THE ESSENTIALS OF INTELLECTUAL PROPERTY, FROM 3G THROUGH LTE RELEASE 12

Quantifying technology leadership in the development of the 3G and LTE standards from their inception through December 2014

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Prepared by
Signals Research Group

SiGNALS Research Group
www.signalsresearch.com

Paper developed for Ericsson

On behalf of Ericsson, Signals Research Group conducted an analysis of 3G and LTE related submissions that companies have made to the 3GPP standards body. Through this effort we were able to identify the companies who were primarily responsible for developing the 3G and LTE standards, based on the number of technical submissions that they made which were approved by their peers. It is our assumption that there is a relationship between a company's success in this endeavor and its essential patent portfolio. This study extends our earlier work to include the 3G (UMTS) standard.

As the sole authors of this paper, we stand fully behind the analyses and opinions that are presented in this paper. In addition to providing consulting services on wireless-related topics, including performance benchmark studies and network economic modeling, Signals Research Group is the publisher of the *Signals Ahead* research newsletter (www.signalsresearch.com).

Executive Summary

Key highlights from this whitepaper

3GPP has become the de facto standards body for developing worldwide cellular standards, including GSM/GERAN, UMTS/HSPA+, LTE/LTE-Advanced and their continued evolution.

Ericsson has been responsible for submitting the highest number of submissions to the 3GPP standards body for the initial and ongoing development of the 3G and LTE standards.

Given the many dependencies between 3G and LTE and the longevity of a typical patent, the 3G patents continue to have relevance.

The technology leadership landscape evolves relatively slowly, suggesting that the companies who are technology leaders today will remain in place for the foreseeable future.

3GPP (Third Generation Partnership Project) is the standards body responsible for developing specifications for the 2G (GSM through EDGE), 3G (UMTS through HSPA+) and LTE (including LTE-Advanced) standards, and their continued evolution. With CDMA2000 rapidly converging on LTE and WiMAX being unable to achieve meaningful market adoption, it is evident that 3GPP is solely responsible for defining the worldwide cellular standards of today and tomorrow.

In our third whitepaper on the topic of technology leadership during the 3GPP standardization process, we expand the scope of our previous studies to include the 3G standard – specifically UMTS and its continued evolution through HSPA+. We increased the scope for two reasons. First, we recognize that many 3G patents are still active and represent value to their owners, in particular given the continued growth of the 3G market. Second, we know that patents which were originally intended to apply to 3G can also apply to LTE, including LTE-Advanced. This extension is due to the commonality that exists between the two standards, basic 3G features that have been incorporated into LTE, as well as their need to interoperate with each other, including multi-mode devices and LTE-3G handovers. In fact, we identified numerous 3GPP technical submissions which applied to both 3G and LTE.

Using an objective methodology that we describe later in this paper, we analyzed 262,773 submissions from 3GPP standardization work on 3G and LTE between 1999 and December 2014. Ericsson was the single largest contributor of the 28,460 submissions that 3GPP ultimately approved which applied to 3G and/or LTE. We also observed that the companies who led in the development of the LTE standard also had a commanding role when it came to the development and continued evolution of 3G. This observation supports our belief that while the market leadership landscape can [and has] rapidly changed, the technology leadership landscape evolves at a much slower pace. Companies with strong technology leadership during the development of 3G and LTE will likely retain their leadership role when the current standardization efforts move toward the next generation of technologies and the "5G" standard is introduced.

Quantifying Technology Leadership

In our two previous whitepapers on this subject we presented several arguments regarding the merits of analyzing 3GPP submissions in order to shed insight into the relative strengths and weaknesses of a company's patent portfolio for standardized cellular technologies. If a company wants to get its technical submission approved by its peers, it must first demonstrate the merits of its idea and prove the validity of its claims. Generally, these steps are accomplished by investing substantial capital and engineering efforts in advance with no guarantee that the idea will be approved. As discussed later in this paper, the 3GPP only approves a small percentage of all technical submissions. Therefore, only the best submissions are accepted while the upfront investment by the companies involved in the process becomes riskier.

We believe that if a company makes a technical submission then it has a vested interest in getting its idea incorporated into the standard.

Given this level of effort, it is our belief [and a fundamental premise of this study] that if a company is proactive during the standardization process by making technical submissions for how the standard should work then it is likely to have a vested interest in getting its idea(s) incorporated into the standard. This vested interest includes the patented rights behind the idea, or at least the company's belief that it has protected its idea with a well-written patent or patent application. Our approach also identifies and weeds out the companies who claim to have a large portfolio of essential patents but who barely participated in the standardization process.

Our approach benefits from the true openness and independence of the standardization process.

Our approach also benefits from the true openness and independence of the standardization process. The plethora of information that we analyzed is readily available on the 3GPP website. We also know that the information – meeting notes, submission documents, etc. – is accurate since the participating companies must approve the meeting records that we analyzed. If an error exists, then it is a clerical error that somehow got past the eyes of all of the companies participating in the standardization process.

By analyzing approved technical submissions we are not suggesting there is a one-for-one dependency between the number of patents/essential patents that a company owns and the number of approved technical submissions. However, we do believe that there is a good correlation between the two sets of data, in particular given the amount of effort associated with making a submission, combined with the realization that only the best submissions are approved. It would be great to simply know the essentiality of each patent and each company's patent portfolio. However, this approach isn't practical since it would require an army of people with a legal and technical background to review each and every patent in existence, including patent applications that have not yet been published, in order to evaluate the relative strength and/or essentiality of each patent.

Patent counting or relying on the unverified claims of companies who have a self-interest to inflate their patent portfolios, also have their obvious shortcomings. Patent counting, for example, may take for granted that a patent with a direct or even casual reference to something pertaining to a cellular technology must be an essential patent. In reality, lots of brilliant [and sometimes ill-conceived] ideas receive patents, but the awarding of a patent doesn't say anything regarding the essentiality of the patent.

3G has continued to evolve in subsequent Releases since it was first introduced in Release '99.

We've done two earlier studies on 3GPP submissions with both studies focused exclusively on LTE. The second study, which we published late last year, expanded the time period of the first study to include all LTE activities within 3GPP through June 2014. In both of those studies, we discussed how a new technology, such as LTE, leverages basic concepts, such as mobility, that have their origin in earlier cellular technologies, namely 2G (GSM/EDGE) and 3G (UMTS/HSPA+). We also discussed how LTE [and 3G] are based on a family of releases. LTE, for example, first got introduced in Release 8 of the 3GPP standard. At the time of this writing, 3GPP has just finished putting the finishing touches on Release 12 with work now shifting to

Release 13. Similarly, 3G was first introduced in Release '99 and the technology has continued to evolve using the same Release numbering as LTE. In fact, Release 12 also introduces some improvements to GSM/EDGE, a technology that achieved commercial status nearly twenty-five years ago!

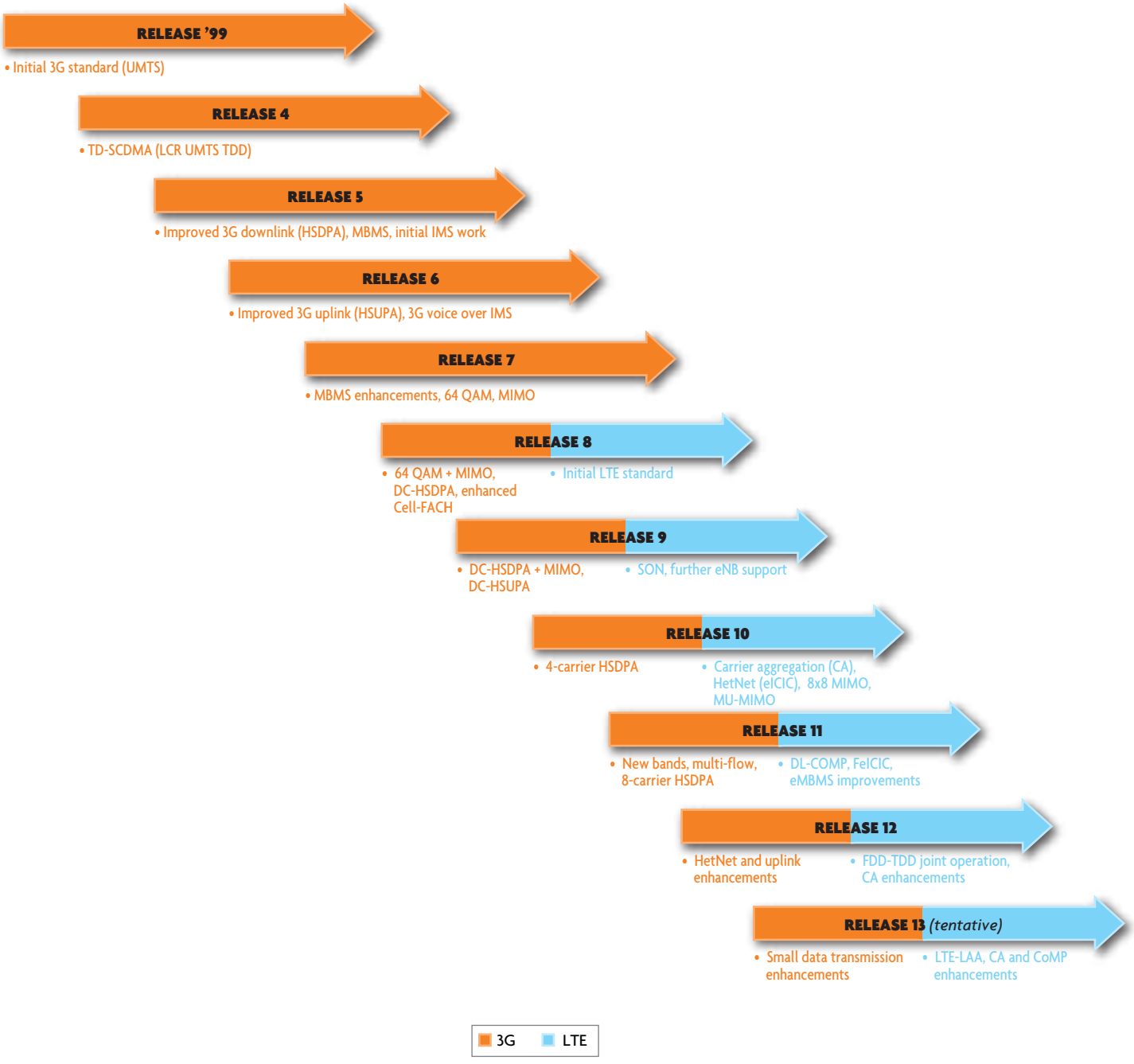
The first Release to introduce a new air interface has a disproportionate number of submissions relative to the Releases that follow it.

There are at least three important implications. For starters, the first Release associated with a new air interface – Release '99 for 3G and Release 8 for LTE – has a disproportionate number of submissions relative to the Releases that follow it. This outcome isn't surprising but it does suggest that a company that wasn't actively involved during the first Release of a new air interface will have a difficult time catching up to its peers in terms of the total number of submissions. Second, since the subsequent Releases build on the existing Releases, the technical merits of the earlier Releases, including the essential patents associated with the earlier Releases, are just as valid today as they were when they were first introduced. An example is Carrier Aggregation (LTE-Advanced, Release 10) which starts off by logically combining two Release 8 LTE radio channels to increase the peak throughput. Ultimately, Carrier Aggregation, as defined in Release 10 will support the logical combining of up to five Release 8 LTE radio channels with even more radio channels foreseeable in future releases.

Finally, and perhaps most importantly, although the industry's focus may be on commercializing the most recent technological advances in 3GPP, such as LTE-Advanced features, and incorporating new enhancements in Release 12 and Release 13, the essential 3G patents are still very important. In addition to these patents applying specifically to UMTS / HSPA+ compatible devices and networks around the world – networks that will remain in place for the foreseeable future – these patents will be critical to support multi-mode devices and interoperability/handovers between the two networks. Further, as mentioned elsewhere in this paper, important concepts and features introduced in legacy technologies frequently get incorporated into the next generation of technologies.

Figure 1 provides some insight into the Releases that have occurred since Release '99. We have identified a few 3G and LTE features in each Release without suggesting that these features are the most important features in that particular Release.

Figure 1. 3GPP Releases and Associated Functionalities



Source: Signals Research Group

The leading contributors from an earlier standardization effort have generally remained leading contributors during a subsequent standardization process – a trend that is likely to continue.

Since at least some initial work has started within 3GPP on Release 13 we have included the Release in the figure. Depending on how things progress, one of the future 3GPP Releases will introduce the next wave of technologies, which have been dubbed 5G. During the 5G standardization process it will be challenging for entirely new companies or for companies who were not major contributors to 3G and LTE standardization efforts to emerge as major contributors to the new standard.

First, it remains unclear how revolutionary the new standard will be relative to the previous standards. A more likely scenario is that 5G will, at least in part, build upon the already existing standards through an evolutionary process instead of starting completely from scratch. Additionally, our analysis of the standardization efforts to date indicates that the leading contributors from an earlier standardization effort generally remain leading contributors during a subsequent standardization process. History has demonstrated that LTE did not replace the need for 3G, just as 3G did not replace the need for 2G. Therefore, it is evident that when a new generation of technologies is introduced it will not replace the legacy technologies which preceded it. Additionally, many basic concepts introduced into earlier generations of technologies are frequently inherited into the next generation of technologies. Lastly, when the new generation of technologies is introduced multi-mode devices will be needed to support both the new technology and the earlier technologies

2.1 Our Methodology

We reviewed 262,773 submissions made to the five 3GPP Working Groups that are primarily responsible for defining those aspects of the 3G and LTE standards that have a high impact on the mobile device. Our focus on these five existing groups, and the early working groups that have since been subsumed into them, remains unchanged from our earlier studies. However, in this study we extended the period of the analysis back to 1999 when the 3GPP standards body started working in earnest on the first 3G Release. We also expanded the scope to include 3G and its ongoing series of Releases.

Table 1. Scope of 3GPP Submission Study (1999 – December 2014)

Working Group	Areas of responsibility
CT1	Responsible for the specifictaions that define the use equipment – core network layer 3 radio protocols and the core network side of the Iu reference point
RN1	Responsible for the specification of the physical layer of the radio interface for UE, UTRAN, Evolved UTRAN and beyond; covering both FDD and TDD modes of the radio interface
RN2	Responsible for the specifications that define the radio interface architecture and protocols, the radio resource control protocols, the strategies of radio resource management and the services provided by the physical layer to the upper layers
SA2	Defines the main functions and entities of the network, how these entities are linked to each other and the information they exchange
SA3	Responsible for security and privacy requirements, and specifying the security architectures and protocols

Source: Signals Research Group

We used an automated approach to objectively identify the technical submissions and to appropriately attribute the submission to the correct company(s).

In general, our methodology remained unchanged from what we used in the last study which focused specifically on LTE. In that study and in this current study we used an automated approach and customized algorithms to categorize each document, identify if the document was approved, and give credit to the company or companies responsible for submitting the document. To keep the study as objective as possible we used a list of keywords and phrases to identify a document as being associated with 3G or LTE. Our list of keywords and phrases also allowed us to identify documents that did not pertain to any portion of 3G or LTE. For example, we identified GSM/GERAN-related (GSM/EDGE Radio Access Network) documents and we identified documents which only tangentially pertained to the 3G or LTE access network – documents that dealt with IMS (IP Multimedia Subsystem), policy control and charging fell into this category. Generally, these documents were found in the CT1 and SA Working Groups. Lastly, we used the keywords and the timing of when the meetings occurred to categorize the submissions by Release number.

For purposes of this study we only counted the approved submissions.

We used Excel VBA to develop a proprietary means of automatically reviewing each document. The program leveraged Microsoft APIs for Word, Excel and PowerPoint. Since many of the submissions were in Adobe PDF format, we had to convert those PDF documents to a text document to analyze their contents. In essence, the program searched each document for the keywords, kept track of which keywords appeared in the document and how many times the keywords appeared, documented the source of the submission, and the status of the submission. We also avoided double-counting a submission by tracking whether or not the document was revised, and ultimately only counting the final revision. If a Change Request (CR) pertaining to a single topic impacted multiple Releases then we only counted it once, attributing the CR to the earliest Release identified in the CR. For purposes of this study we only counted the approved submissions since including non-approved submissions could inadvertently reward a company for making numerous poor submissions that lacked technical merit and which were ultimately rejected by its peers.

We used the "Source" field to identify the company or companies responsible for making the submission.

Finally, we used the "Source" field to identify the company or companies responsible for making the submission. In the event that multiple companies submitted the document we gave each company partial credit. For example, if a single company was responsible for a submission then it received a credit of 1 submission in the count tally. If two companies were responsible for a submission then each company received a credit of 0.5 for the submission.

This approach is the most fair and unbiased method that we identified, however, it isn't perfect. For example, it tends to reward companies who merely provided their support for a submission without originating the idea or conducting all of the technical analysis and simulation studies that are required with the submission. Conversely, companies frequently seek out co-sponsors for their submissions in order to garner enough initial support to get their submission approved. Since we did not attend any of the pertinent 3GPP meetings, it is impossible for us to distinguish between the originator of the submission and its co-sponsors. As a result, our methodology tends to give undue credit to followers at the expense of the 3GPP technology leaders.

Since we included 3G-related documents in this study we also adjusted how we categorized some of the documents relative to what we did in the last study. Specifically, we encountered a meaningful number of documents that pertained to both 3G and LTE, and it wasn't possible to identify an objective means of assigning the document entirely to 3G or LTE. An example is mobility management involving inter-RAT handovers between the 3G and LTE networks, or vice versa. Arguably, this technical feature has LTE and 3G implications so we felt it appropriate to treat it as such. Therefore, in the Results and Analysis section we show three distinct categories of submissions: 3G Only, LTE Only, and 3G and LTE. In the last study, which did not include

3G, we counted the LTE and 3G documents as LTE documents. Both approaches to categorizing the documents are valid, but by using three categories we provide additional clarity and insight into the results.

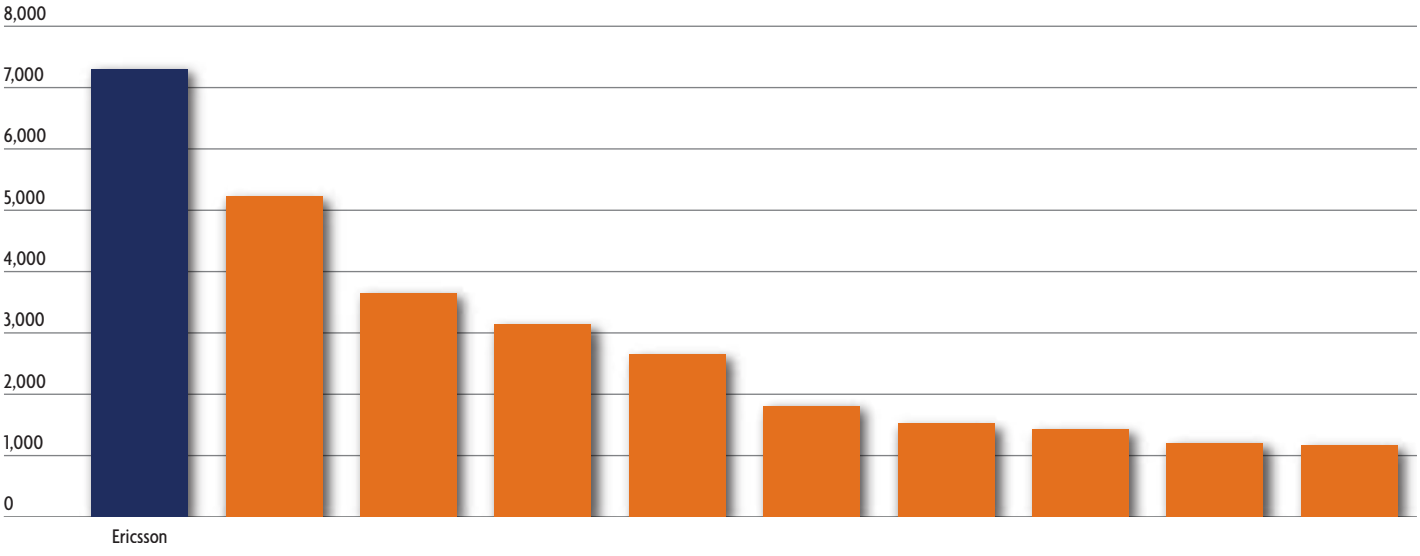
2.2 Results and Analysis

In total, we reviewed 262,773 3GPP submissions that were generated within the five working groups from 1999 through December 2014. Of these submissions, there were 43,917 approved documents. The approved documents include 3G Only, LTE Only, and 3G and LTE documents as well as submissions that fall outside all of these three categories – documents pertaining to GSM/GERAN or IMS are examples.

Ericsson was the top contributor of approved 3GPP submissions.

Figure 2 shows the distribution of the approved submissions for the top ten contributors. Worth noting, the figure includes approved submissions which we believe fall outside the scope of 3G and LTE. We have removed these submissions in most of the subsequent figures that we show in this section or we have placed them in the Other category. Consistent with our analysis of the LTE standardization process, Ericsson was the top contributor of approved 3GPP submissions. Although it isn't shown in the figure, many of the top ten companies from our earlier study are also top ten contributors in our most recent study – and quite often without a major change in their ranking. The only exception to this observation stems from a couple of companies that were previously active in the standardization process and which no longer exist as a standalone entity due to M&A activities.

Figure 2. 3GPP Approved Submissions for Release '99 through Release 12 (1999 – December 2014)

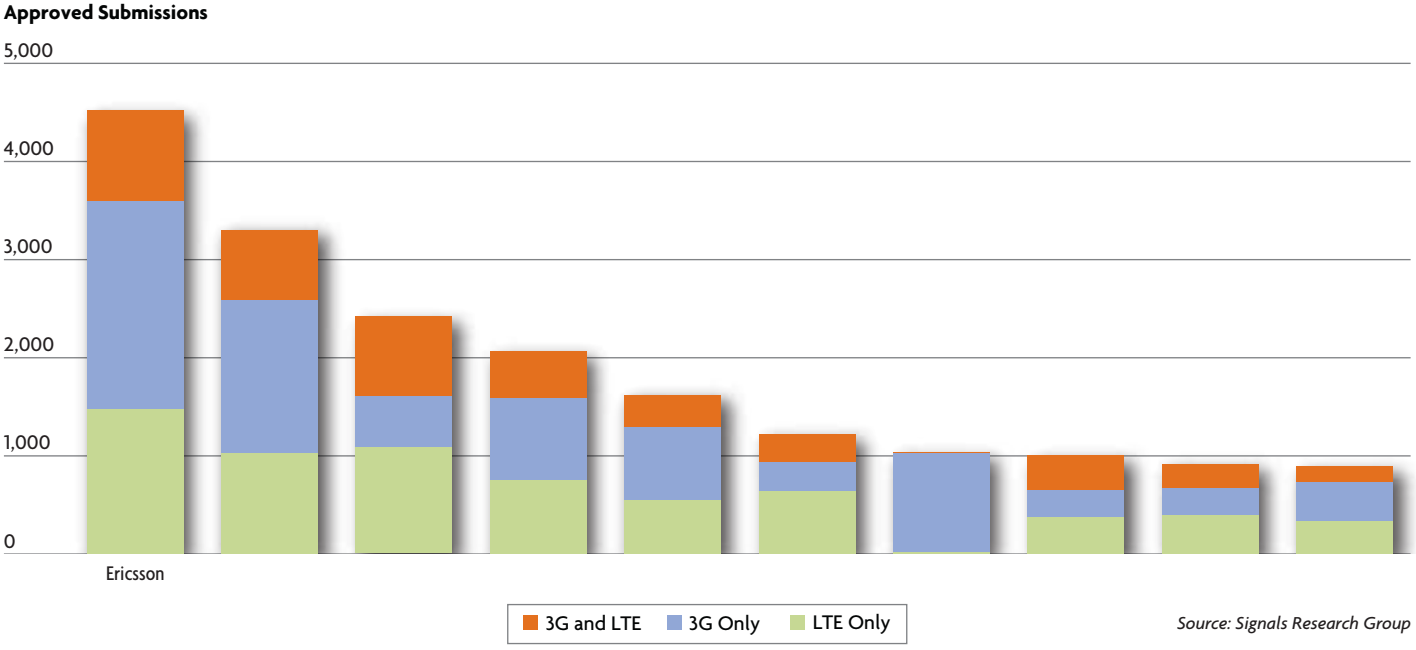


Source: Signals Research Group

Given the need for interoperability and the dependencies between the two air interfaces, it is not surprising that a high percentage of the submissions apply to both 3G and LTE.

The distribution of approved submissions shown in Figure 3 is somewhat similar to the information provided in Figure 2. The primary difference is that in Figure 3 we have excluded those approved submissions which we did not classify as pertaining to 3G and/or LTE. Instead, they pertained to 2G technologies or technology enablers, such as IMS. The figure also shows the split between 3G Only, LTE Only, and 3G and LTE submissions. Given the need for interoperability and the dependencies between the two air interfaces, it is not surprising that a high percentage of the submissions apply to both 3G and LTE. We also remind readers that over the last fifteen years there have been a number of changes in the marketplace. Some companies who used to be quite strong in the cellular industry no longer exist or they have largely exited the cellular market. These changes in the market landscape explain, for example, why one of the columns contains a very large percentage of 3G Only submissions, but relatively few LTE Only submissions.

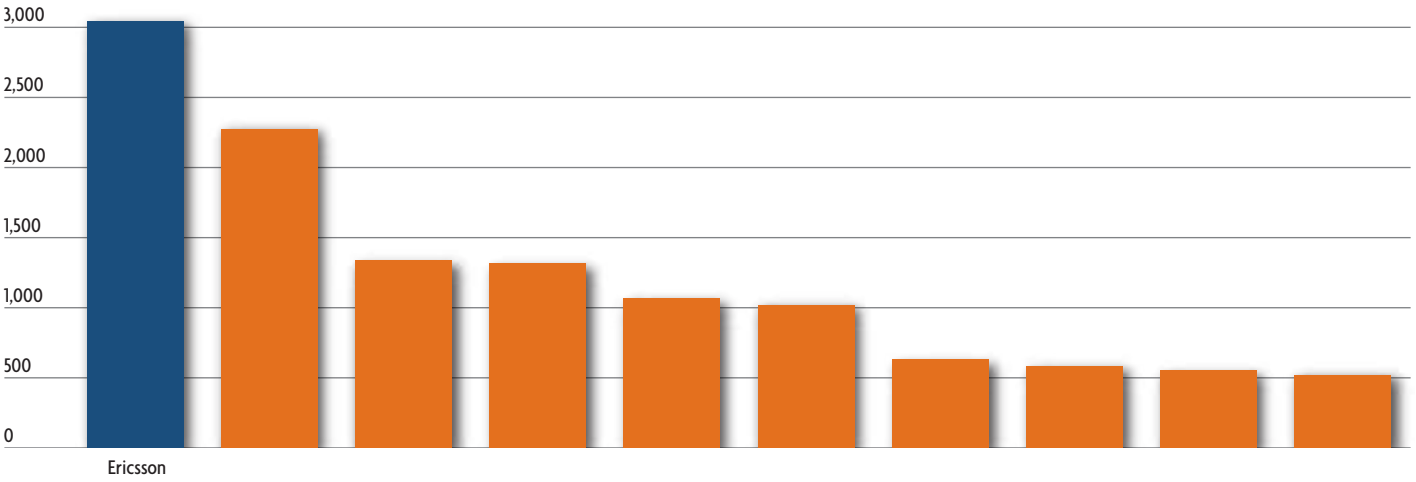
Figure 3. 3GPP Approved Submissions for Release '99 through Release 12 by 3G Only, LTE Only, and 3G and LTE Classifications (1999 – December 2014)



Source: Signals Research Group

As previously indicated in this paper, we identified a large number of technical submissions which impact both 3G and LTE compatible devices/products. In order to demonstrate this phenomenon, we are including the following figures. In the first figure (Figure 4) we show all contributions of Figure 3 that are related to the 3G evolution by consolidating the submissions previously assigned separately to the 3G Only and 3G and LTE categories. In the second figure (Figure 5) we consolidated all of the submissions from the 3G and LTE category with the submissions in the LTE Only category.

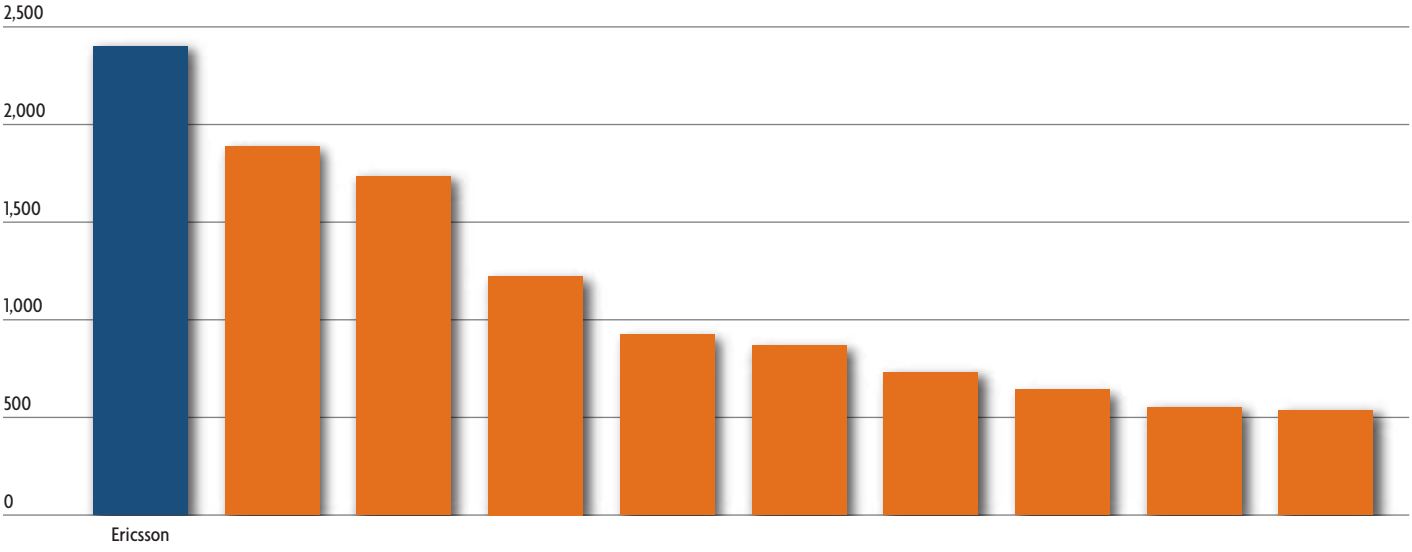
Figure 4. 3GPP Approved 3G Submissions for Release '99 through Release 12 (1999 – December 2014)



Source: Signals Research Group

It is also important to note that we rank ordered the results in each figure, meaning that each column in the two figures could refer to a different company. In fact, although the top ten contributors for the 3G and LTE standardization processes were largely the same, it is entirely possible that an unnamed company appears in one figure but it is not in the other figure. One exception is Ericsson, which as shown in the two figures contributed the most approved submissions regardless of how we treated the 3G and LTE category of submissions.

Figure 5. 3GPP Approved LTE Submissions for Release 8 through Release 12 (2007 – December 2014)

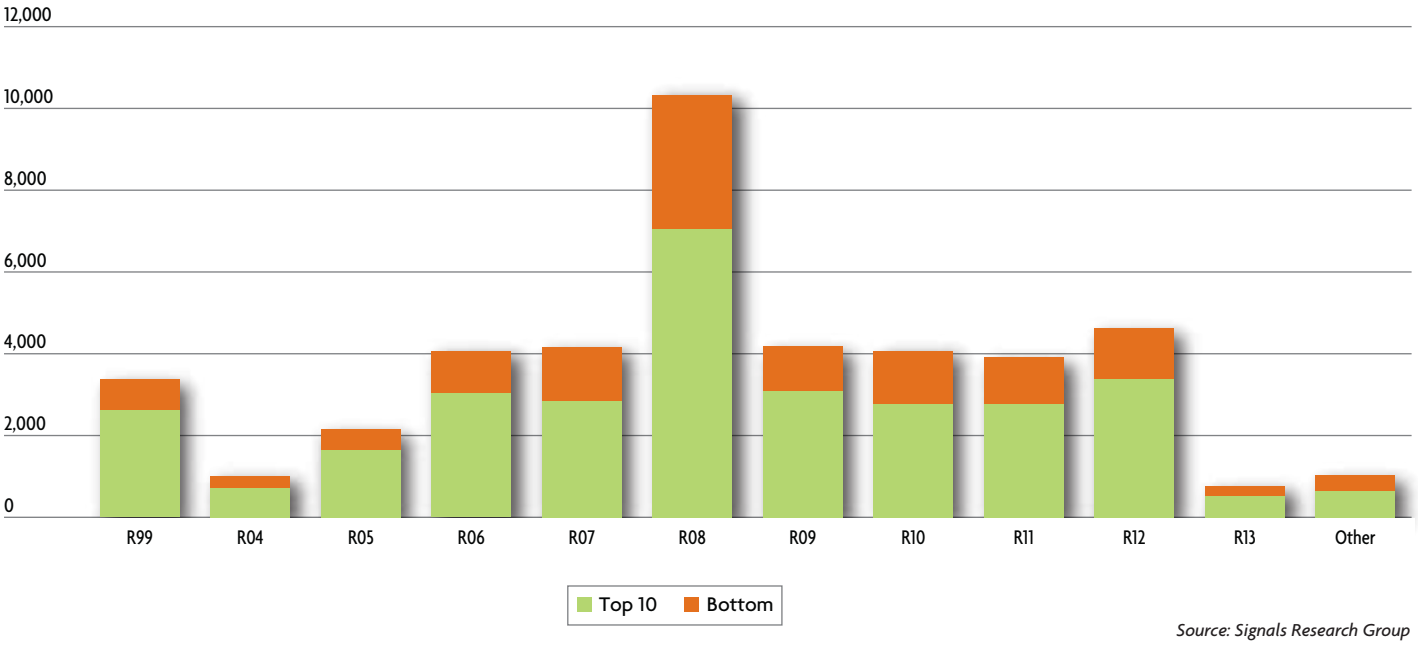


Source: Signals Research Group

The last three figures show the distribution of approved submissions by Release. Figure 6 shows the results for all approved submissions, Figure 7 shows the distribution for approved 3G submissions, and Figure 8 shows the distribution for approved LTE submissions. Since our methodology classified some documents as applying to both 3G and LTE some of the submissions are included in both figures. Further, since Figure 6 shows all approved submissions, the figure includes submissions that do not directly pertain to 3G or LTE access networks.

In all three figures we have separated the approved submissions into two categories – approved submissions from one of the top ten contributors and approved submissions from companies that are not one of the top ten contributors. Using the information shown in Figure 6 we find that the top ten contributing companies accounted for 66% of all approved submissions. No single company outside of the top ten contributors can claim that the contributed to more than 2.5% of the approved submissions.

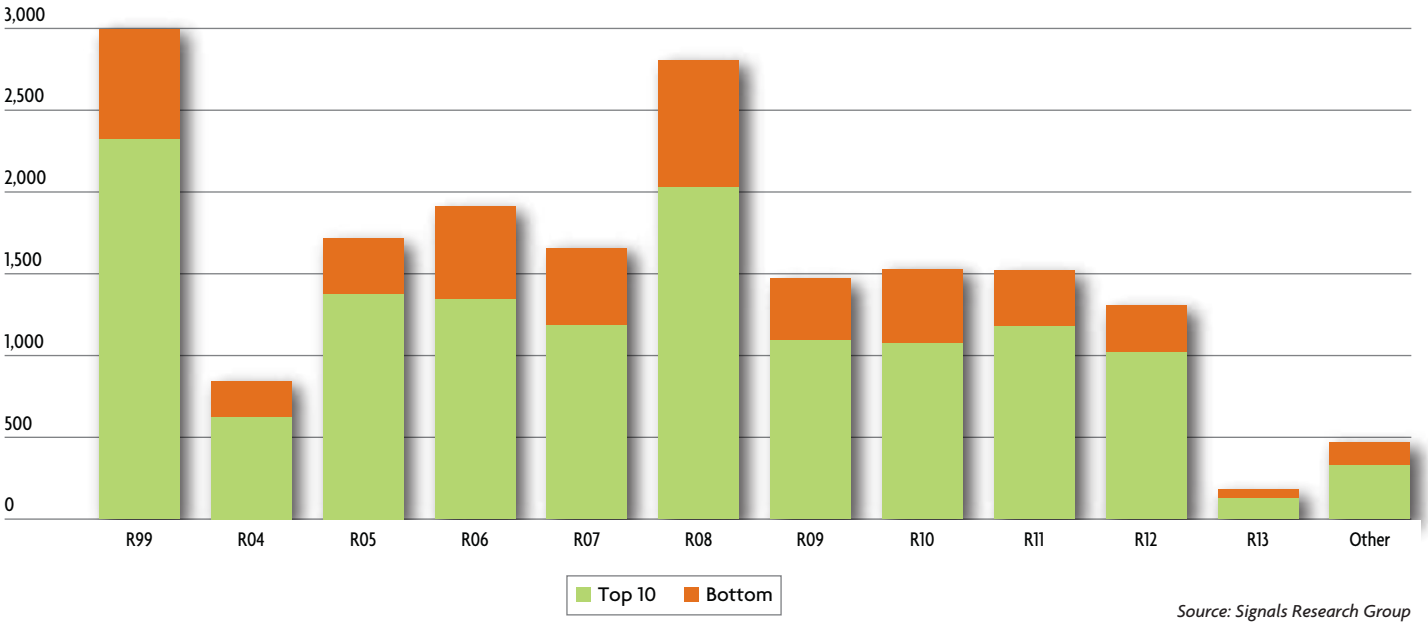
Figure 6. 3GPP Approved Submissions for Release '99 through Release 12 (1999 – December 2014)



Source: Signals Research Group

The big spike of approved submissions in Release 8 (Figure 6) stems from three factors: the introduction of LTE, the impact of LTE on 3G standards (i.e., interoperability), and the continued advancements in the 3G standard. In all three figures, the Other column includes submissions for Release 13 as well as submissions that we could not readily attribute to a specific Release. Additionally, we encountered submissions which impacted a Release that is not normally associated with the pertinent air interface. For example, we identified a few Release 7 submissions which dealt with LTE even though the first industry recognized LTE standard was published in Release 8.

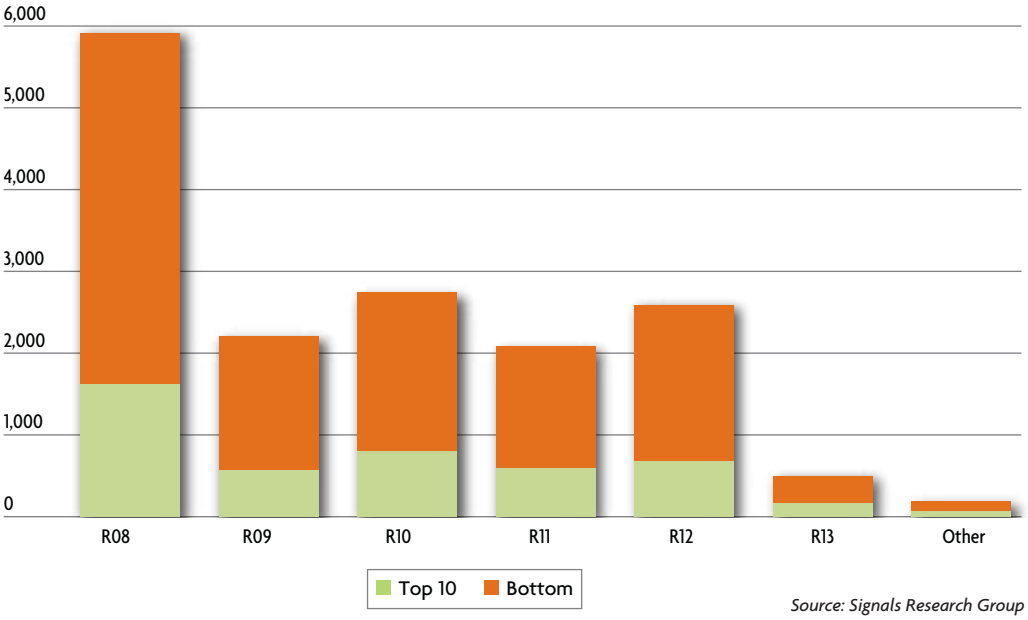
Figure 7. 3GPP Approved 3G Submissions for Release '99 through Release 12 (1999 – December 2014)



Source: Signals Research Group

Figure 8, whch also appeared in our last study, clearly shows that the introduction of LTE in Release 8 resulted in a large number of approved submissions while in subsequent Releases the number of approved submissions was much lower. The spike isn't as obvious in Figure 7 because the Release 8 column includes approved submissions to the 3G standard that were primarily the result of the need for interoperability between 3G and the newly-introduced LTE standard.

Figure 8. 3GPP Approved LTE Submissions for Release 8 through Release 12 (2007 – December 2014)



Source: Signals Research Group

This trend reinforces our belief that the enhancements to a standard do not require nearly as much effort as the original standardization effort. This outcome is true, in part, because these enhancements are largely intended to build on the existing capabilities and inherent features of the original standard. This observation along with our analysis of the detailed data also suggests that companies will have a more difficult time gaining ground in subsequent releases since the number of approved submissions is generally much lower than it was with the initial Release.

Another observation worth making is that once a standard is in place, future Releases associated with the original standard have varying degrees of impact on it. For example, Release 4, which immediately followed the original 3G standard (Release '99), had a relatively modest impact on 3G since the biggest Release 4 contribution was the incorporation of TD-SCDMA (Time Division – Synchronous Code Division Multiple Access), also referred to as UTRA-TDD LCR (UMTS Terrestrial Radio Access – Time Division Duplex Low Chip Rate) in the standard. Outside of China, TD-SCDMA failed to gain market traction. Conversely, Release 5 (HSDPA – High Speed Downlink Packet Access) and Release 6 (HSUPA – High Speed Uplink Packet Access) addressed many of the limitations associated with Release '99 and ultimately lead to the era of mobile broadband on a global basis.

We also note that the enhancements introduced in the subsequent Releases include both features that are absolutely vital for the technology evolution, as well as a number of optional features that may never achieve commercial status. The aforementioned HSDPA and HSUPA features for 3G were clearly vital to the success of 3G, much like carrier aggregation (Release 10) is being

rapidly introduced by operators into their overall LTE network strategy. Conversely, the future is less certain at the moment for in-band relay nodes, which was also introduced in Release 10. In addition to there not being much commercial interest from operators for the feature, the standardization efforts for the relays have no impact on the mobile devices.

Based on market indicators at this time, an LTE feature, such as LTE-Broadcast, falls somewhere in the middle. Some operators are very keen to launch the feature, but have yet to do so even though the feature is fully supported in the already published Releases. Other operators have expressed very little interest in LTE-Broadcast although their views could change in the coming years. Even for those operators that currently have plans to launch LTE-Broadcast services, they will probably make it an optional feature that is initially limited to high-end smartphones and then gradually extend the functionality across their smartphone portfolio over a period of time.

If an enhancement is standardized but not commercially implemented then the inherent value of the associated patented technology is diminished.

If an enhancement is standardized but not commercially implemented then the inherent value of the associated patented technology is diminished. Further, one can conclude that technologies introduced in one Release for a particular standard can have more value than technological advances introduced in other Releases, either because the new technology is never deployed or because it is only supported by a subset of operators around the world and only incorporated in a limited number of mobile devices.

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