliferated to ten to fifty times more than usual. This gave rise to serious traffic congestion, and the existing communication networks were not sufficient enough to deal with this issue, leading to tough security and privacy concerns.

So, through the use of disaster-resilient communication network architecture, as shown in Figure 8, based upon smart Movable and Deployable Resource Units (MDRU) (Sakano *et al.* 2012), the communication and information processing functions can be rapidly restored or transported to the disaster-affected area, and can be deployed within a reasonably short time to establish the network at the disaster zone and it is possible to launch ICT services by using a cooperative approach among the network element.

Conclusion

This paper outlines different network technologies for the next-generation wireless communication, which is expected to support not only the conventional voice and data services, but also customized communication paradigms, such as IoT and D2D services, in a fully automated fashion, with or without minimal human intervention. Some specific issues related to the user and the service provider have been raised in the context of network technology. So, the design issues and implementation challenges discussed above will soon present themselves before the academic institutions, research organizations, different international standardization forums and this will give impetus to devise improvements to the current network technology standards and to design novel pragmatic solutions to the enormous and complex challenges, aided by the next-generation wireless communication.

References

1. Chin Won Song, Hyun-soo Kim, Young Ju Heo and Ju Wook Jang (2015), "A Context-Based Future Network Infrastructure for IoT Services", *Procedia Computer Science*, Vol. 56, pp. 266-270.
2. Ericsson (2015), "Cloud RAN: The Benefit of Virtualization, Centralization & Co-Ordination", White Paper, ERICSSON.
3. FlexiHaul (2012), "Flexible Front and Backhaul for 4G and Beyond", White Paper FlexiHaul.
4. Ge X, Cheng H, Guizani M and Han T (2014), "5G Wireless Backhaul Networks: Challenges and Research Advances", *IEEE Netw.,* Vol. 28, No. 6, pp. 6-11.
5. Ge Xiaohu, Tu Song, Mao Guoqiang *et al*. (2015), "5G Ultra-Dense Cellular Networks", *IEEE Wireless Communications*.
6. Hoydis J, Ten Brink S and Debbah M (2013), "Massive MIMO in the UL/DL of Cellular Networks: How Many Antennas Do We Need?", *IEEE J. Sel. Areas Commun.,* Vol. 31, No. 2, pp. 160-171.
7. Hussain Shahab (2014), "An Innovative RAN Architecture for Emerging Heterogeneous Networks: The Road to the 5G Era", Doctoral Dissertation, Graduate Center, City University of New York.
8. NEC, Self Organizing Network (2009), "NEC's Proposal for Next Generation Radio Network Management", White Paper, NEC Corporation.
9. Reverb Networks (2012), "Multi-Radio Access Technology (RAT) Self-Organizing Networks", Reverb Networks, Inc. 21515, Ridgetop Circle, Suite 290, Sterling, VA USA 20166.
10. Sakano Toshikazu, Fadlullah Zubair Md., Kumagai Tomoaki *et al.* (2012), "Disaster Resilient Networking – A NEW Vision based on Movable and Deployable Resource Units (MDRUs)", *IEEE Transactions on Communications*.
11. Wang C X, Haider F, Gao X *et al*. (2014), "Cellular Architecture and Key Technologies for 5G Wireless Communication Networks", *IEEE Commun. Mag.,* Vol. 52, No. 2, pp. 122-130.
12. Zhang Jian A, Collings Iain B, Chen Chung Shue *et al*. (2013), "Evolving Small-Cell Communications Towards Mobile-Over-FTTx Networks", *IEEE Communications Magazine*.

Reference # 70J-2016-05-02-01