SEMICONDUCTOR ENGINEERING

Gearing Up For 5G

This new communications standard could transform architectural decisions across the industry, but not right away and not necessarily in obvious ways.

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5G has been touted as the new enabler for many market segments, including mobile phones, automotive, virtual reality, and IoT. But there are many questions and much speculation about when and how this new wireless standard will impact different market segments and what effect it will have on semiconductor design.

With a promise of orders of magnitude improvement in communication speed and low latency, systems vendors will need to decide between whether to process data locally or in the cloud, and how much should be done where. That will have a significant impact on semiconductor architectures, from processor and memory choices to on-chip throughput, I/O speeds, power budgets and even battery sizes. In addition, those decisions will be affected by access to 5G infrastructure and frequency of communication.

It could be years before any of this happens, though. Initially, much of the 5G rollout will be in the sub-6GHz range, which has been compared to 4.5G. The biggest beneficiary will be the mobile phone industry, which will remain the largest consumer of the technology for some time. Phones will continue to define standards and drive volume, and they will remain the largest source of funding for this technology.

It’s the next phase of development, when millimeter-wave technology is introduced, where the most significant changes begin to occur. The general rule of thumb is that for any new technology to be successful it has to provide a 10X gain, which can be in the form of performance, power reduction, reduced cost, smaller area or a combination of many attributes. It's here that 5G will really begin to shine.

"5G will provide significant improvements in connectivity and is targeting 1,000X performance over what 4G achieves today," says Steven Woo, vice president for Systems and Solutions and distinguished inventor at Rambus Labs. "In addition to improved bandwidth, 5G promises lower latency and better coverage as well."

In the early days of mmWave, design costs and silicon area will go up significantly. And power consumption will be major concern, depending on infrastructure and load—where signals are being sent and what computing is being done once those signals arrive.

Impact on IoT

One area that could really benefit from 5G is edge computing, where power is a limiting factor. "We'd expect IoT edge devices to use less energy with 5G because the access points will be closer on average," says Neil Robinson, product marketing director at Cadence. "This means less power required during communications compared to greater distances required for 4G."

This opens the door for more complex processing and communication schemes than are available today. "5G will provide higher bandwidth, which means that the growing number of connected endpoints will have an easier time communicating their data to neighboring locations where the data can be processed locally," says Woo. "This means that only higher-level information, and/or the data itself, optionally being transmitted on to cloud data centers."

But this kind of scheme also can get complicated very quickly. "The significantly higher bandwidth and multiple antenna strategies required for 5G mean that by their very nature they are more power-intensive," points out Jean-Marie Brunet, senior director of marketing for the Emulation Division of Mentor, a Siemens Business. "However, there is broad agreement that the majority of IoT will be machine-to-machine (M2M) communications. It's arguable that M2M communication patterns will be more predictable than human-initiated IoT, and therefore low-power algorithms for M2M instances should be much more efficient."

Actual benefits will vary by application and by region. "The bottom line is that 5G provides a 10X to 100X reduction in power per bit with a commensurate 10X bandwidth bump, which could yield a net gain in power longevity and a 10X improvement in power efficiency. This most likely will vary depending on the use modes employed."

Will that be enough to impact architectures? IoT edge devices had started to incorporate inferencing locally to avoid bandwidth impacts associated with transmitting large volumes of raw data to the cloud.

"Higher bandwidth and lower latency will make it easier to do inferencing in the cloud if that is what is needed and/or appropriate," says Cadence's Robinson. "However, privacy, security, latency and power concerns may make it inappropriate."

Lazaar Louis, senior director of product management and marketing for Tensilica IP at Cadence, echoes those concerns. "Scenarios that have privacy and security concerns will continue to run inferencing at the edge," he says. "Communicating the sensor information to the cloud consumes energy, and hence there will be savings in energy consumed at the edge by performing inferencing at the edge."

Rambus Labs' Woo agrees. "Higher bandwidths likely won't eliminate the need for inferencing at the endpoints, but they will allow a much larger number of IoT devices to be interconnected, enabling infrastructure to keep up with the ever-growing demand for more Internet-enabled devices, and for the growing amounts of digital data they capture and communicate."

VR and AR

Virtual reality has hit a roadblock. Without higher data rates, vendors are having difficulty eliminating motion sickness, and that is limiting adoption. Millimeter-wave technology could help solve that. While mmWave signals cannot go through walls and only operate over relatively short distances, VR headsets typically are only feet away from a controller.

“A high-resolution, 8K game streaming activity will certainly kill the battery sooner compared with a previous 4G generation product running the same game,” admits Brunet. “But this is not so much because of 5G. It’s because of the advanced CPU and display characteristics. At mmWave frequencies, there’s an accelerating effect on power efficiencies on transceivers for over-the-air (OTA) power requirements.”

Automotive

Autonomous driving requires many technologies coming together, and 5G is one of them. “Lower latencies bring benefits for connected vehicles with autonomous driving capabilities, where response times are critical, especially at highway speeds,” says Woo. “Improved coverage will be coupled with more local processing capabilities that will allow data to be aggregated and processed closer to the endpoints where it’s generated, reducing data movement. Reducing data movement over long distances is a critical benefit for 5G as it improves both latency and power consumption.”

Cars are likely to become communications hubs. “Cars will be mini transmitters,” says Robinson. “Some are like that now with 802.11p (V2V), 4G / OnStar (V2X). There is resistance from TV networks that want to use the same spectrum that is being allocated for V2V. They claim that with autonomous driving no V2V would be required, instead using V2X at the roadsides to know about the presence/intentions of other vehicles.”

Others agree. “Vehicle to Everything (V2X) will dominate communications, and vehicles will become mobile networks that have many transmitters—in many cases more than one transmitter per functional domain,” says Brunet. “V2X will be a key enabler for safety where LiDAR or RADAR simply can’t see around corners, and where the diversity in 5G depends on reflections around corner to operate.”

Whether they get that information from other cars or from roadside information isn’t clear yet. “Cars will make better decisions on autonomous driving experiences the more information they have available to them,” notes Cadence’s Louis. “Advanced levels of autonomy will benefit from V2X communication from other vehicles or infrastructure. Examples include path planning and lane change assistance."

New communications abilities also will create possibilities not fully considered today. "Connected vehicles are just one of many types of devices that are likely to benefit," says Woo. "The higher bandwidths and improved coverage coupled with more local processing will help vehicles communicate with their surroundings, as well as with local map data, to navigate roadways in the future. Today's connected automobiles already capture large amounts of data, and some of this information is transmitted into the cloud. Cars are expected to continue evolving into information hubs, as they can serve as connection points for passenger devices (much like mobile phones serve as connection points for peripherals like smart watches and fitness devices), as well as perform peer-to-peer communication with other vehicles to communicate intended actions like lane changes, traffic conditions, and hazard information."

Implementation considerations

Most 5G implementations today are prototypes, and not all of the implications have been sorted out yet. For example, 5G can operate between 10 and 20 Gigabits per second, but the digital system has to be capable of operating at this rate to take advantage of those speeds. That could restrict the technology nodes that can be used or require advanced packaging solutions if digital content is to be manufactured at an older node in order to reduce costs.

"It is a combination of Moore's Law slowing down and also the increased complexity of the chips and the processing required," says Frank Ferro, senior director for product management at Rambus. "Instead of doing one large ASIC, you have to ask if it is more cost-effective to disaggregate it. Is it cheaper to do two smaller ASICs or to re-use the mixed-signal content in which you have made a lot of investment? If you have made that investment in a high-speed process technology, do you want to keep scaling that? Or can you use the existing technologies, plus an interface technology, and not have to develop the SerDes every time you change process node?"

Again, different product domains may reach different conclusions. “There’s no 5G node expectation that I am aware of,” says Robinson. “It will come down to a cost evaluation for each individual product or company. The biggest restrictions come when the analog needs to be integrated with the digital in some way. This may be driven by end-product size, cost and power limitations. IoT edge devices are the extreme, where high integration is key. They are also likely to be using an older-node technology to keep costs down, as the performance requirements are typically low. V2X, user equipment and infrastructure typically have separate chips due to the larger sizes and prices.”

There are downstream effects when considering standards. “Everything is driven from the bandwidth requirements or data requirements,” says Sunil Bhardwaj, senior director for Rambus’ India design center. “There is a demand to make faster systems, and this is both for the processing, which is heavily support by the digital domain, as well as how fast the chips are able to get the data out to other chips and systems. This is why the standards are evolving, and those requirements by necessity are driving the constraints around both the digital and analog side to speed up. It is very difficult to support some modern standards using older process nodes. You cannot achieve the data rates by using the digital technologies of yesterday. Technology scaling supports these downstream effects.”

There is a lot of complex processing required for 5G. “By transferring complexity to the digital side and allowing imperfect raw analog characteristics, it is possible to significantly reduce the area and power for the block,” says Manuel Mota, product marketing manager at Synopsys. “The ability to scale analog blocks, such as very-high-speed data converters and antenna arrays, to very small areas is a key enabler driving new market segments such as 5G communications. Multi-GHz operation and signal bandwidth were previously only accessible using external, high-power chips, which were incompatible with the requirement for small form factor and low power associated with battery-powered and handheld devices.”

Conclusion

Much remains unknown about 5G and the impact it will have on a variety of markets.

What is clear is that it has the potential to cause architectures to be reconsidered, and for entirely new application domains to be discovered that were not possible in the past. But a lot of expensive work has to be done at the infrastructure level and in the mobile phone industry before much of this technology will be suitable for other domains.

Mobile phones are expensive items that consumers continue to buy and are supported by services being added on top of the business model. At this point, there is no other market that is an obvious driver of this technology. The automobile industry may be able to support those costs, but the volumes are a fraction of those in the mobile phone industry. Moreover, there is no clear business model to have autonomous vehicles pay for the infrastructure and data that would make them possible. And IoT edge nodes are low cost, and the entire investment will have to be justified by the services offered.

So at least in the beginning, this will be largely about phones. But the really big shifts will extend well beyond what fits in your pocket.

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