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Challenges of 5G Wireless Technologies

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***Abstract*- With the evaluation and simulation of long-term evolution/4G cellular network and hot discussion about new technologies or network architecture for 5G, the appearance of simulation and evaluation guidelines for 5G is in urgent need. This paper analyzes the challenges of building a simulation platform for 5G considering the emerging new technologies and network architectures. Based on the overview of evaluation methodologies issued for 4G candidates, challenges in 5G evaluation are formulated. Additionally, a cloud-based two-level framework of system-level simulator is proposed to validate the candidate technologies and fulfill the promising technology performance identified for 5G.**

***Keywords*- 5G, system-level simulations, performance evaluation, two-level simulator**

I.INTRODUCTION

With the popularization of smart devices and rapid development of internet services, it has been predicted that the traffic of mobile data traffic will increase a thousand-fold till the year of 2020. On one hand, as video and audio services are becoming more and more popularized nowadays, the high definition and bigger volume characteristics of graphic and voice services appeal for higher data transmission rate. On the other hand, even with substantially higher transmission rate and traffic, perfect user experience are expected to be achieved as the same level with fixed Web access service to meet the real- time demands.

The explosive increasing trend of mobile data services and traffic flow motivates new technologies bringing higher spectrum efficiency (SE), higher energy efficiency (EE) and denser cell deployment. Under this background, 5G emerges to introduce advanced key technologies aiming at achieving around 1000 times the system capacity, 10 times the SE, EE and transmission data rate. In order to satisfy higher speed, more stable and lower end-toend delay requirements of future wireless mobile communication systems, new network architecture will be adopted [1].

The emerging new technologies like large scale multi-input multi- output (MIMO), Co-frequency Co-time Full Duplex (CCFD), and Carrier Aggregation (CA) are candidate technologies introduced into 5G .In the future,5G will evolve into a new ultra dense distributed cooperating and self-organized network, with joint radio resource allocation technologies employed by different heterogeneous systems for the purpose of improving resource utilization and system performance. Nevertheless, this new network architecture and consequent key technologies bring new challenges to system-level simulation methodologies and frameworks for5G systems adaption. Firstly, from the perspective of internal storage demand and simulation speed, more complex parameter configuration, larger temporal data storage demand, enormous interactinginformation of users, more diverse performance evaluation metrics appear with the application of large scale antennas. Secondly, traditional network architecture should be updated, which will change the interference distribution situation, the interference calculation becomes more complex and subtle in the new heterogeneous architecture [2].

Thirdly, the distributed coordination and self-organized network make the modification of4G simulation tools like resource scheduling and beam forming necessary. On the way towards 5G, organizations, such as the3rd generation partnership project (3GPP), 3GPP2, International Telecommunication Union (ITU)-2000, all over the world have developed mature system- level evaluation methodologies for 3G, like CDMA2000, WCDMA, long-term evolution (LTE). And these simulation methodologies evolved as the pace of standard progressions. In 2008, ITU-R issued International Mobile Telecommunications-Advanced (IMTAdvanced) [3].

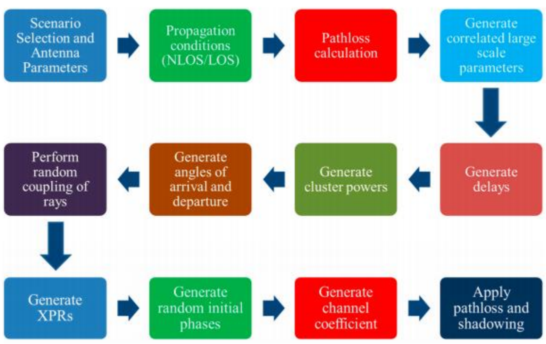

Figure 1. Channel modeling for wireless 5G cellular networks.

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European project Wireless World Initiative New Radio (WINNER) has provide us detailed evaluation and calibration procedures in line with 4G requirements. 802.16m is also issued by IEEE for the evolution of Wi-Max technology providing systematic evaluation methodologies. As analyzed above, 5G systems bring new requirements of architecture and advanced technologies, which trigger the emergence of new evaluation framework in both academic and industrial fields.

One of the projects currently performed based on 5G is the European Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) project. METIS is scenario-driven and denies various scenarios with accompanying test cases characterized. With the expected ultradense deployment and massive antenna arrays, the runtime of simulation process, including performance evaluation and simulation calibration steps, can be predicted to be seriously extended. Currently, according to exhibited new features and promising key technologies in 5G networks, the necessary of Formulating a heuristic guideline and evaluation methodology to test candidate techniques, investigate new network architecture, research on transmission techniques, is urgent. Under This background, this paper addresses implicit challenges and revisions hidden for 5G system evaluation evolved from existing evaluation reports submitted by different evaluation [4].

II. OVERVIEW ON 4G EVALUATIONS

The Evaluation Framework of 4g : According to the evaluation methodologies of ITU, the basic evaluation characteristics and assessment methods for 4G, the simulations, especially system-level simulations, are the most important and complex contents, which cover the largest part of the workload. Shows the modular design of system-level simulation together with two-step calibration. The evaluation setting module implements various ITU test Scenarios and provides specific wireless network deployment environment for system operation. The channel model which is calibrated by step1 includes large fading, additive white Gaussian noise (AWGN),MIMO channel and fast fading.

A.

The cell topology and user generation is set by the predefined test Environments, which are used to specify the environments of the requirements for the technology proposals. Four typical test environments have been chosen such that different deployments are modeled and critical questions in system design and performance can be investigated. Accordingly, to test limits of performance related to capacity and user mobility, the characterized deployment scenarios in evaluation are specified. For each scenario, all configurations including network layout, simulation parameters, antenna patterns and channel models, necessary to evaluate the performance of radio interface technology, are specified [5] .

The system function module accomplishes required functionality within the framework of the 4G in order to simulate the whole system operation procedure. Since the Key algorithm is privately-owned; it has not been formulated by ITU. As each system has its own characteristics, the algorithms should be accordingly adjusted. Power control on the uplink and scheduling on both the downlink and uplink are some examples in the algorithm. Link adaptation algorithm and interference calculation have been standardized and widely used [6].

III. EMERGING TECHNOLOGIES IN 5G

The evolution from 4G to 5G has not been standardized yet, and industrial and academic have not reach a consensus on the ultimate 5G technologies and how to combine these technologies appropriately. There are some emerging and promising technologies, aiming at significantly improving date rates, realizing green communication and perfect user experience, attract much attention. Moreover, the breakthroughs brought by 5G are not limited to this; the explosive growth of mobile traffic data communication implies that the fusion of mobile Communication and data transmission will become the mainstream. These technologies can generally be classified into two groups:

1. New air interface characteristics;
2. New network architecture.

The emergence of brand new technologies imposes new requirements for 5G simulation and evaluation; next we will begin from analysis of candidate technologies and then give its influence on 5G system-level simulation.

1. New Air Interface Characteristics

1.1 MASSIVE/3D MIMO Equipping large excessive antennas on the transmit side is firstly put forward by Marzetta in 2006. The remarkable advantages brought by scaling up MIMO by possibly orders of magnitude compared to current state of art can be summarized on following aspects [7]: Improving spectral efficiency by simply equipping more antennas in current cellular networks and working on multi-user transmission mode.

1. 2 Improving energy efficiency: capable of focusing its emitted energy into a smaller region of space around user locations due to its beam alignment. Besides, there exists limiting factors if Massive MIMO is incorporated into 5G networks, which are under research and discussion. Among these challenges, there are: channel state information (CSI) acquisition, pilot contamination, new radio propagation Characterization. Consequently, under the background of Massive MIMO, the building of 5G system-level simulation evolved from 4G needs to solve the following problems as far as we concerned.

1.3 Propagation Channel Modeling- With large scale antennas on BS side, the channel characteristics render differently from traditional channel model.

1.4 Feedback Bottleneck- With the predictably huge feedback overhead, (explicitly or implicitly) it's within hot discussion whether to adapt codebookbased feedback or employing a totally new feedback mechanism, for example, compressive sensing based feedback schemes.

1.5 Operation Mode- Due to the advantage of utilizing channel reciprocity in TDD mode, which in turn limit the application of Massive MIMO into FDD systems, it has been considered how to settle down the operation modes of Massive MIMO as the combination of TDD and FDD are worked towards an fusion in future networks.

1.6 Pilot Design- Due to the scarcity of spectrum resources, adjacent cells tend to transmit their corresponding pilots in the frequency use factor as 1, which leads to serious pilot contamination. This problem could be mitigated by appropriate pilot pattern different from traditional systems.

1.7 Efficient Processing Ability- With the deployment of massive antennas, enormous volume data need to be processed at the receive side and infrastructure side, which raise a urgent demand for efficient processing ability in 5G simulation systems.

2. Full Duplex Radio

Recent advances carried out by researchers at Stanford and Rice attempt to build in-band full duplex radio systems .The implicit improvement in full duplex could be tremendous, due to that the spectrum utilization can be cut down by half or equivalently system capacity achieve twice as before. However, full duplex implementation is predictably difficult due to the unavoidable self-interference since equipment is designed to transmit and receive simultaneously in full duplex radios.

Fortunately, recent advances have been made, for examples, NEC labs presents their innovational design work to realize full duplex by analog and digital interference cancelation techniques. As a promising technology towards 5G realization and standardization, full duplex radio may prove its feasibility. However, there are some obstacles for full duplex radio to Overcome, for example, additional selfinterference calculation circuits should be designed and interference situation becomes more complex. In the case of building a system-level simulation to evaluate full duplex radio, the complex interference situation should be taken into consideration [8].

2.1 Complex Interference Situation- With the introducing of full duplex, serious interference may happen result from: the high DL self-interference to UL signal, the inter-user UL-DL interference, inter- BS DL to UL interference and inter-cell inter-user UL-to-DL interference in multi-cell network;

2.2 Additional Analog or Digital Circuits- The influence of designing analog and digital self- interference cancelation circuits should be taken into consideration.

2.3 Combination With MIMO: The preliminary method of using full duplex for single transmit antenna and receive antenna has been researched, but the antenna design combining MIMO with full duplex remains a key Challenge.

3. Network Architecture

3.1 Small Cells/Ultra Dense Network- Future mobile broadband services render new characteristics with the rapid development of mobile internet and smart devices. Firstly, from the view of service types, future broadband services demonstrate features of high speed and huge volume data transmission, all through IP, more diverse services types. Secondly, according to the statistics, the 60 percent and 70 percent of voice services and data services, respectively, happen indoor or in hot spot.

Thirdly, from the view of spectrum, spectrum bands tend to be fragmented below 3GHZ, and 3.4GHZ3.6GHZ spectrum has been allocated to mobile communication in WRC-07, therefore 5G communications are likely to operate on idle spectrum band higher than 5GHZ. All in all, those new trends of future communication prompt small cell network architecture become a necessary topology evolution direction for future data growth. By introducing low- power nodes in heterogeneous networks, significant benefits like enhancement of hot spot, enlarging coverage, improving system capacity, reducing energy consumption can be achieved. Regardless of benefits brought by small cells deployment, as small cell nodes become denser, the network topology tends to be complicated. This may lead to serious interference problems if the positions of small cells are not reasonably planned. With respect to its influence on system level simulation, corresponding changes will be made in the following aspects [9].

3.2 Interference Calculation Model- The heterogeneous and ultra-dense network structure determines a totally different interference calculation mode from traditional interference calculation.

3.3 Additional Clustering- Clustering methods designed for small cell networks are taken into consideration;

3.4 Scheduling Method- The resource allocation algorithms within clusters or among different clusters should be appropriately designed, and evaluations with different allocation mechanisms may differ within a wider range.

3.5 Devices-To-Device Communication
Over recent years, as user distribution becomes denser and communications occur more frequently, proximity based information exchange and connecting have become a major area of interest for mobile internet communication, like social networking, _le distribution, and video game. Deviceto-Device (D2D) communication, where users communicate directly while remaining controlled under macro base stations, emerges as a promising technology to improve local spectral efficiency and reduce connecting latency. Compared with traditional 4G cellular network, D2D can afford higher data transmission rate, lower delays and lower power consumption in its local region [10].

The significant benefit achieved relies on that with direct D2D link, multiple wireless hops through routing and BSs are circumvented, which leads to much less latency and interaction signaling resources. In spite of attempting benefits brought by D2D, there still exists some challenges to overcome when incorporate D2D into 5G. Within relevant discussion of D2D, the challenges include interference coordination, D2D triggering condition and balancing between control overhead and net gains.

Firstly, since D2D link reuse cellular frequency resource which causes inter-cell interference? Secondly, net gain achieved by D2D imposes limitations of communication environment, the subtle condition of D2D mode triggering and switching should be determined. Thirdly, building a direct D2D link requires peer discovery and a series of physical layer procedures, which generate extra overheads. From the perspective of system evaluation, with the incorporation of D2D into a 5G system-level simulation, corresponding changes will be made in the following aspects.

3.6 Interference Calculation- the introduction of D2D communication changes frequency duplex structure in links should be taken into consideration.
Resource Scheduling: new resource scheduling schemes need to be carried out mitigating inter-cell interference caused by D2D links.

3.7 Peer Discovery- the detailed process of D2D pairs discovery considering real user mobility and distributed management should be added appropriately. Extra Physical Layer Procedures: channel information of D2D links acquisition requires multiple physical layer procedures like channel estimation and channel feedback

IV. SOFTWARE DEFINED NETWORK

The concept of Software Defined Networking (SDN) is originated by Open Flow (2008) of Stanford University, where network data plane and control plane are isolated through function abstraction. With separable control plane and data planes, network management can be simplified and previously unavailable services and configurations can be introduced conveniently. In this way, the future network can realize dynamic flexible topology control and afford programming ability to deal with ``big data," which is the necessary trend in future communication networks. Although academic and industrial groups have not arrived consensus about the definition of SDN, according to Open Networking Foundation (ONF), SDN is expected to be programmable, open source and flexible.

Applying SDN into mobile wireless communication systems can simplify the management of network for commercial operators and endorse the exponentially increasing data flow in foreseen 5G. Despite that the promised potential SDN brought to provide a fusion of network, data, computation for future networks, communication systems with SDN present relevant challenges. Firstly, how to strike a balance between system performance and flexibility through optimal programmability switch strategy. Secondly, the complexity of standardization and interoperability on the way of transform traditional network to SDN model are still within discussion. What's more, since potential security vulnerabilities exist across the SDN platform, security initiatives need to be carried out to prevent SDN network from malicious attacks [11].

V. REQUIREMENT ON HEAVY DISTRIBUTION OF MOBILE DATA SERVICES

In 5G, high data rate services indoors and at hotspots occupy the main traffic volume of mobile services. The previous macro-dominated design will not be suitable to meet this change. As a result, a new design, local-based IMT, optimized for both indoors and hotspots will be necessary. Local-based IMT needs to coexist and coordinate with macro-based IMT.

VI. STUNNING MOBILE DATA CAPACITY (1000-FOLD) REQUIREMENT

The increasing of cell numbers will be a very efficient way to improve the system capacity in an almost linear ratio when the signal-to interferenceplus- noise ratio (SINR) is guaranteed. However, it is impossible to increase the Number of the current small cells by orders of Magnitude because of the limitations from current Macro-based design such as backward compatibility, Cost, interference, cell management, And cell sites. But in 5G, local-based IMT can be introduced, and small cells can be designed from local perspectives. It is completely possible to increase the number of small cells by orders of magnitude when new architecture and new technologies are adopted. According to, the increase of small cell numbers in the future may far exceed 100 times the current number [12].

VII. ENERGY CONSUMPTION REQUIREMENT

Energy consumption shall be decreased significantly in orders of magnitudes in 5G. But it is impossible in the current framework and current base stations. For example, the goal of EC FP7 EARTH is to decrease energy consumption for base stations by 50 percent, mainly based in the current framework. However, it is possible to reduce power down to orders in magnitude by offloading majority data to local small cells, letting inactive cells sleep, in the macro-local coexisting and coordinating framework. New Available Spectrum RequirementFor 2G/3G and even 4G, most allocated spectrums are mainly below 3 GHz. In addition, the spectrum usage reaches almost the maximum efficiency. A new work item was thus established to seek new potential spectrum for the future terrestrial mobile communication. It seems that the new available spectrum for the future generation is mainly above 3GHz or even higher. Those spectrums will be suitable for local scenarios to improve capacity rather than for a macro scenario to improve coverage. This provides the fundamental condition to the new design of local-based IMT.

VIII. SIGNIFICANTLY RELAX THE REQUIREMENT ON COST

the RF and baseband requirements on the current terminal chipset are based on the physical parameters meeting high mobility and large cell radius, the cost is hard to be significantly reduced. When local-based IMT is introduced, the cost of the RF and baseband chipsets for the local scenario can be decreased because the RF and baseband performance requirements are relaxed to meet low mobility and small cell radius. Moreover, the cost of a small cell, including the cost of maintenance and a cell site, will also be significantly reduced. From 2G to 3G and to 4G, the design principle is macro-based for the design of either the primary physical parameters or the framework. In order to change the situation to some extent, a work item for small cells, probably using a new type of carrier, is introduced in 3GPP. However, great changes will be very difficult in 4G due to the limitations in the framework and backward compatibility. This work item was terminated at the RAN #61 meeting in September 2013. that is why only a small branch has spun off from the main macro-dominated branch together with the requirements for 5G, this step change will bring in some technical trends, described in the following sections.

IX. CONCLUSION

In this paper, we present the challenges of building a simulation platform for 5G brought by emerging new technologies and network architectures. With the introduction of new air interface and network architecture, 5G simulation puts forward a very high request to integration and efficiency. To meet the strict requirements, a cloud-based two-level framework of system-level simulator is proposed. By dividing the system function into layers from the view of system, the two-level simulator will perfectly integrate various simulation scenarios and technologies. Moreover, using cloud computing, simulation efficiency can be greatly improved. Although the benefits of the cloud-based two-level framework of system level simulator are clear and reasonable, the implementation in practice still need in depth research, considering practical constrains.

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