# Opportunities and Challenges for Semiconductor Industry in the 5G Era

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**Abstract:** The rapid development of 5G communication technology has brought development opportunities to a series of new applications, such as Internet of Things and autonomous driving. While 5G brings opportunities to the semiconductor industry, it also brings a series of challenges. In this paper, we outline the opportunities and challenges faced by the semiconductor industry in the 5G era. Our findings in this paper give directions for the development of the semiconductor industry in the future.

## 1. Introduction

The history of mobile communications can be traced back to the 19th century. In 1864, Maxwell theoretically proved the existence of electromagnetic waves. Since then, a new era of radio communication started to take off. The history of modern mobile communications from the early 1920s to the present can be roughly divided into five stages. The first generation of the mobile communication system, i.e., 1G, began in late 1978, when Bell Labs in the United States developed the Advanced Mobile Phone System (AMPS). By the mid-1980s, many countries began to build 1G systems based on technologies including Frequency Division Multiplex Access (FDMA) and analog modulation. The second generation of the mobile communication system, i.e., 2G, uses digital transmission technology to improve confidentiality. There are two types of 2G systems, which are based on two different technologies, namely, Time Division Multiple Address (TDMA) and Code Division Multiple Access (CDMA). Because of the technical challenges introduced in the third generation, a transition of 2.5G appeared before the emergence of 3G, which utilized High-Speed Circuit-Switched Data (HSCSD), Wireless Application Protocol (WAP) and Bluetooth. Driven by the development of mobile networks and the demand for data transmission speed, 3G entered the stage of history, as expected. Soon after, due to the increasing demand for data transmission and sTable connection, 4G has entered our daily lives in recent years. The peak speed of 4G reaches 100 Mbit/s in high-speed mobile scenarios, e.g., on a train or a bus, and 1 Gbit/s in static or low-speed scenarios, e.g., walking or sitting in a cafe.

During the same time period, there are continuous advances in the semiconductor industry. In 1833, Michael Faraday reported that the resistance of specimens of silver sulfide decreases when they are heated. This is contrary to the behavior of metallic substances such as copper and is the first discovery of semiconductor’s unique property. In 1839, the French Alexandre Edmond Becquerel first discovered the photovoltaic effect. The photovoltaic effect is the creation of voltage and electric current in a material upon exposure to light and is a physical and chemical phenomenon. This is the second characteristic of semiconductor. In 1873, In 1873 Willoughby Smith observed that selenium resistors exhibit decreasing resistance when light falls on them, which is the photoconductive effect. This is the third feature. Based on these physical features of semiconductor, scientists and engineers began to put semiconductor into practice. On November 16, 1904, the British scientist John Ambrose Fleming invented the world's first vacuum tube, which is a device that controls electric current flow in a high vacuum between electrodes to which an electric potential difference has been applied. Then John William Mauchly and J. Presper Eckert designed Electronic Numerical Integrator and Computer (ENIAC), which is the first general purpose electronic digital computer. These early computers require a huge room to store and a huge

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electricity to operate, while their computing abilities are quite limited. On December 23, 1947, the first transistor was invented in the Bell Labs, marking the beginning of a rapidly evolving electronic age. In December 1960, the world's first silicon-based integrated circuit was successfully manufactured. In 1968, Robert Noyce and Gordon Moore established the company Intel. 1970, Intel invented the first Dynamic Random Access Memory (DRAM). Power by the increasing popularity of semiconductor devices, personal computers become widely adopted in the 1990s. In the 21st century, the demand for semiconductor devices keep increasing because of the huge market of smart phones, Tablet devices, autonomous vehicles. The progress of the mobile communication also contributes to the rapid development of the semiconductor industry. Not only the base stations, but also the mobile terminals consume a large amount of semiconductor devices.

In this paper, we would firstly summarize the technical progress of 5G mobile communication in Section 2. In Section 3, we summarize the opportunities of semiconductor industry brought by the applications in 5G mobile communication. Then we summarize the challenges of semiconductor industry in Section 4. We conclude this paper and point out the future research directions in Section 5.

## 2. Progress of 5G mobile communication [1]

### 2.1 Technology Features of 5G Mobile Communication

The 5G system will go beyond the concept of a mobile communication system and become an end-to-end ecosystem that enables a high degree of network fusion. It is a heterogeneous network environment with multiple access technologies, multiple layers of networks, multiple devices and multiple user types. 5G is designed to provide a seamless and continuous user experience beyond the time and space constraints.

According to the 5G demand analysis, Next Generation Mobile Networks (NGMN) gives the 5G design principle:

(1) Cost-effective and densely arranged;
(2) Support the dynamic wireless topology;
(3) Simplify the core network, e.g., using the SDN technology;
(4) Use network slicing to improve the flexibility of the system;
(5) Encourage the creation of value and reduce the complexity of new business deployments;
(6) Protect the privacy of users;
(7) Simplify operation, maintenance and management.

The demand for 5G will come from the users and the network itself. The user's demand comes from the Quality of Experience (QoE) improvement, which is represented by the reliability and transmission speed of the connection, mobility support, seamless user experience and context-aware ability. The demand of the network includes the requirements of automated network operation and flexible implementation. The four most important features of 5G include high speed, ubiquitous network, low power consumption, and low latency.

In short, 5G is a revolution. Driven by various technologies, 5G extends from the connection of people to the Internet of everything, from individuals and families to all aspects of society, revolutionizing the economy and our daily life.

### 2.2 Current Progress of 5G Deployment

In this part, we give a summary of current progress of 5G deployment in different countries.

#### 2.2.1 China

China has invested in a 5G national action plan to support its R&D and deployment through the support of the central government. Since 2015, 5G investment has been organized nationwide through three state-owned mobile operators, namely, China Mobile, China Unicom, and China Telecom. By 2020, 5G's extensive commercial launch will target the country's latest five-year plan. China's telecom operators are automatically committed to achieving these goals. In December 2019, 5G operating licenses were issued to all three mobile network operators. The government strongly supports the 5G industry in order to bring more efficient use and technical progress to bring more convenience to people's lives in the future.

### 2.2.2 United States

There are four major mobile network operators (AT&T, Verizon, Sprint, and T-Mobile) in the United States. The 5G plans of these companies will guide the development of 5G in the US in the next few years. All four major operators have begun trials of 5G and plan to put 5G into use officially by the end of 2019.

### 2.2.3 Japan

Since 2014, the government has adopted the 5G roadmap in 2016 and is committed to release more spectrum. Ministry of Internal Affairs and Communications (MIC) has invested about 300 million dollars to promote 5G and future technologies, such as the Internet of Things, robots, etc.

### 2.2.4 South Korea

South Korea's ICT industry policy requires early adopters to support high-tech exports, so its industry and government are now positioned to try to lead commercial 5G products to achieve global sales. To support the early launch of 5G mobile services, the spectrums in the 3.5 GHz and 28 GHz bands were auctioned in June 2018. The government intervenes to open up the major bands which are needed for 5G. In addition, the Ministry of Science and Information and Communication Technology (MSIT) is committed to provide mobile network operators with unrestricted tax benefits if they jointly launch 5G and share a common network. Samsung has announced that it will provide operators with 5G hardware to accelerate the 5G deployment.

## 3. Opportunities of Semiconductor Industry in 5G Era [2, 3]

### 3.1 5G Baseband Chips

The development of 5G has created a huge demand for baseband chips. At present, this field has formed a cruel competition situation. In April 2019, Apple and Qualcomm reached a settlement that Qualcomm will provide baseband chips for Apple's future iPhone. While Intel, whose role is another baseband chip supplier for iPhone previously, officially announced its withdrawal from the 5G chip business of smartphones and a future focus on the development of 5G infrastructure, which include computers, the Internet of Things, and data-centric 5G devices.

### 3.2 Internet of Things

The Internet of Things emphasizes ubiquitous network connectivity, placing a huge demand on low-power and long-connected chips [4, 5]. In the 5G application scenario, network connectivity has become ubiquitous, and how to further reduce the power consumption of the chip has become a more critical issue in promoting the development of the Internet of Things. Specifically, the Internet of Things brings the following requirements to the field of chip design:

(1) Ultra-low-power device design for sensing, information processing, storage, and communication in sensor nodes and networks;

(2) Flexible or other non-traditional materials and equipment used in the large area sensor network or machine learning tasks;

(3) Materials and equipment for size or weight-limited platforms for energy generation, removal, storage, and management;

(4) Complementary Metal-Oxide-Semiconductor Transistor (CMOS) devices and materials for terahertz communication.

### 3.3 Autonomous Driving

5G communication enables a big step forward for the implementation of autonomous driving. A continuous network connection allows autopilot vehicles to update road information, traffic information and weather information in real time, to plan better driving routes. In order to achieve the real autonomous driving, chips for sensor technology, vehicle electronics, and automotive computing are essential [6].

On the other hand, the demand for computing chips in the autopilot computing task is mainly divided into computing power, real-time performance, reliability, and algorithmic generality. The need for computing power needs to consider the amount of data in the information flow on the one hand, and the processing of information on the other hand. Autopilot requires both a general algorithm processor and a dedicated algorithm processor. The general-purpose algorithm processor is highly adaptable and can be used to process various computing tasks, such as Advanced RISC Machine (ARM) and X86 CPU; the dedicated processor is used for professional computing tasks, such as GPUs with large machine learning advantages, Field Programmable Gate Array (FPGA). As the traffic condition changes rapidly, whether the computing chip can meet the real-time requirement of autonomous driving is also an important issue.

### 3.4 Information Security

While bringing people a convenient life, 5G also makes more and more digital traces recorded and stored. These digital traces contain a lot of private information. Although we can protect these private data with passwords, encryption software, etc., the encryption chip will be a more fundamental solution. Therefore, the rise of 5G will also promote the development of encryption chips.

## 4. Challenges of Semiconductor Industry in 5G Era

### 4.1 Technical Challenge

#### 4.1.1 Technical standards

There is no uniform standard for 5G communication until the first 5G standard was officially frozen in June 2018. During this period, 5G research and development has to be carried out while participating in and interpreting the new 5G standard. This will lead to a significant increase in the risk of 5G development, which may result in non-compliance with the new standard after the product development is completed.

#### 4.1.2 Multi-band compatibility

The 5G chip needs to ensure compatibility support for multiple communication modes of TD-LTE, FDD-LTE, TD-SCDMA, WCDMA, and GSM, and also needs to meet the requirements of the operator's SA network and NSA networking. Multi-band compatibility also increases design complexity. The 5GNR spectrum developed by the 3GPP has 29 frequency bands. These frequency bands include some LTE frequency bands and some new frequency bands. Moreover, the frequency bands of different countries and regions are also different, so the 5G baseband chip that the chip manufacturer needs to launch needs to be a general-purpose chip, which can support different frequency bands in different countries and regions. The requirement for multi-frequency compatibility increases the difficulty of designing the chip.

#### 4.1.3 Power Control

In addition to the challenges of the standard and hardware design, power consumption is also a problem that must be considered. The processing power of 5G terminals is more than five times that of 4G, and the problem arises about how to balance power consumption and system cooling. In the future 5G mobile phone, the battery capacity is estimated to be 3000 to 4000 mA, to meet its power consumption requirement. Therefore, when we design chips, we need to reduce power consumption through the improvement of manufacturing technology, and increase battery capacity and charging capacity, e.g., adding the quick charge function.

## 4.2 Commercial Challenge

In the transition from 4G to 5G, many operators will use the same equipment manufacturer to produce 5G-related communication equipment in order to be compatible with 4G equipment and also save costs. This situation has made the industry gradually monopolized by several large equipment manufacturers, and it is increasingly difficult for small and medium-sized manufacturers to survive in the 5G era.

## 4.3 Political Challenge

The 5G communication industry and the semiconductor industry are both pillar industries of a nation, and involve a large number of users' private data, which will cause the public's concerns about national information security. For example, the Japanese government decided to change the equipment made in China to the equipment of European and American companies because of concerns about the safety of Huawei equipment, although this will increase the cost of 5G construction by 100 billion yen [7]. Some countries tend to use equipment and chips made by their own country's manufacturers, even if they do not have the advantage in terms of technology and cost. This guarantees the confidentiality of their own technology, while at the same time maintaining a technological lead to prevent further incursions in other countries.

While providing the most state-of-art products, the United States is trying the suppress the development of other countries, as indicated by the ban of Huawei's products with an excuse of safety issues [8, 9]. This kind of ban would not only cause a huge damage for a small company, but also be fatal to a giant company like Huawei. Similar examples tell us that sometimes, political challenges would be a potential risk for every country who has no core technologies in the semiconductor industry.

# 5. Conclusion

In this paper, we first review the history of mobile communications in different time periods. Then we summarize the technical characteristics of 5G, and then collect the deployment situations of 5G in different countries. We categorized the opportunities and challenges that 5G communication brings to the semiconductor industry. We believe that 5G communication, as an important technology in infrastructure, will promote the development of many types of chips. Because 5G communications involves national security, the semiconductor industry faces not only a range of technical and commercial challenges, but also political challenges that are potential risks for both the company and the government.

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