Hacettepe University

Computer Engineering Department

Wireless and Mobil Networks

Professor
Suat Özdemir

5G

ABSTRACT

After the up rise of 4G wireless mobile technology takes place; researchers, mobile operator industries representative, academic institutions have started to look into the advancement (technological) towards 5G communication networks due to some main demands that are meliorated data rates, better capacity, minimized latency and better QoS (Quality of Service). To established the 5G mobile communication technological foundation, various research works or projects entailing main mobile infrastructure manufacturers, academia and international mobile network operators have been introduced recently. Nevertheless, 5G mobile services to be made available for use, their architecture, and their performance have not been evidently explicated. In this paper, we represent thorough overview of 5G the next generation mobile technology. We mainly throws light on 5G network architecture, 5G radio spectrum, ultra-dense radio access networks (UDRAN), traffic offloading of mobile, cognitive radio (CR), software defined radio (SDR), software defined networking (SDN), mixed infrastructure, and 5G network impact on the society.

5G Concept

In the history of mobile communications, each generation is featured by an iconic KPI and a key technology. For example, 1G systems use FDMA and can provide analog voice service only. 2G systems are mainly based on TDMA and can provide both digital voice and lowdata-rate services. 3G systems, marked by CDMA, can achieve the peak data rates from 2 Mbps to tens of Mbps, and support multimedia services. On the basis of OFDMA technology, 4G sytems can achieve the peak data rates from 100 Mbps to 1Gbps, and support various mobile broadband (MBB) services. Due to the diverse service requirements, 5G will be characterized by more key capabilities than previous generations. Among them are user experienced data rate, connection density, end-to-end latency, energy effi ciency, and mobility. Instead of peak data rate – the core KPI of the previous generations, user experienced data rate has been identifi ed as the most important metric. The consensus view is that user experienced data rate can reflect the real-world data rates perceived by users. Based on the requirements of typical technical scenarios, the user experienced data rate of 5G should reach Gbps level. It is difficult for 5G to meet the extensive range of performance requirements in different scenarios by utilizing a single technology. Furthermore, in recent years, the wireless technology innovations show the diversifi ed development trend. In addition to novel multiple access, massive MIMO, ultra-dense networking, all-spectrum access, and new network architecture are considered as the main technologies for 5G that will fulfi ll the requirements of the main technical scenarios. According to the analysis on the key capability and technologies, 5G concept can be defined as “One iconic KPI + A group of key technologies”. The iconic KPI is Gbps user experienced data rate, and the group of key technologies include massive MIMO, ultra-dense networking, novel multiple access, all-spectrum access, and new network architecture.

Difference between 5G and current technology

Employing millimeter waves and higher frequencies than previous technologies, 5G needs a much more extensive network of antennas and other transmitting devices. Electromagnetic fields (EMF) are invisible areas of energy,7 measured in hertz (Hz). Longer wavelengths with lower frequency are less powerful in terms of energy, while shorter wavelengths at higher frequencies are more powerful. Depending on the frequency, there are two categories of EMF: ionising and non-ionising radiation (see Figure 0)

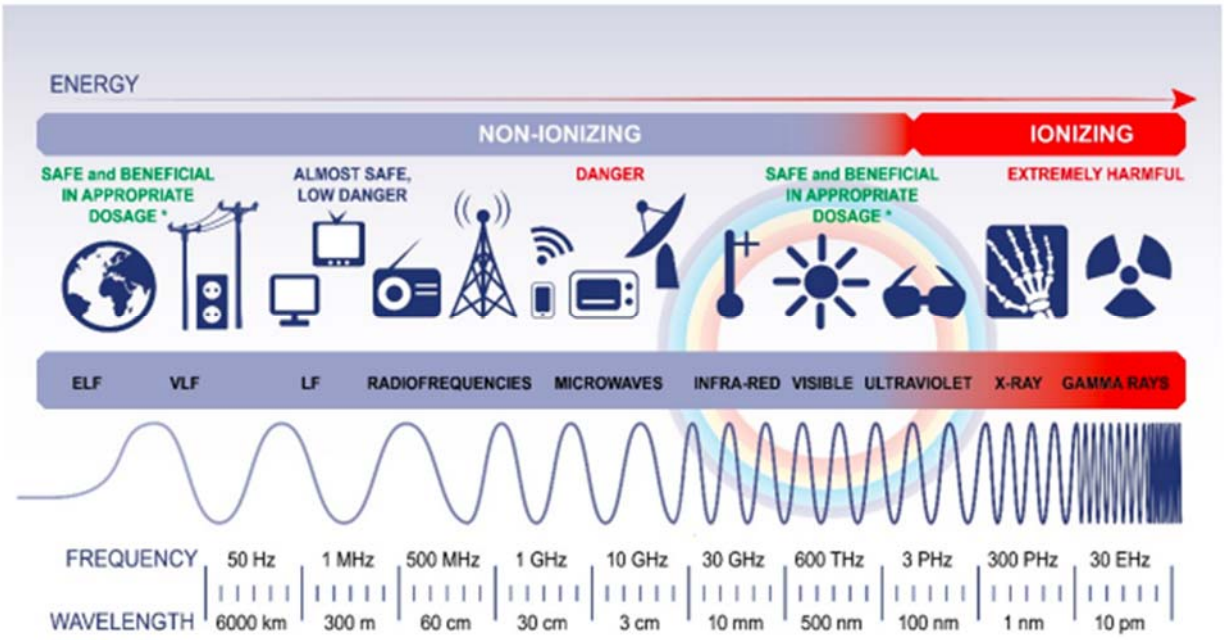


Figure 0 – Electromagnetic spectrum

INTRODUCTION

From the last few years, we have noticed prodigious modification in the telecommunication's world. Now-adays and in the coming future, to accomplish the presuppositions and difficulties of the coming era, mobile communication networks of today will have to develop in various manners. The on-going implementation of 4G mobile networks has encouraged some telecom industries to contemplate more advancement toward future fifth generation technologies and facilities. Fifth generation (5G) wireless technology with an advanced access technology called BDMA (Beam Division Multiple Access) and FBMC (Filter Bank Multi-Carrier Multiple Access) will straightforwardly superseded 4G wireless technology. By contemplating the instance of the BS (base station) communicating with the MS (mobile station), beam division multiple access (BDMA) technique conception is explicated. In this transmission, an orthogonal ray is distributed to each MS (mobile stations), & beam division multiple access technique will split that ray of antenna according to the MS (mobile stations), which in an analogous ameliorate the network's capacity. A notion to switch towards fifth generation is based on drifts of current; it is often presumed

that fifth generation mobile networks must resolved six problems that are not successfully resolved by fourth generation mobile communication networks i.e. higher data rate, massive device connectivity, higher capacity, less cost & consistent, Quality of Experience (QoE) and lower End-to-End latency . The mentioned problems are succinctly shown in the figure 1 along with some possible facilitators to address them. Summary of the problems, facilitators to address problems, & design fundamentals for fifth generation (5G) mobile technology is shown in the figure 1. IEEE standard which are recently introduced i.e. IEEE 80211ac, 802.11ad, & 802.11af are very helpful and function as a fundamental units in the path towards fifth generation (5G) mobile communication networks.

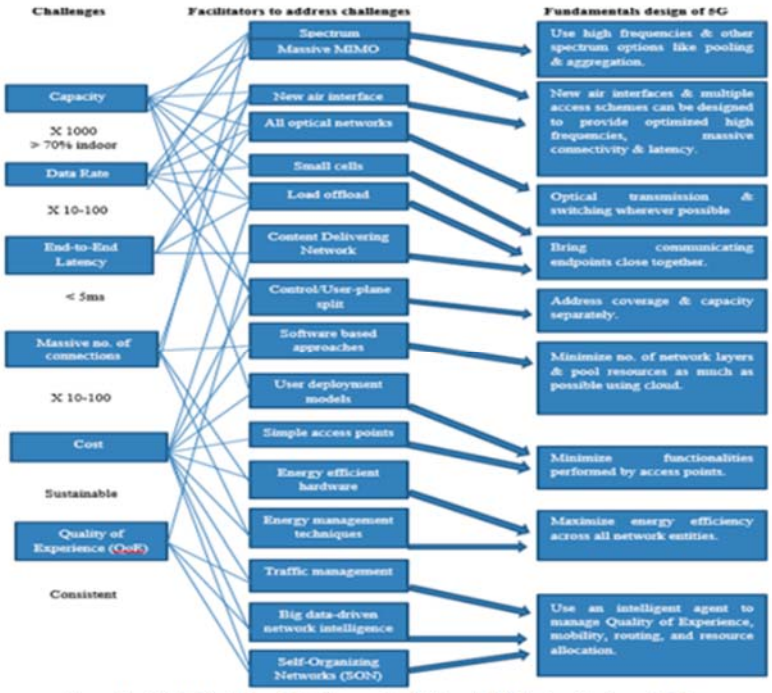


Figure 1:- 5G Mobile Network Challenges, Facilitators, & 5G Design Fundamental [4].

NETWORK ARCHITECTURE OF 5G

Fifth generation mobile communication network is a new revolution in the world of telecommunication. In 2020, many phone companies released phones that contain the fifth generation feature. Fifth generation (5G) mobile networks model is all internet protocol (IP) based model. In the 5G mobile network conception, it is an exceptional approach that the prime priorities of fifth generation (5G) mobile system are user terminals. The terminal has right or opportunity to approach unalike wireless technologies concurrently and it can also able to amalgamate some attributes from other technologies. Fifth generation (5G) mobile communication network is completely concentrated on portability of user as a handset or terminal smartly reacts to select vigorous plan of wireless to ingress wireless networks [10]. A general fifth generation (5G) mobile network architecture is shown in figure 2 and we will go

through all the open systems interconnection (OSI) model layers shown in table 1 of fifth generation (5G) mobile communication network.

Table 1:- OSI Protocol Layer Stack of Fifth Generation (5G)

<table>
<tr><td>Application Layer</td><td rowspan="2">Application (services)</td></tr>
<tr><td>Presentation Layer</td></tr>
<tr><td>Session Layer</td><td rowspan="2">Open Transport Protocol (OTP)</td></tr>
<tr><td>Transport Layer</td></tr>
<tr><td rowspan="2">Network Layer</td><td>Upper Network Layer</td></tr>
<tr><td>Lower Network Layer</td></tr>
<tr><td>Data Link Layer</td><td rowspan="2">Open Wireless Architecture (OWA)</td></tr>
<tr><td>Physical Layer</td></tr>
</table>

PHYSICAL/MEDIUM ACCESS CONTROL LAYER

The uppermost two open systems interconnection (OSI) layers i.e. physical & medium access control layers are interpret as locus of network, in this instance of fifth generation (5G) these two layers elucidate as wireless technology and mobile network of 5G is being founded on open wireless architecture.

NETWORK LAYER

The network stratum is based on internet protocol (IP), as now-a-days there is no race on this stratum. The internet protocol version 4 (IPv4) is spread throughout the world & it has various issues such as confined address space & has not any actual prospect for quality of support (QoS) per flow. These problems are resolved in internet protocol version 6 (IPv6).

OPEN TRANSPORT PROTOCOL LAYER

In the wireless connection transmission control protocol (TCP) retransmit the missing or impaired segments of transmission control protocol (TCP). In fifth generation (5G) mobile technology it is indispensable due to higher download speed & installed speed.

APPLICATION LAYER

Concerning the application, the eventual entreaty from the fifth generation mobile terminal is to furnish intelligent quality of service management over heterogeneity of systems. Parameters of quality of service such as losses, delay, reliability, jitter, and bandwidth will be keep in reserved in a database in the 5G handset with the goal to be utilized by intelligent algorithms

running as system processes in the mobile terminal, which ultimately shall give the foremost wireless connection upon obligatory quality of service (QoS) & individual cost limitations.

RADIO SPECTRUM FOR FIFTH GENERATION (5G)

Usually, new frequency bands & broader spectral bandwidth per radio channel has been allocated to each generation of mobile communication networks. Fifth generation (5G) mobile communication networks will need a great extent of aggregative spectrum to make it possible for pliable bandwidth scaling & enlargement. In order to accomplish that, supplemental harmonic frequency bands must be assigned. In order to enhance the reprocess of frequency, the spectrum will be utilized on radio access technology (RAT) impartial fundament, preferably by implementing concept of cognitive radio (CR) to mini & big cells [13]. The supplemental spectrum for fifth generation may incorporate 100MHz of bandwidth under 1 gigahertz to meliorate rustic wireless broadband access & 500 megahertz of the band betwixt 1 & 5 GHz for increased high data efficiency [14]. The main 3GPP (3rd generation partnership project) frequency bands of 900 MHz, 1800 MHz, 2100 MHz, & 2600 MHz will be utilized for competence enhancement in Long-Term Evolution Advanced and HSPA (high speed packet access). Following the World Radio Conference (WRC) in the year 2015, Long-Term Evolution Advanced will also depend on the frequency band of 700 MHz crossways the ITU Region 1 [15]. The vision for long-term is the confluence of broadband & broadcast facilities in joint multi-media networks covering the UHF (ultra-high frequency) band beneath 700 megahertz. In high capacity hotspot, deployments of small cell will play an indispensable role and the spectrum for that could get from the 3500 megahertz band, where as much as 400 megahertz of bandwidth is utilized for fastened satellite and broadband wireless access services. The consequence is that up to 1.5 gigahertz of the spectrum can be made obtainable by the year 2020, at the minimum 1 GHz will be the customary not divided spectrum & the remainder can be not locked through the use of new spectrumapportioning techniques such as the misuse of TVWS (TV white spaces) through CR (cognitive radio). TV white spaces are big sections of the very highfrequency/ultrahigh-frequency spectrum that are now obtainable in geographic zones where the change over from the analogue to digital TV has been accomplished. Furthermore, the Long-Term Evolution time-division duplexing (TDD) service in the 3.5 gigahertz band, known as LTE-Hi, is also contemplated for hot-spot zones where coverage is not a requirement, & the maximal feasible output is needed. Additionally, unlicensed bands like 2.4 GHz, 5GHz, & 60 GHz proffer affordable spectrum choice for traffic offloading Frequency-domain possibilities anticipated for CR (cognitive radio) that can be utilized for fifth generation is recapitulates in table 2.

Table 2:- 5G cognitive radios spectrum possibilities

Spectrum opportunity	Purpose	CR Function
54-698 Megahertz	TV Bands	Utilized beneath the carrier accumulation conception, i.e., using them as components carrier
2.7-2.9 Gigahertz	Bandwidth scaling from 2.7 to 3.4 gigahertz for improved pliable spectrum usage	Not identify clearly & definitely yet
3.4-3.6 Gigahertz Band 43	A smooth misuse of the Band 43 from WiMAX to LTE	Co-deployment on uppermost of the large layer of cell
3.6-3.8 Gigahertz	Neighboring carrier accumulation provision with the maximal 100 megahertz bandwidth	Carrier aggregation application
3.8-4.2 Gigahertz	Macro cell & mini cell layers' deployment, i.e., heterogeneous networks (HetNet)	Carrier aggregation within HetNet
60 Gigahertz unlicensed band	Small cell backhaul deployment	Not identify clearly & definitely yet

ULTRA-DENSE RAN

A new conception anticipated in the state of affairs of fifth generation (5G) is UDRANETs (Ultra-Dense Radio Access Networks). Ultra Dense Radio Access Networks are envisioned as less power access nodes a few meters apart for within door regions. The prime aim of UDRANETs will be to offer an immensely high traffic capability over highly dependable low-range knots. Ultra-Dense Radio Access Networks will probably function in the frequency range of 10-100 GHz, which has continued virtually unutilized for mercantile cell-phone networks notwithstanding its prospective to give bandwidths of hundreds of megahertz. Modern communication & access technologies have to be flourished & systemized for this sort of systems, needing spectrum apportionment studies in millimeter waves.

TRAFFIC OFFLOADING OF MOBILE

Tablets, smartphone, & mobile broadband gadgets produce exceptionally enormous amounts of traffic. With the present cellular infrastructure, mobile operators companies are encountering great problems to work for such a massive growth of mobile traffic. Traffic offloading consists in utilizing complemented RAN (radio access networks) to convey information initially meant for mobile cellular networks, by that means reducing the blockage on each single radio link and respective backbone connection. Traffic offloading includes comprehensively various panaceas, which can be categorized as overlay and non-overlay panaceas; some of them are discussed in this paper.

COGNITIVE FEMTOCELLS

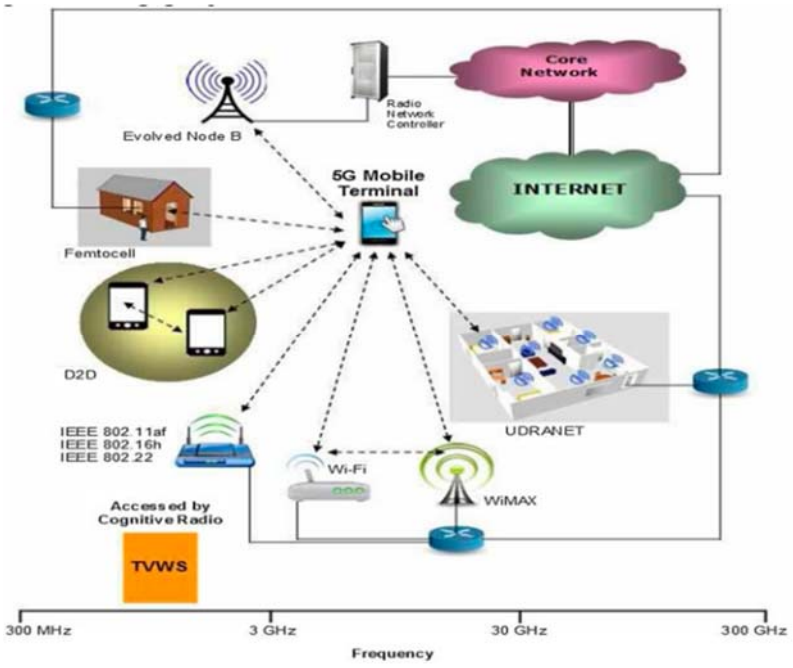
Traffic offloading of femtocell is being founded on the placement of mini, low-capacity mobile BS (base stations) at site or in other within doors regions, backhauled to the interior network of cellular system by a traditional cabled network. Among various advantages of this panacea is the actuality that femtocells are able to control both data & voice traffic with quality of service guarantee. Nevertheless, the utilization of similar spectrum as overlaying macrocells entangles the search for obtainable mediums for femtocells in eminently crowed regions. Thus, intelligent intervention management utilizing CR (cognitive radio) and RRA (reservation random access) arrangement must be applied, basically in

deployment schemata where the position of the femtocells is decided by the end users, example uncoordinated home evolved nodeB. The highly-unforeseeable intervention with macrocells needs strategic spectrum ingress within a hierarchical overlay system as follows: first, the information anent gamut scopes, which are afterwards exploited by the femtocells is given by a sensing method at the macrocell stratum.

ALTERNATIVE SOLUTIONS FOR OFFLOADING

World-wide Interoperability for Microwave Access can be contemplated as other offloading, but it is more appropriate for backhaul for massive Wi-Fi systems. Moreover, 3rd generation partnership project objection mobile networks have not contemplated interoperation with world-wide interoperability for microwave access until now; hence, supplemental standardization would be needed. In an authorized band of frequency, deviceto-device communication is an underlay to mobile networks comparing with mobile ad-hoc networks (MANETs), which function in a similar way but in the unauthorized gamut. The future generation of mobile communication systems could influence offloading chances generated by the amalgamation of the aforesaid solutions & further that may be evolved in the future. Cognitive mobile-traffic offloading is an approach in which these solutions can be further prolonged through the utilization of CR. For example, an outdoor mesh network of white-Fi hotspots & Wi-Fi backhauled to the mobile network via world-wide interoperability for microwave access links or cabled broadband access can treat as an alternative of traffic offloading in fusing with device-to-device links & femtocells (figure 5).

Figure 5 :-Traffic offloading approaches for fifth generation networks



SOFTWARE DEFINED RADIO

(SDR) Infrastructure of future generation network must have an enough immense pliability in order to extend over dissimilar parameter of radio frequency settings in a vigorous & flexible approach to permit systematic management of spectrum. Platforms which are reconfigurable based on SDR will ease the vigorous air interface reconfiguration of the nodes of system by customizations of software, reflecting contemporary exigencies of traffic. The pliability of the radio frequency concatenations must be farther reflected in the baseband processing competencies, where the down-transmuted radio frequency signals are to be processed. As fifth generation networks will require to exploit underused bands of frequency to circumvent the anticipated crunch of spectrum, execution of cognitive radio on software-defined radio platforms should contemplate coaction & interoperation of multitudinous radio technologies, that is, through CRRM (Common Radio Resource Management). This signifies that a platforms which is reconfigurable ought to be competent to function at dissimilar power stratums, frequencies & channel bandwidths, coding stratagems & modulation, amending parameters of transference & features according to the specific restraints of the radio technology standards in utilization; these restraints incorporate undesired emanation in the functioning band, adjacent frequency leakage ratios, or intermodulation results. Encouraging software-defined radio advancement enterprises incorporate the GNU Radio, which is an open-source software advancement toolkit for the execution of software-defined radio on numerous programmable platforms such as USRP (Universal Software Radio Peripheral) boards, & the open BTS, which was not long ago utilized to exemplify the execution of a software-based GSM BS (base station) on the Raspberry Pi hardware platform.

SOFTWARE DEFINED NETWORKING (SDN)

The prime conceptions of software-defined networking incorporate the segregation of the control data plane & a programmable network. Both cognitive radio & software-defined radio technologies do not entail the control of the cellular core network of mobile, at the present phase of advancement. Up to now, no coordination of flows of traffic is feasible at the core network, that is, a handset cannot get numerous dissimilar flows of traffic from different enodeBs concurrently to enhance the rate of data. SDN is a revolutionary conception, aims at offering a coordination that has an international perspective of infrastructure of network, as a result of that easing a number of functionalities of networking. Packets of data passing via link devices (routers, switches, etc) are categorized into flows to make pre-flow transmitting decisions. A flow is illuminated by a set of corresponding regulations in twelve idiosyncratic fields of quintessential IP/Ethernet/User Datagram Protocol header (Layer 2 & Layer 3 addresses, ports, Virtual Local Area Network information etcetera). Every time a packet of data amalgamated to a particular flow gain access to a device, a counter is upgraded at the controller. This makes it feasible for the controller to have an international perspective of the status of each component of network. Thence, the controller can make the conclusion to transmit the traffic via a reduced crowded path, or utilize a radio channel that fleetingly

undergoes a pleasant state to transmit the packet of data to the end user. Software-defined networking intends to hold up a much more desirable amalgamation of all prevailing wireless networks (2G to 4G, Wi-Fi, and etcetera) .It would be feasible to carry out a coherent handover, not merely within similar technology as already prevails, yet also athwart H-RATs. Furthermore, software-defined networking will considerably ease the management of disorganized deployments of huge amounts of mini cells in longterm evolution networks.

5G IMPACT ON SOCIETY

From the social view, fifth generation networks have the capability to ameliorate the cell-phone broadband connections in rustic regions. The expenditure of wealth for installing a huge number of BS & the less ARPU (average revenue per user) has deferred the wide-ranging coverage of rustic environments. By utilizing TV White Space & offloading of traffic elucidations, the placement of 5G networks in rustic regions will be feasible at a lesser budget thanks to further favorable propagation situations in the very high-frequency/ultrahigh-frequency gamut that unswervingly transform into littler base stations.

CONCLUSION

A comprehensive study of future fifth generation wireless technology has been done. We presented fifth generation network challenges, facilitators & design fundamental, network architecture along with OSI protocol stratum stack, 5G radio spectrum, ultra-dense radio access networks, traffic offloading of mobile, cognitive femtocell, Wi-Fi & White-Fi, alternative solution for offloading, cognitive radio, softwaredefined radio, software-defined networking, 5G impacts on the society in this paper. This paper is one which may be offering a better platform to prompt the industries representatives, academia, & researchers for better results of different sorts of issues & challenges in future fifth (5G) generation wireless networks.

The 5G mobile phone is intended as an unbolt podium on unusual layers, starting from physical layer up to the application. The future perception acclimatizes Open Wireless Architecture projected for 4G mobile terminals, and affords additional alterations from network up to the concern application layer.

The two sub-layers of network are intending to endow with all-IP connectivity in surroundings with profusion of wireless/mobile technologies and network service suppliers. Open Transport Layer is projected with endeavor to tolerate practice of wireless explicit realizations of transport protocols. In conclusion, there is an opportunity for assortment of unusual wireless technologies upon diverse Quality-of-Service constrictions for dissimilar services and for such reason, 5G mobile terminals ought to keep up database to maintain statistical information concerning the services and the existing wireless technologies. At present, the current work is on the components/units that shall endow with the unsurpassed Quality-of-Service and lowly outlay for a specified 5G service by means of one or more wireless technology concurrently.

REFERENCES

[1] C.-X. Wang et al., ``Cellular architecture and key technologies for 5G wireless communication networks,'' IEEE Commun. Mag., vol. 52, no. 2, pp. 122_130, Feb. 2014.

[2] M. Fallgren et al., Scenarios, Requirements and KPIs for 5G Mobile and Wireless System, document ICT-317669-METIS/D1.1, Apr. 2013.

[3] Industry Proposal for a Public Private Partnership (PPP) in Horizon 2020 (Draft Version 2.1), Horizon 2020 Advanced 5G Network Infrastructure for the Future Internet PPP. [Online]. Available: http://www.networks-etp-eu/_leadmin/user_upload/Home/ draft-PPP-proposal.pdf

[4] P. Agyapong, M. Iwamura, D. Staehle, W. Kiess, and A. Benjebbour, ``Design considerations for a 5G network architecture,'' IEEE Commun. Mag., vol. 52, no. 11, pp. 65_75, Nov. 2014.

[5] E. Perahia and R. Stacey, Next Generation Wireless LANs: Throughput, Robustness, and Reliability in 802.11n. Cambridge, U.K.: Cambridge Univ. Press, 2008.

[6] E. H. Ong, J. Kneckt, O. Alanen, Z. Chang, T. Huovinen, and T. Nihtila, ``IEEE 802.11ac: Enhancements for very high throughput WLANs,'' in Proc. IEEE 22nd Pers. Indoor Mobile Radio Commun., Sep. 2011, pp. 849_853.

[7] E. Perahia and M. X. Gong, ``Gigabit wireless LANs: An overview of IEEE 802.11ac and 802.11ad,'' ACM SIGMOBILE Mobile Comput. Commun. Rev., vol. 15, no. 3, pp. 23_33, Jul. 2011.

[8] E. Perahia, C. Cordeiro, M. Park, and L. L. Yang, ``IEEE 802.11ad: De_ning the next generation multi-Gbps Wi-Fi,'' in Proc. 7th IEEE Consum. Commun. Netw. Conf., Jan. 2010, pp. 1_5.

[9] A. B. Flores, R. Guerra, E. W. Knightly, P. Ecclesine, and S. Pandey, ``IEEE 802.11af: A standard for TV white space spectrum sharing,'' IEEE Commun. Mag., vol. 51, no. 10, pp. 92_100, Oct. 2013.