5G Key Technologies: Identifying Innovation Opportunity

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Abstract—**The "not yet officially defined" 5G standard leads to the consequence that its relevant technological innovation is still widely open. For identifying innovations opportunity, we should discover the specific technical area to contribute to the technological development of 5G. This paper dicusses a framework answering the main question: In which technological area one may contribute to the innovation? The answer shall benefit countries, firms, universities and research institute which intends to contribute to the formulation of official 5G standard.**

First, we reviewed the key technologies of 5ᵗʰ generation mobile communication technology (5G). Ubiquitous and interoperability of the network are main technical focus. A flat IP-based network concept was reviewed, as well as cognitive radio technology to reach the terminal which have artificial intelligence. BDMA technology was proposed to help achieving system efficiency in terms of multiple access system. Second, we identified technological challenges, focusing on the issues related to security and problems to deal with limited frequency spectrum resources. Subsequently, we mapped the innovation opportunity based on technical area which is recently published in research article. We concluded that innovation opportunities lies on the research regarding security, network, technological implementation and applications issues.

Keywords—5G; innovation; standard

I. INTRODUCTION

Today, changes in the realm of telecommunication technology have occurred and will remain happening. Mobile telecommunication grows from first generation, known as 1G, to 2G, 3G, and now to the fourth generation that still in implementation stage in several countries, 4G. Every generation of technology have several differences and innovations.

5G is a terminology that is used for the 5th generation mobile technology. Telecommunication companies or standardization bodies of telecommunication such as 3GPP, WiMax Forum, or ITU-R haven't issued the official standard for 5G [1]. The absence of official standard makes the 5G have limitless possibilities. However several expectations have been raised about how 5G should and will be.

The 5G technology is expected to complete the 4G technology and provide solutions to the shortage arising from 4G technology. This technology will be a new technology that makes users able to access different Radio Access Technologies (RATs) using one mobile [2]. 5G has been proposed to assemble the existing wireless and wired communication techniques into an all IP (Internet Protocol) high performance world wide network [3]. 5G technology will help perfecting World Wide Wireless Web (WWWW) [4]. WWWW itself is an attempt to create a circumstance where subscriber can savor the great quality and quick access of internet, dynamic movement, favorable Bit Error Ratio (BER) and great security as on wired communications in their wireless communication devices. Limitations of frequency resources making 5G shall have a technical development, which uses other resources than frequency/time resources in order to increase a capacity of the system [1].

In this paper, we try to identify innovation opportunity of the 5G technological development. It explored the fundamental literature framework to answer a question: in which technological area one may contribute to the innovation? The answer shall benefit countries, firms, universities and research institute which intends to contribute to the formulation of official 5G standard.

The second section of this paper provides the review of the key technologies of 5th generation mobile communication technology (5G). The third section presents our identification of technological challenges, focusing on the issues related to security and problems to deal with limited frequency spectrum resources. In the fourth section, we mapped the innovation opportunity based on technological area which is recently published in research article.

II. REVIEW OF 5G KEY TECHNOLOGIES

There are several key technologies which are expected to help fulfilling the need of improvement for 5G. Those are Flat IP Based Network and Cognitive Radio (CR).

A. Flat IP Based Network

Previous works by Toni Janevski from University Sv Kiril I Metodij define the basic concept of 5G mobile network which is seen as user-centric concept instead of operator-centric as in 3G or service-centric concept as seen for 4G. The 5G mobile phone is designed as an open platform on different layers, from physical layer up to the application [5].

The network layer at 5G networks will be divided into several sub-layers to provide all-IP connectivity anywhere and anytime. The use of the Internet Protocol (IP) in the network layer is inevitable, given the IP system is the best and most used system to support and expand the network layer nowadays. All IP Network (AIPN) system has started well since the development of LTE.

All IP Network (AIPN) system has started well since the development of LTE as an an evolution of the 3GPP system. Flat IP Network is a key concept that is expected to make 5G acceptable to all kinds of technology [1]. Flat IP architecture provides a way to identify each device using symbolic names, unlike the hierarchical architecture commonly used in the usual IP address [1]. With the shift to flat IP architectures, mobile operators will be able to [1]:

- Reduce the number of network elements in the data path, thereby reducing operations costs and capital expenditure.

- Splitting the cost of service delivery from the amount of data that is sent to equate infrastructure capabilities to the requirements of emerging applications

- Minimize system latency and enable applications with a lower tolerance for delay; upcoming latency enhancements on the radio link can also be fully realized.

- Evolve radio access and packet core networks independently of each other to achieve greater development and make better flexibility in network planning and deployment.

- Develop a flexible core network that can be the basis of innovative services for mobile and generic IP access network.

Create a platform that will enable mobile broadband operators to be competitive with wired networks in terms of price and performance.

IPv6 is the best possible system that can support a flat IP network for technology implementation 5G later. IPv6 is the latest revision of the IP system is expected to overcome the shortcomings of the predecessor version of IPv4. Each device will then have a fixed IPv6 address, and multiple addresses Care of Address (CoA). The number of CoA for the device is according to the number of access networks where device is connected. There are 3 sub-layers of the network layer, the lower network layer, middleware layer and the upper network layer. Lower network layer use CoA, middleware network layer translates CoA into IPv6 so the upper network layer using IPv6 addresses.

Device is expected to be provided by a variety of options in order to get the best wireless connection in accordance with the type of device and current network conditions. QoS parameters such as delay time, jitter, bandwidth, reliability and so on will be stored in a database that can be used for training intelligent algorithms in a mobile terminal, thus the 5G technology can choose the best connections for the device at the given time and condition.

B. Cognitive Radio

For mobile and wireless communications technologies, since the 4G, interoperability was an important thing, as it is also applied for 5G. Interoperability system means any system with different technologies can work together and communicate with each other. The network architecture for 5G mobile system consists of a user terminal and a number of independent, autonomous radio access technologies [6]. Within each of the terminals, each of the radio access technologies is seen as the IP link to the outside Internet world [6]. With the use of cognitive radio terminal, 5G can achieve interoperability and still have a good quality of service. In the cognition system, the system recognizes the location, position and condition to determine the best option for network. With this system, users can choose a suitable network for communication and different wireless networks will be able to integrate and communicate with each other via cognitive radio devices.

Cognitive radio is an intelligent communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind: highly reliable communication whenever and wherever needed; efficient utilization of the radio spectrum [7].

By that definition, the cognitive terminal is a smart terminal with intelligence to choose the proper network from all the existing wireless networks [5]. The choice is based on some information such as time, demand, and resource. The 5G technology proposes a universal terminal, which should include all of the radio predecessors features into a single device [5]. This terminal convergence is strongly sustained by the users' needs and demands; therefore, cognitive radio becomes the ideal 5G terminal candidate [5].

III. TECHNOLOGIVAL CHALLENGES

By understanding the key technologies of 5G, we identified the technological challenges which mainly lie on the problems concerning security as well as limited frequency resources.

A. Security

Being able to scan the available spectrum, select from a wide range of operating frequencies, adjust modulation waveforms, and perform adaptive resource allocation– all of these in real-time– these new Cognitive Radio technology will be able to adapt to a wide variety of radio interference conditions and adaptively select the most efficient communication mechanisms [8]. However, in addition to the advantages and potential of the cognitive radio technology, there are a number of challenges related to security, especially in cognitive radio terminals. The paradigm of cognitive radio systems poses a new threat on security, such as selfish misbehaviors, harmful interference, licensed user emulation, competition between licensed users and eavesdropping [9].

There is an opportunity and need to develop a system that able to prevent the misuse in the highly open and granular

control which is provided to the radio interface. One of them was proposed by [8] with a framework known as TRIESTE which is short term for Trusted Radio Infrastructure for Enforcing SpecTrum Etiquettes. TRIESTE will be able to ensure that radio devices are only able to access and use the spectrum in a manner that conforms to their privileges [8].

B. Limited Frequency Spectrum Resources

Limited spectrum resources yielded a major challenge for mobile and wireless technologies. Those limited frequency and time are divided to be used among multiple users. Due to this condition, it is expected to improve efficiency in order to enhance the capacity and quality of the system. To achieve this, several multiple access techniques used today, for example, Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), etc. However, in all of multiple access system that are used nowadays, the capacity of a mobile communication system depends on time and frequency. This generates a challenge to develop a multiple access system which is able to resolve the dependencies of capacity to the limited frequency spectrum. Korean research and development has suggested BDMA as a radio interface for 5G, which is not depended on frequency/time resources [1].

The BDMA technique of the present invention divides an antenna beam according to locations of the mobile stations to allow the mobile stations to give multiple accesses, thereby significantly increasing the capacity of the system [1]. In such a concept, mobile stations and a base station are in a Line of Sight (LOS) state, so they exactly know each other's positions. In this condition they will be able to transmit beams which direct to each other's position to communicate without interfering with mobile stations at cell edge [1].

For adapting the BDMA system into 5G, the development of the phase array antenna is required. The smart antenna with the ability to switch its beam is needed. Switched beam antennas support radio positioning via Angle of Arrival (AOA) information collected from base and mobile stations. The use of adaptive antenna arrays is one area that shows opportunity for improving the capabilities.

IV. INNOVATION OPPORTUNITIES

Opening up innovations opportunity means to discover the technical area as the guidance to conduct research work on such particular technological agenda. We monitored the spread of technical issues related to 5G in various scientific and engineering journals. There are 18 research articles which have stated 5G as the main corresponding topic in their research work. Those publications include 7 conference papers, 7 journal papers, 3 conference reviews and 1 document review.

Subsequently, we map the technical area based on 40 keywords mentioned in those 18 research articles. Table 1 lists the keywords and the corresponding number of research articles. In general, it mainly indicates that technical area is not yet heavily concentrated on certain technological agenda. However, more researches were conducted concerning topics of relay selection, mobile ad hoc network and one hop cooperative MAC, while other topics are equally distributed.

We identified that the keywords are likely relevant to three technological agenda, i.e. security, network, and technological implementation and applications issues.

TABLE I. KEYWORDS ON 5G RESEARCH PUBLICATIONS

Keyword on the research articles	Number of research publications
Relay selection	4
Mobile Adhoc Networks (MANETS)	3
One-hop cooperative MAC	3
Ad hoc On-Demand Distance Vector (AODV)	2
Architecture for humanity	2
Blacklisting	2
Dnynamic Source Routing (DSR)	2
Error Vector Magnitude (EVM)	2
GNU Radio	2
Multihop wireless network	2
Orthogonal space time codes	2
Prognoses	2
Remote monitoring	2
Two-hop cooperative communication	2
Universal Software Radio Peripheral (USRP)	2
Wireless optics	2
All IP networks	1
Collision avoidance	1
Constellation sizes	1
Cooperative protocols	1
Core networks	1
Denial of Service (Dos)	1
Dense network	1
Heterogeneous networking	1
Linear complexity	1
MIMO channels	1
Modulation technique	1
Multi-hops	1
Network achitecture	1
OFDM systems	1
Packet delivery ratio	1
Parallel transmission	1
Piraeus	1
Service oriented architecture	1
Space diversity	1
Space time code	1
Spatial diversity	1
Spectrum efficiency	1
Throughput improvement	1
Ubiquitous and pervasive computing	1

Security technological agenda spreads over collision avoidance, Denial of Service (DoS), blacklisting, etc. Meanwhile, network technological agenda consists of protocol, all IP network, ad hoc network, etc. Some other technological agenda that remain being the most researched topic are frequency hopping topic, MIMO system, space time codes, relay selection techniques, multi hop systems, etc. There are also a few of topics other those main topics, which are covering about implementation of the proposed 5G applications, such as

implanted medical devices, remote monitoring and telemedicine.

Based on those findings, we may formulate the concept to exploit opportunity on certain technological agenda. Researchers may work on those specific areas, which can lead to new innovation on 5G. Such a concept is mainly benefit the developing country which intends to increase their innovation and technological competitiveness. For example, since relay selection has been frequently researched, a new researcher may establish the cooperative work with other researchers working on that field. As in the future, wireless network is forecasted will able to support the relay-based communication, where the relay node is well-placed to receive messages from the source node, process it, and then forward it to the node of its intended destination [10]. Alternatively, developing country can put more concentration on another topic such as spatial diversity, AODV, or technique to improve collision avoidance, since the works on those fields are relatively less conducted.

As the continuous upgrading of wireless technologies, the basic concept of 5G is to open up all the doors of possible methods, technologies and techniques used to leverage telecommunication for human life. Combining with the perspective of 5G key technologies, in particular about flat-based IP and cognitive radio, any researchers may contribute to the development of relevant standard. Such research activities are not only to improve faster data access, but also to create innovation on many technical areas as shown in Table 1.

Finally, it is commonly known that technological development of preceeding standards (1G, 2G and 3G) were dominantly controlled by developed countries such as USA, Japan and some European countries. Therefore, in current and future time, developing countries should contribute to 5G technological development by utilizing innovation opportunities. Results of research works on 5G can be made into technical submission to the international standardization bodies, such as ITU. Meanwhile, developing countries can also push their national industries to develop patents and to create innovation on relevant 5G technical areas. It is believed that those schemes may influence the global standards development and increase the country's competitiveness.

V. CONCLUSIONS

Key technologies in the seam of 5G has been reviewed, i.e. Flat IP Based Network and Cognitive Radio. The key technologies help us to spot the 5G technological challenges.

The challenges mainly exist in the security area and the limited frequency resources problem.

We have identified innovation opportunity regarding the technological development of 5G standards from understanding technological challenges and exploring fundamental literature framework. There is an opportunity and demand to develop a system that will be able to prevent the misuse of control, maintain the security and enhance the capacity of system. As the result of exploring literature framework, we conclude three technological agenda in which one may contribute to, i.e. security, network, and technological implementation and applications issues. Accordingly, researchers can make new research focusing on those technical area and make new innovation for the 5G technological development. It is expected that research works may result a relevant submission to the international standardization bodies. On the other hand, innovation can be also made by pushing national industries to develop patents and to create innovation on such relevant 5G technical areas.

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