A Global Perspective of 5G Network Performance

Michael Thelander, President

October 2019
Key Highlights

- 5G is providing meaningful capacity gains to LTE networks on a global basis with LTE extending the coverage, reliability and speeds of high bit rate transmissions.

- Millimeter wave signals are far more resilient than generally perceived, including indoors, with additional performance gains coming.

- 5G capacity gains can have a meaningful impact on the user experience:
  - Application downloads
  - Video streaming

- Although the comparisons are nuanced, 5G can be just as energy efficient as LTE, with a full day of battery easily achieved with most scenarios.
Today’s Agenda

- 5G networks on a global basis are providing a meaningful capacity layer to existing LTE networks
- 5G millimeter wave signals are more resilient than generally perceived with additional performance gains coming
- Indoor deployments of 5G millimeter wave are already occurring with favorable results
- 5G capacity gains improve the user experience, especially in capacity-constrained environments
- The energy efficiency of 5G can exceed that of LTE while delivering a full workday’s worth of smartphone usage
5G Performance in Seoul (Gangnam)

- ~4.6 km walk test near COEX in Gangnam
- LTE-only and 5G-capable LG V50 phones operating in parallel
- 192.8 GB of transferred data
5G Performance in Seoul (Gangnam)

Median Throughput (Measured and Normalized)

- 5G-capable phone was 2.6x faster than the LTE-only phone
- With RB normalized results, the gain was 1.9x.
5G Performance in Central London

EN-DC Throughput (5G + LTE)

- EE has LTE 5CCA (BW = 95 MHz)
- 5G deployed at 3.5 GHz (BW = 40 MHz)
- ~135 GB of transferred data
- 6.75 km
5G Performance in Central London

LTE and 5G Throughput Contributions

- OnePlus 7 Pro smartphone
- Average speeds @ 220 Mbps
- Peak speeds @ 600 Mbps
- Testing leveraged common applications (Google Drive, etc.)
5G Performance in Bern Switzerland

EN-DC Throughput (5G + LTE)

- Swisscom has LTE 4CCA (BW=70 MHz)
- 5G deployed at 3.5 GHz (BW = 100 MHz)
- ~45.8 GB of transferred data
- ~8 km² area
5G Performance in Bern Switzerland

5G-Capable versus LTE-Only Smartphones

- Two OPPO Reno 5G smartphones running in parallel
- 5G-capable phone was 1.5x faster than the LTE-only phone
- LTE contributed ~17% to the overall speed of the 5G phone
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- **5G millimeter wave signals are more resilient than generally perceived with additional performance gains coming.**

- Indoor deployments of 5G millimeter wave are already occurring with favorable results.

- 5G capacity gains improve the user experience, especially in capacity-constrained environments.

- The energy efficiency of 5G can exceed that of LTE while delivering a full workday’s worth of smartphone usage.
5G Millimeter Wave Performance in Minneapolis, MN (April 2019)

Geo plot of Measured Signal Quality (BSINR)

- Testing done just after Verizon launched commercial 5G services
- Figure shows signal quality (BSINR), as reported by the Motorola Moto Z3 smartphone with 5G module
5G Millimeter Wave Performance

Geo plot of Nicollet Mall Walk Test

- Four 5G cell sites (PCIs) provide coverage over the ~1 block walk
- Highlighted intersection served by three 5G sites, including reflected beams from 1.5 blocks away
5G Millimeter Wave Performance

5G Cell Site Along 11th Avenue

- PCI 49 points down 11th avenue and toward the highlighted intersection
- PCI 50 points ~135 degrees away and toward a building and Skyway, which crosses 11th avenue
Although EN-DC wasn’t supported, LTE provided meaningful throughput when 5G wasn’t available. Reflected signals generated data speeds approaching 200 Mbps.
5G Millimeter Wave Performance

5G and LTE Cell Sites and 5G Signal Strength

- Time series plot in which the start and end of the figure occurs at the highlighted intersection

- Loss of 5G signal corresponds with a change in the LTE anchor cell (strong 5G signal throughout)
5G Millimeter Wave Performance

5G NLOS Coverage Based on Signal Strength (BRSRP)

- 5G PCI 99 points into the 3rd floor of a multi-floor office building
- Millimeter wave signals somehow extend around the corner at the nearby intersection
- Captured with Motorola phone
5G Millimeter Wave Performance

Performance Differences with the “Grip of Death”

- With considerable effort (and two hands) it is possible to significantly impact millimeter wave RF performance – also degrades LTE
- With normal hand placement the impact should be manageable
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US Bank Stadium – Minneapolis, MN

Commercial 5G Outdoors (April 2019)

Commercial 5G INDOORS (September 2019)
~1.9 Gbps PHY Layer Throughput in my seat

But protocol behavior can limit the user experience
Sample results show near ubiquitous coverage on the upper level

Results extend to virtually all areas within the stadium
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5G millimeter wave signals are more resilient than generally perceived with additional performance gains coming.

Indoor deployments of 5G millimeter wave are already occurring with favorable results.

5G capacity gains improve the user experience, especially in capacity-constrained environments.

The energy efficiency of 5G can exceed that of LTE while delivering a full workday’s worth of smartphone usage.
Due to capacity constraints in the LTE network, the LTE-only smartphone reverted to a lower resolution format while the video playback took slightly longer.
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- 5G capacity gains improve the user experience, especially in capacity-constrained environments.
- The energy efficiency of 5G can exceed that of LTE while delivering a full workday’s worth of smartphone usage.
Higher energy efficiency translates into an ability to download more data for a given battery life (4400 mAh).

Results depend on backlight display setting.
Energy consumption due to data connectivity has little bearing on overall battery life

Even with very conservative assumptions, a 5G smartphone can last a full workday

**KEY ASSUMPTIONS**

- 1.5 GB of transferred data
- 80% of data sent at 5 Mbps; 10% at 30 Mbps and 10% at max speed (measured)
- 50% display brightness
- 3 hours of VoLTE (5G present)
- 4 hours of other activity which requires the backlight
- Idle time reflects excess energy divided by current requirements
Dedicated and highly-reliable data connectivity services, combined with real-time measurements of network and device/chipset parameters.
Final Thoughts

- Since the first commercial launch six months ago, 5G performance has continued to improve
  - Support for EN-DC (5G + LTE throughput)
  - Cell handovers (between 5G cell sites and beam indices)

- Consumers [and mobile operators] are already benefiting from the new capacity layer

- Continued improvements are in the works
  - Better utilization of 5G and LTE (EN-DC)
  - More concurrent 5G channels in millimeter wave (wider bandwidth)
  - Sub 6 GHz FDD deployments with DSS and chipset support
  - Leveraging NR-NR DC to improve coverage and increase data speeds / capacity