

Wireless market and operator competitiveness – 2023

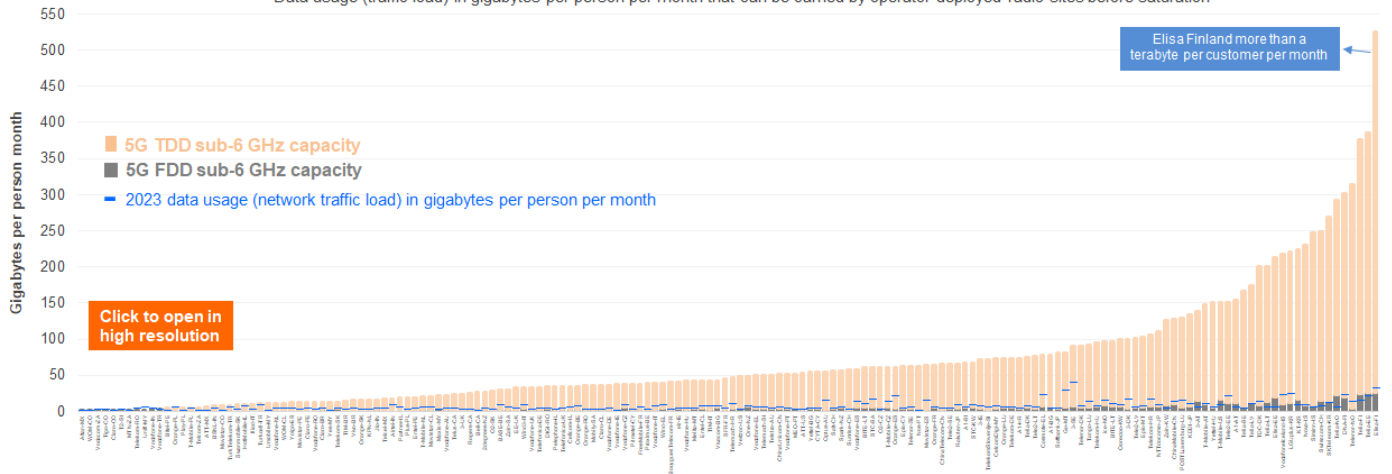
50 wireless markets and 168 mobile network operators

A comprehensive analysis and database of mobile network operator and wireless market competitiveness metrics. The database includes mobile subscribers, 5G Standalone, 5G-4G radio sites, radio site density, spectrum holdings, network data traffic load, data usage, spectrum usage, radio network capacity utilization, capacity limit, capacity potential, network performance, prices for 5G-4G voice plans, 5G voice plans, 5G fixed wireless broadband plans and many more wireless competitiveness metrics.

Rewheel research PRO study – December 2023

2030 capacity potential

Data usage (traffic load) in gigabytes per person per month that can be carried by operator deployed radio sites before saturation



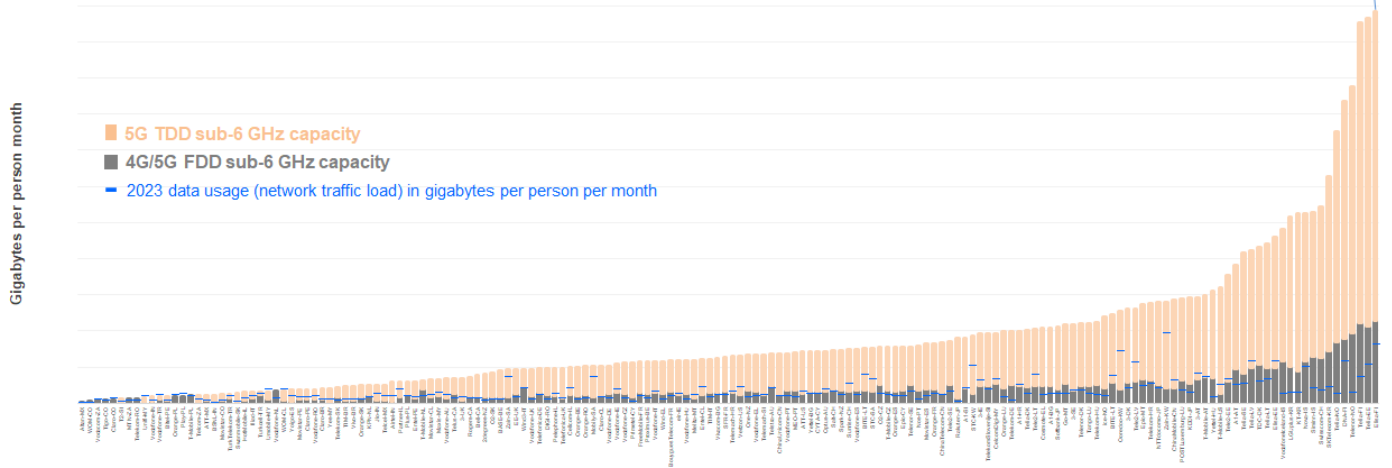
All operator 5% most loaded sectors equipped with 5G SA: up to 1 x 20 MHz 5G FDD sub-1 GHz carrier + up to 1 x 20 MHz 5G FDD sub-6 GHz carrier + up to 4 x 100 MHz 5G TDD sub-6 GHz carriers. Network traffic load of 2023 is expressed in per person (operator data volume/country population) rather than per subscriber usage to illustrate the absolute capacity potential of each operator irrespective of its subscriber base size.

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How many gigabytes per person per month were used in average over mobile networks in 2023? Have mobile networks run out of 4G capacity and how many more gigabytes per person per month can they carry with 5G? How dense are mobile networks across the 50 wireless markets and does that matter? How does radio site density and spectrum holdings effects network capacity and performance? Which operators have already deployed 5G Standalone in a substantial part of their radio network?

2023 capacity limit

Data usage (traffic load) in gigabytes per person per month that can be carried by operator 2023 deployed radio sites before saturation



T-Mobile's US 5% most loaded sectors equipped with 5G SA: 1 x 20 MHz 5G FDD 600 MHz carrier + 1 x 20 MHz 5G FDD 1900 MHz carrier + 1 x 100 MHz 5G TDD 2600 MHz carrier + 1 x 81 MHz 5G TDD 2600 MHz carrier. All other operator 5% most loaded sectors equipped with 5G NSA with 4G-5GDC: up to 3 x 20 MHz 4G FDD sub-6 GHz carriers + up to 1 x 20 MHz 5G FDD sub-6 GHz carrier + up to 1 x 100 MHz 5G TDD sub-6 GHz carrier. Network traffic load of 2023 is expressed in per person (operator data volume/country population) rather than per subscriber usage to illustrate the absolute capacity potential of each operator irrespective of its subscriber base size.

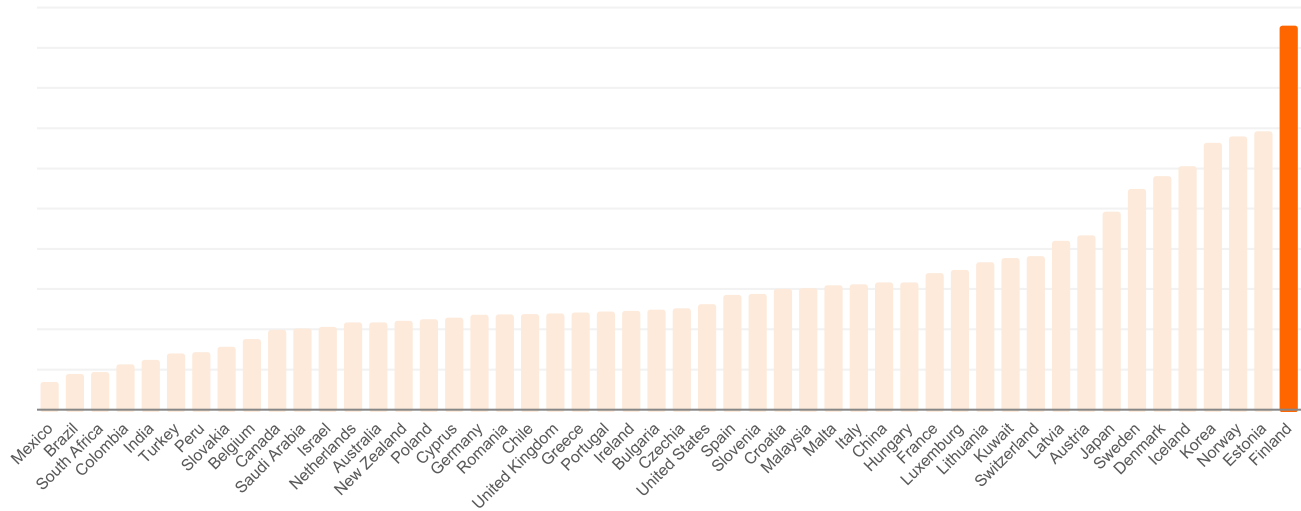
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- Elisa Finland was the operator that had the highest capacity limit in 2023 and the highest projected capacity potential in 2030.
- Many mobile network operators have already run out of 4G capacity.
- In Poland, where the 3.5 GHz band was still not in use in 2023, capacity was scarce and performance was subpar.
- In Finland, where networks are very dense a fraction of the total available capacity was used in 2023 – despite average data usage approaching 100 gigabytes per person per month.
- In 2030 operators with dense radio networks will have enough capacity to accommodate a terabyte per customer per month.

Radio site density – Operator deployed radio sites per 1 million population

- How dense are mobile networks across the 50 wireless markets and does that matter? Mobile networks are densest in Finland and other Nordic countries such as Estonia and Norway.

Radio site density - 2023
Deployed radio sites per 1 million population

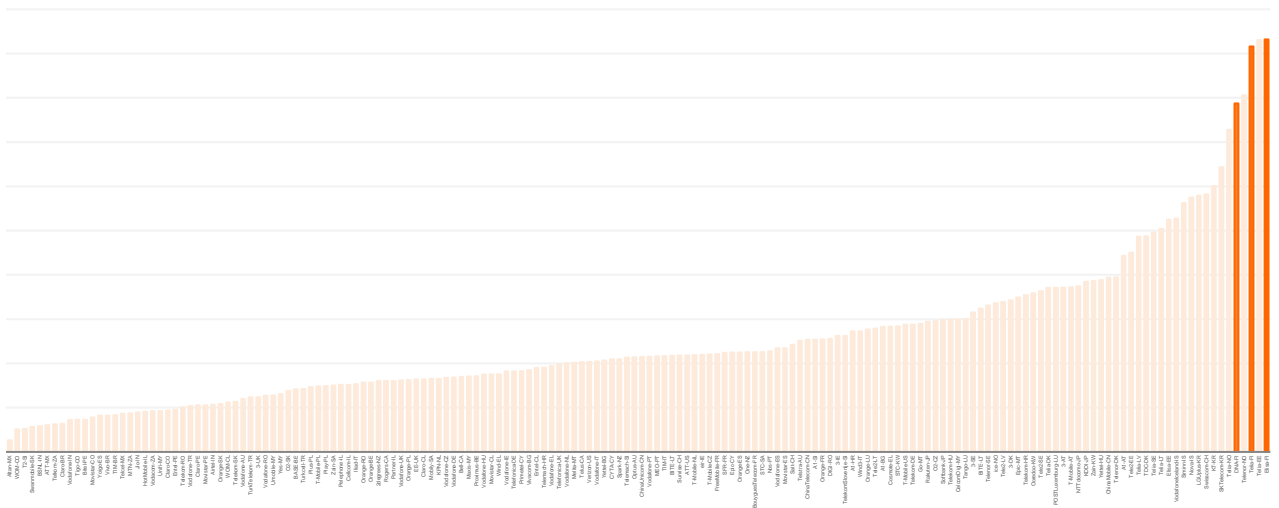


Country deployed sites is the sum of country's mobile network operators deployed sites. In some countries (e.g., US) the site count includes substantial amount of small cells.

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- Elisa Finland had the densest mobile network in the world (i.e., among the 168 operators included in the study). Telia Finland was ranked third in radio site density behind Telia Estonia while DNA Finland was ranked fifth behind Telenor Norway.

Radio site density - 2023
Deployed radio sites per 1 million population



Mobile network operator deployed radio sites. For some operators (e.g., US operators) the site count includes substantial amount of small cells.

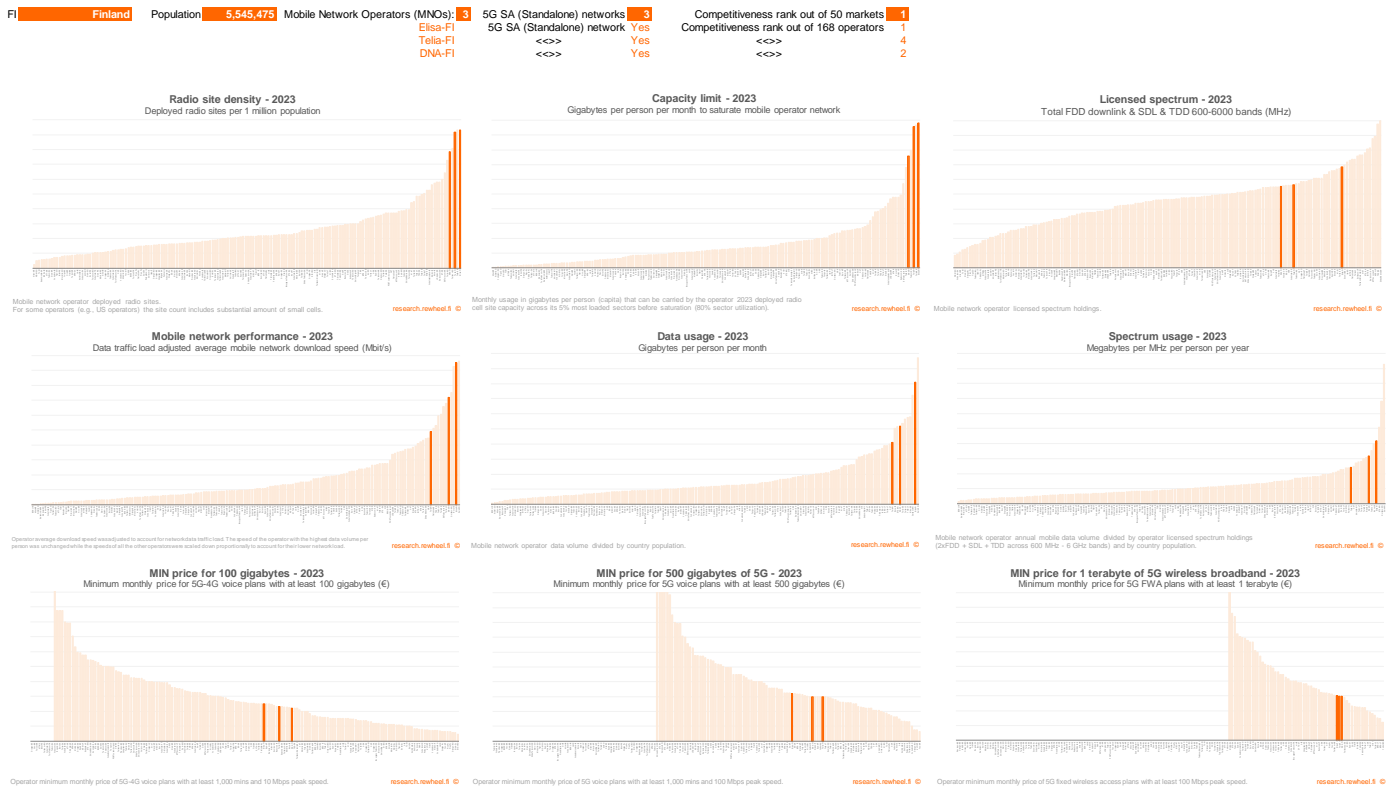
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Wireless market and mobile network operator competitiveness dashboards – 50 countries 168 operators

- Competitiveness dashboards included for each of the 50 wireless markets with both country and operator rankings across nine competitiveness metrics.



High resolution dashboard charts are included in the Annex of the PRO full version of the study.



Wireless market overall competitiveness rankings and rankings across nine competitiveness metrics

- The wireless market with the highest rankings across the 9 competitiveness metrics – lowest sum of ranking scores across the 9 metrics – was ranked as the overall most competitive market.
- In 2023 Finland was ranked as the most competitive wireless market and South Africa as the least competitive.

Overall competitiveness rank	Country name	Country rankings for each of the nine competitiveness metrics: 1 highest rank...50 lowest rank									Ranking positions sum
		Radio site density	Spectrum holdings	Capacity limit	Data usage	Spectrum usage	Network performance	Price 100 GB 5G-4G	Price 500 GB 5G	Price 1 TB 5G FWA	
1	Finland	1	7	1	2	2	1	22	19	13	68
2	Estonia	2	6	2	4	4	7	18	24	8	75
3	Denmark	6	2	6	10	19	5	16	9	18	91
4	Latvia	10	20	10	3	3	3	33	17	2	101
5	Austria	9	22	7	7	9	9	21	10	17	111
6	Lithuania	13	36	12	5	5	8	17	16	3	115
7	Malaysia	20	10	35	9	8	19	4	1	15	121
8	Sweden	7	13	9	11	10	10	31	25	24	140
9	Croatia	21	17	17	12	14	11	24	12	14	142
10	Bulgaria	26	4	23	27	25	17	13	6	1	142
11	Slovenia	22	16	21	19	27	22	9	3	4	143
12	Iceland	5	34	5	8	6	4	23	35	27	147
13	Switzerland	11	25	11	17	21	14	8	18	30	155
14	Korea	4	8	4	21	17	6	36	30	33	159
15	Kuwait	12	35	13	1	1	2	40	32	28	164
16	Japan	8	9	8	23	34	24	26	13	19	164
17	Italy	18	18	31	18	15	27	6	22	9	164
18	Ireland	27	32	27	14	16	23	10	5	21	175
19	Chile	31	15	36	15	11	31	2	11	33	185
20	United States	24	1	18	13	18	15	44	36	25	194
21	Norway	3	21	3	30	33	13	35	39	29	206
22	Israel	39	33	38	16	12	26	7	4	33	208
23	Spain	23	12	22	28	29	32	15	14	33	208
24	France	15	31	20	25	26	21	12	39	22	211
25	Australia	37	5	34	22	22	16	32	27	23	218
26	Poland	35	43	46	26	13	30	3	8	16	220
27	Malta	19	38	16	24	23	28	28	21	33	230
28	Hungary	16	19	15	35	43	39	37	20	7	231
29	China	17	26	19	20	24	20	45	38	33	242
30	Luxemburg	14	37	14	29	28	18	42	29	33	244
31	United Kingdom	30	49	32	34	44	41	14	7	5	256
32	Cyprus	34	28	28	40	39	33	19	26	11	258
33	Saudi Arabia	40	46	33	6	7	12	48	37	31	260
34	Czechia	25	29	26	32	38	35	39	31	10	265
35	Romania	32	45	39	39	40	44	1	2	33	275
36	India	46	3	43	36	30	42	5	39	33	277
37	Greece	29	11	24	37	45	37	38	23	33	277
38	Netherlands	38	40	44	38	31	25	29	15	33	293
39	Germany	33	30	29	43	46	36	43	34	12	306
40	Portugal	28	44	25	41	42	34	41	28	33	316
41	New Zealand	36	41	30	42	41	38	46	39	20	333
42	Peru	44	42	42	33	36	46	20	39	33	335
43	Canada	41	24	40	44	37	29	50	39	32	336
44	Slovakia	43	47	41	47	50	45	25	33	6	337
45	Colombia	47	27	49	46	35	50	11	39	33	337
46	Turkey	45	48	48	31	20	40	34	39	33	338
47	Brazil	49	14	45	48	48	49	30	39	33	355
48	Belgium	42	23	37	45	49	43	47	39	33	358
49	Mexico	50	39	47	49	47	48	27	39	33	379
50	South Africa	48	50	50	50	32	47	49	39	26	391

Mobile network operator overall competitiveness rankings and rankings across nine competitiveness metrics

- The mobile network operator with the highest rankings across the 9 competitiveness metrics – lowest sum of ranking scores across the 9 metrics – was ranked as the overall most competitive mobile network operator.
- In 2023 Elisa Finland was ranked as the most competitive mobile network operator and ATT Mexico as the least competitive.

Overall competitiveness rank	Mobile network operator name	Operator rankings for each of the nine competitiveness metrics: 1 highest rank...168 lowest rank									Ranking positions sum
		Radio site density	Spectrum holdings	Capacity limit	Data usage	Spectrum usage	Network performance	Price 100 GB 5G-4G	Price 500 GB 5G	Price 1 TB 5G FWA	
1	Elisa-FI	1	15	1	2	4	2	77	51	19	172
2	DNA-FI	5	17	5	8	7	5	66	43	17	173
3	Telia-FI	3	16	3	11	14	12	71	39	18	187
4	Telia-EE	2	12	2	7	9	8	48	55	62	205
5	Telia-LV	18	60	17	5	10	6	92	36	6	250
6	TDC-DK	17	2	16	25	64	10	65	20	39	258
7	3-DK	35	6	33	37	54	13	38	18	25	259
8	3-AT	28	69	24	12	13	20	63	19	23	271
9	Elisa-EE	14	13	14	4	8	19	124	67	11	274
10	Telenor-DK	21	43	39	51	37	37	42	29	24	323
11	Tele2-LV	36	120	32	6	6	9	90	33	4	336
12	Tele2-LT	53	114	45	13	11	25	45	30	8	344
13	Telekom-HR	33	34	30	27	38	22	99	46	20	349
14	Telia-LT	15	115	15	21	17	15	53	38	62	351
15	3-IE	58	102	52	23	29	30	22	9	33	358
16	A1-BG	52	9	43	71	82	53	30	15	15	370
17	Nova-IS	11	110	10	10	5	3	67	105	50	371
18	T-Mobile-AT	27	68	23	16	20	23	110	56	29	372
19	SKTelecom-KR	7	19	7	35	44	7	100	92	62	373
20	A1-SI	61	41	54	41	76	39	44	22	5	383
21	Tele2-EE	19	14	20	19	27	40	79	105	62	385
22	Telia-SE	16	23	18	26	36	26	106	80	62	393
23	Zain-KW	24	111	28	1	1	1	109	79	53	407
24	CelcomDigi-MY	42	28	50	22	25	45	31	105	62	410
25	KT-KR	8	20	11	59	65	16	93	76	62	410
26	Telia-DK	30	44	46	69	63	47	39	23	62	423
27	LGUplus-KR	10	21	12	62	55	27	94	90	62	433
28	A1-AT	20	67	19	31	68	33	121	63	27	449
29	3-SE	40	50	40	50	46	46	82	57	40	451
30	T-Mobile-US	49	3	21	29	52	11	153	95	42	455
31	A1-HR	56	54	47	30	34	35	85	60	62	463
32	Yettel-BG	89	10	74	79	86	58	56	11	1	464
33	Ooredoo-KW	32	112	34	3	2	4	128	102	51	468
34	Wind3-IT	55	58	111	36	24	73	10	42	62	471
35	Epic-MT	34	122	31	32	45	43	76	41	62	486
36	Telenor-SE	38	49	61	58	39	51	86	64	41	487
37	Sunrise-CH	79	77	69	28	33	38	73	37	55	489
38	Salt-CH	64	78	71	54	60	49	20	34	62	492
39	BITE-LT	80	121	67	15	30	41	88	49	3	494
40	BITE-LT	80	121	67	15	30	41	88	49	3	494
41	Tele2-SE	31	48	56	53	32	50	107	58	62	497
42	NTTdocomo-JP	26	35	29	42	87	54	111	87	28	499
43	Swisscom-CH	9	76	8	49	102	34	75	86	62	501
44	TelekomSlovenije-SI	57	40	51	48	94	62	64	31	62	509
45	Optus-AU	85	11	72	46	62	42	83	71	47	519
46	Siminn-IS	12	108	9	38	50	21	130	91	62	521
47	ChinaMobile-CN	22	80	27	24	48	14	145	105	62	527
48	Telia-NO	6	66	6	64	97	32	102	105	54	532
49	STC-KW	50	113	53	9	3	18	146	101	52	545
50	Entel-CL	98	31	88	33	28	78	23	105	62	546
51	Telstra-AU	63	5	79	40	51	36	131	105	46	556
52	Vodafone-IT	90	57	94	55	57	71	11	65	62	562
53	Umobile-MY	133	45	144	47	12	63	41	17	62	564
54	Partner-IL	117	105	127	43	15	69	17	10	62	565
55	Telemach-HR	97	55	84	57	69	48	69	24	62	565
56	Cellcom-IL	123	104	105	39	41	68	18	7	62	567
57	WOM-CL	139	33	142	44	16	84	26	21	62	567
58	Verizon-US	91	1	83	34	43	59	125	94	43	573
59	Movistar-ES	65	7	59	96	109	100	62	26	62	586
60	Vivacom-BG	99	26	86	89	95	61	52	16	62	586
61	POSTLuxemburg-LU	29	117	26	52	66	28	136	75	62	591
62	KDDI-JP	25	36	25	60	116	67	148	89	30	596
63	Yettel-HU	23	65	22	118	134	109	96	40	10	617
64	Telemach-SI	86	61	80	85	108	96	36	5	62	619
65	Telenor-NO	4	131	4	61	105	24	134	105	56	624
66	Orange-FR	60	97	58	73	80	57	34	105	62	626
67	VodafoneIceland-IS	13	109	13	70	88	44	138	105	57	637
68	Pelephone-IL	124	106	107	65	72	83	14	6	62	639
69	O2-CZ	45	91	65	67	85	90	114	83	13	653
70	Jio-IN	151	8	130	68	61	65	8	105	62	658
71	TIM-IT	81	56	87	115	115	118	12	66	12	662
72	ATT-US	78	4	75	56	71	70	154	96	62	666
73	CYTA-CY	88	87	73	74	96	66	80	68	34	666
74	Go-MT	47	123	41	77	101	64	103	52	62	670
75	Softbank-JP	44	37	42	78	122	81	147	88	31	670
76	Unifi-MY	148	63	160	98	22	104	13	2	62	672
77	Vodafone-IE	102	101	99	45	67	82	97	44	37	674
78	Tango-LU	41	118	38	66	84	52	137	77	62	675
79	SFR-FR	73	98	85	82	75	72	29	105	62	681
80	Orange-ES	71	53	63	107	120	108	37	61	62	682
81	STC-SA	68	151	66	20	42	31	143	103	60	684
82	Vodafone-ES	66	52	68	93	107	123	60	59	62	690
83	Cosmote-EL	51	24	44	86	132	74	144	82	62	699
84	Epic-CY	72	88	62	106	126	79	50	105	14	702

Overall competitiveness rank	Mobile network operator name	Operator rankings for each of the nine competitiveness metrics: 1 highest rank...168 lowest rank										Ranking positions sum
		Radio site density	Spectrum holdings	Capacity limit	Data usage	Spectrum usage	Network performance	Price 100 GB 5G-4G	Price 500 GB 5G	Price 1 TB 5G FWA		
85	Telekom-HU	43	64	37	87	118	97	129	69	62	706	
86	eir-IE	76	103	91	72	83	101	46	105	35	712	
87	Yes-MY	132	62	136	139	77	146	6	1	21	720	
88	BouyguesTelecom-FR	69	99	92	108	98	87	33	105	36	727	
89	Mobily-SA	112	152	102	18	19	29	151	99	61	743	
90	Rakuten-JP	46	38	55	164	162	156	72	25	26	744	
91	ChinaTelecom-CN	62	81	57	91	91	75	127	105	62	751	
92	Play-PL	126	143	155	75	21	103	4	105	22	754	
93	Maxis-MY	107	39	122	63	40	99	120	105	62	757	
94	Movistar-CL	104	79	123	84	47	128	27	105	62	759	
95	T-Mobile-NL	77	130	124	100	106	56	78	27	62	760	
96	FreeMobile-FR	74	100	96	97	81	98	47	105	62	760	
97	Iliad-IT	122	59	146	102	31	122	16	105	62	765	
98	Zain-SA	125	153	113	17	18	55	141	100	58	780	
99	Claro-CL	113	32	101	116	111	141	2	105	62	783	
100	Vodafone-AU	137	25	121	90	93	76	112	105	38	797	
101	ice-NO	37	132	36	112	138	86	91	105	62	799	
102	Melita-MT	93	124	89	94	58	147	84	48	62	799	
103	Vodafone-RO	134	148	138	110	78	117	9	4	62	800	
104	Telefonica-DE	101	95	109	80	100	92	123	84	16	800	
105	T-Mobile-CZ	75	90	64	92	129	88	116	85	62	801	
106	Orange-PL	115	140	156	88	23	107	7	105	62	803	
107	Airtel-IN	141	18	128	113	89	127	28	105	62	811	
108	Vodafone-EL	96	29	81	109	137	120	115	62	62	811	
109	T-Mobile-PL	127	141	154	111	53	113	40	13	62	814	
110	HotMobile-IL	150	107	147	127	70	130	19	8	62	820	
111	3-UK	135	165	119	123	112	119	35	12	7	827	
112	ChinaUnicom-CN	84	82	78	101	110	80	126	104	62	827	
113	Yoigo-ES	156	96	141	103	49	116	61	47	62	831	
114	Orange-RO	121	147	103	129	145	124	3	3	62	837	
115	Plus-PL	128	142	126	95	79	115	5	105	62	857	
116	Orange-LU	54	119	49	125	136	85	122	105	62	857	
117	KPN-NL	111	128	131	119	99	60	105	54	62	869	
118	Vodafone-PT	83	145	77	99	114	106	117	72	62	875	
119	Spark-NZ	87	134	70	83	117	77	149	105	62	884	
120	DIGI-RO	59	150	108	138	127	137	1	105	62	887	
121	Wind-EL	103	42	93	145	155	144	98	45	62	887	
122	MEO-PT	82	144	76	121	124	102	119	74	62	904	
123	Vodafone-HU	105	47	90	140	157	149	95	70	62	915	
124	Telefonica-UK	95	163	106	130	135	143	58	35	62	927	
125	Vodafone-NL	94	129	143	132	123	89	104	53	62	929	
126	Telekom-DE	48	93	48	152	163	125	140	98	62	929	
127	Vodafone-UK	116	164	110	141	146	139	43	28	44	931	
128	Turkcell-TR	129	159	145	76	74	94	89	105	62	933	
129	Nos-PT	67	146	60	142	151	114	118	73	62	933	
130	Telus-CA	92	75	120	136	104	95	156	105	59	942	
131	One-NZ	70	133	82	120	128	112	135	105	62	947	
132	EE-UK	114	162	112	122	143	110	87	50	49	949	
133	Proximus-BE	106	70	95	128	148	105	133	105	62	952	
134	Claro-CO	147	83	164	131	56	155	51	105	62	954	
135	Vodafone-CZ	110	92	98	135	149	136	108	78	62	968	
136	Bell-CA	108	74	117	134	121	91	157	105	62	969	
137	Rogers-CA	118	73	118	126	130	93	158	105	62	983	
138	Primetel-CY	100	89	97	163	166	153	49	105	62	984	
139	T2-SI	166	154	163	162	90	157	21	14	62	989	
140	Claro-PE	143	137	139	117	103	135	59	105	62	1000	
141	Vodafone-IN	160	46	159	160	133	162	15	105	62	1002	
142	Entel-PE	146	138	125	114	131	138	55	105	62	1014	
143	Vodafone-DE	109	94	100	133	153	111	155	97	62	1014	
144	Movistar-PE	142	136	140	124	92	152	68	105	62	1021	
145	Vodafone-TR	144	160	158	81	35	133	160	105	62	1038	
146	TIM-BR	154	51	134	151	147	154	81	105	62	1039	
147	Tigo-CO	159	85	165	154	125	161	24	105	62	1040	
148	Orange-BE	120	71	104	137	150	134	160	105	62	1043	
149	BASE-BE	130	72	114	144	152	132	142	105	62	1053	
150	Movistar-CO	157	84	150	159	142	164	32	105	62	1055	
151	Claro-BR	161	30	137	147	158	151	113	105	62	1064	
152	BSNL-IN	164	22	151	168	168	168	57	105	62	1065	
153	Vivo-BR	155	27	133	143	139	150	160	105	62	1074	
154	TurkTelekom-TR	136	161	149	105	73	126	160	105	62	1077	
155	Telcel-MX	153	125	129	104	119	121	160	105	62	1078	
156	2degrees-NZ	119	135	116	157	154	145	132	105	32	1095	
157	O2-SK	131	157	115	149	160	142	101	81	62	1098	
158	WOM-CO	167	86	167	167	159	166	25	105	62	1104	
159	Vodacom-ZA	149	166	166	148	59	140	159	105	45	1137	
160	Swanmobile-SK	165	158	148	165	167	165	70	105	9	1152	
161	Telekom-SK	138	156	135	153	161	131	139	93	62	1168	
162	Orange-SK	140	155	132	150	156	129	150	105	62	1179	
163	Altan-MX	168	127	168	166	164	167	74	105	62	1201	
164	Telkom-ZA	162	168	153	146	113	160	160	105	62	1229	
165	MTN-ZA	152	167	162	156	141	148	152	105	48	1231	
166	Bitel-PE	158	139	157	158	140	163	160	105	62	1242	
167	Telekom-RO	145	149	161	161	144	159	160	105	62	1246	
168	ATT-MX	163	126	152	155	165	158	160	105	62	1246	

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1 Study context and methodology

How many gigabytes per person per month were used in average over mobile networks in 2023? Have mobile networks run out of 4G capacity and how many more gigabytes per person per month can they carry with 5G?

How dense are mobile networks across 50 wireless markets and does that matter? How does radio site density and spectrum holdings effects network capacity and performance? Which operators have already deployed 5G Standalone in a substantial part of their radio network?

Are there significant differences in mobile data and spectrum usage across the 50 countries? Is spectrum put into efficient use?

This is Rewheel's sixth annual study of mobile data usage, spectrum usage, radio network capacity utilization, capacity limit and untapped capacity potential.

This sixth study includes key mobile network metrics such as radio site density, spectrum holdings, network performance, data usage, spectrum usage, radio network capacity utilization, capacity limit, capacity potential and as well three key price metrics for 168 mobile network operators that were present during 2023 in 50 European, American, Asian Pacific, Middle East and African countries.

Moreover, this study for the first time includes competitiveness dashboards for each of the 50 wireless markets with both country and operator rankings across 9 competitiveness metrics. The nine metrics used to rank the 50 wireless markets and the 168 mobile network operators were:

- a. radio site density
- b. downlink spectrum holdings
- c. capacity limit
- d. average data usage
- e. average spectrum usage
- f. network performance
- g. minimum price for 5G-4G voice plans with 100 GB
- h. minimum price for 5G voice plans with 500 GB
- i. minimum price for 5G fixed wireless broadband plans (FWA) with 1 terabyte

In the unlimited wireless broadband era where average mobile data usage is measured in hundreds of gigabytes rather than in few gigabytes per month the capacity limit and capacity potential of mobile network operators will undoubtedly dictate

their mobile data pricing power and their mobile network performance.

As with our fifth study¹ that was released in March 2022 the key objective of this sixth release is to estimate how heavily were mobile networks utilized in 2023 and when – at what usage level – will operators run out of 4G (some of them have already run out) and 5G capacity. The last few years operators in most of the 50 countries acquired 5G spectrum holdings in the sub-6 GHz bands and as a result greatly enhanced their 5G capacity potential.

In the fifth release, we estimated the 2021 radio network capacity utilization of mobile operators in the 5% of their most loaded sectors (i.e., cells) and their capacity potential by taking into account all of their existing FDD, SDL and TDD sub-6 GHz licensed spectrum holdings, their reported or estimated number of radio sites including small cells, their reported or estimated 2021 mobile data traffic volume and by applying typical data traffic geo-distribution, BusyHour, spectral efficiency, carrier modulation, antenna configurations, etc.

In this sixth release, we present the 2023 radio network capacity utilization, capacity limit and capacity potential of mobile operators in the 5% of their most loaded sectors by taking into account their existing FDD, SDL and TDD sub-6 GHz licensed spectrum holdings, their 2023 year-end deployed number of radio sites including small cells, their reported or estimated 2023 mobile data traffic volume and by applying typical data traffic geo-distribution, BusyHour, spectral efficiency, carrier configurations, modulation, antenna configurations, etc.

Detail sector bandwidth limits, carrier configurations, spectral efficiencies, average number of sectors per site, traffic geo-distribution, BusyHour traffic share and other 4G, 5G NSA and 5G SA capacity dimensioning parameters can be found in Section 3 of the full version of the report.

Please note that the 2023 radio network capacity utilization and 2023 capacity limit figures presented herein are the utilization and capacity limit of the 2023 operator deployed site grid. The actual radio network capacity utilization of 2023 may be substantially higher – and capacity limit may be substantially lower – for operators which have not upgraded their most loaded sectors with 5G, with their readily available

¹https://research.rewheel.fi/downloads/Mobile_data_usage_2021_capacity_potential_170_operators_50_countries_PUBLIC_VERSION.pdf

spectrum and/or with advanced base station and antenna technology configurations.

mmWave spectrum has not been included in the capacity calculations presented herein. According to our understanding, by end of 2023, only a hand full of operators (e.g., Verizon US) had deploy mmWave spectrum in substantial parts of their networks. As of December 2023, 66 out of the 168 mobile network operators held mmWave spectrum in the 24-39 GHz bands.

As of December 2023, 18 out of the 168 operators had commercially deploy 5G SA in substantial parts of their network.

The Finnish wireless market ranked as the overall most competitive wireless market in 2023. Finland topped the rankings in 3 out of 9 competitiveness metrics. Finland mobile networks had the highest radio site density, network performance and capacity limit. Furthermore, Finland had the second highest mobile data and spectrum usage among the 50 countries, behind Kuwait.

Elisa Finland, ranked as the overall most competitive mobile network operator in 2023. Elisa topped the rankings in radio site density and capacity limit. Elisa had the second highest mobile data usage, the second highest network performance and the fourth highest spectrum usage among the 168 mobile network operators. The 2030 capacity potential of Elisa's mobile network in Finland well exceeds a terabyte per customer per month.

We use the terms '*mobile*' and '*wireless*' in interchangeable manner in this report but essentially both terms which are typically used in Europe and North America respectively refer to 5G, 4G LTE and where still available 3G HSPA technologies, subscribers, etc. Similarly, we use the terms 'sector' and 'cell' in interchangeable manner in this report.

About Rewheel

Mobile data and broadband pricing, mobile operator competitiveness rankings, market modelling & analysis, competition analysis (consolidation, 4 to 3 mobile mergers, effective remedies, new market entries), MNO near-zero marginal data cost, MVNO economics, mobile capacity-only play, mobile centric convergence (MCC) pro-competitive strategies and 4th MNO business case.

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.

Rewheel has delivered management consultancy work for clients in the United Kingdom, United States, Germany, Ireland, Switzerland, Finland, Sweden, Belgium, Greece, Poland, Slovenia, Hungary, Russia, Romania.

The following authorities have acquired access to Rewheel's independent pricing, mobile market competitiveness, 4 to 3 merger analysis and remedy assessment research: The European Commission Directorate for Competition, the United States Department of Justice, the New York, California and many other US State Attorney General Offices, the national competition authorities of Canada, Australia, the Netherlands and Greece, the Ministry of Economic Affairs of the Netherlands, the Ministry of Industry and Trade of Czechia, the Korean Electronics and Telecommunication Research Institute, the sector regulators of the United Kingdom, Germany, France, the Netherlands, Ireland, Finland, Portugal, etc.

Rewheel's mobile data pricing, strategy, competition analysis, merger assessment, network economics, spectrum, profitability and competitiveness focused reports have been cited by OECD Economic Surveys, The Economist, The Financial Times, The New York Times, Reuters, Bloomberg, WSJ and publicly referenced by the UK telecoms regulator Ofcom, BIPT, Vodafone, Telefonica, Tele2, Elisa, DNA, GSMA, VPs of the EU Commission responsible for Competition, MEPs, IEEE, ITU.

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