Wider horizons for next-generation testing

The evolution from drive testing to multi-level automated testing in 5G

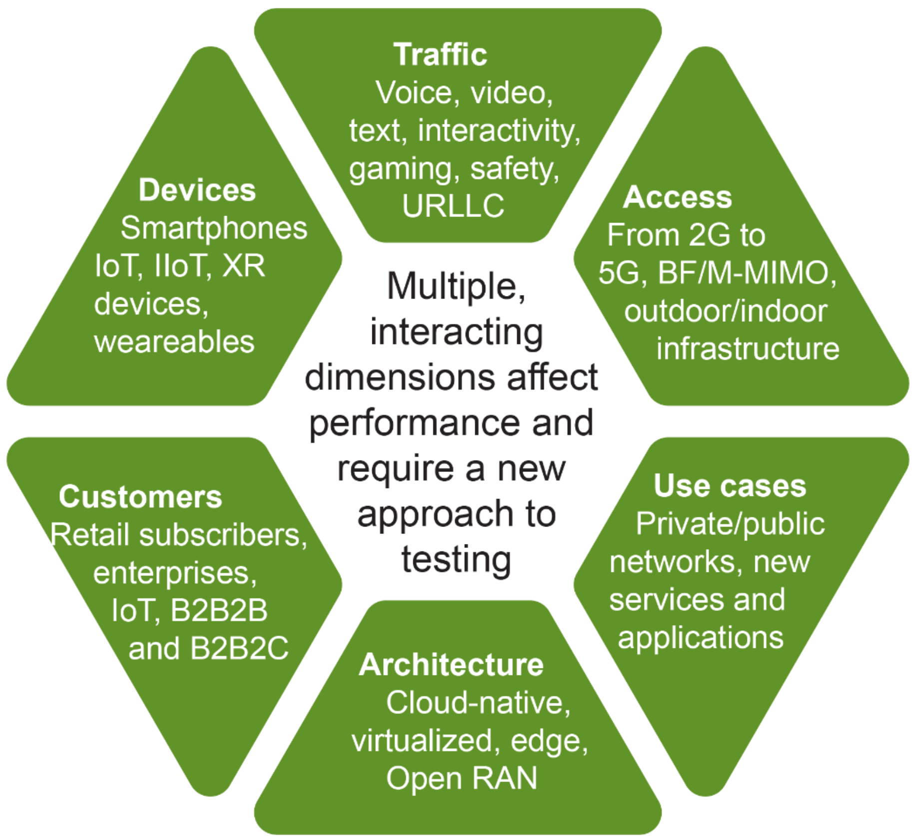
The wireless evolution to 5G, digital services, IoT, cloud-native and virtualized architectures is creating networks that are more powerful and sophisticated, but also more complex to manage and optimize. To keep up with the new requirements and expectations, operators have to widen the scope of testing and adopt a new approach that combines tried-and-tested tools with new ones. Wireless networks have to do more, and so does testing.

The new next-gen testing paradigm is emerging from three evolutionary directions:

- **Networks are more complex: legacy and new access technologies coexist, and they support a wider range of devices and services.**
- **The set of testing targets is broader: in addition to traditional KPIs, operators need to test for both network performance and perceived performance (i.e., user experience), and for specific traffic types and services.**
- **New tools and devices are available for testing: artificial intelligence, machine learning, automation, remote testing, and crowdsourcing create new testing methodologies which can use dedicated or off-the-shelf devices.**

The result is a new testing environment that operates in real-time and at multiple levels, is more powerful and flexible, and complements the existing testing methodology with new solutions. This more granular approach to testing allows operators to extract all the benefits new technologies promise, that subscribers enjoy the experience they promised and that their networks meet their sustainability targets.

This paper looks at how testing is evolving and how operators can meet their new testing requirements without increasing costs.



What new testing platforms need

- Assess subscriber perceived performance
- Test for specific services, traffic types, devices
- Add location, time and context awareness
- Increase precision and granularity
- Include data from multiple sources
- Preserve scalability in increasingly complex networks
- Enable multi-level testing, with the ability to drill down when needed
- Automate the testing process to reduce costs and manage the increased volume of test data
- Conduct testing without the active participation of skilled RF engineers
- Combine new testing methodologies with traditional ones

Increased network complexity and capabilities demand more granularity in testing

New use cases. Traditional engineer-led drive testing has served operators well to ensure they had the coverage, mobility support, voice quality and call reliability, latency and throughput that basic voice and data services needed. Dropped calls and MOS scores were the main metrics defining network performance when voice dominated. Now, throughput and latency are equally crucial, but they fail to characterize network performance at the granularity operators need as they move to 5G and new use cases. Online gaming and IoT (see table on the right) are two examples of how the scope of testing is widening.

New metrics. Old KPIs may need to be complemented by additional ones. For instance, in addition to dropped calls and MOS scores, operators need to test voice quality within applications or for other services. Latency has to be measured over the RAN and for end-to-end connectivity, with uplink and downlink latency measured separately. Operators need to know how long it takes to launch services or applications, or to receive content, as subscribers have little patience, and long wait times may result not just in bad experiences but in churn or reduced service revenues due to cancellations.

Metric interactions. The collection of old and new metrics has to be fine-tuned based on context, location, time, device and service and be able to capture the interaction among these dimensions. Averages are good for financial reports but not very helpful in understanding or improving network performance. Average latency metrics, for instance, do not explain why some subscribers have a good online gaming experience and some do not. Is the difference due to location (indoor versus outdoor, basement versus top floor, cell-edge versus cell-center) or band or RAN features? Most likely, it is the interaction of these factors, and the results will vary across areas or markets.

Two new testing use cases: online gaming and IoT

Online gaming is one of the services we know some subscribers are willing to pay for and that 5G networks can support at scale. Before offering a subscription service, mobile operators must test their network performance specifically for gaming. High throughput, good coverage and low latency are necessary but insufficient to predict a good gaming experience.

As an interactive service with a heavy video and motor response component, operators must go beyond roundtrip latency. They must ensure one-way latencies below 15 msec, with low jitter, good downlink throughput and reliable uplink.

It is unlikely that an operator can support this level of performance throughout its network, and it needs to know where and under which conditions it can. How well can 4G support online gaming if 5G is not available? Can users play in indoor locations? Where? Is network slicing necessary to guarantee good online gaming? How does the gaming experience decline as traffic load grows, or if traffic is encrypted or behind a VPN? Is the performance affected by the gaming platform, device model, OS, network architecture, or spectrum band?

IoT has a huge growth potential that depends on wireless networks' ability to meet a large set of performance targets. Many IoT devices are fixed, and drive testing is not an ideal solution. Some IoT services need little bandwidth but may need high reliability and low latency and jitter. Other IoT services may require high throughput but have less demanding latency and jitter requirements. Some IoT services are deployed in public networks, others in private networks; some use edge infrastructure, and some are cloud-based.

Operators need to know which IoT services they can support, what SLAs they can offer, and how this changes across their network. In private networks, enterprises need access to testing capabilities that are specific to the services they run on their networks.

Application and service-based testing. Wireless use cases, services and applications are growing in number, but also in the diversity of requirements. An IoT temperature sensor has different requirements from a metaverse headset or a drone camera. Collecting a wide range of metrics helps operators predict an application or service performance by looking at their specific requirements. But explicitly testing for an application or service may provide a more valuable and precise characterization of performance.

Dynamic testing. Most metrics fluctuate with the time of day or day of the week, but they also change as operators upgrade and expand their networks and traffic increases. The increasing frequency of these changes transforms testing into an ongoing activity that runs in concert with network monitoring and planning. Has a network update resolved a performance issue? Do additional steps have to be taken? A dynamic, incremental testing approach can answer these questions.

User-perceived performance. Testing has traditionally focused on network performance, but what really matters is the subscriber's perception of performance. Network performance is, to a large extent, a proxy for user-perceived performance, but it does not include, for instance, the role of the receiving device in determining latency, delays, or throughput for different applications. Device testing alone does not address this issue, but device awareness in testing may provide additional insight when network performance does not accurately predict user performance.

Beyond old-school testing

Traditional drive testing – still a large part of today's testing – involves an RF engineer running tests while driving, using hardware designed to collect network performance and subscriber-experience data.

Can this approach be used to meet the new testing requirements? In theory, it can, but it would be unsustainable in terms of costs, time and effort required. Operators would have to hire more RF engineers – more than available in many countries – but use their expertise inefficiently for repetitive tasks. Engineer-led drive testing works well in complex troubleshooting scenarios when the testing is very focused, and the overall volume of tests is low.

Because of the lack of automation of testing and the limited ability to compare results across tests, engineer-led drive testing is insufficient to meet all testing needs cost-effectively and efficiently.

Does this mean that we no longer need drive testing? Not at all. Drive testing can be automated and conducted by non-experts under the remote supervision of RF engineers. This allows one RF engineer to oversee many drive-test teams, reducing costs and increasing scalability.

Rather than being the primary testing methodology, engineer-led drive testing becomes one of the testing tools that operators can use when needed. Because it requires more dedicated resources and is more expensive, operators may want to restrict its role, using automated testing first – via a vehicle, a mobile device carried by a person, a drone or a fixed testing device – and only reverting to engineer-led drive testing when necessary.

Technological advances increase testing efficiency

As networks become more technologically advanced, so does testing with the addition of new tools that make it more efficient and scalable while keeping costs and resources needed under control. Testing can gradually evolve to meet operators' growing needs to assess performance as they upgrade their networks and move to 5G, adding new testing layers in a more comprehensive testing platform.

Automation and AI/ML are probably the most crucial enablers of the evolution of testing. With the increase in network complexity and sophistication, and the expansion in testing targets we just discussed, we would quickly fall victim to a combinatorial explosion of tests to be conducted and a flooding of results we would not be able to analyze. Automation driven by AI and machine learning are necessary to manage, prioritize the search space, define the tests to run throughout the process (e.g., go deeper only in directions that require further attention) and the appropriate testing methodology (e.g., drone-driven, an off-the-shelf device carried around by a contractor, or drive testing). As the testing results are collected, the testing platform can analyze the large data sets to direct further tests if warranted and generate reports.

Testing orchestration and unified management follow from the automated, AI/ML-driven platform. They coordinate testing requirements with network resources and testing capabilities to ensure the requested tests are completed and the results reported. Because multiple test modalities and human/device resources may be required, it is important to have a centralized mechanism to coordinate activities. A unified management system also allows comprehensive network-wide analysis, for instance, to assess how performance changes across the network for each metric included in the testing process.

With **real-time analysis,** testers can see when they have successfully completed a task, and operators no longer need to wait for the

Everybody, every device can participate in testing

With automation and the use of off-the-shelf or remotely managed devices, RF engineers are no longer required to directly conduct repetitive and time-consuming tests out in the field. Instead, testing devices can be remotely operated by the testing platform with the guidance of RF experts, and carried around by non-specialized employees or temporary contractors, who may be driving or walking into indoor locations and following directions from an app installed on the testing device.

Alternatively, testing devices can be installed in vehicles (e.g., delivery trucks, rideshare vehicles) for testing that does not require to be conducted at specific locations.

Subscribers can also participate in testing by allowing testing apps to be installed on their devices. While the depth of information gathered via crowdsourcing cannot match dedicated network testing, it greatly increases the volume of performance data that can be gathered and provides an excellent complement to more targeted network testing.

Remote testing opens new opportunities for testing with devices such as drones or fixed devices that do not require human presence during testing.

Drones may reduce testing costs and allow testing at different heights outside high-rise buildings that can assess indoor coverage in buildings where testers cannot easily enter.

Fixed unsupervised testing devices can be used for active testing and may be valuable for testing IoT devices and applications.

testers to drive back to the office, upload and manually analyze the data they collected. By analyzing data as it is collected, they can further refine testing and explore specific concerns immediately while the tester is still on the scene by remotely sending testing requests to the device and directions to the tester.

Remotely managed devices further increase the cost efficiency and the scalability of testing. Test driving typically relies on hardware specifically designed for testing, and that requires an RF expert for operation. Increasingly, testing can be hosted on off-the-shelf devices with dedicated apps or firmware, or on testing devices (e.g., specifically designed drones) that do not require RF expertise or human intervention to run tests and transmit the collected data. While dedicated, high-end devices will continue to play a role in challenging situations, virtually all network terminals and elements can become part of the testing platform, transforming testing from a narrowly defined function in time and space to an ongoing activity capability throughout the network that can be activated when needed, as needed.

Do we still need RF engineers?

Will AI-driven testing platforms remove the need for the experience and skills of RF engineers? Certainly not in the foreseeable future. Automated and AI-savvy testing will make it possible to run large numbers of tests, analyze the impact of many metrics and their interactions in real time, and collect vast amounts of historical data. The results will assess network performance, identify potential issues and suggest possible solutions. But RF engineers will have to manage the process, request more detailed test activities, review and fine-tune the results, make recommendations, and analyze them within the operator-specific context and strategy.

For instance, an operator may find that the network is not ready to support online gaming in scale throughout the network but decide that the changes necessary to do so are too expensive or that current demand and potential revenues do not justify the cost. Or it may find that with a small investment, paid online gaming services can be offered in some areas where the operator expects high demand. In such cases, RF engineers can design additional tests to get more detailed data, probe some scenarios, evaluate the tradeoffs of the proposed changes, or suggest alternative changes.

A multi-level approach gets the most value out of testing

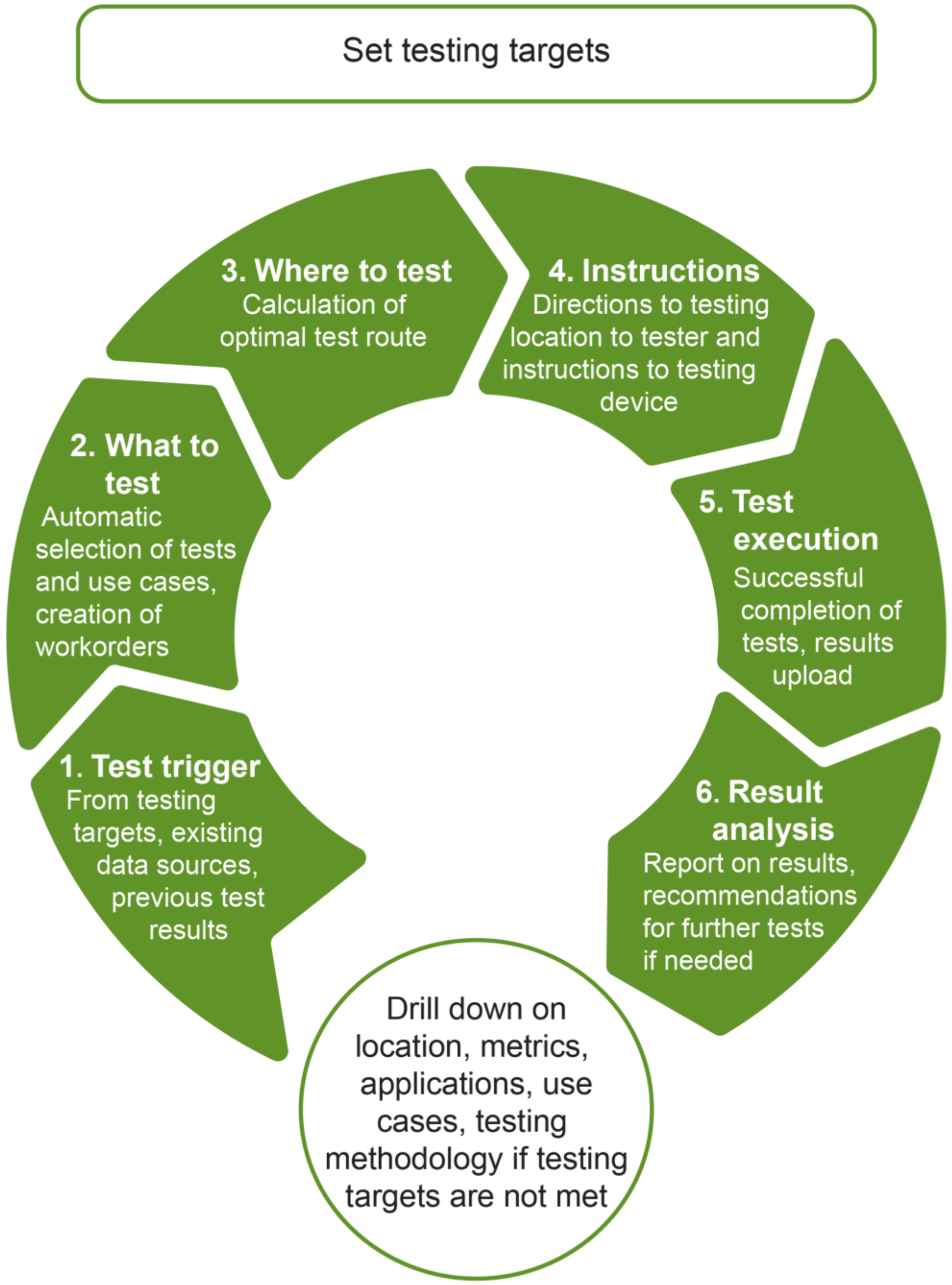
The testing tools described in the previous section allow us to expand the scope of testing, increase the number and type of tests, and analyze large result data sets at a low marginal cost. Yet, this does not mean that operators should run as many tests as possible. It would be wasteful and unnecessary.

A strategy is needed to minimize the number of tests to be conducted without sacrificing the quality, reliability and depth of the results. This is where a multi-level approach that uses AI/ML-driven automation and real-time analysis helps operators select the most appropriate tests at any time and place for their specific testing goals.

Rather than having a fixed hierarchical structure, operators have different options to choose from, enabling them to pursue testing paths that provide more detailed or different data to characterize network performance to their targets.

In most cases, this multi-level approach will involve multiple stages, as the testing platform may recommend further tests based on results from completed tests. This process would repeat until the desired results have been collected.

For instance, to test the user experience in online gaming, an operator may start with high-level tests to ensure that basic performance requirements are met across the area of interest. If this is the case, it may want to look in more detail at the performance in outdoor versus indoor locations, at the cell-edge performance, at latency/jitter detailed measurements, at how different devices or game types affect user experience, and how the network compares to the competition. Different testing methodologies would be appropriate depending on the test's goal. For instance, indoor testing may require a tester to walk into buildings, but drone testing may provide useful additional data. Device and game testing may be conducted on subscriber devices. Crowdsourcing is more appropriate to benchmark network performance. The list of tests to be completed, their granularity and the methodology will be compiled as results come in from initial tests. If the network does not meet the basic requirements to support online gaming, the operator may choose not to proceed with further testing.



Source: Infovista, Senza Fili

Takeaways: The expanded role of testing

A gradual evolution path toward a richer and more efficient, multi-level testing platform

As networks gradually evolve to include new technology features, so does testing.

New tools are added to traditional testing solutions, such as engineer-led drive testing, to meet the expanded testing needs of operators.

Automation, AI/ML, and real-time analysis create a multi-level testing platform with unified orchestration and management.

By enabling anybody and any device to conduct testing, operators can conduct more extensive tests in a cost-effective manner, with the resources they already have.

Increasing granularity and scalability in testing complex and dynamic networks

Wireless networks are becoming increasingly complex and heterogeneous, run more diverse traffic flows, applications and services, and connect to more device types.

Testing for network performance using a small set of KPIs is no longer sufficient to assess performance for specific use cases.

Operators need to track more metrics and conduct more detailed tests to understand how their network performance varies depending on factors such as location, application, device or RAN architecture.

Testing solutions covering subscriber experience and IoT terminals

Testing exclusively for network performance is still crucial, but it may not accurately capture subscriber experience.

Testing for new metrics that assess factors such as interactivity or conducting tests from subscriber devices (with their permission) yields a better understanding of end-user experience or the perceived network performance.

IoT terminals also require new testing solutions which can assess the wide range of specific requirements of IoT use cases.

Wider testing approach to cover specific use cases

A flexible testing platform will continue to evolve as new use cases emerge or become more widely used.

The growth of IoT and private networks will require adapting testing platforms to enterprise environments.

Network slicing will also require the ability to test the performance of individual slices.

The metaverse and, more generally, XR use cases and URLLC will increase the performance requirements of the network and will further increase the depth of the testing requirements.

Beyond testing

Wireless networks have become dynamic as the frequency of software and hardware updates increases and new services and capabilities are introduced. Testing becomes an ongoing activity to access the impact of any network update or change.

This evolution naturally takes testing closer to network monitoring and planning. Many testing capabilities may merge with or contribute to monitoring and planning.

The convergence of testing, monitoring and planning may increase the efficiency of network management and avoid duplication of efforts.

Testing may also expand to areas such as sustainability and power efficiency, which are becoming more central to operators.

About Infovista

Infovista is the global leader in network lifecycle automation (NLA) for the next-gen networks era. With its unique NLA approach, Infovista allows communications service providers (CSPs) and enterprises to improve their network performance and customer experience, optimize their productivity, and reduce their costs, while maximizing return on their investments. Spanning the entire network lifecycle, Infovista's products and solutions leverage an open, integrated, cloud-native portfolio that automates tasks, flows, analytics, and decisions to the greatest extent possible. More than 1,700 customers, including 400 Mobile Network Operators, around the world rely on Infovista to plan, design, deploy, test, operate, support, optimize, evolve, report on and monetize their networks – www.infovista.com

About Senza Fili

Senza Fili provides advisory support on wireless technologies and services. At Senza Fili, we have in-depth expertise in financial modeling, market forecasts and research, strategy, business plan support, and due diligence. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless, and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations. We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, use these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafili.com.

About Monica Paolini

Monica Paolini, PhD, founded Senza Fili in 2003. She is an expert in wireless technologies and has helped clients worldwide to understand technology and customer requirements, evaluate business plan opportunities, market their services and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She frequently gives presentations at conferences, and she has written many reports and articles on wireless technologies and services. She has a PhD in cognitive science from the University of California, San Diego (US), an MBA from the University of Oxford (UK), and a BA/MA in philosophy from the University of Bologna (Italy).