Heterogenous Networks and their Role in 5G

When a new generation of cellular technology is launched, services associated with such technology may initially be offered in limited geographic areas and then expanded gradually over a multi-year period to large areas including nationwide coverage and continentwide coverage. Unless a new operator is carrying out "greenfield deployment," an existing infrastructure is reused to the extent possible. For example, the facilities (e.g., tower and buildings) where the radio equipment of a previous generation cellular technology is residing are upgraded to accommodate the newer generation cellular technology. Deployment of 5G on the top of 4G LTE has often occurred with such approach. There are special coverage extension or enhancement needs such as in-building coverage in large venues (e.g., large exhibition halls and convention centers). Similarly, there are special capacity needs in densely populated areas, requiring densification of the network (i.e., relatively more cells per unit area) to increase the available capacity. While traditional coverage extension and densification may involve Distributed Antenna Systems, Fixed Wireless Access, and small cells can be utilized with 5G, newer infrastructure trends are also emerging.

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One of the solutions to meet the ever-increasing data rate requirements in 5G and beyond is the deployment of heterogeneous networks (HetNets). HetNets consist of macro-, micro-, pico- and femto-cells. This type of solution significantly improves network coverage inside and in areas like large venues. Localized HetNets are not new, however, 5G HetNets will utilize new technologies, new frequency bands and will require new techniques to test the heterogeneous network effectively and efficiently.

Cellular Data Use Trends

4G/LTE has changed the way we use our phones. Increased data bandwidth from 3G to 4G/LTE enabled the mass expansion of cell phone usage by supporting new applications that require a significant amount of send/receive data. The popularity of app services among smartphone users presents a serious challenge to mobile operators: data consumption is soaring, and with an expected 10-fold increase in the next 5 years, investments to merely transfer the sheer amount of data are inevitable.

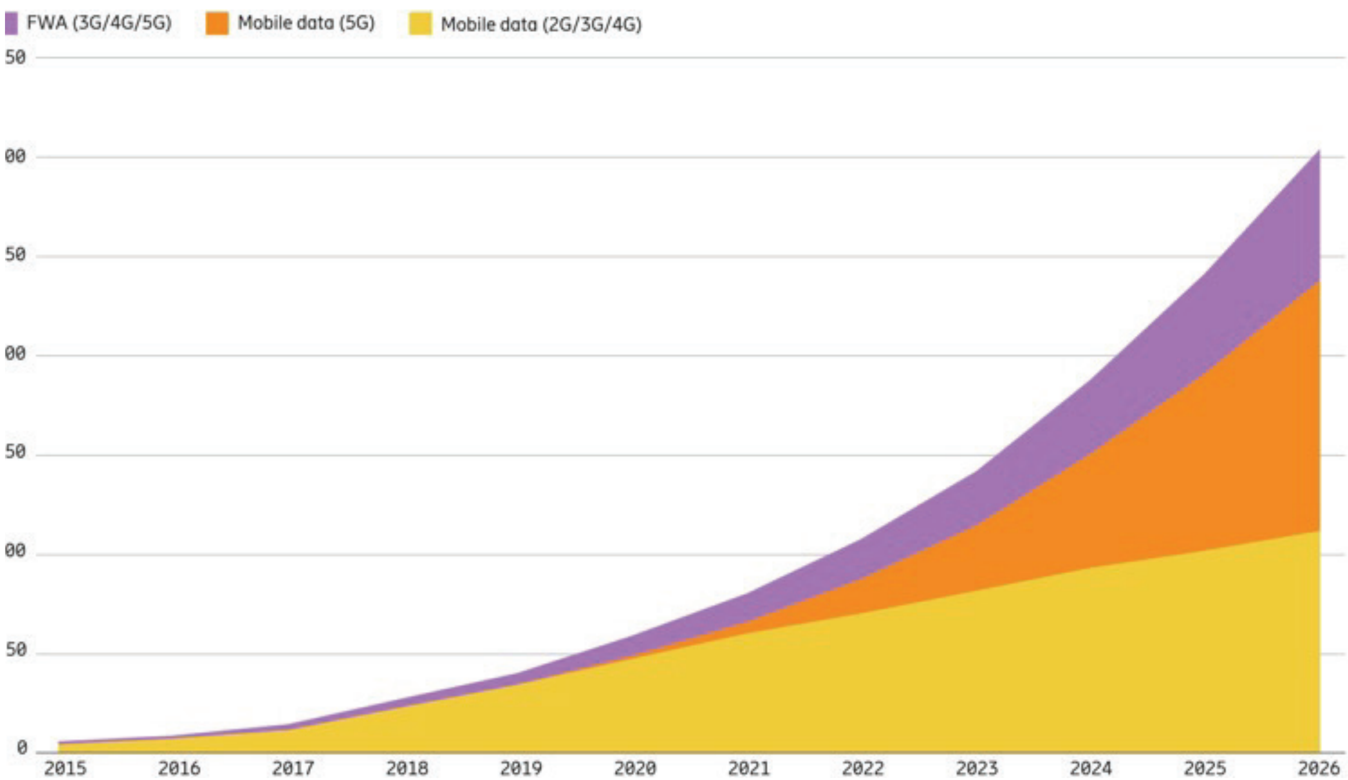


Figure 1. Global mobile network data traffic, EB per month (Ericsson mobility report)

80% of mobile data traffic today is generated indoors. This indoor-outdoor split is not expected to change as trends like working from home and online gaming continue to grow. While indoor certainly refers to the users' homes, it also includes large office and enterprise buildings.

These buildings are often modern and new, with windows consisting of low-emissivity glass (low-e glass) to effectively reflect and absorb infrared and heat energy to improve indoor thermal control. Unfortunately, these types of windows also effectively attenuate radio waves, causing degraded cell phone reception. Consequently, to fulfill indoor communication needs via outdoor base stations, operators must deal with an attenuation range of 20 to 30 dB, and even more for higher frequencies.

Network densification increases network capacity through adding more cell sites via radio access networks (RANs), macro sites, in-building wireless and small cell deployments. These cell sites are commonly implemented near urban areas and large venues where there are higher numbers of digital users. In urban areas, mid band and high band spectrum is used to meet the demands of the end-users. Network densification inherently leads to the potential for radio interference. As a result spectrum clearing, planning and testing is becoming more critical to ensure a high quality of experience (QoE) for users in heavily traveled areas.

For carriers, it is imperative to improve indoor cellular capacity and coverage, which contributes to an enhanced quality of experience (QoE) for users. If end user needs are not met, they will soon look for another carrier that can meet their demands.

The Evolution of the RAN

RAN is no longer one size fits all. Networks today require RAN to be adaptable to a specific use case, and there are more use cases today than ever before. The network is no longer just supporting mobile coverage or IoT. Today, it could be about broadband or low latency for gaming, health monitors or safety devices. Massive IoT requires connecting hundreds, or even thousands of devices such as vehicles, scooters, credit card machines and more. Most users have multiple types of devices today, and that trend is expected to grow as new use cases and applications are discovered and deployed. End users will have multiple types of devices, not just tablets and smartphones.

HetNet Basics

So, how can network operators best address increasing indoor network capacity and performance demands? One approach is to invest in one of the many cost-efficient smart macro network enhancements available today, including carrier aggregation, 4×4 MIMO, and antenna tilt optimization. Another approach is the adoption of HetNets.

The term HetNets, or heterogeneous networks, describes the interworking of different radio network layers (the macro cell layer and one or more small cell layers). HetNets increase network capacity through adding more cell sites; i.e., radio access networks, macro sites, in-building wireless and small cell deployments. In short, HetNets use a combination of macro, pico, and femto cells to offer network densification. HetNets appear as one ubiquitous, seamless network that incorporates different access technologies like 4G, 5G, and Wi-Fi.

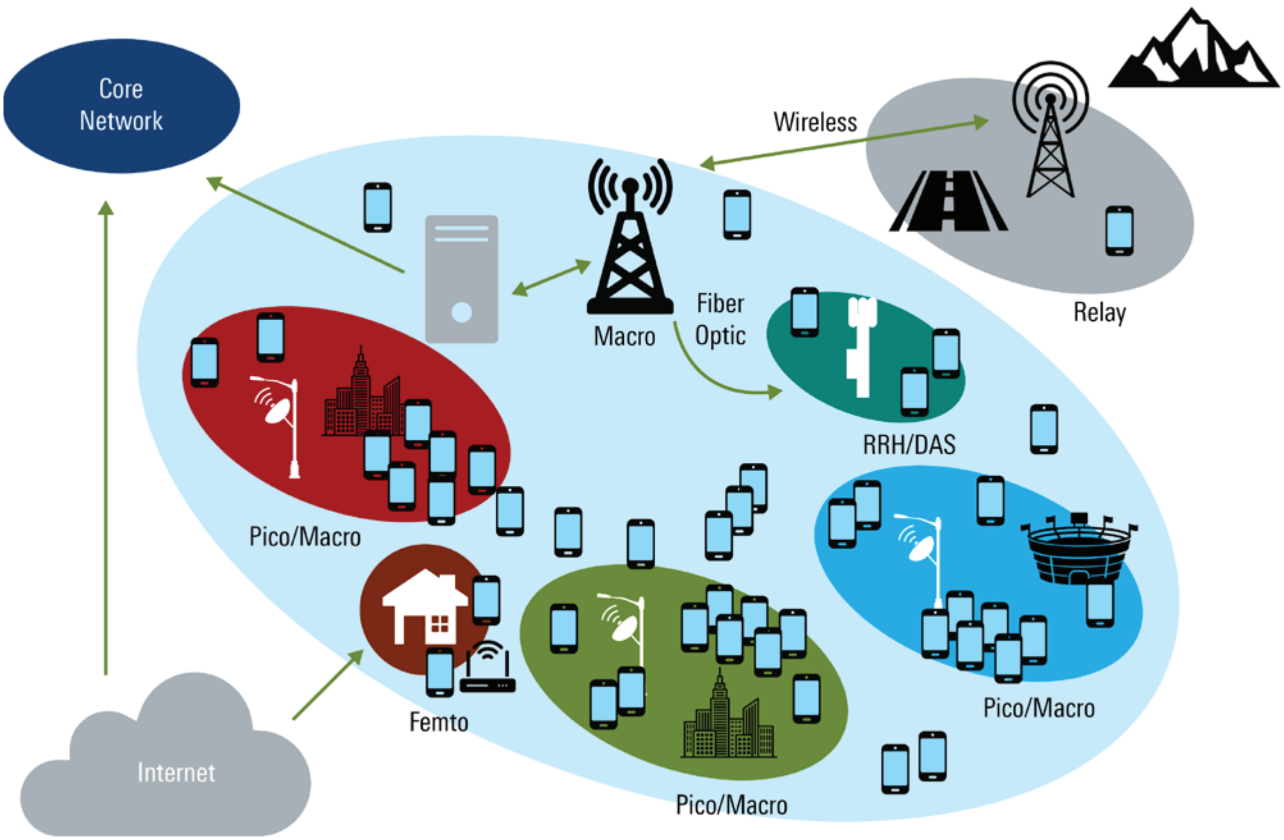


Figure 2. Heterogenous (HetNet) Networks

HetNets not only significantly improve network coverage, they can also reduce power consumption and improve overall spectral efficiency. HetNets offer relief and optimally benefit operators and users alike, but only if their installation is close to where additional capacity is required (i.e., close to the people) and a higher Signal-to-Interference-and-Noise-Ratio (SINR) can be achieved compared to the existing (macro cell) deployment. A high SINR results in high additional indoor capacity created by the new base stations.

In LTE, all network layers can use the same air interface resources. Consequently, interworking in a coordinated way is required to avoid interference among the different network layers. However, 5G HetNets will be more complicated.

How Will 5G Impact the HetNet Ecosystem?

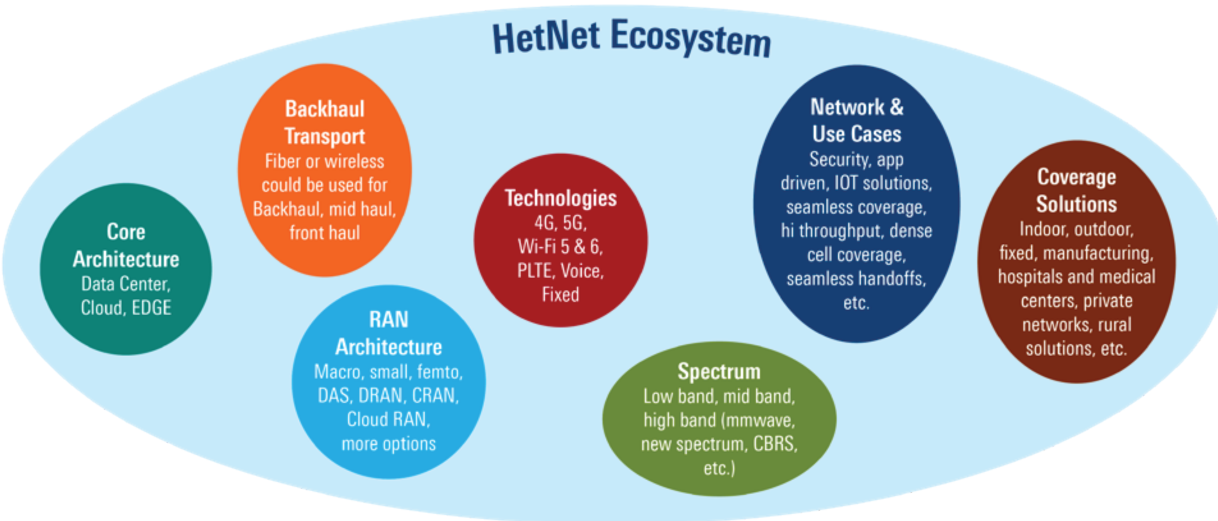


Figure 3. The HetNet Ecosystem for 5G

In the move to 5G, we are seeing new technologies, new frequencies and new architectures. The HetNet ecosystem is at the fore-front of this coexistence utilizing many of these new capabilities to deliver a wide variety of cutting-edge use cases.

RAN Connectivity

5G RAN (Radio Access Network) is expected to take advantage of multiple form factors – like macro cell and small cells – further driving the HetNet (Heterogeneous Networks) concept that started during the LTE deployment cycle. The 5G network requires RANs to be adaptable to specific use cases.

RAN, Technology and Spectrum Models

- RAN
  - Macro
  - Small
  - Mini macro
- Technologies
  - 4G outdoor coverage mostly
  - Wi-Fi – indoor and hotspot coverage mostly
  - 5G – indoor and outdoor
- Spectrum
  - Low-band for outdoor wide area coverage, mostly 4G
  - Mid-band – indoor and outdoor coverage, mostly 4G today but moving to 5G very quickly
  - High-band – while currently 4G and outdoor coverage, will be moving to 5G very rapidly and become indoor and hotspot coverage.

A RAN can be several different types of sites. It could be small or macro or a derivation of the two. Indoors or outdoors. The thing to look at is how 4G, 5G, and Wi-Fi will work together, and perform handoffs seamlessly without the user knowing. 5G RAN models are evolving, but one big question is how the different spectrums will provide different solutions? This is a challenge for designing and implanting 5G HetNets.

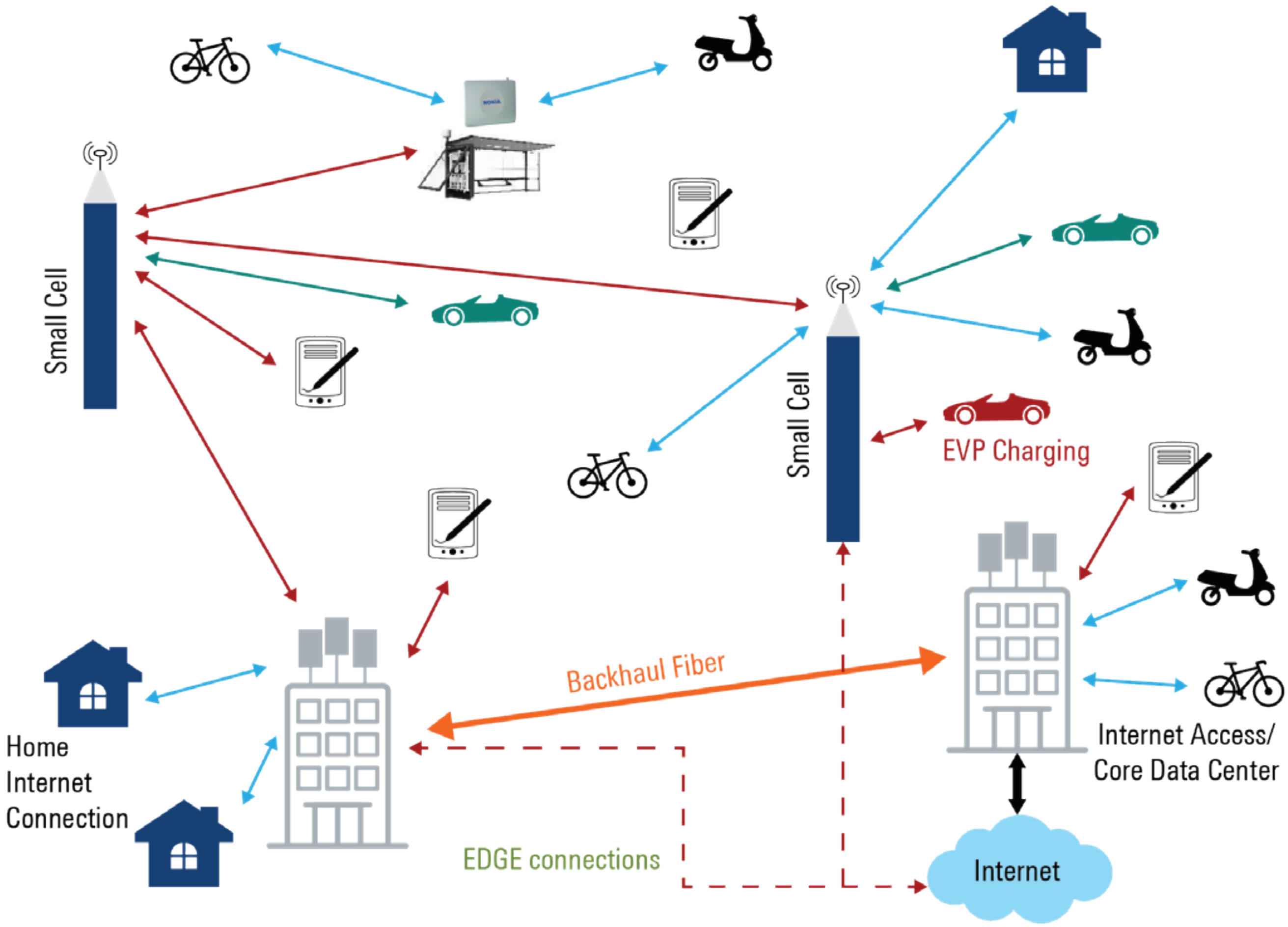


Figure 4. RAN connectivity for multiple applications and use cases.

5G HetNet Use Cases

There are more use cases today than ever before - not just IoT and mobile coverage. Today, it could be about broadband or low latency, while tomorrow it is about massive IoT.

Most users have multiple devices, and that trend is expected to grow as new use cases and applications are discovered and deployed. The end user could be a broadband user in a home using a 5G modem as a hotspot feeding a home or business. Common 5G HetNet use cases include:

- Wireless Connectivity for Mobile devices
  - Any spectrum or technology used today
- Fixed Wireless Access
  - Broadband to the home, business, or any device using mid-band & high-band frequencies
- Broadband or Low Latency Applications
  - Dense area coverage, could use mmwave or mid-band frequencies
  - May need an Edge server at the site
  - Should be 5G and/or Wi-Fi
- IoT
  - Could use any band, maybe LoRa WAN or CAT M1, for connectivity
- Private Networks
  - Most likely to use CBRS spectrum with PLTE today, 5G in the future
  - Using Wi-Fi in addition to LoRa for connectivity.

5G capabilities and expectations will impact the deployment of HetNets and what test solutions are required to meet these new challenges. 5G HetNets are ideal for implementation near urban areas and large venues where there are higher numbers of digital users. In urban areas, mid band and high band spectrum will be used to meet the demands of the end-users. Here, spectrum clearing, planning, and testing will become more critical.

5G HetNet Equipment and Hardware

While a HetNet includes multiple technologies and site models, the 5G configuration is adding more pieces to the overall network. 5G mobile network infrastructure is growing along with the need for reliable network performance in various use cases, ranging from sporadic data bursts to fast and reliable low-latency transmission. Trends like cloudification, disaggregation and multi-access edge computing (MEC) are targeting smart, agile, and flexible networks. The challenge is to bridge the gap between centralization, lower energy consumption and lower complexity versus hierarchical disaggregated network deployment fostering low latency, intelligent RAN control and QoS optimized scheduling aspects. The 3GPP's integrated access and backhaul (IAB) feature enables access and backhaul via the same 5G air interface technology, leveraging fast deployment of infrastructure components.

5G equipment is getting physically smaller with specific capabilities to target precise customers/use-cases. New 5G equipment is focused on solving more customer problems than before. For example, smart antenna arrays use Multiple Input / Multiple Output (MIMO) at both the source (transmitter) and the destination (receiver) to improve signal quality. Smart antennas offer continuous connectivity to improve coverage and optimize capacity by focusing RF signals where they are needed. Smart antennas also improve device handovers.

The ever-increasing diversification and complexity of mobile network infrastructure equipment is often combined with demands such as cost efficiency and fast time-to-market. These requirements need to be reflected in innovative and flexible test and measurement solutions. Common industry drivers not only lead the entire mobile network ecosystem, but also demand tailored, future-proof test & measurement solutions.

Testing HetNet Networks

The migration of the HETNET to incorporate 5G technology adds layers of potential complexity compared to just the 'old' macro network. In many cases, 5G HetNet brings the network closer to the customer to provide better coverage and bandwidth, however this can also uncover some deployment challenges. An example is an unwanted signal that may not have been affecting the macro network when the base station was two or three miles away, but is now an issue when deploying small cells, in which the base station is now closer to the interfering signal.

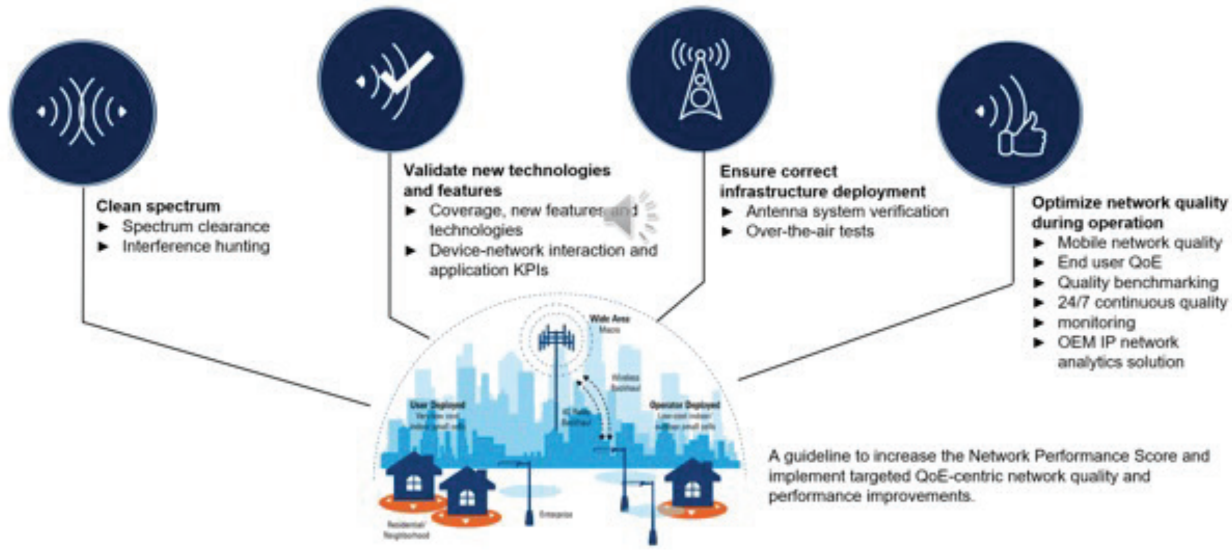
With deployment of evolved 5G HETNET architectures, testing of these complex networks is crucial. The interaction of the macro network, with the small cell network and HetNet should be validated to ensure expected network quality and end user QoE is not affected. If some portion of a HetNet is not working in unison with the other networks present, quality and user experience will suffer.

Today, network operators can perform complete network testing by collecting data and verifying the proper operation of a HetNet using a fully integrated testing platform. Modern test & measurement platforms can cover various use cases and testing scenarios, along with extensive drill down functionality with data analytics to give operators confidence that the HetNet is working as designed and expected.

5G network measurements are split into passive measurements using network scanners and active measurements using commercial devices like smartphones or other UE type devices. Mobile network testing provides solutions for the complete lifecycle of a mobile network, which includes network engineering, interference hunting, operations & installation, network optimization, quality benchmarking and network monitoring. A wide range of measurement tools can be utilized to address these different deployment stages, whether they be handheld portable analyzers, mobile phone based testing tools, RF scanners, benchmarking systems or long term monitoring solutions.

Each new cell site needs to be verified to ensure correct network performance and quality of service (QoS). A typical site acceptance procedure involves spectrum measurements conducted over-the-air (OTA) in order to analyze the transmitter in the frequency and time domains and troubleshoot issues. 5G HetNets have a new requirement for functional tests which verify the connection to the network and gather performance KPIs such as latency, download speed and upload speed using a smartphone. Finally, signal decoding is used to verify network information and synchronization signals for the 5G and LTE anchor signals. Once the network is operational, any technical issues can be diagnosed and resolved using functional, spectral and signal decoding procedures.

Key Testing Aspects



HetNet Test Solutions

Rohde & Schwarz offers various testing solutions to deploy 5G networks, depending on what phase of network deployment you are in. Solutions for these different phases are described next.

Spectrum Clearance and Interference Hunting

An important precondition for good 5G network quality is clean spectrum. For Spectrum Clearance and Interference Hunting we offer network scanners (TSMx6) as well as handheld spectrum analyzers (FPH, FSH), monitoring receivers such as the PR200 along with the automatic interference locating SW Mobile Locator kit.

R&S®FPH 44GHz

R&S®PR2000

R&S®MobileLocator

Site Troubleshooting and Acceptance

For verifying the correct deployment, we also offer Site Acceptance Solutions: QualiPoc Android for quick functional test, SpectrumRider FPH for OTA spectrum measurements and the 5G STS for site troubleshooting due to 5G decoding.

QualiPoc Android

R&S®5G STS

5G NR Network Measurement Solutions

The 5G network measurement are split into passive measurements using networks scanners and active measurements using commercial devices like smartphones, or other UE type devices. Our mobile phone based testing tool, Qualipoc Android, runs on commercial smartphones and provides detailed insights on RF environment from a UE perspective and QoE measurement results from end-user perspective. Portable drive and walk test hardware options like the TSME6/TSMA6 network scanners, provide a passive means of understanding the RF environment and potentially identifying underlying RF conditions which can cause the HETNET to work improperly.

R&S®FreeRider4

R&S®ROMES4

Data Analytics

In addition to the scanners and mobile based tools, Real-time and in-field analysis software: ROMES4 and SmartBenchmarker provide immediate visibility of test results, whereas our data analytics software suite, SmartAnalytics, analyzes the data in post processing and brings important insights to the operator's attention (also with support of machine learning algorithms).

Smart Analytics

Network Performance Score (NPS)

Conclusion

The HetNet is a wireless ecosystem, comprised of a variety of mobile and wireless technologies and infrastructure, interoperable with the macro-cellular network providing harmonious voice and data communications. HetNets significantly improve network coverage, reduce power consumption, and improve overall spectral efficiency. However, 5G HetNets utilize new technologies and new frequency bands that require new testing approaches. Test equipment needs to cover a broad range of use cases – ideally, one instrument covering multiple use cases. Testing efficiency will become more important as HetNets add more items to test. Testing tools are vital to help deploy, verify, analyze, and ensure the upmost network quality and user quality of experience when it comes to a simple or complex HETNET environment.

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The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.
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