5G Implications for the Compound Semiconductor Industry

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Abstract

Next generation 5G NR (new radio) technology will create new opportunities for the compound semiconductor industry. As spectrum assets, mobile networks and mobile devices become available across different markets beginning in late 2018 and accelerating in 2019, this paper highlights the timeline for standards completion, spectrum availability, massive MIMO technology, mobile network launches, business use cases, and end user devices and the impact on the demand for semiconductors.

INTRODUCTION

Each new generation of mobile technology introduced undergoes the same process cycle before large scale adoption worldwide can begin. The main process steps are:

1. Standards Completion by the 3rd Generation Partnership Project (3GPP) and the International Telecommunications Union (ITU)
2. Development of modem technology and other RF semiconductors
3. Regulatory adoption on a country and regional basis for associated spectrum
4. Development of end user devices
5. Spectrum auctions/issuance to mobile network operators
6. Deployment of mobile networks
7. Commercial launch of services

5G NR USE CASES

5G technology is the next evolution in mobile networks. With each successive generation of mobile technology, enhancements are targeted for a 100x-1000x increase in performance metrics. The most complicated and misunderstood issues regarding 5G NR technology are the potential use cases. There are three main core areas of technological advances in 5G NR vs. legacy 4G LTE-based technology.

1) Enhanced mobile broadband (eMBB) is an extension of current mobility technology from 4G LTE-based solutions.

2) Ultra reliable and low latency communications (uRLLC) is focused on new business cases including industrial internet of things (IIoT).

3) Massive machine type communications (mMTC) will focus on business cases including Smart Cities and other sensor –based networks including the internet of things (IoT).

Each one of the six key performance metrics shown in TABLE I and Fig. 1 support one or more of the core areas for 5G.

TABLE I
4G LTE VS. 5G NR PERFORMANCE COMPARISONS

Metric	4G LTE	5G NR
Mobile Data Volume	10 Gb/s/km^2	10 Tb/s/km^2
Peak Data Rate	100 Mb/s	10 Gb/s
Mobility	350 km/h	500 km/h
Number of Devices	1K/km^2	1M/km^2
Reliability	99.99%	99.999%
Radio E2E Latency	10 ms	<1 ms

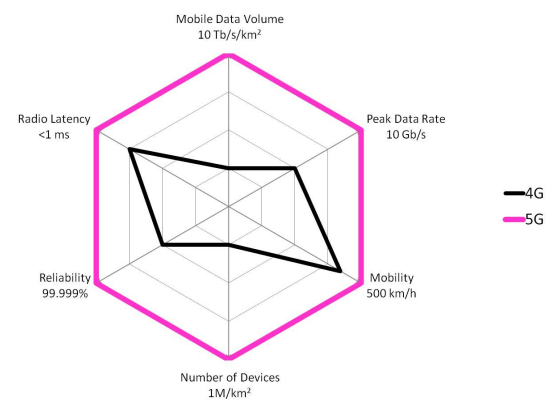

Fig. 1 4G LTE vs. 5G NR Performance Comparisons

The eMBB segment of 5G is dependent on the Mobile Data Volume, Peak Data Rate and Mobility metrics while the uRLLC segment of 5G is dependent on the Radio Latency and Reliability metrics. The mMTC segment is dependent on Number of Devices, Reliability, and Mobile Data Volume metrics.

3GPP Standards Update for 5G Related Technology

This section examines the timeline for 3GPP Rel-15 Phase 1 NSA (non-stand alone) and Phase 2 SA (stand alone) as well as Rel-16 technical specifications. Fig. 2 shows the current standards and commercialization timelines for 3GPP Rel-15, -16, and -17.

There are two versions of the Rel-15 standard:

- Stand Alone (SA)
- Non-Stand Alone (NSA)

The NSA version relies on the use of an existing Long-Term Evolution (LTE) core network that supports both LTE and 5G NR radio access networks (RAN). All mobile operators except for China Mobile are launching NSA 5G networks. China Mobile will be the first mobile operator to launch a 5G SA mobile network.

The Rel-15 Phase 1 NSA specifications were completed at the end of 2017 while the Phase 2 SA specifications were completed in June 2018. The focus for Rel-15 is the enhanced mobile broadband (eMBB) aspects of 5G for both mobile and fixed wireless access (FWA) applications in the sub-6GHz and microwave/mmwave frequency bands.

Rel-16 will allow for new features supporting the uRLLC and mMTC use cases of 5G including C-V2X for vehicular communications.

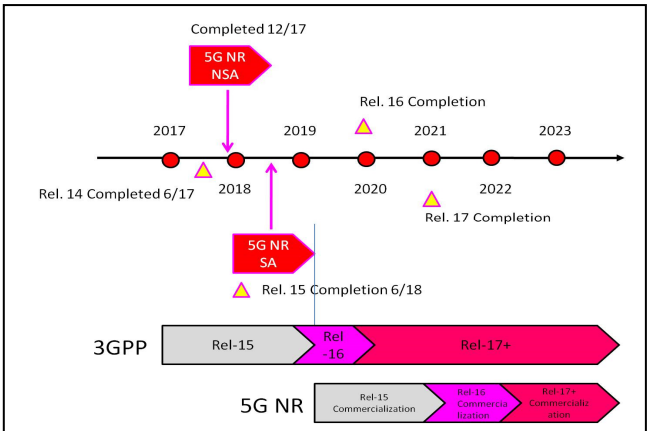

Fig. 2 3GPP 5G Standards Timeline

5G Global Spectrum Policy

5G will push adoption of spectrum usage in both traditional mobile cellular bands <2.7GHz as well as higher frequency bands such as C-Band (3.3-4.9GHz) and microwave Ka-Bands (24-40GHz) in addition to V-Band (60GHz) and E-Band (71-86GHz) and potentially other higher bands. Eventually, all legacy 4G LTE bands will be converted to 5G NR use.

There are three primary frequency bands allocated globally for 5G services (excluding the United States). These are:

- 700MHz (for wide area coverage of uRLLC and mMTC)
- 3.4-3.8GHz (for eMBB coverage)
- 26GHz (for eMBB hotspot coverage)

China will also use 4.8GHz for eMBB coverage.

Mobile operators are expected to launch 5G-based eMBB services using the 3.4-3.8GHz spectrum.

Within the United States, the primary frequency bands allocated for 5G services are:

- 600MHz (for wide area coverage of uRLLC and mMTC)
- 2.5GHz (for eMBB coverage)
- 24/28/37/39/47GHz (for eMBB hotspot coverage)

The 3.7-4.2GHz band is being considered for eMBB coverage by the Federal Communications Commission (FCC).

>6GHz 5G Global/Regional Spectrum Allocation Update

For 5G spectrum >6GHz, the majority of the countries have chosen to focus on the 26GHz frequency band initially with other higher frequency bands under consideration. South Korea and Japan, along with the United States have chosen the 28GHz frequency band. What sets the United States apart from the other countries is that the 24-39GHz frequency bands will be the primary 5G bands for the two largest mobile operators, AT&T Wireless and Verizon Wireless. As such, supply and demand for mmwave semiconductors will a key focus for 5G in the United States.

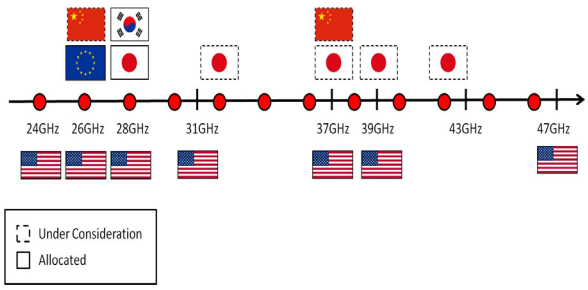

Fig. 3 5G >6GHz Spectrum Allocation Chart

The shift to microwave/mmwave spectrum for 5G access radios will shift demand to compound semiconductor technologies, primarily GaAs and GaN as well as SiGe. As these systems are massive MIMO based, the number of radio channels (typically 32-256) per system will drive significant demand for semiconductor chips.

5G Backhaul Spectrum

While mmwave spectrum is the focus for 5G radio access, it is also the focus for 5G backhaul. Optical fiber will continue to be the primary choice for 5G mobile network backhaul connectivity where available however we believe that there will be many 5G sites that will not be able to connect via optical fiber. In such instances, the use of traditional microwave frequency bands between 5-42GHz may not provide enough through put to support the requirements for 5G sites.

We believe that many 5G sites will be collocated with existing 4G sites and total backhaul requirements will typically range from 5-10 Gbps. To support the higher capacities and throughputs for 5G sites, E-Band point to point radio links operating in the 71-86GHz frequency bands will be the primary wireless solution. Additional frequency bands under consideration across various regulatory agencies include W-Band (92-115GHz) and D-Band (130-175GHz) as shown in Fig. 4.

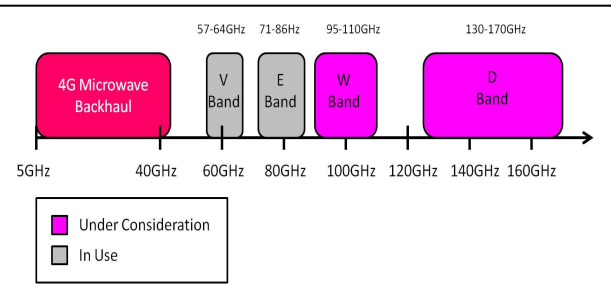

Fig. 4 5G Wireless Backhaul Spectrum Bands

Additionally, the single channel radio architecture of the past will migrate to MIMO and massive MIMO radio architectures with multiple antenna elements. The net impact on compound semiconductors will be more radio channels per system, resulting in more semiconductors and the potential for InP and GaN technologies to displace GaAs technology in the backhaul radio market.

Massive MIMO Impact of Compound Semiconductor Demand for Mobile Networks/Devices

Legacy 4G- LTE-based mobile networks and devices have been based upon the network deployment of non-massive MIMO-based systems including 2x2, 4x4, 8x8 MIMO, coupled with 2x2 and 4x2/4x4 MIMO-based user equipment (UE). The introduction of LTE-Advanced Pro technologies is currently driving mobile network updates to higher order MIMO-based systems (4x4) and devices.

Future 5G NR-based mobile networks will relay on massive MIMO-based systems (16x16, 32x32, 64x64, 128x128 and beyond) using 16-256 RF channels and up to 1,024 antenna elements. These systems will also be primarily deployed using S-Band/C-Band (3-5GHz), K/Ka-Band (24-40GHz) and V-Band (47GHz) frequencies where traditional silicon –based semiconductor solutions are no longer viable.

While it is possible to continue to use silicon LDMOS technology for RF power amplifiers in the 2.5GHz spectrum for massive MIMO systems, we see a technology shift to GaN for 5G massive MIMO systems operating in the 3.4-4.8GHz spectrum bands. A typically 5G massive MIMO system requires 64 transmit channels, resulting in a multiplying factor compared to current LTE-Advanced 4x4 MIMO radio systems of 16x. While overall average power output per amplifier is much lower for 5G systems (3-5W) when compared with 4G systems (40-60W), the total amount of semiconductor material will be a net positive for 5G systems.

The shift to GaN technology is also due to the much wider channel bandwidth requirements of 100-800MHz for 5G compared with 5-20MHz for 4G as well as substantially increased thermal power requirements.

Fixed and mobile end user devices will also rely on massive MIMO technology in primarily C-Band and Ka-Band spectrum. While there are potential silicon/silicon germanium-based RF components being introduced for UEs, we believe that the majority of RF semiconductors will rely on traditional GaAs technology as well as GaN technology for power amplifiers in 5G handsets.

CONCLUSIONS

The conclusion is the 5G NR technology will be a major driver for compound semiconductor usage, primarily GaN and also GaAs for network equipment and for end user equipment.

The key drivers are:

1) Multiplicity impact of massive MIMO radio/antenna architecture

2) Significantly wider channel bandwidths of 100MHz to 800MHz

3) Higher operational frequency bands using C-Band (3-5GHz) and K/Ka-Band (24-39GHz) spectrum

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REFERENCES

N/A

ACRONYMS

3GPP-Third Generation Partnership Project
C-V2X-Cellular Vehicle-to-Everything
eMBB-Enhanced Mobile Broadband
FWA-Fixed Wireless Access
GaAs-Gallium Arsenide
GaN-Gallium Nitride
IIoT-Industrial Internet of Things
InP-Indium Phosphide
IoT-Internet of Things
ITU-International Telecommunications Union MIMO-
LDMOS-Laterally Diffused Metal Oxide Semiconductor
LTE-Long Term Evolution
MIMO-Multi Input Multiple Output
mMTC-Massive Machine Type Communications
NR-New Radio
NSA-Non Stand Alone
RAN-Radio Access Network
SA-Stand Alone
SiGe-Silicon Germanium
uRLLC-Ultra Reliable Low Latency Communications