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Benchmark Measurements in 5G NR Networks

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As 5G continues to be deployed around the world, regulators have begun to benchmark radio network coverage to ensure that service providers meet the conditions of their spectrum allocations. Requirements vary depending on where in the world they are employed. For example, service providers in the European Union are expected to provision 5G coverage to all urban areas and major terrestrial transport paths by 2025, and regulators are evaluating coverage requirements for many other markets.

To ensure service providers are meeting their coverage requirements, 5G performance and app coverage must be measured where app coverage is the geographical area where an application, or app, works as expected, and the user has a positive network experience. However, there are challenges in terms of how the 5G measurements are to be made. Ericsson has found that the methodology commonly used for the benchmark measurements in 2G/3G/4G networks is not suitable for 5G networks and does not provide benchmark results that can be meaningfully compared across 5G service providers and network equipment providers.

This paper presents challenges with the benchmark measurements in the 5G networks, outlining system differences between 5G and 4G that cause these challenges, and proposes a preferred way to conduct the benchmark measurements in 5G networks based on actual end-user performance.

Measuring 2G / 3G / 4G Network Performance

Measuring the signal strength of the control channels in idle mode has been the most widely used method for assessing network coverage and availability of the mobile service in previous access technologies.

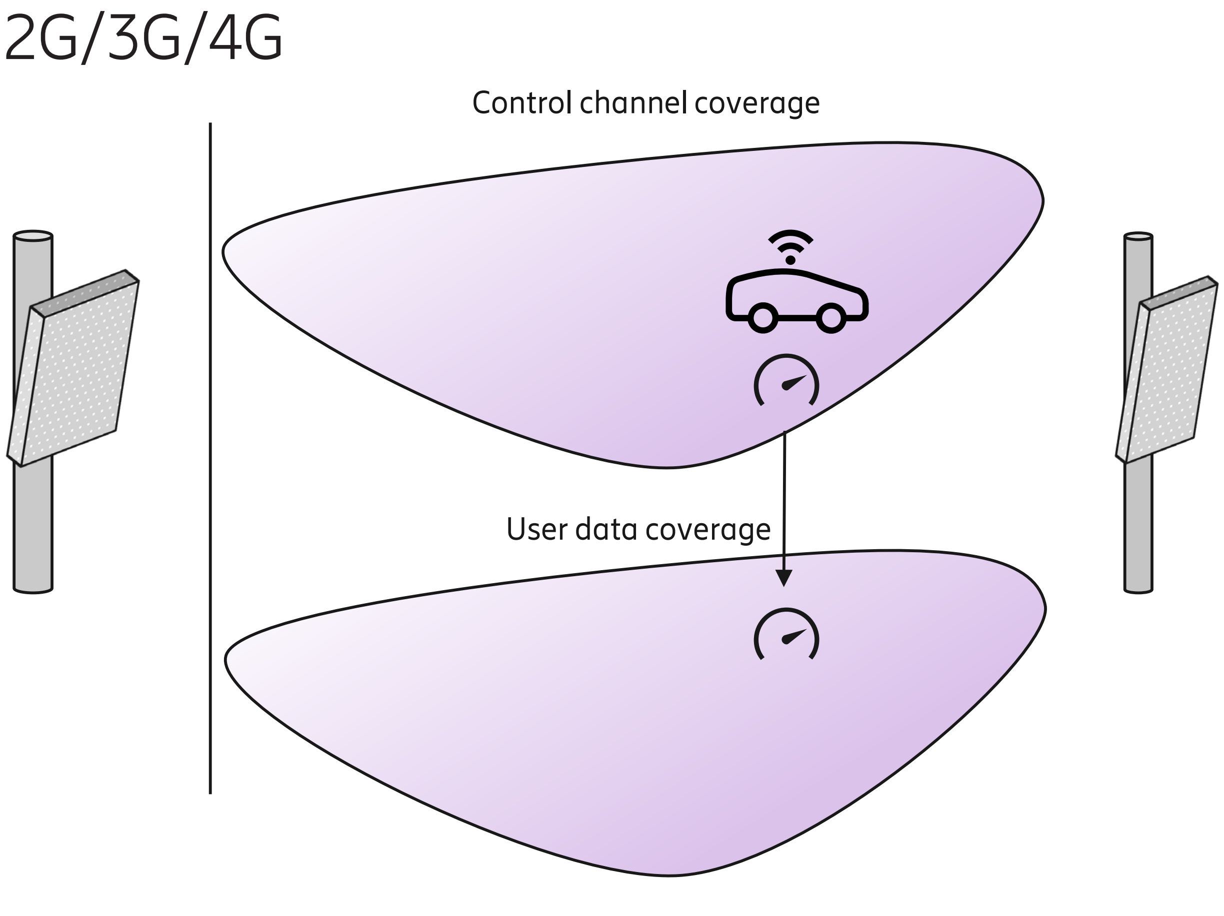
Each generation of mobile technology has three types of channels in the air-interface:

- Control channels in the idle mode – these are the channels used by the mobile phone, or User Equipment (UE) to monitor and connect to the network
- Control channels in the connected mode – these are the channels used when the UE is sending, or receiving user data to monitor or control connections
- User data channels in the connected mode – these are the channels used to send and receive the actual user data

The benchmark performance measurements based on the control channels in idle mode have proven to be suitable for 4G, and earlier technologies, for base stations using two transmitters and two receivers (ie. 2T2R) which represent most deployments. These measurements are relatively simple to make and the similarities between the 4G control channel in idle mode and 4G data channel results in a strong positive correlation between the two (Figure 1). In addition, the correlation between control channel in idle mode and the user data channels in the connected mode for 4G networks is defined by standardization when beamforming is not used, and for these cases, will not vary significantly based upon the radio equipment deployed in the network.

Therefore, for non-beamformed networks, measuring the control channel in idle mode has provided a good assessment of the actual end-user experience in the 4G network and fair comparisons between the different service providers and equipment manufacturers can be made. Typically, a strong 4G control channel measurement for a 2T2R radio in idle mode is highly indicative of the availability of a quality user data channel and good 4G network performance.

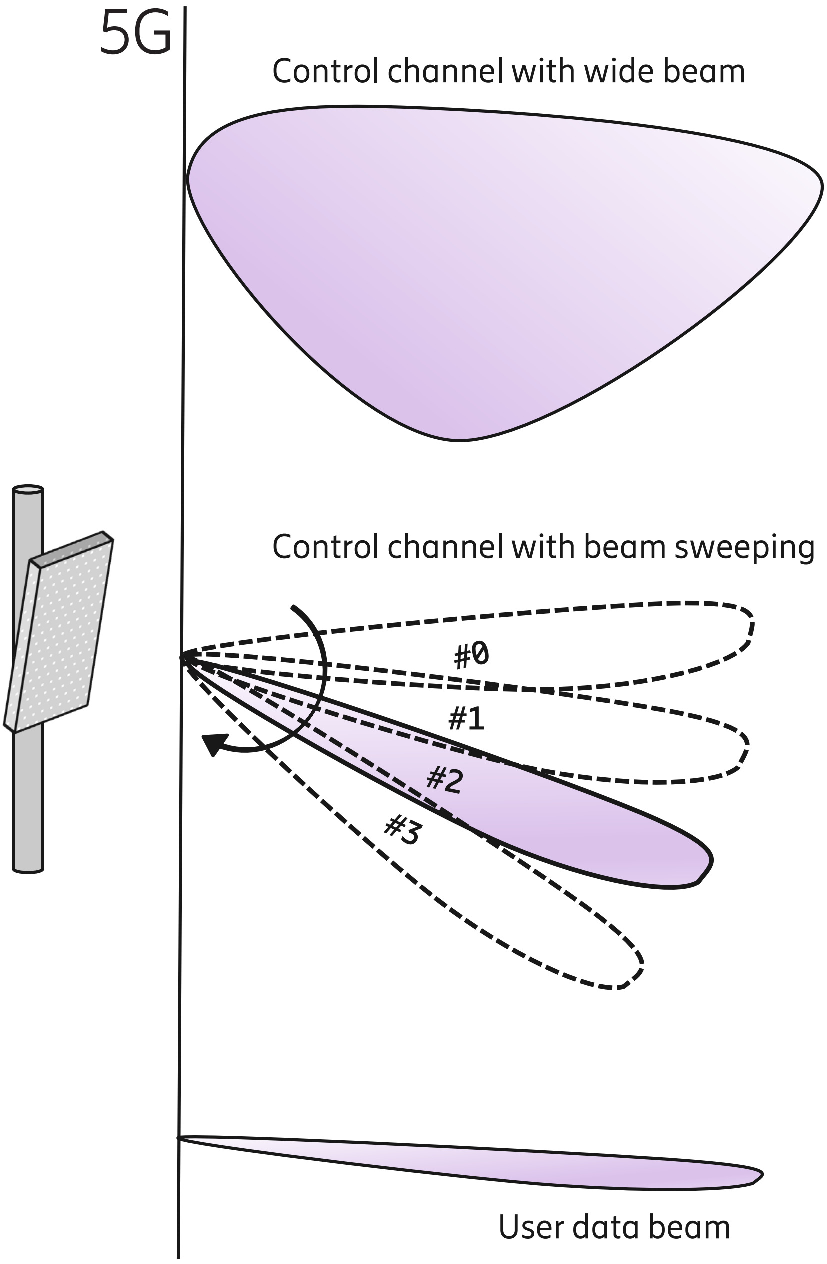
Figure 1: 4G control channel coverage is highly correlated with user data coverage for a 2T2R radio (which represents most 4G deployments today)



5G networks require different benchmark measurements

In contrast, the 5G standardization allows for more flexibility in how the control channels in idle mode are configured. One of the main differences compared to 4G networks is that control channels in idle mode for 5G networks are more frequently beamformed where beamforming supports a radio transmission on a stronger, more focused signal across a smaller area (Figure 2).

Figure 2: With beamforming, control channel coverage does not correlate with user data coverage



The 5G standardization allows for flexibility regarding how beams are configured for the control channel in the idle mode and the user-data channel in the connected mode. This flexibility means that for different 5G deployments across different equipment manufacturers and different service providers, the correlations between the control channel and the user data channel will vary widely. This is a change from 4G where traditionally, for a 2T2R radio, the control channel and data channel signal qualities are strongly correlated.

With 5G, there is no cell-level reference channel from where the coverage of the cell can be measured. Instead, each cell has one or multiple Synchronization Signal Block (SSB) beams which the UE uses to search for and synchronize with 5G NR cells. The SSB beams collectively cover the cell area, and the UE searches for and measures the SSB beams, maintaining a set of candidate beams which may stem from multiple cells.

Furthermore, it is the data channels in connected mode that will practically define end-user experience, and these user data channels in connected mode may be beamformed. However, these beams are shaped differently from the beams used for the control channels, with the beam shapes depending on the implementation.

Therefore, measuring the control channels in idle mode for 5G is unlikely to generate a reliable assessment of the actual end-user experiences in the 5G network and does not provide the basis for a fair comparison between 5G service providers, or network equipment manufacturers.

Direct coverage comparisons between 5G infrastructure vendors is not straight forward because 5G coverage is often beam based, not cell-based — a fundamental change in 5G.

Benchmark results based upon the common channel, SSB Reference Signal Received Power (RSRP), are not reliable for making 5G network comparisons

Third-party benchmarking companies, regulators and service providers often attempt to measure 5G performance based simply on SSB signal strength measurements. However, SSB RSRP measurements are not a reliable way to measure 5G network performance.

When analyzing 5G coverage, measuring the quality of SSB beamforming may provide an indication of the UEs ability to access the cell. However, there is little correlation between SSB beamforming and data channel beamforming, and the SSB has little relation to the actual 5G network performance. For example, a 5G capable UE may indicate that it is within 5G coverage by displaying the 5G coverage bars or 5G symbol on the UE display screen. However, the quality of the 5G user experience, once the cell has been accessed, is directly related to the quality of the data channel in both downlink and uplink which may not be sufficient.

Some mobile network operators tend to put a lot of focus on NR coverage comparisons based on SSB RSRP measurements, especially when comparing solutions from different equipment suppliers. However, different beamforming techniques and implementations specified under the 3GPP 5G standards further make SSB RSRP measurements an unreliable indicator of network performance.

For example, one SSB implementation is to use swept wide-beams. Here, SSB control channel beams in idle mode can cover only part of a targeted area. Therefore, multiple beams need to be sequentially created to cover the whole area, using the so-called beam sweeping technique. In contrast, another SSB implementation achieves a wide area coverage using a common SSB beam—referred to as a sector-wide beam. A sector-wide SSB beam has the advantage of requiring less overhead and is therefore more spectrally efficient, enabling higher cell data throughput and lower latency. Because different manufacturers use different SSB beam implementations, a direct comparison between the different 5G manufacturers based on absolute SSB RSRP levels does not provide a true network performance comparison and can lead to erroneous conclusions.

In addition, where one vendor might be able to achieve a better RSRP in parts of the cell coverage area using multiple swept wide-beams, there might be some directions where a sector-wide beam gain is higher making a direct comparison inconclusive. In addition to the different SSB beamforming and transmission techniques applied by different vendors, there are also other factors that have a direct impact on RSRP values:

- Transmitted power (including power per Resource Element)
- SSB coverage scenarios/patterns
- Antenna tilts

The only case where coverage comparisons based on SSB RSRP values may be meaningful to a 5G performance discussion is when different regions of an operator network that use equipment from the same manufacturer are considered. This is because one can ensure that similar strategies and configurations are applied across the different regions due to the use of a single vendor.

In summary, benchmarking measurements conducted on the control channel in idle mode, though largely effective for non-beamformed 2T2R based networks, is unlikely to generate a reliable assessment of user experiences in the 5G network and provide fair comparisons between service providers, smartphones or vendors. This is due to the fundamental differences in the 5G common control and 5G data channels.

Field measurements in two networks with different common channel configurations

Ericsson conducted several benchmark measurements between 5G networks with different configurations for the common channel and the results support the conclusion that it is not appropriate to compare 5G networks based on the common channel measurements. Some of the benchmarking results are presented here.

Measurements were conducted for two service providers that use different configurations for the common channel in idle mode. Communications Service Provider "A" (CSP "A") has a control channel configuration with beam sweeping while CSP "B" has a control channel configuration using the sector-wide common-beam implementation.

Measurements were conducted in several locations. At each location, three measurements were conducted, and the average results are presented in Table 1.

It is evident from the measurements that the end-user experience demonstrated through the downlink and uplink throughput were better for CSP "B" even though the control channels typically had a lower RSRP signal strength. This is a consequence of the different configurations that these two CSPs used for the control channels in idle mode. The CSP "A" used swept wide-beams for control channels in idle mode resulting in higher SSB measured signal strength. However, both downlink and uplink throughput were better for the CSP "B" which used a common sector-wide beam.

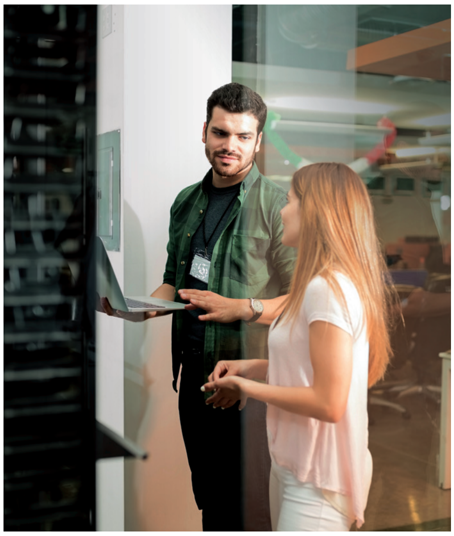


Table 1: Comparison of SSB RSRP and data throughput for different control channel configurations

Multiple SSB beams

Network "A" static test results			
Reference Point	Reference Signal Received Power (dBm)	Downlink Throughput (Mbps)	Uplink Throughput (Mbps)
Point 1	-81 +4 dB	495	5 < 10Mbps
Point 2	-84	234	11
Point 3	-70	341	12
Point 4	-80	726	23
Point 5	-83 +1 dB	464	2 < 10Mbps
Point 6	-69	702	37
Point 7	-62	644	26
Point 8	-75	722	26
Point 9	-89	519	14
Point 10	-85	135	27
Point 11	-78 +9 dB	565	6 < 10Mbps
Point 12	-71	626	20
Point 13	-61	652	56
Point 14	-62	798	38
Point 15	-51	667	56
Average	-73	553	24

Single SSB beam

Network "B" static test results			
Reference Point	Reference Signal Received Power (dBm)	Downlink Throughput (Mbps)	Uplink Throughput (Mbps)
Point 1	-85	514	65
Point 2	-84	725	60
Point 3	-82	499	68
Point 4	-92	510	59
Point 5	-84	506	68
Point 6	-76	617	82
Point 7	-92	472	15
Point 8	-106	445	20
Point 9	-91	388	36
Point 10	-91	715	51
Point 11	-87	929	60
Point 12	-79	650	68
Point 13	-74	1024	73
Point 14	-73	890	75
Point 15	-69	454	74
Average	-84	623	58

Despite lower SSB RSRP, user throughput is higher for CSP "B".

Throughput as the main 5G performance indicator

The 5G end-user experience is defined, in practice, by the user data channels in connected mode. Therefore, the preferred way of evaluating 5G networks is to conduct end-user performance-driven benchmark measurements. These measurements should use uplink and downlink data throughputs as the main performance indicators.

Throughput measurements are inherently more complex to conduct than measurements based upon signal strength, and the network traffic level at the time of the measurement may also impact the result. However, throughput measurements will present an accurate snapshot of the real end-user experiences at the time of the measurement.

Today, however, there is no perfect solution to the current need to conduct an objective 5G network benchmark measurement with the simplicity and efficiency of the previous generation of mobile networks. If it is necessary to use control channel signal strength measurements for 5G networks benchmarking, then measurements need to be normalized between networks to reflect the different control channel configurations.

Conclusion and the way forward

5G has brought new levels of performance and innovative characteristics to existing telecom networks. As such, 5G networks require different benchmark measurements compared to earlier generations. Service providers, third-party benchmarking companies and government regulators have so far primarily measured 5G networks in terms of New Radio (NR) coverage in the air-interface, based on the RSRP of the synchronization signal block (SSB).

A universal methodology for measuring 5G performance and app coverage must be both developed and adopted by the wireless industry. If SSB RSRP measurements are to be used, the industry needs to come up with an alignment on how signal strength measurements can be conducted for 5G networks in a meaningful way. This alignment should include an agreement on how, in a practical manner, the normalization can be introduced for networks with different SSB channel configurations, allowing meaningful comparisons to be made.

However, the preferred and optimal way to conduct benchmark measurements is to make end-user performance-driven measurements. We recommend that service providers avoid RSRP map plots and instead focus on user experience. These performance benchmarks should be based upon downlink and uplink throughput as well as latency—to reflect actual end-user experience in the measured network.

Ericsson recognizes an industry-wide challenge related to the methodology for making 5G benchmark measurements. To advance this discussion, Ericsson is continuing to study methodologies for measuring 5G throughput and will provide additional reports and updates as the best means to effectively measure 5G performance are refined.

> "In all radio technologies, the Sync and Broadcast Channels are just a reference to decode the rest of the channels, but never give the real Service Coverage. The only way to compare the performance of 5G networks is to measure the throughput in Downlink and Uplink independently to know the Service performance real coverage."
> -Prinicipal Engineer, Vodafone Group

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