One of the marquee advantages of 5G networks is low-latency operation. One of the mechanisms for that is an evolution in the slot-based framework used in LTE and 5G communications. John Smee, senior director of engineering Qualcomm Research, Qualcomm Technologies, explained this and other aspects of 5G technology in a recent webinar sponsored by the IEEE. He also provided a summary regarding where 5G technology is along the path toward commercialization.

New developments in cellular technology are introduced in numbered releases. For example, the switch from 3G to 4G (LTE) began with Release 8. The industry is now about halfway through Release 15.

Just as 3G and 4G coexist, 4G and 5G will too. Further, Smee pointed out, 4G and 5G will not only coexist, but both infrastructure and edge devices will be dual-mode. That will not only ease the transition from one generation of technology to the next, but operators will be able to use 4G and 5G systems simultaneously to augment each other.

Technologies established in Release 15 thus far include:

- scalable OFDM-based air interface – supports diverse spectrum
- slot-based framework – enables low latency
- advanced channel coding – supports large data blocks
- massive MIMO – for increased coverage, capacity
- mobile millimeter wave (mmWave) – for increased capacity, throughput

The slot-based framework is one of the less frequently discussed aspects of 5G NR; it is also one of the mechanisms for having 5G work with 4G. With this framework comes the ability to scale subcarrier slot duration. A practical result of this mechanism is that it allows operators to adjust both latency and quality of service (QoS) as needed.

LTE has 15 kilohertz subcarrier spacing, with 1 millisecond slots (or subframe) each supporting 14 symbols. Similarly, 5G allows for a 15 kHz subcarrier with a 1 millisecond slot for 14 symbols, in a deliberate attempt to align 4G with 5G.

But 5G has other options, including 30 kHz subcarrier with a 500 microsecond slot plus the option for a “mini-slot,” 60 kHz with a 250 microsecond slot, and 120 kHz with a 125 microsecond slot. The 120 kHz option enables very efficient millimeter wave communications. By way of contrast, the 30 kHz option will be predominant in mid-band time division duplex (TDD) spectrum between 3 MHz and 5 MHz, Smee said.

The mini-slot represents a means of jamming more symbols into a slot. A mini-slot will be able to carry two symbols, four symbols, or as many as seven symbols within a slot that ordinarily would
Smee pointed out that a mini-slot at 30 kHz will allow for even lower latency than the 250 microsecond and 125 microsecond slots at 60 kHz or 120 kHz, respectively.

This should be exceedingly useful in IoT applications in which devices – sensors, for example – need to communicate small amounts of data rapidly.

The TDD slots are self-contained, which means the slot structure can be variable. You could, for example, include additional headers. A practical result is that uplink and downlink can be adaptive.

“You can switch between uplink and downlink based on the needs of the network, the needs of the devices, and the required communications flow in each direction,” said Smee. "Dynamic uplink and downlink is made possible by the self-contained TDD slot structure with downlink control and uplink control specified at the beginning and end of each slot."

Originally 5G NR was expected to be TDD in the midband spectrum, Smee noted, but there will be a mix of frequency division duplex (FDD) and TDD.

Channel coding will be important for energy efficiency, complexity, and low latency, in terms of how quickly you can decode a packet. Those working on 5G standards determined the best choice was multi-edge low density parity check (LDPC).

EDN has examined how MIMO will help with spectrum reuse, and will help deliver higher data rates (see Realizing 5G New Radio massive MIMO systems). Smee pointed out another, practical benefit of massive MIMO: it will enable operators to use existing cell sites, which were spaced for transmitting at 2 GHz, even though 5G will operate at 4 GHz, where propagation issues are more challenging.

The combination of all these technologies will combine to make faster communication between base station and device, he noted.

Systems that use mmWave spectrum can have even greater capacity, and with MIMO and beamforming, the system can reuse spectrum at a very high rate, opening up even more deployment models and use cases, Smee said.

Dual connectivity will be key for initial deployments of 5G. The ability to leverage 4G and 5G at the same time will enable cellular systems to switch between the two – even in the course of a single phone call – to guarantee connectivity and QoS, Smee said. He added that dual connectivity can be used to enhance coverage and capacity.

During the transition from LTE to 5G, the user plane can be on 5G NR, while control is still done with LTE enhanced packet core (EPC). That the devices are dual-mode and the infrastructure is dual-mode is the stepping stone that will enable carriers to start offering 5G NR services later this year, Smee explained.

Continuing to look ahead, there will be additional elements in Release 15. A current work item is 5G NR ultra-reliable low latency communications (URLLC) to support mission-critical applications, for example industrial automation. URLLC will also be useful for efficient multiplexing with mobile broadband.
Another study item is looking at non-orthogonal multiple access that would be useful in IoT applications where data exchanges would be small. One example would be the use of resource spread multiple access (RSMA) technology. There’s also a study item on vehicle-to-vehicle communications; one on integrated access and backhaul; and yet another on non-terrestrial (satellite) 5G NR.

Beyond all that, Releases 16, 17, and 18 are anticipated. The industry will move into Release 16 in second half of this year and continue into 2019.

Today, using 5G NR in unlicensed spectrum is a study item. This is one of the technologies scheduled to be implemented in Release 16. **MulteFire** is one example. It is a proposal for using LTE in unlicensed frequency bands backed by Qualcomm, Nokia, Intel, and Ericsson.

On the commercial side, most of the current activity is testing and prototyping, Smee noted. Qualcomm, for example, is involved in 5G NR interoperability testing and trials with AT&T, China Mobile, Docomo, SK Telecom, Sprint, Telstra, Verizon, Vodafone, Ericsson, Nokia, ZTE, and others yet to be publicly identified, focusing on various aspects of 5G NR technology, including a scalable OFDM air interface, the low-latency slot-based framework described above, advanced channel coding, and others.

Test RF ICs for mmWave exist; **Qualcomm has a prototype IC for handsets**, along with a reference design. The company also has released the SnapDragon X50 5G modem.

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**Scalable 5G NR slot duration for diverse latency/QoS**

![scalable 5g nr slot duration](image)

**Source:** Qualcomm

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**Brian Santo** has been writing about science and technology for over 30 years, covering cable networks, broadband, wireless, the Internet of things, T&M, semiconductors, consumer electronics, and more.

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