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Study and Analysis of 5G Research Activities

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Abstract

This paper summarizes the key initiatives in favor of 5G wireless communication networks. Recent program and project activities and documents are highlighted. A closer examination of a series of 5G-related projects in the European Union is carried out. The literature review is limited to recent issues of IEEE Communications 5G Journal and related white papers from various sources. The aim is to shed light on what 5G is: what are the foundations of the basic concept of 5G systems, what the key challenges are, and how to overcome them. The researched benchmarks indicate that in addition to the technologies that increase capacity, 5G must offer, such as low latency, super-reliable communication, and massive connectivity. Therefore, the most demanding part of the 5G development process will be the design of a system concept platform that is sufficiently flexible to enable the successful integration and management of various discrete technologies optimized for different use cases.

Keywords: wireless communication, Network, data, 5G systems, Internet

INTRODUCTION

Increased data traffic on the Internet has driven capacity demand for the currently deployed 3G and 4G wireless technologies. Today, intensive research on 5th generation wireless communication networks is progressing on many fronts. 5G technology will be used around 2020. This article has overcome the surface of over 5 g different activity by checking a series of European research projects, recent documents and white paper of the main players of wireless technology. The goal is to help understand what 5 g is related and how different 5G initiatives are targeting. There is no unique definition (again) for 5g [1], [2]. However, a general consensus built around the idea that 5G is simply the integration of some techniques, scripts and use cases instead of inventing a radio access technology Unique new. Technical requirements of existing technologies (4G) [3] List the following items: • Mobile data data more than 1000 times per zone, • Typical user ratio high More than 10 to 100 times, • The number of connections is 10 to 100 times higher. Equipment, • Battery life is 10 times longer for low-capacity devices, • Reducing 5 times later. remaining of paper is organized as follows. Section II deals with the essentials of the various European projects related to 5G that are underway. Part III reviews IEEE Wireless Communications Journal's Topic Issues on 5G Wireless Communication Systems: Prospects and Challenges, Part 1 in February 2014 [4-13] and Part 2 in September 5 years 2014 [14-22] and finally the selection of the white paper on 5G [23-29]. Part IV then draws on the concluding remarks followed by the biography.

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EUROPEAN 5G PROJECTS

This section mainly covers the spectrum and radio access projects of the European Union's 7th Framework Program (FP7) [30] that govern a large part of European research on 5G. New research programs and actions are coordinated by Horizon 2020 [31] and the 5G Infrastructure Public Private Partnership (5GPPP) [32]. Mobile and Wireless

Communications Facility for Twenty-Twenty Information Associations (METIS) is the largest FP7 5G project (29 partners) [33], [14] with the goal of creating a platform of the 5G system and act as a consensus generator towards standardization. METIS has identified test cases and scenarios to illustrate and address the key challenges that 5G will face. The scenarios are listed as follows: 1) "Amazingly fast", 2) "Great service in the crowd", 3) "Best experience according to you", 4) "Finished". super-reliable and real-time connections", and 5) "Things with pervasive communication". The primary purpose is to provide very high data rates with very low latency (instant connections). The second scenario needs to ensure a reasonable user experience in densely populated areas such as shopping centers, stadiums and rock concerts. The third scenario focuses on the user's mobilization ability, such as car communication, again with a high service experience. The fourth scenario shows new use cases / applications with strict reliability and delay requirements. The final script involves managing the effectiveness of a huge number of devices (eg, machines, sensors). metersis also identified horizontal objects contributed (HTS) to integrate technology components to form a global system concept. They are: 1) device-to-device direct communication (D2D), 2) large machine interface (MMC), 3) mobile network (MN), 4) ultra-dense network (UDN) and 5) Extremely reliable communication (URC). Finally, there is an architectural framework to combine different centralized and decentralized approaches into a consistent concept. According to [34], METIS has selected the technological components “Direct device-to-network controlled device communication with noise suppression” and “New FBMC/OQAM Waveform” for the test bands , as they must have a high-tech impact and relevance for the 5G system concept.

The 5th Generation Non-Orthogonal Waveforms for Asynchronous Signals (5GNOW) project [35], [8] proposes a scalable and efficient air interface that eliminates the strict principles of Orthogonality and synchronization are followed in older generation networks. Globally filtered multichannel carrier (UFMC), filter bank multicarrier (FBMC) and generalized frequency division multiplexing (GFDM) are some examples of promising waveforms that may perform better. Orthogonal frequency division multiplexing (OFDM) in the context of 5G. In addition to the multi-carrier waveform design itself, 5GNOW also addresses aspects such as unified frame structure, filtering, sparse signal processing, robustness, and ultra-low latency transmission.

Project Advanced Multi-Carrier Technology for Adhoc and Professional Mobile Network Based

Communications (EMPhAtiC) project [36] develops a highly efficient and flexible filter bank processing framework and functionality Channel estimation, equalization and synchronization are required therein. Furthermore, the feasibility of multi-carrier schemes based on filter banks in some specific environments (forward, multi-step, cooperative) where synchronization is difficult to maintain, will be evaluated.

Transceiver design [37] of project Energy Efficient Bands Transceiver for Future Networks

(E3NETWORK) aims to achieve high power and spectrum efficiency using digital modulation state-of-the-art multilevel and highly integrated circuits (advanced SiGe technology BiCMOS) in front-end analog RF.

Physical Layer Wireless Security (PHYLAWS)

Project [38] aims to improve wireless interface privacy in wireless networks through physical layer security and secret encryption. Reliable radio waveforms and access protocols are designed and tested in real test Wi-Fi setups and simulated LTE scenarios. Fullduplex Radios for Local Access Project (DUPLO) [39] is based on radio transceiver technology where the same carrier frequency can be used simultaneously for transmission and reception. This new transmission model can significantly increase link capacity and provide new means for flexible spectrum utilization and networking. The CROWD (Connection Management for Energy Optimized Wireless Density Networks) project [40] is aimed at very dense heterogeneous access networks integrated with wireless / wired interconnection capabilities. wire. The goals are to provide power proportional to density when needed, optimize the MAC mechanism for such environments, enable traffic-proportional power consumption, and ensure quality user experience through intelligent connection management designs. Project Dense Collaborative Wireless Cloud Network (DIWINE) [41] uses a "virtual relay-based automated wireless cloud" model, which has a simple and clear interface with terminals, to solve the problem of wireless communication in networks especially with dense interference. Project Connect and Participate in Design of Open Access Network Architecture and Backhaul Network for Small Cells Based on Cloud Networks (iJOIN) [42] will use radio access network (RAN) based concept Open and centralized computing platform with cloud infrastructure. Topology and access are jointly designed and optimized. The TROPIC project (Distributed computing, storage and resource allocation across collaborative femtocells) [43] seeks answers to the following questions: what kind of communication/computing technology is needed for convergence Converging popular femto network infrastructure and computing in the cloud? What spectrum/energy/service efficiency can be achieved through the proposed femtocloud methods? Wireless Technology for Remote Rural Communities in Developing Countries Based on 3G Femtocell Network Mobility Project Deploy (TUCAN3G) [44] Leveraging New Wireless Accessibility (3G → 4G femtocell) and heterogeneous backhaul technologies (Long Distance WiFi, WiMAX, VSAT) in outdoor scenarios to establish an economically viable and economically viable solution for rural environments. Beyond 2020 The Millimeter Wave (MiWaveS) small-scale cellular heterogeneous wireless network with access and reverse processing [45] is an industry-oriented large-scale integration project. It researches and demonstrates the key enabling technologies and features that support the integration of mm wave microcells into future heterogeneous networks. Special project concerns lie at the level of network functions and algorithms as well as integrated antenna and radio technologies. Dynamic Spectrum Advanced 5G Mobile Network Using the Licensed Shared Access (ADEL) Project [46] focuses on investigating the following research issues under the Licensed Shared Access model (LSA): 1) dynamic allocation and optimization of spectrum and power resources at both seconds to millisecond scales, 2) guaranteed quality of service for users of all networks sharing the reference spectrum. and 3) reduce the overall power consumption of the LSA network. Spectrum Over Lay through Unhomogeneous Distributed Bands Set (SOLDER) The main objective of the project [47] is to efficiently synthesize discontinuously distributed spectral bands licensed for heterogeneous networks. (HetNets) and heterogeneous radio access technologies (hRATs) and thus propose a new spectrum overlay technology. Coordination activity of the Cognitive Radio Standardization (CRSi) initiative [48] coordinates and supports current and future FP7 projects. Their Cognitive Radio Access and Dynamic Spectrum Access results are exploited through a centralized approach and prepared for standardization. Project Cognitive Radio for Satellite Communications (CoRaSat) [49] studies dynamic spectrum sharing by researching, developing and demonstrating cognitive radio techniques related to satellite networks. The aim is to demonstrate that the new benefits and business opportunities of using flexible spectrum outweigh their potential disadvantages. The goals of project Self-Management for Unified Heterogeneous Radio Access Networks (SEMAFOUR) [50] are to develop the functions of multiple radio access technology (multiRAT) and self-organizing networks multilayer (SON) (incorporating a closed control loop for configuration, optimization, and troubleshooting) and integrated SOUND management system design.

The TROPIC project (Distributed computing, storage and resource allocation across collaborative femtocells) [43] seeks answers to the following questions: what kind of communication/computing technology is needed to converge Common femtonetwork infrastructure and computing in the cloud? What spectrum/energy/service efficiency can be achieved through the proposed femtocloud methods? Wireless Technology for Remote Rural Communities in Developing Countries Based on 3G Femtocell Network Mobility Project Deploy (TUCAN3G) [44] Leveraging New Wireless Accessibility (3G → 4G femtocell) and heterogeneous backhaul technologies (Long Distance WiFi, WiMAX, VSAT) in outdoor scenarios to establish an economically viable and economically viable solution for rural environments. Beyond 2020 The MillimeterWave (MiWaveS) small-scale cellular heterogeneous wireless network with access and reverse processing [45] is an industry-oriented large-scale integration project. It researches and demonstrates the key enabling technologies and features that support the integration of mmWave microcells into future heterogeneous networks. The project`s interest is particularly at the level of networking functions and algorithms, and integrated radio and antenna technologies. Advanced Dynamic spectrum 5G mobile networks Employing Lisensed shared access (ADEL) project [46] has focus on investigating the following research problems within the lisensed shared access (LSA) paradigm: 1) the dynamic and optimized allocation of spectral and power resources at time scales from seconds to even milliseconds, 2) quality of service guarantees to the users of all participating spectrumsharing networks, and 3) overall energy expenditure minimization of LSA networks. Spectrum OverLay through aggregation of heterogeneous DispERsed bands (SOLDER) project`s [47] main goal is to efficiently aggregate of noncontinuous dispersed spectrum bands licensed to heterogeneous networks (HetNets) and heterogeneous Radio Access Technologies (hRATs) and thereby come up with a new spectrum overlay technology. Cognitive Radio Standardization initiative (CRSi) coordination action [48] coordinates and supports current and future FP7 projects. Their cognitive radio and dynamic spectrum access results are exploited via concentrated approach and prepared toward standardization. Project COgnitive RADio for SAtellite Communications (CoRaSat) [49] studies dynamic spectrum sharing by researching, developing and demonstrating cognitive radio techniques related to satellite networks. The aim is to demonstrate that the new benefits and business opportunities of using flexible spectrum outweigh their potential disadvantages. The goal of the [50] Self-managing Unified Heterogeneous Radio Access Network (SEMAFOUR) project is to develop the functions of multiRAT and self-organizing multilayer networks (SEMAFOUR). SON) (which incorporates a closed control loop for configuration, optimization, and recovery) and to design an integrated SON management system. The Massive MIMO for Efficient Transport (MAMMOET) project [51] aims to take high-volume MIMO from a very promising theoretical concept to a practical level of implementation using software. Innovative hardware, low cost but effective and flexible. The High-Capacity Network Architecture Project with Remote Headset and Parasite Antenna Array (HARP) [52] plans to achieve distributed multi-antenna wireless access by combining Head-to-head technology remote radio (RRH) with electronically adjustable passive network radiator (ESPAR) technology. This will geographically expand fiber optic radio connections over a widely distributed access area via fiber optic radio and provide a single active RF string multi-antenna type functionality. The Mobile Cloud Network (MCN) Project [53] creates resilient cloud-based mobile networks on demand. Of particular interest are advanced package systems and their lifecycle management. Growing Mobile Internet Project with Innovative End-to-End Offload Technology (MOTO) [54] to address 5G challenges by exploiting different sets of offloading plans, for example , from cellular to WiFi, and use D2D connections opportunistically. Offloading of network-controlled IP traffic is also included. European Cooperation in Science and Technology (COST) Action on Collaborative Radio Communication for Smart Green Environment (COST IC1004) [55], as the name suggests, has a scientific focus on High speed, energy efficient and environmentally smart radio communication systems and networks. The Project Networking Excellence in Wireless Communications (NEWCOM #) [56] focuses on long-term, interdisciplinary research. Examples of research objectives explore the ultimate limits of efficient source and spectrum communication, networks and communications, as well as opportunistic and collaborative communications. In addition, NEWCOM # promotes cooperation between academia and industry and trains new researchers, for example by organizing seasonal schools. SOftwareDefined Access using LowEnergy Subproject (SODALES) [57] to develop a new wireless access connectivity service that targets fixed low cost 10 Gbps access and provides systems transmission service for fixed and mobile subscribers. The converged network architecture includes an advanced management and control plane with open access and multicarrier capabilities. Project Linksonthefly Technologies for Powerful, Efficient, and Intelligent Communications in Unpredictable Environments (RESCUE) [58] finds that the heterogeneous and dense networks of the future form a suitable basis for Network concept based on lossy communication links. Transportation and public safety applications are at the heart of RESCUE. Project Aerial Base Stations with Opportunity Links for Unexpected and Temporary Events (ABSOLUTE) [59] focuses on future public safety communication systems. The proposed heterogeneous network architecture is based on the following: 1) Aerial Low Altitude LTEA Base Station (AeNodeB), 2) Land Mobile LTEA Base Station

(TeNodeB), and 3) Equipment enhanced multi-mode LTEA business terminal. The Low EMF Exposure Futures Network (LEXNET) project [60], [61] has the very specific objective of developing effective mechanisms to reduce by at least 50% public exposure to electromagnetic fields (EMFs) without affecting service quality.

A REVIEW ON 5G

A large number of publications related to 5G and many more will come out every month. Therefore, the literature selected in this section is limited to very recent well-known journal articles and selected white papers. Specifically, the IEEE Communications Journal published a two-part topic on 5G in February and May 2014, and the articles therein are briefly summarized here. A. IEEE Communications Magazine Feb. The 2014 5G Section Paper [4] challenges us to rethink the relationship between energy and spectral efficiency (EE vs. SE). The encrypted design of these should be an important part of 5G research. The ideal future system should have an improvement in EE for each SE point, a larger and smaller EESE trade-off area, and a smaller slope in the EESE trade-off region. More Cells is another statement that 5G is moving from a cell-centric mindset to flexible designs that are user-centric and GRAN. The third point is to review signaling and control mechanisms for different types of traffic. The fourth aspect [4] introduces the concept of invisible base stations. It consists of massive implementations of MIMO in the form of irregular antenna arrays, where antenna elements can be embedded in the medium (thus making base stations virtually invisible). Finally, duplex radio is proposed as a useful technology component for 5G. As in the previous article, Boccardi et al. in [5], lists five groundbreaking views on 5G. Conventional cellular architectures based on base stations (uplink/downlink, control/data channel) should give way to more flexible device-centric architectures where the multiplicity nature traffic patterns and network nodes can be better managed. Large additional bandwidths are available in millimeter waveforms and should be used. Massive MIMO has potential for 5G as it is a technology that is scalable at the node level and enables new implementations and architectures. Devices are getting smarter and this will be reflected both at the node level and at the higher architectural level. For example, D2D connectivity and mobile device caching have implications for 5G system design. An integral part of 5G must also be native support for machine-to-machine (M2M) communication, where the number of connected devices can be very large and require high reliability and low latency. Network density is the main area of interest of [6]. The two dimensions of this trend are space and frequency. The spatial domain is mainly covered by a dense deployment of small cells, while the frequency domain density consists of larger sets of radio spectrum fragments from different bands for efficient use. In parallel, high-capacity and low-latency links should be developed to ensure improved user experience. Reference [7] makes the following key observations: 1) capacity growth of the macrocell is likely to reach its limit, 2) cellular performance metrics need to be updated, and 3) diversity The variety of radio access technologies and devices increases. The 5G era requires co-optimization of networks, devices, and applications to achieve the necessary improvements in service efficiency and performance. Project 5GNOW's vision for 5G waveform design is reflected in [8]. The idea is to relax the design uniformity and orthogonality requirements and allow the amount of waveform crosstalk to be controllable. The generated multicarrier waveforms have a competitive advantage over the well-established OFDM technology. The lower end of the frequency spectrum has been largely devoted to various legacy systems. Therefore, contiguous large bandwidths are only available at high center frequencies, e.g. millimeter waves. Reference [9] discusses the millimeter wave beamforming and its feasibility as a candidate technology for 5G. In addition to the theoretical views, the state of prototyping is revisited so that the practical aspects of millimeter wave communication are also addressed. Full Duplex (FD) technology is a potential building block to consider for 5G. The article [10] focuses on this technology and in particular the self-interference minimization that must be effective in FD systems to make them practical. References [11] distinguishes outdoor and indoor scenarios in the design of 5G cellular architecture to avoid high through-wall losses. Distributed Antenna System & # 40; DAS & # 41; and massive MIMO technologies contribute to this. Indoor coverage can be provided through short-range wireless technologies such as Wi-Fi, femtocells, visible light communication (VLC), and millimeter wave, while outdoor users are served by a heterogeneous architecture consisting of large MIMO networks, mobile femtocells, and cognitive radio networks. Caching popular content in intermediate servers reduces redundant traffic in the core network and thus reduces network congestion problems. Current and foreseeable caching techniques for 5G are discussed in [12]. Fettweis and Alamouti [13] acknowledge that mobile telephony has a huge impact first on voice services and then on data transmission. However, when it comes to the Internet, 5G technology still has a lot to be exploited. Thus, a future user-centric touchscreen Internet will utilize technological advances in content delivery, control (response time) and monitoring (durability). B. IEEE Communications Review May 2014 5G Section The second 5G topic opened by the METIS project vision of the methodology, requirements and scenarios for wireless access networks strings in the future [14]. METIS scenarios and horizontal engines have been described in part II.

The next paper [15] proposes a change in development paths towards 5G. Previous generations were dominated by macrocell development, but coordinated macro/local symbiosis will be a more efficient direction in the future. Improving the spectral efficiency and coverage of cell edge users are the main goals of [16]. As a tool to achieve the goal, there is a smart combination of small cell deployment, Joint Transmission Coordination Multipoint (JT CoMP) and large MIMO techniques with reasonable complexity. Advanced interference management is considered one of [17] as an important early technology driver towards 5G. This article studies the common interference detection/decoding in user equipment and general programming as a network side interference management scheme. Paper [18] promotes cell density through the intense deployment of small cells. Scenarios divided into residential, enterprise, and hotspot deployments have their own service requirements. Synchronization, graph-based carrier selection, and inter-cell power control are also important aspects of cooperative optimization of distributed small cells. Cloud technology is rapidly emerging in modern internet usage and will certainly play some role in the 5G radio access network. Reference [19] presents the concept of Radio Access Network (RAN) as a service (RANaaS) as a flexible centralized processing platform for 5G. Public-private spectrum sharing is seen as a practical way to deliver the high quality of experience (QoE) required by 5G.[20] The different types of D2D communication and their specific challenges are discussed in [21]. The communication modes are divided into device and operator control programs. In addition to technical performance, pricing of D2D services is assessed. The final paper in this series [22] focuses on designing a framework for collaborative green heterogeneous networks that achieve a balance between spectrum and energy efficiency and quality of service. C. White Paper on 5G 4G Americas recently released a 44-page summary of global 5G initiatives [23] assessing 5G activity in the region in Europe, Asia and Asia America. In addition to research projects, 5G-related activities in standards organizations (e.g. 3GPP, ITU, IEEE), associations (e.g. TIA), alliances (e.g. NGMN and WWRF) and l industries are listed. Nokia Network and Solutions White Paper [24] agrees that 5G is unlikely to be just a new radio access technology (RAT), but rather a combination of existing air interface technologies in both countries. licensed and unlicensed bands with several new technologies optimized for use cases and scenarios (e.g. ultra-dense deployments). In addition, more spectrum base stations and small cells (network density) and improved network performance (e.g. zero virtual latency) are needed to make 5G a reality.

Huawei defines the so-called "5G HyperService Cube" [25] to show the difference between Ser in 3D representation. Figure 1. Development of service types in the mobile phone generation. Vise fits inside. The dimensions of the cube are 1) throughput (kbps / km2), 2) delay (ms), and 3) number of connections (per km2). For example, multi-user ultra-high-definition telepresence and intelligent sensors are in the opposite corner of the cube. The former requires very high throughput, a small number of connections and low latency, and the latter service allows for high latency with low throughput. Yes, but it requires a lot of links. The main design goals of 5G are 1) high capacity and connectivity, 2) support for very different services, applications, users and requirements, 3) efficient and flexible of all available discontinuous frequency resources. Use. Ericsson [26] considers the following characteristics to be an integral part of 5G: Very high ubiquitous mobile broadband service level, ultra-high traffic capacity and data rate, communication devices like numerous low power machines, proximal communication, ultra-reliable communication, energy efficiency and sustainability, and new frequency allocation. Datang Whitepaper [27] sees evolution, convergence and innovation as the technological route to 5G. coward. Figure 1 shows how the services supported are evolving from 1G voice to 3G multimedia to the diversity of 5G networks. The ZTE [28] sees user experience as the focus of 5G research, rather than simply increasing network capacity. From a technical point of view, the main challenges are 1) heavy traffic, 2) gradual migration to intelligent cloud architectures, 3) full integration of networks and services, 4) more configurable networks. It is a transition to a new function. NTT DOCOMO [29] emphasizes the importance of effectively integrating low and high frequency bands to achieve the intended 5G system capacity (1000x) and standard data rate (100x). increase. This can be supported by the phantom cell concept (the control plane and the user plane are separated) and flexible duplication. High frequencies require new numerology and waveform design, and low frequencies can use non-orthogonal multiple access (NOMA**).**

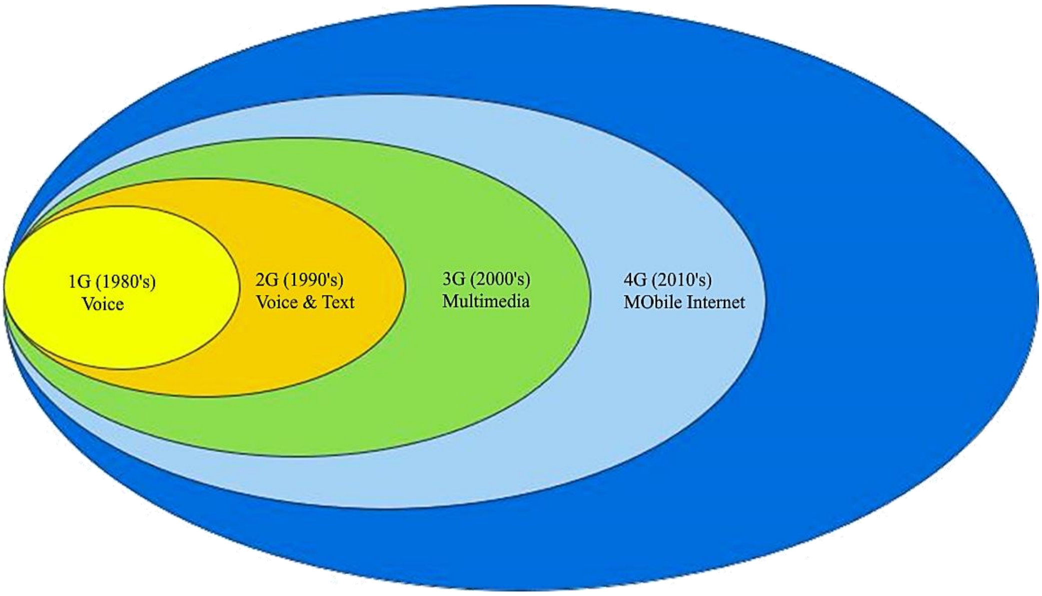

Figure 1. Development of service types over wireless mobile generations.

CONCLUSION

This paper outlines various 5G activities around the world, especially in Europe. Particular attention will be paid to key literature, projects, and programs focused on 5G technology. The concept of 5G is still under development, but testing has revealed new commonalities. Performance improvements are primarily network densification (eg Small Cell, D2D), extended spectrum (enhanced carrier aggregation, spectrum sharing, frequencies above 6 GHz), and enhanced wireless communication technology (eg: 6 GHz and above). Massive MIMO, new waveform, virtual zero latency RAT). Machine communication increases the percentage of network connections and data traffic. The combination of mobile networks and highly reliable communications requires truly innovative solutions due to the stringent technical requirements under difficult propagation conditions. Network virtualization, especially in the form of cloud RAN development, also plays an important role in 5G. Overall, use cases, scenarios, and frequency allocations have a very high level of volatility, so integrating the concepts of the entire 5G system requires maximum agility, scalability, and reconfiguration**.**

REFERENCES

1. 5G wikipedia page. [Online]. Available: http://en.wikipedia.org/wiki/5G
2. J. G. Andrews, S. Buzzi, W. Choi, S. V. Hanly, A. Lozano, A. C. K. Soong, and J. C. Zhang, “What will 5G be?” IEEE J. Sel. Areas Commun., vol. 32, pp. 1065–1082, Jun. 2014.
3. P. Popovski, V. Braun, H.-P. Mayer, et al. “ICT-317669-METIS/D1.1 V1 Scenarios, requirements

and KPIs for 5G mobile and wireless system," Tech. Rep., May 2013. [Online]. Available: https://www.metis2020.com/wp-content/uploads/deliverables/ METIS D1.1 v1.pdf.
4. C.-L. I, C. Rowell, S. Han, Z. Xu, G. Li, and Z. Pan, "Toward green and soft: a 5G perspective," IEEE Commun. Mag., vol. 52, pp. 66–73, Feb. 2014.
5. F. Boccardi, R. W. Heath Jr., A. Lozano, T. L. Marzetta, and P. Popovski, "Five disruptive technology directions for 5G," IEEE Commun. Mag., vol. 52, pp. 74–80, Feb. 2014.
6. N. Bhushan, J. Li, D. Malladi, R. Gilmore, D. Brenner, A. Damnjanovic, T. Sukhavasi, C. Patel, and S. Geirhofer, "Network densification: the dominant theme for wireless evolution into 5G," IEEE Commun. Mag., vol. 52, pp. 82–89, Feb. 2014.
7. B. Bangerter, S. Talwar, R. Arefi, and K. Stewart, "Networks and devices for the 5G era," IEEE Commun. Mag., vol. 52, pp. 90–96, Feb. 2014.
8. G. Wunder, P. Jung, M. Kasparick, T. Wild, Y. Chen, S. ten Brink,Gaspar, N. Michailow, A. Festag, L. Mendes, N. Cassiau, D. Kt´enas, M. Dryjanski, S. Pietrzyk, B. Eged, P. Vago, and F. Wiedmann, "5GNOW: non-orthogonal, asynchronous waveforms for future mobile applications," IEEE Commun. Mag., vol. 52, pp. 97–105, Feb. 2014.
9. W. Roh, J.-Y. Seol, J. Park, B. Lee, J. Lee, Y. Kim, J. Cho, K. Cheun, and F. Aryanfar, "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results," IEEE Commun. Mag., vol. 52, pp. 106–113, Feb. 2014.
10. S. Hong, J. Brand, J. I. Choi, M. Jain, J. Mehlman, S. Katti, and P. Levis, "Applications of self-interference cancellation in 5G and beyond," IEEE Commun. Mag., vol. 52, pp. 114–121, Feb. 2014.
11. C.-X. Wang, F. Haider, X. Gao, X.-H. You, Y. Yang, D. Yuan, H. M. Aggoune, H. H. S. Fletcher, and E. Hepsaydir, "Cellular architecture and key technologies for 5G wireless communication networks," IEEE Commun. Mag., vol. 52, pp. 122–130, Feb. 2014.
12. X. Wang, M. Chen, T. Taleb, A. Ksentini, and V. C. M. Leung, "Cache in the air: exploiting content caching and delivery techniques for 5G systems," IEEE Commun. Mag., vol. 52, pp. 131–139, Feb. 2014.
13. G. Fettweiss and S. Alamouti, "5G: personal mobile internet beyond what cellular did to telephony," IEEE Commun. Mag., vol. 52, pp. 140– 145, Feb. 2014.
14. A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. A. Uusitalo, B. Timus, and M. Fallgren, "Scenarios for 5G mobile and wireless communications: the vision of the METIS project," IEEE Commun. Mag., vol. 52, pp. 26–35, May 2014.
15. S. Chen and J. Zhao, "The requirements, challenges, and technologies for 5G of terrestrial mobile telecommunication," IEEE Commun. Mag., vol. 52, pp. 36–43, May 2014.
16. V. Jungnickel, K. Manolakis, W. Zirwas, B. Panzner, V. Braun, M. Los-sow, M. Sternad, R. Apelfrojd,¨ and T. Svensson, "The role of small cells, coordinated multipoint, and massive MIMO in 5G," IEEE Commun. Mag., vol. 52, pp. 44–51, May 2014.
17. W. Nam, D. Bai, J. Lee, and I. Kang, "Advanced interference man-agement for 5G cellular networks," IEEE Commun. Mag., vol. 52, pp. 52–60, May 2014.
18. J. Xu, J. Wang, Y. Zhu, Y. Yang, X. Zheng, S. Wang, L. Liu, K. Horne-man, and Y. Teng, "Cooperative distributed optimization for the hyper-dense small cell deployment," IEEE Commun. Mag., vol. 52, pp. 61–67, May 2014.
19. P. Rost, C. J. Bernandos, A. De Domenico, M. Di Girolamo, M. Lalam, Maeder, D. Sabella, and D. W ubben,¨ "Cloud technologies for flexible 5G radio access networks," IEEE Commun. Mag., vol. 52, pp. 68–76, May 2014.
20. J. Mitola III, J. Guerci, J. Reed, Y.-D. Yao, Y. Chen, T. C. Clancy,Dwyer, H. Li, H. Man, R. McGwier, and Y. Guo, "Accelerating 5G QoE via public-private spectrum sharing," IEEE Commun. Mag., vol. 52, pp. 77–85, May 2014.
21. M. Nader Tehrani, M. Uysal, and H. Yanikomeroglu, "Device-to-device communication in 5G cellular networks: challenges, solutions, and future directions," IEEE Commun. Mag., vol. 52, pp. 86–92, May 2014.

22. R. Q. Hu and Y. Qian, "An energy efficient spectrum efficient wireless heterogeneous network framework for 5G systems," IEEE Commun. Mag., vol. 52, pp. 94–101, May 2014.
23. "4G Americas' summary of global 5G initiatives," White Paper, 4G Americas, Jun. 2014. [Online]. Available: http://www.4gamericas.org/documents/2014 4GA Summary of Global 5G Initiatives Final.pdf
24. "Looking ahead to 5G – building a virtual zero latency gigabit experience," White Paper, Nokia Solutions and Networks, Dec. 2013. [Online]. Available: http://nsn.com/sites/default/files/document/nsn 5g white paper.pdf
25. "5G: a technology vision," White Paper, Huawei, Nov. 2013. [Online]. Available: http://www.huawei.com/5gwhitepaper
26. "5G radio access," White Paper, Ericsson, Jun. 2013. [Online]. Available: http://www.ericsson.com/res/docs/whitepapers/wp-5g.pdf
27. "Evolution, converge, and innovation – 5G white paper," White Paper, Datang Wireless Mobile Innovation Center, Dec. 2013. [Online]. Available: http://www.datanggroup.cn/upload/accessory/201312/2013129194455265372.pdf
28. "5G – driving the convergence of the physical and digital worlds," White Paper, ZTE, Feb. 2014. [Online]. Available: http://wwwen.zte.com.cn/en/products/bearer/201402/P020140221402214153295713 22.pdf
29. "5G radio access: requirements, concepts and technologies," White Paper, NTT DOCOMO, Inc., Jul. 2014. [Online]. Available: https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/whitepaper 5g/DOCOMO 5G White Paper.pdf
30. "5G radio network architecture," White Paper, Radio Access and Spectrum FP7 - Future Networks Cluster, Feb. 2014. [Online]. Available: http://www.ict-ras.eu/
31. Horizon 2020 – The EU Framework Programme for Research and Innovation. [Online]. Available: http://ec.europa.eu/programmes/ horizon2020/
32. The 5G Infrastructure Public Private Partnership. [Online]. Available: http://5g-ppp.eu/
33. FP7 Integrating Project METIS (ICT 317669). [Online]. Available: https://www.metis2020.com/
34. P. Popovski, V. Braun, G. Mange, P. Fertl, D. Gozalves-Serrano, N. Bauer, H. Droste, A. Roos, G. Zimmermann, M. Fallgren, A. H oglung,¨ H. Tullberg, S. Jeux, O. Bulacki, J. Eichinger, Z. Li, P. Marsch, K. Pawlak, M. Boldi, and J. F. Monserrat, "ICT-317669-METIS/D6.2 V1 Initial report on horizontal topics, first results and 5G system concept," Tech. Rep., Apr. 2014. [Online]. Available: https://www.metis2020.com/wp-content/uploads/deliverables/ METIS D6.2 v1.pdf
35. FP7 STReP project 5GNOW (ICT 318555). [Online]. Available: http://www.5gnow.eu/
36. FP7 STReP project EMPhAtiC (ICT 318362). [Online]. Available: http://www.ict-emphatic.eu/
37. FP7 STReP project E3NETWORK (ICT 317957). [Online]. Available: http://www.ict-e3network.eu/
38. FP7 STReP project PHYLAWS (ICT 317562). [Online]. Available: http://www.phylaws-ict.org/
39. FP7 STReP project DUPLO (ICT 316369). [Online]. Available: http://www.fp7-duplo.eu/
40. FP7 STReP project CROWD (ICT 318115). [Online]. Available: http://www.ict-crowd.eu/
41. FP7 STReP project DIWINE (ICT 318177). [Online]. Available: http://diwine-project.eu/
42. FP7 STReP project iJOIN (ICT 317941). [Online]. Available: http://www.ict-ijoin.eu/
43. FP7 STReP project TROPIC (ICT 318784). [Online]. Available: http://www.ict-tropic.eu/
44. FP7 STReP project TUCAN3G (ICT 601102). [Online]. Available: http://www.ict-tucan3g.eu/
45. FP7 Integrating Project MiWaveS (ICT 619563). [Online]. Available: http://www.miwaves.eu/
46. FP7 STReP project ADEL (ICT 619647). [Online]. Available: http://www.fp7-adel.eu/
47. FP7 STReP project SOLDER (ICT 619687). [Online]. Available: http://ict-solder.eu/
48. FP7 Coordination Action CRS-i (ICT 318563). [Online]. Available: http://www.ict-crsi.eu/
49. FP7 STReP project CoRaSat (ICT 316779). [Online]. Available: http://www.ict-corasat.eu/
50. FP7 STReP project SEMAFOUR (ICT 316384). [Online]. Available: http://fp7-semafour.eu/
51. FP7 STReP project MAMMOET (ICT 619086). [Online]. Available: http://www.mammoet-project.eu/
52. FP7 STReP project HARP (ICT 318489). [Online]. Available: http://www.fp7-harp.eu/

53. FP7 Integrating Project MCN (ICT 318109). [Online]. Available: http://www.mobile-cloud-networking.eu/
54. FP7 STReP project MOTO (ICT 317959). [Online]. Available: http://www.fp7-moto.eu/
55. COST Action IC1004. [Online]. Available: http://www.ic1004.org/
56. FP7 NoE project NEWCOM# (ICT 318306). [Online]. Available: http://www.newcom-project.eu/
57. FP7 STReP project SODALES (ICT 318600). [Online]. Available: http://www.fp7-sodales.eu/
58. FP7 STReP project RESCUE (ICT 619555). [Online]. Available: http://www.ict-rescue.eu/
59. FP7 Integrating Project ABSOLUTE (ICT 318632). [Online]. Available: http://www.absolute-project.eu/
60. FP7 Integrating Project LEXNET (ICT 318273). [Online]. Available: http://www.lexnet-project.eu/
61. M. Tesanovic, E. Conil, A. De Domenico, R. Aguero,¨ F. Freudenstein, L. M. Correia, S. Bories, L. Martens, P. M. Wiedemann, and J. Wiart, “The LEXNET project: wireless networks and EMF: paving the way for low-EMF networks of the future,” IEEE Veh. Technol. Mag., vol. 9, pp. 20–28, Jun. 2014.

