Bill Impact

Modeling the impacts on speed and coverage – NORTHSTREAM

November 14, 2018

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1. Speed and Coverage Impact Analysis

1.1 Objectives

1. The overall objective of the speed and coverage impact analysis is to illustrate the effects that a delay in the release of spectrum and lack of investment would have on average user speeds and 4G coverage levels in South Africa during the years 2018 through to 2025. This is expected to happen as a result of the 2018 Electronic Communications Amendment Bill.

2. The aim is therefore to quantify in detail the detrimental consequences of the Bill to mobile subscribers in South Africa, in terms of average user speed and coverage.

1.2 Methodology

3. Overall, the methodology focuses on calculating the average user speed that is achieved by each operator. By its nature, the method used to calculate the average user speed also yields estimates of population and geographic coverage.

4. The overall average national speeds for South Africa are derived by calculating the weighted average of the speeds of the individual operators. The weighting factors are the market shares of the operators as displayed below. The market shares are held constant between 2018 (current year) and 2025, while different figures are used for 2017 (the baseline year).

Table 1 Operator market shares used throughout the model

	Vodacom	MTN	Cell C	Telkom
2017	45.4%	33.4%	16.8%	4.5%
2018 – 2025	47.5%	30.5%	16.5%	5.6%

5. The following paragraphs mainly describe the method used to calculate the average speed[1]; the approach used to retrieve coverage-related parameters is highlighted in the relevant places.

Average Speed Calculation Method

6. In its simplest form, the average speed experienced by a certain number of users in a particular cell[2] is calculated as follows:

$$Average\ Cell\ Speed\ = (Total\ Cell\ Throughput)\ /\ (Number\ Cell\ Users) \qquad [1]$$

7. The overall objective is to calculate the average speed that each operator achieves on a national basis, across all technologies, i.e., 2G, 3G and 4G. Therefore, as a first step, the above speed calculation is carried out for 2G, 3G and 4G separately. Subsequently, the average national speed per operator in a given year is the weighted

[1] Note that this is a simplified description with some omissions. A detailed methodology is provided in the Appendix.
[2] "Cell" refers to the area covered by a physical site. In the actual calculations, the cell is broken down into sectors. It is assumed that there are three sectors per site, i.e., three sectors per cell.

average of those three figures, with the weights being equal to the share of customers that are on the respective technology in that year.

8. Within each technology, the above speed calculation equation is carried out at the level of each individual cell across the towns with coverage in the year being modeled (i.e., those parts that have 2G/3G/4G coverage), then averaged out to give a single national average value for 2G, 3G and 4G, respectively. The weights used for the averaging are the subscriber shares of the towns.

9. For each operator, we estimate the covered parts of the country for 2G, 3G and 4G in the baseline year (i.e., 2017) on the basis of the following parameters and assumptions:

    a. An estimate of the number of physical 2G, 3G and 4G sites of each operator (considered to be a known value).

    b. The assumed average distance between the physical sites, also known as the inter-site distance (ISD) and the corresponding surface area covered by the site (i.e., the site coverage area; also considered to be a known value)[3].

    c. The assumption that site deployment prioritizes densely populated towns (or cities) over less populated areas such as rural towns.

10. Specifically, in descending order of population density, each town is assumed to be covered by a number of sites, which is calculated as:

$$Number\ of\ Sites\ in\ a\ Town = (Town\ Area)\ /\ (Site\ Coverage\ Area) \qquad [2]$$

11. Starting from the most densely populated town, the above equation is applied in every town until the cumulative number of sites reaches the total number of sites that each operator is assumed to have in the baseline year.

12. The above method results in two key parameters:

    a. Baseline geographical and population coverage: Using census data, we can directly deduce, from the above method, the population and surface area covered by each operator in the baseline year.

    b. Subscriber distribution across the covered towns: Using census population distribution as a proxy, we can approximate the proportion of the subscribers, out of the total, in each town and for each operator. This is then used to calculate a weighted average of the speeds achieved in each town to give a national average speed.

13. The above method also allows us to calculate the number of subscribers in a cell[4] (i.e., the denominator in Equation [1]) as:

$$Cell\ Subscribers = (Total\ Subs.\ in\ Town)\ /\ (Number\ of\ Cells\ in\ Town) \qquad [3]$$

[3] The network area given by the ISD is also referred to as the ISD grid or the baseline grid.
[4] Note that this number is further divided by the Contention Ratio (CR), see the Assumption section for further details.

14. Starting with 2018, the approaches that lead to equations [1], [2] and [3] continue to be applied in a similar fashion. However, for 4G, the model then incorporates increases in coverage through additional site roll-outs as the years progress.

15. For each operator, the additional sites are rolled out starting with the town after the one last covered by the baseline coverage in 2017. The roll-out is continued by decreasing population density as described above.

16. All subsequent site coverage areas are no longer based on the ISD metric used to determine the baseline grids, but on the surface area that is covered by the lowest 4G band which is available to each operator during the year in question, i.e., the band with which the new sites would most likely be rolled out.

17. In doing so, the coverage improvement provided by the high-demand low band spectrum relative to the operators' current 4G spectrum is illustrated starting with the year 2022 (the year the low frequency bands are assumed to become available).

18. The coverage extension is continued downwards, by decreasing population density of the towns, until the cumulative number of newly rolled out sites reaches the number of 4G coverage sites the operator in question is assumed to roll out in the year at hand.

19. The equation below is used to calculate the number of sites necessary to cover a town that is not already covered with the ISD grid (i.e., an incremental town); based on the coverage reach (i.e., cell range) achieved by the lowest band deployed at those sites. It is thus an adjustment of equation [2].

$$Number\ of\ sites\ in\ a\ Town = (Town\ Area)\ /\ (Site\ Coverage\ Area\ of\ Band\ x) \quad [4]$$

20. The incremental population and geographical coverage in the towns where Band x is deployed can be deduced from census data on town population and surface area.

21. The above described procedure of coverage expansion is illustrated in the figure below.

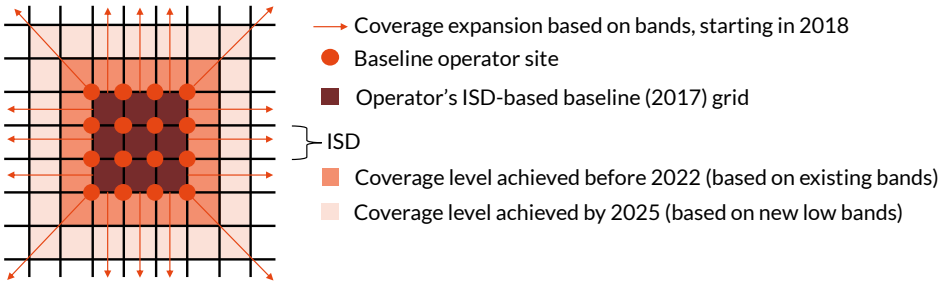

Figure 1 Logic of coverage expansion

1.3 Scenario Description

1.3.1 Spectrum release

22. In order to reflect the impact of the Bill, two scenarios for spectrum release are considered:

a. the "Bill" scenario – under this scenario the 2018 Bill gets fully implemented in its current form

b. the "No Bill" scenario – under this scenario the Bill is not implemented in its current form; it is instead assumed that the spectrum allocation remains similar to what was initially set out in the 2016 ITA[5]

23. Under the "No Bill" scenario, the 2600 MHz band is assumed to become available in 2019; the 700 MHz and 800 MHz bands are assumed to become available in 2022. Under the "Bill scenario", the 2600 MHz band is assumed to only to become available in urban areas in 2023 after the rural coverage obligations have been met; the 700 MHz and 800 MHz are all assumed to become available in 2022 (similar to the "No Bill" scenario).

1.3.2 Subscriber migration to 4G and its connection to the spectrum release

24. It is assumed that a delay in the spectrum release will also delay subscriber migration from 2G and 3G to 4G.

25. Between 2017 and 2020, the same migration rates are assumed for both the "No Bill" scenario and the "Bill" scenario.

26. Starting from 2021, the migration rate of the "Bill" scenario is considered to become slower than that of the "No Bill" scenario. This effectively is assumed to make it so that, in 2025, the technology mix in the "Bill" scenario will equal that of the "No Bill" scenario in 2023.

1.3.3 Coverage roll-out scenarios

27. Furthermore, two different scenarios for the roll-out of additional 4G coverage sites are considered, in order to reflect the presumed lowered investment that operators would likely make as a result of the 2018 Bill.

a. "No Bill" scenario: Additional 4G coverage sites are rolled out throughout all years between 2018 and 2025.

b. "Bill" scenario: Additional 4G coverage sites are rolled out between 2018 and 2020, exactly as under "No Bill". Starting with 2021, only half the number of additional coverage sites (compared to "No Bill") are rolled out. The latter does not occur for operator Cell C, as they are assumed to receive a Lot without low-band spectrum in the "Bill" scenario, and thus subsequently be less incentivized to roll out into previously uncovered areas. Thus, for "Bill", Cell C is presumed to stop rolling out after 2020.

1.3.4 Spectrum re-farming onto 4G

28. Beyond the release of new spectrum, the model also incorporates re-farming of existing 2G/3G spectrum onto 4G as the years progress as follows:

a. "No Bill" scenario:

[5] For more detail, please see Frontier Economics report, Part I.

A. Telkom re-farms 10 MHz of its 2G spectrum (assumed to have been assigned to voice) on the 1800 MHz band onto 4G in 2021.

B. Both Vodacom and MTN re-farm 10 MHz of their 3G spectrum (assumed to have been assigned to data) on the 2100 MHz band onto 4G in 2023. In parallel, 5 MHz on the 900 MHz band are assumed to be re-assigned from 3G voice to 3G data, respectively.

C. Cell C re-farms 10 MHz of its 2G spectrum (assumed to have been assigned to voice) on the 1800 MHz band onto 4G in 2023. In parallel, 5 MHz on the 900 MHz band are assumed to be re-assigned from 3G voice to 3G data.

b. "Bill" scenario: All re-farming and re-assignment actions described above are expected to occur one year later, respectively.

1.4 Input Data

29. Below is a summary of the input data used to calculate the average speeds and coverage-related metrics. The actual values are detailed in the Appendix:

a. The annual growth rate of the overall subscribers in South Africa is assumed to be 2.04%. The baseline subscriber number for 2017 is assumed at 46,088,000.

b. The operator market shares (held constant throughout the modeling timeline), as they were displayed in Table 1.

c. The subscriber technology mix for each operator across the years 2017-2025 for both the "No Bill" scenario and "Bill" scenario.

d. The baseline number of 2G, 3G and 4G sites held by each operator.

e. The number of additional 4G coverage sites to be rolled out annually per operator.

f. The ISDs and their corresponding surface areas for various types of the propagation environment[6].

g. The surface areas corresponding to various spectrum bands in different propagation environments.

h. The maximum theoretical throughputs achievable with 2G, 3G and 4G for a given carrier bandwidth.

i. Each operator's current spectrum holdings and the respective assignment of spectrum across 2G, 3G and 4G.

j. For the "No Bill" scenario, the most beneficial spectrum band combinations in terms of maximum theoretical downlink throughput for each operator that correspond to each of the relevant Lots of the original 2017 ICASA ITA.

[6] The differentiation between types of environment accounts for the difference in signal propagation. Generally, the signal travels farther in rural environments than it does in built-up urban environments.

k. For the "Bill" scenario, the most beneficial spectrum band combinations in terms of maximum theoretical downlink throughput for each operator that correspond to potential Lots conceived in accordance with the overall spectrum distribution suggested in the 2018 Draft Policy Directive by the Government.

1.5 Overall Analytical Assumptions

30. For the spectrum assigned to 2G and 3G in the baseline year 2017, the following splits for the spectrum usage between voice and data are assumed:

    a. Vodacom: 2G – 900 MHz band is used for voice; 1800 MHz band is used for data. 3G – 900 MHz band is used for voice; 2100 MHz band is used for data.

    b. MTN: 2G – 900 MHz band is used for voice; 1800 MHz band is used for data. 3G – 900 MHz band is used for voice; 2100 MHz band is used for data.

    c. Cell C: 2G – 900 MHz band and 10 MHz on the 1800 MHz band are used for voice; 2 MHz on the 1800 MHz band are used for data. 3G – 900 MHz band is used for voice; 2100 MHz band is used for data.

    d. Telkom: 2G – 10 MHz on the 1800 MHz band are used for voice; 2 MHz are used for data. 3G – 5 MHz are used for voice; 10 MHz are used for data.

31. The 2018 market shares of the operators remain constant through to 2025.

32. For the "No Bill" scenario, it is assumed that the operators would receive spectrum that corresponds to the following original 2016 ITA Lots:

    a. Vodacom: Lot C.

    b. MTN: Lot D.

    c. Cell C: Lot B.

    d. Telkom: Lot E.

33. For the "Bill" scenario, it is assumed that the operators would receive spectrum in accordance with the allocation suggested in the 2018 Draft Policy Directive. From the Directive, hypothetical auction Lots are conceived and allocated to the operators as follows (the Lots themselves for both scenarios can be found in the Appendix):

    a. Vodacom: Lot C.

    b. MTN: Lot D.

    c. Cell C: Lot B.

    d. Telkom: Lot E.

34. In the "Bill" scenario, operator Cell C is assumed to receive Lot B, which in that case would leave them without low-band spectrum and thus disincentivize them from rolling out further coverage sites after 2020.

35. The ISDs are common between operators.

36. All current (baseline) respective subscribers of the four operators are assumed to be located within those operators' respective covered areas, regardless of whether the lowest band that is currently at each operator's disposal covers the entire ISD-based sector area or not.

37. Whenever new spectrum is added on top of the existing holdings, the coverage reaches of various bands (such as 2600 MHz) are considered. The calculation accounts for the fact that higher frequency bands cover a relatively smaller area than lower frequency bands; and therefore, only a proportion of subscribers can benefit from such high frequency bands. This proportion depends on how far the respective additional bands reach, relative to either the ISD-based sector area (for baseline sites) or to that of the band with which the site has initially been rolled out starting from 2018.

38. Starting with 2018, it is assumed that the number of additional 4G coverage sites is the same in each year per operator, i.e., through to 2025. However, the model does consider differences between the operators in terms of how many sites they roll out per year. No additional coverage roll-out for 2G/3G or densification for any technology is modeled.

39. Starting with 2018, it is assumed that the operators will roll out their additional 4G coverage sites on the bands named below. Before the low frequency band ITA spectrum is released in 2022, they are assumed to roll out on the lowest frequency band they currently have assigned to 4G. Starting with 2022 (with the exception of Cell C in the "Bill" scenario), they are assumed to roll out on the lowest frequency band that is awarded through the Lot they are expected to receive.

    a. Vodacom: 1800 MHz (2018-2021); 700 ("Bill")/800 MHz ("No Bill") (2022-2025).

    b. MTN: 1800 MHz (2018-2021); 700 ("Bill")/800 MHz ("No Bill") (2022-2025).

    c. Cell C: "No Bill" – 2100 MHz (2018-2021); 700 MHz (2022-2025). "Bill" – 2100 MHz (2018-2020).

    d. Telkom: 2300 MHz (2018-2021); 700 MHz (2022-2025).

40. In line with the coverage expansion on the frequency bands stated above, the following is assumed in terms of which subscribers profit from the frequency bands deployed starting from 2019:

    a. 2600 MHz: As this band is released in 2019 (in the "No Bill" scenario), only the subscribers that have been covered by the baseline frequency band (i.e., 1800/2100/2300 MHz) by 2019 are assumed to benefit from it. In the "Bill" scenario, the band is released in 2023, but the same coverage logic as for "No Bill" is assumed.

    b. 700/800 MHz: All subscribers shall receive these low frequency bands, while all sites that are rolled out starting with 2022 (the year these frequency bands become available in both scenarios) are assumed to solely be equipped with these low frequency bands.

c. Re-farmed 1800/2100 MHz: Only the sites that had coverage with the respective baseline frequency band (i.e., 1800/2100/2300 MHz) by 2021 are assumed to profit from re-farming.

41. There is no pre-defined limit for 4G coverage expansion, which means that 4G coverage can thus end up exceeding the respective baseline coverage levels for 2G and 3G coverages.

42. It is presumed that only a fraction of subscribers within any given sector, in any given town, are accessing data resources simultaneously. A contention ratio of 10% is used. This value is assumed to reflect the Busy Hour period.

1.6 Results & Conclusion[7]

1.6.1 Average Speed

43. The figure below shows the development of average user speeds in South Africa between 2017 and 2025 across the scenarios considered.

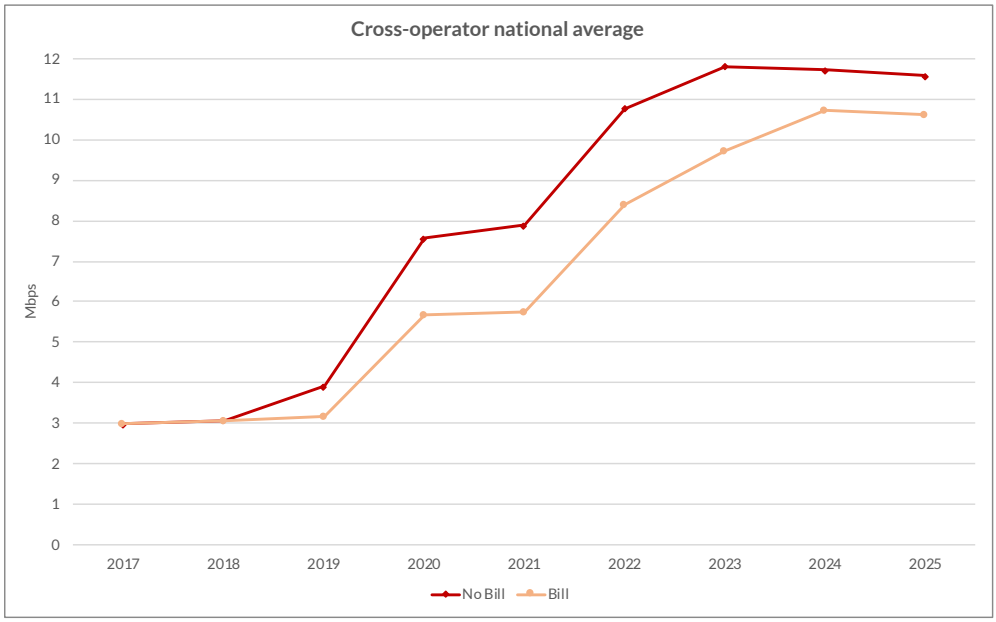

Figure 2 Projected cross-operator national average speeds in South Africa 2017-2025

44. The following observations can be made:

a. The Bill, i.e., the delay of 2600 MHz spectrum and the reduction in low-band spectrum made available to the MNOs, would lead to lower average user speeds across all operators by 2025.

b. In 2020-2021, the difference in average speeds between the ”No Bill” scenario and “Bill” scenario is above 30%; by 2025 it is still at roughly 9%.

[7] A subset of results is shown to in order to support the key conclusions. A more extensive set of results is provided in the Appendix.

1.6.2 Coverage

45. The tables below show the progression of both population and geographic coverage between 2017 and 2025, for both the ”No Bill” scenario and “Bill” scenario, respectively.

Table 2 Coverage development for the ”No Bill” scenario

"NO BILL"	2017	2018	2019	2020	2021	2022	2023	2024	2025
Vodacom									
Population	68,17%	80,78%	86,27%	89,50%	91,62%	94,80%	96,05%	98,01%	98,94%
Area	2,33%	2,91%	3,49%	4,07%	4,65%	6,59%	10,51%	22,74%	34,93%
MTN									
Population	61,35%	65,87%	67,44%	67,97%	68,14%	75,99%	94,14%	96,97%	98,94%
Area	1,39%	1,53%	1,67%	1,81%	1,95%	2,61%	5,87%	14,58%	35,04%
Cell C									
Population	19,40%	22,16%	23,69%	24,96%	26,19%	30,74%	33,82%	35,75%	37,34%
Area	0,24%	0,25%	0,25%	0,26%	0,27%	0,30%	0,34%	0,37%	0,41%
Telkom									
Population	15,20%	16,11%	17,49%	18,53%	24,85%	57,05%	61,34%	68,11%	83,08%
Area	0,14%	0,16%	0,19%	0,21%	0,26%	0,82%	1,38%	1,87%	3,11%

Table 3 Coverage development for the ”Bill scenario”

"BILL"	2017	2018	2019	2020	2021	2022	2023	2024	2025
Vodacom									
Population	68,17%	80,78%	86,27%	89,50%	90,67%	93,66%	94,88%	95,03%	96,89%
Area	2,33%	2,91%	3,49%	4,07%	4,36%	5,55%	6,74%	7,89%	14,11%
MTN									
Population	61,35%	65,87%	67,44%	67,97%	68,11%	68,14%	68,14%	85,06%	93,26%
Area	1,39%	1,53%	1,67%	1,81%	1,87%	1,95%	1,95%	3,33%	5,33%
Cell C									
Population	19,40%	22,16%	23,69%	24,96%	24,96%	24,96%	24,96%	24,96%	24,96%
Area	0,24%	0,25%	0,25%	0,26%	0,26%	0,26%	0,26%	0,26%	0,26%
Telkom									
Population	15,20%	16,11%	17,49%	18,53%	18,95%	39,38%	54,91%	60,27%	61,31%
Area	0,14%	0,16%	0,19%	0,21%	0,22%	0,47%	0,75%	1,02%	1,30%

46. The following observations can be made:

    a. Under the assumption that a delay in spectrum release would lead to the operators slowing down the roll-out of new 4G coverage sites post-2020, this delay would lead to considerably lower coverage levels by 2025.

    b. With the “No Bill” scenario, the highest coverage levels that can be achieved by 2025 are those of Vodacom with 98.94% of the population and 34.93% of the area, respectively. This comes close to the 100% coverage level that was originally set forth as a requirement in the ITA. Even though the ITA originally requested this level to be reached by 2020, it was then assumed that the low frequency band spectrum would become available sooner (i.e., before 2020). As this model incorporates the low frequency band spectrum only starting from 2022, these results can still be considered to be in line with the initial ITA requirements.

2. Appendix

2.1 Carrier Aggregation Combinations

Table 4 Possible CA combinations in South Africa and minimum required bandwidths (Italics indicate TDD spectrum)

Spectrum	Bands	Minimum bandwidths (MHz) required per carrier	Maximum bandwidths (MHz) possible per carrier
No CA, single bands only			
700	28	-	-
800	20	-	-
900	8	-	-
1800	3	-	-
2100	1	-	-
2300	*40*	-	-
2600	7	-	-
Intra-band CA with >20 MHz total on 2300 TDD			
2300 + 2300 (2CA intra-band)	*40 + 40*	*10 + 10*	*20 + 20*
2300 + 2300 + 2300 (3CA intra-band)	*40 + 40 + 40*	*10 + 10 + 10*	*20 + 20 + 20*
2CA inter-band			
700 + 900	28 + 8	5 + 3	20 + 10
700 + 1800	28 + 3	5 + 3	20 + 20
700 + 2100	28 + 1	5 + 5	20 + 20
700 + 2300	*28 + 40*	*5 + 5*	*20 + 20*
700 + 2600	28 + 7	5 + 5	20 + 20
800 + 900	20 + 8	5 + 3	10 + 10
800 + 1800	20 + 3	5 + 5	20 + 20
800 + 2100	20 + 1	5 + 5	20 + 20
800 + 2300	*20 + 40*	*10 + 10*	*20 + 20*
800 + 2600	20 + 7	5 + 10	20 + 20
900 + 1800	8 + 3	3 + 5	10 + 20
900 + 2100	8 + 1	3 + 5	10 + 20
900 + 2300	*8 + 40*	*3 + 5*	*10 + 20*
900 + 2600	8 + 7	3 + 10 / 5 + 5	10 + 20
1800 + 2100	3 + 1	3 + 5	20 + 20
1800 + 2300	*3 + 40*	*1.4 + 5*	*20 + 20*
1800 + 2600	3 + 7	5 + 5	20 + 20
2100 + 2300	*1 + 40*	*5 + 5*	*20 + 20*
2100 + 2600	1 + 7	5 + 10	20 + 20
2300 + 2600	*40 + 7*	*5 + 5*	*20 + 20*

Spectrum	Bands	Minimum bandwidths (MHz) required per carrier	Maximum bandwidths (MHz) possible per carrier
3CA: 1 inter-band + 2 intra-band			
700 + 2300 + 2300	*28 + 40 + 40*	*5 + 10 + 10*	*20 + 20 + 20*
1800 + 2300 + 2300	*3 + 40 + 40*	*5 + 10 + 10*	*20 + 20 + 20*
2100 + 2300 + 2300	*1 + 40 + 40*	*5 + 10 + 10*	*20 + 20 + 20*
2300 + 2600 + 2600	*40 + 40 + 7*	*10 + 10 + 5*	*20 + 20 + 20*
3CA: 3 inter-band			
700 + 900 + 1800	28 + 8 + 3	5 + 3 + 5	20 + 10 + 20
700 + 900 + 2100	28 + 8 + 1	5 + 3 + 5	20 + 10 + 20
700 + 1800 + 2100	28 + 3 + 1	5 + 5 + 5	20 + 20 + 20
700 + 1800 + 2300	*28 + 3 + 40*	*5 + 5 + 5*	*20 + 20 + 20*
700 + 1800 + 2600	28 + 3 + 7	5 + 5 + 5	20 + 20 +20
700 + 2100 + 2600	28 + 1 + 7	5 + 5 + 10	20 + 20 + 20
800 + 900 + 2600	20 + 8 + 7	5 + 3 + 10	10 + 10 + 20
800 + 1800 + 2100	20 + 3 + 1	5 + 5 + 5	20 + 20 + 20
800 + 1800 + 2600	20 + 3 + 7	5 + 5 + 10	20 + 20 + 20
800 + 2100 + 2600	20 + 1 + 7	5 + 5 + 10	20 + 20 + 20
900 + 1800 + 2100	8 + 3 + 1	3 + 5 + 5	10 + 20 + 20
900 + 1800 + 2600	8 + 3 + 7	5 + 5 + 5	10 + 20 + 20
900 + 2100 + 2600	8 + 1 + 7	5 + 5 + 10	10 + 20 + 20
1800 + 2100 + 2300	*3 + 1 + 40*	*5 + 5 + 5*	*20 + 20 + 20*
1800 + 2100 + 2600	3 + 1 + 7	5 + 5 + 10	20 + 20 + 20
1800 + 2300 + 2600	*3 + 40 + 7*	*5 + 5 + 5*	*20 + 20 + 20*
2100 + 2300 + 2600	*1 + 40 +7*	*5 + 5 + 10*	*20 + 20 +20*
4CA: 1 inter-band + 3 intra-band			
700 + 2300 + 2300 + 2300	*28 + 40 + 40 + 40*	*5 + 10 + 10 + 10*	*20 + 20 + 20 + 20*
1800 + 2300 + 2300 + 2300	*3 + 40 + 40 +40*	*5 + 10 + 10 + 10*	*20 + 20 + 20 + 20*
2300 + 2300 + 2300 + 2600	*40 + 40 + 40 +7*	*10 + 10 + 10 + 5*	*20 + 20 + 20 + 20*
4CA: 2 inter-band + 2 intra-band			
700 + 1800 + 2300 + 2300	*28 + 40 + 40 + 40*	*5 + 10 + 10 + 10*	*20 + 20 + 20 + 20*
4CA: 4 inter-band			
700 + 1800 + 2100 + 2600	28 + 3 + 1 + 7	5 + 5 + 5 + 10	20 + 20 + 20 + 20
800 + 1800 + 2100 + 2600	20 + 3 + 1 + 7	5 + 5 + 5 + 10	20 + 20 + 20 + 20
900 + 1800 + 2100 + 2300	*8 + 3 + 1 + 40*	*3 + 5 + 5 + 5*	*10 + 20 + 20 + 20*
900 + 1800 + 2100 + 2600	8 + 3 + 1 + 7	5 + 5 + 5 + 10	10 + 20 + 20 + 20
1800 + 2100 + 2300 + 2600	*3 + 1 + 40 + 7*	*5 + 5 + 5 + 10*	*20 + 20 + 20 + 20*
5CA: 1 inter-band + 4 intra-band			
-	-	-	-
5CA: 2 inter-band + 3 intra-band			
700 + 1800 + 2300 + 2300 + 2300	*28 + 3 + 40 + 40 + 40*	*5 + 5 + 10 + 10 + 10*	*20 + 20 + 20 + 20 + 20*
5CA: 3 inter-band + 2 intra-band			
-	-	-	-
5CA: 5 inter-band			
-	-	-	-

2.2 Average Speed and Coverage Calculation Methodology

2.2.1 Average Speed Calculation

48. The general methodological approach for the average speed calculation for each operator is displayed in the figure below. The following paragraphs describe the steps involved in the average speed calculation, as numbered in the figure below.

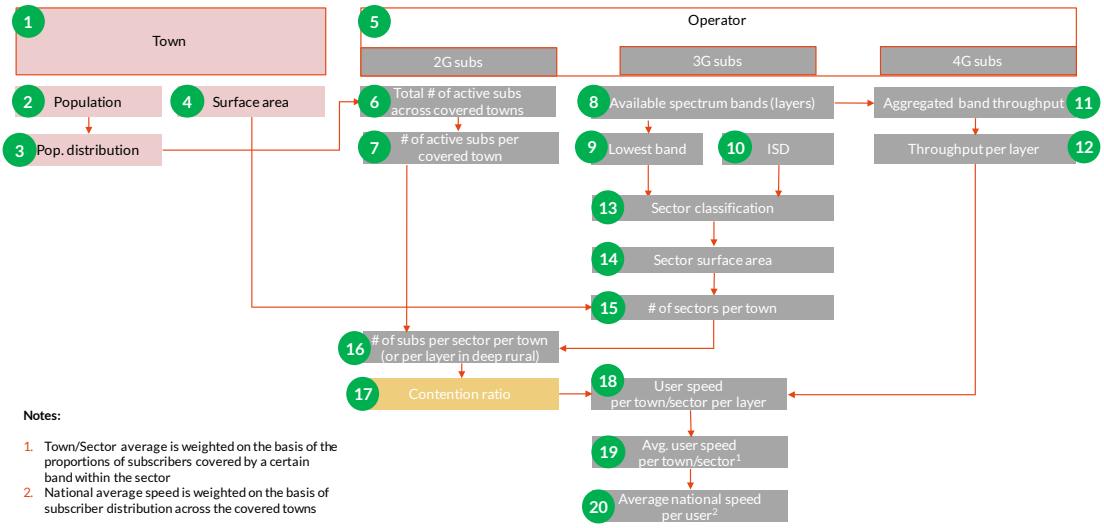

Figure 3 Overview of average national speed calculation

49. The calculations are carried out on a town-by-town basis (1). In doing so, a total of 13,331 towns are considered. Taken together, they encompass the entirety of the area and population of South Africa.

50. The total population (2) considered amounts to 51,032,770 people in accordance with the 2011 South African census.

51. The population per town (3) is obtained from the 2011 South African Census.

52. The surface area per town (4) is in accordance with the 2011 South African census.

53. The speed calculations are conducted separately for all four of the main operators in South Africa, i.e., Vodacom, MTN, Cell C and Telkom. For each operator, the speed calculations are carried out separately for each technology (i.e., 2G, 3G and 4G). Following these calculations, a within-operator average (5) is calculated across all technologies as the weighted sum of the average speeds achieved by each of the three technologies. The weights are the shares of subscribers that are on each technology during the year at hand.

54. Lastly, a cross-operator national average is calculated by weighting each operator's average speed during the year at hand with that operator's respective market share (market shares are kept constant over time).

55. The total number of data subscribers (6) for each operator are obtained by multiplying their respective market shares with the total number of data subscribers in South Africa in the particular year considered.

56. The number of data subscribers in each town for each operator (7) is obtained by proportionately distributing the total number of data subscribers according to the population distribution across the towns (based on 2011 South African Census).

57. The spectrum bands and the corresponding CA layers (i.e., 4CA, 3CA, etc.) used as starting points (8) for each operator are their spectrum holdings in the year at hand, starting with their baseline spectrum holdings in 2017, and subsequently adding newly released ITA spectrum and/or re-farmed spectrum in accordance with what has been described in section 1.3.

58. The maximum cell throughput is obtained by considering the highest achievable CA combination (11), as supported by 3GPP at the time of writing this report.

59. In cases in which a certain proportion of subscribers use some of the spectrum bands or layers (e.g., one or two bands out of four possible bands), the throughput provided by each spectrum band (12) is used to calculate the average speed experienced by these users.

60. In order to determine the average user speed per sector (18), it is firstly the number of sectors per town (15) that is calculated by dividing each town's area (4) by the corresponding sector surface area (14).

61. The sector surface area (14) originates in the classification of the towns (13) according to six types that reflect decreasing population density: Large city, Medium city, Small city, Medium town, Small town and Deep rural. These types also reflect variations in the signal propagation characteristics of the environment.

62. In the baseline year, for all types except Deep rural, the sector area (14) originates in the respective inter-site distance (ISD) applicable for the town type in question (10). For the ISDs, see table 14 in section 2.2.2.

63. For Deep rural, the sector area (14) originates in the respective lowest band (9) deployed. For the band sector areas, see table 15 in section 2.2.2, column "Rural".

64. For all years starting with 2018, the sector areas for newly rolled-out sites are based on the bands these sites are assumed to be equipped with and the town type in question. For the band sector areas, see table 15 in section 2.2.2.

65. The number of subscribers per sector per town (16) is computed by dividing the number of subscribers per town (7) by the number of sectors per town (15).

66. For each CA layer, the average user speed within any sector of the town in question (18) is subsequently calculated by dividing the throughput per CA layer (12) by the number of subscribers per sector per town (16), adjusted with a contention ratio (17). The latter reflects that only a fraction of users actually contends for data resources at any given point in time.

67. The overall average user speed per town (19) is a weighted average of the speeds attainable across the different CA layers (18).

68. In order to obtain these weights, the share of each band sector area (see table 15 in section 1.4) out of the overall sector area (as defined either by the ISD relevant for each town type or by the band on which the site has initially been deployed) is calculated. This is done for all bands involved in the respective CA combinations. For

instance, the narrowest band, 2600 MHz, only covers 43% of the sector area in a large city environment. Thus, only 43% of subscribers in large cities would benefit from the 4CA throughput. The second narrowest band, 2100 MHz, in turn, covers 65% of subscribers in the same environment. Thus, 65%-43%=22% of all subscribers in that given large city would experience a 3CA speed. The remaining users would be distributed across 2CA and 1CA throughputs using the same logic.

69. The figure below illustrates the calculation of the speeds across the CA layers (19):

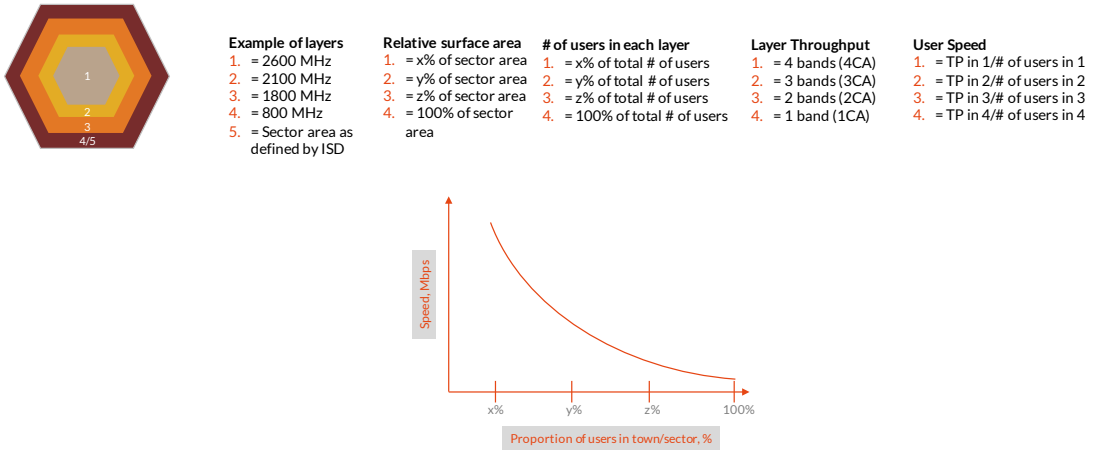

Figure 4 Calculation of the speeds in a town across the various CA layers

70. The average national user speed (20) for each technology for each operator is then calculated as the weighted average of the average speeds per town. For each technology, the weights are based on the respective subscriber share of each town.

2.2.2 Input Data

71. The following operator market shares are used throughout the entire period of 2017-2025.

Table 5 Operator market shares used throughout the model

	Vodacom	MTN	Cell C	Telkom
2017	45.4%	33.4%	16.8%	4.5%
2018 – 2025	47.5%	30.5%	16.5%	5.6%

72. The following yearly subscriber numbers are used (based on a CAGR of roughly 2.04% from the baseline number):

Table 6 Yearly total subscriber numbers in South Africa used in the model

Year	Subscribers
2017	46,088,000
2018	47,028,195
2019	47,987,570
2020	48,966,517
2021	49,965,434
2022	50,984,729
2023	52,024,817
2024	53,086,123

2025	54,169,080

73. The following subscriber technology shares are used for the "No Bill" scenario:

Table 7 Subscriber technology mix per operator for the "No Bill" scenario

2017 Baseline 2G / 3G / 4G split (Based on Vodacom input)			
Operator	2G	3G	4G
Vodacom	50,40%	36,00%	13,60%
MTN	32,40%	60,30%	7,30%
Cell C	42,70%	54,40%	2,90%
Telkom	19,30%	53,20%	27,50%

2018 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	45,59%	36,62%	17,80%
MTN	29,12%	61,33%	9,55%
Cell C	40,88%	55,33%	3,79%
Telkom	9,91%	54,11%	35,98%

2019 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	39,47%	37,24%	23,29%
MTN	25,12%	62,38%	12,50%
Cell C	38,76%	56,28%	4,97%
Telkom	0,00%	52,92%	47,08%

2020 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	35,78%	33,75%	30,47%
MTN	24,01%	59,63%	16,35%
Cell C	38,13%	55,37%	6,50%
Telkom	0,00%	38,39%	61,61%

2021 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	33,87%	31,95%	34,18%
MTN	23,44%	58,21%	18,35%
Cell C	37,81%	54,90%	7,29%
Telkom	0,00%	30,89%	69,11%

2022 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	31,72%	29,93%	38,34%
MTN	22,80%	56,62%	20,58%
Cell C	37,45%	54,38%	8,18%
Telkom	0,00%	22,47%	77,53%

2023 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	29,32%	27,66%	43,01%
MTN	22,08%	54,83%	23,09%
Cell C	37,04%	53,79%	9,17%
Telkom	0,00%	13,02%	86,98%

2024 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	26,63%	25,12%	48,25%
MTN	21,27%	52,83%	25,90%
Cell C	36,59%	53,12%	10,29%
Telkom	0,00%	2,43%	97,57%

2025 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	23,60%	22,27%	54,13%
MTN	20,37%	50,58%	29,06%
Cell C	36,08%	52,38%	11,54%
Telkom	0,00%	0,00%	100,00%

74. The following subscriber technology shares are used for the "Bill" scenario:

Table 8 Subscriber technology mix per operator for the "Bill" scenario

2017 Baseline 2G / 3G / 4G split (Based on Vodacom input)			
Operator	2G	3G	4G
Vodacom	50,40%	36,00%	13,60%
MTN	32,40%	60,30%	7,30%
Cell C	42,70%	54,40%	2,90%
Telkom	19,30%	53,20%	27,50%

2018 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	45,59%	36,62%	17,80%
MTN	29,12%	61,33%	9,55%
Cell C	40,88%	55,33%	3,79%
Telkom	9,91%	54,11%	35,98%

2019 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	39,47%	37,24%	23,29%
MTN	25,12%	62,38%	12,50%
Cell C	38,76%	56,28%	4,97%
Telkom	0,00%	52,92%	47,08%

2020 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	35,78%	33,75%	30,47%
MTN	24,01%	59,63%	16,35%
Cell C	38,13%	55,37%	6,50%
Telkom	0,00%	38,39%	61,61%

2021 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	34,70%	32,74%	32,57%
MTN	23,69%	58,83%	17,48%
Cell C	37,95%	55,10%	6,94%
Telkom	0,00%	34,15%	65,85%

2022 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	33,55%	31,65%	34,81%
MTN	23,35%	57,97%	18,68%
Cell C	37,76%	54,82%	7,42%
Telkom	0,00%	29,62%	70,38%

2023 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	32,31%	30,49%	37,20%
MTN	22,98%	57,06%	19,97%
Cell C	37,55%	54,52%	7,93%
Telkom	0,00%	24,78%	75,22%

2024 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	31,00%	29,24%	39,76%
MTN	22,58%	56,08%	21,34%
Cell C	37,33%	54,20%	8,48%
Telkom	0,00%	19,60%	80,40%

2025 2G / 3G / 4G split			
Operator	2G	3G	4G
Vodacom	29,59%	27,92%	42,50%
MTN	22,16%	55,03%	22,81%
Cell C	37,09%	53,85%	9,06%
Telkom	0,00%	14,07%	85,93%

75. The following tables illustrate the baseline spectrum holdings used for the four operators[8]:

Table 9 Current spectrum holdings of Vodacom

Vodacom	**2G**	**3G**	**4G**	**SUM**
900 MHz FDD	2 x 6 MHz	2 x 5 MHz		**2 x 11 MHz**
1800 MHz FDD	2 x 2 MHz		2 x 10 MHz	**2 x 12 MHz**
2100 MHz FDD		2 x 15 MHz		**2 x 15 MHz**
SUM	**2 x 8 MHz**	**2 x 20 MHz**	**2 x 10 MHz**	**2 x 38 MHz**

Table 10 Current spectrum holdings of MTN

MTN	**2G**	**3G**	**4G**	**SUM**
900 MHz FDD	2 x 6 MHz	2 x 5 MHz		**2 x 11 MHz**
1800 MHz FDD	2 x 2 MHz		2 x 10 MHz	**2 x 12 MHz**
2100 MHz FDD		2 x 15 MHz		**2 x 15 MHz**
SUM	**2 x 8 MHz**	**2 x 20 MHz**	**2 x 10 MHz**	**2 x 38 MHz**

[8] Sources: Vodacom; ICASA.

Table 11 Current spectrum holdings of Cell C

Cell C	2G	3G	4G	SUM
900 MHz FDD	2 x 6 MHz	2 x 5 MHz		**2 x 11 MHz**
1800 MHz FDD	2 x 12 MHz			**2 x 12 MHz**
2100 MHz FDD		2 x 5 MHz	2 x 10 MHz	**2 x 15 MHz**
SUM	**2 x 18 MHz**	**2 x 10 MHz**	**2 x 10 MHz**	**2 x 38 MHz**

Table 12 Current spectrum holdings of Telkom

Telkom	2G	3G	4G	SUM
900 MHz FDD				**0 MHz**
1800 MHz FDD	2 x 12 MHz			**2 x 12 MHz**
2100 MHz FDD		2 x 15 MHz		**2 x 15 MHz**
2300 MHz TDD			60 MHz	**60 MHz**
SUM	**2 x 12 MHz**	**2 x 15 MHz**	**60 MHz**	**2 x 27 MHz + 60 MHz**

76. For the "No Bill" scenario, the original 2017 ITA spectrum and the Lots are considered based on the following table:

Table 13 Spectrum to be awarded in the "No Bill" scenario

	700 MHz	800 MHz	2600 MHz
Lot A[9]	*2 x 15 MHz*	-	*25 MHz (TDD)*
Lot B	2 x 5 MHz	2 x 5 MHz	2 x 20 MHz
Lot C	-	2 x 10 MHz	2 x 20 MHz
Lot D	-	2 x 10 MHz	2 x 20 MHz
Lot E	2 x 10 MHz	-	2 x 10 MHz

77. For the "Bill" scenario, hypothetical Lots are created in accordance with the 2018 Draft Policy Directive. The Lots are also set up to reflect a distribution similar to that of the original ITA:

Table 14 Spectrum to be awarded in the "Bill" scenario

	700 MHz	800 MHz	2600 MHz
WOAN	-	2 x 25 MHz	2 x 20 MHz + 25 MHz (TDD)
Lot B	-	-	2 x 10 MHz
Lot C	2 x 10 MHz	-	2 x 20 MHz
Lot D	2 x 10 MHz	-	2 x 20 MHz
Lot E	2 x 10 MHz	-	-

78. The following ISD data points are used.

[9] Lot A is not subject to the ITA; it is not considered for this analysis.

Table 15 ISDs and sector areas[10].

	ISD (in km)	Sector area (in sqkm)
Large city	1.06	0.32
Medium city	1.73	0.86
Small city	2.55	1.88
Medium town	2.55	1.88
Small town	3.79	4.14

79. In the cases where the cell size is calculated based on the band deployed, the following data points are used.

Table 16 Sector areas in square km[11]

	Dense urban (used for "large city")	Urban (used for "medium city", "small city" and "medium town")	Suburban (used for "small town")	Rural (used for "deep rural")
700 MHz	0.95	2.84	22.16	140.37
800 MHz	0.78	2.33	18.06	114.22
900 MHz[12]	0.73	2.18	16.80	106.57
1800 MHz	0.27	0.80	5.42	37.71
2100 MHz	0.21	0.60	4.00	27.69
2300 MHz	0.17	0.50	3.35	23.08
2600 MHz	0.14	0.40	2.63	18.06

80. For the calculation of 2G and 3G speeds, the following spectral efficiencies are assumed for a carrier bandwidth of 5 MHz throughout the entire period of 2017-2025:

Table 17 Spectral efficiencies for 2G and 3G[13]

2G	474 kbps / 200 kHz = 11.85 Mbps / 5 MHz
3G	42 Mbps / 5 MHz

81. For the calculation of 4G LTE speeds, the following spectral efficiencies, in combination with QAM and MIMO capabilities are used:

Table 18 4G LTE speed capabilities[14]

	2017-2019	2020-2025
Max. CA	Up to 5 x 20 MHz	Up to 5 x 20 MHz
QAM applied (downlink)	64	256
MIMO applied (downlink)	2x2	4x4
Max. theoretical downlink	150	390

[10] Source: Vodacom.
[11] Source: https://www.gsma.com/spectrum/wp-content/uploads/2013/07/ZTE-LTE-APT-700MHz-Network-White-Paper-ZTE-June-2013.pdf
[12] Interpolated values.
[13] Source: EDGE, HSPA and LTE: The Mobile Broadband Advantage, Rysavy Research: https://www.slideshare.net/eanimou/edge-hspa-lte-the-mobile-broadband-advantage
[14] Based on: http://anisimoff.org/eng/lte_throughput_calculator.html and http://the8layers.com/wp-content/uploads/2016/12/4g-lte-tdd-throughput-calculator.xlsx

throughput for a 20 MHz FDD carrier (Mbps)		
Max. theoretical downlink throughput for a 20 MHz TDD[15] carrier (Mbps)	100	270

82. The following table lists the maximum aggregable 4G spectrum and the corresponding maximum theoretical throughput of each operator in the baseline year, i.e., 2017. It thus only considers spectrum currently already allocated to 4G.

Table 19 Maximum achievable 4G theoretical downlink throughputs in 2017

	Vodacom	MTN	Cell C	Telkom
Max. aggregable spectrum	10 MHz	10 MHz	10 MHz	60 MHz TDD
Enabling CA combinations	1800	1800	2100	2300 + 2300 + 2300
Corresponding max. throughput	75.0 Mbps	75.0 Mbps	75.0 Mbps	300.0 Mbps

83. The following table lists the maximum aggregable 4G spectrum and the corresponding maximum theoretical throughput of each operator by 2025 in the "No Bill" scenario, given the Lot allocations and re-farming assumed earlier.

Table 20 Maximum achievable theoretical 4G downlink throughputs per operator by 2025

	Vodacom with Lot C	MTN with Lot D	Cell C with Lot B	Telkom with Lot E
Max. aggregable spectrum	50 MHz	50 MHz	45 MHz	80 MHz (= 20 MHz FDD + 60 MHz TDD)
Enabling CA combinations	800 + 1800 + 2100 + 2600	800 + 1800 + 2100 + 2600	700 + 1800 + 2100 + 2600	700 + 1800 + 2300 + 2300 + 2300
Corresponding max. throughput (2017-2019)	375.0 Mbps	375.0 Mbps	337.5 Mbps	450.0 Mbps
Corresponding max. throughput (2020-2025)	975.0 Mbps	975.0 Mbps	877.5 Mbps	1,200.0 Mbps

84. The following table lists the maximum aggregable 4G spectrum and the corresponding maximum theoretical throughput of each operator by 2025 in the "Bill" scenario, given the Lot allocations and re-farming assumed earlier. Note the difference for Cell C between this scenario and the previous one.

Table 21 Maximum achievable theoretical 4G downlink throughputs per operator by 2025

	Vodacom with Lot C	MTN with Lot D	Cell C with Lot B	Telkom with Lot E

[15] A TDD configuration of 6 sub-frames for download, 3 sub-frames for upload and 1 special frame is assumed.

Max. aggregable spectrum	50 MHz	50 MHz	30 MHz	80 MHz (= 20 MHz FDD + 60 MHz TDD)
Enabling CA combinations	700 + 1800 + 2100 + 2600	700 + 1800 + 2100 + 2600	1800 + 2100 + 2600	700 + 1800 + 2300 + 2300 + 2300
Corresponding max. throughput (2017-2019)	375.0 Mbps	375.0 Mbps	225.0 Mbps	450.0 Mbps
Corresponding max. throughput (2020-2025)	975.0 Mbps	975.0 Mbps	585.0 Mbps	1,200.0 Mbps

85. The table below lists the number of 2G, 3G and 4G sites assumed to be currently deployed by the four operators in South Africa.

Table 22 Baseline sites by generation and operator[16]

	Vodacom	MTN	Cell C	Telkom
2G	11,589	9,580	5,060	2,891
3G	11,433	9,058	5,060	2,891
4G	7,910	5,985	2,800	1,616

86. The table below lists the number of additional 4G coverage sites assumed to be rolled out by the four operators in South Africa between 2018 and 2025, both for the "No Bill" and the "Bill" scenario (exception Cell C in the "Bill" scenario only rolls out until 2020).

Table 23 Additional 4G coverage sites rolled out per operator (2018-2025)[17]

	Vodacom	MTN	Cell C	Telkom
"No Bill"	410	691	49	755
"Bill"	205	346	25 (2018-2020)	377

2.2.3 Detailed Speed Results

Table 24 Detailed cross-operator national average speed results (in Mbps)

Cross-operator average	"No Bill" scenario	"Bill" scenario
2017	3.00	3.00
2018	3.07	3.07
2019	3.92	3.19
2020	7.57	5.69
2021	7.88	5.75
2022	10.77	8.41
2023	11.80	9.74
2024	11.71	10.74
2025	11.58	10.63

[16] Source: Vodacom
[17] Adapted from Vodacom

Table 25 Detailed national average speed results for Vodacom (in Mbps)

Vodacom	"No Bill" scenario	"Bill" scenario
2017	2.71	2.71
2018	2.59	2.59
2019	3.16	2.59
2020	5.31	3.85
2021	5.31	3.83
2022	7.57	5.87
2023	8.00	7.20
2024	7.97	7.70
2025	7.93	7.61

Table 26 Detailed national average speed results for MTN (in Mbps)

MTN	"No Bill" scenario	"Bill" scenario
2017	2.94	2.94
2018	3.25	3.25
2019	4.18	3.30
2020	7.43	5.17
2021	7.40	5.15
2022	10.29	8.07
2023	11.46	9.94
2024	11.49	11.05
2025	11.57	10.97

Table 27 Detailed national average speed results for Cell C (in Mbps)

Cell C	"No Bill" scenario	"Bill" scenario"
2017	1.74	1.74
2018	1.75	1.75
2019	2.46	1.73
2020	4.90	3.03
2021	4.84	2.97
2022	5.81	2.91
2023	8.51	3.73
2024	8.35	6.37
2025	8.20	6.25

Table 28 Detailed national average speed results for Telkom (in Mbps)

Telkom	"No Bill" scenario	"Bill" scenario
2017	10.98	10.98
2018	10.08	10.08
2019	13.37	12.00
2020	35.51	32.03
2021	41.37	33.56
2022	55.44	48.26

2023	55.71	48.05
2024	54.80	47.82
2025	52.72	47.58