VIAVI Solutions

Application Note

The Role of C-band in 5G

The C-band frequency range for 5G is a rich opportunity for operators. It delivers a balance between coverage and bandwidth which will benefit many verticals and applications. As is often the case in mobile communications, not all radio spectrums are equal. Sub 1GHz offers the best coverage profile; however, the amount of low band spectrum available is limited. Frequency range two (FR2), i.e. from 24.25 GHz to 52.6 GHz, offers a large amount of spectrum with a significantly wide bandwidth (up to 400MHz), but it offers limited coverage. In fact, it is an excellent radio channel for gigabit throughput, but the coverage is limited to hundreds of feet. C-band spectrum, on the other hand, which is part of frequency range one (FR1), and also called mid-band spectrum, offers a good compromise between coverage and high throughput. As part of 3GPP release 15, three bands n77, n78, and n79 were identified for 5G operation in the C-band, with a potential service bandwidth of up to 100 MHz. See Table 1.

Band	Band Name	Duplex Type	Freq (GHz)	Ul/DL Freq (GHz)	Channel Bandwidth (MHz)										
					10	15	20	30	40	50	60	70	80	90	100
n77	C-Band	TDD	3.7	3.3-4.2	■	■	■	■	■	■	■	■	■	■	■
n78			3.5	3.3-3.8	■	■	■	■	■	■	■	■	■	■	■
n79			4.7	4.4-5.0					■	■	■		■		■

Table 1: C-Band spectrum

With 100 MHz of bandwidth, C-Band can truly enable enhanced mobile broadband (eMBB) use cases for 5G. One thing to note is that C-band offers only Time Division Duplexing (TDD). TDD delivers a full-duplex communication channel over a half-duplex communication link. This means both the transmitter and receiver use the same frequency but transmit and receive traffic at different times by using synchronized time intervals.

C-band availability in the US and its implications:

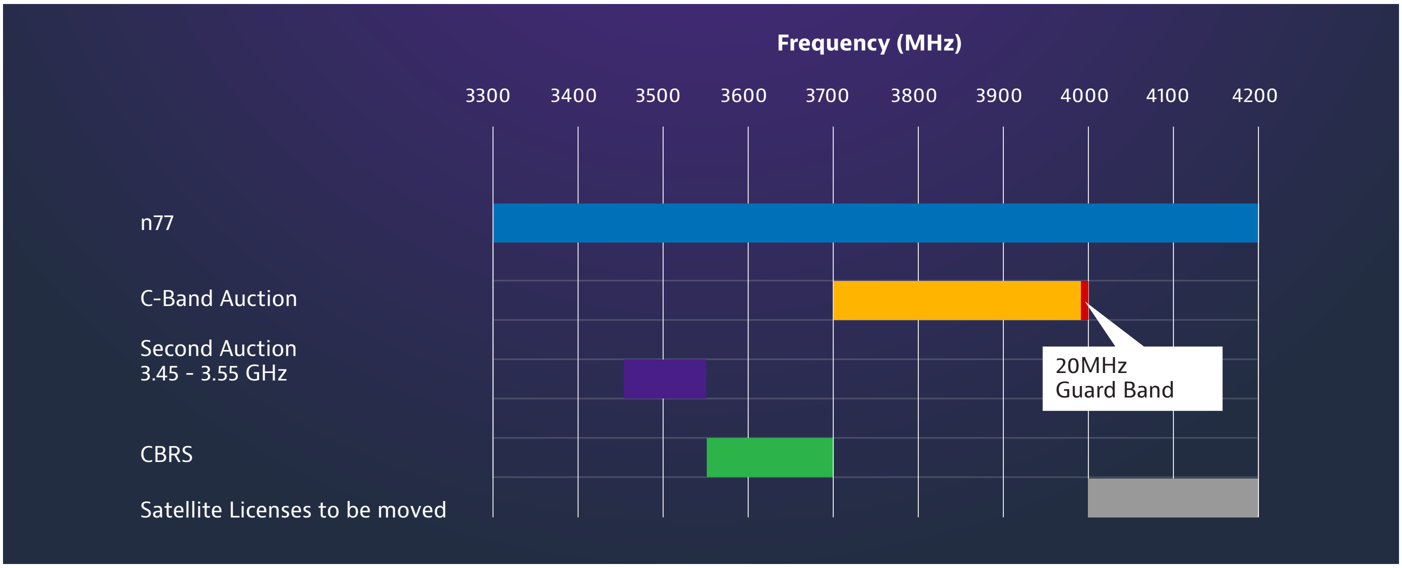

Figure 1: C-band spectrum in the US

For a detailed view on when C-band channels for the top 100 Partial Economic Area (PEA) markets refer to https://www.allnetinsights.com/blogs/news/c-band-auction-markets-and-when-the-spectrum-will-be-available. From figure 1 it appears that around 520 MHz of mid-band spectrum will be made available for future 5G deployment which will open up deployments for both public as well as private 5G networks. A key consideration is that a lot of this spectrum, which is currently being used by different entities from the federal government to satellite services, needs to be cleared. In 2020, for example, the FCC in the US voted to clear 280MHz of C-band spectrum for new broadband wireless services and as shared earlier, the timeline for relocation was also agreed with the incumbent services. This spectrum, on one hand, offers a great opportunity for deploying 5G at the same time it presents challenges in terms of coordinating and managing interference-related issues with incumbent services.

Challenges of Deploying 5G services in the C-band Spectrum

C-band is considered the "waterfront property" of RF spectrum, meaning it offers the best compromise between RF coverage and RF bandwidth. However, C-band 5G networks may require a different level of attention in terms of planning, deployment, and maintenance. Some of the key consideration for C-band deployment include:

1. Ensuring Spectrum is cleared and no interference issues between the new 5G services and the satellite earth stations.

Before a 5G RAN is installed, spectrum clearance is the first step in ensuring optimal performance of the future 5G network. Using a spectrum analyzer with a directional antenna can help under certain test scenarios identify the presence of unnecessary signals that may not have been cleared. Post network launch interference detection and interference hunting can be performed when an interference-related performance issue is identified. The VIAVI OneAdvisor-800™ Interference Analyzer function along with InterferenceAdvisor™ offers the most comprehensive, fully automated RF interference hunting solution. Easy to set up and simple to use, it allows one RF engineer to identify and locate an interference source in just hours, simply by following the voice prompts on a familiar map-style application on an Android tablet.

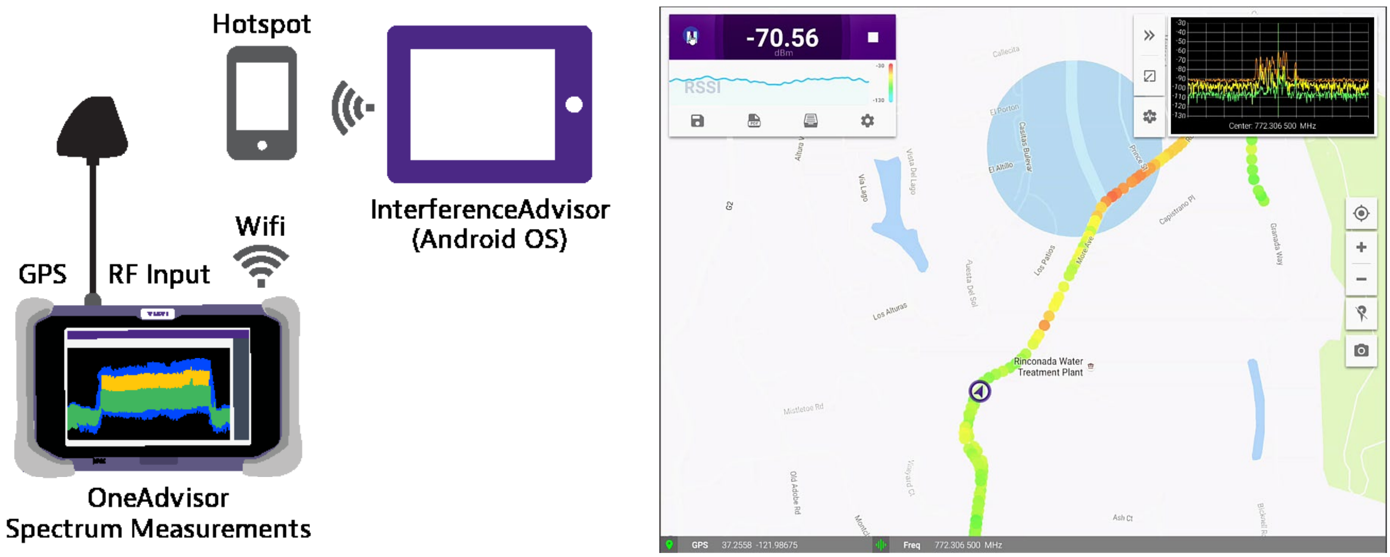

Figure 2: Spectrum Analyzer and InterferenceAdvisor solution overcome RF interference challenges

Another interference-related issue that service providers may need to pay attention to is the effect of 5G base stations on the satellite receive bands. Advanced 5G features such as massive MIMO and beam steering can deliver significant power and can potentially interfere and saturate the low noise block (LNB) downconverter of the satellite antenna system and cause interference, especially if the 5G base stations are close to the satellite earth station. Therefore, it is important during the planning phase to understand the impact of 5G base stations on the satellite earth station.

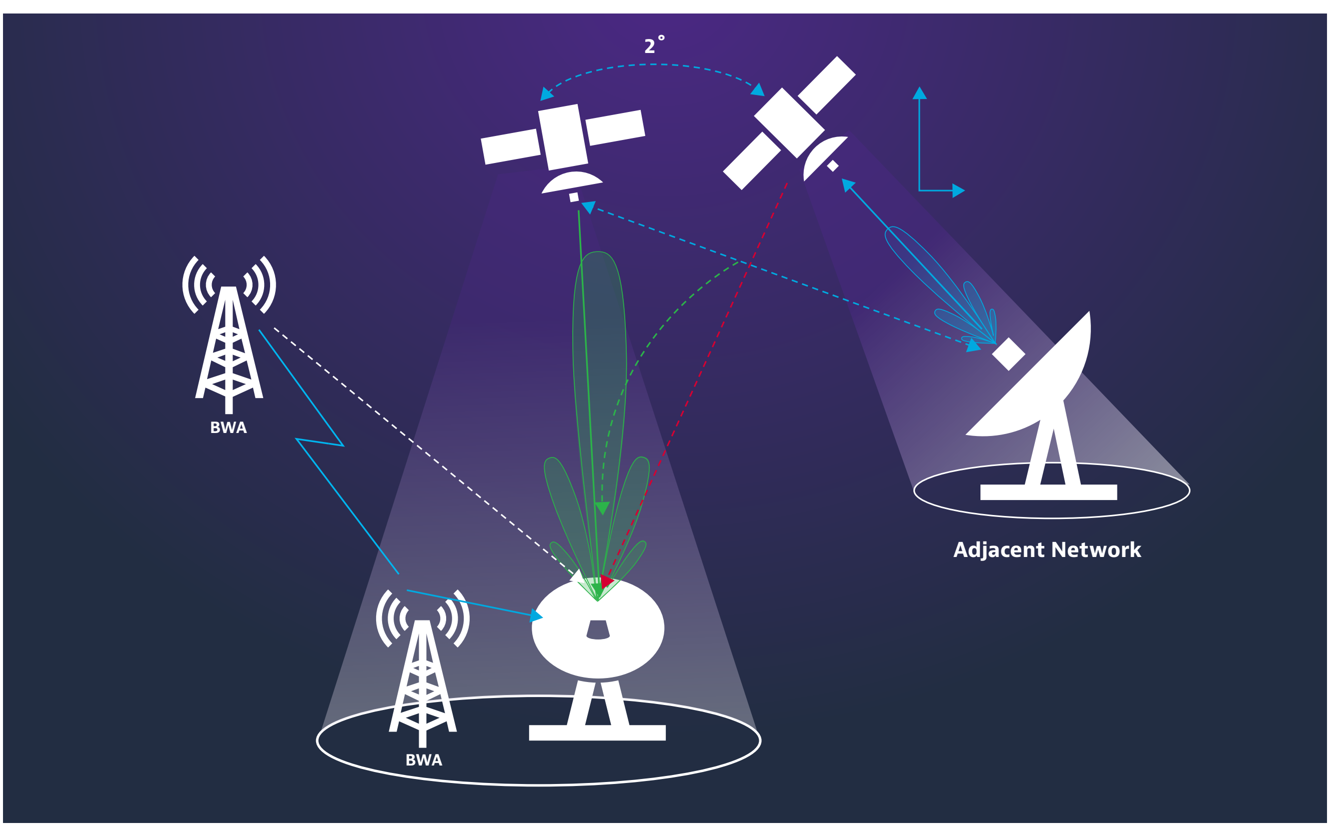

Figure 3: Interaction between satellite earth stations and broadband wireless nodes

2. Enhanced Importance of Antenna Alignment

Massive MIMO and beamforming will play an important role in 5G radio networks. Beamforming can be used to point signals in a specific direction to achieve higher quality and faster connections. Even minor distortions in the direction of the signals could affect the key performance indicators (KPI). Mobile operators use 5GNR modeling software with advanced propagation models, complex antenna array, and full multi-technology capacity simulators to deliver an optimized RF coverage plan. Failure to install per planned specification can lead to sub-optimal 5G network performance. Similarly, failure to identify near-field RF obstacles not identified by the 5G modeling software may render the cell unusable. To maximize mid-band frequencies and massive MIMO beamforming antenna performance, precise antenna alignment and line-of-sight surveys are critical during installation.

As a result, many mobile operators already require tower service companies to use GPS-based antenna alignment tools and provide line-of-sight reports. These tools use satellite signals to accurately calculate azimuth, tilt, and roll, hence eliminating the guesswork.

The VIAVI RF Vision Antenna Alignment Tool uses GNSS dual-frequency technology, which delivers accurate and fast antenna alignment readings (Azimuth, Tilt, and Roll) even in high-density urban environments. With a built-in camera, it displays the line-of-sight view of the antenna on a five-inch touch screen display, while augmented reality is implemented to show a crosshair and bullseye, allowing for easy and precise alignment.

Figure 4: VIAVI RF-Vision antenna alignment solution

3. Higher RF bandwidth/capacity may require eCPRI on the fronthaul

Common public radio interface (CPRI), used extensively in LTE, provides a dedicated transport protocol specifically designed to transport radio waveforms between the RRU and BBU. CPRI frames expand with increased radio channel bandwidth and the number of antenna elements. CPRI does not support statistical multiplexing, and cannot scale to the demands of 5G, especially when large bandwidths in the magnitude of hundreds of MHz and massive MIMO are deployed. Ethernet as a transport medium is very appealing, as it allows for backward compatibility with CPRI and also supports new packet technologies like eCPRI and O-RAN. By splitting BBU functions, 5G offers a flexible and more optimal mid-haul and fronthaul (also known as x-haul). This new x-haul architecture allows for scalable, packet-based transport technology.

eCPRI technology is based on a functional split in the LTE Physical Layer (PHY) component. eCPRI is designed to enable efficient and flexible radio data transmission over a packet-based fronthaul transport network. Using Ethernet for transport makes a lot of sense as it is backward compatible, allowing for commodity equipment, enabling greater convergence of access networks, and enabling statistical multiplexing, which will help lower the aggregate bit-rate requirement. However, synchronization can be challenging as eCPRI, unlike CPRI, is not a synchronous technology. GPS, precision time protocol (PTP), synchronous Ethernet, or something similar can be used to overcome this challenge.

Whether service providers are deploying a new technology or launching a greenfield network, all components, connections, and the overall network integration need to be tested. After ensuring all physical layer tests are completed (fiber inspection and certification), it is important to run higher-layer tests along with timing and sync to ensure the best return on investment. Failure to test can cause network launch delays, poor 5G system performance, and excessive, unplanned capital expenditure. Ultimately, neglecting to test can negatively affect the customer experience, cause end-user churn, and hurt the topline.

Service level agreements (SLAs) for the new mid-haul network will be very similar to backhaul, which means testing requirements will be similar:

A. Bandwidth measurement/committed information rate

B. Delay and jitter

C. Packet or Frame Loss

D. RFC 2544 and Y.1564 Test

SLAs for fronthaul networks will grow more stringent as higher capacity and ultra-low latency and reliability services are deployed.

Fronthaul transport network node (FTN) is introduced to manage the Ethernet access ring that can deliver a converged fronthaul supporting legacy CPRI and 5G eCPRI as shown in Figure 5. This resolves some topology challenges, but it is important to make sure that FTN networks do not create excessive delays and meet the delay and synchronization budgets for the access network.

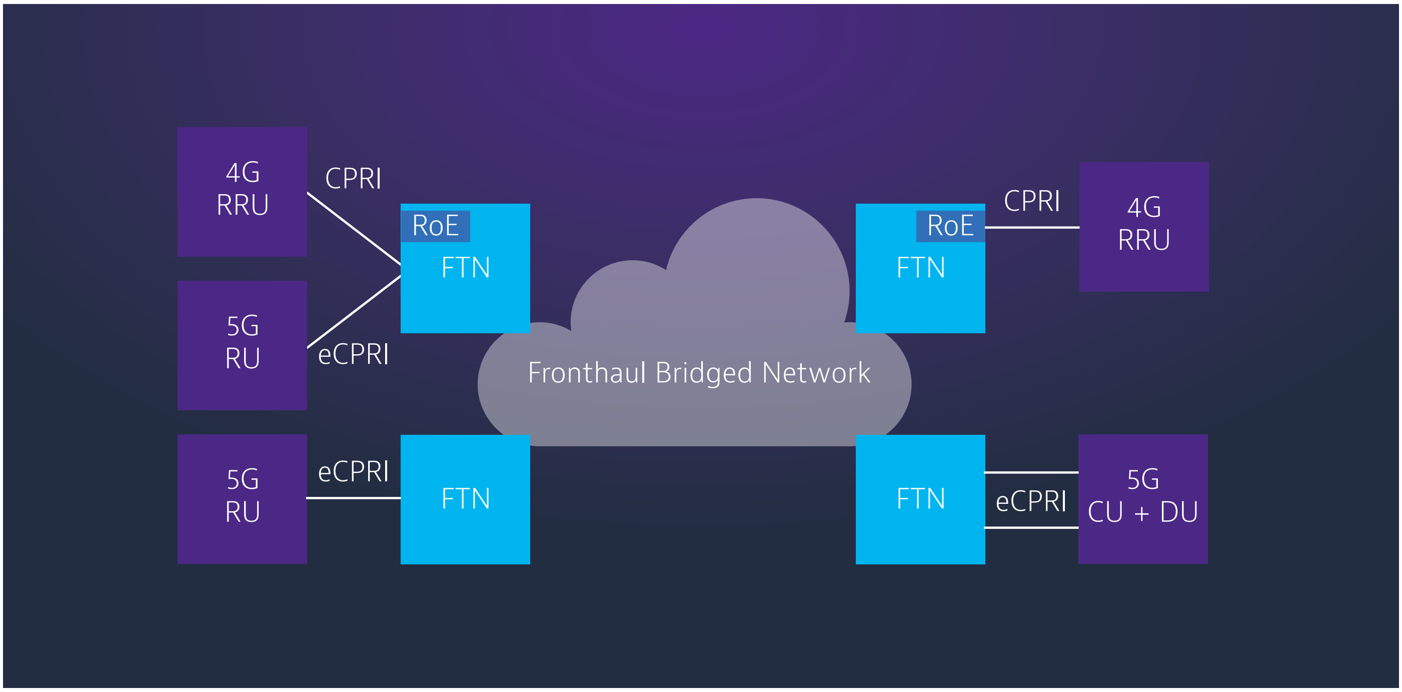

Figure 5: FTN Network architecture

Today multiple network equipment manufacturers (NEMs) are using the VIAVI T-BERD®/MTS-5800-100G in the lab to validate FTN performance. The T-BERD/MTS-5800-100G can perform eCPRI tests and measure throughput, delay, and packet jitter. By using a T-BERD/MTS-5800 engineers can configure eCPRI message types according to eCPRI specification, measure bandwidth for each message type, and measure round trip delay (RTD) with sub-5ns accuracy. By performing FTN tests, engineers can validate the delay and synchronization requirements for the FTN and can ensure it is within the designed network specifications. In the future, this test can also be used in the field to validate the fronthaul network performance.

The VIAVI T-BERD/MTS 5800 can perform the following tests for 5G fronthaul networks:

- Verify connectivity to an RU
- Measure One Way Delay (OWD) against an RU
- Verify PTP connectivity, and measure PTP Time Error
- Generate and analyze eCPRI signals (10/25GE)
- Verify proper QoS for eCPRI message types (Measure bandwidth/delay/jitter for each message type)
- Generate/filter eCPRI subheaders
- RTD measurement < 5 ns accuracy
- C&M, SNMP/UDP/TCP test
- Emulate PTP Slave/master
- Measure Time Error, Wander, PDV, MTIE/TDEV
- GPS Signal Strengths, Trails

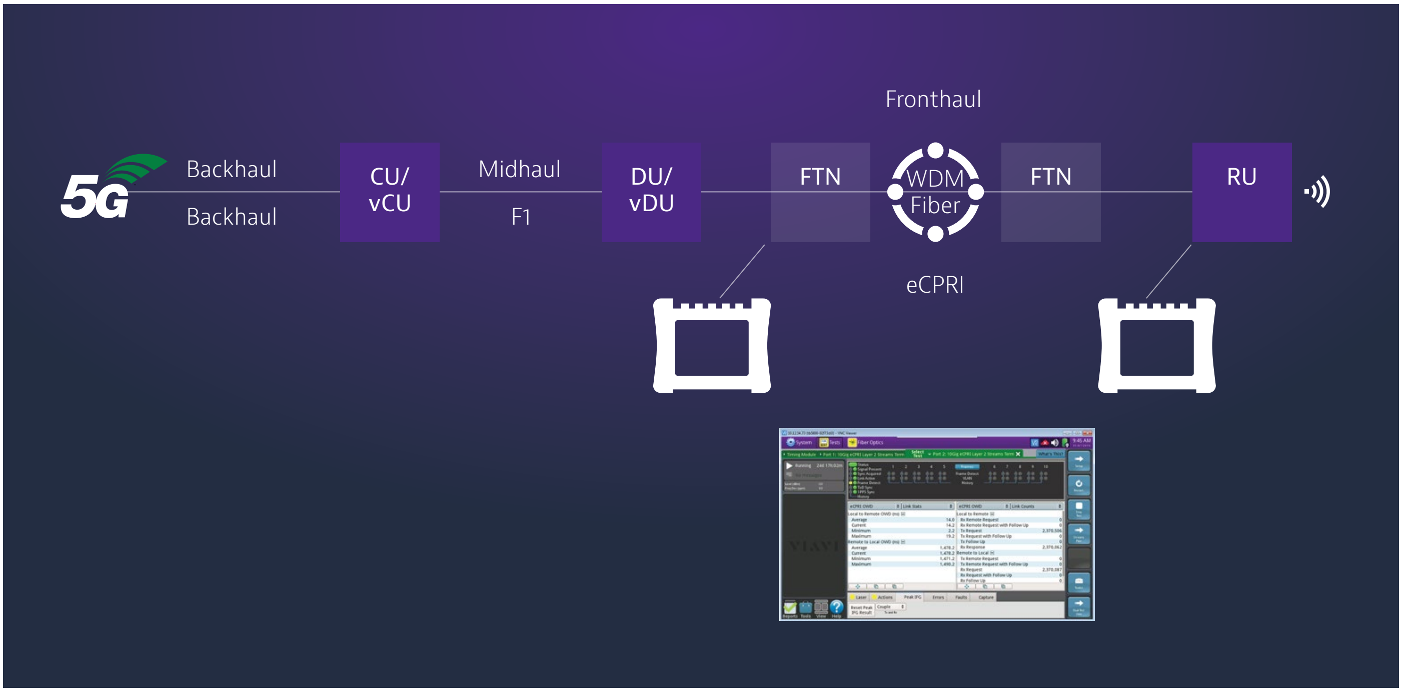

Figure 6: Example of 5G fronthaul RU connectivity and delay test

4. Implications of TDD on stringent Timing and Synchronization requirements

TDD turns out to be a more attractive option from a spectral efficiency point of view because it requires only unpaired spectrum for operation which is beneficial considering the scarcity of frequency resources. Also, physical layer features such as massive MIMO, beamforming, and precoding, which rely on channel state information (CSI) measurement in the uplink, are more robust due to channel reciprocity. While TDD brings spectral efficiency, it introduces a critical challenge: timing and synchronization. Stringent timing restrictions are imposed on a TDD system to avoid interference as both downlink (DL) and uplink UL shares the same spectrum. If the radio clock loses synchronization accuracy, or the radios are not synchronized, in a TDD channel, TDD framing will drift outside the guard period and interfere with adjacent cell-sites. The less accurate the clock source, the higher the probability for time shifts which ultimately bring performance and interference challenges. To avoid inter-cell interference use cases all base stations in a network should be synchronized with a common phase clock reference (e.g. UTC - Coordinated Universal Time). Per ITU-T standards recommendation, both 5G-NR TDD and LTE-TDD networks need to be phase synchronized in order to limit the end-to-end time error to under 1.5μs. This 1.5μs comprises of 1.1μs absolute time error up to the access point and 0.4μs over the fronthaul to the radio. Different timing synchronization solutions can be used to ensure all the radio units in the network are synchronized which will allow the schedular at the base stations to make sure interference is minimized.

In 5G, synchronization for backhaul will be very similar to that of LTE; however, in the absence of a synchronous fronthaul, deploying satellite receivers at every RU will not be cost-effective, especially for small cells, C-band radios, and mm-wave radios. We will still see satellite connections at the C-RAN hub location with tight timing controls out to the radios. Basically, timing and synchronization distribution is collapsed to work over Ethernet. In most cases, PTP (IEEE 1588v2) will be used to distribute time of day (ToD) and SyncE will be used to distribute frequency so that RUs will be synchronized over Ethernet (Figure 7).

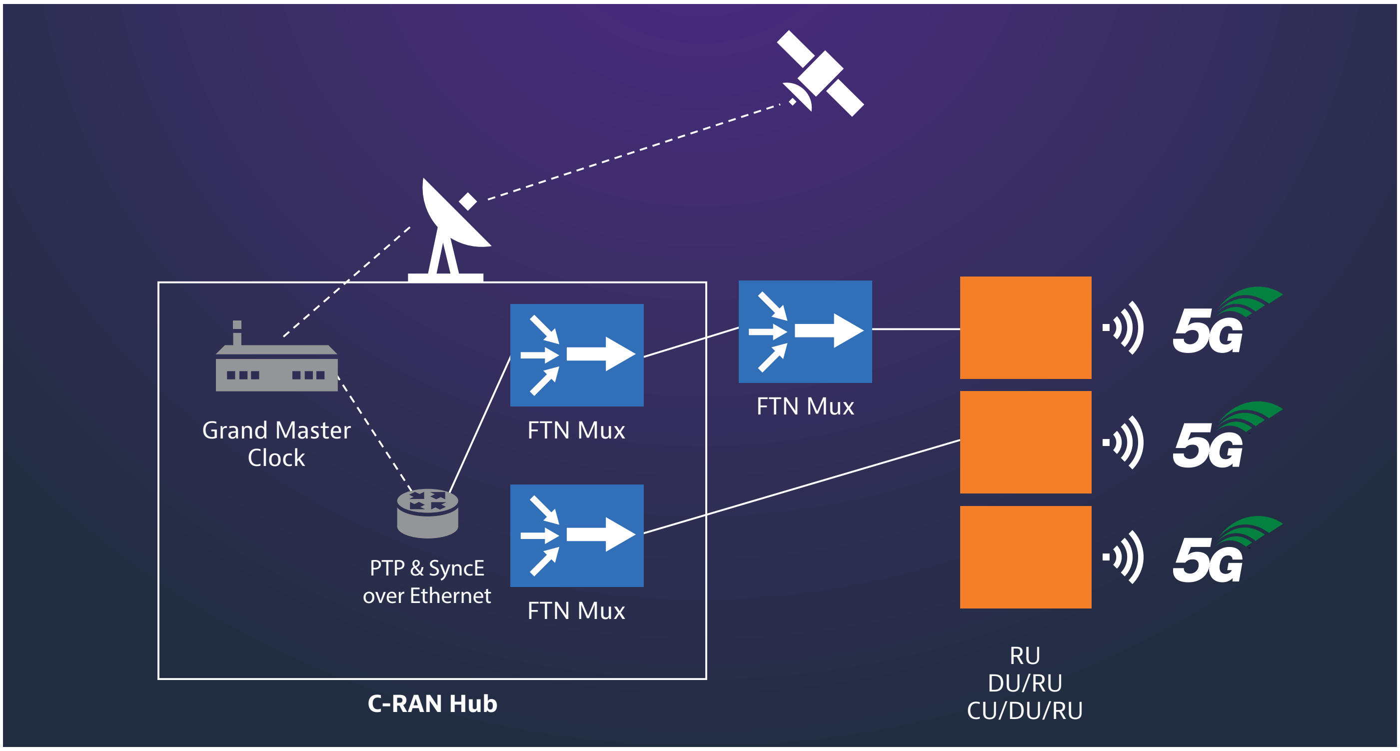

Figure 7: Timing distributed over 5G-NR network

Another consideration for TDD and TDD deployments, in addition to frequency and phase synchronization, is to avoid intercell interference. A compatible frame structure should be used between collocated networks with adjacent frequency assignments, or adjacent networks sharing the same frequency or adjacent channels. Essentially carriers must prevent simultaneous UL and DL transmission occurrence. i.e., at any given moment in time. Either all networks transmit in DL or all networks transmit in UL adopting a single frame structure for all TDD networks involved as well as synchronizing the beginning of the frame across all networks. Refer to ECC Report 296 and its recommendations for more details.

To summarize, the DL spectrum may leak onto the adjacent channels. For FDD, this is acceptable since UL and DL channels are separated by a guard band. For TDD, UL and DL share the same channel. Any DL spectral imperfection may thus create interference in the UL signal of the adjacent operator, especially when the two cells are at the boundaries of each other.

Hence, if two 5G networks operating in adjacent channels are not synchronized, an additional guard band of 25MHz, as well as extra filters on the emitters may need to be provisioned.

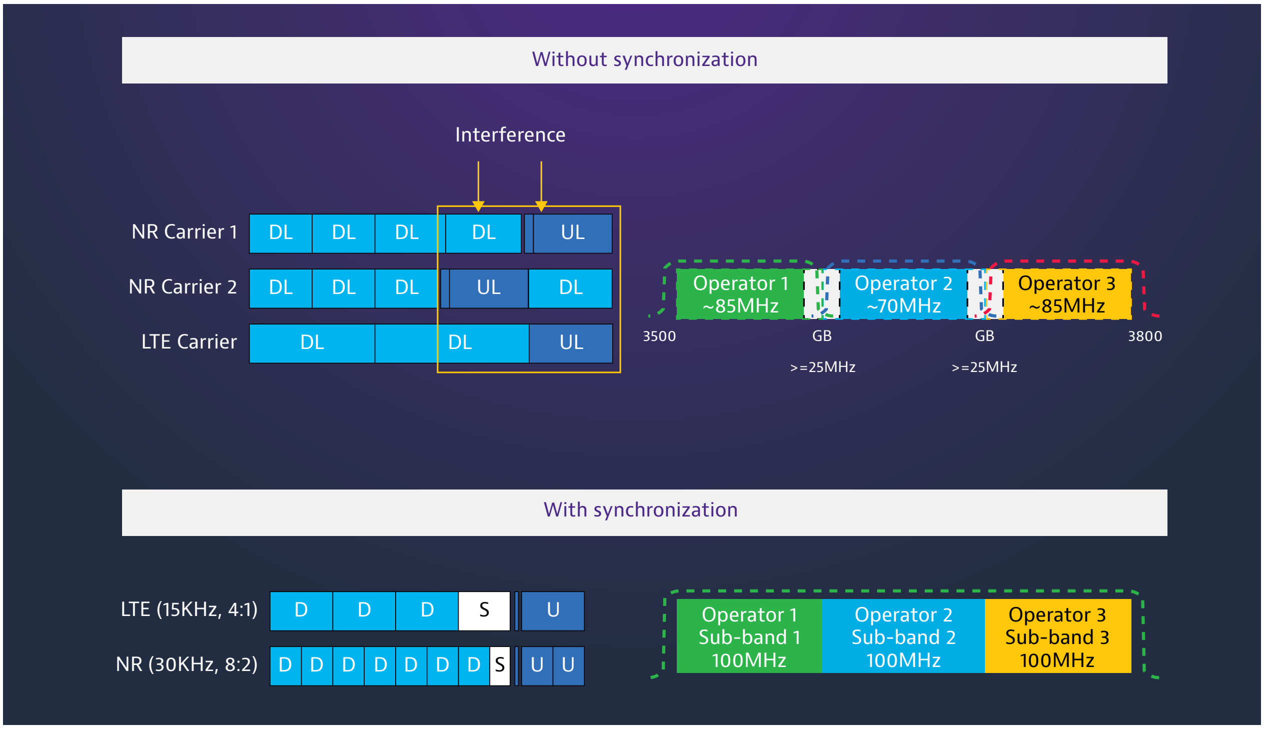

Figure 8: Frame synchronization

Using a VIAVI CellAdvisor™ 5G, an RF engineer or a technician quickly can validate over-the-air (OTA) frequency and time errors, ensuring synchronization conforms to the +/- 1.5µs vs UTC. This can be tested for the adjacent channel network as well. Validation of adjacent networks to ensure they conform to the agreed slot and frame formats can prevent intercell interference between adjacent networks. The CellAdvisor 5G can help by performing the following measurements:

- Frequency Error < +/- .05 ppm versus GPS
- Time Error < +/-1.5µs versus GP
- Validate frame format for multiple operators by making over-the-air measurements.

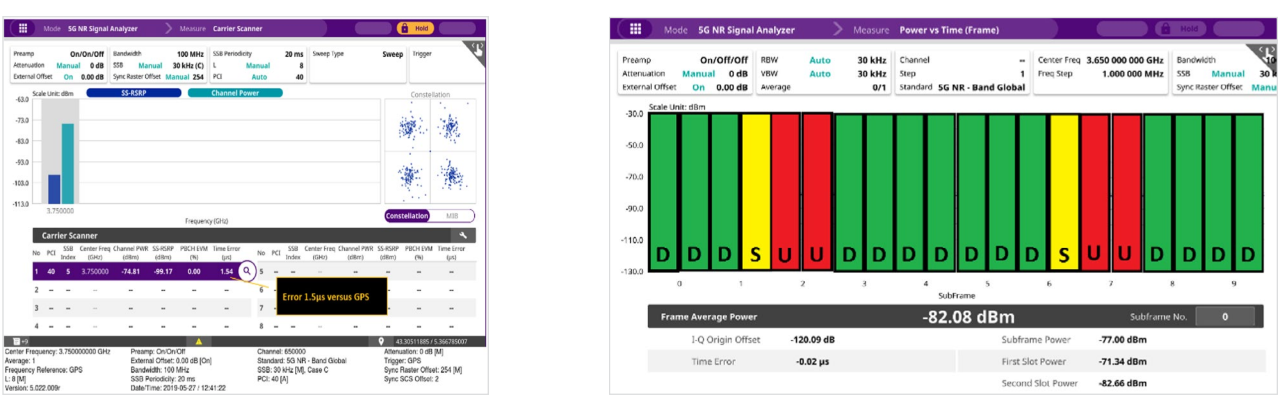

Figure 9: Over-the-Air Frequency and Time Error and Frame Synchronization measurement with the CellAdvisor 5G

5. Maintaining a 5G Advanced Antenna System (AAS) with higher-order MIMO and beams

Massive MIMO and antenna beamforming are the key technologies enabling 5G, which will change from static cell-centric coverage to dynamic user-based coverage for 5G radio access networks. Beamforming is the ability to generate and shape multiple beams using a much larger antenna array by manipulating the phase and amplitude of the arrays, thereby directing energy to a user's specific service area. At higher frequencies, C-band and millimeter-wave small wavelength makes it easy to integrate a larger array into a relatively smaller form factor.

Validating beam performance is a challenge for operators who need to perform beam-centric radio planning and optimization and need to quickly troubleshoot and identify the root cause of poor massive MIMO and beamforming performance. The CellAdvisor 5G allows engineers to easily validate beam performance and ensure that they are taking advantage of massive MIMO and beamforming.

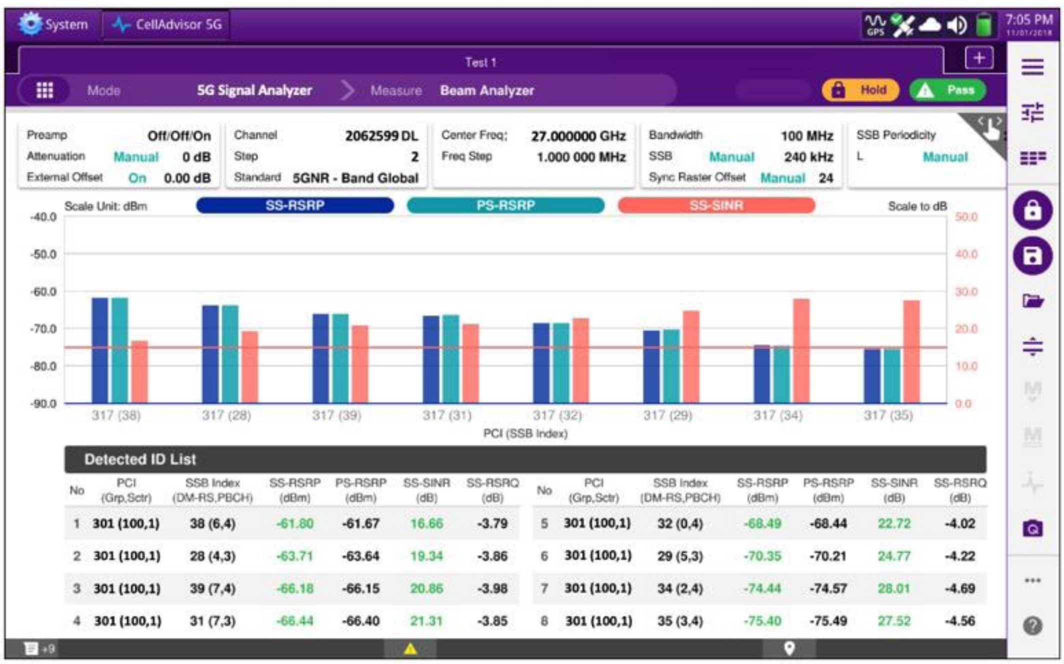

Figure 10: CellAdvisor 5G Beam Analyzer (8 strongest beams)

Another key aspect of C-band validation is to ensure that OTA network performance and coverage meet the network design specifications. CellAdvisor 5G route map functionality provides a basic RF coverage map depicting service availability developed from a walk or drive test. Location is tracked through an integral GPS receiver and the heat map measurements are captured using a special omni-directional antenna system and the CellAdvisor 5G Beam Analyzer function. In addition, to the continually updated display results, CellAdvisor 5G also captures a log file that can be exported to off-line coverage analysis tools. The 5G route map is used by field technicians to verify and measure:

- Cell Coverage: identifies the physical cell ID for each data point
- Beam Availability: attributes the beam index for each data point
- Beam Propagation: provides the measured beam power and beam Signal to Noise Ratio (SNR) at each data point.

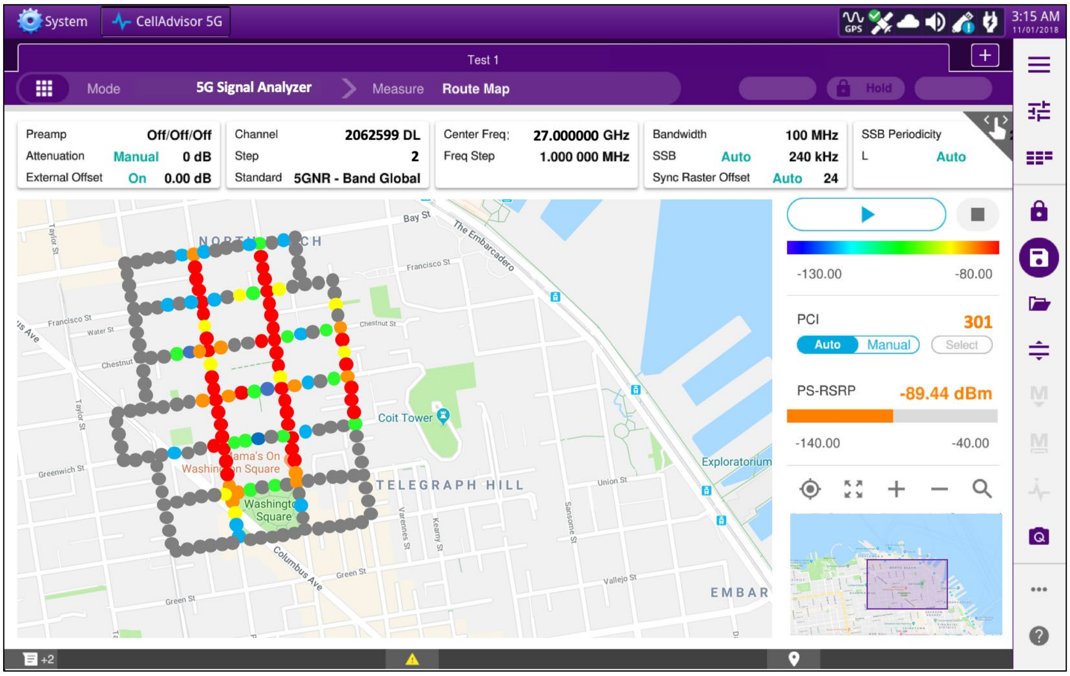

Figure 11: CellAdvisor 5G coverage map analysis

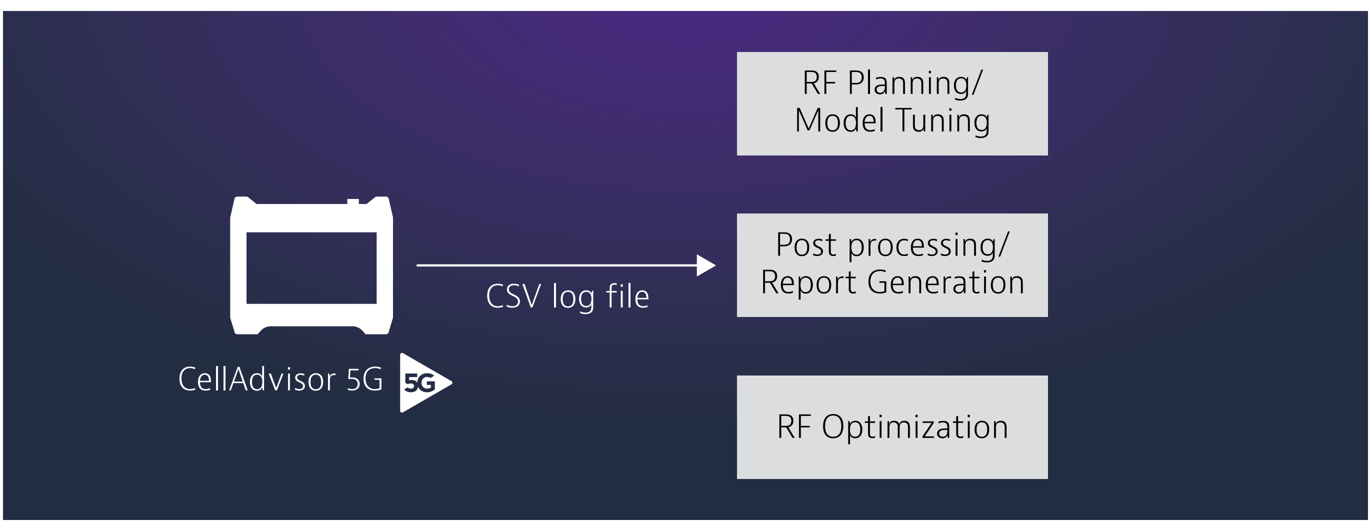

Figure 12: CellAdvisor 5G coverage map analysis

Conclusion

Overall, there is an expectation that C-band 5G deployment truly will deliver the coverage and capacity that 5G use cases need. However, deploying and maintaining 5G's complex technology and network architecture will not be a trivial exercise. Time-to-market and network quality will depend on the rigor of test and measurement during the complete life cycle of the network. VIAVI is the industry leader in test and measurement and is best positioned to deliver the most comprehensive end-to-end network test solution. Operators and their partners can be assured of a smooth network roll-out and sustainable network lifecycle with the fully integrated portfolio of cloud-enabled instruments and systems, software automation, and services for network testing, performance optimization, and service assurance VIAVI brings.

VIAVI Solutions

Contact Us **+1 844 GO VIAVI**
(+1 844 468 4284)

To reach the VIAVI office nearest you,
visit viavisolutions.com/contact

cband5g-an-nsd-nse-ae
30193060 900 0421