5G WIRELESS INFRASTRUCTURE SEMICONDUCTOR ANALYSIS

SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

EXECUTIVE SUMMARY

On behalf of SIA, a wireless market intelligence firm has analyzed all of the semiconductor function product families within the key elements of a 5G radio access network (RAN)- baseband unit (BBU) and active antenna unit (AAU)/remote radio unit (RRU) systems for 5G base stations along with the current domestic United States and foreign/international semiconductor suppliers.

Our conclusion is that despite the United States maintaining overall market-share leadership in semiconductors with a 45% share of the global market, substitutes for U.S. components exist for nearly every semiconductor product family required to build a complete RAN infrastructure. In fact, our analysis indicates that of the more than fifty critical semiconductor elements necessary to design, manufacture, and sell a competitive 5G RAN network[1], only 3 components could face supply constraints outside the United States in the event of an export restriction. For each of those three components, we have further concluded that alternatives are currently being deployed or under active development, especially within China by Huawei's semiconductor design arm, HiSilicon.

OUR CONCLUSION FOR THE BASEBAND UNIT SYSTEM FOR A 5G BASE STATION IS THAT THE TWO KEY SEMICONDUCTOR PRODUCT FAMILIES THAT MAY PRESENT SUPPLY ISSUES OUTSIDE OF THE UNITED STATES ARE:

- Commercial off-the-shelf Field Programmable Gate Arrays (FPGAs)
- 10Gbps Ethernet PHY Transceivers/Switches

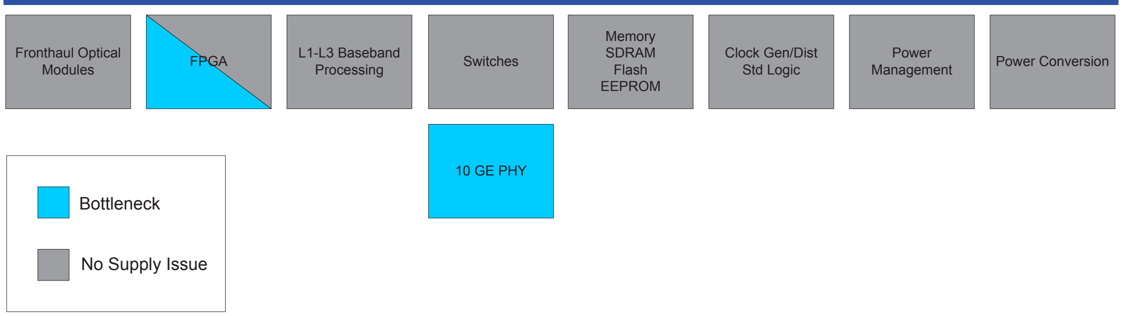
This is based upon current available information regarding foreign/international semiconductor suppliers, their current products, and performance metrics. For FPGAs, this bottleneck only applies to merchant FPGAs, as several BBU vendors including Huawei, Ericsson, and Nokia have long had internal capability to develop their own Application Specific Integrated Circuits (ASICs) that can replicate the minimum necessary requirements of an FPGA within a baseband unit. This is called the ASIC crossover, as vendors first deploy FPGAs in initial product release then deploy ASICs to reduce costs and improve power efficiency. These ASICs are designed in-house with fabrication outsourced to leading foundries, typically at the 14nm FinFET node. ASICs for wireless infrastructure are developed on the same advanced process nodes as merchant chips. Deploying an ASIC as opposed to an FPGA does not degrade the overall functionality of the BBU. For merchant FPGAs, we note that state-of-the-art process nodes are at 7nm FinFET using Taiwan Semiconductor Manufacturing Company (TSMC) silicon foundry services. Current state of the art FPGAs available from Chinese domestic suppliers are at a 28nm process node. While it is logical that foreign FPGA suppliers have access to all of the process nodes at TSMC, Chinese suppliers will likely attempt to develop and scale FPGA designs to be on par with the U.S.-based suppliers.

[1] For the purposes of this report we identified only semiconductor components deemed "critical" to aspects of a 5G RAN network. Critical is defined as essential for the design, manufacturing, and sale of 5G RAN equipment and possessing technical performance parameters unique to 5G networks.

For Gigabit Ethernet PHY transceivers and switches, we note the availability of 1Gbps Ethernet PHY transceiver and switch solutions from foreign/international semiconductor suppliers but no availability for 10Gbps Ethernet PHY transceiver and switch solutions outside the U.S. Within the 5G base station systems, the 10GE standard is predominantly used for optical/electrical transport functions. We understand that China-based suppliers, as identified in this report, are rapidly closing the gap between their current capability of 1Gbps to 10Gbps, and we project the gap can be closed in the next eighteen months.

We are convinced time is the only issue for development of non-U.S.-based designs and availability for these two functional product families. Non-U.S. based chip designs will continue to have access to leading semiconductor electronic design automation (EDA) tools and the best semiconductor foundries, enabling rapid development and manufacturing. We are also convinced the amount of investment capital available in China is not an issue in preventing the evolution of the domestic semiconductor design industry.

EXHIBIT 1: BBU FUNCTION PRODUCT FAMILY BOTTLENECK ANALYSIS

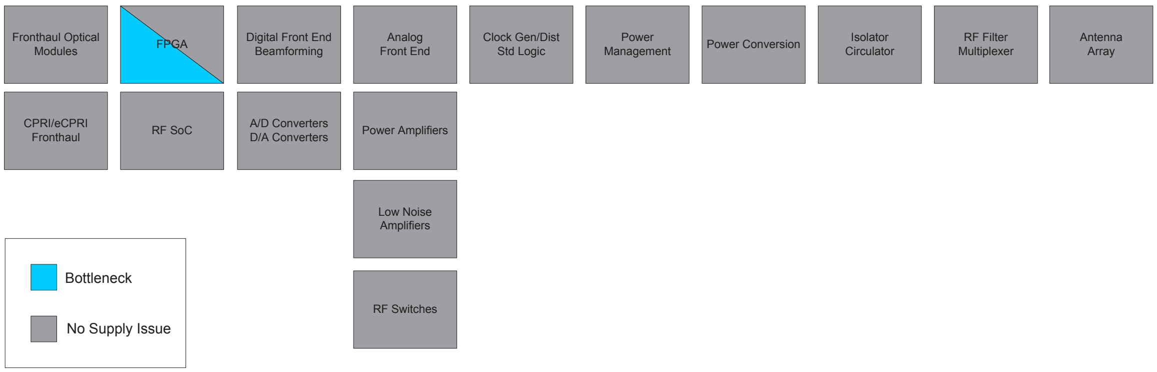


OUR CONCLUSION FOR THE AAU/RRU SYSTEM FOR A 5G BASE STATION IS THAT THERE IS ONLY A SINGLE POTENTIAL SUPPLY CONSTRAINT, AGAIN BEING THE FPGA. ALTHOUGH, AS NOTED ABOVE, VENDORS SUCH AS HUAWEI HAVE ALREADY DEVELOPED ASIC SOLUTIONS THAT REPLACE THE FUNCTIONALITY OF THE FPGA. IN EFFECT, THIS POTENTIAL SUPPLY CONSTRAINT DOES NOT IMPACT HUAWEI, BUT COULD IMPACT OTHERS.

Similar to our outlook for research and development of such semiconductor products, it is simply time and money, neither of which is limited from the perspective of the domestic Chinese semiconductor design industry. We do not have a timeline as to how quickly and when such products will become available at the same performance as current U.S.-supplied solutions.

For radio frequency (RF) functions such as power amplifiers, GaN has been identified as a key enabler for 5G radio systems due to the inherent wider bandwidth of operation as well as thermal performance. Additionally, we believe that the current evolution of 4G radio systems will also require GaN technology to achieve optimal performance. We believe that foreign/international availability of GaN power amplifiers is sufficient and will not be a supply chain issue currently. We also note that while domestic Chinese supply of GaN may be performance limited, research and development will not be impacted by a lack of investment capital.

EXHIBIT 2: AAU/RRU FUNCTION PRODUCT FAMILY BOTTLENECK ANALYSIS



EXECUTIVE SUMMARY

The potential for development of domestic Chinese semiconductor products is based upon access to semiconductor foundries for silicon, silicon germanium (SiGe), silicon on insular (SOI), gallium arsenide (GaAs), indium phosphide (InP), silicon carbide (SiC), and gallium nitride (GaN) semiconductor materials.

WE NOTE THE FOLLOWING NON-U.S. BASED COMPOUND SEMICONDUCTOR FOUNDRIES AND THEIR LOCATIONS:

- Advanced Wireless Semiconductor Company (Taiwan)
- Global Communications Semiconductors (U.S., Taiwan)
- OMMIC S.A. (France)
- United Monolithic Semiconductors (France)
- Wavetek Microelectronics Corporation (Taiwan)
- WIN Semiconductor (Taiwan)
- Sanan Integrated Circuits (China)

WE ALSO NOTE THE FOLLOWING NON-U.S. BASED SiGe FOUNDRIES AND THEIR LOCATIONS:

- Innovation for High Performance (Germany)
- Tower Jazz (U.S., Japan, Israel)

We believe that any potential supply chain bottlenecks to the specific semiconductor functional products highlighted in this analysis is merely a temporary "blip" in the supply chain. While there may be some level of disruption and performance degradation due to the unavailability of these specific products, we expect that these issues will be resolved.

WIDESPREAD FOREIGN AVAILABILITY FOR KEY AAU/RRU SEMICONDUCTOR COMPONENTS

FRONTHAUL OPTICAL MODULES

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company L
- Company M
- Company N
- Company O
- Company P
- Company Q

FPGA RF SoC

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I

DIGITAL FRONT END

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K

ANALOG FRONT END Tx AMPLIFIER

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company L
- Company M
- Company N
- Company O

ANALOG FRONT END Rx LOW NOISE AMPLIFIER

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company L
- Company M
- Company N

ANALOG FRONT END RF SWITCH

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H

ISOLATOR/CIRCULATOR

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company I
- Company L
- Company M
- Company N

RF FILTER/MULTIPLEXER

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company I
- Company L
- Company M

ANTENNA ARRAY

- Company A
- Company B
- Company C
- Company D
- Company E
- Company F
- Company G
- Company H
- Company I
- Company J
- Company K
- Company I
- Company L

INTRODUCTION: WHAT IS 5G?

The 5G standard, also known as IMT-2020, is the next evolution for the wireless industry. Every ten years, the wireless industry adopts a new, next generation standard for the network architecture as well as the radio waveform.

The official industry standard defining the transition between the 4G Long Term Evolution (LTE) standard and 5G is 3rd Generation Partnership Project (3GPP) Release 15, approved in December 2017. 3GPP Release 16 is scheduled to be completed by December 2019 and adopted in 2020. The new 5G NR standard has two variants, non-stand alone (NSA, or new 5G RAN but core network utilizes existing 4G LTE core infrastructure) and stand alone (SA, i.e. both RAN and core are 5G compliant) which relates to the mobile core network (CN). Verizon Wireless created its own standard, Verizon Technical Forum (VTF), based upon 3GPP Release 15 NSA specifications due to the necessity of launching fixed wireless access (FWA) services in October 2018 in the United States.

THERE ARE THREE PRIMARY GROUNDBREAKING ASPECTS OF 5G THAT THE 3GPP SPECIFICATIONS SUPPORT:

1. Enhanced Mobile Broadband (eMBB)
2. Ultra Reliable Low Latency Communications (uRLLC)
3. Massive Machine Type Communications (mMTC)

eMBB is the continued evolution of wireless data for mobile networks with the goal of a 10X improvement in downlink (DL) speeds to mobile devices, achieving 10 Gb/sec compared with 1Gb/sec for 4G LTE services.

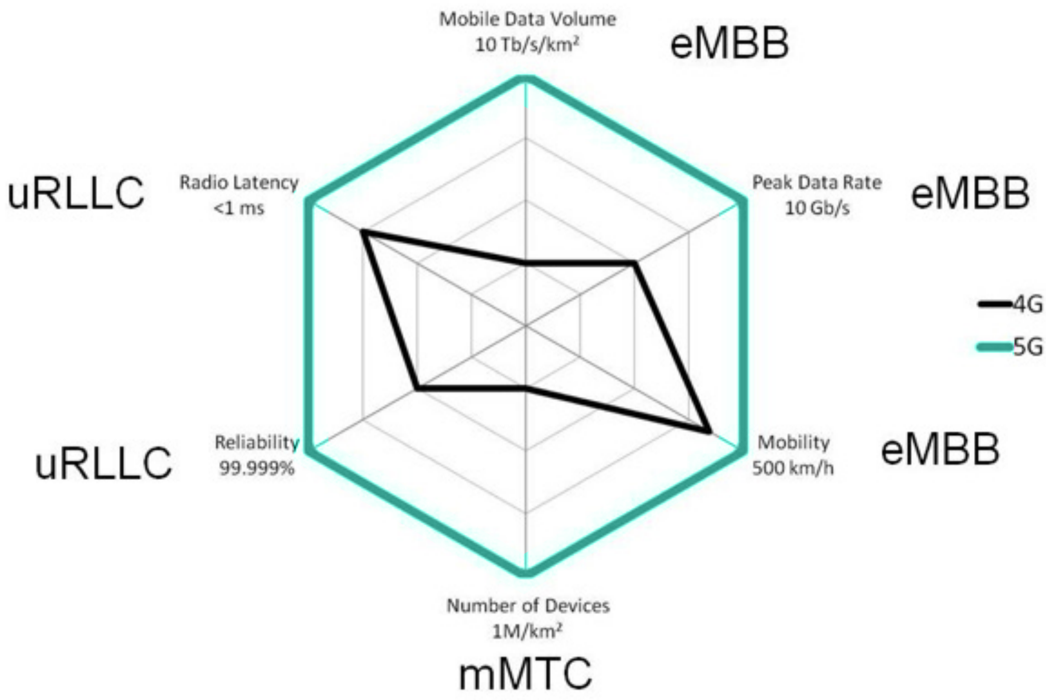
uRLLC is a new type of wireless communications service that supports low latency applications of <1ms round trip as well a high reliability (99.9999% uptime) applications. These applications include the following vertical markets:

- Augmented Reality (AR)/Virtual Reality (VR)
- Autonomous Vehicles (Land/Air/Marine)
- Industrial Automation (Industry 4.0)
- Public Safety/Mission Critical Applications
- Remote Surgery and Healthcare Services
- Smart City

mMTC is an extension of existing 4G LTE narrowband IoT (NB-IoT) and Category M (Cat-M) technologies with the ability to handle extended battery life as well as massive density of devices (>1M per km2) for Smart X applications.

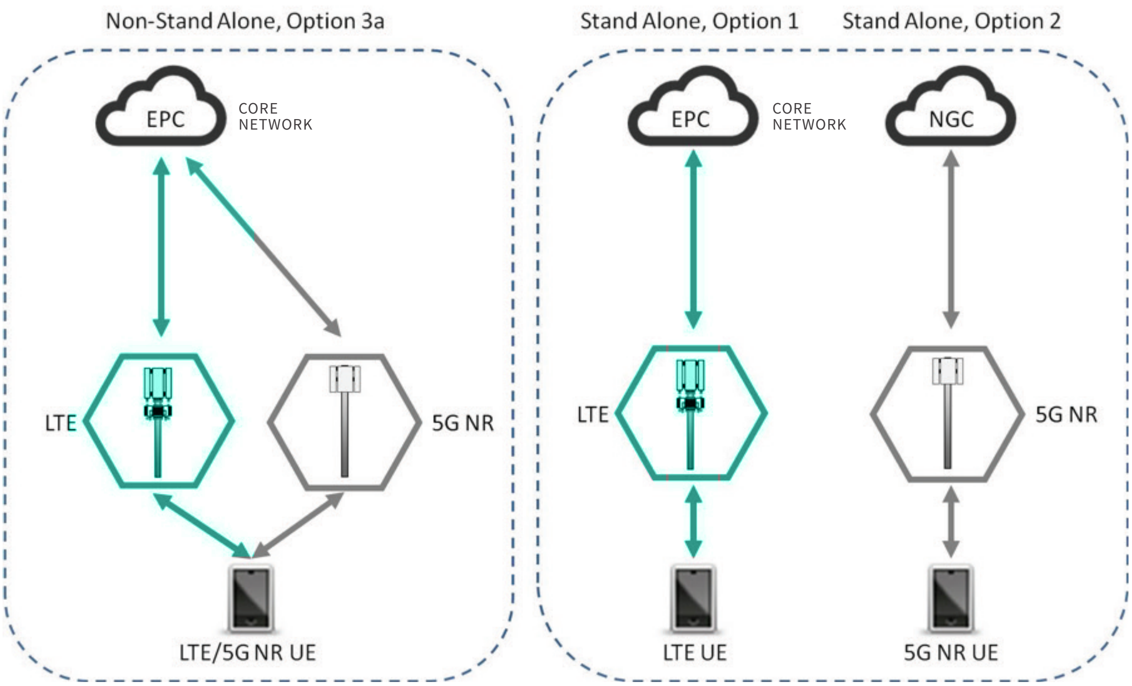
5G is essentially a 10x+ increase in all technical parameters compared with existing 4G technology today.

EXHIBIT 3: COMPARISON OF 4G VS. 5G TECHNICAL SPECIFICATIONS



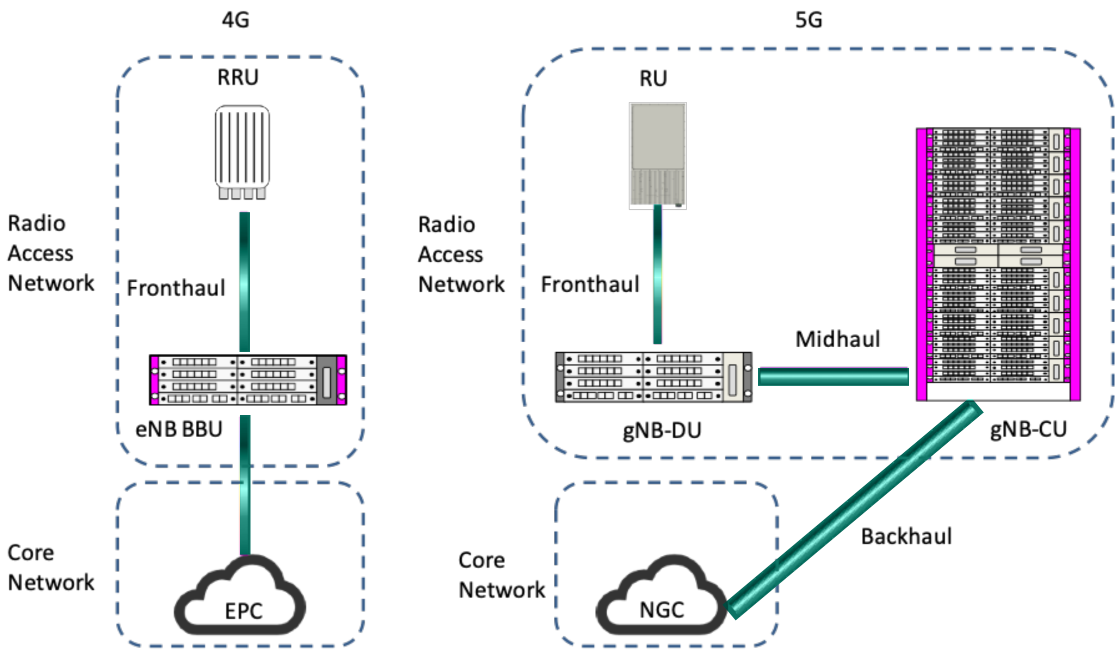
As with prior generation wireless network architecture upgrades, true standalone (SA) 5G will require a new core network as well as a new radio access network (RAN). We show the most likely immediately migration path, NSA Option 3a, which allows a mobile operator to build out a new 5G RAN while utilizing the existing 4G core network. This will save costs for network operators in the short-term, while allowing initial deployment of 5G network services. Ultimately, we believe mobile networks will evolve to a SA Option 1/2 architecture where there are two distinct and separate mobile networks, layered on top of each other. To fully utilize the uRLLC and mMTC technologies of 5G, a separate core network must be built. In the short term non-standalone 5G will remain the predominant version of 5G deployment around the world.

EXHIBIT 4: 5G NETWORK EVOLUTION, NSA OPTION 3A VS. SA OPTION 1/2



The other significant change in the network architecture is in the RAN portion of the mobile network. The 4G evolved node B (eNB) performs the networking Layer 1-2 L1-L3 baseband processing functions, transport, and operations & maintenance functions. The 5G next generation node B (gNB) is split into two logical and physical blocks, gNB-DU (5G distributed unit) and gNB-CU (5G centralized unit). The distributed unit (DU) performs all of the low latency real time processing of the radio signals while the central unit (CU) performs all of the non-real time processing of the radio signals. It is important to note that in a first generation 5G mobile network, the vast majority of mobile operators are implementing a NSA network architecture where all of the traditional eNB functions are performed by the gNB. The CU-DU split of the gNB will likely occur when the 5G network transitions to a SA network architecture.

EXHIBIT 5: RADIO ACCESS NETWORK ARCHITECTURE, 4G VS. 5G



The final major changes in 5G are the radio implementation for the duplex mode, frequency bands, channel bandwidth, and a focus on massive MIMO radio units.

Current 4G LTE frequency bands operate at frequencies <4GHz. The initial 5G networks will focus on using a combination of low band (600-900MHz) and mid band (2.5-4.5GHz) spectrum as well as high band (24-47GHz) millimeter wave (mmWave) frequency bands. Eventually, all existing 4G LTE spectrum will be converted to 5G NR spectrum.

The current maximum 4G LTE single channel bandwidth is 20MHz. 5G NR single channel bandwidths can be up to 100MHz, a 5x increase.

4G LTE networks are frequency division duplex (FDD) centric with China Mobile and Sprint as the two major networks using the time division duplex (TDD) mode. 5G NR networks will be TDD centric for all frequency bands in the mid-band and high band spectrum and FDD in the low band spectrum.

Current 4G LTE remote radio units (RRU) use 4x4 MIMO 4T4R architectures for frequency division duplex (FDD) mode and 8x8 MIMO 8T8R for time division duplex (TDD) mode. We expect low band FDD radio units (RU) to be 4x4 MIMO 4T4R while mid band RUs will use a combination of 8x8 MIMO 8T8R and massive MIMO 32T32R/64T64R RUs. High band RUs will use a lower order MIMO but with high antenna elements (AE), typically with 128AE to 512AE configurations.

EXHIBIT 6: 5G RU VS. MIMO ORDER VS. FREQUENCY BAND

THE EXISTING WIRELESS NETWORK EQUIPMENT SUPPLIERS FOR 4G LTE NETWORKS ARE ALSO THE SAME VENDORS FOR 5G NR NETWORKS. THESE ARE:

- China Information and Communication Technologies Group Corporation (CICT)
- Telefonaktiebolaget LM Ericsson
- Huawei Technologies Co., Ltd.
- Nokia Corporation
- Samsung Networks
- ZTE Corporation

Due to the emergence of the O-RAN Alliance, there is a new group of potential wireless equipment and software suppliers for 5G NR networks that will comply with the open specifications that the alliance is developing. The twenty-two mobile operator members of the O-RAN Alliance include the major operators in the United States, South Korea, Japan, India, China, and Europe. While the O-RAN Alliance is driving towards a software defined networking focus that would rely on "white- box" hardware integration, these O-RAN vendors will have to rely on the same standard network architectures, hardware design blocs, and semiconductor components as the existing incumbents.

5G VENDOR NEUTRAL FUNCTIONAL REFERENCE ARCHITECTURES

THIS SECTION IDENTIFIES 5G WIRELESS EQUIPMENT VENDOR NEUTRAL FUNCTIONAL REFERENCE ARCHITECTURES FOR THE FOLLOWING SYSTEMS:

1. Baseband Unit (BBU)
2. Remote Radio Unit (RRU)
3. Active Antenna Unit (AAU)/Antenna Radio System (ARS)

This functional reference was developed by analyzing each of the vendor design-bloc choices for the above three systems, then aggregating design similarities into a "vendor-neutral" model.

WE CLASSIFY A WIRELESS EQUIPMENT VENDOR AS ONE OF THE FOLLOWING COMPANIES:

1. CICT (China)
2. Ericsson (Sweden)
3. Huawei Technologies (China)
4. Nokia Networks (Finland)
5. Samsung Networks (South Korea)
6. ZTE Corporation (China)

BASEBAND UNIT (BBU)

Each baseband unit vendor has a slightly different system architecture for their respective solutions, yet still retain many inherent similarities in order to meet 3GPP 5G standards compliance.

CICT

CICT (China Information and Communications Technology Group Corporation) is a result of a state merger between FiberHome Telecommunications Technologies Co., Ltd. (also known as Wuhan Hongxin Communication Technologies Co., Ltd.) and Datang Mobile Communications Equipment Co., Ltd. in mid-2018 during the U.S. export ban on ZTE Corporation.

The company uses a typically 8 slot 19" wide 2 rack unit (2U) chassis system for its 5G BBU. One of the slots is reserved for up to two power supplies while another is for the transport card, leaving up to six slots for baseband processing.

EXHIBIT 7: CICT 5G BBU

ERICSSON

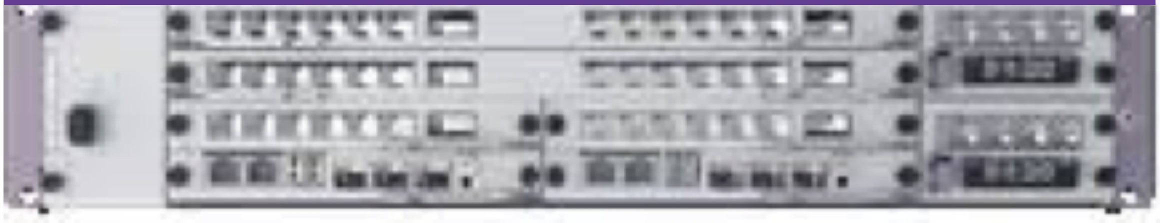
Ericsson is the only baseband unit vendor that does not use a upgradeable chassis solution for its baseband unit. The unit is fixed in terms of hardware capability and ports for backhaul as well as Fronthaul. The Ericsson 5G BBU is a 19" wide 0.75U height chassis.

EXHIBIT 8: ERICSSON 5G BASEBAND 6630

HUAWEI TECHNOLOGIES CO., LTD.

Similar to CICT, Huawei uses an 8 slot 19" wide 2 rack unit (2U) chassis system for its 5G BBU. Two of the slots are reserved for backhaul transport cards, leaving up to six slots for baseband processing.

EXHIBIT 9: HUAWEI 5G BBU5900



NOKIA NETWORKS

Nokia Networks uses a larger 8 slot 19" wide 3U height chassis for its 5G BBU. Two slots are reserved for the power supply/transport functions, leaving six slots available for baseband processing.

EXHIBIT 10: NOKIA 5G AIRSCALE BBU

SAMSUNG NETWORKS

Samsung Networks also uses a 19" wide 2U height chassis for its 5G BBU but the chassis only supports four cards, three radios and one transport. We believe that a special high capacity variant of this solution specific for the South Korean market is between 4-5U in height supporting up to five radio cards instead of the standard three radio cards.

EXHIBIT 11: SAMSUNG 5G BBU

ZTE CORPORATION

Similar to CICT and Huawei, ZTE uses an 8 slot 19" wide 2 rack unit (2U) chassis system for its 5G BBU. One of the slots is reserved for the power supply while another is for the transport card, leaving up to six slots for baseband processing.

EXHIBIT 12: ZTE 5G V9200 BBU

The reference architecture that we have chosen to use is representative of a multi-slot 5G BBU chassis solution where multiple baseband processing cards may be used within a single chassis. The reference architecture refers to the combination of one baseband processing card and one transport/timing card.

For architectures that use more than one baseband processing card within the BBU chassis, the major types of semiconductor integrated circuits (ICs) that would be duplicated on the additional baseband processing cards would be the following:

- L1 DSP/ASIC
- DDR4 SDRAM
- sRIO Switch/ASIC
- eCPRI FPGA/ASIC

Additionally, there would be power management and power conversion ICs as well as timing and logic ICs.

REMOTE RADIO UNIT (RRU)

We believe that the primary configuration for 5G NR TDD RRUs will be 8T8R for all mid-band 5G NR frequencies (2500-4500MHz). While we acknowledge that many countries will also use low-band frequencies (600-700MHz) in FDD mode for 5G NR, we believe that the RRU configuration will be 4T4R.

The 8T8R RRUs will be high power using 20W-40W per RF carrier with a total system RF power of 160-320W. The 8T8R RRU is connected to a separate passive sectorized antenna panel via nine RF coaxial jumper cables.

THE RRU SYSTEM CAN BE DIVIDED INTO THREE MAIN SUBSYSTEMS:

1. CPRI Fronthaul + L1 Baseband Processing
2. Digital IF/Analog RF Radio Transceiver
3. Filter

EXHIBIT 13: ERICSSON RADIO 8823 3.5GHZ 8T8R RRU

EXHIBIT 14: NOKIA NETWORKS 8T8R RRU

EXHIBIT 15: HUAWEI RRU5258 3.5GHZ 8T8R RRU

EXHIBIT 16: SAMSUNG NETWORKS 3.5GHZ 8T8R RRU

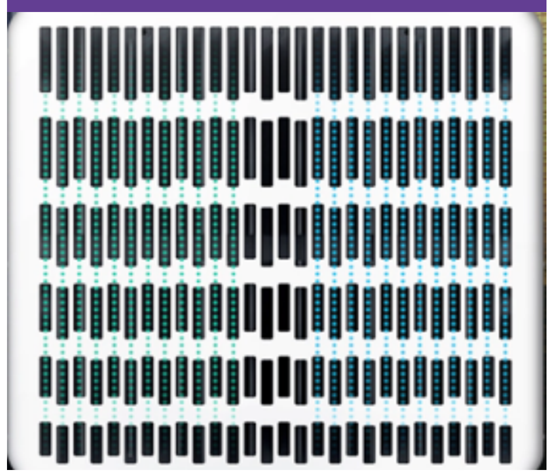


EXHIBIT 17: ZTE ZXSDR R8998 3.5GHZ 8T8R RRU

Sources: Ericsson, Nokia, Huawei, Samsung, ZTE

ACTIVE ANTENNA UNIT (AAU)/ANTENNA RADIO SYSTEM (ARS)

The primary radio units for 5G NR networks using mid-band frequencies (2500-4500MHz) will be configured as a massive MIMO type of active antenna unit (AAU) or antenna radio system (ARS). The typical radio transceiver configurations will be 32T32R or 64T64T with average RF power levels varying from 100W up to 320W.

The xTxR massive MIMO configuration of the radio transceiver implies 32 or 64 radio transceivers where x=32 or x=64. A typically 64T64R massive MIMO antenna system is configured in a 16H4V antenna dipole array with 8 columns (H) and 12 rows (V) with 2 polarizations (+45/-45). This is typically designated in the following manner and is shown in Exhibit 23 below:

8(H) x 12 (V) x 2

Each radio transceiver drives three (3) antenna elements on the vertical plane and one (1) antenna element on the horizontal plane. The typical radio transceiver to antenna element ratio is a 1:3 in a 64T64R massive MIMO system for the wireless industry. We define a antenna dipole as formed by two antenna elements.

THE AAU SYSTEM CAN BE DIVIDED INTO THREE MAIN SUBSYSTEMS:

1. eCPRI Fronthaul + L1 Baseband Processing
2. Digital IF/Analog RF Radio Transceiver
3. Filter/Antenna

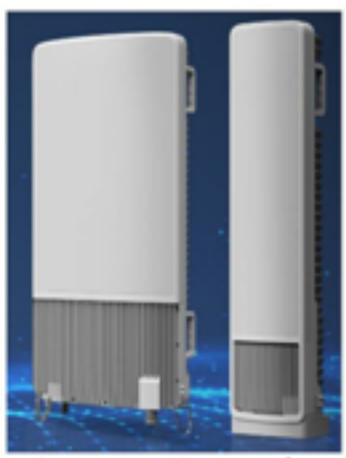
EXHIBIT 18: AAU EXAMPLES BY VENDOR

CICT

Ericsson

Huawei

Nokia Networks



Samsung Networks

ZTE

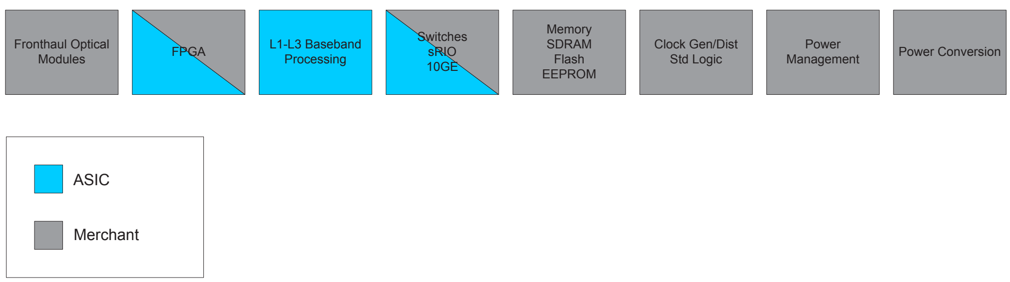
Source: Ericsson, Huawei, Nokia, Samsung Networks, ZTE Corporation

ASIC VS. STANDARD MERCHANT ICs

BBU

The exhibit below illustrates where the focus for application specific integrated circuit (ASIC) development has been within the baseband unit. Given the very high costs of ASIC development, initial prototype equipment is usually designed around the use of field programmable gate array (FPGA) products to allow for flexibility as system design parameters and specifications shift during the product development cycle.

EXHIBIT 19: BBU ASIC VS. MERCHANT IC ACROSS FUNCTIONAL PRODUCT FAMILIES



Additionally, given the high costs for design engineers, as well as CAPEX costs associated with wafer mask sets on leading foundry process nodes, the decision to go down the ASIC route carries a very high financial and strategic risk. We believe that the majority of baseband unit designs for 5G use ASICs from the various wireless equipment suppliers for the L1-L3 baseband processing functions within the BBU. We also believe that the high speed switching function is also migrating towards an ASIC solution from merchant solutions.

ASIC VS. STANDARD MERCHANT ICs

A key decision factor for choosing to develop an ASIC solution is performance optimization. While merchant solutions may allow for specific functions to be performed, they are developed and brought to market for generic use cases and typically do not factor in specific software functionality support at the hardware level. The development of an ASIC solution allows an equipment vendor to tailor the level of software required and hardware required to achieve maximum performance of the system.

WE ARE AWARE OF ASIC SOLUTIONS AT THE FOLLOWING WIRELESS EQUIPMENT SUPPLIERS FOR THEIR BBU ARCHITECTURES:

- Ericsson
- Huawei Technologies (using HiSilicon)
- Nokia Networks
- Samsung Networks
- ZTE

AAU/RRU

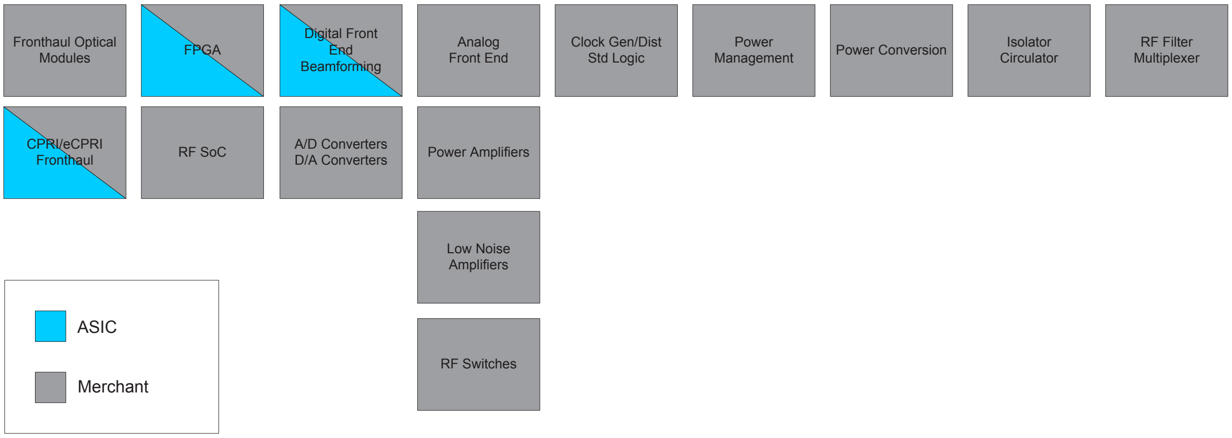
FOR THE AAU AND RRU SYSTEMS, WE NOTE THAT THE FOCUS FOR ASIC DEVELOPMENT HAS BEEN ON DIGITAL FRONT END FUNCTIONS INCLUDING:

- Digital Up Conversion (DUC)
- Digital Down Conversion (DDC)
- Digital Pre Distortion (DPD)
- Beamforming

All of these functions can be supported with FPGAs, however we are seeing a migration within AAU system designs to focus ASIC development on the antenna beamforming function. We are also seeing a migration for some equipment vendors to ASIC development for the common public radio interface (CPRI) and evolved common public radio interface (eCPRI) fiber optic links that connect the AAU/RRU to the BBU. This remains uncommon as it is simply much easier to use an FPGA to perform this function. We are also seeing "ASIC" or custom development for the antenna arrays, as this non semiconductor function is critical for the AAU performance.

The DUC, DDC, and DPD functions within the radio system can be supported with FPGAs. We have not seen internally developed RF IC solutions for any of the wireless equipment vendors that address the transmit (Tx) and receive (Rx) functions of the radio system.

EXHIBIT 20: AAU/RRU ASIC VS. MERCHANT IC ACROSS FUNCTIONAL PRODUCT FAMILIES



WE ARE AWARE OF ASIC SOLUTIONS AT THE FOLLOWING WIRELESS EQUIPMENT SUPPLIERS FOR THEIR AAU/RRU ARCHITECTURES:

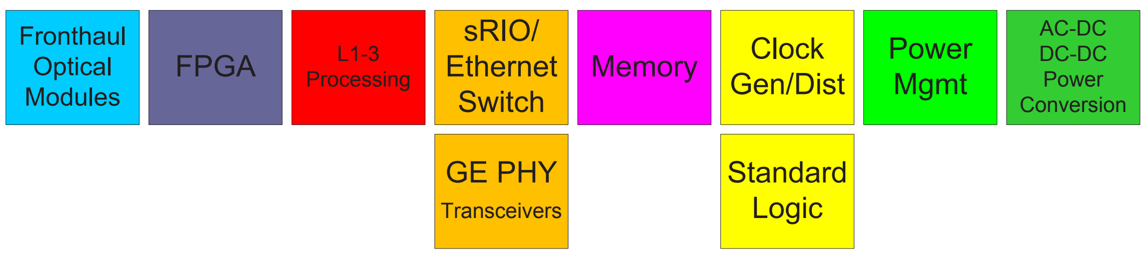
- Ericsson
- Huawei Technologies (using HiSilicon)
- Nokia Networks
- ZTE

SEMICONDUCTOR IC FUNCTIONAL FAMILIES/ SUPPLIERS

WE HAVE IDENTIFIED THE FOLLOWING SEMICONDUCTOR IC PRODUCT FUNCTION FAMLIES FOR THE 5G BBU REFERENCE ARCHITECTURE:

- Fronthaul Optical SFP/SFP+/QSFP Module
- Field Programmable Gate Array (FPGA)
- L1-L3 Baseband/Network Processor
- Switch, sRIO, PCIe, and Ethernet
- GE PHY Transceivers
- Memory, SDRAM and Flash
- Clock Generation/Distribution
- Standard Logic
- Power Management
- Power Conversion, AC-DC, DC-DC

EXHIBIT 21: SEMICONDUCTOR IC FUNCTIONAL FAMILIES FOR 5G BBU SYSTEMS



WE HAVE IDENTIFIED THE FOLLOWING SEMICONDUCTOR IC PRODUCT FUNCTION FAMILIES FOR THE 5G RRU AND AAU REFERENCE ARCHITECTURES:

- Fronthaul Optical SFP/SFP+/QSFP Module
- Field Programmable Gate Array (FPGA)
- RF SoC
- Digital Front End
- Analog Front End
    - Tx Gain Blocks, Driver Amplifiers, Power Amplifiers
    - Rx Low Noise Amplifiers
    - RF Switches
- Clock Generation/Distribution
- Power Management
- Power Conversion, AC-DC, DC-DC

NON-SEMICONDUCTOR FUNCTIONAL PRODUCT FAMILIES WITHIN THE RRU AND AAU INCLUDE:

- Isolator/Circulator
- RF Filter
- Antenna Array

EXHIBIT 22: SEMICONDUCTOR IC FUNCTIONAL FAMILIES FOR 5G RRU/AAU SYSTEMS

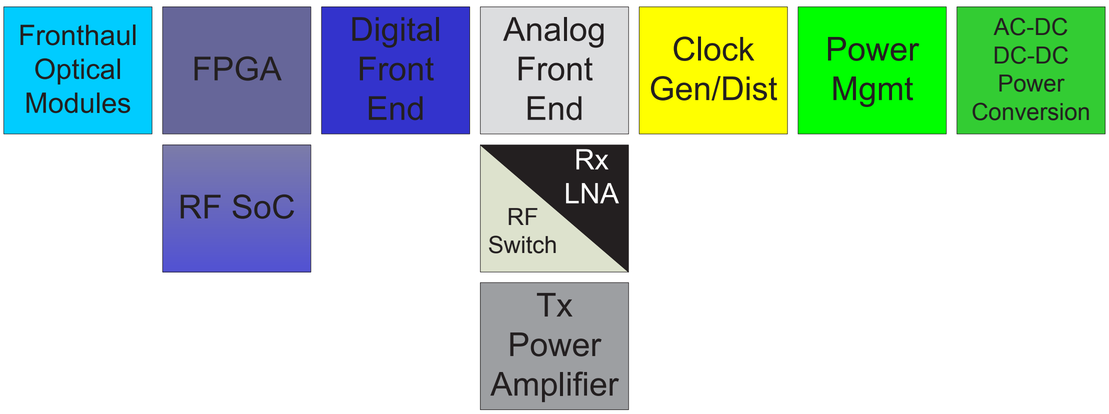


EXHIBIT 23: NON SEMICONDUCTOR FUNCTIONAL FAMILIES FOR 5G RRU/AAU SYSTEMS