SHARING

SELF-ORGANIZED HETEROGENEOUS ADVANCED RADIO NETWORKS GENERATION

Deliverable D2.4

Market analysis and performance targets

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Abstract:

This deliverable presents market forecasts which include an evaluation of the small cells & Wi-Fi markets (2014-2019) for the worldwide and European markets. An evaluation of off-loading strategies and a presentation of current and expected Wi-Fi deployments and their impact on the mobile market is also included. In its next version, this deliverable will also give the performance targets linked with the above mentioned market analysis in terms of KPIs defined in D2.2.
The potential for Sharing scenarios will be detailed in the 2015 version of this market forecast

Keywords:

Small cells, offloading, WiFi, carrier WiFi

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EXECUTIVE SUMMARY

This deliverable presents market forecasts of the small cells & Wi-Fi markets (2014-2019) for the worldwide and European markets. An evaluation of off-loading strategies and a presentation of current and expected Wi-Fi deployments and their impact on the mobile market is also included.

The exploding data consumption is putting a heavy strain on mobile networks. Densifying the network in selected areas will enable carriers to cope with the increasing demand for throughputs. Small cells are part of the answer but this approach will have to be completed with other approaches aimed at increasing spectral efficiencies (e.g higher order MIMO, higher modulation scheme …).

Mobile traffic offloading is one of the answers to this mobile traffic evolution and this solution is progressing rapidly. Our assumptions for mobile traffic offloading range from 40% in the rest of the world in 2013 to 80% in 2017 in Europe and the Americas.

The small cells market
In this report, the term 'small cells' embraces the three distinct units of femtocells, picocells and metrocells. Initially, femtocells were used as extensions to provide additional coverage in homes or business locations. Now they are used to provide capacity and are a full part of the mobile network.

The heterogeneous network (HetNet) will be the mainstream feature of mobile access infrastructure, especially for LTE deployment. This involves a network composed of macrocells plus a range of small-cell solutions such as picocells, microcells, femtocells and WiFi hotspots. The key benefit here is to boost network density by expanding capacity and lightening the traffic load away from the congested macrocell, at a lower cost.

According to our median scenario, we forecast that in 2019, the small cells *installed base*[1] will reach 12,816,000 units wordwide.

The WiFi market
Although small cells enable operators to bring more capacity and coverage in densely populated areas, WiFi may complement this solution by intelligently off-loading traffic. WiFi has been available for a long time, even for mobile operators, but up to now, people had to go through a whole registering process that did not make the service seamless. Users surely have an interest to connect to WiFi whenever possible in order to avoid using their mobile data allowance but as long as the process of using WiFi is not seamless, no massively adopted behaviour is possible.

With the development of Hotspot 2.0 and the use of EAP-SIM and EAP-TTLS, things are about to change with the possibility for seamless registration of users either based on SIM credential (EAP-SIM) either based on login and password (EAP-TTLS) to support non-SIM based devices such as tablets. With the further capabilities of carriers to support handover between WiFi and cellular network (Dual Stack Mobile IP) or even the possibility to maintain both cellular and WiFi connectivity for specific services, carrier WiFi is set to become, together with small cell deployment a cornerstone of operators' strategies in two to three years from now.

According to our median scenario, we forecast that in 2019, the total number of WiFi access points installed base will reach 51,551,000 units wordwide.

In its next version, this deliverable will also give the performance targets linked with the above mentioned market analysis in terms of KPIs defined in D2.2[i].
The potential for Sharing scenarios will be detailed in the 2015 version of this market forecast

[1]: the installed base is the number of installed small cells

1 THE MOBILE MARKET – TRENDS AND DATA

1.1 Subscribers by RAT

The percentage of users on different radio access technologies highlights the level of market advancement in the deployment of mobile technologies and is of particular importance for an operator willing to develop its network toward more capacity and throughputs. The number of 2G users will indeed indicate to the operator how far it can refarm its spectrum with 3G or 4G and in which way it should focus its investments. The penetration of LTE for instance could be of particular importance when deciding to deploy Voice Over LTE (VoLTE) solutions on the network.

Table 1: Mobile subscribers by RAT technologies in selected countries

	2012	2013	2014	2015	2016	2017	2018
USA	326 475	333 210	340 993	348 236	354 919	361 350	367 186
2G	38%	17%	7%	4%	3%	2%	1%
3G	51%	56%	51%	42%	27%	17%	11%
4G	11%	27%	42%	55%	71%	81%	87%
Europe	683 496	691 528	701 469	711 698	721 305	729 219	735 613
Of which France	73 123	77 108	79 786	81 805	83 489	84 833	85 833
2G	55%	50%	43%	34%	23%	13%	8%
3G	45%	48%	50%	51%	51%	47%	41%
4G	0%	1%	6%	14%	25%	39%	50%
Of which Germany	113 158	114 317	115 724	116 734	117 351	117 809	118 092
2G	70%	64%	52%	40%	27%	13%	4%
3G	29%	34%	39%	43%	45%	44%	41%
4G	1%	2%	9%	17%	28%	43%	55%
Of which Italy	97 559	98 710	99 953	101 350	102 716	103 926	104 979
2G	57%	54%	47%	35%	19%	9%	3%
3G	43%	45%	48%	52%	57%	52%	46%
4G	0%	1%	5%	13%	24%	39%	51%
Of which Spain	53 207	51 825	51 750	52 673	53 859	55 031	56 190
2G	31%	21%	10%	5%	3%	2%	2%
3G	70%	78%	83%	81%	74%	63%	51%
4G	0%	2%	7%	15%	24%	35%	47%
Of which UK	85 043	85 513	86 172	86 767	87 360	87 949	88 535
2G	46%	40%	32%	24%	16%	11%	9%

3G	54%	58%	60%	60%	57%	49%	38%
4G	0%	2%	8%	16%	27%	40%	53%
Asia Pacific	3 195 559	3 420 082	3 622 415	3 812 222	3 988 073	4 140 791	4 268 132
Of which Japan	133 419	141 952	148 140	153 003	156 795	159 646	161 812
2G	1%	1%	1%	1%	1%	0%	0%
3G	91%	85%	79%	73%	64%	55%	49%
4G	8%	14%	20%	26%	35%	44%	51%
Of which South Korea	53 623	54 521	55 361	56 095	56 721	57 288	57 798
2G	6%	10%	10%	8%	6%	3%	2%
3G	64%	39%	24%	16%	10%	7%	4%
4G	30%	51%	66%	76%	84%	90%	94%

Source: IDATE

From this table, we see very different situations depending on the countries. A high 4G penetration level in most advanced countries such as South Korea, US or Japan can be explained differently.

In South Korea for instance, 2G has already a very small penetration among users, which is even more the case in Japan. However, in the latter country, the more important level of penetration of 3G has probably played as a delayer in the deployment of LTE networks. South Korea in some ways was able to jump more quickly to 4G because 3G infrastructures were probably not as good as in Japan. In the US also, the quick move to LTE can be partly explained by the late deployment of 3G in the country.

In the end however, the trend is relatively the same for every market with a strong decline of 2G penetration and the progressive decline of 3G in favour of LTE.

1.2 Spectrum fragmentation

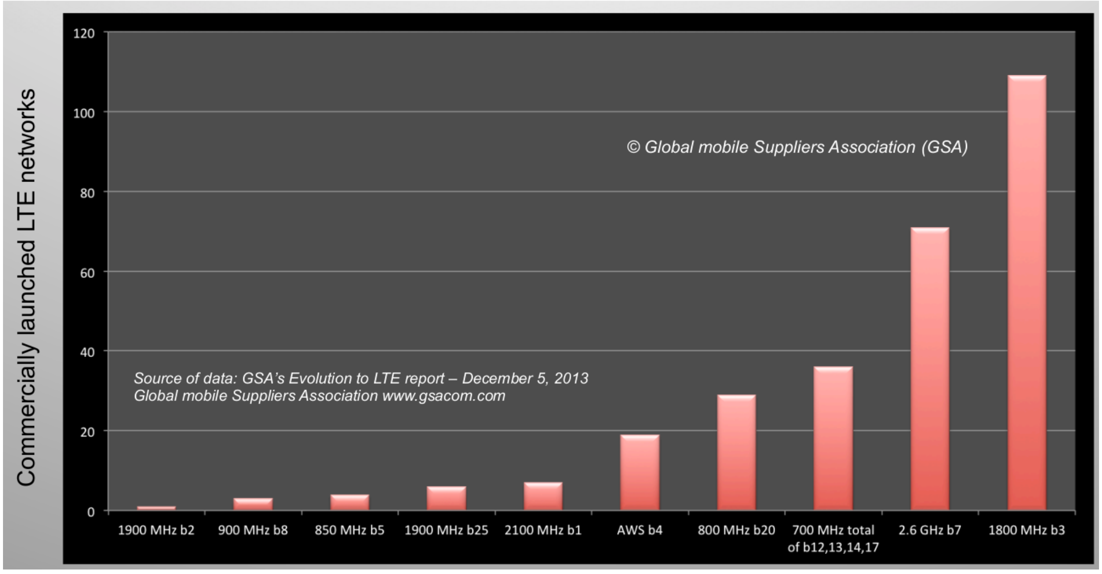
The unprecedented number of bands used by a single radio access technology was initially seen as a big challenge for the development of the technology, especially in terms of device ecosystem and more generally because the difficulty to support several LTE bands in one single device would have hampered interoperability of devices across different networks. At the beginning, the band 13 (700 MHz block C) ecosystem (used by Verizon) was by far the most important ecosystem and it took until 2012 before smartphones were able to support European LTE frequencies such as the band 7 (2.6 GHz).

Since then, the LTE device ecosystem has seen the significant growth of other bands, helped also by the technological improvement enabling the support of even more bands in one single device. This fact is illustrated by table 2 below. A device such as the iPhone 5s is able to support up to 13 different LTE bands.

Interestingly, band 3 (1800 MHz) is the most popular band used in LTE devices. This can be explained because of its wide use across the world with GSM network. While GSM 900 MHz band was early used for 3G refarming, band 3 was still used for 2G and was the choice band candidate for 4G refarming. It was one of the few LTE bands supported by the first LTE iPhone (iPhone 5).

This band has one of the strongest progressions in terms of device adoption if we compare the situation between November 2013 and end of June 2014. Band 7 (2600 MHz) comes just after, followed by band 1 (UMTS 2100) which suggests that operators are starting to increasingly refarm their "old" spectrum with 4G. This is also what the progression of band 5 (850 MHz) and band 8 (900 MHz) suggests with a growth of the number of devices available superior to 80%.

Figure 1: Spectrum used in commercial FDD LTE deployments



Source: GSA[ii]

In the future, even more bands will be used for the operation of LTE networks. With the development of TD-LTE, new bands will be increasingly supported, as well as higher frequencies such as the band 42 (3.5 GHz) which is generally currently used by BFWA service providers and that will provide a smooth evolution path toward LTE for those players.

When deploying small cells, those TDD bands might become of particular importance for operators, especially in outdoor small cell scenarios. The first TDD-3.5 GHz smartphone was demonstrated at Mobile World Congress (MWC) 2014 by Huawei.

Table 2: Frequency bands supported by LTE devices

	Number of devices on the market	Share of devices supporting this band
LTE FDD		
1800 MHz band 3	769	40.7%
2600 MHz band 7	740	39.2%
2100 MHz band 1	544	28.8%
800 MHz band 20	467	24.7%
800/1800/2600 tri - band	413	21.9%
AWS band 4	405	21.4%
700 MHz bands 12, 17	379	20.1%
850 MHz band 5	345	18.3%
900 MHz band 8	335	17.7%
700 MHz band 13	308	16.3%

1900 MHz band 2	220	11.6%
1900 MHz band 25	107	5.7%
LTE TDD		
2300 MHz band 40	361	19.1%
2600 MHz band 38	360	19.1%
1900 MHz band 39	203	10.7%
2600 MHz band 41	183	9.7%
3500 MHz band 42,43	24	1.3%

Source: GSA as of end of July 2014

1.3 Traffic forecasts

In the revised version of the IDATE mobile traffic model, we anticipate that total voice and data traffic will reach 73.6 Exabytes (EB) in 2017 compared to 18.8 EB in 2013. This represents a 291% increase over the period 2013-2017 ans is illustrated in the table below.

Table 3: Total mobile annual traffic 2013-2017

Total mobile annual traffic (in EB per year)	2013	2014	2015	2016	2017
Europe	4.5	7.2	10.2	13.6	17.4
Americas	3.8	6.1	9.0	12.0	15.7
Asia	8.5	13.2	18.9	24.9	33.6
Rest of the world	2.0	3.0	4.2	5.4	6.9
World	18.8	29.5	42.3	55.8	73.6

Source: IDATE – August 2014

Video already represents close to 50% of total mobile traffic worldwide. We expect this share to exceed 60% in 2017 in Europe and in the Americas (encompassing North and South America).

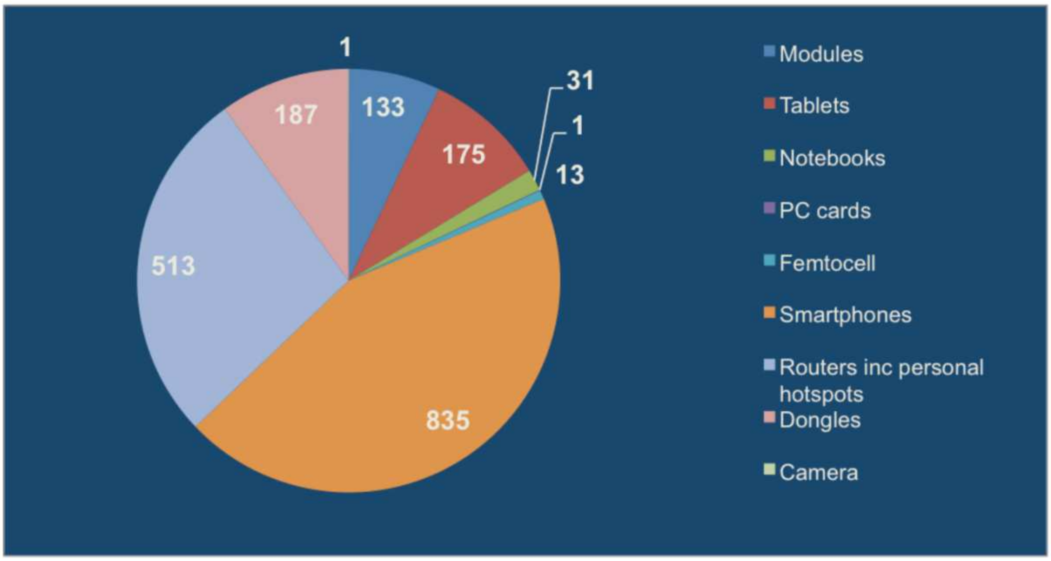
Our assumptions for mobile traffic offloading are based upon the observations by mobile operators presented earlier in this report. They range from 40% in the rest of the world in 2013 to 80% in 2017 in Europe and the Americas.

1.4 Devices

As the Figure 2below highlights it, the LTE device ecosystem is diversified with different kind of devices, from connectivity-only devices such as dongles, personal hotspots or data modules[2] to more evolved devices such as smartphones, tablets, laptops. Smartphones and mobile hotspots are by far the most popular devices available.

[2] Data modules are connectivity modules used for M2M (Machine to Machine) applications

Figure 2: Distribution by type of LTE device



Source: GSA as of end of June 2014

The popularity of mobile hotspot highlights the fact that except smartphones, most consumer devices have only WiFi connectivity and lack support for cellular connectivity. Indeed, most tablets, notebooks are WiFi only devices and mobile hotspot brings more flexibility than having embedded LTE connectivity in every device with a SIM card and its associated mobile data contract or shared data option.

Furthermore, it is more cost effective to change only a device that provides connectivity (the mobile hotspot) to support latest features of LTE than changing a device with supplemental functions that do not need to be changed such as a tablet or a notebook.

Taking into account the variety of devices on the market is important, as each device has a different impact on the traffic. It is known for instance that more mobile traffic will derive from a tablet than from a smartphone on a per unit basis. On the other hand, an important penetration of mobile hotspot may also impact the number of WiFi only devices relying on a cellular backhaul rather than on traditional WiFi connectivity at home.

1.4.1 Mobile phones and smartphones

Smartphones account for the most important number of LTE devices on the market. We expect them to account for around 85% of all devices shipped in 2018, as illustrated in table 4. This situation can be explained by the fact that they are truly mobile, always with us. Thus we are more prone to using them when looking for something on the go, unless we are in a planned situation with more adapted devices at our disposition, e.g a tablet at home.

Table 4: LTE smartphone shipments (thousand)

	2012	2013	2014	2015	2016	2017	2018
USA	42 455	79 671	126 978	147 664	161 058	171 655	179 070
France	284	1 824	5 052	7 896	12 713	16 627	18 589
Germany	413	2 819	7 523	11 229	17 225	21 716	23 424
Italy	275	1 829	4 882	7 275	11 547	14 900	16 467
Spain	232	1 581	4 081	6 352	9 925	13 058	14 396
UK	397	2 720	7 547	11 886	18 388	23 961	26 246
Japan	8 633	17 250	29 113	33 219	37 514	40 858	44 224
South Korea	4 409	9 648	16 440	20 417	22 435	24 473	26 377

Source: IDATE estimates, as of end 2013

We typically know that smartphones generate less traffic on a per unit basis than a tablet or a laptop but this may change in the future because of smartphones using bigger screens (something that has been observed on the market in the recent years) or because smartphones are more and more used as tethering devices. Wearable market may massively rely on smartphone connections to retrieve and process information on one hand. On the other hand, sharing its smartphone connection with other WiFi only devices in place of a dedicated mobile hotspot may also significantly impact mobile traffic generated by smartphone devices.

Globally, we expect that in 2018, 51% of smartphones will support LTE, but with of course a lot of difference in terms of maximum throughputs supported. Indeed, the capability to support carrier aggregation and more than 2x2 MIMO in user device will enable the throughputs to increase significantly with the most recent devices. As of mid 2014, fastest commercial LTE networks supported Cat 6 throughputs, which mean 300 Mbps in the downlink, by aggregating 2x20 MHz. While far higher throughputs have been reached in trials and demonstrations, they do not involve mobile devices. Because of their constrained formfactors, it takes more time to integrate the support for higher throughputs in the devices as power consumption, heat dissipation and physical space which are serious challenges that need to be taken up.

Also, we do not really expect to see significant amount of devices supporting throughputs superior to 300 Mbps shipped before 2016. In 2015, SK Telecom (South Korea) has stated that it wanted to launch services based on the aggregation of 3 Component Carriers of 20 MHz to reach throughputs of 450 Mbps but this will be constrained by the availability of basebands supporting this user equipment. Therefore we take a more cautious approach by suggesting first cat 9 LTE smartphones to be launched in 2016.

In table 5 below, we estimate the distribution of smartphones depending on the throughputs that they will be able to support. In 2018, for instance, we estimate that 68% (701,275) of LTE smartphones will support cat 4 throughputs.

Table 5: Distribution of LTE smartphone shipment by the category of speed supported (in throusands)

	2012	2013	2014	2015	2016	2017	2018
Cat 3 (100 Mbps)	74 044	128 595	180 394	185 036	187 094	163 489	152 519
Cat 4 (150 Mbps)	-	32 725	117 688	270 609	412 328	590 198	701 275
Cat 6 (300 Mbps)	-	-	2 574	6 945	17 989	47 410	122 328
Cat 9 (450 Mbps)		-	-	-	6 236	16 349	40 672

Source: IDATE estimates

Also, while nearly all LTE smartphones are multimode devices supporting 4G as well as 3G and 2G, there will be some room in the future for LTE-only devices, especially in countries where LTE has reached a nationwide coverage. This could help release cheaper devices and potentially more power efficient devices. However, because there will always be some need to rely on 2G or 3G abroad in countries with no LTE, we consider this market should remain limited for smartphone devices. In 2018, 10% of shipped smartphones could be LTE only devices.

1.4.2 Data modules (hotspots, dongles)

Data modules are generally the first kind of devices that comes to the market with a new generation of wireless technology because it is the easiest way to add connectivity and is a relatively simple device with few constraints to support. Battery life is not an issue since it is powered by the host device (usually a computer with a USB port) and above all it is a data only device so it doesn't need to support voice. In table 6 we estimate the number of LTE dongle shipments by geographic regions.

Table 6: LTE dongle and data-only devices shipments (thousand)

Shipments	2012	2013	2014	2015	2016	2017	2018
North America	3015	2228	3062	3552	3608	4360	5571
Europe	343	1616	3474	4130	4165	4578	5350
Asia Pacific	2587	2966	4203	6338	8456	8984	9919
Middle East Africa	37	215	774	1413	2023	2850	2345
Latin America	18	224	718	1717	2495	3193	2697
World	6000	7249	12231	17150	20748	23965	25882

Source: IDATE as of end 2013

As the market develops and the technology matures, mobile hotspots enter the market. We actually believe that mobile hotspots will represent the gist of the market in the next years because it is more suited for the providing of connectivity to any kind of devices. With people having more and more WiFi devices at home and on the go, mobile hotspots appear more relevant than mere dongles.

1.4.3 Tablets and notebooks with integrated cellular connectivity

Market figures show that most of tablet devices only support WiFi and only some of them support cellular connectivity. We don't believe this fact is going to change all the more as mobile hotspot or smartphone tethering will be more adapted to the providing of mobile internet access to more and more devices owned by users. Some carriers currently propose multi-SIM offers but the price asked for this option is often a barrier to the development of multi-SIM usage. In cases where users tap in their smartphone data allowance, there is no justification from the user's point of view to pay a monthly premium for that.

It is to be noted that most of tablets with cellular connectivity are not attached to a data contract but only periodically used with a SIM card.

In table 7, we estimate the number of tablet shipment in the world with the distribution between WiFi only and cellular + WiFi devices

Table 7: Tablet shipments (thousand)

Tablets shipments	2012	2013	2014	2015	2016	2017	2018
North America	42781	55080	59427	60713	61881	57864	54007
wifi only	37647	46818	49324	49177	48267	43398	40505
cellular + wifi	5134	8262	10103	11535	13614	14466	13502
of which LTE+wifi	1557	4131	7577	9574	11844	13019	12422
Europe	30945	47723	62488	73468	82341	90011	97887
wifi only	27232	40565	51865	59509	64226	67508	73415
cellular + wifi	3713	7158	10623	13959	18115	22503	24472
of which LTE+wifi	76	804	2935	5584	10869	16877	19577
Asia Pacific	46197	70699	90879	104832	113275	123765	131641
wifi only	40653	60094	75430	84914	88355	92824	98731
cellular + wifi	5544	10605	15449	19918	24921	30941	32910
of which LTE+wifi	570	1429	2601	4980	7476	11448	14810
Middle East Africa	5038	8249	12353	17056	21470	24110	23628
wifi only	4434	7012	10253	13815	16747	18083	17721
cellular + wifi	605	1237	2100	3241	4723	6028	5907
of which LTE+wifi	6	53	261	518	945	1507	1831
Latin America	5038	8249	12353	17056	21470	25717	30379
wifi only	4434	7012	10253	13815	16747	19288	22784
cellular + wifi	605	1237	2100	3241	4723	6429	7595
of which LTE+wifi	2	35	167	454	945	1672	2658
World	130000	190000	237500	273125	300438	321468	337542
wifi only	114400	161500	197125	221231	234341	241101	253156
cellular + wifi	15600	28500	40375	51894	66096	80367	84385
of which LTE+wifi	2210	6452	13541	21110	32079	44523	51298

Source: IDATE, as of end 2013

1.4.4 Other consumer electronic devices

While most of LTE devices will be smartphones, tablets and data modules, there will be some place, although limited for other kind of consumer electronic devices with embedded LTE connectivity. Such devices can be mobile game consoles, televisions, smartwatches, digital cameras or any other wearable device. Figure 3 provides an example of consumer electronic device that embed LTE connectivity. We believe that the market for such devices would be limited in itself because direct LTE connectivity is not necessarily required. Television will probably be connected to a set top box (see section 1.4.6) or will use WiFi as a connection means in the household.

As for the other more mobile equipment, they will rather use either smartphone connectivity (tethering), either mobile hotspot devices. For wearables, most of them will remain as today, i.e. connected to the smartphone or tablet with low range low power technology such as Bluetooth Low Energy (BTLE).

We forecast that by 2018, 20.3 millions of such devices will be shipped from 781,000 in 2012, as illustrated in table 8.

Table 8: Other LTE Consumer electronic devices shipment (in thousands)

Region/Year	2012	2013	2014	2015	2016	2017	2018
North America	781	1910	3890	6116	8729	13242	20368
Europe	89	1386	4414	7110	10077	13904	19558
Asia Pacific	670	2544	5341	10913	20458	27284	36261
Middle East Africa	10	184	984	2432	4895	8657	8574
Latin America	5	192	912	2956	6037	9698	9860
World	781	1910	3890	6116	8729	13242	20368

Source: IDATE, as of end 2013

Figure 3: Example of LTE camera with the Samsung Galaxy NX

Source: Theunlockr.com

1.4.5 M2M

Up to now, M2M cellular modules have been largely 2G only modules because of their inferior cost and energy consumption critical to many vertical markets where only a small volume of data is transmitted with often no connection to the electric grid. In this respect 3G and 4G modules have had small traction on the market and the shutdown of 2G network in various countries is seen as drama, especially for equipment that are supposed to last more than 10 years and which can't be simply replaced.

However 4G modules (either multimode or LTE-Only) may be of interest in some vertical markets. M2M usages are manifold and LTE offers several advantages to vertical markets because of the download speeds, the upload speeds, and latency that it supports.

Download speeds for instance are particularly suitable for consumer electronics or the providing of mobile internet in the car. Uplink speeds on the other side may be particularly suited for applications such as video surveillance, which is an upload intensive application and currently use other technology than cellular connectivity. Lastly, LTE offers reduced latency as compared to other technologies, which is an advantage for healthcare and other critical applications.

For other verticals market where cost and battery life is of critical importance, LTE solutions are not yet adapted to that kind of usage, although a player like Sequans has decided to specifically address this market with a solution tailored for that market with its StreamLite LTE and designed to function with an “ultra-small” footprint. This, however doesn't completely solve the cost and energy efficiency issue for those usages where 2G only modules are still used and 3G modules are quasi inexistent. This is all the more an issue as some operators have already announced that they would switch off their 2G network relatively soon, leaving M2M players with no choice but to switch to another technology. In the US, AT&T has notably announced that it will switch its 2G network off in 2017 for refarming reasons.

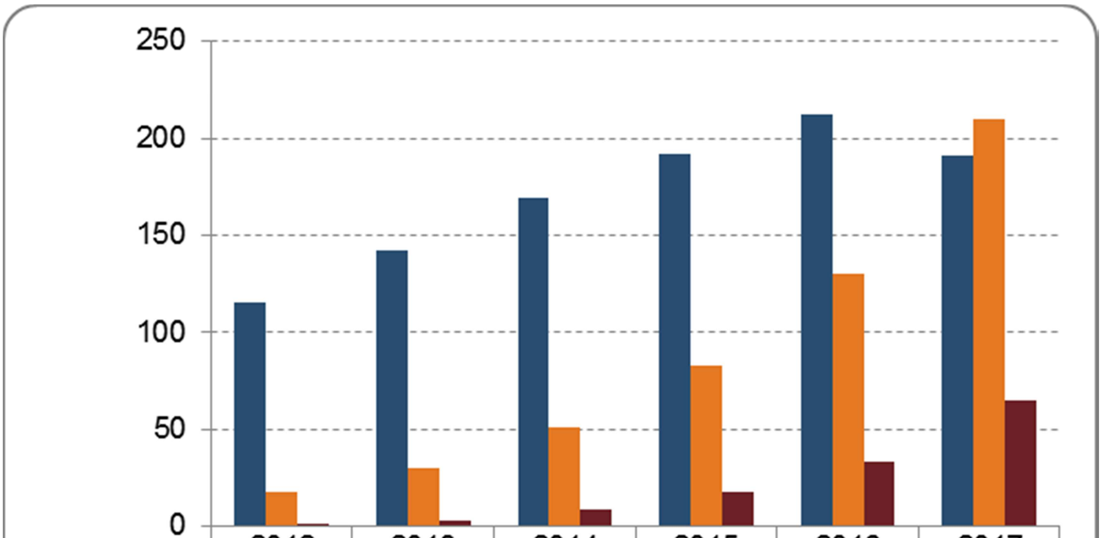
For those reasons, works are being carried to include specifications in the Release 12 of 3GPP to include some support of Machine Type Communication (MTC). The idea is basically to create specifications for some kind of narrowband LTE, that is spectrally more efficient than any other wireless cellular technology today and reduce as much as possible energy and cost.

This will notably be achieved through measures such as:

- Use of single receive antenna instead of 2, the minimum required for receive diversity.
- Reduced bandwidth with baseband data channel of 1.4 MHz. The peak data rate is thus to be reduced to 1 Mbps.
- Reduction of transmit power to 15 dB.
- Half-duplex operation for further cost reduction.

In Figure 4, we estimate the number of cellular M2M modules installed and the distribution of each cellular technology.

Figure 4: World cellular M2M markets by technology (million units installed)



	2012	2013	2014	2015	2016	2017
2G/2.5G	115.2	142.3	169.1	192.4	212.1	191.3
3G	17.3	30.0	51.2	83.0	130.4	209.9
4G	1.0	3.2	8.4	17.9	33.5	65.3

Source: IDATE World M2M markets

By 2017, we expect 13% of M2M modules to support LTE. By that time, 4G and overall 3G will become significant, with respectively 130% and 65% Compound Annual Growth Rate (CAGR), between 2012 and 2017. 3G technology will lead from 2017. Later on, the implementation of MTC (Machine Type Communications) will probably prompt some players to directly switch from 2G to 4G but that horizon is still uncertain, as MTC features have been pushed further from LTE Rel 12 to the Rel 13 due to be frozen in March 2016.

1.4.6 Set Top Boxes with WiFi

Although Set Top Boxes will mostly be connected to the household fixed broadband connection, there might be a small percentage of them with an embedded LTE connection, such as the SVELTE Set Top Box (STB) presented by Technicolor and Qualcomm in September 2013. This device is a hybrid device with a DVB tuner for live TV Broadcast and LTE only for on-demand programs. In the future, one can imagine Set Top Box supporting LTE Broadcast (eMBMS) as well.

In Table 9 we estimate the shipment of connectable STB by geographic regions.

Table 9: Connectable Set Top Box shipments (in thousands)

	2012	2013	2014	2015	2016	2017	2018
North America	2937	3584	3815	3891	3969	4038	4085
USA	2493	3076	3307	3443	3524	3568	3576
Europe	7744	6539	6355	6330	6235	6156	6074
France	2510	2450	2269	2250	2206	2158	2090
Germany	641	533	577	596	611	619	620
Italy	-	-	-	-	-	-	-
Spain	20	30	58	102	118	138	170
United Kingdom	3	-	-	-	-	-	-
Asia Pacific	18153	18758	19713	19967	23410	24590	26041
Japan	1109	1215	1249	1073	1039	989	959
South Korea	2071	1469	1584	1656	1684	1697	1704
Latin America	156	474	819	1545	2442	3369	3701

Source: IDATE in Connectable video devices observatory, September 2014

2 THE RATIONALE FOR SMALL CELLS AND CARRIER WIFI

2.1 Small cells and carrier WiFi: towards more agile networks

Small cells used to be referred to sometimes as 'femtocells' – a not entirely correct usage, as the notion of small cell was long growing to encompass more. Initially, they were used as extensions to provide additional coverage in homes or business locations. Now they are used to provide capacity and are a full part of the mobile network. In this report, the term 'small cells' embraces the three distinct units of femtocells, picocells and metrocells.

With telecommunications becoming ever more mobile, the number of subscribers on the market is pushing network capacities to the brink. Mobile operators have to find solutions to avoid network overload and to offer their clients the best QoS possible. These concerns explain the growing popularity of small cells. Indeed, Mobile Network Operators (MNO) need to ensure network availability to subscribers by increasing the number of radio elements and overlaying them. Small cells are a perfect answer to these new requirements. They are easier to install than macrocells and demand less expensive backhauling. Additionally, their limited dimensions make it more convenient to install multiple radio units in confined and congested spaces.

While femtocells are deployed at a customer's home and involve some form of payment, picocells and metrocells are deployed by the mobile operators and are fully integrated with macro-network architecture.

2.2 Small cell emerges as important part of mobile networks

The heterogeneous network (HetNet) will be the mainstream feature of mobile access infrastructure, especially for LTE deployment. This involves a network composed of macrocells plus a range of small-cell solutions such as picocells, microcells, femtocells and WiFi hotspots. The key benefit here is to boost network density by expanding capacity and lightening the traffic load away from the congested macrocell, at a lower cost.

In table 10, we explain the differences between each of the different small cells.

Table 10: Small cell characteristics

	Femtocell	Enterprise femtocell	Picocell	Metrocell
Capacity	4-8 channels	16-32 channels	32-64 channels	32-64 channels
Configuration	Automatic	Automatic	Automatic or manual	Automatic or manual
Power	20 mW	200 mW	200 mW-2 W	200 mW-5 W
Coverage	10-20 m	10-50 m	50-100 m	Up to 1 km
Location	Indoors	Indoors	Indoors/outdoors	Outdoors

Source: IDATE

Typically used in urban areas, small cells are characterised by a coverage range of a few dozen metres; they are mainly used indoors and, more recently, have been introduced in aircrafts. Their key advantages in terms of reduced associated expenditure by MNOs are:

- Lower capex: Small-cell products cost far less than macrocells and can be deployed in a matter of days or weeks, whereby carriers can deploy them with a build-as-you-grow strategy. In the case of LTE, one can start out by covering the urban area where the concentration of early 4G adopters will be higher and then move on from there as demand grows.
- Lower opex: Small base stations do not require the expensive real estate of macrocells; they use far less power, and those deployed indoors will require very little maintenance. To reduce travel time for

service technicians, carriers can also use distributed antenna systems (DAS) technology to extend signals out from centrally-located base stations, as in hotels.

Metrocells are expected to be installed in city centres, airports, hotels, stadiums and shopping malls. Their main characteristics are described in table 11 below:

Table 11: Metrocell characteristics

The difference between	Macro cells	Metro cells
Max users per cell	2 000	200
Max range	30 Km	200m in urban areas
Max transmit power	60 W	5W
User types	Fast moving	Stationary and slow moving

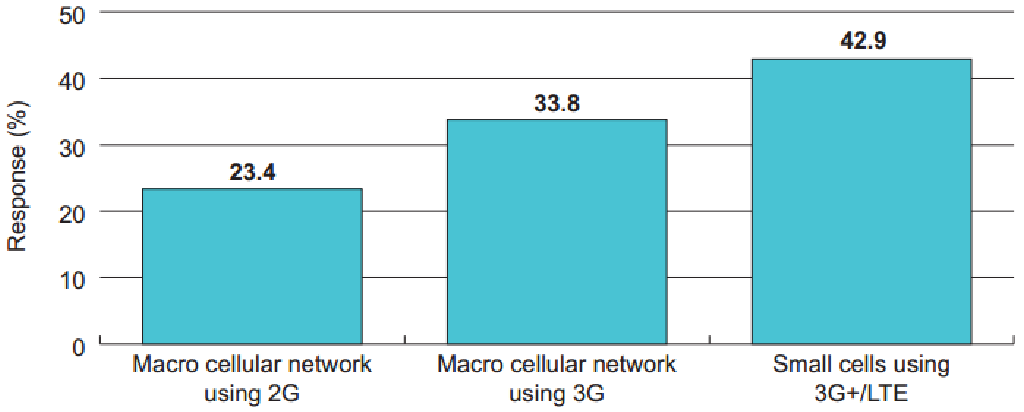
Source: Alcatel-Lucent

2.3 Small cells evolutions

2.3.1 Small cells in rural environment

Although the interests are not as obvious as for urban areas, some players are pushing the concept of using small cells in rural areas. The idea behind is to reduce deployment costs by deploying small cells only to cover tiny spots where population is located , instead of offering wide coverage in places where people are not located. Indeed, the main driver for operators to cover rural areas is often the regulatory obligations stating that a certain percentage of the population has to be covered. Deploying macro network in those cases often proves economically less interesting than covering only adequate places. This explains the result of this survey carried out by Informa on the behalf of iDirect, a satellite backhaul provider, and illustrated in figure 5.

Figure 5: What is the best technology for providing wireless / mobile access in rural areas?



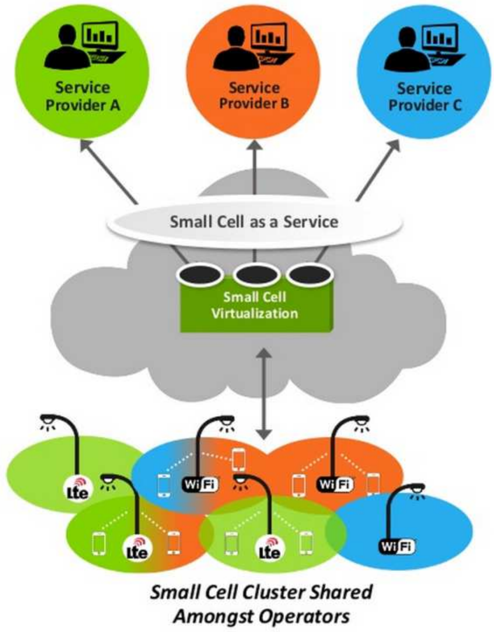
Source: Informa Telecom & Media

The main issue with this use case remains the backhaul, which can be provided with all the traditional means such as copper (not likely), fiber (not likely as well because of deployment costs), microwave transmission, or satellite backhaul.

2.3.2 Small cell as a service (small cell sharing)

As more and more functions of the network are being virtualized and sharing agreement between operators are more and more popular among operators, it appears that sharing agreement for small cells could enable operators to further decrease their CAPEX and OPEX while improving both capacity and coverage. This is what the Small Cell as a Service is all about.

Figure 6: Small cell as a service as a means of sharing small cells among carriers



Source: Interdigital[iii]

Practically, the idea would be to have one or several players invest in the deployment of small cells in a particularly crowded place and virtualize network function to be able to serve several operators for whom it would be difficult to deploy their own densified network otherwise.

This "host" small cell network could be deployed by different players:

- A mobile network operator could decide to do the initial investment because it believes bringin more capacity to a specific zone would definitely bring value to its own service. By proposing Small Cell as a Service to other (competing) carriers, initial investment would be mitigated.
- A Joint Venture between several operators, similar to network sharing agreement already exisiting in the industry for the macro cell network.
- A third party such as an infrastructure vendor willing to offer additional managed services to either MNOs or MVNO. Ericcsson notably made an announcement at the Mobile World Congress related to its own SCaaS (Small Cell as a Service) proposition. Other players such as municipalities or real estate owners could as well decide to make the investment to foster better capacity while monetizing the investment.

2.3.3 Small cell and SON

Self-Organizing-Network (SON) is a feature that was introduced with LTE Rel 8 and further enhanced in Rel 9, 10 and 11. It brings self-configuration, self-optimization and self-healing capabilities to Radio Access Networks.

- Self-configuration functions enable eNode B to be automatically configured and integrated into the network at launch. Parameters are automatically loaded and the base stations gets discovered from other base stations in the neighbourhood so that their technical parameters (emission power, antenna tilt ..) are adjusted and interferences avoided.
- Self-optimization enable configuration parameters to be adjusted to take into account a new base station in the neighbourhood for instance or the disappearing of a base station, either because it is out of order or because it has been voluntarily been switched off. This scenario may be met for

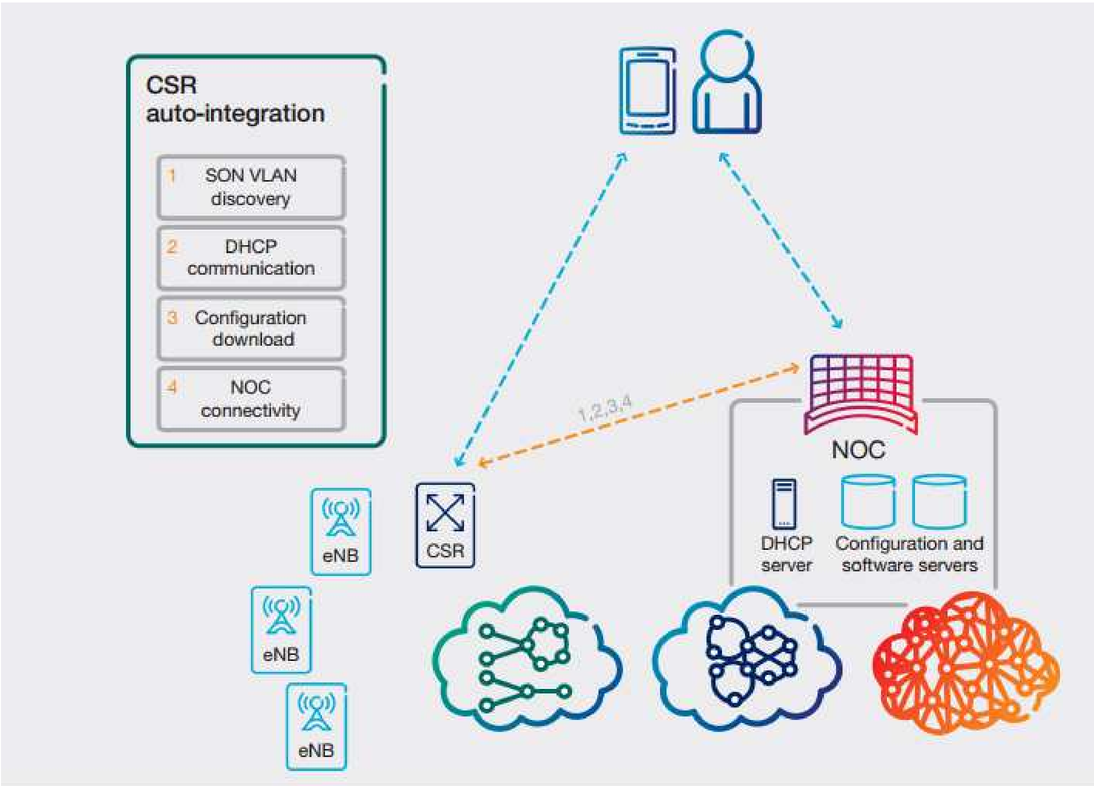
example during night hours when need for capacity is less important. Switching off some base stations enables to reduce OPEX and consume less energy.

- Self-healing prompt base stations in the neighbourhood to adjust their parameters to compensate for the loss of the base stations. Meanwhile, failed base stations identify themselves directly to speed up their recovery.

The benefits of SON functions are reduced OPEX and improved Quality of Experience. The SON features are especially important in a heterogeneous network because the density of base stations deployed is changing quite quickly. Even when all the small cells have been deployed, they can be switched on and off dynamically to cope with surging data traffic / usage. In those conditions, the network has to be able to reconfigure itself so as to take interferences into account and act accordingly.

As of today, SON features pertain to the Radio Access Network but SON capabilities for the backhaul are also under study. They would enable to further reduce OPEX and improve deployment, operation and maintenance. Auto integration of a Cell Site Router to the network would enable, according to Ericsson[iv] to enable 15% faster rollouts and 50 percent competence cost reduction. Figure 7 illustrates how the Cell Site Router could be automatically integrated. The SON feature would enable the backbone link to be configured automatically by first establishing a temporary User to Network Interface with the Network Operating Center (NOC) in order to download a configuration file that will set up the permanent Network to Network Interface.

Figure 7: Using SON features for auto-integration of a Cell Site Router



Source: Ericsson

2.3.4 Limited and open Small cell access

Small cells can be set up to have different access restrictions. They can of course be made available to every subscribers to an operator, as will be probably the case most of the time but small cells can also be restricted to a certain group of people, as is the case with femtocells where only selected subscribers (the one that have installed the femtocells) can use it. Operators however can decide to make these femtocells available to other subscribers, as are doing Softbank and Free/Iliad.

Hybrid access of course is also possible with some players having preferred access to the small cell.

3 Small cell market

3.1 Operators strategy

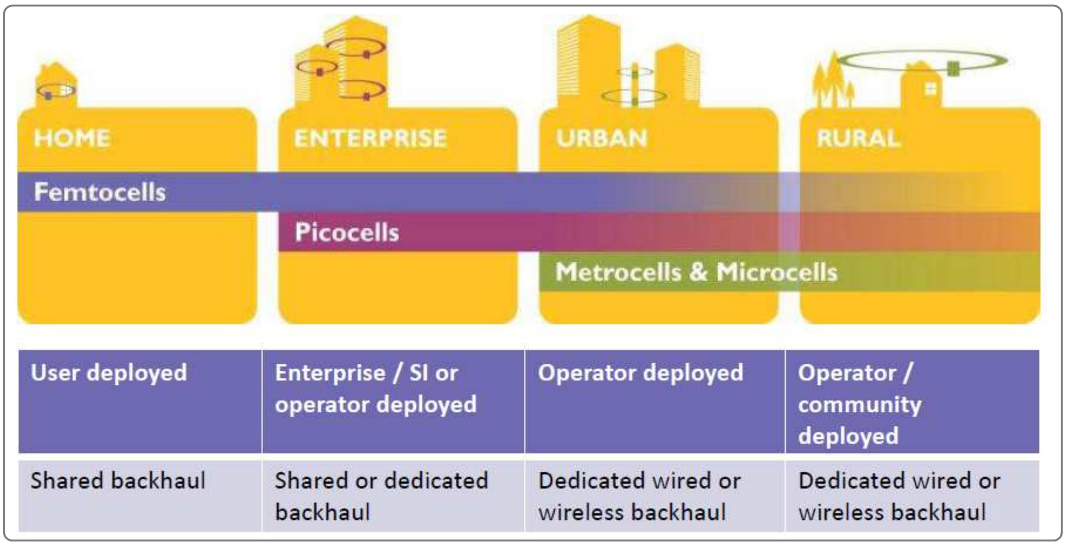
With the explosion of data traffic, most operators recognize the need for small cell and hetnet deployment. Although concepts such as femtocells have existed for a long time, massive deployments have been limited so far. With LTE-Advanced features such as eICIC, Coordinated MultiPoint, Self Organising Network or Carrier Aggregation, the work being carried out around finding new spectrum to deliver both capacity and coverage for mobile broadband, small cells are set to become one of the most important part of operators LTE architecture in the future.

As of today, operators are still relatively shy with deployments but small cell should ramp up progressively in 2015, 2014 being the year where most advanced operators try the technology. Many challenges exist in building a dense small cell network and it seems like most operators follow a multi-step strategy:

- First, focus on indoor deployment with femtocells for residential and companies. This is currently the easiest step, as interferences with the macro network are limited. As for backhauling as well as power sources, they are not an issue since they rely on the subscribers' fixed broadband connection. Femtocells have been tested with 3G in the past and now exist with LTE in both FDD and TDD flavour, although the latter one is more recent.
- After private indoor coverage, the focus is set on indoor coverage in large public places such as business districts, stadiums or other densely populated areas. Then again, interferences with macro network is still limited because of reduced indoor coverage of the macro network (hence the interest of small cells).
- Outdoor small cell deployment is the last step in small cell deployment.

Figure 8 illustrate the small cells applications.

Figure 8: Applications of small cells



Source: Small Cell Forum[v]

3.2 Operator case studies

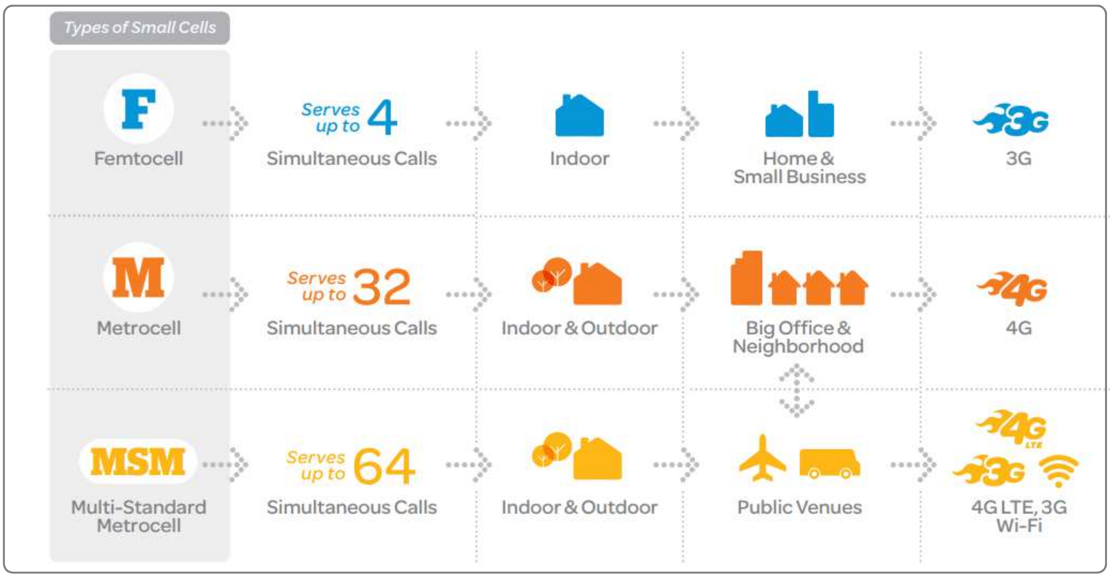
Surveys among Mobile Network Operators tend to show that they intend to start deploying small cells in 2014 but that those deployments should only be sporadic. 2015 would be a better estimation for the start of mass deployment.

The limiting factor here could be the willingness to continue with super macro cells, more sectors inside the same cell and multiple Radio Access Technologies.

3.2.1 AT&T

AT&T announced its small cell and carrier WiFi plan as part of its 3 years investment Velocity IP (VIP) project in fall 2012. Distributed Antenna Systems are parts of the plans. It currently operates more than 32,000 WiFi hotspots and has roaming agreement that enables AT&T to provide access to more than 461,000 hotspots. Figure 9 illustrate AT&T use of small cells depending on the area to cover.

Figure 9: AT&T small-cell categories

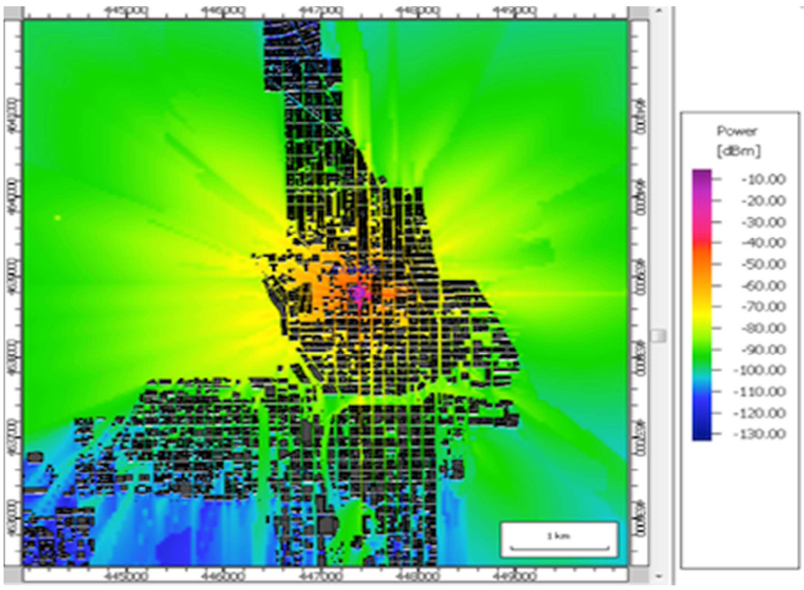


Source: AT&T

After testing small cells in 2013, making sure that it did not interfere with the macro network, the operator is on the point where it plans to massively deploy LTE and HSPA+ small cells in 2014. Several vendors have been tested. Small cells are being deployed with the help of proprietary developed software called Hetnet Analysis and Resources Planning (HARPA).

At the end of 2013, AT&T had deployed HSPA small cells in 18 states. Those cells have coverage of around 1000 feet and support HSPA+, LTE and WiFi. By 2015, AT&T plans 40,000 small cells to have been deployed. This deployment will be supported by a software developed in house and illustrated in figure 10.

Figure 10: AT&T HARPA software



Source: AT&T

3.2.2 Verizon

In May 2013, Verizon said that it could use small cells primarily in business districts or shopping malls to improve capacity and coverage, in complement to Distributed Antenna Systems. The carrier was to deploy 200 small cells in 2013 with the intent to ramp up deployment in 2014 with no further precision. Small cells are to be deployed on AWS spectrum. Ericsson and Alcatel Lucent were the vendors retained by Verizon.

But challenges exist with small cells. Verizon mentioned the emergency power supply and the backhaul. More recently at the end of 2013, a Verizon executive reportedly mentioned cost of small cells solutions as a possible deterrent to any small cell strategy, which could explain apparent delays in small cell deployments.

3.2.3 Sprint

Sprint seems to put small cell at the core of its network deployment strategy. The company, recently purchased by the Japanese player Softbank, initially announced its plan in mid-2012 with three major steps and an initial focus on indoor. The initial focus on indoor seems logical as outdoor small cells require more interference management as with indoor small cells. Outdoor also requires mobility and handhover management. The three steps described at the time by Sprint are the following:

1. The first step started in H2 2012 and continued in 2013. It was focused around deploying femtocell for both residential and businesses but principally to address indoor coverage for voice call. Sprint is said to have deployed more than 1 million such femtocell but only with support for 3G.
2. In 2013, the operator was due to start rolling out thousands of picocells to assure indoor coverage and capacity in large buildings and venues such as stadiums or airports. On average, in each venue between 100 and 200 picocells were due to be rolled out.
3. Late 2013 and 2014, but probably also in 2015, Sprint was to start deployment of outdoor small cells.

In September 2013, Sprint started receiving picocells from Alcatel Lucent and Samsung, which tend to show that there has been some delay in the execution of Sprint’s initial small cells plan. The picocells are to be deployed on the 1.9 GHz band.

According to Sprint's network chief John Saw[3], only a small number of single mode LTE picocells had been deployed as of mid 2014 but the deployments are to be continued in the next months. Sprint pico cell won’t necessarily support all three Spark bands. Sprint small cells will support either the single 1900 MHz or 2.5 GHz band either the two of them but not the 800 MHz which will remain used for macro coverage.

3.2.4 T-Mobile USA

Having announced the completion of their merger on 2 May 2013, T-Mobile USA and MetroPCS now combine more than 41 million subscribers, mostly from the former. The deal will also allow the two carriers to form a single LTE network on AWS frequencies and refarm the MetroPCS 1900 MHz CDMA spectral resources for HSPA+ services.

The merged entities will benefit from 76 MHz of spectrum in the 25 biggest metro markets. The deal also gives T-Mobile new infrastructure made of 6,000 Distributed Antenna Systems (DAS) already installed by MetroPCS.

Even if DAS are not what are called small cells, the strategic asset formed by the MetroPCS distributed antenna systems gives T-Mobile what it calls a “small cell role”. Indeed, according to T-Mobile executives, DAS bring high capacity and improved indoor coverage.

The new common network will use these antennas located in such heavily-crowded metropolitan areas as downtown Los Angeles and Manhattan. Given the large quantity of spectrum brought by the merger, T-Mobile will consider the extension of DAS to fill high-capacity needs in specific zones.

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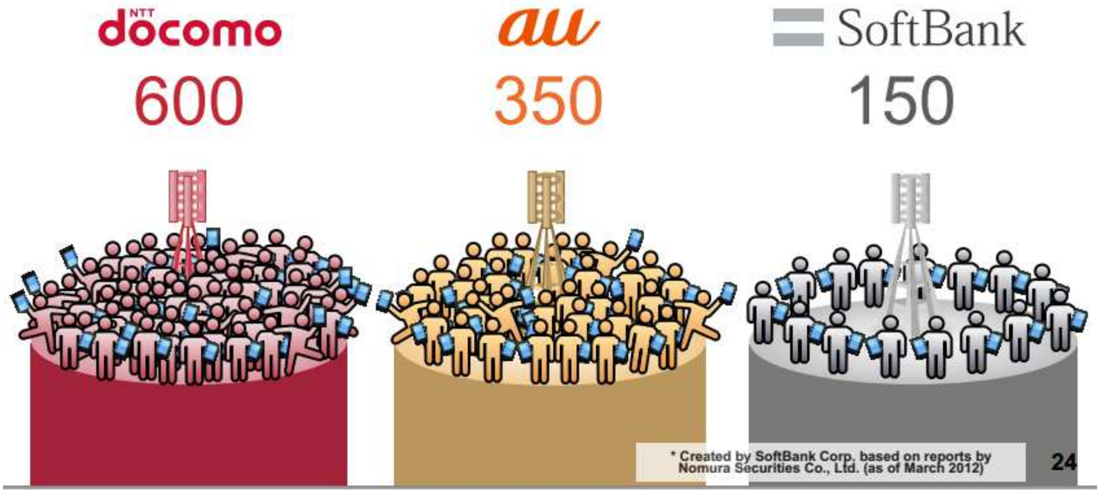
[3] http://www.lightreading.com/mobile/5g/sprints-saw-5g-opp-is-moving-signal-closer-to-customers-/d/d-id/709571

3.2.5 Softbank

When SoftBank[vi] purchased Willcom in December 2010, it acquired its PHS network made up of a wide and dense network of microcells and launched in February 2012 its TD-LTE compatible network based on AXGP (Advanced eXtended Global Platform) technology in band 41 (2.6 GHz). AXGP is basically a very dense TD-LTE with strong interference management capabilities. In other words, AXGP is a TD-LTE network based on small cells. More than 160,000 microcells are thus spread across the main urban areas of Japan. This gives Softbank an advantage as compared to their competitors since they have fewer users to serve per cell, as illustrated byFigure 11.

Figure 11: Number of users per Base Station (subs /number of base stations)



Source: Softbank

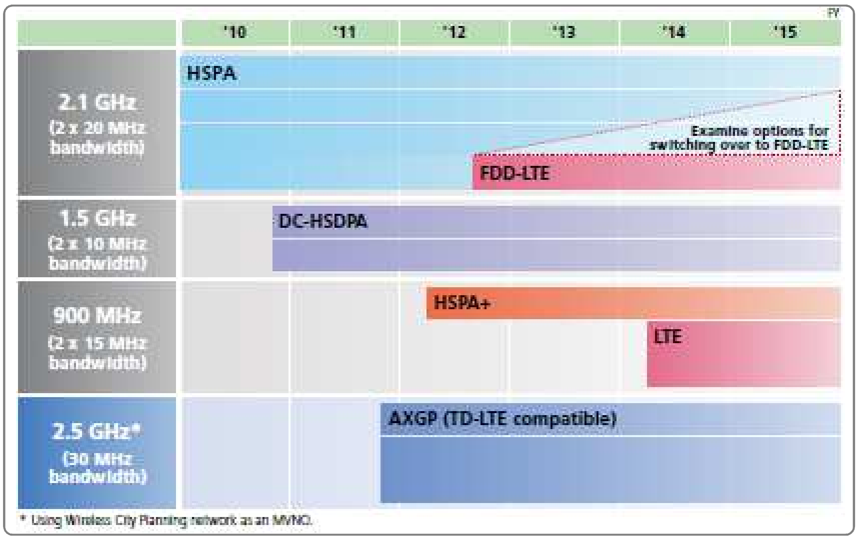
According to SoftBank, the TD-LTE rollout is clearly a means to face the surge in mobile data traffic that could well grow some 32-fold in the coming five years. To apply TD-LTE, which suits better data usage, in highly-crowded areas over a network that offers a density of 150 microcells per km², is part of their strategy to face the future traffic challenge. It plans to support around 100 people per small cell.

During the recent 2013 TD-LTE Summit, Wireless City Planning demonstrated how current microcells are an integrated part of their global small-cell strategy, based on the following steps:

- Expanding its network and raising its density with a whole range of cells from pico units to macro units, thus responding to a whole spectrum of concerns ranging from capacity issues to coverage needs.
- Refarming its spectrum bands gradually from UMTS use to LTE use, within the next five to ten years.

In figure 12, the spectrum ressources of Softbank are illustrated.

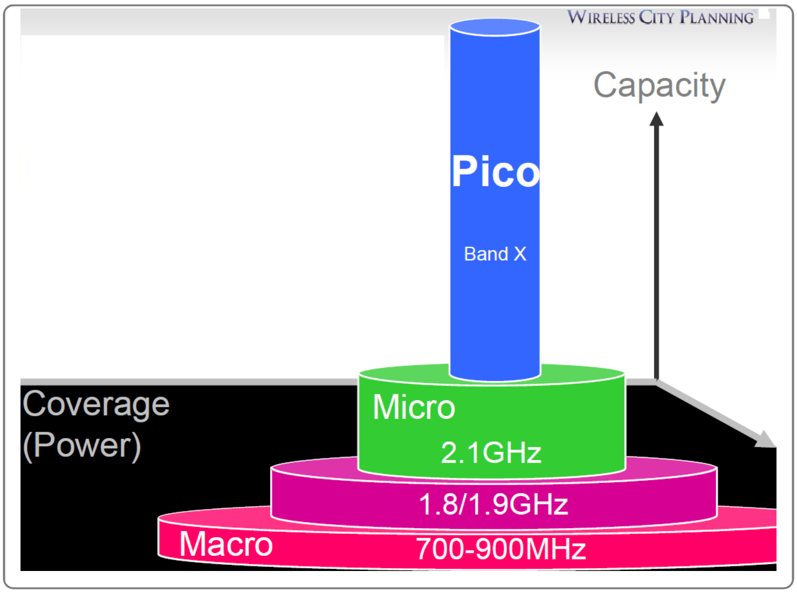
Figure 12: SoftBank spectral resources and refarming schedule



Source: SoftBank

Of course the allocation of bands will respect the balance between coverage and capacity needs, and so the different bands will be used by the various types of small cells. It should be noted that TD-LTE band 41 is already in place on the microcells even if this is not indicated in the figure 13 below.

Figure 13: SoftBank spectral assignment to small-cell units



Source: SoftBank

Small cells deployed by Softbank will be complemented with WiFi offloading and based on a dense network of Hotspots. As of April 18, 2013 Softbank had 460,000 spots as compared to 220,000 for KDDI and 120,000 for NTT Docomo. Those public hotspots were complemented in March 2013 by 3.4 million residential spots.

3.2.6 NTT Docomo

As of November 2013, Docomo had reportedly started to roll out small cells for indoor coverage in a few major prefectures including Tokyo, Osaka and Kyoto. Those small cells operate on multiple bands (1.5, 1.7 and 2 GHz bands) and are LTE-A ready, supporting eICIC and carrier aggregation, something that should be activated when Docomo launches carrier aggregation around 2015. Previously, NTT Docomo had launched in December 2012 a femtocell supporting 3G and LTE.

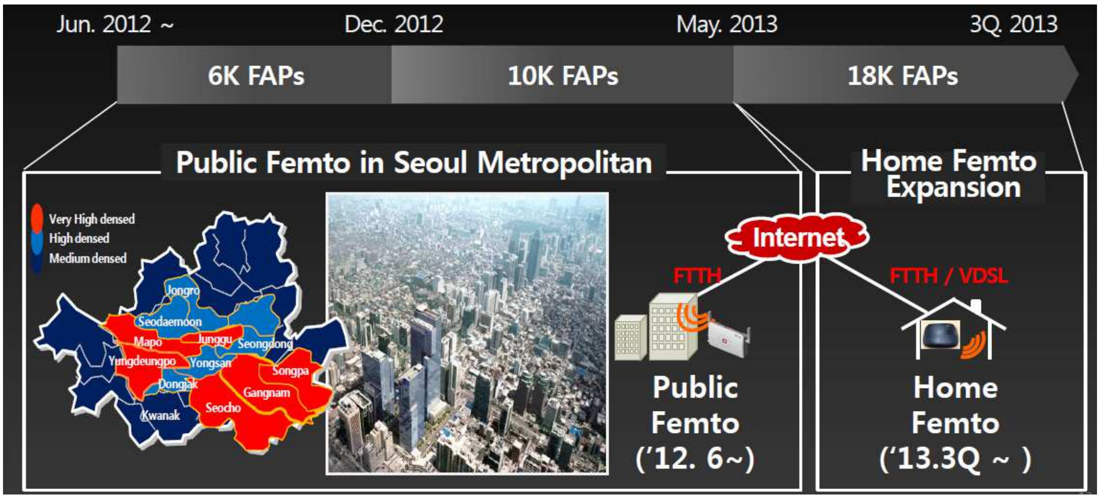
Docomo calls those small cells "add-on" cells. In Docomo's infrastructure, small cell will be supervised by macro cell, which will enable better mobility. In this scheme, the macro cell will be called the Phantom Cell.

3.2.7 KT

The South Korea operator KT has commercially deployed LTE public femtocells since June 2012. Some 10,000 femtocells were deployed between June 2012 and May 2013, and a further 18,000 femtocell access points (FAPs) were planned for rollout during Q3 2013. KT is providing seamless service to its customers between the LTE and WiFi networks.

In Figure 14, KT small cell deployment in Seoul is illustrated

Figure 14: KT small-cell deployment in Seoul



Source: KT

3.2.8 SK Telecom

SK Telecom has also put small cells at the core of its strategy. As of June 2013, the South Korean carrier had deployed 50,000 femtocells including 3,000 LTE femtocells. Reportedly, small cell deployments started early during the first half of 2012, with Mindspeed and Cavium as the small cell solution vendors. Small cell base stations support both LTE and WiFi as an offload technology.

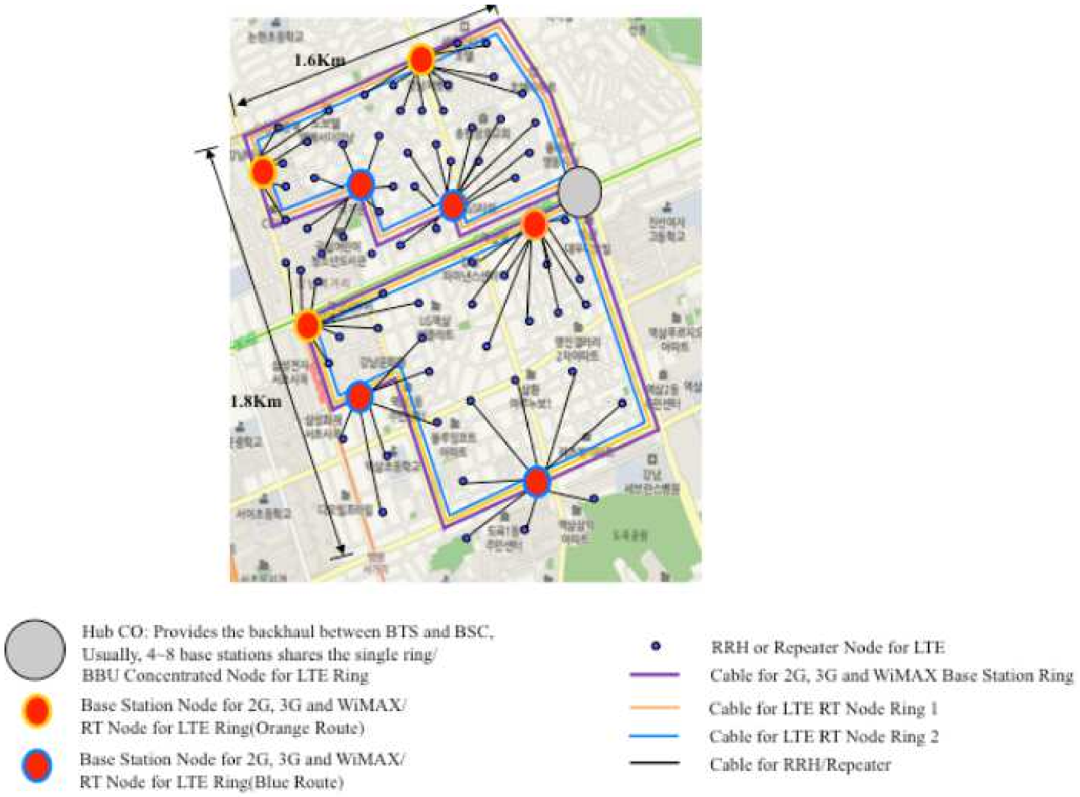
As a complement to their indoor small cell strategy SK Telecom deployed 200,000 Remote Radio Heads fronthauled to 12,000 base stations via fiber connectivity. Up to 30 Radio Remote Heads can be supported by one base station node.

In addition to small cells, SK Telecom has deployed 120,000 WiFi access points in South Korea in data-concentrated areas.

It is estimated that 100,000 small cells had been deployed in South Korea.

Figure 15 illustrate SK Telecom Gangnam small cell architecture

Figure 15: SK Telecom Gangnam SCAN architecture



Source: Solid.com

3.2.9 China Mobile

China Mobile[vii] will also deploy small cells in its network supporting TD-LTE. For this matter, it selected Alcatel Lucent and its Lightradio architecture specifically designed to operate outdoor. In the past, China Mobile had deployed TD-SCDMA femtocells but reportedly with limited success. This limited success is due to the poor maturity of TD-SCDMA femtocells combined with a small number of TD-SCDMA small cell vendors with deep telecom background.

Small cell will however be particularly important for China Mobile has it is using high frequencies for its TD-LTE network, which provide good outdoor coverage but limited/bad indoor coverage. Also, because VoLTE has not been launched, small cells deployed by China Mobile will have to support also 3G/2G in the places where indoor coverage is poor.

In terms of WiFi support, it is to be noted that China mobile stopped the roll-out of its carrier WiFi network in July 2014, stating that it did not generate enough revenues, accounting for 74% of data traffic but representing only 2.6% of the revenues. Instead, China Mobile will focus on the deployment of its TD-LTE network.

3.2.10 Free / Iliad

With the launch of its own mobile network in 2012, Free/Iliad made it clear that femtocells were parts of its deployment strategy. It started offering the 3G femtocell module (10 EUR of shipping costs) for existing customer before including it with each new Freebox.

Countrary to other players, the aim of deploying femtocell is rather driven by cost reduction than improving capacity. Indeed, deploying femtocell in each Free Broadband subscribers household enable to save roaming fees with Orange, which provide 2G and 3G access in areas where Free has not deployed its nascent network. This strategy is complemented with systematic WiFi offload when possible. Free was the first operator to support SIM-EAP seamless authentication on its network.

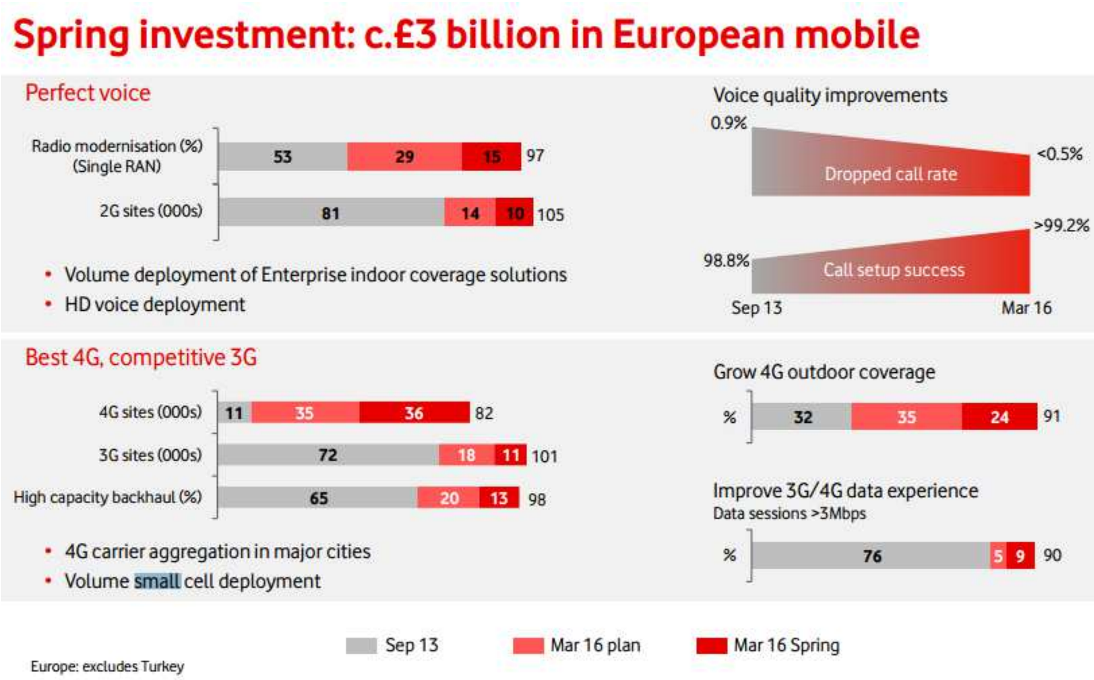
Currently, Free femtocell only support HSPA+ with maximum throughputs up to 21 Mbps. Support for 4G is of course planned but we have no visibility on their plan. We estimate that Free could have around 1 million femtocells deployed as of mid 2014.

3.2.11 Vodafone

As part of its network expansion plan called Spring Investment, Vodafone has set the target of 18,000 small cell deployments by 2015 in Europe globally. In Africa Middle East and Asia Pacific, the target is the deployment of 36,000 WiFi access points. In trials, Vodafone had been able to offload 25 to 30 % of macro traffic in a dense outdoor area of Barcelona.

Figure 16 illustrate Vodafone deployment plans.

Figure 16: Vodafone deployment plans



Source: Vodafone

By March 2016, Vodafone plans to have deployed around 70,000 of small cells in Europe with a combined support for WiFi. In July 2014, Alcatel was selected by Vodafone as a supplier of reference for small cells. This deployment will be supplemented by investment in the backhaul to support the increased capacity in the Radio Access Network. 87,000 new high capacity backhauls are thus to be built by March 2016.

3.3 Market forecast

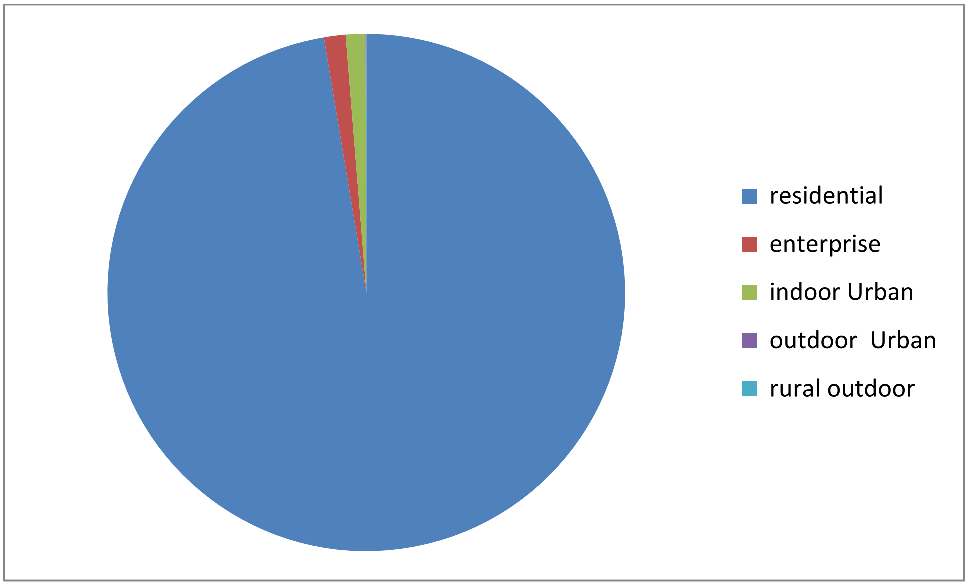
3.3.1 Industry sources

According to the Small Cell forum, 7.9 million small cells had been deployed worldwide at the end of the year 2013. Those small cells are mostly femtocells, because, as we have seen, femtocells are easier to integrate to the network and produce less interferences than pico or metro or microcells.

However, the market is slowly moving toward small cell deployments in larger indoor environments such as in enterprise or in other urban environments, which clearly show that the market is getting mature as challenges are little by little overcome.

As of the end of 2013, 96.8% of deployed small cells were thus femtocells and only 0.06% were outdoor small cells as illustrated in figure 17. The market is still mostly a 3G market.

Figure 17: Small cell deployment as of end 2013



Source: Small Cell Forum

However, with the time, the enterprise and public indoor small cell segment of the market should develop as figures from the Small Cell Forum highlights it, showing an 86% growth of enterprise small cell shipments and an 84% growth for public indoors small cells.

3.3.2 Drivers and hurdles

3.3.2.1 Adoption drivers

3.3.2.1.1 Traffic growth

The exploding data consumption both in relative and absolute terms (people will consume more data individually and more people will consume mobile data) will put a particular strain on mobile networks. Densifying the network in selected parts will enable carriers to cope with the increasing demand for throughputs. This approach however will have to / may be completed with other approaches aimed at increasing spectral efficiencies (e.g higher order MIMO, higher modulation scheme …).

3.3.2.1.2 Technical drivers

Several features of LTE will facilitate the adoption of small cells by facilitating the management of heterogeneous networks:

- eICIC : a feature introduced in LTE Rel 10 that aims at mitigatingg interferences between cell sites. It will be of particular importance with the densification of cells and the overlapping of the small cells with the macro cells.
- CoMP: Coordinated Multipoint feature enable to improve performance at the cell-edge. It requires an effective backhaul to coordinate the different cell.
- Self Organising Network: a feature that was introduced with LTE Rel 8 and further enhanced in Rel 9, 10 and 11. It brings self-configuration, self-optimization and self-healing capabilities to Radio Access Networks. It will help decrease deployment and maintainance time and cost of each additional cell. A densier network will be easier to manage.

3.3.2.2 Hurdles to adoption

3.3.2.2.1 Regulatory

Because higher frequencies will usually bring more capacity and throughputs, operators with no such high frequencies will find it more difficult to densify their networks. The inability to get the required spectrum licenses will be a hurdle to the adoption.

Another regulatory issue could be the difficulty to obtain authorization for cell sites or a complex process that would make the deployment of small cells difficult and lenghty.

3.3.2.2.2 Cell sites installation

The deployment of mobile network has prompted fears among the population over the medical consequences that radiation may have on the population, especially on children. The deployment of small cells could raise opposition from the population and/or from the entities responsible for giving the authorisations (e.g political).

3.3.2.2.3 Security

While cell towers are not easily accessible, small cell sites on poles might pose security threats if people can easily have access to the pole or place where the small cell is located.

3.3.2.2.4 Costs

Previously mentioned difficulties could increase deployment costs and slow-down small cells efforts from Mobile Network Operators. Also, the backhaul could prompt increased cost depending on its availability. This should however not be too difficult, as small cells will primarily be deployed in dense areas where fixed broadband is already well available.

3.3.3 Main assumptions

3.3.3.1 Mobile broadband development

As mentioned in section 1.1, we expect more than 50% of mobile subscribers to benefit from 4G in most European countries and around 90% in the US and in South Korea by 2018. Worlwide, we forecast 2 billion 4G subscribers by 2018.

3.3.3.1.1 Base station & cell sites forecasts

2013 Europe[4]

In Europe (EU 27), we estimate that there was around 425,000 cell sites for 2G, 3G and 4G. We make this assumption based on the number of cell sites in Germany as compared to the population of the country, remarking that this ratio is similar to the one found in the US (around 1100 persons served on average by a cell).

2013 USA

In the US, according to the CTIA[viii] there was 304,360 cell sites as compared to 253,086 at the end of 2006, showing an increase of 6% per year between 2010 and 2013 on average. The gist of the growth however was done in 2011 as growth in 2013 was only 0.9%, indicating on the whole that LTE deployments are well advanced.

2013 Wordwide

According to data available in our databases, we estimate there were 6.5 million cell sites worldwide as of end 2013.

3.3.3.1.2 Macro/small cells ratio

According to the Small Cell Forum, there were 7.9 million small cells in the world at the end of 2013 but 98.7% of those small cells were femtocells. We thus take the hypothesis there was 1 macro cell site for 1 small cell. We assume that this ratio is similar for the EU.

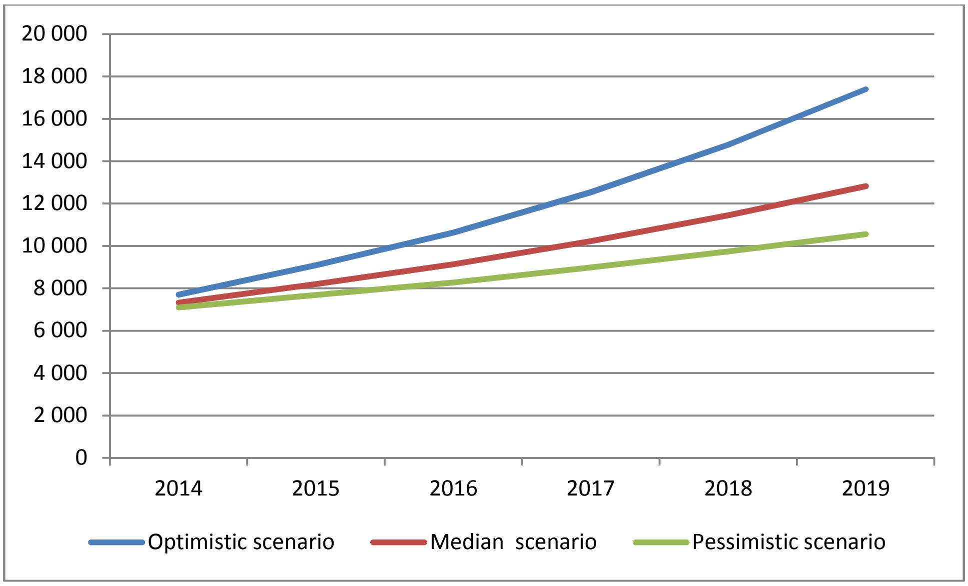
3.3.4 The small cells market

3.3.4.1 Wordwide

We made three different scenarios assuming different evolution paths for the ratio macro / small cell. The pessimistic scenario assumed there would be 5 macro cell sites for 10 small cells. In the evolutionary scenario, we assumed that by 2024, there would be 3.5 macro cell sites for 10 small cell sites. To end with, in the optimist scenario, we assume that there will be 2 macro sites for 10 small cell sites. The three scenarios are illustrated in figure 18.

[4] 2014 figures not yet available

Figure 18: Growth of the small cell installed base (in thousands) – worldwide



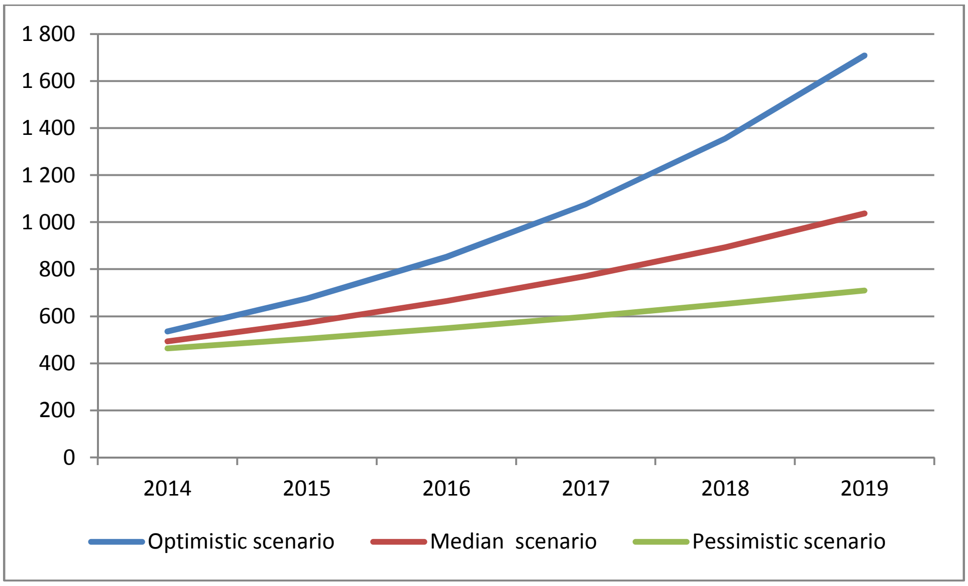
Source: IDATE

According to our median scenario, we forecast that in 2019, the small cells installed base will reach 12,816,000 units wordwide.

3.3.4.2 Europe

We made three different scenarios assuming different evolution paths for the ratio macro / small cell. The pessimistic scenario assumed there would be 5 macro cell sites for 10 small cells. In the evolutionary scenario, we assumed that by 2024, there would be 2.5 macro cell sites for 10 small cell sites. To end with, in the optimist scenario, we assume that there will be 1 macro sites for 10 small cell sites.

Figure 19: Growth of the small cell installed base (in thousands) in EU 27



Source: IDATE

According to our median scenario, we forecast that in 2019, the small cells installed base will reach 1,036,000 units in Europe (EU 27).

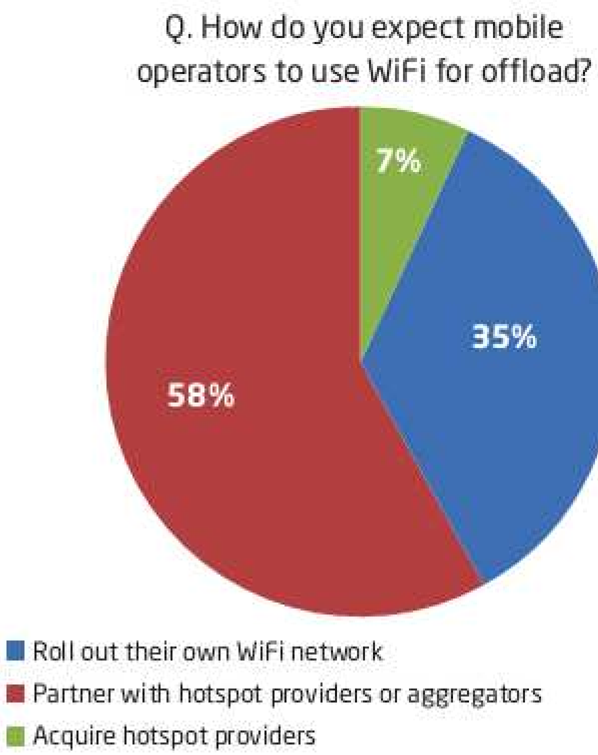
4 CARRIER WIFI MARKET

Although small cells enable operators to bring more capacity and coverage in densely populated areas, WiFi may complement this solution by intelligently off-loading traffic. WiFI has been available for a long time, even from operators, but up to now, people had to go through a whole registering process that didn't make the service seamless. Users surely have an interest to connect to WiFi whenever possible in order to avoid using their mobile data allowance but as long as the process of using WiFi is not seamless, no massively adopted behaviour is possible rendering offloading useless.

With the development of Hotspot 2.0 and the use of EAP-SIM and EAP-TTLS, things are about to change with the possibility for seamless registration of users either based on SIM credential (EAP-SIM) either based on login and password (EAP-TTLS) to support non-SIM based devices such as tablets. With the further capabilities of carriers to support handover between WiFi and cellular network (Dual Stack Mobile IP) or even the possibility to maintain both cellular and WiFi connectivity for specific services, carrier WiFi is set to become, together with small cell deployment a cornerstone of operators' strategies in two to three years from now.

Mobile operators are already benefiting from Wifi offloading and they are likely to increase their involvement in Wifi access points as shown in Figure 20.

Figure 20: Expected use of WiFi for offload by operators



Source: Accuris network

4.1 Seamless offloading

4.1.1 Hotspots 2.0 specifications (passpoint)

Established in 2012 by the Wi-Fi Alliance and promoted and supported by the Wireless Broadband Alliance[ix] (WBA), Hotspot 2.0 is a technical specification. It is not a necessity for seamless WiFi offloading even if it is intended to make WiFi use very close to cellular technology.

4.1.1.1.1 Progress of WiFi Certified Passpoint programme

The WiFi Certified Passpoint is an interoperability programme that ensures that WiFi networks and WiFi devices designed by various vendors can work properly together. Passpoint-certified devices will search for and seamlessly and automatically establish WPA 2-secured WiFi connections.

In mid-2012, four UK operators – BSkyB, BT, Everything Everywhere (EE) and TalkTalk – signed an agreement to start field trials within the WiFi Certified Passpoint programme late in 2012. The trials were a step within the WBA schedule that is set to lead to the deployment of the first Next Generation hotspots using WiFi Certified Passpoint equipment in H1 2013.

The Passpoint programme answers a real need of consumers and their calls for more simplicity and security. In fact, according to the Wi-Fi Alliance, large proportions of WiFi users are ready to switch to this technology immediately if it was offered by WiFi providers.

4.1.1.1.2 IEEE 802.11u: Network discovery and selection

IEEE 802.11u was published on 25 February 2011. It allows access to a WiFi network without a need for a SSID stored on the mobile device in a specific list.

When the 802.11u functions on the WiFi access point and on the mobile device, the handset continually sends queries for the different APs searching for the network access identifier (NAI). This is a list that regroups all the names of mobile providers whose clients are allowed to move automatically from cellular connectivity to a WiFi one. Whenever one's mobile operator is on this list permission is given to the device to automatically authenticate access to the WiFi access point.

802.11u is not a prerequisite for deploying carrier-class WiFi in order to enable WiFi offload. It does, though, make it more efficient; it facilitates roaming on WiFi partner networks; and it can even adapt to other features such as the type of the WiFi network the handset is going to connect to and the specific location of the user.

4.1.1.1.3 802.11i technology

802.11i-2004, implemented as WPA2, is included in Hotspot 2.0 technical specifications. The technology has been in existence since 2004 and is currently implemented in almost all the carrier-class WiFi products.

IEEE 802.11i or 802.11i-2004 brings an improvement to the IEEE 802.11-1999 with the Robust Security Network (RSN) that uses two protocols: the Group Key Handshake and the 4-Way Handshake.

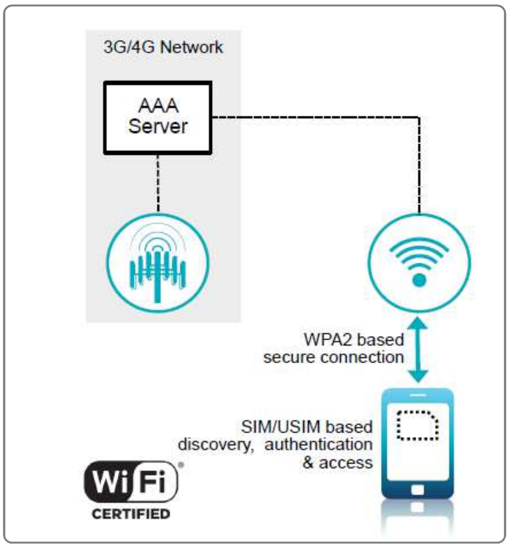
With the use of the RSN, the network only communications to be established using the robust security network associations (RSNAs) that assure data integrity and give the established communication an enhanced confidentiality.

Passpoint technology was standardised by the Wi-Fi Alliance and provides enhancements for public WiFi hotspot users, for both enterprises and consumers:

- Roaming capabilities allow access to visited hotspots when travelling.
- Security with the support of 802.11i and WiFi Protected Access (WPA).

Passpoint is a key enabler for mobile operator data offload in public hotspots. An example of seamless 3G/4G/Wifi roaming is shown in Figure 21.

Figure 21: Passpoint – seamless 3G/4G/WiFi roaming



Source: Qualcomm

The major advantage of Passpoint is provision of automatic discovery and access with no user intervention. Authentication for 3G/4G/ is SIM/USIM-based. Roaming is provided among WiFi networks and between 3G/4G WiFi networks. Deployments of Passpoint started in 2013.

4.1.1.2 Adoption of Hotspot 2.0 by device manufacturers

It is important to understand that Passpoint is the brand for the certification programme operated by the Wi-Fi Alliance based on the Wi-Fi Alliance Hotspot 2.0 specification.

Laboratory tests started at the end of June 2012 and implementation of additional features may happen during H2 2013. 14,000 devices are to be certified Passpoint. The first to be declared as certified by the Wi-Fi Alliance are:

- BelAir 20E
- Broadcom Dualband 11n WiFi and Dual Band 802.11n Access Point
- Cisco CT2500 Series WLAN Controller and LAP1260 Series Access Point
- Intel® Centrino® Advanced-N 6230
- Marvell Plug – 88W8787 802.11 a/b/g/n Reference Design
- MediaTek Hotspot 2.0 Client V1
- Qualcomm Atheros Dual-Band XSPAN™ 3-Stream 802.11n Access Point and Dual-Band XSPAN 2-stream 802.11n WLAN Adapter
- Ruckus Wireless ZoneFlex 7363 and ZoneDirector 1100

Samsung and Apple now support Passpoint with Hotspot 2.0 specifications in the Galaxy S4 and Apple iOS 7 smartphones. This represents a major support for mobile operators willing to implement Hotspot 2.0 rapidly.

4.1.2 Roaming

When it comes to WiFi offload, operators are currently facing two main choices regarding the need to expand the base of accessible WiFi hotspots for their clients:

- Either they roll out their own access points on a massive scale, or
- They conclude multiple roaming agreements with such WiFi players as Boingo Wireless or Fon.

Both strategies have their pros and cons, but globally it seems that the second choice is the one being adopted increasingly by carriers. Even the largest carriers with wider WiFi networks – AT&T is an example – are inking roaming agreements.

In January 2013, AT&T announced an international roaming programme that was the first to automatically connect customers to WiFi hotspots through SIM authentication when roaming abroad. SIM authentication is one of the key features of the Next Generation Hotspot (NGH) programme which uses Passpoint-certified equipment running on the Hotspot 2.0 standard.

Other mobile operators involved in this trend are NTT DOCOMO, China Mobile, KT and Orange. The technology is expected to start being widely deployed in 2014.

4.1.2.1 Advantages

It is hard indeed to find an example of an industry in which size matters more than in telecoms. It is the very stuff of network industries. The problem is, though, that it is often impossible for an operator to extend its network everywhere, especially in countries where it has no presence or where it does not hold a strong position.

As reported above, AT&T illustrated this 'roaming agreement' approach well by partnering with one of the leading WiFi players, Boingo Wireless.

AT&T subscribers to the 'Data Global Add-On with WiFi' package, which costs 60 USD for 300 MB or 120 USD for 800 MB, will benefit from 1 GB free of charge on the Boingo network on US territory or abroad.

More broadly, roaming agreements can induce benefits for mobile carriers that go beyond the simple act of extending the footprint of services accessible for their subscribers.

The advantages of multiplying roaming agreements are as follows:

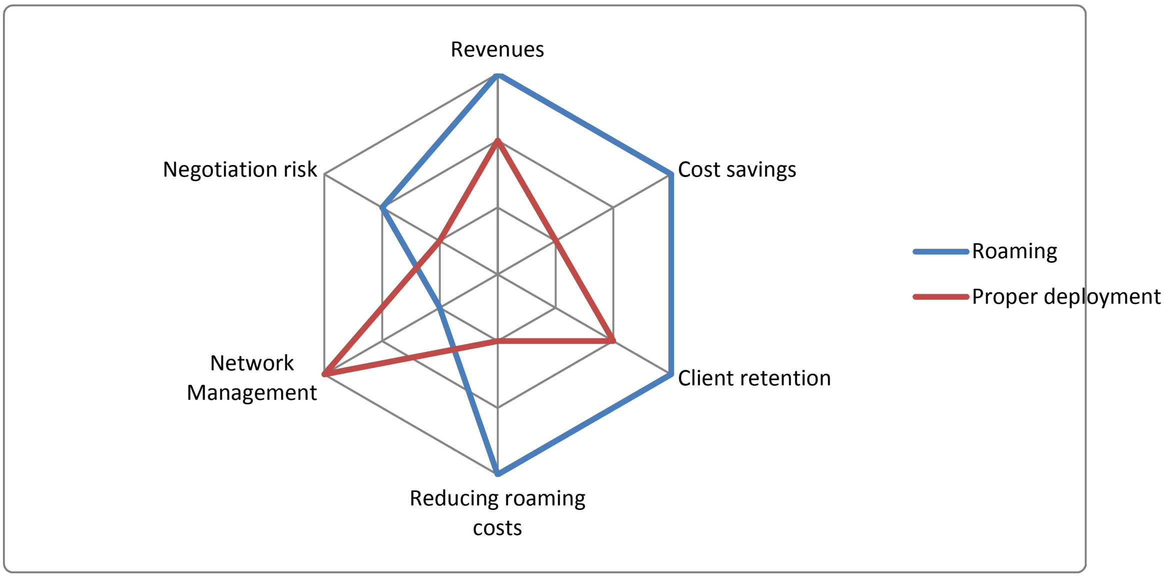
- Increasing revenues: Roaming partnerships will allow players to increase revenues more than individual initiatives. For example, in the AT&T-Boingo agreement, the American carrier benefits from revenues collected from Boingo when its subscribers enter the US territory and connect to AT&T hotspots. They represent potentially almost 300,000 new customers for AT&T.
- Savings on network rollout: Currently, the AT&T WiFi network counts 32,000 hotspots. Partnering with Boingo would enlarge its network by 700,000 additional access points, or nearly 22 times the size of the carrier's current network. The savings here can be counted in billions of dollars.
- Client retention: WiFi services are currently offered by almost all operators as free add-on services, generally as a way to offer ubiquitous coverage for their mobile customers who thus have greater overall client satisfaction and consequently feed client retention. Such a deal between the two players will be a solution for AT&T to reduce the bill-shock effect that frequently occurs when mobile subscribers travel abroad. It is also a way to reduce the frequency of this cause of dissatisfaction.
- Reducing roaming costs: This point is fundamental, especially for small-size operators who have to endure rather asymmetrical and unfavourable financial revenues for roaming. Their being able to push their customers to seamless WiFi on partner networks will be a means to cut down roaming costs.
- Standardisation: Establishing roaming interactions between global WiFi players and large operators with a WiFi network already is one way to push standardisation worldwide. This will benefit the WiFi industry globally, as well as mobile carriers that can both interact with other pure WiFi players or other mobile operators and decrease their capex when investing in cheaper WiFi infrastructures.

4.1.2.2 Risks

The other side of the coin is that choosing to expand a WiFi network through roaming agreements includes at least two major risks for operators, as shown in Figure 22:

- Losing control of network management: As seamless WiFi offload gains popularity as the next big leap in data offloading, integrating the WiFi network to the pre-existing network and managing the interaction between both networks is a major key for success by operators. It is indeed the case that operators who roll out their own network can manage the level of interaction between radio and core networks; implement their own rules of traffic management; easily choose to adapt hardware to their services; or simply select the location where implanting APs is the best financial choice for them.
- Market risk: This risk is of course inherent to outsourcing on a market. Choosing to outsource WiFi activity through roaming partnerships brings risks for the mobile carrier which is mainly linked to the position held by the WiFi player on the market. Partnering with a single player occupying a monopolistic position may be tricky for small operators who may not be able to fix the price of the service at their convenience. In reality though, the market of WiFi global players is an oligopoly, since there are few players operating worldwide.

Figure 22: WiFi roaming, Advantage-risk diagram



Source: IDATE

4.1.3 Handover between WiFi and cellular technologies

Beyond seamless discovering and connecting to a WiFi access point, mobile devices must be able to make smart handover decision betwee WiFi and 3GPP network depending on criterion such as the real time performance of each access network. To enable this, different technologies have been developed by the 3GPP. While some of them are already available in commercial products, some other are still reserved for future usage

ANDSF

Access Network Discovery and Selection Function (ANDSF) is a function that was introduced in LTE Rel 8 to bring network selection rules and capability to LTE devices when non 3GPP networks are available. It was first defined in LTE Rel 8 and further allow in Rel 10 simultaneous connection to 3GPP and non 3GPP access. This means that a device can be connected to a cellular network and to a WiFi network as well. This multiple access can be provided differently with Mapcon (Multi Access PDN Connectivity), IPFOM (IP Flow Mobility) or Non-seamless offload.

ANDSF works on a server/client architecture, where the device's ANDSF client connects to the server to get the network selection policy depending on where the device is. Once the device is connected to an offloaded network such as WiFi, it is still connected either to the visited or Home Operator ANDSF server to possibly select another network if the network conditions evolve. The connection to the server is secured differently depending whether the offloaded network is considered trusted or untrusted.

ANDSF doesn't currently use all the data collected by Passpoint, especially traffic load data are not yet used. Some vendors have developed proprietary solutions to overcome those pitfalls but standardized solutions are essential to drive adoption among carriers.

Other technologies

Other technologies have been developed to complement ANDSF and improve integration of WiFi into 3GPP networks

- SaMOG, which stands for S2a Mobility based on GTP (GPRS Tunelling Protocol) is a feature introduced in LTE Rel 11 aimed at securing connection between the device connected to an access point and the MNO core network. With LTE Rel 12, SaMOG enable devices to take network selection decisions based on traffic load real time data
- IP Flow Mobility, Multi Access PDN Connectivity are different ways of supporting the connection of a device to multiple Radio Access Network at the same time. It enables only some part of the traffic to go through the WiFi access point while the other part is still being processed by the cellular network. In one case (IP Flow Mobility), both 3GPP and non 3GPP are connected to the same PDN (Packet Data Network). In the other case (MAPCON), each network interface is connected to different PDN.

4.2 Carrier WiFi market

The carrier WiFi market has existed for a long time. It is made up of pure players (operators only providing WiFi access) and carriers that have turned to develop their own access point, first as a way to extend their business, but then also as a way to enable data offloading. Because WiFi access point are to become complementary to small cells, it is to be expected to see more and more deals between the various players, either carrier or pure players. A related business case could see pure players and operators monetize the knowledge they have on customers logging in on their hotspot to sell them to retailers. We would be in a B2B2C where retailer would pay operators to provide internet access for free to retail's customers and as a result get information on those customers. This would drive the widening of hotspot networks and make the positioning of those hotspots even more strategic.

In this scenario, we may think that operators could have more information to leverage than pure players though.

4.2.1 Pure players

Pure players have often been the first players to invest on WiFi technology as a means of providing broadband access, generally in public places at a time where mobile internet did not exist. Additionally, providing easy access to the internet abroad and away from services of its own operator or ISP became the added value of those players.

Today most pure players have developed partnership with operators to complement their own WiFi offering and the convenience of their triple/quadruple play broadband services. The interest for operators to partner with pure players is indeed more a question of convenience for their subscribers than a way to increase network offload.

There might be a business case for becoming a wholesale access provider for network operators in their countries of operations but we see this scenario as not very likely to occur.

Main WiFi pure players are presented in table 12 below:

Table 12: WiFi pure players

Name	**Hotspots '000**	**Revenues '000 EUR**	**Comments**
Fon (Spain)	12450	28000	Fon is a community WiFi router provider that works on the following principle: whenever an individual or a business installs a Fon WiFi router it has to share a part of its signal with other Fon subscribers. In return, the client can have access to other Fon WiFi routers across the world.
iPass **(USA)**	2200	83756	iPass[x] manages the largest WiFi network in the world composed of more than 1.2 million hotspots across 123 countries distributed as follows (as of December 2013): • Europe: 680,00 • Asia: 914,00 • North America: 537,00 • Oceania: 1,900 • MEA: 8,300 • Open access WiFi: 61,303 In 2012, iPass started partnerships with operators. The WiFi player counts SK Telecom, Etisalat and China Mobile among its clients.
Boingo Wireless **(US)**	700	78313	Boingo Wireless is a pure WiFi player created in 2001; it started with 400 access points. The provider moved quickly to install its hotspots in large venues such as airports and hotels to serve business travellers in particular.
Trustive	700	3000 (estimates)	Founded in 2003, Trustive is one of the largest European WiFi providers. The company has partnered with 80 operators including BT, China Mobile and Telefónica, to offer access to 700,000 hotspots across 130 countries with WiFi plans that range from per minute plans to tiered prices.

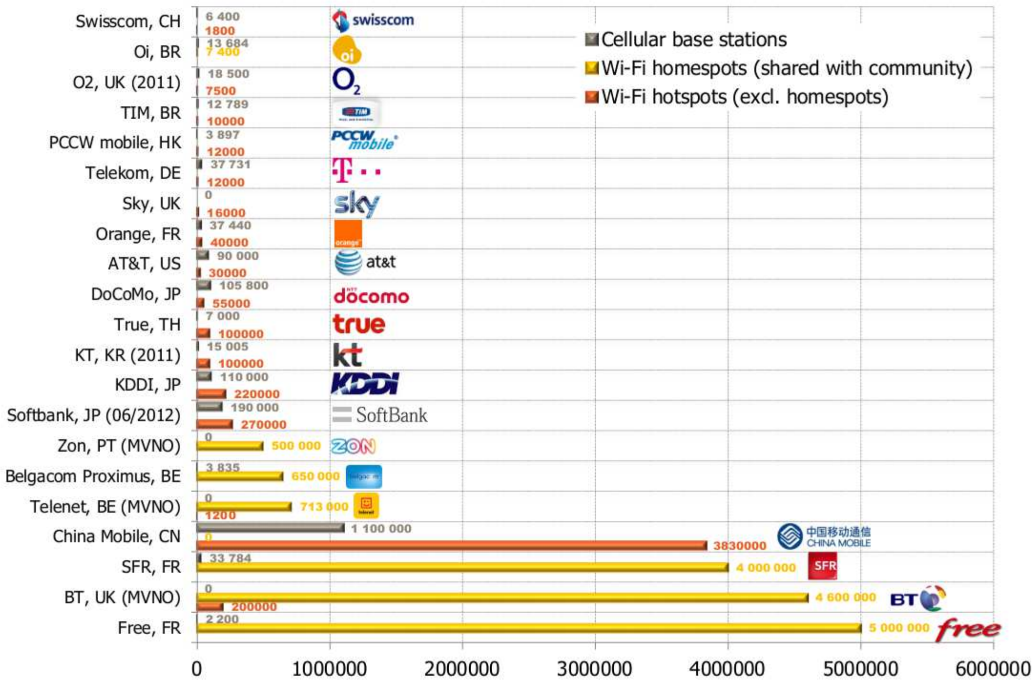
The Cloud (BSkyB) **(UK)**	30	28241	The Cloud is a WiFi provider acquired by BSkyB in 2011. It owns and manages more than 30,000 WiFi hotspots in the UK. Besides offering WiFi services to its six million registered customers, The Cloud offers several partnerships with businesses such shopping centres in order to provide them with, for example, access to its customer base so as to allow targeted-management actions. The provider also allows shops to develop services including cross-selling or to include WiFi within their marketing strategy
Airangel	15	1600	Airangel is a WiFi access provider that installs and manages WiFi networks in business buildings and venues. It specialises in hotels. From an end-user point of view Airangel is completely seamless. It offers white-branded solutions to hotels and venues, which brand the WiFi access with their own name and are free to charge it or not to their clients.
Meteor Network **(France)**	2	NA	The Meteor Network is the leading pure WiFi player in France. Its services range from WLAN installation to network management.The provider deploys its networks in public and private venues but works essentially with hotels and restaurants.

Source: IDATE

4.2.2 Operators

With the time, operators have also developed their own hotspot/homespot services, this time rather as a way to provide added value and differentiate on the market but also as a way to somehow offload one part of data traffic which has exploded with the development of the smartphone and tablet market. Not all operators have deployed a network of hotspot and neither have they reached the same coverage/availability, as Figure 23 highlights it. Table 13 shows the number of hotspot deployed by major operators.

Figure 23: Comparison between cellular infrastructures and number of WiFi access points



Source: Tefficient[xi]

Different profiles of operators can be determined depending on the rationale for their homespots / hotspots deployment. Free/Iliad is an interesting example as the operator is the one with the most important number of homespots deployed.

Homespots are WiFi access points deployed on the subscribers Set Top Box, different from the one used by the subscriber himself but that share the common broadband access. Free / Iliad was one of the earliest operators to deploy and enable them on their customer devices. In the case of Free, homespots are clearly used as a means to offload the cellular network. This is all the more important for Free that have a still limited cellular network because of a late entry on the market. As a comparison, Free had a cellular network made up of 2,200 base stations as compared to SFR for instance and its 33,784 base stations to cover the whole country. Deploying WiFi access points at customer's premise is thus both a way to compensate a small network and a way to mitigate costs incurred by the roaming agreement with Orange. The data offload is made seamless thanks to the use of EAP-SIM.

Thanks to this strategy, Free/Iliad was able to quickly reach breakeven on EBITDA (Earnings before Interest, Tax, Debt and Amortization) level. As of H1 2012, the operator had a -44 M EUR EBITDA. It reached 2M EUR in H2 2012 and 54.2 M EUR in H1 2013. This is a result of Free's offloading strategy.

Table 13: Number of hotspots owned by operators

Operators	Hotspots '000 (2013)
NTT	120
AT&T	*30*
Verizon	5
China Mobile	3830
Deutsche Telekom	12
France Telecom	40
KDDI	220
Softbank	460
BT WiFi	192
China Telecom	1000

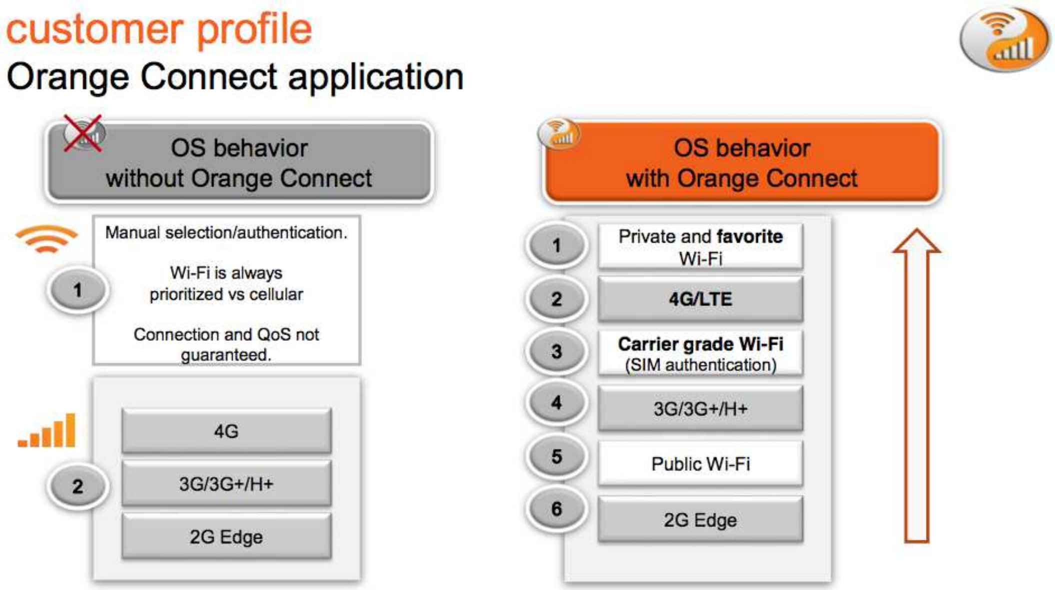
Source: IDATE

4.3 Operators strategies

4.3.1 Orange

Orange France is believed to have 40,000 hotspots in France in addition to the Livebox being used as homespot since 2012. The number of Livebox with homespot features enabled is not known. In the feature, Orange could use those trusted WiFi access points as seamless mobile data offloading tool. It has already stated that WiFi was part of Orange's strategy to offload its cellular network and the contribution of Orange to the development of Hotspot 2.0 is also of public knowledge so the deployment of small cells with WiFi support should not come as a surprise. Orange Connect Application, shown in Figure 24 represents an example of such implementation.

Figure 24: Orange connect application



Source: Orange

In addition to including WiFi consumption in its classical mobile plans known as 'Origami' allowing its mobile customers to enjoy unlimited WiFi connections to Orange hotspots in France, the carrier also markets WiFi prepaid and postpaid plans.

The prepaid offers, shown in Figure 25 range from a pay as you pass priced at 4.50 EUR per hour to a 30-day pass costing 19.90 EUR.

Figure 25: Orange prepaid WiFi subscriptions

Source: Orange

The postpaid plans presented in Table 14 are called Business Everywhere (BE) and include 3G and WiFi connections. Indeed, in addition to 3G services, the subscriber can have unlimited use of the Orange WiFi network and ten hours on partner WiFi networks.

Table 14: BE plans

Offer	Price	3G	WiFi
BE Basic	5 EUR/month	1 Mb	Unlimited access on Orange networks plus 10 hours on partner networks
BE Libre	98 EUR/month	unlimited	Unlimited access on Orange networks plus 10 hours on partner networks

Source: Orange

4.3.2 KDDI

KDDI is the number 2 operator in Japan with 39 million subscribers as of Sept 2013 and a network whose number of base station is estimated to be superior to 100,000. KDDI has deployed around 220,000 hotspots complemented by 1.65 million residential WIFi units.

As shown in Figure 26, it is currently offloading a sizable share of its mobile data traffic with WiFi, since 43% of mobile data traffic was offloaded on the WiFi network deployed by Ruckus Wireless during busy hours. Offloading is supported through a specific solution implemented on Android devices. It is not clear whether and how iPhones are supported in that respect.

Figure 26: Share of mobile data traffic offloaded on WiFi and Wimax

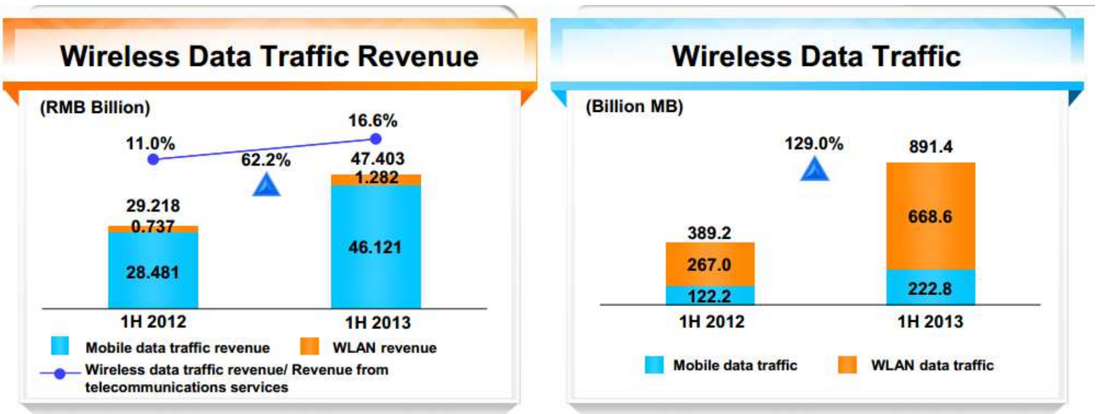
Source: Tefficient based on operator quarterly report

4.3.3 China Mobile

China Mobile has developed the biggest WiFi hotspot network in the world with 4.2 million access points as of mid 2013 (excluding homespots) around the country. According to their initital plans, 6 million hotspots were to be deployed by 2016. This mass deployment strategy could be understood in regard of the fact that China Mobile had found it difficult to gain as much market share on 3G as on 2G because of the difficulties related to the homegrown 3G technology they had to use (TD-SCDMA). This partly explains the high share of wireless data traffic being carried by WiFi as compared to cellular technology. The small share of revenue derived from those hotspots highlight the offload function of the WiFi hotspot. China mobile has stated that half of the traffic offloaded on WiFi hotspots was offloaded seamlessly. See Figure 27 for more details on China Mobile wireless data traffic figures.

With the launch of TD-LTE network, this share should start to decrease, especially as the company announced in July 2014 that it would stop investing in the roll-out of its carrier WiFi network, stating that it did not generate enough revenues, accounting for 74% of data traffic but representing only 2.6% of the revenues. Instead, China Mobile will focus on the deployment of its TD-LTE network.

Figure 27: China Mobile wireless data traffic

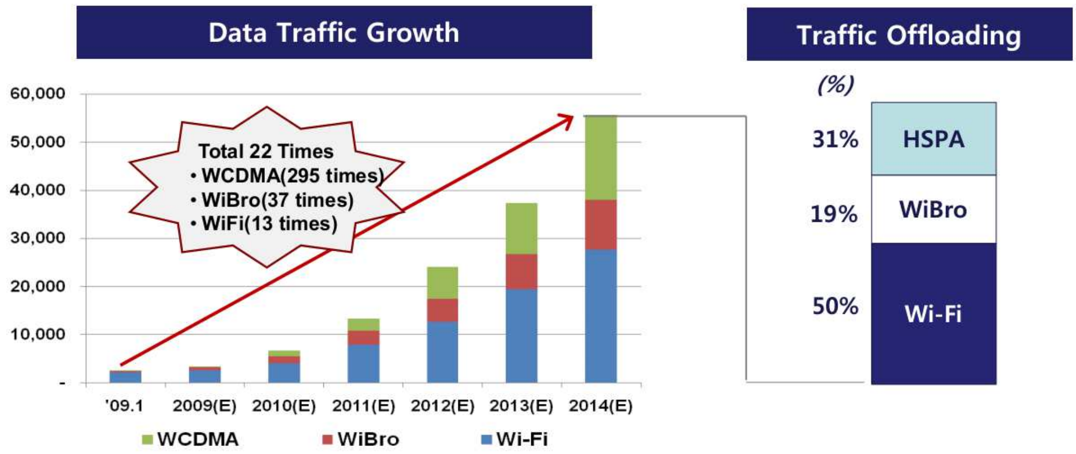


Source: China Mobile

4.3.4 KT

KT has around 15000 base stations and around 100,000 WiFi hotspots. It started to have its own dedicated WiFi service called olleh WiFi but appears to support data offload although it is not known how this would be supported. As shown in Figure 28, Wifi carries 50% of the traffic generated by KT' mobile devices and Wibro 19%.

Figure 28: KT data traffic offloading



Source: KT

4.3.5 AT&T

AT&T has a relatively small network of WiFi hotspots deployed in the US, around 30,000 at the end of 2012 but this network is comparatively the biggest one in the US if we compare it to its carriers' competitors. Verizon, for instance had only 5,000 such hotspots.

Reportedly AT&T recorded more than 2.7 billion connections to its WiFi network during 2012, more than double the number recorded in 2011. Of those 2.7 billion connections, 80% come from AT&T customers (as opposed to users of operators with a roaming agreement with AT&T). This year, the mobile data traffic also tripled to 5.2 million MB. However, this only represents a small share of the total mobile data traffic (around 1%) as of mid-2012.

In addition to its own network of hotspots, AT&T has passed agreements with other hotspot networks and claims to have more than 402,000 hotspots available worldwide to its customers in more than 100 countries.

4.4 Carrier WiFi advantages

4.4.1 Different technologies (from 802.11b to 802.11ac)

WiFi, as standardised by IEEE, uses unlicensed frequency bands in the 2.4 and 5 GHz frequency bands. The latest technical improvements involve wider bandwidth and the use of MIMO to boost data rates. The various WiFi generations and their respective characteristics are presented in table 15 below.

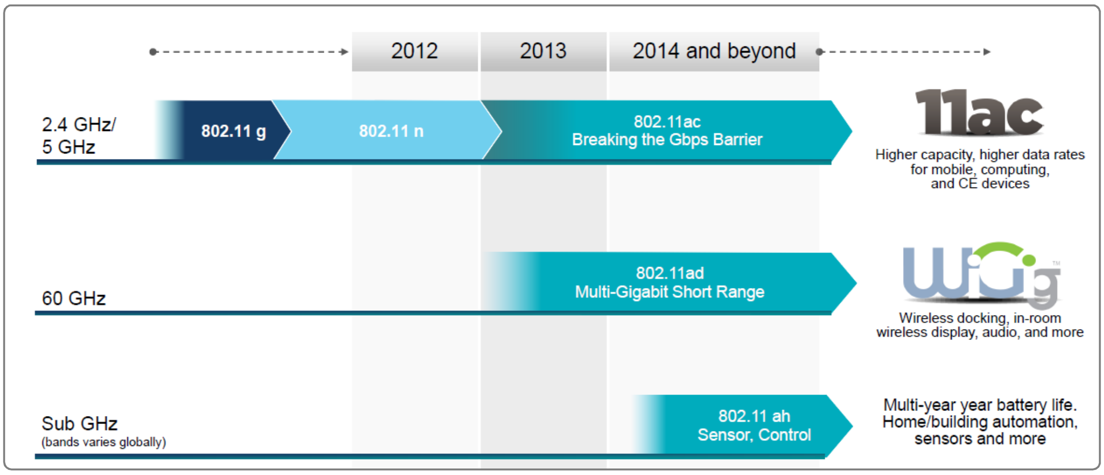
Table 15: WiFi generations

WiFi generation	Date of release	Frequency band	Bandwidth	Maximum theoretical data rate	MIMO	Outdoor range
802.11a	1999	5 GHz	20 MHz	54 Mbit/s	No support	~110 m (5 GHz)
802.11b	1999	2.4 GHz	22 MHz	11 Mbit/s	No support	~130 m
802.11g	2003	2.4 GHz	22 MHz	54 Mbit/s	No support	~130 m
802.11n	2009	2.4 and 5 GHz	20 MHz, 40 MHz	Up to 600 Mbit/s (in 4x4 MIMO and 40 MHz bandwidth configuration)	Up to 4 x 4	~240 m
802.11ac	2012	5 GHz	20, 40, 80 or 160 MHz	Up to 6.77 Gbit/s (in 8 x 8 MIMO and 160 MHz bandwidth configuration)	Up to 8 x 8	n/a

Source: IDATE

802.11ac is now being implemented in a variety of devices including smartphones and tablets. The 60 GHz band will be used by the 802.11ad version of WiFi and will allow very high data rates for short-range communications.

Figure 29: WiFi evolution path



Source: Qualcomm

4.4.1.1 802.11a and 802.11b

WiFi generations 802.11a and 802.11b were developed at the same time and the two generations were released at the same time in 1999.

802.11a delivers a theoretical data rate up to 54 Mbit/s in the 5 GHz band. The use of higher frequencies leads to an increased sensitivity to obstacles. Besides the higher cost of implementing 802.11a, WiFi led the 802.11b generation to quickly become more popular than the 802.11a standard.

Furthermore, due to the difference in implementation cost, the 802.11a standard found itself being used principally by businesses while 802.11b spread widely among consumer products, to such a point that many users think that 802.11a was developed after 802.11b.

The 802.11a and 802.11b standards are incompatible with each other. Even if some vendors have marketed multi-mode networks working with both WiFi generations, such cases have been very few and far between, and such networks were not common.

4.4.1.2 802.11g

Products supporting the 802.11g WiFi generation emerged on the market in 2003. The purpose behind the new standard was to adopt the positive aspects of both 802.11a and 802.11b. It means a high data rate working in the 2.4 GHz band. This detail allowed 802.11g devices a full compatibility with 802.11b networks and vice-versa.

Due to widespread popularity, the already-crowded 2.4 GHz band had to support large numbers of mobile devices especially laptops that were converted from dual-mode (a/b) to tri-mode (a/b/g). This led to a certain degree of suffering from interference especially with Bluetooth equipment.

4.4.1.3 802.11n

Released in 2009, the WiFi 802.11n generation experienced the strongest and fastest rate of adoption ever known among WiFi standards. This new standard was developed to improve the data rate supported by the 11g standard through using MIMO.

Since there was undoubtedly a significant gain in performance between 802.11g and 802.11n standards, the rates of migration from 11g and the adoption of 11n by businesses were unprecedented. Indeed, one-third of businesses indicated, some time before the 802.11n release, that they were ready to migrate to or adopt 802.11n by the end of 2010.

Besides, high download rate capacities made the 11n generation the ideal candidate for multimedia usage. In less than three years between 2009 and 2012, this generation was implemented on almost all currently commercialised mobile devices, ranging from smartphones to laptops including tablets.

By December 2012, the transition to 802.11n was almost complete with 84% of WiFi access point shipments based on the WiFi 802.11n generation.

4.4.1.4 802.11ac

Released in December 2012, the 802.11ac generation allows functioning with several configurations depending on the choice of bandwidth (from 20 MHz to 160 MHz) and the MIMO setting (up to 8 x 8).

Given that every configuration allows a certain data rate, scenarios of use present the possibility of adopting the configuration by the type of device on which 802.11ac is implemented. For example, television sets with 4K resolution can be configured up to 8 x 8 MIMO using a bandwidth of 160 MHz for ultra-HD streaming. Meanwhile, handheld devices can function with a single antenna configuration on 80 MHz bandwidth.

This flexibility will certainly be one of the major elements in the widespread dissemination of the 802.11ac generation.

During the MWC 2013 in Barcelona, the South Korean operator SK Telecom demonstrated WiFi routers working on 802.11ac and able to deliver data rates up to 1.3 Gbit/s. The carrier indicated its intent to bring these routers to market during 2013. As for the implementation of the standard in access points and mobile devices, the first products were expected to be shipped in Q3 2013, thereby boosting the growth of the WLAN market. It passed the milestone of 1 billion USD for the first time at the end of 2012.

802.11ac chips have started shipping in significant quantities in 2013. We expect that, by the end of 2014, 802.11ac will be included in close to 50 per cent of all WiFi systems produced.

4.4.2 Seamless handover (Hotspot 2.0)

Hotspot 2.0 is a technology aimed at enabling seamless authentication and connection to a WiFi network using either SIM or non SIM credentials (see 4.1.1). Its main advantage is that it makes the offload transparent to the user, meaning that he doesn’t have to manually fill-in credentials to use a WiFi hotspot. Instead the user will be connected without even knowing it or doing anything. This of course brings convenience to the end-user but more importantly multiply the potential for data traffic offloading. Also, it makes WiFi roaming agreements easier to implement.

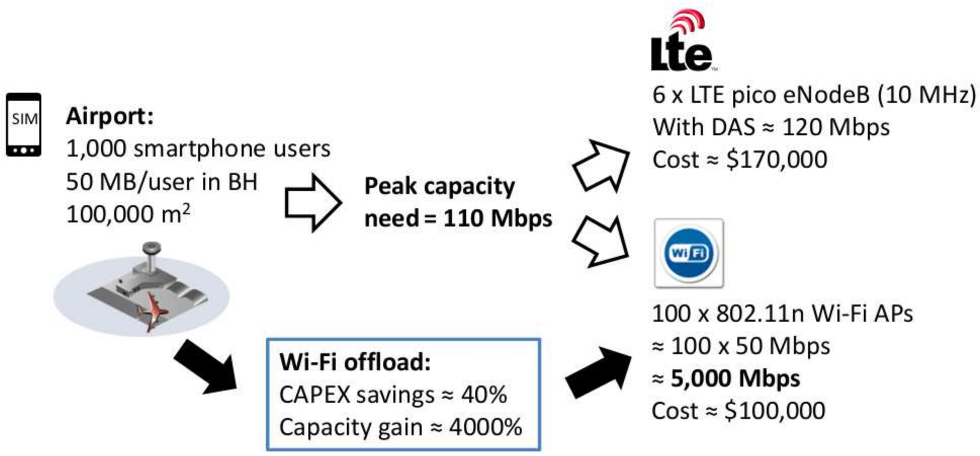
Here are some specs and standards on which Hotspot 2.0 is based:

- Secured connection (WPA2).
- Authentication technologies (EAP-SIM and EAP-TTLS).
- 802.11u: improvement of interworking with external networks.
- DSMIP : Dual stack mobile IP for seamless handover of traffic (Rel 8).
- IP Flow Mobility which is a part of the 3GPP Release 10, allows splitting the traffic between a WiFi network and a cellular network for a given application, for example.

4.4.3 Capex reduction

Because WiFi is an unlicensed technology available in nearly all mobile devices it has enabled the development of a very wide network and user equipment ecosystem. The direct impact of this is more affordable infrastructure and thus reduced CAPEX as shown in Figure 30.

Figure 30: Cost advantage of WiFi deployment in small cell environment



Source: Hetting Consulting

4.5 Market forecast

4.5.1 Industry sources

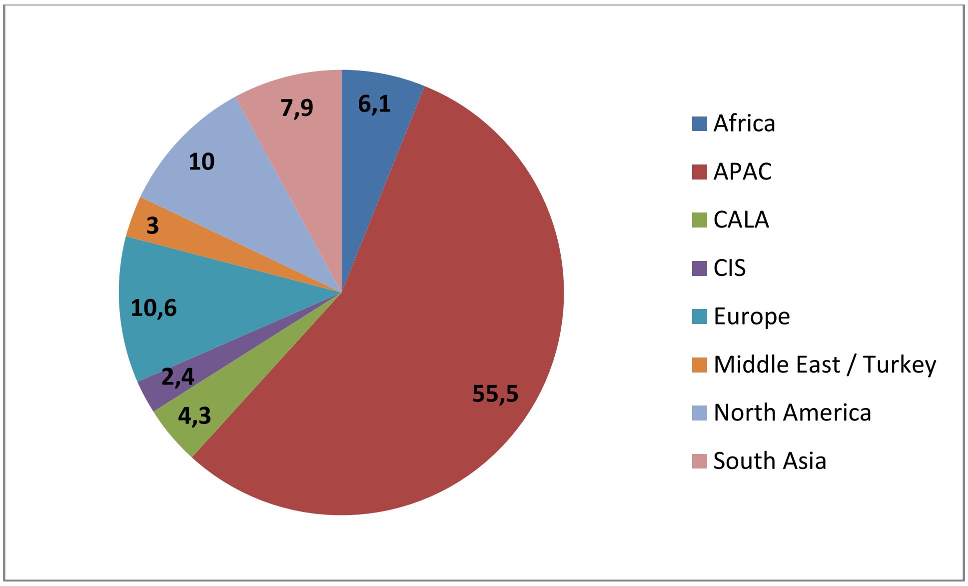
According to ABI research, 4.2 million WiFi hotspots deployed by both operators and pure players had been deployed worldwide in 2013 and expectations are they will pass the 7 million threshold in 2015 and 10 million mark in 2018.

As mobile traffic continues its rapid growth and capacity limits are tested by subscribers, operators are increasingly committed to integrating WiFi within their wireless broadband infrastructure, either by extending their own hotspot network, either by integrating WiFi right in their mobile network with small cells also supporting WiFi.

According to a survey carried out by the Wireless Broadband Alliance, tier 1[5] operators expect to have 75% of their small cells deployed with support for WiFi offload by 2018. As a result, it is expected that the cumulative number of WiFi hotspots including small cells with WiFi will reach around 55 million (excluding homespots). In those deployments (see Figure 31), Asia is expected to represent 55.5% of the total installed base, followed by Europe and North America with around 10% of the installed base only and South Asia with 8%.

[5] Tier 1 operators are leading operators in each market in terms of market share

Figure 31: Installed base in millions of carrier-grade hotspots by region 2018 (excluding homespots)



Source: Wireless Broadband Alliance

According to the same survey, by 2018, operators expect WiFi only to contribute 20% of additional mobile data capacity. A further 21% will come from small cells with integrated WiFi. This represents a shift in the market as most of WiFi traffic comes from non-mobile devices today.

4.5.2 Drivers and hurdles

4.5.2.1 Adoption drivers

4.5.2.1.1 <u>Interoperability</u>

WiFi technology is compatible with the older version of the standard, meaning that an old device for instance supporting only 802.11b will be capable to connect to the latest 802.11ac access points, although at the rate that 802.11b support. Conversely an 802.11ac device will be able to connect to a 802.11b access point. This enable access point to address every WiFi standard without having to deploy multiple access points.

4.5.2.1.2 <u>Increased integration with 3GPP networks</u>

Technologies such as Hotspot 2.0, ANDSF (Access Network Discovery and Selection Function), SaMOG, IP Flow Mobility, Multipath TCP … will enable a better integration of non-3GPP technology in cellular networks. User device will be dynamically offloaded to the most relevant network depending on network conditions, user status and data plan, enabling mobile carriers to better manage their users and implement smart offloading strategies.

4.5.2.1.3 <u>Increased use of the 5 GHz band</u>

While 802.11b only used the crowded 2.4 GHz unlicensed band, further releases have been developed to support the much wider and less crowded 5 GHz band. All mobile devices do not currently support this band but the increased penetration of latest WiFi standard will progressively enable less congested WiFi networks.

4.5.2.1.4 <u>Multiplication of non-cellular devices</u>

While mobile phones all support cellular connectivity, only a small share of non smartphone devices have an embeded cellular technology. It is often considered that 80% of tablets for instance are WiFi only devices. While one could argue that non-cellular devices are not supposed to be the business of mobile operators, those devices often belong to users with a mobile data plan with their smartphone. Addressing this market of non cellular devices is also a way to increase loyalty and potentially increase ARPU of mobile networks operators with support for WiFi.

4.5.2.2 Hurdles to adoption

4.5.2.2.1 Development of LTE-U

While LTE in the unlicensed band is still only a proposition part of the Rel 13 of LTE, due to be finished in March 2016, its adoption by operators would necessarily play against the use of WiFi by carriers on the long term.

4.5.2.2.2 Integration within the cellular network

While integration of WiFi to cellular networks will be improved in the years to come, it will require operators to implement new tools. Beyond the fact that those features are still relatively new and that operators have little experience with them, MNOs could prefer focusing on technologies they already know and that they will have anyway to deploy.

4.5.2.2.3 Radio interferences in the unlicensed bands

Last but not the least, unlicensed bands do not offer the same stability and quality of service that licensed bands can offer. This explains that unlicensed bands will probably be used only as a complement to licensed bands. In a worst case scenario, carriers could prefer to remain with their licensed spectrum.

4.5.3 Main assumptions

In our model, we assume that 65% of public hotspots are owned by fixed or mobile operators. In our different scenarios, we make different hypothesis regarding the percentage of small cells supporting WiFi in addition to cellular connectivity.

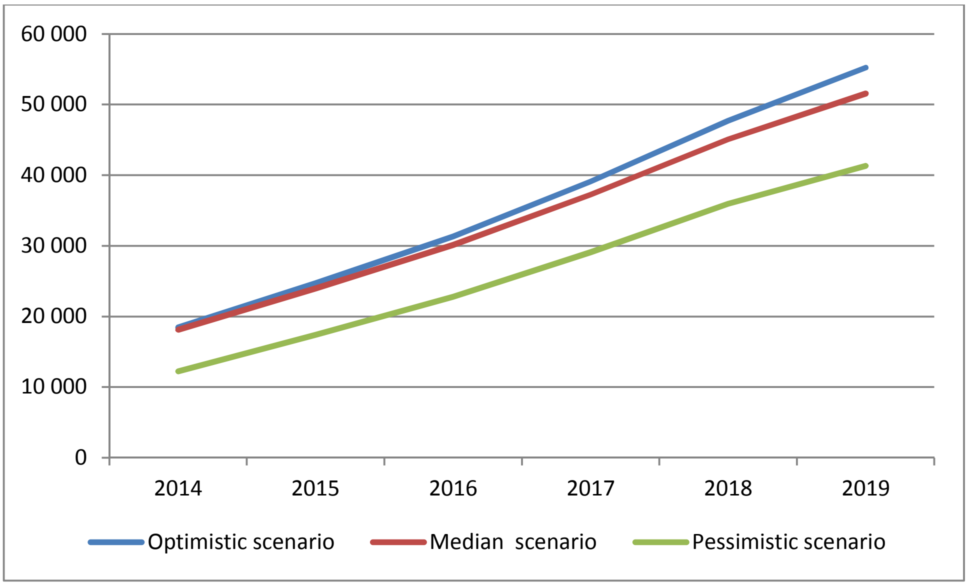
In the pessimistic scenario, we assume that 0% of small cells will support WiFi. In the median and optimistic scenario, we assume that 80% of small cells will support WiFi.

4.5.4 Forecasts

4.5.4.1 Worldwide

According to our median scenario shown in Figure 32, we forecast that in 2019, the total number of WiFi access points
installed base will reach 51,551,000 units wordwide from 12.9 million in 2013.

Figure 32: Installed base of WiFi access points worldwide (in thousands)

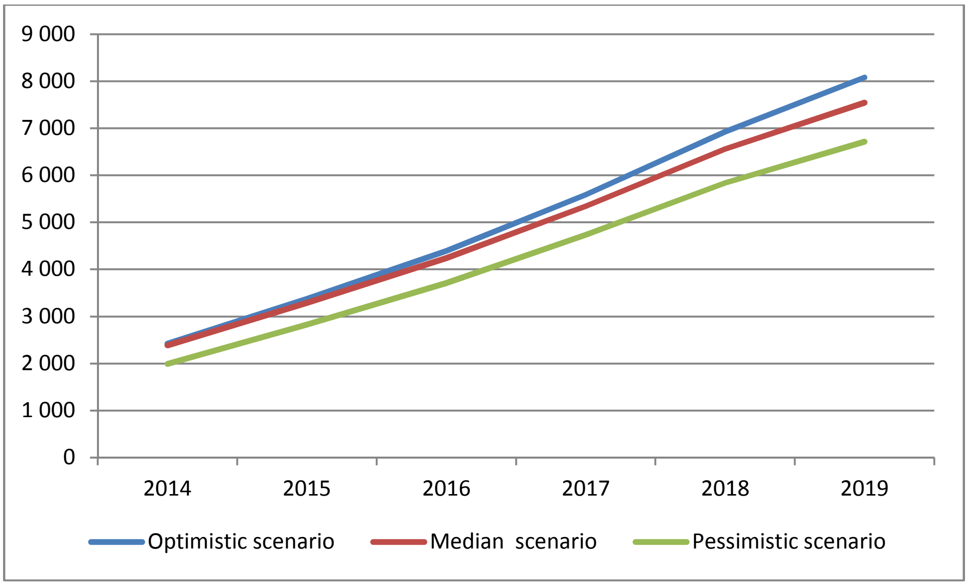


Source IDATE

4.5.4.2 Europe

According to our median scenario, we forecast that in 2019, the WiFi access points installed base will reach 7,546,000 units in Europe from 1.6 million in 2013.

Figure 33: Installed base of WiFi access points in EU 27 (in thousands)



Source IDATE

5 Technological evolution

If small cells, carrier wifi and more generally heterogeneous networks are part of LTE-Advanced, other features may enable other kind of off-loading for various users. Device to device, relay functions and LTE broadcast are other ways of using spectrum differently and more efficiently, especially for specific users such as PPDR.

5.1 Device to device and Relays

Devices to Device (D2D) and Relays, which are part of SHARING work, are two functions initially envisioned in LTE-Rel 12 to be frozen in September 2014. However some of those functions may be postponed to later releases, probably Rel 13 (frozen in March 2016) or for some of them even in Rel 14.

As for the Relay function, it enables a device to relay network signal to other devices possibly located outside of the network coverage. The obvious use case would be the extension of network coverage in case of disaster to enable better emergency response. In the Relay scenario, the device acts as a repeater, it doesn’t interfere with the signal, just transmits it. A device here may be understood in a broad sense; it could either be a smartphone, tablet, either a small device dedicated to extending coverage (e.g a Customer Premise Equipment).

5.1.1 Device to Device

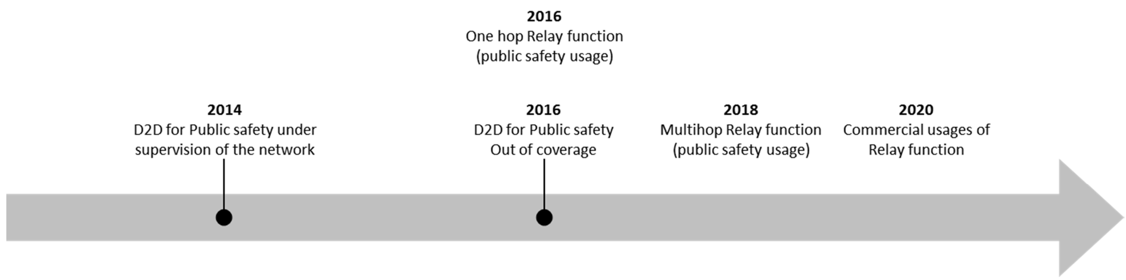
Device to Device is a mode that enables two devices to discover themselves directly and communicate with or without the need for a network. This is in some way similar to WiFi Direct, which use an ad-hoc connection between two WiFi device. When under supervision of the network however, the range can be longer, in the range of up to 1km. The discovery could even work when users would be located in different cells.

Although commercial usages are being discussed in the 3GPPP working group, focus is currently rather on public safety applications and use cases which foresee network supervision. The case where devices would be able to discover themselves without a network is not discussed (because of lack of resources) and will more likely not be discussed until later release of LTE.

Inside the working group, American people are focused on public safety use case with the idea of being able to bring TETRA functionalities to LTE and thus make the switch when possible. Few operators have pushed for the inclusion of commercial usages. Among those who reportedly showed interest in this use case is KDDI.

As a result of the work being done in the standardization group, use cases seem rather limited in the short term, since only Public Safety would be able to use this function of LTE and since discovery is limited to the situation of network coverage. The estimated timeline for D2D and Relay features availability is shown in Figure 34 below:

Figure 34: Estimated timeline for D2D and Relay features availability



Source: IDATE

However, usages for public safety are important as well and heavily rely on proximity services and discovery, something that the combined use of D2D and Relay mode will enable in the future, whether in Rel 12 or later.

Below are some examples of use cases envisioned regardless of works in the standardization group, some of which won't likely see the day in a short to mid term.

- Device discovery: it would be the first step. Discovering devices nearby to possibly communicate and interfere. Discovering could have several levels of precision.
  - Knowing that a device is available around.
  - Knowing precisely where the device is (how many meters).
- It could trigger automatic actions (or not). For example, your device discovers that a known device is nearby and could alert you. In this respect, the function would be very similar to the Bluetooth low energy Proximity sensing functions.
- Device discovery would enable easy configuration (zeroconf) of communication, with no need to login and type a password for non-sensitive applications.
- Device discovery could be used in very crowded environments to ease the finding of person, exchanging each person's position and signaling to the other person where the other person is located.
- Devices could be used as an Avalanche Transceiver (ARVA) in mountains to ease and speed up the physical discovery (under the snow) of a body/person. The Signal to Noise Ratio (SNR) would be efficiently used to determine the location. In the case of the presence of several persons on the field, each SNR could transmit its SNR to the searched body/person to each rescuer to triangulate and locate the body more precisely.
- Depending on the presence of a network or not, different scenarios could be envisaged. A device under coverage of the network could get a "master" or "slave" status to lead the communication between the two devices.

5.1.2 Relay

Different Relay functions exist some of which are related to network extension by additional light infrastructures (not under the scope of this deliverable), some other are related to devices being used as a relay. In the latter case, Relay function is envisioned as a specific use case of Device to Device. Different relay function configurations are shown in Figure 35 below:

Figure 35: Relay nodes function

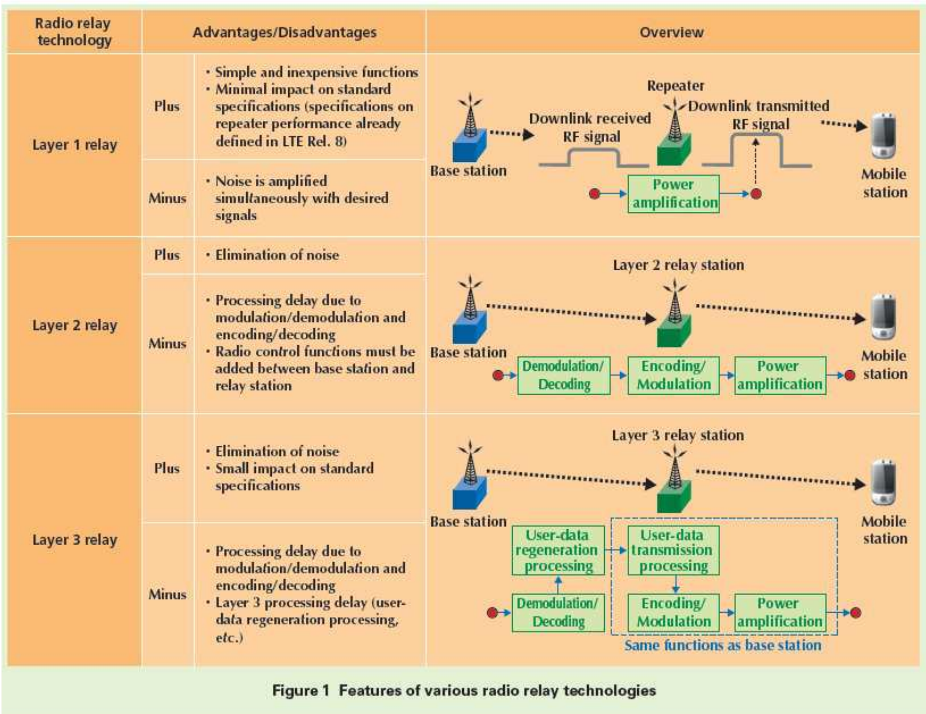


Figure 1 Features of various radio relay technologies

Source: NTT Docomo

Current standardization efforts for this function are once again focused on public safety. It is important to note that given resources available, this function will likely be postponed to Rel 13 or maybe later. For the moment, the standardization is not really advanced and lot of things remains to be decided. For instance, the way Relay function could be activated. Who would activate the relay mode on the device? Would a device with specific authorization be able to request this relay function?

So far, only one hop relay is envisioned and multihop relay would only come later. It could then create some kind of mesh networks. This function however will however likely be a Rel 14 function..

Below are some examples of use cases envisioned regardless of works in the standardization group, some of which won't likely see the day in a short to mid term.

- Extend or improve coverage for user equipment located at the edge of a cell, either inside a building where reception exist but is of poor quality because of propagation loss either outside in areas where coverage is not wide enough.
- Relay function could be used as a way to establish mesh networks, either in situation where people's devices are used in an uncontrolled environment or in a controlled environment where small relay (dedicated) devices are rapidly deployed to reach for instance an uncovered emergency area.
- The function could be used in moving scenarios, such as on motorway or isolated road for instance, to transmit data from sensors located on the road. The transmission would happen only when a relay vehicle pass around. In case where the relay device is not itself connected to the network, it could act as a buffer and save the data to be transmitted until network coverage is available again.
- Because of the potential additional battery drain this may incur on the relay device, this could be limited to certain emergency scenarios. A specific data packet (one bit?) could for instance activate the (emergency) relay mode when required.

5.2 Market sizing for D2D and Relay functions

The D2D and relay features of LTE-Advanced will be primarily features aimed at serving PPDR (Public Protection and Disaster Relief) users. However, non-public safety users in specific industries may also be interested by those features (e.g public utilities industries). This means that both mission critical and non-mission critical users have to be taken into account in the sizing of the market for such-features.

5.2.1.1 Mission critical users

By mission critical users, we refer here to PPDR users, i.e users from the Police, Firemen, Civil protection, health services, guard coasts, etc. As shown in Table 16 below, we estimate that there was around 2 million PPDR users in EU 27 in 2013, with a ratio of around 400 users for 100 000 persons.

Table 16: Mission critical users in Europe 17

Country	Total Inh (million)	Police and gendarmes ('000)	Fire ('000) and civil protection Road security	Ambulances & paramedics ('000)	Total profession/ Total radios* ('000)
Belgium	10.4	30 / 25	16 / 7	1.5 / 2	47.5 / 34
Czech Rep	10.2				
Denmark	5.3	12	6	0.5	18.5 / 4.7
France	60.2	130 / 104	230	100 / 50	
Germany	82.3	283 / 250	27 (pro) / 300	114 / 100	424 / 423
Finland	5.2	10 / 6	21 / 10 (digital)	Incl. in Fire	31 / 16
Hungary	10.1				
Italy	57.8	308 /	33 /		341 / 150

Ireland	4.0	11 /	30 /	62 /	103 /
Netherlands	16.2	50 / 35	25 / 8	3.5 / 3	78.5 / 46
Norway	4.5	15 /	3 /	5 /	23 / 5.8
Poland	38.1	98 /	29 /		127 / 110
Portugal	10.4	29 /	30 /	7 /	66 / 15.5
Spain	42.3	180 /	15 /	18 /	213 / 90
Sweden	8.9	14 /	13 /	3 /	30 / 40
Switzerland	7.3	25	5	18	48 / 12.1
UK	60	153 /	61 /		274 / 180
Total					**1728.5 / 1191.4**

Source: ECCrep102

5.2.1.2 Non critical mission operations

It is estimated that there was approximatically 4 million of people using PPDR services for non critical mission operations in Europe in 2013. Some of them belong to public safety institution (e.g administration…) while other belong to vertical markets where operations require some sort of specific services that only PPDR specific communication means can serve. An example of such market is the construction industry or Petrol Industry where workers need to communicate and collaborate on the field like PPDR users.

5.3 Existing PPDR services

The main question is which feature needs to be implemented in LTE and which functions can be merely provided by a custom application/server. An implemented function will be easier and more efficient, while an application and server will be able to be modified and easily adapted to the need of the users.

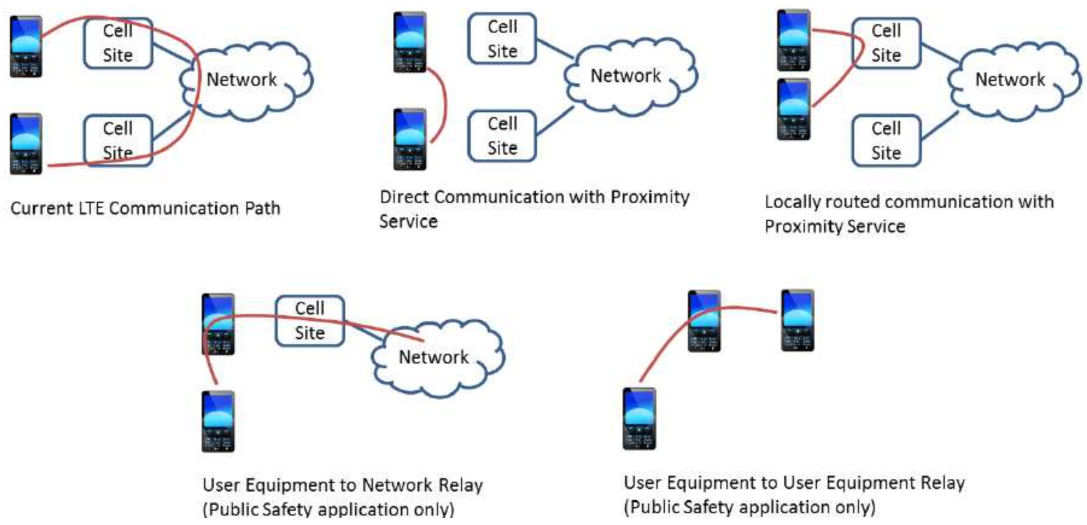
5.3.1.1 Proximity based services

Public safety needs in terms of proximity services are the identification of mobile phones in physical proximity and the possibility to pass optimized communications between them. They consist of two main elements:

- Network assisted discovery of users with a desire to communicate who are in close physical proximity and the facilitation of direct communication between such users with, or without, supervision from the network.
- Direct communication means a radio connection is established between the users' mobiles without passing by the network. This saves network resources and can also allow public safety communication in areas outside network coverage.

Proximity services described in Figure 36: Proximity services examplesFigure 36 meet the need for communication among public safety users even if they are not in coverage of the network. In the commercial area proximity services can support features like new modes of social networking, convenient file transfer between devices belonging to the same user and targeted advertising. In the commercial context 3GPP's standards will ensure that use of licenced spectrum is controllable and billable by the network operator.

Figure 36: Proximity services examples



Source: 3GPP, July 2013

5.3.1.2 Direct Mode Operation (DMO)

DMO is an important means of communicating voice and narrowband data. It is used in several ways:

- when there is no coverage (e.g. in buildings, tunnels etc.), or when there is a risk of loss terrestrial coverage, which is especially important for the police and fire organisations.
- to extend coverage by enabling a low powered person-worn or hand portable terminal to communicate with a higher powered vehicle mounted terminal located within the coverage range of the terrestrial infrastructure.
- as extra capacity e.g. in case the terrestrial network (WAN) is congested.
- as a fall-back when the terrestrial network fails.
- for foreign units crossing the border etc.

The expectation is that “Broadband data DMO” capability will also be needed to facilitate ‘device-to-device’ data communication.

3GPP is working on the inclusion of DMO into LTE. This was something initially due to be included in LTE Rel 12 but this feature will be partially shifted to further releases. Indeed, only Device to Device modes under the supervision of the network will be specified in this release. Direct mode independently of a network is as a consequence something that will be standardized later on, mostly due to the lack of resources in the working groups.

5.3.1.3 AGA (Air-Ground-Air) communications

PPDR organisations may also have requirements for broadband airborne applications as used in the terrestrial PPDR network (Wide Area Networks, WAN). These typically involve a video stream being relayed from a camera mounted on a helicopter to a monitoring station on the ground. Ideally the airborne PPDR communication system should be compatible (i.e. within the tuning range) with the terrestrial broadband networks (WAN).

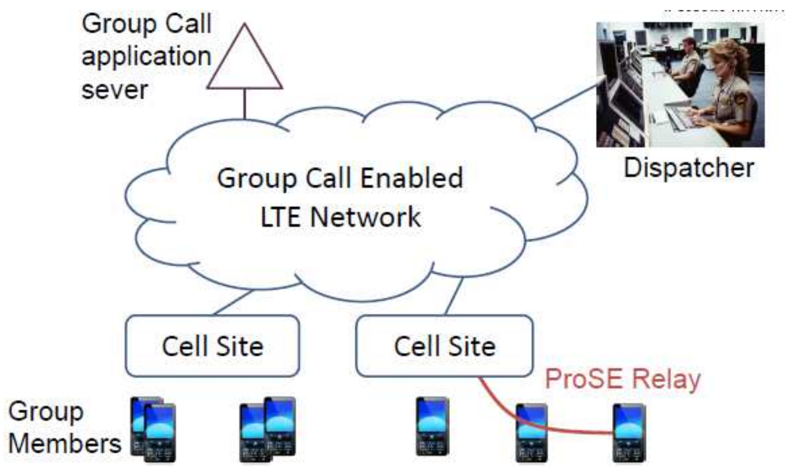
This service could involve both Relay and Device to Device features but also LTE Broadcast in the case where the content would be delivered to several users on the ground.

5.3.1.4 Group Communication System Enablers

PPDR users frequently need to communicate in dynamic groups that might involve both mobile users on the scene and fixed users (“dispatchers”) working in a remote control centre. Often these groups operate in a PTT (Push-To-Talk) mode. Figure 37 shows an example of group calling architecture.

One aspect of group communication still being considered is how much functionality should be “baked in” to the LTE infrastructure and how much should be delivered by non-standardised application servers. The use of application servers will allow different organizations or regions to customize the system operation to their own needs whereas "baked in" solutions may be more efficient. It is expected that further discussion will take place on how to handle session management for public safety group communication and possible impacts on technology like the IP IMS (IP Multimedia Sub-system).

Figure 37: Group calling



Source: 3GPP, July 2013

This functionality will be included in Release 12 of the standard although some functionality may be delayed until Release 13. This release is unlikely to be complete before 2015.

5.3.1.5 Critical network resilience and PTT (Push-To-Talk)

Another area of weakness in existing LTE is the capacity for "graceful degradation of service" present in PMR networks. Indeed, it is always possible for the base station to provide PTT voice services and voice broadcast services making use of the radio link in PMR networks on a local basis. It is vital for critical communications systems to support continuous mission critical network operations regardless of the existence of the backhaul link.

To address those scenarios, the EPC-less E-UTRAN Operation for Public Safety work is scheduled within the Release 13 of 3GPP LTE standards (2016) .This work item will seek to address additional concerns about resilience of LTE networks and their suitability for public safety and other critical communications systems.

5.3.1.6 Prioritization

Preferential treatment for access to and utilization of a LTE network can be supported by the Multimedia Priority Service (MPS) specified by 3GPP. MPS is a subscription-based service that creates the ability to deliver and complete high-priority session in times of network congestion.

Other functionalities may include:

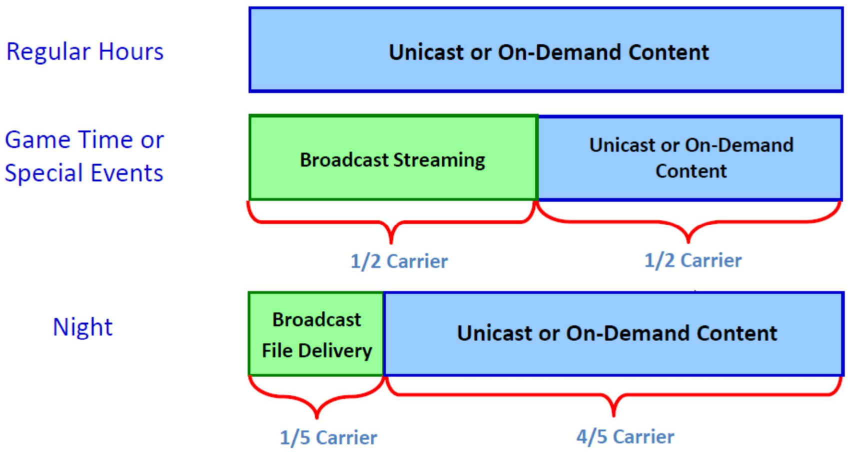
- Fast call set-up
- Emergency calling
- Group management and fleet management
- Late entry to a call already in progress
- Area selection (a group call based on the location of individual subscribers)
- Dynamic groups
- Encryption
- Enhanced broadcast
- High-power mobile
- Public safety-grade performance

5.4 LTE Broadcast

The Evolved Multimedia Broadcast Multicast Service (eMBMS) is the broadcast standard in LTE. The eMBMS standard is supported in 3GPP Release 9. Implementation of eMBMS should be trouble-free as devices will not be specific. The main barrier linked to MBMS adoption for 3G which was the need for specific devices has been removed.

eMBMS is a promising technology and is likely to be deployed from early 2015 in the USA with the Super Bowl target. Unlike the MBMS failure, the eMBMS is supported by telecom heavyweights (Verizon and Qualcomm), and this is the main factor of success. With eMBMS, LTE networks will be able to support broadcast and multicast along with unicast, and the same frequency layer can be used for all these distribution modes. The most interesting feature of eMBMS is that it will enable dynamic broadcasting, or dynamic traffic allocation on the least congested networks, in real time as shown in Figure 38. Technically, up to 60% of capacity could be allocated to eMBMS traffic and the rest to unicast (40%). Moreover, some new business cases for eMBMS have already been identified.

Figure 38: Dynamic allocation of spectrum to unicast and broadcast



Source: Qualcomm Labs

At the beginning of 2014, only 2 trials were undertaken by Telstra in Australia and Verizon in the US and Vodafone recently announced that it would launch trials in Germany.

The most popular case identified and demonstrated is the providing of sport contents in a stadium. Different views of the play could be broadcasted to spectators with the ability to choose the angle, slow motion, etc.

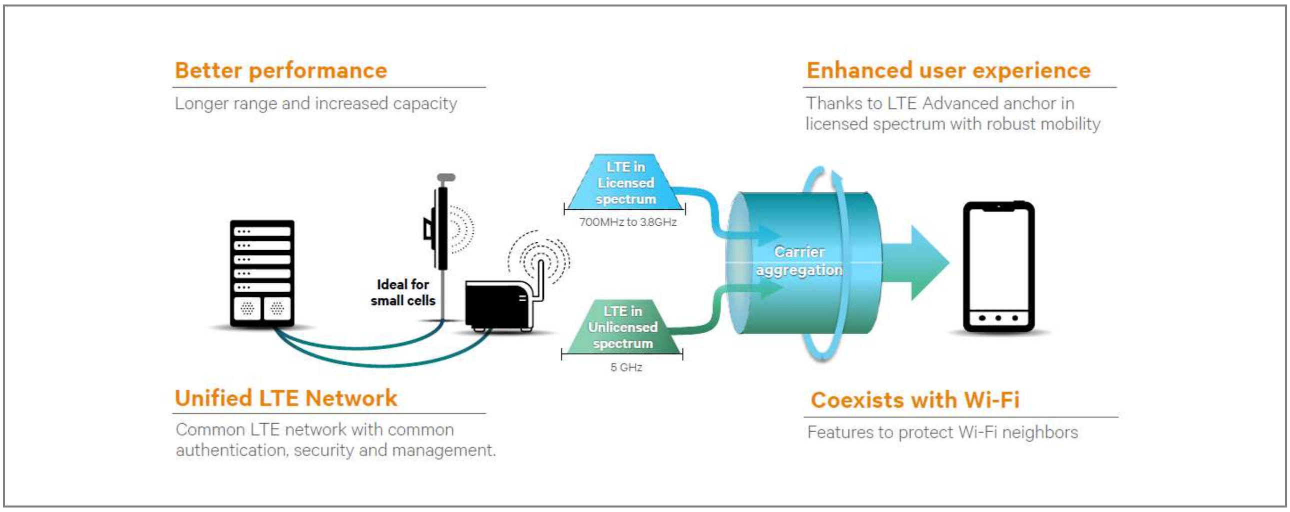
More generally, LTE Broadcast could be used to provide contextualised content such as advertising content, delivery of information in case of emergency. There might be also an interest for the deployment of software updates.

5.5 LTE in unlicensed bands

In November 2013, Qualcomm announced the extension of the use of LTE-Advanced in unlicensed bands. On top of LTE licensed bands between 700 MHz and 2.6 GHz, the 5 GHz band would be used for the downlink only as shown in

Figure 39. This combination is well suited to heavy-traffic indoor areas. The main benefit for a mobile operator would be the decreasing complexity in managing a single network instead of interworking management of a cellular and Wifi networks. Carrier aggregation between licensed and unlicensed bands would enable higher data rates and capacity.

Figure 39: LTE in the 5 GHz band

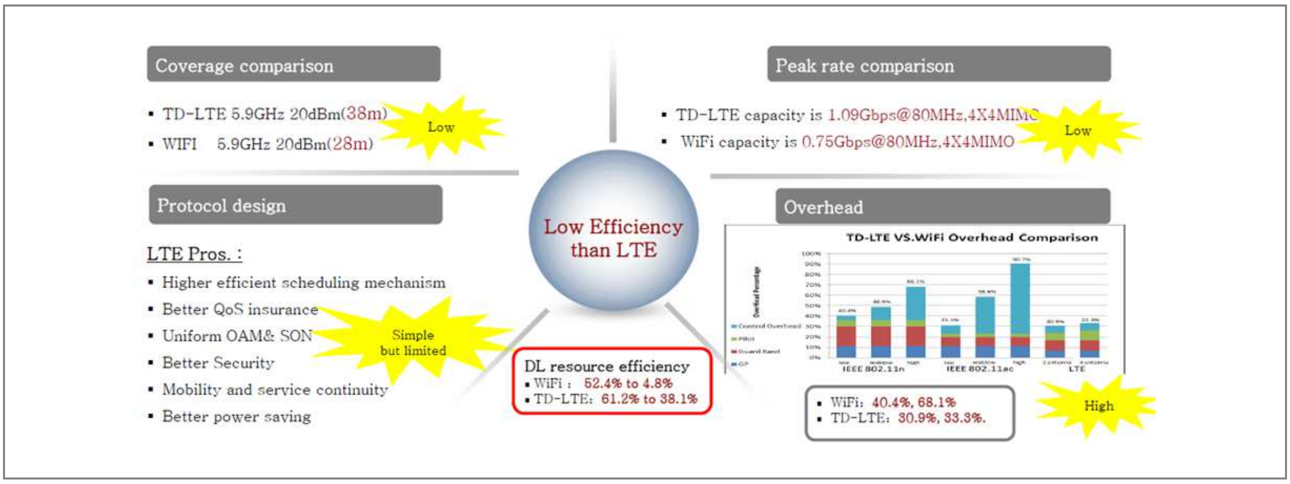


Source: Qualcomm

As the unlicensed band would be used in conjunction with licensed bands, if interference arises in the 5 GHz band, it will only lower the data rate on the downlink but will not cut the connection.

Huawei is also working on LTE in unlicensed bands and calls it U-LTE. The manufacturer pushed in order to introduce the technology in 3GPP Release 13. Huawei indicates that the U-LTE platform will provide benefits without changing the core network and backhaul and will reduce capex. LTE-U benefits over Wifi appear in Figure 40

Figure 40: LTE-U benefits over Wifi



Source: Huawei

Huawei emphasises the following advantages of using LTE in unlicensed spectrum:

- Higher coverage;
- Higher peak rate;
- Lower overhead;
- Higher transmission efficiency.

In the September 2014 RAN plenary of 3GPP, a new Study Item (SI) on LTE-U has been launched. It is expected to end in June 2015. The abovementioned initial performance/comparison claims announced by several companies (such as Qualcomm, Huawei etc.) will be clarified within the context of this SI.

6 List of Abbreviations, Acronyms, and Definitions

3GPP	Third Generation Partnership Project
AAS	Active Antenna Systems
ABS	Almost Blank Sub-frame
ACTS	Advanced Communications Technologies and Services
ADSL	Asymmetric Digital Subscriber Line
AMC	Adaptive Modulation and Coding
ANR	Agence Nationale de la Recherche
AP	Access Point
ARPU	Average Revenue Per User
ASIC	Application Specific Integrated Circuit
Axgp	Advanced eXtended Global Platform
AWS	Advanced Wireless Spectrum
BAN	Body Area Network
BBU	Base Band Unit
BeFEMTO	Broadband evolved FEMTO
BER	Bit Error Rate
BFWA	Broadband Fixed Wireless Access
BTLE	Bluetooth Low Energy
BRAN	Broadband Radio Access Network
BS	Base Station
BTS	Base Transceiver Station
CA	Carrier Aggregation
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CC	Component Carrier
CCIR	Comité Consultatif International des Radiocommunications
CDF	Cumulative Distribution Function
CDMA	Code Division Multiplexing Access
CEPT	Conférence Européenne des Postes et Télécommunications
CO	Confidential
CoMP	Coordinated Multi-Point
COST	european Cooperation in Science and Technology
CPE	Customer Premise Equipment
C-RAN	Centralized Radio Access Network
CRC	Cyclic Redundancy Check
CRS	Common (or Cell specific) Reference Signal
CS	Coordinated Scheduling
CSG	Closed Subscriber Group
CSI	Channel State Information
CSIT	Channel State Information at Transmitter
CT	Core network and Terminals
CTO	Chief Technical Officer
CTU	Chief Technical Officer
CWC	Centre for Wireless Communications
D2D	Device-to-Device

DARPA	Defense Advanced Research Projects Agency
DAS	Distributed Antenna System
DL	DownLink
DRX	Discontinuous Reception
DSL	Digital Subscriber Loop
DSTL	Defense Science and Technology Laboratory
DTX	Discontinuous Transmission
DVB	Digital Video Broadcasting
E2E	End-to-End
EAP-SIM	Extensible Authentication Protocol - Subscriber Identity Module
EAP-TTLS	Extensible Authentication Protocol - Tunneled Transport Layer Security
EARTH	Energy Aware Radio and network tecHnologies
EB	Exabytes
EBITDA	Earnings before interest, taxes, depreciation, and amortization
EC	European Commission
eICIC	Enhanced Inter-Cell Interference Cancellation
eNB	Evolved NodeB
EPC	Evolved Packet Core
EPON	Ethernet Passive Optical Network
ES	Energy Saving
ETSI	European Telecommunications Standards Institute
EU	European Union
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FPGA	Field Programmable Gate Array
FRN	Fixed Relay Node
FTP	File Transfer Protococl
GA	General Assembly
Gbps	Gigabit per second
Gbyte	Gigabyte
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile
GSMA	GSM Alliance
GW	GateWay
HARQ	Hybrid Automatic Repeat reQuest
HDR	Habilitation à Diriger les Recherches
HeNB	Home eNB
HF	High Frequencies
HO	Hand Over
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HW	Hardware
IA	Interference Alignment
IC	Interference Cancellation
ICIC	Inter-Cell Interference Cancellation
IEEE	Institute of Electrical and Electronics Engineers

IMS	IP Multimedia Sub-system
IMT	International Mobile Telecommunications
IP	Internet Protocol
IPFOM	IP Flow Mobility
IPR	Intellectual Property Rights
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union-Radio
JP	Joint Processing
KPI	Key Performance Indicator
L2S	Link-to-System
LAN	Local Area Network
LDPC	Low Density Parity Check
LE	Low Energy
LMMSE	Linear Minimum Mean Squared Error
LPN	Low Power Node
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
M2M	Machine-to-Machine
MAC	Medium-Access Control
MADM	Multiple Attribute Decision Making algorithm
Mapcon	Multi Access PDN Connectivity
MBB	Mobile BroadBand
Mbps	Megabit per second
Mbyte	Megabyte
MC	Multi Carrier
MIMO	Multiple Input Multiple Output (MU-MIMO see MU)
MME	Mobility Management Entity
MNO	Mobile Network Operator
MRN	Mobile Relay Node
MS	Mobile Station
MTC	Machine Type Communications
MU	Multi-User
MVNO	Mobile Virtual Network Operator
MWC	Mobile World Congress
NA	Not Applicable
NAS	Network Access Server
NFC	Near Field Communications
NGMN	Next Generation Mobile Networks
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	OFDM Access
OPEX	Operational Expenditure
OSS	Operations Support System
OSTBC	Orthogonal Space Time Block Code
PA	Power Amplifier
PAPR	Peak to Average Power Ratio
PC	Personal Computer
PCC	Primary Component Carrier

PDCP	Packet Data Convergence Protocol
PDF	Probability Density Function
PDN	Packet Data Network
PDR	Packet Delivery Rate
PER	Packet Error Rate
PHY	Physical Layer
PM	Project Manager
PPDR	Public Protection and Disaster Relief
PSNR	Peak Signal to Noise Ratio
PTT	Push-To-Talk)
PU	Public
QMR	Quarterly Management Report
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RLC	Radio Link Control
RN	Relay Node
RNC	Radio Network Controller
RRC	Radio Resource Control
RRM	Radio Resource Management
RTD	Research and Technical Development
RTT	Round Trip Time
RX	Receiver
SaMOG	S2a Mobility based on GTP (GPRS Tunelling Protocol)
SC	Single Carrier
SCaaS	Small Cell as a Service
SCME	3GPP Spatial Channel Model Extended
SER	Symbol Error Rate
SINR	Signal to Interference plus Noise Ratio
SISO	Single Input Single Output
SME	Small and Medium Entreprise
SMS	Short Message Service
SNR	Signal to Noise Ratio
SON	Self Optimizing/Organizing Network
STB	Set Top Box
STBICM	Space-Time Bit Interleaved Coded Modulation
SW	Software
TA	Tracking Area
Tbps	Terabit per second
Tbyte	Terabyte
TC	Test Case
TCO	Total Cost of Ownership
TCP	Transmission Control Protocol
TD	Time Division
TDD	Time Division Duplex

TM	Task Manager
TR	Technical Requirement
TTI	Transmission Time Interval
TUDR	Typical User Data Rate
TX	Transmitter
UE	User Equipment
UK	United Kingdom
UL	Uplink
UMTS	Universal Mobile Telecommunication System
UT	User Terminal
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Access Network
UWB	Ultra Wide Band
VNI	Visual Networking Index
VoIP	Voice over Internet Protocol
VoLTE	Voice Over LTE
VPL	Vehicle Penetration Loss
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiplexing Access
WiFi / Wi-Fi	Wireless Fidelity
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package
WPL	Work Package Leader

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