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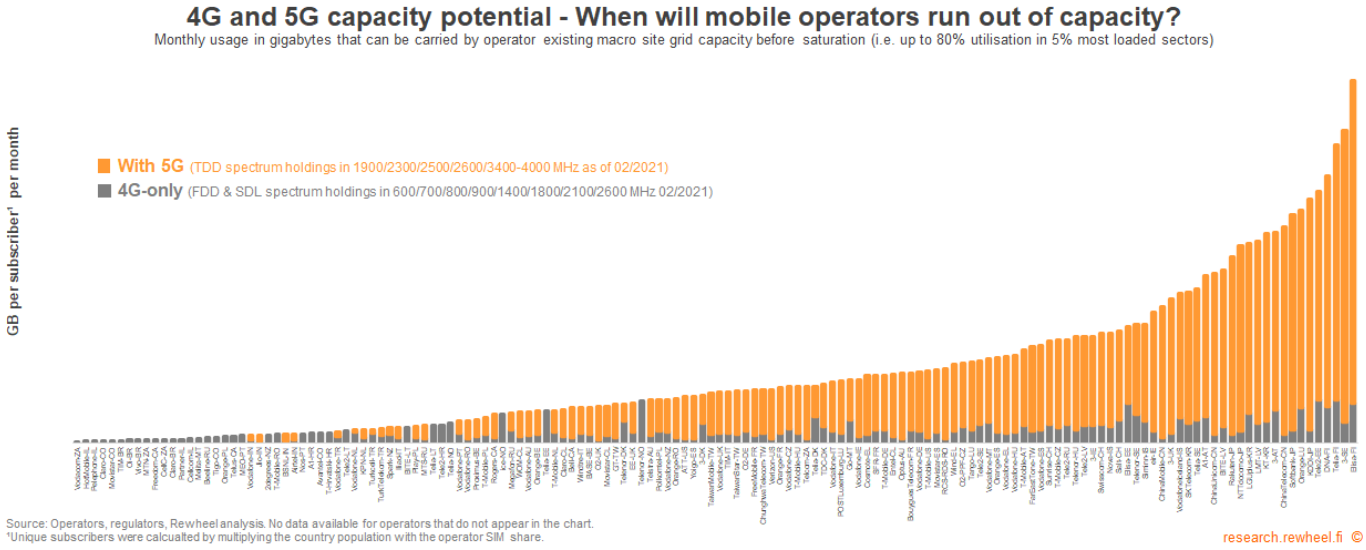
5G capacity potential – more than 500 gigabytes/sub/month

When will mobile network operators run out of 4G capacity and how many more gigabytes per subscriber per month can they carry with 5G? A study of 169 European, American, Asian Pacific and African operators.

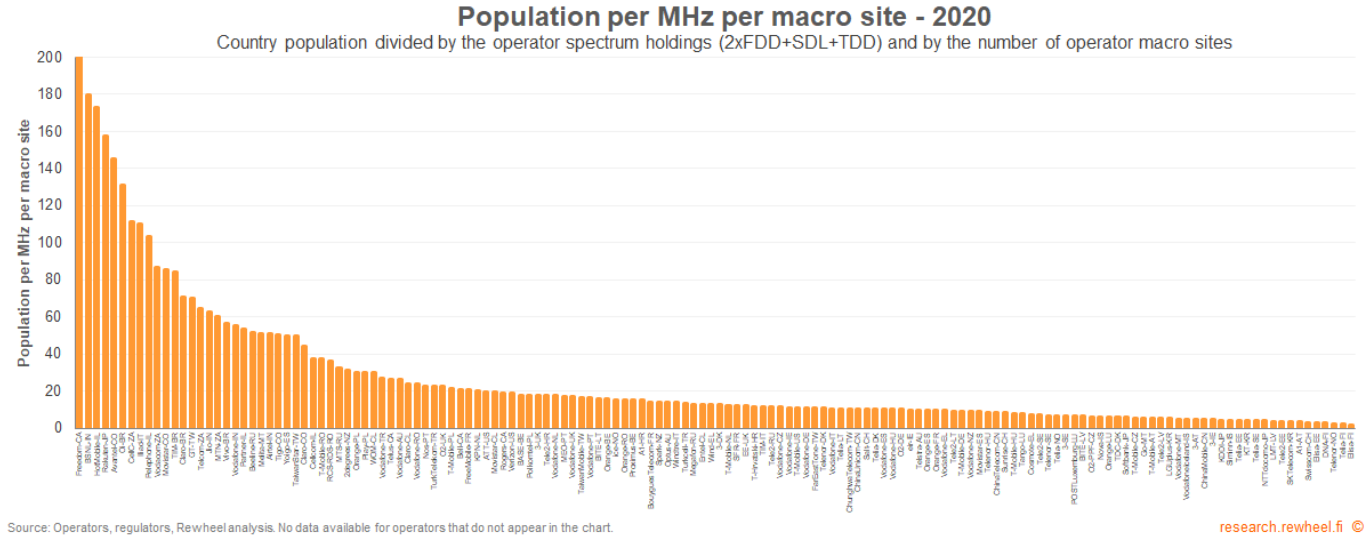
Capacity ≈ macro sites X spectrum X spectrum efficiency

Rewheel research PRO study, March 2021

Highlights



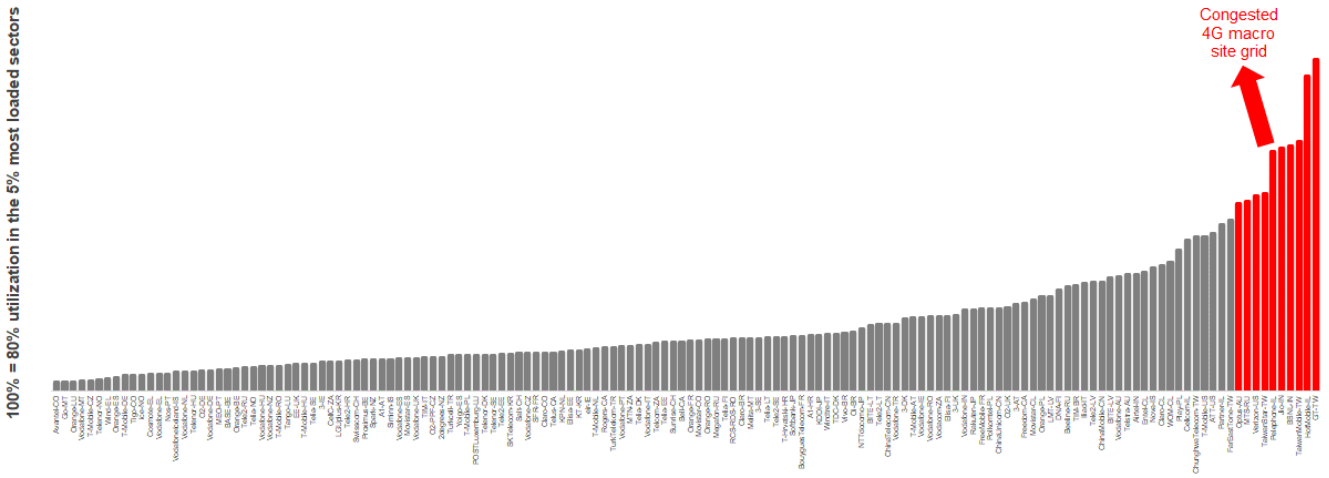
- Elisa Finland is the operator with the highest combined 4G&5G capacity potential in the world.
- Jio India, Verizon US and MTS Russia were among the operators that had the highest 4G capacity utilization (most congested macro site mobile networks) in 2019.
- Play Poland was the European operator with the highest 4G capacity utilization of 75% in 2019, up from 63% in 2018.
- Japanese and Chinese operators, T-Mobile US and Elisa Finland are among the operators that hold the highest 5G TDD spectrum holdings.
- Telenor Norway and Elisa Finland, have the densest mobile networks (highest amount of macro sites relative to country population). Nordic, Baltic and Korean operators have mobile networks with dense macro site grids.
- Canadian, US and Indian operators were among the operators with the least dense macro site grids.



The 4G capacity utilization, 4G capacity potential and 5G capacity potential are calculated assuming operators have or will deploy – where needed – all their spectrum. The 4G, 5G and combined 4G&5G capacity potential shown in the chart above are expressed in terms of operator unique subscribers. In previous studies the potential were expressed in terms of reported SIM cards and hence were lower for many operators. Please note that the capacity potential shown in the chart above is calculated taking into account the operator existing subscribers. Hence, the chart depicts the maximum gigabytes per month that each of the existing operator subscribers can use before saturation. Thus, an operator with fewer subscribers – if all other things such as spectrum and number of macro sites being equal – will be depicted with a higher capacity potential versus an operator that has more subscribers.

4G radio network capacity utilization of existing macro cell site grids - 2019

Annual average, existing FDD & SDL (600/700/800/900/1400/1800/2100/2600) MHz holdings, macro sites, downlink, 5% most loaded sectors



Source: Operators, regulators, Rewheel analysis. No data available for operators that do not appear in the chart.

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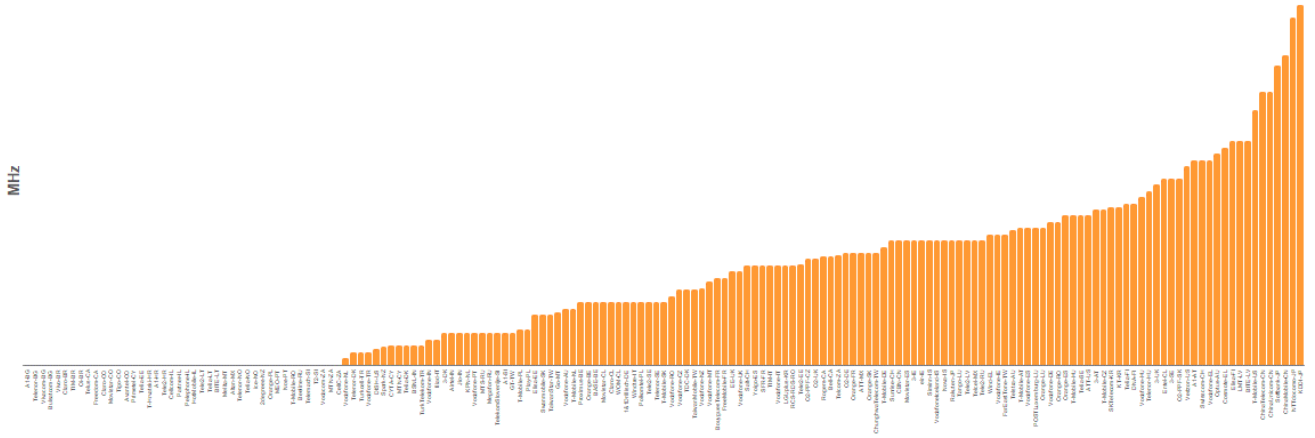
5G capacity mid-band spectrum holdings - 2020

Operator TDD spectrum holidngs in the 1900, 2300, 2500/2600 and 3400 - 4000 MHz bands as of February 2021



Source: Operators, regulators, Rewheel analysis.

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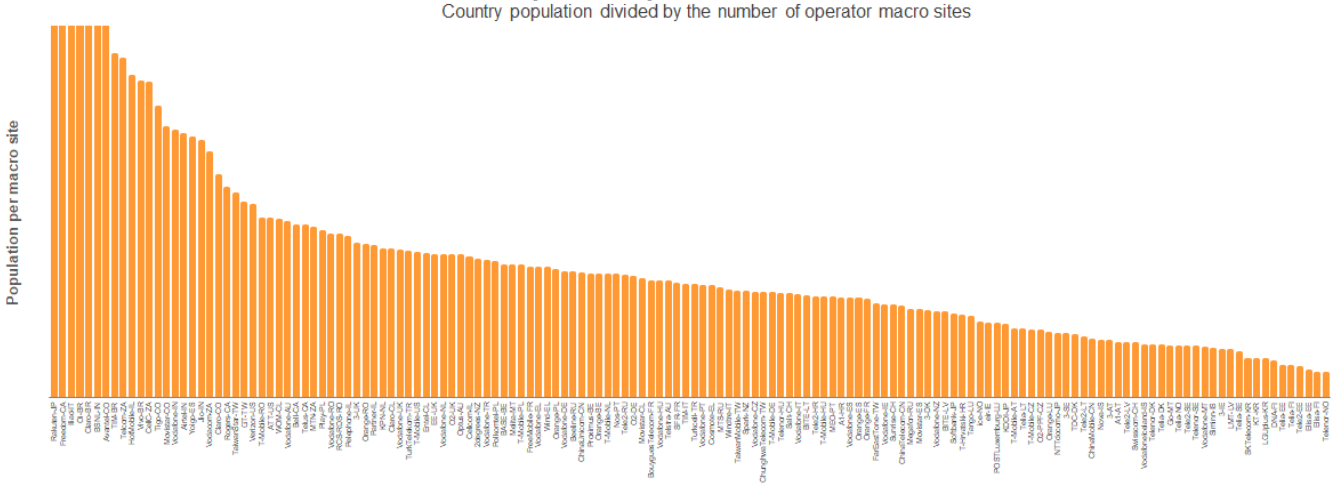
Population per macro site - 2020

Country population divided by the number of operator macro sites



Source: Operators, regulators, Rewheel analysis. No data available for operators that do not appear in the chart.

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Founded in 2009 and incorporated in Finland, Rewheel is a privately owned independent telecom research firm and boutique management consultancy. Our clients are mobile network operators, telco groups, MVNO groups, competition authorities, telecom sector regulators, governments, global internet firms, mobile data-centric start-ups, PE and VC investors.

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⇨ http://research.rewheel.fi/downloads/The_state_of_4G_5G_pricing_DFMonitor_14_release_2H2020_PUBLIC.pdf

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⇨ http://research.rewheel.fi/downloads/4G_5G_prices_Germany_Italy_France_Spain_UK_June_2020_PUBLIC.pdf

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⇨ http://research.rewheel.fi/downloads/The_state_of_4G_5G_pricing_DFMonitor_13_release_1H2020_PUBLIC.pdf

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⇨ http://research.rewheel.fi/downloads/The_state_of_4G_pricing_DFMonitor_12th_release_2H2019_PUBLIC.pdf

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⇨ http://research.rewheel.fi/insights/2018_may_pro_1h2018_release/

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⇨ http://research.rewheel.fi/insights/2017_nov_pro_2h2017_release/

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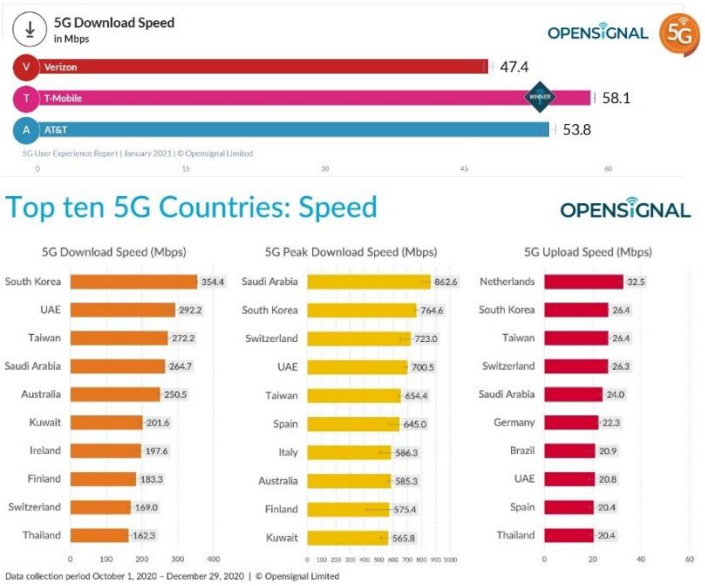
1 Study context and methodology

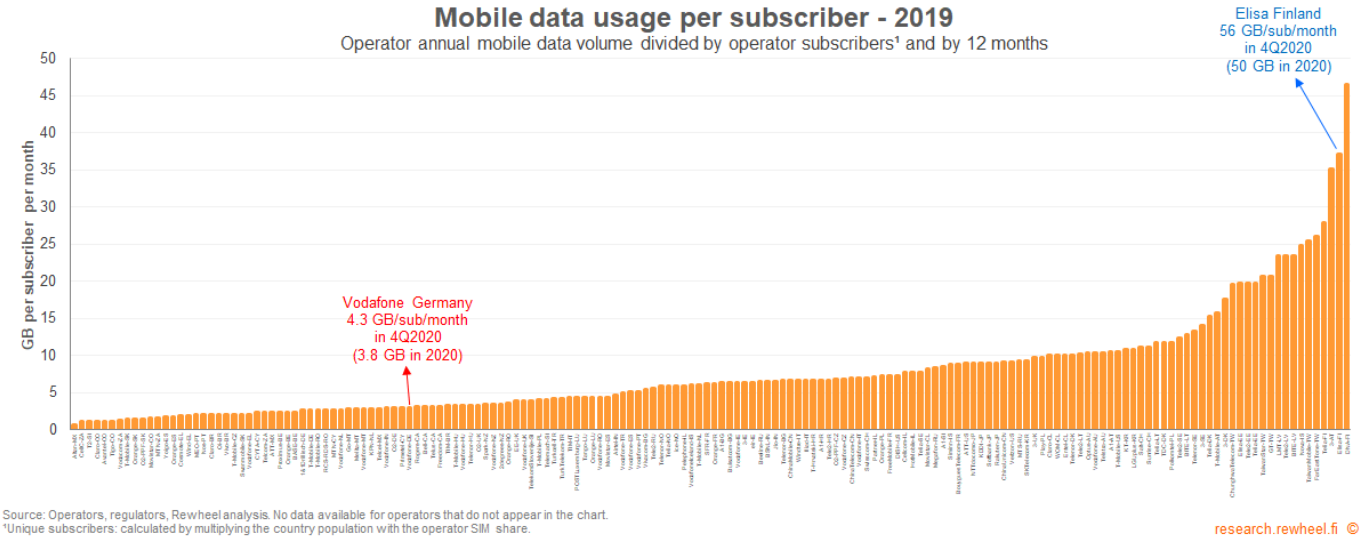
1.1 Context and methodology

Mobile network performance and in particular average speeds measured by crowd sourced specialists such as OpenSignal[12], Ookla and Tutela or other mobile network analytics vendors such as Rootmetrics and P3 have received a fair amount of media coverage the last three years. Unsurprisingly, operators or countries that achieve top rankings in such benchmarks rush to claim the crown of the '*best network*' in a given country or even the title of the '*best network'* in the entire world.



While such tests do offer some valuable insights into the current state of mobile network performance, they do have a number of significant limitations. For example, crowd sourced apps measure network performance under very dissimilar network loads, using different measurement protocols and probing methods that often distort the measurements. Crowd sourced benchmarks fail to account for plans where the user speed is intentionally limited by the network (e.g. Finnish operator or Vodafone's Europe speed-tiered unlimited volume plans) or plans where speed has been throttled due to the depletion of the plan's finite volume.

More importantly though, these tests shed no light on two very important questions: how heavily utilized are mobile networks today and when – at what usage level – will operators run out of 4G or 5G capacity? Undeniably, the capacity potential of every mobile operator will largely dictate its mobile network performance in the wireless broadband era where average mobile data usage will be measured in hundreds of gigabytes rather than in few gigabytes per month.



[1]https://www.opensignal.com/2021/02/03/benchmarking-the-global-5g-experience
[2]https://www.opensignal.com/reports/2021/01/usa/mobile-network-experience-5g

As seen in the chart above the average mobile data usage in Elisa's network in Finland reached[3] 56 gigabytes per subscriber month during the 4th quarter of 2020. In Vodafone's network in Germany, it was[4] 4.3 gigabytes per subscriber month in 2019 or ~13x lower.

Does that mean that Elisa's mobile network in Finland was ~13x more congested than Vodafone's network in Germany? No, far from it. As we shown herein the 4G capacity utilization in Elisa's Finnish mobile network during 2019 was at very manageable level. On the other hand, Vodafone in Germany utilized in 2019 a fraction of its available 4G capacity.

As with our third annual capacity utilization and capacity potential study that was released in October 2019 the key objective of our fourth annual capacity utilization and capacity potential study is to shed light on these two very important questions: how heavily utilized were 4G mobile networks in 2019 and when – at what usage level – will operators run out of 4G and 5G capacity? In late 2019 and in 2020 a number of operators acquired 5G spectrum holdings in the 3400 - 4000 MHz TDD bands and as a result greatly enhanced their 5G capacity potential.

Nearly four years ago, in March 2017, we released a novel study[5] titled '*Capacity utilization and fixed-to-mobile broadband substitution potential – A study of 64 European operators*'. This was our first comprehensive study that examined the state of capacity utilization and estimated the fixed-to-mobile broadband substitution potential of European mobile networks.

Therein we reported the estimated 2016 yearly average capacity utilization and the fixed-to-mobile broadband substitution potential (i.e. capacity potential) of 64 European mobile operators' spectrum holdings and macro site grids. Our main finding concerning the 2016 capacity utilization was that most European mobile operators utilized in 2016 a tiny fraction of their available network capacity and hence there were significant fixed-to-mobile broadband substitution gains that can be realized if operators unleashed the abundant capacity in their networks by offering unlimited data plans. In particular our study showed that many mobile operators could carry 100 gigabytes per person per month and will soon have enough 5G capacity (TDD/massive MIMO) for carrying hundreds of gigabytes per person per month or up to ~1 terabyte per household.

Two and a half years ago, in September 2018, we released an update[6] to our first capacity utilization study titled '*Capacity utilization and fixed-to-mobile broadband substitution potential with existing macro site grids – 2017*'. Therein, we presented the 2017 yearly average radio network capacity utilization estimates for 80 mobile operators: the 64 European operators we included in our first study and 16 more mobile operators from the United States, Japan, Korea, Australia and New Zealand. Similarly, to our first study we calculate the network capacity utilization and fixed-to-mobile broadband substitution potential of the existing operator macro site grids.

Our second capacity utilization analysis showed that most mobile operators − save few exceptions such as Verizon US and Play Poland − utilized a fraction of their available macro site network capacity in 2017. Further to that we showed that many operators have very significant untapped 5G capacity potential.

In October 2019 we release a third study[7] titled "*2018 capacity utilization and 5G capacity potential of mobile operator existing macro cell site grids*". Therein, we presented the 4G capacity utilization of 2018, the 4G capacity potential and the 5G capacity potential of existing macro site grids for over 100 (out of 143) mobile operators that were present in the 41 EU28 & OECD markets during 2018.

Similarly, to our 2016 and 2017 capacity utilization calculations, our 2018 capacity utilization calculations did not include capacity from already built micro and/or small cells or from existing or future deployment of TDD 1900/2300/2600/3400-4000 MHz spectrum in small cells. See the dedicated sub section below concerning the role of small cells and their limitations.

In this fourth annual update, we estimate the 4G capacity utilization of 2019 of mobile operators in the 5% of their most loaded macro site sectors by taking into account all of their existing FDD 600/700/800/900/1800/2100/2600 and SDL 700/1400 MHz spectrum holdings, the reported (or in some cases estimated) number of macro sites, the reported (or in some cases estimated) 2019 mobile data volume and by applying typical data traffic geo-distribution, busy hour and spectrum efficiency profiles (corresponding to typical 4x4 MIMO and 256QAM macro sector capacity).

[3] https://elisa.com/corporate/investors/
[4] https://investors.vodafone.com/reports-information/results-reports-presentations
[5] http://research.rewheel.fi/downloads/Capacity_utilization_fixed_mobile_broadband_substitution_potential_21032017_PUBLIC.pdf
[6] http://research.rewheel.fi/downloads/Capacity_utilization_fixed_mobile_broadband_substitution_potential_2017_PUBLIC.pdf
[7] http://research.rewheel.fi/downloads/2018_capacity_utilization_potential_macro_site_grids_PUBLIC.pdf

Please note that the 4G capacity utilization of 2019 estimations presented herein, for 169 operators from 48 European, American, Asian Pacific and African countries for which data were available, are neither directly comparable with the capacity utilization figures of 2017 nor with those of 2016. In the 2017 capacity utilization estimation besides the FDD and SDL existing spectrum holdings we took into account the existing TDD 2500/2600 MHz spectrum holdings while in the 2016 capacity calculations we took into account only the existing FDD operator holdings. In the 2018 and 2019 capacity utilization calculations we excluded all existing TDD 1900/2300/2600/3400-4000 MHz spectrum holdings from the 4G capacity utilization calculations and instead included them in the 5G capacity potential calculations.

Due to this change, operators that hold substantial TDD 2500/2600 MHz spectrum holdings appear with much higher capacity utilization in 2019 and 2018 compared to 2017 and 2016. For example, by accounting for Sprint US's ~137 MHz of TDD 2500/2600 MHz spectrum holdings we estimated that Sprint's capacity utilization in 2017 was only 15%. In our 2018 estimate Sprint's capacity utilization jumped to 119% − indicating a congested network − because Sprint at the time held very little FDD spectrum.

However, Sprint that is now acquired by T-Mobile, has already deployed[8] TDD 2500/2600 MHz spectrum using massive MIMO in a number of major metropolitan areas across the United States such as New York, Los Angeles, Phoenix, etc. Hence, Sprint's actual average capacity utilization in its 5% most loaded sectors in 2018 was most likely much lower than our 119% estimation. When Sprint's substantial TDD 2500/2600 MHz spectrum holdings are taken into account in the 5G capacity potential calculations Sprint's 5G advantage becomes apparent. As we show herein, T-Mobile that acquired Sprint spectrum holdings and mobile sites, is the US operator that currently has the highest 5G capacity potential.

It is important to note that the 4G capacity utilization of 2019 estimations that we present herein assume that operators have deployed – where needed – all of their available FDD and SDL (Supplementary Downlink) spectrum holdings. So, it is the utilization of the readily available macro site grid capacity resources rather than the capacity utilization of the spectrum and equipment actually deployed by operators in their sites in 2019.

For example, the 2019 actual capacity utilization of an operator in its top 5% most loaded sectors could be substantially higher than the figures we present herein simply because that given operator has not yet deployed all of its FDD and SDL spectrum holdings (e.g. 2600 FDD and 1400 SDL not yet deployed) and/or because it still uses most of its 900 and 1800 spectrum for GSM service.

Having estimated the 4G capacity utilization of 2019, in the next step, we estimate the 4G capacity potential, 5G capacity potential and combined 4G&5G capacity potential. We express the operator 4G and 5G capacity potential in terms of the operator SIM (total reported SIM's in 2019 excluding m2m) average monthly data usage, as we did in the third annual study that was released in October 2019, and as well in terms of the operator unique subscriber (unique subscribers were calculated by multiplying the country population with the operator SIM share) average monthly data usage that can be carried by the operator's existing macro site grid capacity before saturation i.e. up to 80% utilization in 5% most loaded macro site sectors.

In the 4G capacity potential calculations we use the operator FDD 600/700/800/900/1800/2100/2600 MHz and SDL 700/1400 MHz spectrum holdings while in the 5G capacity potential calculations we add the operator TDD 1900/2300/2500/2600/3400-4000 MHz spectrum holdings into the mix by assuming that those will be deployed with massive MIMO.

Our latest findings re-confirm our field experience gained through our recent 700/1400/3400-4000 MHz spectrum valuation and fixed-to-mobile broadband substitution business case consulting engagements: many mobile operators are still utilizing only a fraction of their readily available 4G capacity potential. So, expect more launches of unlimited smartphone, mobile broadband and wireless broadband plans.

[8] https://newsroom.sprint.com/sprint-lights-up-true-mobile-5g-in-new-york-city.htm

Moreover, mobile operators that have acquired hundreds of MHz of TDD spectrum and have dense macro site grids (e.g. Elisa Finland, KT Telecom Korea, 3 UK, etc.) have very substantial 5G capacity potential. A subscriber of those operators could be generating − in few years from now – hundreds of gigabytes every month over the 5G network. An average household with a 5G wireless broadband connection could be generating up to ~1 terabyte per month watching 4K TV and playing games online.

Recent launches of 5G home wireless broadband plans from 3 UK "*5G is in the house*"[9], Sunrise Switzerland "*5G Internet + 4K TV*"[10] and Elisa Finland 5G Homenet[11] are paving the way for a wirelessly connected world.

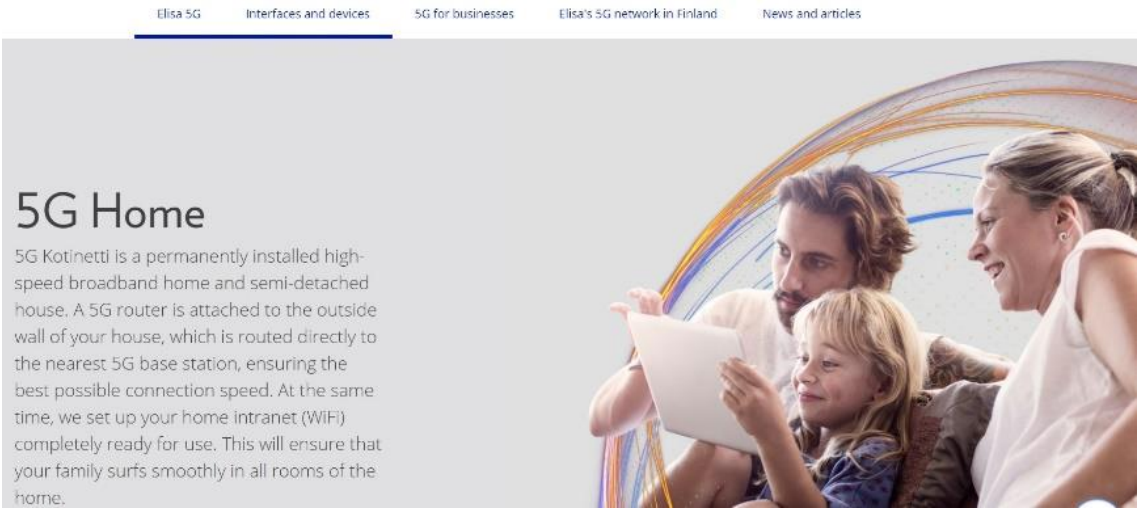
Latest Company News.

Three switches on 5G today: 5G is in the house

Latest Company News.

Three switches on 5G today: 5G is in the house

- One single 5G home broadband plan with truly unlimited data for £35 per month
- No landline, no fibre and no engineer required
- Three showcases 5G through 5G fuelled living room of the future alongside designer Henry Holland



[9] http://www.threemediacentre.co.uk/news/2019/19-08-2019a.aspx
[10] https://www.sunrise.ch/en/corporate-communications/medien/press-releases.html
[11] https://elisa.fi/5g/laitteet#5g-kotinetti

1.2 Small-cell capacity not included in the calculations

As of 2019, only a handful of US, Korean, Japanese and Canadian operators have deployed significant numbers of small cells. T-Mobile in the US reported during the 1Q2020 that it owned 26,000 small cells and Distributed Antenna Systems (DAS) and that it planned to eventually double the figure to 40,000 or 50,000. However, following the acquisition of Sprint T-Mobile stated[12] that "*the operator's interest in adding small cells to its network has certainly softened following the close of its merger with Sprint. T-Mobile plans to add capacity to its network by deploying Sprint's 2.5GHz spectrum onto macro towers instead of adding more small cells.*".

Telus in Canada is another operator that has built[13] several thousand small cells, primary covering sub-urban residential areas. Now while Korean and Japanese operators have been boosting their capacity potential by complementing their dense macro site networks with small cell rollouts, that is not the case for US and Canadian operators.

US and in particular Canadian operators have very weak macro cell site networks (~6 to 9x less dense than Finnish mobile networks), hence their small cell rollouts are more like '*pothole road-repair'* than '*building new avenues*'. Small cells can '*super-charge*' the capacity potential of the macro site grid, but they cannot substitute the macro grid capacity, not if cost is a factor. Operators will need to deploy hundreds of thousands of small cells in small countries and millions of small cells in big countries to achieve similar level of service that is typical to a dense macro site grid.

Moreover, there are a number of contentious issues with the permits, deployment, safety, aesthetics, upgradability and cost of small cells both in downtown and urban residential environments.

- Permitting could become an increasingly contentious[14] and expensive matter as more and more small cells are deployed
- Permitting could become an increasingly contentious[15] and expensive matter as more and more small cells are deployed
- Higher bandwidth will require proportionally higher emitted RF power exacerbating the already wide-spread health and safety concerns[16] from the proximity of small cells to people's houses
- Higher power will increase the physical size of the equipment and will require more supporting structures that might not be feasible to create in the existing poles that small cells are currently mounted
- Similarly, the phsysical size for massive MIMO antenna arrays and the required supporting structures could become a bottleneck
- Maintenance and field services can become a very costly affair due to the massive amount of site visits required for every upgrade
- Small cell astethics will be a factor that will determine acceptance by the local communities especially in western and Northern European cities
- Contingency: there are issues with the small cells power supply, consumption and battery backup (no place for batteries)
- Costs: small cells require many separate backhaul end points

The picture illustrates[17] a *so-called* small cell site in the US.

[12] https://www.lightreading.com/5g/t-mobile-network-chief-on-building-lots-of-small-cells-its-nightmarish/d/d-id/761818
[13] http://research.rewheel.fi/downloads/Root_cause_weak_competition_Canada_wireless_market_PUBLIC.pdf
[14] https://www.bizjournals.com/kansascity/news/2019/04/02/5g-small-cell-local-permitting-challenges.html
[15] https://www.bizjournals.com/kansascity/news/2019/04/02/5g-small-cell-local-permitting-challenges.html
[16] https://www.abc.net.au/news/2019-01-07/huawei-small-cell-network-comes-to-sydney/10688124?pfmredir=sm
[17] http://smallcellsinmontgomerycounty.blogspot.com/2018/10/montgomery-county-zta-18-11-will-allow.html