

A Perceptual Viewpoint on the Issues of 5G Mobile Radio Systems

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ABSTRACT

The issues addressing in 5G (fifth generation) wireless communication systems are reviewed in this article. The standard 5G radio network protocols are not yet definitely defined. A huge number of studies with research reports have been published on the subject of 5G systems. According to the basic viewpoint of radio systems, the adopted radio MMW (millimeter wave), the MIMO (multiple-input multiple-output) beam forming transmission technique, and the green communication cognitive radio signalling concept are becoming very hot research topics. This report is based on reviewing the new events for 5G wireless communications, and aiming at deploying 5G issues for audiences to follow up and peak their interest.

Keywords: 5G wireless communication, MIMO, MMW, beam forming transmission.

對於 5G 行動無線通訊系統之議題的認知觀點

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摘 要

本文著重於第五代(fifth generation, 5G)無線通訊系統議題的認知式回顧。雖然，5G通訊網路的所有標準協定尚未塵埃落定，其相關之研究成果已有十分大量地研究報告出爐。根據無線通訊系統的基本觀點，採取之無線毫米波(millimeter wave, MMW)，多輸入多輸出(multiple-input multiple-output, MIMO)波束成型(beam forming)傳輸技術，以及綠能通訊觀念，及至感知無線電(cognitive radio)訊號的應用等等，全部相關於5G之探討，正逐漸地變成非常熱門的研究議題。基於5G無線通訊之新事件的回顧，作者於文中聚焦於探討提出一些5G系統的熱門研究議題，作為提供給予此一研究領域之讀者在部署相關研究議題時可以遵循，而且是足以引起共鳴的一些5G研究議題之上。

關鍵詞：5G無線通訊，MIMO，MMW，波束傳輸

I. INTRODUCTION

The progress in different mobile wireless radio system generations has greatly increased the speed of technological and social change. 4G wireless communications are quickly followed by the development of 5G wireless networks. This work is based on the relevant published research articles on 5G research issues. A number of papers have addressed 5G wireless communications issues. In [1] Gohil *et al.* reported on existing research work in mobile communications related to 5G technology. They reminded readers that researches in 5G are related to the development of WWW (worldwide wireless web), DAWN (dynamic Ad-hoc wireless networks) and real wireless communication. The most important technologies for 5G are 802.11 WLAN (wireless local area networks) and 802.16 WMAN (wireless metropolitan area networks), Ad-hoc WPAN (wireless personal area network). 5G technology is designed to make use of mobile phones within a very high bandwidth. The consumer has yet to experience technology as valued as 5G. The 5G technologies include all types of advanced features that will make 5G technology the most dominant technology in the near future [1]. Lawson discussed the next generation wireless communications in [2], hinting that there are four categories of next generation wireless technologies, typically implemented via chipsets, radio transceivers and antennas. GSM-based wireless services include 2.5G general packet radio service; 2.5G enhanced data GSM environment (EDGE); 3G wideband CDMA (WCDMA), used in the UMTS (Universal Mobile Telecommunications System); and 3.5G High-Speed Downlink Packet Access. The technologies mentioned above are all currently in use except HSDPA, which is in trials. Analyst Will Strauss said that with forward concepts, they are forecasting that traditional GSM sales will be down by 20 percent in units and that UMTS- and EDGE-based technologies will be sharply up. "WCDMA, currently deployed in

Europe and Japan, uses a 5-MHz-wide channel, which is big enough to enable data rates up to 2 Mbps downstream. The technology also increases GSM's data rates using higher-capacity CDMA, instead of GSM's usual TDMA, modulation techniques. However, WCDMA uses different protocols than CDMA and is thus incompatible with it. Zheng Wei-Bo, *et al.*, in [3] combined 5G-next generation mobile multimedia internet and e-business models to propose a new business model for mobile business that bring people a new lifestyle future. The objective is three-fold. The first is to propose a theoretical mobile business model framework for doing business in the future wireless mobile multimedia Internet era. The second is to propose a classification scheme for the mobile business model. The final objective is to define critical success factors and a platform for the future factual management questions. The future generations of mobile wireless communication networks including 4th, 5th, 6th and 7th generations are predicted in [4] by the Xichun Li, *et al.*, The main objective of this paper [4] is to propose a technical framework for the future 5G industry. The focus is on the specifications for future generations wireless mobile communication networks. Robert Gilmore, who is faculty with Vice President, Engineering QUALCOMM Inc., in a Plenary Speaker announces that towards the 5G Smartphone, the specifications will be with greater system capacity, more bands, faster data rates, advanced applications and longer battery life [5]. Chris Edwards, in [6] describes that the increasing data-communications density will mean finding a new spectrum and being as smart as possible about using existing frequency bands. The mobile industry and its confederates have already started down that road with 4G, by introducing small-cell base-stations or femtocells that work alongside 'macro cells', to cover much wider areas. These very short-range base-stations are designed to be packed into city streets in dense meshes, possibly hanging from street lamps or even deployed in

users' homes where they double up as Wi-Fi access points. As wavelength is inversely proportional to frequency, higher frequencies will make it easier to pack more antennas into the handset. Although designers are struggling to squeeze multiple antennas for sub-2GHz bands into extant designs because of the need to use structures appropriate for them, the wavelengths above 20GHz are at least ten times smaller. So-called 'massive MIMO' antennas, such as the 64-element structure used by Samsung in its 1Gbit/s transmission over 2km at 28GHz experiment, have become realistic. As higher frequencies are introduced for small cells, the industry will have the opportunity to reallocate spectrum to make the best use of existing bands. In general, the lower the frequency, the further it tends to propagate. In order to review the key 5G mobile communication technologies, Cantika Felita *et al.*, in [7] present a framework answering the main question: Which technological area may contribute to the innovation?

The answer for last question can be concluded that innovation opportunities lie in the research regarding to security, network, technological implementation and applications that benefit countries, firms, universities and research institutes intend to contribute to the formulation of the official 5G standard. Federico Boccardi *et al.*, described five technologies in [8], where the issues could lead to both architectural and component disruptive design changes: device-centric architectures, MMW, M- MIMO, smarter devices, and native support for machine-to-machine communications. The key ideas for each technology are described, along with their potential impact on 5G and the research challenges that remain. Naga Bhushan, in [9] explores network densification as the key mechanism for wireless evolution over the next decade. Network densification includes densification over space (*e.g.* dense deployment of small cells) and frequency (utilizing larger portions of the radio spectrum in diverse bands). Large-scale cost-effective spatial densification is facilitated by self-organizing networks and intercell interference management. The authors claim that the full benefits of network

densification can be realized only if it is complemented by backhaul densification and advanced receivers capable of interference cancellation. In [10] Gerhard Fettweis and TU Dresden Siavash Alamouti definitely hinted that the cellular technology has dramatically changed our society and the way we communicate. First, it impacted voice telephony, and has been making consistent inroads into data access applications and services. However, today the potential capabilities of the Internet have not yet been fully exploited by cellular systems. With the advent of 5G we will have the opportunity to leapfrog beyond current Internet capabilities. The aforementioned work reports have roughly presented the perspective and the issues for addressing the 5G research direction. However, there are still a huge range of issues not illustrated here.

In this review paper we try to show some important issues in 5G radio communications for follow up to address in future research. The organization of this paper is therefore as follows: work reports from the view point of 5G system configuration are discussed in section II [11]-[15]. In section III the MMB (millimetre band) techniques are illustrated in advanced [16]-[22]. The issues in system parameters for establishing the 5G are described in section IV [23]-[27]. One of the important issues in wireless communications is the so-called "full channel" presented in section V [28]-[38]. The conclusion section is drawn in section VI.

II. 5G SYSTEM CONFIGURATION

It is known that infrastructure is assigned with 5 layers for the 5G wireless systems. For example, the Physical and Medium Access Control layers *i.e.*, OSI layer 1 and OSI layer 2, are combined together to define the wireless technology as shown in Table I. For these two layers the 5G mobile networks are likely to be based on Open Wireless Architecture [11]. In [12], proposed a multi-network data path for 5G real wireless multimedia world. In order to design this

Multi-network data path, they proposed a new data model shown in Figure 1. This model is based on any two networks overlaying an area. When a mobile node comes into the overlay area, both of the two networks can supply services for the mobile node simultaneously. In this model, the MN (mobile node) request can go through the first connection (MN $\rightarrow$ BS $\rightarrow$ PDSN $\rightarrow$ CN) and the resulting reply can come from the second connection (CN $\rightarrow$ PDSN $\rightarrow$ AP $\rightarrow$ MN), where PDSN is packet data service node (PDSN). In Figure 2, the bandwidth management function is to install and delete bandwidth monitor components dynamically, when it receives indication messages from the mobile IPv6 protocol. The bandwidth management is located at both ends of the sender and the receiver. On each path, there is one bandwidth monitor installed. The bandwidth monitor function is to monitor the available bandwidth and calculate the proper transmission rates on the corresponding path. The current existing path is informed by the bandwidth management after installing/deleting each bandwidth monitor. The bandwidth monitor will provide the rates information when it receives the current existing path information from bandwidth management. The bandwidth selection function is to calculate and report encoding rates to the encoder, and then IPv6 applications will be encoded to the appropriate paths. The packet receiver accepts incoming packets from the bandwidth monitor, filters and reorders before sending them to the decoder. Milosavljevic *et al.*, hoped to increase the SINR (signal-to-interference ratio), and enable future networks to meet MCC (multi-carrier-CDMA) demands. They proposed self-organized cooperative 5G RANs (radio access networks) with intelligent elastic optical backhauls and the overall 5G network structure, which are shown in Figures 3 and 4, respectively. Effective joint optical and radio resource management is implemented to satisfy the stringent delay requirements of emerging MCC applications and increase the overall cell throughput. In addition, cellular network

spatiotemporal data are observed, analysed, and stored constantly during network operations [13]. Shown with the measurement data, Yaniv Azar *et al.*, in [14] claimed that they presented the world's first empirical measurements for 28 GHz outdoor cellular propagation in New York City. Measurements were made in Manhattan for three different base station locations and 75 receiver locations over distances up to 500 meters. A 400 mega chip-per-second channel sounder and directional horn antennas were used to measure propagation characteristics for future MMW cellular systems in urban environments. This paper presents measured path loss as a function of the transmitter - receiver separation distance, the angular distribution of received power using directional 24.5 dBi antennas, and power delay profiles observed in New York City. The measured data show that a large number of resolvable multipath components exist in both non line of sight and line of sight environments, with observed multipath excess delay spreads (20 dB) as great as 1388.4 ns and 753.5 ns, respectively. The widely diverse spatial channels observed at any particular location suggest that MMW mobile communication systems with electrically steerable antennas could exploit resolvable multipath components to create viable links for cell sizes on order of 200 m. Moreover, Gerhard Wunder *et al.*, in [15] mentioned some challenges in the LTE design paradigms of orthogonality and synchronicity within a single cell and within a single contiguous frequency band. Various emerging trends reveal major shortcomings of those design criteria: (1) Fraction of MTC (machine-type-communications) is growing fast. (2) Collaborative schemes have been introduced to boost capacity and coverage CoMP (coordinated multi-point transmission/reception), and wireless networks are becoming increasingly more heterogeneous following the non-uniform distribution of users. (3) The advent of the Digital Agenda and the introduction of carrier aggregation are forcing transmission systems to deal with fragmented spectrum. The obedience of LTE and

LTE-Advanced to strict synchronism and orthogonality would become a challenged event. It will develop new PHY and MAC layer.

III. THE MMW TECHNIQUES, SMALL CELL CONCEPT AND IoT-BASED 5G SYSTEM

The MMW small cell concept and IoT-based 5G system technologies are addressed in the following subsection. Recent studies suggest that MMW frequencies could be used to augment the currently saturated 700 MHz to 2.6 GHz radio spectrum bands for wireless communications [16]. In [17] for announcing that new MMW cellular systems, methodology, and hardware for measurements and offer a variety of measurement results that show 28 and 38 GHz frequencies can be used when employing steerable directional antennas at base stations and mobile devices. Further, the authors mentioned that MMW carrier frequencies allow for larger bandwidth allocations, which translate directly to higher data transfer rates. MMW spectrum would allow service providers significantly expand the channel bandwidths far beyond the present 20 MHz channels used by 4G customers [18]. By increasing the RF channel bandwidth for mobile radio channels, the data capacity is greatly increasing, while the latency for digital traffic is greatly decreasing, thus supporting much better internet-based access and applications that require minimal latency. MMW frequencies, due to the much smaller wavelength, may exploit polarization and new spatial processing techniques, such as M-MIMO and adaptive beamforming [19]. The advanced measurement results from the report [20] present reflection coefficients and penetration losses for common building materials at 28 GHz for the design and deployment of future MMW mobile communication networks. Reflections from walls and buildings and penetration losses were measured for indoor and outdoor materials, such as tinted glass, clear glass, brick, concrete, and drywall at 28 GHz in New York City. Furthermore,

the report in [21] gives the measurements for outdoor cellular channels at 38 GHz made in an urban environment with a broadband (800-MHz RF passband bandwidth) sliding correlator channel sounder. Extensive AOA (angle of arrival), path loss, and multipath time delay spread measurements were conducted for steerable beam antennas of differing gains and beam widths for a wide variety of transmitter and receiver locations. Coverage outages and the likelihood of outage with steerable antennas were also measured to determine how random receiver locations with differing antenna gains and link budgets could perform in future cellular systems. This paper also provides measurements and models that may be used to design future 5G MMW cellular networks and gives insight into antenna beam steering algorithms for these systems. The same research group demonstrated a spread spectrum sliding correlator channel sounder operating at a centre frequency of 73.5 GHz with an 800 MHz null-to-null bandwidth and showed the data in [22]. Data collected and processed from the measurements shows that strong received power can be achieved from the multipath-rich indoor environment, in the presence of multiple obstructions. The data obtained from this measurement campaign may be utilized for the design of future fifth generation MMW indoor cellular systems. To satisfy the multivendor, virtualized and future-proof HetNet requirements for 5G standards, an up-to-date cloud RAN (radio access network) deployment combined with virtualization based on a CPRI (common public radio interface) defined split between the physical network function representing a remote radio head and the VNF (virtual network function) is illustrated in Figure 5. The key benefits and drivers are 5G configuration centralization and virtualization with small cell RAN functionality implemented in the physical network function component [38].

Reference [39] pointed out that the IoT-based 5G networks will be deployed at microwave frequency ranges where there is a spectrum crunch. Thus, there are recommendations at the physical (PHY) layer, such as, (a). Low-cost energy-efficient transceiver, (b). Non-orthogonal

transmission with hardware imperfections, (c). Compressive signal processing for massive IoT systems, (d). Spectrum management for wireless IoT, (e). Cross layer design for end to end system reliability, (f). Low complexity cooperative techniques.

IV. SYSTEM PARAMETERS FOR ESTABLISHING 5G

It is believed that future generations of access technologies are challenged by QoE (quality-of-experience) for the user and continue to raise traffic in mobile radio networks by 100% per annum, especially during busy hours. Congestion will occur increasingly more often, leading to a much worse QoE for everyone involved. Increasing the supply side using the improved spectral efficiency of 5G radio networks cannot work on its own if demand is increasing faster than supply. Reference [23] provides models for the user behaviour based on survey results. It is the first work to answer questions about what incentive will lead to what user reaction. Thus, the authors quantitatively describe the user block in a system theoretic framework. The results indicate that shaping user behaviour works well and the simulation results analysis prove that significant gains are achievable with UIL (unclamped inductive loading). The discussion in [24] focuses on the issue of cooperating BS selection, given that a set of MTs has been scheduled for transmission. The authors start observing that most of existing approaches have been developed for flat fading channels, or for sets of parallel flat fading channels, *i.e.*, OFDM transmissions. However, 3GPP LTE (long term evolution) standard provides the use of SC-FDMA (single carrier frequency division multiple accesses). With this transmission format a single carrier signal is allocated to a number of subcarriers in the frequency domain using DFT (discrete Fourier transform). Reference [25] discusses how next-generation mobile network capacity, in which

growth could be achieved in a ten-year time frame, could evolve. Techniques that expect to have the highest opportunity for increasing the system capacity and estimate their gains based on analysis and simulation is pointed out. The authors observe that the main driver of capacity growth is expected to come from network architecture advancements, with heterogeneous networks and the convergence of information and communication technology being two of the key techniques. To estimate that the air-interface evolution is also focused on improving the link and system spectrum efficiency but also on facilitating the required network efficiency improvements. Evaluation of the potential impact of SIC to different applications as a function of this vector is held in [26], the beginning discussion is with applications that require no standards modification before studying those that will require 5G standardization. The authors finish on a more general note, discussing SIC applications beyond 5G cellular networks. The conversation frame first discussed the general architecture of an SIC solution, highlighting the drivers of performance and integration, and then begin with applications that can leverage SIC with absolutely no change or modifications in existing standards or infrastructure. Among these applications, we order them beginning with those employed on the infrastructure side before moving on to those that can also be employed on the handset side. Lastly, a conclusion is drawn by discussing the long-term implications of SIC in 5G, the impact of different degrees of regulatory acceptance, and what we believe will be the inflection points driving standards and spectrum policy adoption. Because the demand for rich multimedia services over mobile networks has increased at a tremendous pace over recent years, in [27], the authors first study techniques related to caching in current mobile networks, and discuss potential techniques for caching in 5G mobile networks, including evolved packet core network caching and radio access network caching. A novel edge caching scheme based on the content-centric networking or information-centric

networking concept is proposed. Using trace-driven simulations, we evaluate the performance of the proposed scheme and validate the various advantages of caching content in 5G mobile networks. Furthermore, we conclude the article by exploring new relevant opportunities and challenges. Moreover, there still exist quiet lots of challenges in the way to approach the establishment to system designing and testing for 5G system as shown in Figure 6 [40].

V. 5G CHANNEL MODELS/FULL-DIMENSION MIMO

The high 5G wireless communications potential data rate capacity gain is highly dependent on the multipath richness, because a fully correlated MIMO radio channel only offers one sub channel, while a completely decorrelated radio channel potentially offers multiple sub channels depending on the antenna configuration. A huge number of researches have explored the MIMO issue.

All previously mentioned results were obtained from the azimuth direction propagation channel assumption. However, the MIMO-beam forming signalling evaluation should consider the elevation direction for wave propagation, i.e., the vertical direction must be included in channel model discussions [28]. There is a MIMO channel situation rewritten as follows. For the next generation systems, in order to enable system performance optimization, the technique considers channels between the antenna elements rather than between antenna ports. Investigations applying the use of 3D beamforming usually assume that the antennas are arranged in a 2D array where each column contains M antenna elements. There are exactly K antenna elements per antenna port with pattern A_E given using

$$A_E(\phi_e, \theta) = G_{E,\max} \{ -(A_H(\phi_e) + A_V(\theta)), A_m \}, \quad \text{where} \\ A_m = 30\text{dB}, G_{E,\max} = 8\text{dBi}, \text{ and } A_H(\phi_e) = -\min[12(\phi_e/\phi_{3\text{dB}})^2, A_m], \\ \text{where } \phi_{3\text{dB}} = 65^\circ, \text{ moreover, where } \\ A_V(\theta) = -\min[12(\theta - \theta_{\text{ilt}}/\theta_{3\text{dB}})^2, \text{SLAV}] \quad , \quad \text{in which}$$

SLAV=30 and $\theta_{3\text{dB}} = 65^\circ$ [28]. There are two situations, choosing $K = M$ in which the number of antenna ports per column will be equal to M or setting $K = 1$ considered using the 3GPP group TSG-RANWG1. Each column in the situation will correspond to one port with the same polarization. Therefore, each column would correspond to two ports, (one port per polarization), if cross-polarized elements are used. A weighted sum of channels with the K elements is assigned in the element. The channel with a given antenna port is more formally, the channel between the t -th receiving antenna and the s -th antenna port corresponding to the n th path given by

$$[\bar{H}_n]_{s,t} = \sum_{\text{antenna port } s} \omega_{\text{antenna}} H_n J_{\text{antenna},t} \quad (1)$$

where the sum presented above is performed over all antenna elements in port s .

Consider a MIMO system employing N_T transmitters and N_R receiver antennas equipped with the receiver signal vector $Y_R \in \mathbb{C}^{N_R \times 1}$ and the transmit signal vector $X_T \in \mathbb{C}^{N_T \times 1}$, respectively. Normally, the radio MIMO channel is a $N_T \times N_R$ matrix able to be re-written as

$$H(t, \tau) = \int \bar{g}_r(\Psi)^T h(t, \tau, \Omega, \Psi) \bar{g}_T(\Omega) \times \bar{a}_R(\Psi)(\bar{a}_T(\Omega))^T d\Omega d\Psi \quad (2)$$

where $\bar{g}_r$ and $\bar{g}_T$ are the patterns of the receiving and transmitting antennas, respectively. $\bar{g}_r(\Psi)$ and $\bar{g}_T(\Omega)$ are 2×1 vectors whose entries represent the vertical and horizontal field patterns, when polarization is considered. Vectors $\bar{a}_R(\Psi)$ and $\bar{a}_T(\Omega)$ are the array responses of the transmitting and receiving antennas whose entries are given by $[\bar{a}_R(\Psi)]_i = \exp(j\bar{k}_{R,\Psi} \cdot \bar{x}_{R,i})$, $[\bar{a}_T(\Omega)]_i = \exp(j\bar{k}_{T,\Psi} \cdot \bar{x}_{T,i})$, respectively, and where $\bar{x}_{R,i}$ is the location vector of the i -th receiving antenna whereas $\bar{x}_{T,i}$ is that of the i -th transmitting antenna. The transmitted signal power is constricted as the value equivalent to the number of transmitter antennas.

In the previous work, the authors shed light on the current 3GPP activity around 3D (three dimensions) beamforming and FD-MIMO. They

enabled enhancing the understanding of current industrial challenges as well as indicating the standard vision for 3D beam forming. Initial implementations of the 3D beam forming technology support the potential of this technique for yielding significant gains in real indoor and outdoor deployment [29]. One way to exploit the additional degree of freedom of 3D channels is to adapt for each user the beam pattern in the vertical direction, thereby improving the signal strength at the receiver and at the same time reducing the interference to other users. The authors were encouraged by the preliminary results in [30], and extended the research activity on 3D channel model carried out by both theoretical researchers and industrials [31]. In [32] the authors investigated interference coordination for 3-dimension (3D) antenna array systems in multi-cell MIMO and OFDMA (orthogonal frequency division multiple-access) wireless networks. They took the specification down tilts of the subscriber into consideration for the interference coordination to maximize both the cell-edge users' and cell centre users' throughput. An extension of the ITU2D channel model to 3D is proposed [33] by adding a distance dependent elevation spread based on observations from ray tracing. Through the observation to the system-level simulation results, it concludes that the 3D MIMO behaviour is greatly impacted by the 3D channel model.

The overall development of FD-MIMO (full dimension MIMO) technology in the context of next generation evolution towards B4G and 5G cellular systems is investigated in [34]. FD-MIMO relies on a large number of antennas placed in a 2-dimensional antenna array panel at base stations (BSs). Utilizing the 2-dimensional antenna array, FD-MIMO simultaneously transmits to a large number of mobile stations (MSs) effectively realizing high order multi-user MIMO (MU-MIMO) well beyond what is possible today. This paper discusses the research and standardization effort in 3GPP to incorporate the features and performance benefits of FD-MIMO in the next evolution of LTE standards. In [35], authors

present reflection coefficients and penetration losses for common building materials at 28 GHz for the design and deployment of future MMW mobile communication networks. Reflections from walls and buildings and penetration losses were measured for indoor and outdoor materials, such as tinted glass, clear glass, brick, concrete, and drywall at 28 GHz in New York City. A 400 Mega-chip-per second sliding correlate channel sounder and 24.5 dBi steerable horn antennas were used to emulate future mobile devices with adaptive antennas that will likely be used in future MMW cellular systems [1]. Measurements in and around buildings show that outdoor building materials are excellent reflectors with the largest measured reflection coefficient of 0.896 for tinted glass as compared to indoor building materials that are less reflective. The focus of [36] is to present the basic 5G mobile communication system concept involving Nano antennas in brief and detailed discussions of THz band Nano antennas. It covers the basic concept, analysis, design considerations and effect of various parameters on the antenna performance. It also discusses the formation of SPs (Surface Plasmons) at the interface of metal-dielectrics and the existence of SPP (Surface Plasmon Polariton) resonances. Some fundamental indications about wireless communications beyond LTE/LTE-A (5G), representing the key findings of the European research project 5GNOW is proposed in [37]. It identifies the drivers for making the transition to 5G networks. Just to name one, the advent of the IoT (Internet of Things) and its integration with conventional human-initiated transmissions creates a need for a fundamental system redesign. The paper makes clear the strict paradigm of synchronism and orthogonality as applied in LTE prevents efficiency and scalability. Finally, the report challenges this paradigm and proposes new key PHY layer technology components such as a unified frame structure, multicarrier waveform design including a filtering functionality, sparse signal processing.

VI. CONCLUSION

An academic viewpoint of 5G wireless communication systems is discussed in this report. There are a huge number of studies with research reports of the issue addressing in 5G wireless systems. However, on standard protocols of 5G radio network is still not definitely defined. From the basic 5G system referred to as 4G+MMW the adopted radio MMW, the MIMO beam forming transmission techniques, and the green communication concept, even the cognitive radio signalling, etc. It is known that there are issues about 5G that will be controversial and intense topics. Based on reviewing the new events for 5G wireless communications, the authors in this report focus on deploying issues for audiences to follow and focus their attention.

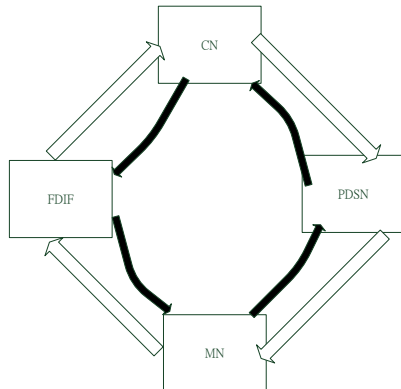


FIG. 1 MULTI-NETWORK DATA PATH MODEL DESIGN

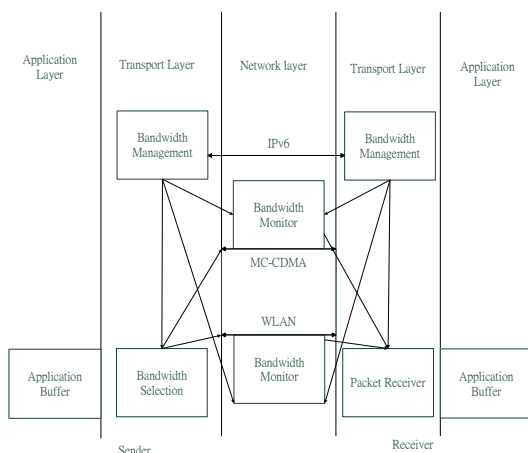


Fig. 2 Overall layers of the 5G network [13]

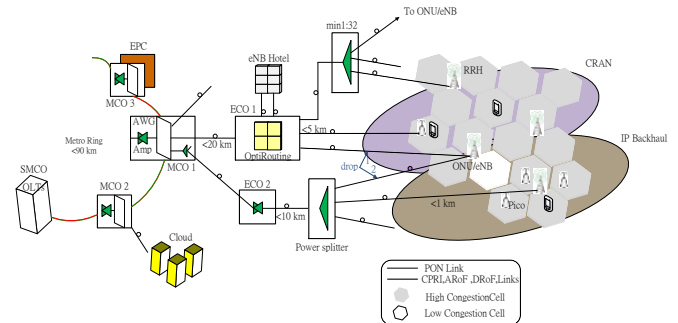


Fig. 3 Overall structure of the 5G network [13]

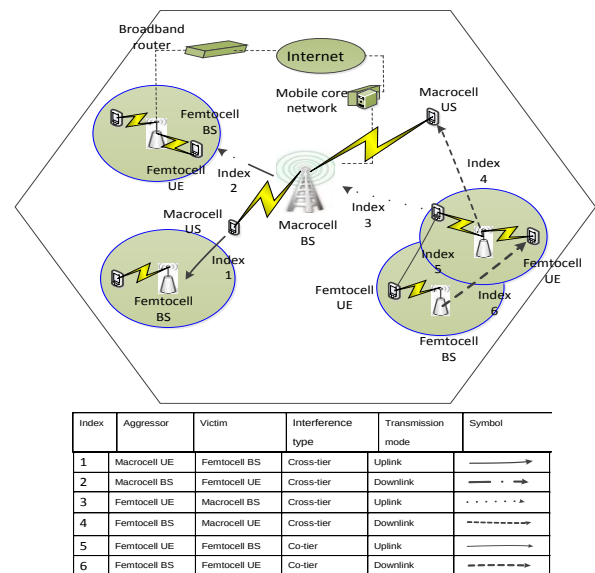


Fig. 4 5G Cellular Configuration [13]

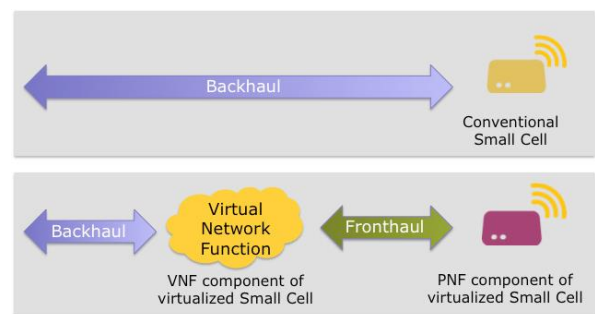


Fig. 5 Fronthaul and virtualized small cells [38]

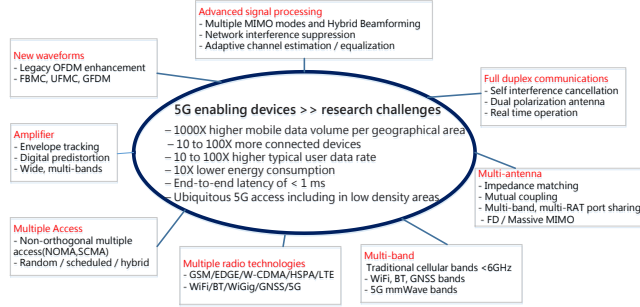


Fig. 6 A variety of enabling technologies, devices and methods for 5G [40]

TABLE I. Protocol stack for 5G wireless systems

Application Layer	Application (Services)
Presentation Layer	
Session layer	Open Transport Protocol (OTP)
Transport Layer	
Network layer	Upper network layer
	Lower network Layer
Data link Layer(MAC)	Open Wireless Architecture (OWA)
Physical Layer	

REFERENCES

- [1] Asvin Gohil, Hardik Modi, Shobhit K. Patel, "5G Technology of Mobile Communication: A Survey", 2013 International Conference on Intelligent Systems and Signal Processing (ISSP), pp. 288-292, 2013.
- [2] George Lawton, "What Lies Ahead for Cellular Technology?", IEEE International Symposium on Multimedia (ISM2005), Dec. 12-14, 2005, Irvine California, USA, pp. 14-16, 2005.
- [3] Zheng Wei-Bo, LI Xi-Chun, Sharan Kaur, "The Emplacement of Synchronal Mobile Business on 5G Wireless World", 2008 International Conference on Management Science & Engineering (15th), Long Beach, USA, pp. 1379-1385, Sep. 10-12, 2008.
- [4] Xichun Li, Abudulla Gani, Rosli Salleh, Omar Zakaria, "The Future of Mobile Wireless Communication Networks", International Conference on Communication Software and Networks, pp. 554-557, 2009.
- [5] Robert Gilmore, "Towards the 5G Smartphone: Greater System Capacity, More Bands, Faster Data Rates, Advanced Applications and Longer Battery Life", IEEE Radio Frequency Integrated Circuits Symposium (RFIC), pp. 6, 2012.
- [6] Chris Edwards, "5G Searches for Formula to Shake off Shannon", Engineering & Technology www.EandTmagazine.com, pp. 82-85, Sep. 2013.
- [7] Cantika Felita, Muhammad Suryanegara, "5G Key Technologies: Identifying Innovation Opportunity", Quality in Research, pp. 235-238, 2013.
- [8] Robert W. Heath Jr, Angel Lozano, Thomas L. Marzetta, Petar Popovski, "Five Disruptive Technology Directions for 5G", IEEE Communications Magazine, pp.74-80, Feb. 2014.
- [9] Naga Bhushan, Junyi Li, Durga Malladi, Rob Gilmore, Dean Brenner, Aleksandar Damnjanovic, Ravi Teja Sukhavasi, Chirag Patel, and Stefan Geirhofer, "Network Densification: The Dominant Theme for Wireless Evolution into 5G", IEEE Communications Magazine, pp. 82-89, Feb. 2014.
- [10] Gerhard Fettweis, Siavash Alamouti, "5G: Personal Mobile Internet beyond What Cellular Did to Telephony", IEEE Communications Magazine, pp. 140-145, Feb. 2014.
- [11] Jivesh Govil, Jivika Govil, "4G:

- Functionalities Development and an Analysis of Mobile Wireless Grid”, First International Conference on Emerging Trends in Engineering and Technology, pp. 270-275, 2008.
- [12] Xichun Li, Rosli Salleh, Abdulla Aani, Omar Zakaria,” Multi-network Data Path for 5G Mobile Multimedia”, International Conference on Communication Software and Networks, pp. 583-587, 2009.
- [13] Milos Milosavljevic, Stratis Sofianos, Pandelis Kourtessis, and John M. Senior, ”Self-organized Cooperative 5G RANs with Intelligent Optical Backhubs for Mobile Cloud Computing”, 2013 IEEE ICC'-Workshop on Optical-Wireless Integrated Technology for Systems and Networks, pp. 900-904, 2013.
- [14] Yaniv Azar, George N. Wong, Kevin Wang, Rimma Mayzus, Jocelyn K. Schulz, Hang Zhao, Felix Gutierrez, Jr., Duck Dong Hwang, Theodore S. Rappaport, ”28 GHz Propagation Measurements for Outdoor Cellular Communications Using Steerable Beam Antennas in New York City”, IEEE ICC 2013 - Wireless Communications Symposium, pp. 5143-5147, 2013.
- [15] Gerhard Wunder, Martin Kasparick, Stephan ten Brink, Frank Schaich, Thorsten Wild, Ivan Gaspar, Eckhard Ohlmer, Stefan Krone, Nicola Michailow, Ainoa Navarro, Gerhard Fettweis, Dimitri Ktenas, Vincent Berg, Marcin Dryjanski, Slawomir Pietrzyk, Bertalan Eged,” 5GNOW: Challenging the LTE Design Paradigms of Orthogonality and Synchronicity”, Vehicular Technology Conference (VTC Spring), 2013 IEEE 77th , pp.1-5, 2013.
- [16] Z. Pi and F. Khan, ”An Introduction to Millimeter-wave Mobile Broadband Systems,” IEEE Communications Magazine, Vol. 49, no. 6, pp. 101-107, Jun. 2011.
- [17] Theodore S. Rappaport, Shu Sun, Rimma Mayzus, Hang Zhao, Yaniv Azar, Kevin Wang, George N. Wong, Jocelyn K. Schulz, Mathew Samimi, and Felix Gutierrez,” Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!”, Access, IEEE, pp. 335-349, 2013.
- [18] T. S. Rappaport, J. N. Murdock, and F. Gutierrez, ”State of the Art in 60 GHz Integrated Circuits & Systems for Wireless Communications,” Proc. of IEEE, Vol. 99, no. 8, pp. 1390-1436, Aug. 2011.
- [19] F. Rusek, D. Persson, B. Lau, E. Larsson, T. Marzetta, O. Edfors, and F. Tufvesson, ”Scaling up MIMO: Opportunities and Challenges with Very Large Arrays,” IEEE Signal Process. Mag., Vol. 30, no. 1, pp. 40-60, Jan. 2013.
- [20] Hang Zhao, Rimma Mayzus, Shu Sun, Mathew Samimi, Jocelyn K. Schulz, Yaniv Azar, Kevin Wang, George N. Wong, Felix Gutierrez, Jr., Theodore S. Rappaport, ”28 GHz Millimeter Wave Cellular Communication Measurements for Reflection and Penetration Loss in and around Buildings in New York City”, IEEE ICC 2013-Wireless Commun. Symposium, pp. 5163-5167, 2013.
- [21] Theodore S. Rappaport, Felix Gutierrez, Jr., Eshar Ben-Dor, James N. Murdock, Yijun Qiao, Jonathan I. Tamir, ”Broadband Millimeter-Wave Propagation Measurements and Models Using Adaptive-Beam Antennas for Outdoor Urban Cellular Communications”, IEEE Trans. on Antennas and Propagation, Vol. 61, no. 4, pp. 1850-1859, Apr. 2013.
- [22] Shuai Nie, George R. Mac Cartney Jr., Shu Sun, Theodore S. Rappaport, ”72 GHz Millimeter Wave Indoor Measurements for Wireless and Backhaul Communications”, 2013 IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications: Mobile and Wireless Networks, pp. 2429-2433, 2013.
- [23] Rainer Schoenen, Gurhan Bulu, Amir Mirtaheri, Tamer Beitelmal, Halim Yanikomeroglu, ”Quantified User Behavior in User-in-the-Loop Spatially and Demand Controlled Cellular Systems”, European Wireless, 2012. EW. 18th European Wireless Conference, pp. 1-8, 2012.
- [24] Paolo Baracca, Stefano Tomasin, and Nevio

- Benvenuto, "Backhaul Rate Allocation in Uplink SC-FDMA Systems with Multicell Processing", , IEEE Transactions on Wireless Communications, Vol. 13, Issue. 3, pp. 1264 - 1273, 2012.
- [25] Qian (Clara) Li, Huaning Niu, Apostolos (Tolis) Papathanassiou, and Geng Wu, "5G Network Capacity", IEEE Vehicular Technology Magazine, pp.71-78, Jan. 2014.
- [26] Steven Hong, Joel Brand, Jung Il Choi, Mayank Jain, Jeff Mehlman, Sachin Katti, and Philip Levis, "Applications of Self-Interference Cancellation in 5G and Beyond", IEEE Communications Magazine, pp. 114-121, Feb. 2014.
- [27] Xiaofei Wang, Min Chen, Tarik Taleb, Adlen Ksentini, Victor C. M. Leung, "Cache in the Air: Exploiting Content Caching and Delivery Techniques for 5G Systems", IEEE Communications Magazine, pp.131-139, Feb. 2014.
- [28] Abba Kammoun, Hajer Khanfir, Zwi Altman, M'rouane Debbah, Mohamed Kamoun, "Survey on 3D Channel Modeling: From theory to standardization", arXiv:1312.0288v1 [cs.IT] 1 Dec. 2013.
- [29] Koppenborg, H. Halbauer, S. Saur, and C. Hoek, "3D Beamforming Trials with an Active Antenna Array," in ITG Workshop on Smart Antennas, 2012.
- [30] R1-122034, "Study on 3D Channel Model for Elevation Beamforming and FD-MIMO Studies for LTE," 3GPP TSG RAN Plenary # 58, Dec. 2012.
- [31] Y. Wang, W. Zhang, O. Li, P. Zhang, "Interference Coordination in 3D MIMO-OFDMA Networks," IEICE Trans. Commun., Vol. E97-B, no. 3, Mar. 2014.
- [32] T. A., Thomas, F.W., Vook, E. Mellios, G. S. Hilton, A. R., Nix, E. Visotsky, "3D Extension of the 3GPP/ITU Channel Model," Vehicular Technology Conference (VTC Spring), 2013 IEEE 77th, pp. 1-5, 2013.
- [33] Younsun Kim, Hyoungju Ji, Hyojin Lee, and Juho Lee, Boon Loong Ng and Jianzhong (Charlie) Zhang, "Evolution Beyond LTE-Advanced with Full Dimension MIMO", IEEE International Conference on Communications 2013: IEEE ICC'13-Workshop Beyond LTE-A, pp. 111-115, 2013.
- [34] Mathew Samimi, Kevin Wang, Yaniv Azar, George N. Wong, Rimma Mayzus, Hang Zhao, Jocelyn K. Schulz, Shu Sun, Felix Gutierrez, Jr., and Theodore S. Rappaport, "28 GHz Angle of Arrival and Angle of Departure Analysis for Outdoor Cellular Communications Using Steerable Beam Antennas in New York City", 2013 IEEE 77th Vehicular Technology Conference (VTC Spring), pp. 1-6, 2013.
- [35] Banmali S. Rawat, Anupama Bhat, Jaromir Pistora, "THz Band Nano Antennas for Future Mobile Communication" 2013 International Conference on Signal Processing and Communication (ICSC), pp. 48-52, 2013.
- [36] Gerhard Wunder, Peter Jung, Martin Kasparick, Thorsten Wild, Frank Schaich, Yejian Chen, Stephan ten Brink, Ivan Gaspar, Nicola Michailow, Andreas Festag, Luciano Mendes, Nicolas Cassiau, Dimitri Kténas, Marcin Dryjanski, Slawomir Pietrzyk, Bertalan Eged, Peter Vago, Frank Wiedmann, "5GNOW: Non-Orthogonal, Asynchronous Waveforms for Future Mobile Applications", IEEE Communications Magazine, pp. 97-105, Feb. 2014.
- [37] Wonil Roh, Ji-Yun Seol, JeongHo Park, Byunghwan Lee, Jaekon Lee, Yungsoo Kim, Jaeweon Cho, Kyungwhoon Cheun, Farshid Aryanfar, "Millimeter-Wave Beamforming as an Enabling Technology for 5G Cellular Communications: Theoretical Feasibility and Prototype Results", IEEE Communications Magazine, pp. 106-113, Feb. 2014.
- [38] Small cell forum Release 8.0, "Document 108.08.01, Virtualized Small Cells Overview", www.smallcellforum.org, Oct. 2016.
- [39] Shree Krishna Sharma, Tadilo Endeshaw

Bogale, Symeon Chatzinotas, Xianbin Wang, Long Bao Le, “Physical Layer Aspects of Wireless IoT”, 2016 International Symposium on Wireless Communication Systems (ISWCS), pp. 304-308. 2016.

- [40] Greg Jue, Sangkyo Shin, “Keysight Technologies Implementing a Flexible Testbed for 5G Waveform Generation and Analysis White Paper “; Keysight Technologies, Published in USA, June 14, 2016.