



A Review 5 G Multi-tier Cellular Wireless Network Higher Data Rates Transmission in MIMO Systems

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ABSTRACT: In the near future, i.e., beyond 4G, some of the prime objectives or demands that need to be addressed are increased capacity, improved data rate, decreased latency, and better quality of service. To meet these demands, drastic improvements need to be made in cellular network architecture. This paper presents of a detailed survey on the fifth generation (5G) cellular network architecture and some of the key emerging technologies that are helpful in improving the architecture and meeting the demands of users. In this detailed survey, the prime focus is on the 5G cellular network architecture, massive multiple input multiple output technology, and device-to-device communication (D2D). Along with this, some of the emerging technologies that are addressed in this paper include interference management, spectrum sharing with cognitive radio, ultra-dense networks, multi-radio access technology association, full duplex radios, millimeter wave solutions for 5G cellular networks, and cloud technologies for 5G radio access networks and software defined networks. In this paper, a general probable 5G cellular network architecture is proposed, which shows that D2D, small cell access points, network cloud, and the Internet of Things can be a part of 5G cellular network architecture. A detailed survey is included regarding current research projects being conducted in different countries by research groups and institutions that are working on 5G technologies.

Keywords: 5G, massive MIMO, base station, antenna arrays, D2D, millimeter wave, cell, heterogeneous network.

I. INTRODUCTION

The rapid increase of mobile data growth and the use of smart phones are creating unprecedented challenges for wire- less service providers to overcome a global bandwidth short- age [1], [2]. As today's cellular providers attempt to deliver high quality, low latency video and multimedia applications for wireless devices, they are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz. As

the global spectrum bandwidth allocation for all cellular technologies does not exceed 780 MHz, where each major wireless provider has approximately 200 MHz across all of the different cellular bands of spectrum available to them. Servicing legacy users with older inefficient cell phones as well as customers with newer smart phones requires simultaneous management of multiple technologies in the same band-limited spectrum. Currently, allotted spectrum for operators is dissected into disjoint frequency bands, each of which possesses different radio networks with different propagation characteristics and building penetration losses. This means that base station designs must

service many different bands with different cell sites, where each site has multiple base stations (one for each frequency or technology usage e.g. third generation (3G), fourth generation (4G), and Long Term Evolution - Advanced (LTE-A)) [3], [4]. To procure new spectrum, it can take a decade of administration through Mobile broadband networks need to support ever-growing consumer data rate demands and will need to tackle the exponential increase in the predicted traffic volumes. An efficient radio access technology combined with more spectrum availability is essential to achieve the ongoing demands faced by wireless carriers.

II. THE WIRELESS EVOLUTION

To date, four generations of cellular communication systems have been adopted in the USA with each new mobile generation emerging every 10 years or so since around 1980rst generation analog FM cellular systems in 1981; second generation digital technology in 1992, 3G in 2001, and 2011,4G LTE-A [6]. The evolution from 1G to 4G is summarized.

Table 1: Requirements and realities of 1G through 4G cellular systems.

Generation	Requirements	Comments
1G	No official requirements. Analog technology.	Deployed in the 1980s.
2G	No official requirements. Digital Technology.	First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA and GSM.
3G	ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	Primary technologies include CDMA2000 1X/EV-DO and UMTS-HSPA. WiMAX now an official 3G technology.
4G	ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency.	No technology meets requirements today. IEEE 802.16m and LTE-Advanced being designed to meet requirements.

First generation cellular networks were basic analog systems designed for voice communications. A move to early data services and improved spectral efficiency was realized in 2G systems through the use of digital modulations and time division or code division multiple access. 3G introduced high-speed Internet access, highly improved video and audio streaming capabilities by using technologies such as Wideband Code Division Multiple Access (W-CDMA) and High Speed Packet Access (HSPA). HSPA is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), which extends and improves the performance of existing 3G mobile telecommunication networks utilizing WCDMA protocols. An improved 3GPP (3rd Generation Partnership Project) standard, Evolved HSPA (also known as HSPAC), was released in late 2008 with subsequent worldwide utilization beginning in 2010. HSPA has been deployed in over 150 countries by more than 350 communications service providers (CSP) on multiple frequency bands and is now the most extensively sold radio technology worldwide [7], although LTE is closing the gap rapidly. The International Mobile Telecommunications-Advanced (IMT-Advanced) standard is the next-generation of mobile communications technology defined by the ITU and includes capabilities outstripping those of IMT-2000 (3G) mobile communication. ITU refers to IMT-Advanced as a 4G mobile communications technology, although it should be noted that there is no universally accepted definition of the term 4G. LTE radio access technology has been developed by the 3GPP to offer a fully 4G-capable mobile broadband platform [8]. LTE is an orthogonal frequency-division multiplexing (OFDM)-based radio access technology that supports a scalable transmission band width up to 20 MHz and advanced multi-antenna transmission. As a key technology in supporting high data rates in 4G systems,

Multiple-Input Multiple-Output (MIMO) enables multi-stream transmission for high spectrum efficiency, improved link quality, and adaptation of radiation patterns for signal gain and interference mitigation via adaptive beam forming using antenna arrays [9]-[10]. The coalescence of HSPA and LTE will increase the peak mobile data rates of the two systems, with data rates exceeding 100 Mbps, and will also allow for optimal dynamic load balancing between the two technologies [8]. As the demand for capacity in mobile broadband communications increases dramatically every year, wireless carriers must be prepared to support up to a thousand-fold increase in total mobile traffic by 2020, requiring researchers to seek greater capacity and to and new wireless spectrum beyond the 4G standard [12]. To improve the existing LTE network, the wireless technology roadmap now extends to IMT-Advanced with LTE-Advanced defined to meet IMT-Advanced requirements, which will be theoretically capable of peak through-put rates that exceed 1 Gigabit per second (Gbps). LTE-Advanced supports heterogeneous networks with co-existing large macro, micro, and pico cells, and Wi-Fi access points. Low cost deployment will be realized by self-organizing features and repeaters/relays As fifth generation (5G) is developed and implemented, we believe the main differences compared to 4G will be the use of much greater spectrum allocations at untapped mm-wave frequency bands, highly directional beam forming antennas at both the mobile device and base station, longer battery life, lower outage probability, much higher bit rates in larger portions of the coverage area, lower infrastructure costs, and higher aggregate capacity for many simultaneous users in both licensed and unlicensed spectrum (e.g. the convergence of Wi-Fi and cellular). The backbone networks of 5G will move from copper and fiber to mm-wave wireless connections, allowing rapid deployment and mesh-like connectivity with cooperation between base stations.

III. 5G WIRELESS

The evolution of wireless communication systems requires global collaboration, involving worldwide mobile communication companies and governments. The Electronics and Telecommunication Research Institute (ETRI) in Korea has actively contributed to the development of 4G systems. In 2002, the Mobile Communication Research Laboratory (MCRL) of ETRI initiated the R&D of the 4G radio transmission system for HSPA and proposed their vision of 4G radio mobile communications [13]. According to ETRI, the 4G system would satisfy the data rate requirement of 100 Mbps for high mobility with Systems Beyond IMT-2000 (SBIMT) and would provide high quality service for both low-tier and high-tier cellular systems. In the early 2000s, aiming at integrating voice and web data in an IP-based mobile communications system (i.e. 4G wireless network), Sun Microsystems engineers were designing and implementing mobile IP-based protocols and tools to implement secure, versatile and responsive wireless communication technologies [14], [15]. A memorandum of understanding (MoU) was signed by the government of Karnataka in India with Charmed Technologies Inc. from Beverly Hills, California, and Software Technology Parks of India in Karnataka to develop "4G" wireless technology in the year 2001 [16]. In 2005, Samsung envisaged the increasing demands of higher data rates, and the eventual convergence of digital multimedia and ubiquitous computing [17]. Samsung's 4G vision has mainly focused on digital convergence including implementations of bi-directional HDTV, increasing e-health and e-education services, and ubiquitous wireless network services. With an evolution from fixed broadband to mobile broadband, more converged, personalized, convenient and seamless secure services will be achieved, and Samsung has recently made contributions in the area of mm-wave wireless [2], [11]. Recently, Korea has carried out a series of R & D activities toward beyond 4G evolution. It aims to establish "Giga Korea" during 2013 to 2020 for hyper connected IT infrastructure deployment. Those activities include the acquisition of wider spectrum, green networks and devices, special purpose networks, and new network topologies and media. Nokia Siemens Networks (NSN) has conducted research activities in radio, together with industry and research partners, making contributions to the 3GPP LTE standard. NSN believes that with improvement in digital processing power, radio implementation bandwidth, and the availability of optical fiber, the radio evolution will continue. The next evolutionary stage, beyond 4G, is likely to support up to 1,000 times higher traffic volumes than 2010 traffic levels, with peak and cell

edge rates higher than 10 Gbps and 100 Mbps respectively with latency less than 1 ms for local area networks [5], and will realize wide scale small cell (heterogeneous) deployments, fast interference coordination and cancellation, Cognitive Radio Networks (CRNs), and Self Organizing Networks (SONs) [12]. Further, future networks may require the combinations of diverse radio access technologies such as LTE, HSPA, Wi-Fi, and B4G [12]. The University of Surrey, England, has set up a world research hub for 5G mobile technology with a goal to expand UK telecommunication research and innovation [1]. New York University (NYU) and NYU-Poly recently established.

IV. MILLIMETER WAVE SOLUTION FOR FUTURE 5G CELLULAR NETWORKS

Despite industrial research efforts to deploy the most efficient wireless technologies possible, the wireless industry always eventually faces overwhelming capacity demands for its currently deployed wireless technologies, brought on by the continued advances and discoveries in computing and communications, and the emergence of new customer handsets and use cases (such as the need to access the internet). This trend will occur in the coming years for 4G LTE, implying that at some point around 2020, wireless networks will face congestion, as well as the need to implement new technologies and architectures to properly serve the continuing demands of carriers and customers. The life cycle of every new generation of cellular technology is generally a decade or less (as shown earlier), due to the natural evolution of computer and communications technology. Our work contemplates a wireless future where mobile data rates expand to the multi gigabit-per-second range, made possible by the use of steerable antennas and mm-wave spectrum that could simultaneously support mobile communications and backhaul, with the possible convergence of cellular and Wi-Fi services.

Recent studies suggest that mm-wave frequencies could be used to augment the currently saturated 700 MHz to 2.6 GHz radio spectrum bands for wireless communications [2]. The combination of cost-effective CMOS technology that can now operate well into the mm-wave frequency bands, and high-gain, steerable antennas at the mobile and base station, strengthens the viability of mm-wave wireless communications [2]. Further, mm-wave carrier frequencies allow for larger bandwidth allocations, which translate directly to higher data transfer rates. Mm-wave spectrum would allow service providers to significantly expand the channel bandwidths far beyond the present 20 MHz channels used by 4G customers [1].

By increasing the RF channel bandwidth for mobile radio channels, the data capacity is greatly increased, while the latency for digital traffic is greatly decreased, thus supporting much better internet-based access and applications that require minimal latency. Mm-wave frequencies, due to the much smaller wavelength, may exploit polarization and new spatial processing techniques, such as massive MIMO and adaptive beam forming [4]. Given this significant jump in bandwidth and new capabilities offered by mm-waves, the base station-to-device links, as well as backhaul links between base stations, will be able to handle much greater capacity than today's 4G networks in highly populated areas. Also, as operators continue to reduce cell coverage areas to exploit spatial reuse, and implement new cooperative architectures such as cooperative MIMO, relays, and interference mitigation

between base stations, the cost per base station will drop as they become more plentiful and more densely distributed in urban areas, making wireless backhaul In communications, MIMO implies multiple-input and multiple-output and is used by combinations of multiple transmitters/receivers or antennas at both sides of digital communication systems. It can be termed as replica of smart antennas array group. In wireless communications MIMO techniques is evolving technology that offers considerable increase in data bandwidth without any extra transmission power. Due to these properties, MIMO technology is a vital aspect of modern cellular and wireless communication standards of today. These emerging fields includes WiMAX, HSPA+, 5G cellular, energy efficient satellites etc.

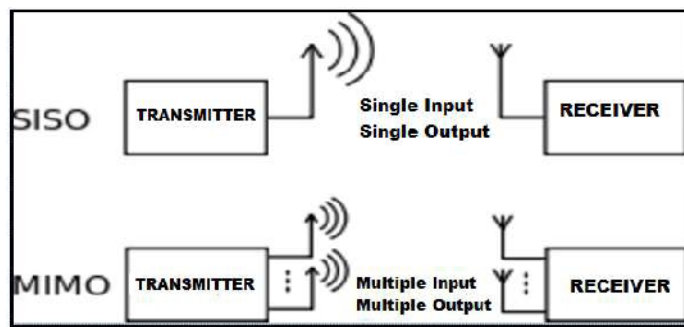


Fig. 1. Block diagram of SISO and MIMO systems.

Massive MIMO. It has been observed that massive MIMO networks can provide higher performance than partial multi-user MIMO since the multiple antennas used are much smarter. Massive-MIMO systems can be termed as the scenario of multi-user MIMO in which the number of transmitter terminals is very less than the number of BS (base station) antennas. For scattered environment, merits of massive MIMO technology could be further developed by using simple ZF (zero forcing) or MRT (maximum ratio transmission). Practically, for orthogonal channels the reception and transmission data lacks the channel coherence time. If more than one base stations (antenna) exist in this scenario, the devices renders these channels to various machines maintaining orthogonality optimal multiplexing. It can be argued that in the current text of disruption of emerging technologies massive - MIMO is the best choice for future generation wireless evolution for 5G.

V. MASSIVE-MIMO AND 5G CELLULAR

In massive MIMO present research challenges include estimation of criticality of coherent channels. Propagation impairments for massive MIMO in present context could also be hypothetically calculated on experimental basis for channel orthogonality. This could be further implemented on the basis of lower costs in the context of hardware power consumption in each of the antennas. Considering present scenario 5G has many merits over 4G

- i) Non- bulky in space
- ii) Directive antennas
- iii) Coherent angle spread of the propagation

There are limited number of antennas in MIMO employing single-user that is fit for current standard of cellular communication. But massive MIMO is not limited if TDD (Time Division Duplex) is incorporated for enabling channel characterization.

This relative scenario has massive MIMO's application which governs the multiple antennas distributed in which a small town or university campus or city could be utilized.

Millimeter Wave (mm-Wave). The frequencies in the range of 600 MHz to 1600 MHz are currently in use for cellular . This little range can hardly be exploited for future generation wireless access systems by reframing the system. Higher spectrums in the ranges of GHz and THz could be deployed by utilizing techniques in cognitive radio. The highly potential field is exploited by wavelength in millimeter range and hence the term millimeter wave is in practice. Today different cellular and wireless firms want a radical increase in capacity emerging trends which has to be carried in coming years beyond fourth generation of wireless standards in Long Term Evolution (4GLTE). Around 2020, the cellular networks would face a very high speech and data traffic and thereby higher capacity demands for data rate and bandwidth. For wireless future wireless generation of 5G mobile data rates must increase up to several gigabit per second (Gbps) range, which can only be processed by using the millimeter wave spectrum steerable antennas. This would support 5G cellular backhaul communications in addition [17] to integration of world-wide fidelity in wireless services. Since Massive MIMO is a spatial processing technique which would have orthogonal polarization and beam-forming adaptation, this smaller millimeter wavelength is suitable frequencies. The highly populated geographical regions could be covered by 4G+ to 5G technologies by setting backhaul link using massive MIMO in case of greater bandwidth challenges. Cost per base station will significantly reduce due to innovative architectures of co-operative MIMO, thereby minimizing interference relays and servicing base stations.

VI. CONCLUSIONS

In the quest for higher data rates and lower latencies beyond 4G network capabilities, the next generation of wireless mobile communications has to adopt revolutionary ways of using the radio spectrum. In addition to better ways of exploiting the already allocated frequency bands through enhanced modulation schemes and traditional network scaling, an opportunistic access to the underused spectrum through cognitive radio will further increase the systems' capacity. Moreover, different offloading techniques will contribute to an "unlimited" access to large amounts of multimedia data anywhere and anytime. The software-

defined radio technology will enable reconfigurable platforms for the implementation of the cognitive radio paradigm in underlay cellular networks and traffic offloading solutions, whereas software-defined networking will facilitate the programmable operation of the core network. The evolution towards 5G, as outlined in this paper, opens new research problems. Although we have briefly surveyed the key research projects recently launched in Europe, efforts to develop 5G technologies are being carried out worldwide. Further standardization for cooperation and interoperability between different radio access technologies will be needed, too. With this paper, we intend to motivate the search for innovative solutions to all these challenges.

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