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Research Activities of the Fifth Generation Mobile Communication Promotion Forum

Radio access technologies towards the fifth generation mobile communications system

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***Abstract*— In this paper, latest research activities of radio access network technologies in the Fifth Generation Mobile Communication Promotion Forum and essence of its preceding works in '*ARIB 2020 and beyond ad hoc*' are reported. In order to serve variety of use cases in a flexible and efficient manner, "heterogeneous network" combining genuine new radio access technologies for '5G' with other radio access technologies will be the key. The paper also summarizes studies on utilization of higher frequency spectrum in SHF or EHF bands, as well as several cutting edge radio access technologies being studied for '5G'.**

Keywords—The fifth generation mobile communications system; Radio Access Network technologies; The Fifth Generation Mobile Communications Promotion Forum

I. INTRODUCTION

Wireless communication system has been utilized all over the world as one of the most fundamental social infrastructures. Towards 2020s, it is both important to provide innovative communication service and cope with the increasing traffic demand. In response to these situations, research and development related to the fifth generation ('5G') mobile communications have been promoted in Europe, China and Korea. In the meantime, The Fifth Generation Mobile Communication Promotion Forum (5GMF) was established in September 2014 in Japan. The 5GMF studies use cases and its corresponding demands and radio access network technologies for '5G' with collaboration among industry and academia.

In this paper, latest research activities of radio access network technologies in the 5GMF and its preceding works in Association of Radio Industries and Businesses (ARIB) 2020 and beyond ad hoc (20B AH) are summarized and reported. As a flexible and effective technology to cope with the increasing and diversifying mobile traffic, 'heterogeneous network', which combines new radio access technologies and other different types of radio access technologies (RATs), is the key.

II. RESEARCH ACTIVITIES OF THE FIFTH GENERATION MOBILE COMMUNICATIONS SYSTEM

For the past decades, one of the main themes of development of mobile communication systems has been improvement of spectrum efficiency in order to achieve efficient utilization of the finite and precious frequency spectrum. Owing to series of dedicated elaborations, foot print of the mobile communication systems and their traffic volume

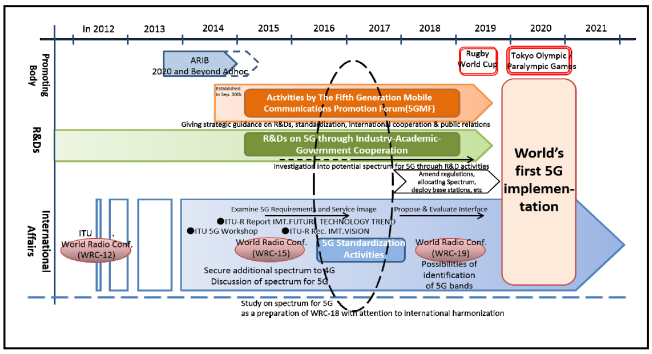

Fig. 1 Roadmap towards '5G' [1]

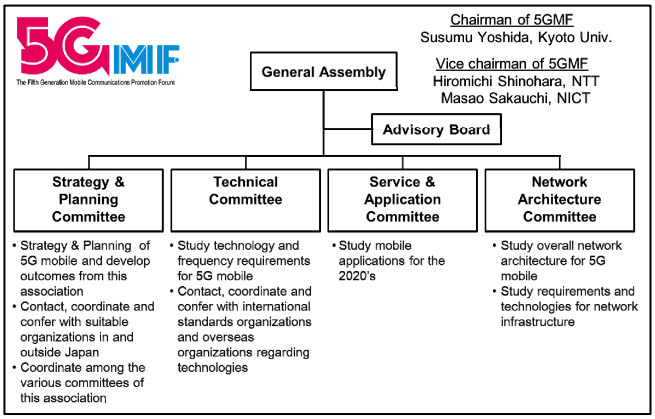

Fig. 2 Structure of 5GMF [2]

(mainly for voice calls at the beginning) have been increased continuously over the years.

For the coming decade, mobile communication systems will be widely used in every scene of every activity in everyday lives, industries etc. Taking these situations into consideration, it would be essential and urgent to elaborate sophisticated mobile communication systems which could provide best features and performance suited to every usage scenario in a flexible and cost effective manner.

Looking ahead these future demands, several research activities for so called '5G' were started in Europe, China and Korea and have been progressed steadily.

In the meantime, 5GMF was established in October 2014 in Japan in order to progress the research and development for '5G' which goal is to provide the best shaped mobile communication systems serving to the marked in 2020s (See Fig. 1 [1]). 5GMF consists of experts and talents from academia, industries and regulators, and its study area spans market demands, use cases, applications, network and radio communications technologies (see Fig. 2 [2]).

In the following sections, some of the study activities in 5GMF are summarized. Since 5GMF succeeds its preceding investigations carried out in ARIB 20B AH, part of its activities are also depicted.

A. Traffic trends of mobile communications

In Japan, total sum of traffic volume of the mobile communication systems are more than 20% of total fixed communication traffic (Fig. 3 [3]). Traffic increasing rates of the mobile communication systems is shown in Fig. 4. As can be seen in the chart, the traffic increasing rates tend to be calming down slightly however, they still show relatively higher increasing rate at around 50% per year. If this level of increasing rate is kept, it will result in 1000 folded traffic within 20 years. Similar observations could be made in other nations or regions where strong demands for mobile communications has been developed for the past decades though, Japanese market has been one of the leading market in mobile communications and could be a good market towards vivid and matured society in future. In order to cope with this traffic increase, enormous efforts are being made in '4G' systems (AKA LTE-Advanced) and apparently '5G' system should provide superior solution for the foreseen huge traffic in the future.

It would be worthwhile to point out that, for the time being, certain amount of the traffic increase of the mobile communications would be contributed by existing usages in the current fixed communication networks. That would mean one could expect similar use cases in coming mobile communication systems as in the existing fixed communication networks. However, it would also be true that evolving mobile applications markets are developing totally brand-new use cases and their traffic behaviors would have fundamental difference to the ordinary ones either in the existing fixed or mobile communication systems. Accordingly one of the main goals of '5G' system should comply with, not only the expanding traffic in quantitative context but also, such

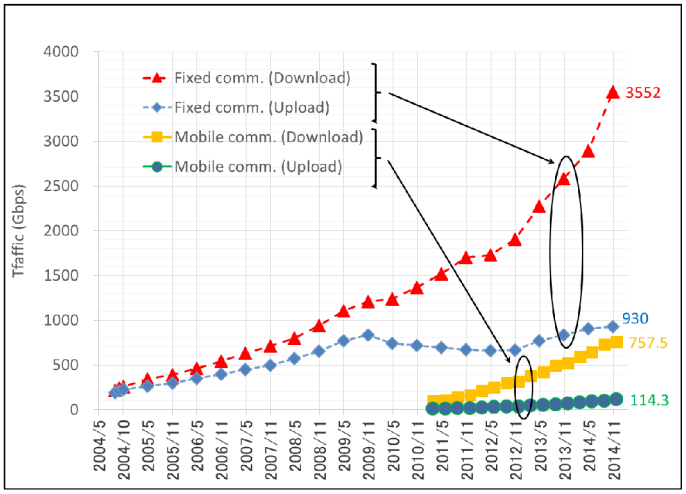

Fig. 3 Communication traffic in Japan [3]

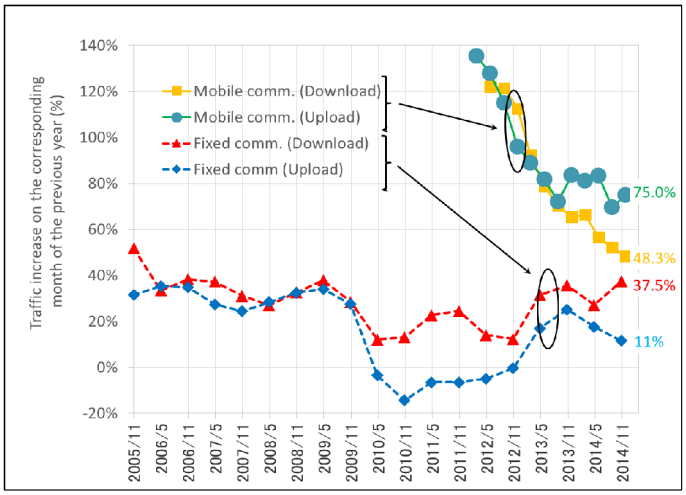

Fig. 4 Increasing rate of communication traffic in Japan [3]

Fig. 5 Market and User trends [4]

qualitative context in order to support these 'band-new' applications in an efficient and flexible manner.

B. *Market demands and user trends*

As has been expected already, 'everything' are going to be connected to communication networks (Fig. 5 [4]) and '5G' system should comply with such 'diverted' and variety of demands accordingly. Considering these aspect, such as aging society with digitally enabled services in Japan, 5GMF continues the study of these use cases to elaborate further probable use scenarios in future.

C. *Framework of '5G' system*

In 20BAH, fundamental framework of '5G' mobile communication systems was studied. Considering the use cases mentioned above, it was concluded that the framework consists of several aspects such as: providing relatively higher throughput (faster, stable and comfortable communications) to the 'average' users (compared with that of '4G' system), increased capacity that is supporting extremely dense (and could be temporal) traffic happens e.g. in sports stadiums, and coverage expansion by enabling radio communication services with reasonable level in very sparse areas in an efficient and economic manner. Fig.6 [4] illustrates a framework of '5G' applying user density as horizontal axis and expected user throughput under typical traffic conditions as vertical axis respectively. Compared to a well-known illustration for '4G' system in [5], in which axes chosen there were 'peak useful data rate' and 'mobility', the framework of '5G could be regarded as more conscious of user experiences.

In order to realize the framework, it is considered that a system with a new radio access technologies (new RAT(s)) tightly coupled to enhanced LTE-Advanced (to be enhanced from LTE-Advanced) would be promising one. As a whole radio communications system, '5G' would involve radio local area networks (RLAN, also known as WLAN stands for Wireless LAN) or Broadband Wireless Access systems (BWA) by way of interworking schemes and should support variety of use cases properly and cost effective manner (Fig. 7 [4]).

D. *Required capabilities of '5G' system*

Required capabilities of '5G' are being investigated in 5GMF based on study results accomplished by 20BAH. The study results show several useful observations of the capabilities referring to '4G' system's capabilities as references (Fig. 8 [4]). It should be noted that Fig. 8 connects all the expected maximum capabilities of each axis associated to variety of use cases and it does not mean these maximum capabilities should be satisfied as a set simultaneously at every use cases. Fig. 9 [4] picks up some scenarios as examples and shows their corresponding required capabilities expected. Once again the theme of '5G' system is to provide proper capabilities in flexible and cost effective manner since required capabilities vary considerably depending on the use cases in question.

In the examples shown in Fig. 9, three elements of 'User throughput', '(User-plane) latency' and 'Mobility' are applied as capability indexes as examples. In case different factors are chosen, the chart would have different view. More importantly,

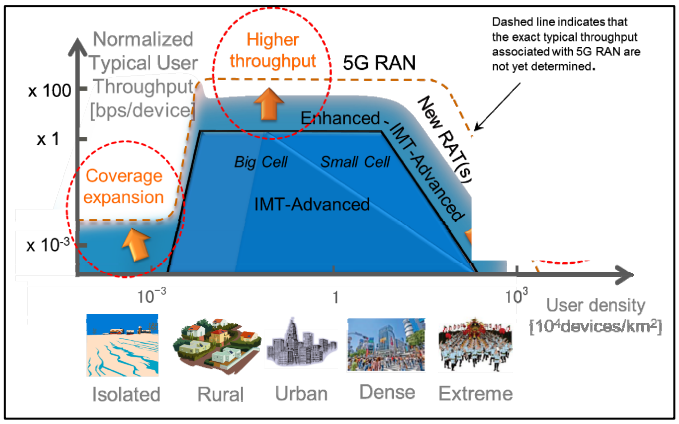

Fig. 6 Framework of '5G' [4]

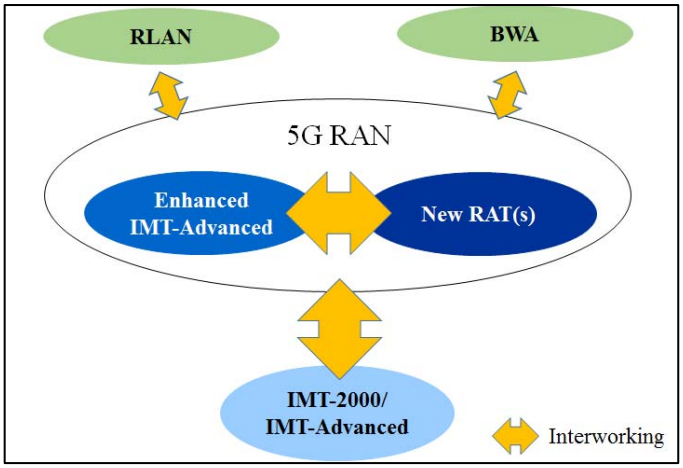

Fig. 7 Interworking of '5G' RAN and multiple RATs [4]

the chart does NOT say that providing Machine-to-Machine (M2M) type communications would be easier or simpler than the others because of its smaller triangle. For the case of M2M scenario, every radio module should have to operate extremely longer time without replacing the batteries. As such, every scenario may have different types of challenges of its own.

E. *Frequency spectrum related studies towards '5G'*

Towards '5G', several primary studies of radio frequency bands have been carried out in 20BAH and they are succeeded by 5GMF. In order to get higher speed or wider bandwidth communication services available, utilizing wider radio spectrum bandwidth would be one of the attractive solution in '5G' era.

In '4G' system (LTE-Advanced), it applies so called 'Carrier Aggregation (CA)' technology which uses multiple frequency bands simultaneously either or both in down link and uplink. In CA cases, up to five component carriers of maximum 20MHz bandwidth each are aggregated and forms (at most) 100MHz bandwidth communication link. As an implementation challenge, getting wider communication bandwidth by aggregating more component carriers will require more cascaded RF (radio frequency) filters, e.g.

diplexers or duplexers, in receivers and transmitters in the system and inevitable insertion losses of the RF signals in the receivers or transmitters chains cause degraded receiver sensitivities or extra power consumption there.

In order to eliminate these fundamental losses caused by the RF signal combiners, applying single wider (continuous) radio spectrum and forming a wider single communication link would be a useful way. Since it is difficult to get a frequency band of several hundred MHz width or more in UHF band (RF carrier frequency ranging from 300MHz to 3GHz), it is envisaged that utilizing higher frequency spectrum either in SHF (3 to 30GHz) or lower part of EHF (30 to 300GHz) would be attractive despite several technical challenges there.

The technical challenges foreseen in these higher frequency bands are: elaborating design method of mobile radio communication link taking into account radio propagation characteristics in these bands, developing small and inexpensive RF devices or components, and signal processing technologies handling extremely wideband signals in base band regions.

As a part of starting investigation in these areas, Fig. 10 [4] summarizes more than 100 research results of semiconductor devices for power amplifiers in SHF or EHF band and shows their saturation output power levels in these frequency bands.

F. Radio access technologies for '5G'

'5GMF' is studying radio access technologies (RAT) applicable for '5G' utilizing comprehensive preparatory study outcomes from 20BAH. In 20BAH, candidate technologies of '5G' RAT(s) were studied (See Fig. 11[4]) and categorized into groups that would be useful or necessary to provide the following aspect. Item 1 to 7 in the list below were based on the subjects captured in an ITU-R recommendation M.2320 [6].

1) *Technologies to enhance the radio interface.*
2) *Technologies to support wide range of emerging services.*
3) *Technologies to enhance user experience.*
4) *Technologies to improve energy efficiency.*
5) *Terminal Technologies.*
6) *Network Technologies.*
7) *Technologies to enhance privacy and security*
8) *Technical studies on millimeter wave and centimeter wave.*

Taking "technologies to enhance the radio interface" as an example, several technologies such as Non-orthogonal multiple access [7], 3D (three dimensional) Massive MIMO (multiple input/output) [8] or splitting control (C)-plane and user data (U)-plane between macro-cell layer and small-cell layer in the overlaid cellular networks [9] are involved and considered as technologies to enhance the radio interface of '5G'. As the successor of these study outcomes, 5GMF is elaborating further studies of these technologies considering actual requirements derived from variety of use cases.

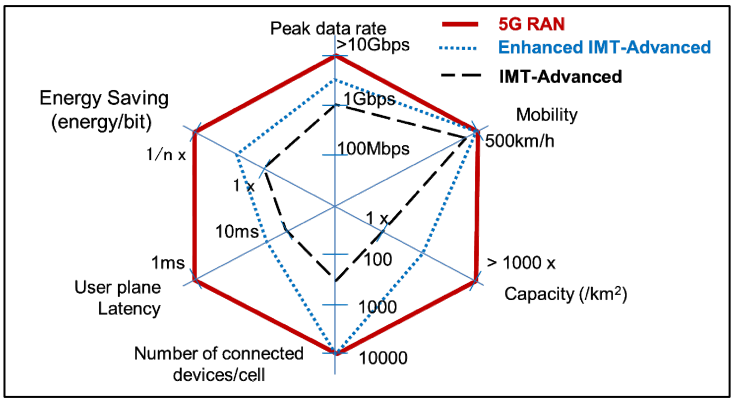

Fig. 8 Maximum system capabilities [4]

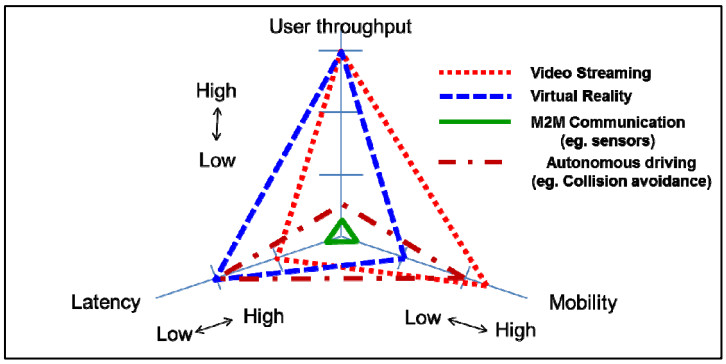

Fig. 9 Required capabilities vs. use cases [4]

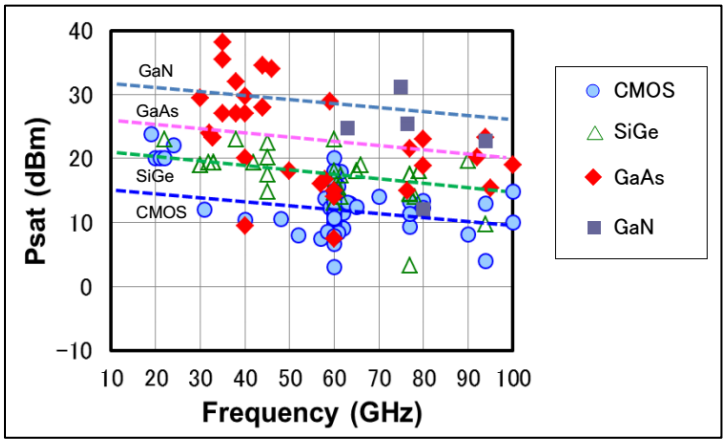

Fig. 10 Semiconductor devices for higher spectrum [4]

G. 'Heterogeneous network' in '5G' RAT(s)

'Heterogeneous network' is considered as one of the key technology in '5G' mobile radio communications system so as to serve variety of use cases in flexible and cost effective manner. In the study of 20BAH, it categorized heterogeneous network scheme (or technology) as a technology to 'enhance the radio interface' [4]. By consolidating new '5G' RAT(s) and 'non-cellular radio access technologies' such as RLAN (Wi-Fi)

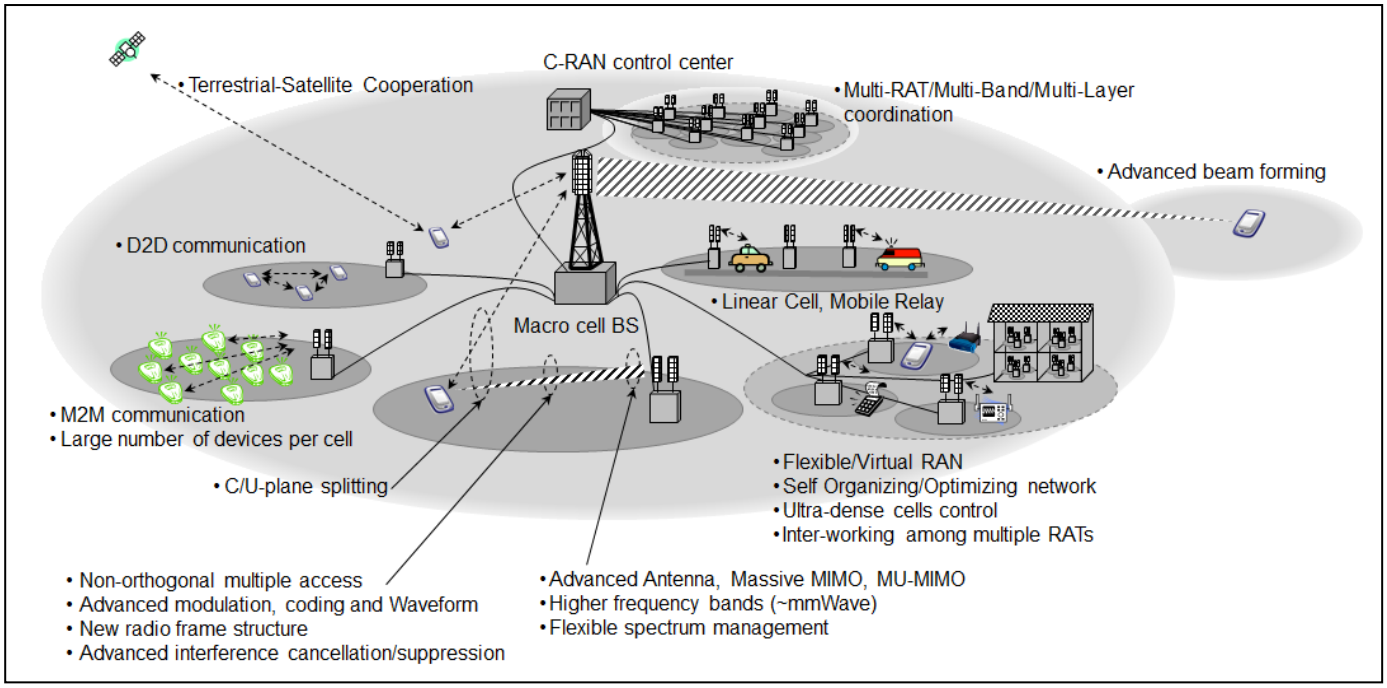

Fig. 11 Overview of '5G' Radio Access Technologies [4]

together with centralized or distributed control schemes, '5G' system would provide flexible scheme to choose most suitable radio access technology according to each use case or required QoS.

Studies on heterogeneous networks is going on in 5GMF and one of the promising idea would be gathering plural radio access technologies under C/U split scheme and allowing not only the existing 'mobile telephone services' but also enriched network services in private networks as well, where variety of network types with different communication speed, different levels of security or priority control schemes will be required.

III. Conclusion

Ongoing study activities towards '5G' mobile communication systems in 5GMF are introduced together with their preceding researches accomplished by 20BAH in ARIB.

One of the main goals of '5G' is to establish mobile communications system capable to the foreseen communication traffic load which quantity will be extremely large and its quality will be largely spread out. It means that '5G' should comply with 'diverted' and variety of demands covering very heavy traffic in dense area such as sport stadiums with several thousands of users as well as sparse area where fewer and seldom traffic is observed. Accordingly capabilities of '5G' should span all of these requirements in different use cases in a flexible and cost effective manner.

Considering the demands for higher traffic density or high speed transmission, it would be useful to consider developing new radio access technologies capable to handle wider transmission bandwidth of several hundred MHz or more and utilizing higher frequency spectrum either or both in EHF or SHF.

Heterogeneous network scheme will be a key factor in '5G' and will have an important role there. It will enable combining the new radio access technologies and other radio access networks (e.g. RLAN or BWA systems) in a sophisticated manner and consolidate them in an efficient way.

5GMF will continue its effort to establish '5G' mobile radio communication networks which will be one of the fundamentals to realize vital and matured social activities in 2020s.

References

[1] "Final Report from the Radio Policy Vision Council", Ministry of Internal Affairs and Communications, Japan, December 2014.

[2] S. Yoshida, "5GMF activities to implement the 5G mobile communications systems towards 2020 and beyond," The 18th Meeting of the APT (Asia-Pacific Telecommunity) Wireless Group (AWG-18) 9 - 13 March, 2015 Kyoto, Japan.

[3] "Mobile communication traffic in Japan," Data base of ICT statistics, Ministry of Internal Affairs and Communications, Japan, Apr. 2015.

[4] "Mobile Communications Systems for 2020 and beyond," ARIB 2020 and Beyond Ad Hoc Group White Paper.

[5] "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000," Rec. ITU-R M.1645-0, June 2003.

[6] "Future technology trends of terrestrial IMT systems," REPORT ITU-R M.2320-0, Nov. 2014.

[7] Y.Saito, Y.Kishiyama, A.Benjebbour, T.Nakamura, A.Li, and K.Higuchi, "Non-Orthogonal Multiple Access (NOMA) for Cellular Future Radio Access," Proc. IEEE 77th Vehicular Technology Conference (VTC2013-Spring), pp. pp.1-5, 2-5 June 2013.

[8] S. Suyama, J. Shen, T. Obara, M.Sumi, M Nakajima, and Y.Okumura, "Basic Performances of Super High Bit Rate Massive MIMO Transmission Using Higher Frequency Bands", IEICE Tehnical Report, RS2013-348, Mar. 2014 (in Japanese).

[9] NTT DOCOMO, "Requirements, candidate solutions & technology roadmap for LTE Rel-12 onward," 3GPP RWS-120010, June 2012.