Making 5G Work

Accelerating testing across the workflow to put 5G devices in the hands of customers
Introduction

The 5G Device Relay Race

5G is moving fast. Accelerating 5G deployments globally are having a ripple effect throughout the mobile ecosystem.

5G also represents an exponential increase in technical complexity. Key challenges come from 5G new radio (NR), massive multiple input multiple output (MIMO), millimeter-wave (mmWave) frequencies, and over-the-air (OTA) test methods.

Device makers must effectively overcome these challenges to reach commercialization faster than the competition.

Like a relay race, 5G consists of four sprints for devices—design, conformance, carrier acceptance test (CAT), and manufacturing. This paper includes useful tips to help you accelerate your time to market across the workflow and reach first-to-market status.

The 4 Sprints of the 5G Device Workflow
Contents
Complete the four sprints to commercialization and win the 5G race

SPRINT 1
Accelerate 5G Designs
5 Strategies for Better Designs
Go to Sprint 1 >

SPRINT 2
Achieve 5G Conformance
4 Insights to Speed Up Conformance Testing
Go to Sprint 2 >

SPRINT 3
Succeed at Carrier Acceptance
3 Ways to Accelerate CAT for Your Device
Go to Sprint 3 >

SPRINT 4
Master 5G Manufacturing
4 Techniques to Reduce Test Times and Costs
Go to Sprint 4 >
SPRINT 1
Accelerate 5G Designs
5 Strategies for Better Designs
5G offers a dramatic improvement over 4G capabilities. Specifications aim to achieve data rates 100 times faster and provide less than 1 millisecond latency.

Device engineers need to:

- Design to the new standards
- Validate protocols for numerous and widely different use cases
- Verify RF performance to deliver the expected quality of service (QoS)

Leverage the following five strategies to develop more robust devices faster:

1. Reduce Prototype and Rework Costs with Simulation

Building mmWave prototypes is costly. Modeling an antenna in a simulated system with channel models and base station links provides insights early in the design cycle.

Simulation data becomes an important part of the design process, and can be used to troubleshoot throughout the development workflow.

Different impairments added to the simulation help to optimize the design prior to developing hardware prototypes.
2. Adopt Versatile Tools to Support Numerous Use Cases

Understanding 5G NR waveforms across the frequency, time, and modulation domains is important. New capabilities in NR specifications, including flexible numerologies with different subcarrier spacing, dynamic time division duplex (TDD), and bandwidth parts add to the complexity of creating and analyzing waveforms.

Having software and hardware that can create and analyze a 5G waveform for the many different use cases at sub-6 GHz, and in the new mmWave frequencies with greater bandwidths, is essential.

3. Characterize Signal Quality with IQ Constellation and Numeric EVM Measurement

Factors that impact signal quality include baseband signal processing, modulation, filtering, and up conversion. IQ impairments, phase noise, linear and nonlinear compression, and frequency error can cause distortion in the modulated signal.

Devices must be designed to overcome the physical challenges in wide bandwidth mmWave signals. Evaluating a signal’s modulation properties provides one of the most useful indicators of signal quality.

Viewing the IQ constellation helps in determining and troubleshooting distortion errors. Numeric error vector magnitude (EVM) measurement provides an overall indication of waveform distortion.
5G MODULATION SCHEMES INCREASE IN DENSITY

- **π/2-BPSK** - 1 bit per symbol
  - Q: 0, 1
  - I: 0, 0

- **QPSK** - 2 bits per symbol
  - Q: -1, 1
  - I: -1, 1

- **16-QAM** - 4 bits per symbol
  - Q: 0000, 0011, 0100, 0111
  - I: 0000, 0011

- **64-QAM** - 6 bits per symbol
  - Q: 000000, 000011, 000100, 000111
  - I: 000000, 000011

- **256-QAM** - 8 bits per symbol
  - Q: 0010 0100
  - I: 0010 0100
4. Evaluate Device Performance with Real-World Impairments

Most device testing is done in a controlled environment. However, devices need to operate in environments with signal propagation issues including excessive path loss, multi-path fading, and delay spread.

A network emulator is an efficient method for testing beam end-to-end throughput. Adding a channel emulator to your test setup enables characterization of end-to-end full stack data throughput, while emulating a variety of real-world radio conditions.
5. Reduce Distance and Path Loss in OTA Test Setups with IFF

5G cellular communication links need to be evaluated using far-field assumptions. Due to the nature of radiated waves, the far-field distance and associated path loss grows bigger with the frequency.

The 3rd Generation Partnership Project (3GPP) has approved an indirect far-field (IFF) test method, based on a compact antenna test range (CATR). While this method is limited to measuring a single signal, it reduces the distance and path loss for measuring mmWave devices, compared to the direct far-field (DFF) method.

OTA EXPERTISE SAVES TIME

A typical OTA test solution includes an anechoic chamber, different probing techniques, and test equipment to generate and analyze the radiated signals in a spatial setting. It can take a considerable amount of time to implement an OTA test solution on your own.

Since specific requirements and test methods are not fully defined, ensure that your test partner has expertise in 3GPP specifications, and early knowledge of requirements.

Expertise in 5G OTA test methods across chambers, probing, and the test equipment used to address a wide range of RF, demodulation and functional test requirements, in both mmWave and sub-6 GHz, for 5G new radio designs, is needed to avoid unnecessary rework.
Achieve 5G Conformance

4 Insights to Speed Up Conformance Testing
Defined by the 3GPP radio access network (RAN) working committees, conformance tests ensure a minimum level of performance in devices and base stations.

Passing conformance tests is one of the biggest hurdles device companies must overcome with 5G to release their products in the marketplace.

5G NR can operate in frequency range 1 (FR1: 410 MHz to 7.125 GHz) and frequency range 2 (FR2: 24.25 to 52.6 GHz). FR2 significantly increases test complexity. Test cases are growing exponentially. And standards continue to evolve. Conformance test requirements and test methods are less than 50 percent complete.

Use the following four tips to speed up 5G conformance testing:
1. Leverage the Minimum Requirements from 3GPP RAN2 and RAN4 Documents

5G NR documents are available in the 38.xxx series documents located on the [3GPP website](#).

Conformance test specifications originate from the minimum requirements specified in the 3GPP RAN2 and RAN4 documents.

Designers can use the minimum requirements as a guide to test their 5G NR products because they are more stringent than the specifications.

<table>
<thead>
<tr>
<th>Technical Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS 38.101-1</td>
<td>Radio Transmission and Reception; Part 1: Range 1 Standalone (FR1 Conducted)</td>
</tr>
<tr>
<td>TS 38.101-2</td>
<td>Radio Transmission and Reception; Part 2: Range 2 Standalone (FR2 Radiated)</td>
</tr>
<tr>
<td>TS 38.101-3</td>
<td>Radio Transmission and Reception; Part 3: Range 1 Range 2 Interworking Operation with Other Radios (FR1 Conducted &amp; FR2 Radiated)</td>
</tr>
<tr>
<td>TS 38.101-4</td>
<td>Radio Transmission and Reception; Part 4: Performance Requirements</td>
</tr>
</tbody>
</table>

2. Simplify the Test Setup with Flexible Test Solutions

Test equipment needs adequate range to cover the requirements from sub-6 GHz to the different mmWave operating bands.

Test equipment used for FR2 needs to cover wider frequency and bandwidth requirements.

Many tests require multiple sources for receiver tests, and multiple analyzers for transmitter tests.

A modular platform will reduce the test footprint and simplify the test setup.

3. Address Various Needs by Implementing Standard Platforms

5G NR aims to support many different use cases and deployment scenarios over FR1 and FR2 operating bands. The test combinations create a vast matrix of test cases.

5G NR can operate in standalone (SA) or non-standalone (NSA) mode. There are various options to choose from. Devices need validation for one or multiple deployment options. E-UTRA and 5G NR dual connectivity (EN-DC) also requires testing.

With the addition of MIMO and carrier aggregation combinations across multiple operating bands, this equates to more than 1,000 user equipment (UE) test cases.

Use a common hardware platform that scales across frequency ranges and UE conformance tests including RF, RRM, and protocol to:

1. Maximize test case coverage
2. Scale to wider bandwidths and higher frequencies
3. Resolve and validate issues early
4. Get through testing faster

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AVAILABLE 5G NR DEPLOYMENT OPTIONS

NON-STANDALONE MODE (NSA)

OPTION 3: Non-Standalone NR, LTE assisted, EPC connected

OPTION 3A: Non-Standalone NR, LTE assisted, EPC connected

OPTION 3X: Non-Standalone NR, LTE assisted, EPC connected

OPTION 7: Non-Standalone NR, LTE assisted, SG-C connected

OPTION 7A: Non-Standalone NR, LTE assisted, SG-C connected

OPTION 7X: Non-Standalone NR, LTE assisted, SG-C connected

OPTION 4: Non-Standalone eLTE, NR assisted, SG-C connected

OPTION 4A: Non-Standalone eLTE, NR assisted, SG-C connected

STANDALONE MODE (SA)

OPTION 2: Standalone NR

OPTION 5: Standalone LTE Rel-15, connected

OPTION 2: Standalone NR

OPTION 5: Standalone LTE Rel-15, connected

Accelerating testing across the workflow to put 5G devices in the hands of customers
4. Keep up with 5G NR Standards with Scalable Test Solutions

Conformance tests for various use cases and network deployment options for Release 15 are still work in progress. Carrier aggregation, FR2, and RRM test cases are less than 10 percent complete.

Expected in early 2020, Release 16 continues with 5G NR optimization, new use cases, and identifies new types of services, devices, deployment models, and spectrum bands.

To future-proof your test solutions, ensure your test equipment can evolve as the standards change. Consider how quickly your test vendor can provide software releases to update to the latest test cases.

As standards evolve to higher frequencies and wider bandwidths, scaling the test hardware is a physical limitation. Consider purchasing or leasing test equipment that has broader coverage initially or adopt test equipment that easily scales.
SPRINT 3
Succeed at Carrier Acceptance
3 Strategies to Accelerate CAT for Your Device

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Carrier Acceptance Test: Meeting the Requirements of Mobile Network Operators

Between conformance and manufacturing, carrier acceptance is an important phase in the device workflow. CAT aims to ensure that devices meet user expectations in terms of functionality and performance. 5G devices must demonstrate adequate performance and security features for operators to accept them on their network.

Leading operators have developed comprehensive CAT programs that span interoperability testing, field trials, protocol and RF conformance, and network simulation. Most operators perform conformance testing, and all operators conduct network vendor interoperability testing and field trials. Operators also have tests that focus on features and functions specific to their networks such as network reliability or coverage.

Implement the following three strategies to accelerate carrier acceptance for your device:

**SPRINT 3**

Accelerating testing across the workflow to put 5G devices in the hands of customers | 16
1. Leverage Conformance Toolsets to Test Ahead of Time

Device engineers can test ahead of time using conformance and CAT toolsets.

Generic test suites span RF characteristics, radio resource management (RRM), and protocol. They represent the most likely network configurations, and are enough for some use cases.

Flexible conformance test solutions that allow customization of test cases beyond the certification requirements enable device engineers to test for configurations and use cases that are specific to a given network.

2. Stress Devices to Optimize Power Consumption

More features and functions are added on devices constantly. mmWave operating bands and 5G NR dual connectivity make it critical for devices to maintain quality communications with base stations. Battery consumption is a significant competitive factor in mobile devices.

5G use cases have widely different battery requirements and performance. Device engineers should proactively select representative use cases and stress devices to ensure battery life with many different permutations and combinations of activities, using network emulators and power analyzers.
5G’S BREADTH OF USE CASES

5G requires testing a large matrix of use cases that vary widely:

- Enhanced mobile broadband (eMBB) focuses on high data throughput. It aims to provide lightning-fast downloads, augmented reality (AR), and high-definition videos.
- Massive machine-type communications (mMTC) focuses on connecting billions of “things”. Use cases include smart farming and optimal traffic management.
- Ultra-reliable low-latency communications (URLLC) will enable autonomous vehicles, remote surgery, and virtual medical visits.

Source: ITU: 5D/TEMP/390-E
3. Perform Virtual Drive Testing to Test Real-World Device Performance

New initial access procedures in 5G NR have increased the importance of testing for handovers compared to 4G. Conformance tests are not sufficient to determine the user experience during different field conditions and to cover all operator-specific handover scenarios. Traditional drive testing is expensive.

Virtual drive testing (VDT) can help device makers test the real-world handover device performance, prior to deployment in a live network. VDT uses data captured in the field to build tests that replay drive or indoor test routes by emulating real-world RF network conditions in a controlled laboratory environment. This helps reduce the time needed for field testing, in turn accelerating acceptance testing.
SPRINT 4
Master 5G Manufacturing
4 Techniques to Reduce Test Times and Costs
Manufacturing Test: Winning the 5G Race at Scale

Device makers are moving full-speed ahead towards commercialization. Once they have passed conformance and acceptance, the cost of test and test times determine profitability and first-to-market status.

In 5G, device makers need to overcome new manufacturing test challenges not faced in 4G - more frequency bands, mmWave frequencies, and wider bandwidths.

Taking 5G devices through the manufacturing workflow is not easy. Device manufacturers must master the complexities of 5G to innovate, transform, and win in 5G quickly.

Deploy the following four techniques to reduce test times and the cost of test:

1. Accelerated Measurements

   Accelerated measurements help test engineers start closer to the finish line.

   Hardware-based field programmable gate array (FPGA) measurements yield significant reductions in test times.

   Test speed increases across power and frequency ranges for multiple channels and radio formats.

2. Multi-Device Testing

   Testing more devices at once accelerates test times for device manufacturers.

   Advanced test sequencing and single-acquisition multiple measurements (SAMM) help maximize throughput and yield.
3. Cloud Data Processing
Cloud data processing can help test throughput reach extremely high levels.

Critical calculations run in parallel on fast cloud-based servers. The test architecture is highly efficient, increasing measurement throughput.

Manufacturers repurpose test stations increasing test asset utilization and flexibility.

4. Measurement Consistency
Using the same measurement algorithms across the device workflow helps to reduce development time.

Engineers have higher confidence in their measurement results.

Traceability back to design accelerates resolution.
SUMMARY
The 5G Device Relay Race

A relay race is a track and field event that typically consists of four sprints. In the world of 5G devices, these four sprints are design, conformance, carrier acceptance test, and manufacturing.

Delivering on the extreme data rates and low latency promised by 5G will be challenging. Device makers need to leverage high-performance, flexible, and scalable test solutions to overcome the technical challenges coming from 5G NR, mMIMO, and mmWave frequencies. They must also rethink their overall test strategy across the workflow to capitalize on the synergies and gain the first-mover advantage.

FOR MORE INFORMATION

For more insights on how to accelerate 5G innovation across the device workflow, check the following links:

To accelerate development time for 5G devices, check out the First Steps in 5G four-part white paper series: 5G New Radio Standard, Millimeter-Wave Spectrum, MIMO and Beamforming, and Over-the-Air Test.

To speed up conformance testing, download Prepare for 5G New Radio Conformance Test Challenges; the newly released 5G New Radio Standards and Conformance Tests poster can also help you keep key information at your fingertips.

To reduce test times and costs, check out Mastering 5G Manufacturing.