Submitted for presentation at Wireless2005, June 2005

3G CELLULAR STANDARDS AND PATENTS

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***Abstract*— At the beginning of 2004, the standards for third generation (3G) cellular technology were embodied in 486 Technical Specifications published by the two partnership projects: 3GPP and 3GPP2. Corporate members of the partnership projects are encouraged to identify intellectual property that is essential to implementing the standards. We have studied 7,796 patents and patent applications declared essential to the two standards. The patents are clustered in 887 families, where each family covers one invention. Three quarters of the declared patents are assigned to four companies. A preliminary evaluation of one patent from each family suggests that approximately 21% of the declared patents are actually essential. This paper presents the distributions of patents declared essential and patents judged essential according to technical category and patent ownership.**

Keywords-WCDMA, CDMA2000, 3GPP, 3GPP2, patents, standards

I. STANDARDS AND PATENTS

As information technology professionals, we are educated to seek the best technical solution to the tasks we address. However, we find that the success or failure of our efforts, as indicated by the adoption of our contributions, depends on many factors besides the quality of our work. Two of these factors are technical standards and intellectual property rights (IPR) to technology that complements or competes with our own solutions. Standards can accelerate technology proliferation; they can also be barriers to innovation [1]. Governments issue patents to reward innovation and stimulate technology creation. However, distortions in the patent system can stifle creativity and block deployment of the best technology [2],[3].

A recent article in *IEEE Spectrum* documents the tug of war between patent ownership and formulation of information technology standards[4]. Open (as opposed to proprietary) standards promote positive externalities and encourage widespread technology deployment. On the other hand, patents, by their nature as exclusionary monopolies, restrict technology deployment in order to encourage technology creation. Organizations that formulate open standards would like to exclude patented technology from the standards. If that is not possible, as is often the case, they prefer that patent owners grant free licenses to implement their patents in products that conform to the standards. In practice, however, information technology standards organizations are populated by representatives of companies that aim to profit from ownership of their IPR. From the point of view of the public interest, standards organizations have to compromise between the goal of unimpeded access to the standard and the possibility that "excluding a patented invention from a standard can unreasonably restrain trade by … excluding a technically advanced product from the market"[5]. To reconcile the contradiction between open standards and patent ownership, standards organizations encourage members to disclose "essential" patents and to agree to license the patents to all interested parties on "fair, reasonable, and non-discriminatory" terms.

II. EVOLUTION OF CELLULAR TECHNOLOGY

Cellular telecommunications dates from the 1970s, when the first experimental systems demonstrated the technical feasibility of a radically new approach to telephony. The first commercial systems appeared in the early 1980s and since then technical progress has been measured in "generations". First generation technology relied on analog frequency modulation to transmit voice signals. Second generation systems, introduced in the 1990s, transmit speech in digital format. To promote network security and enable international roaming, they employ standardized signaling protocols for communication among elements of the infrastructure of base stations, mobile switching centers and databases. There are two broad categories of second generation systems, distinguished by their approaches to multiplexing and multiple access of radio signals. Some systems employ time division (TDMA) and others employ code division (CDMA). There are two standards for signaling in the core network: the mobile applications part (MAP) of the Global System for Mobile Communications (GSM) and Interim Standard 41, published by the Telecommunications Industry Association (TIA). In December 2004, there were 1.52 billion cellular subscribers worldwide, with 1.25 billion using GSM TDMA technology and 200 million using CDMA. The remainder used networks that employ various forms of TDMA that differ from GSM [6].

In recent years, GSM network operators have introduced two major upgrades to the original radio transmission technology. EDGE introduces 8-level phase shift keying modulation alongside the original binary modulation technique of GSM,

Gaussian minimum shift keying. GPRS is a packet data overlay to the original circuit-switched technology of GSM. Both EDGE and GPRS are often referred to as "2.5G" technologies.

In 2005, many network operators are migrating to third generation (3G) technologies, with standardization guided by two "third generation partnership projects", 3GPP[7] and 3GPP2[8]. The original partnership project, 3GPP, is concerned with descendents of GSM. The technology standardized by 3GPP is often referred to as WCDMA (wideband code division multiple access). The other project, 3GPP2, is concerned with advanced versions of the original CDMA cellular system. The technology standardized by 3GPP2 is often referred to as CDMA2000.

Table 1: Organizational Members of the Partnership Projects

Organizational Member	Nationality	Affiliation
Association of Radio Industries and Businesses	Japan	3GPP and 3GPP2
Alliance for Telecommunication Industry Solutions	United States	3GPP
China Communications Standards Association	China	3GPP and 3GPP2
European Telecommunication Standards Institute	Europe	3GPP
Telecommunications Industry Association	North America	3GPP2
Telecommunications Technology Association	Korea	3GPP and 3GPP2
The Telecommunication Technology Committee	Japan	3GPP and 3GPP2

The partnership project members are regional and national standards organizations and "individual members," companies affiliated with one or more of the constituent standards organizations. Table 1 lists the standards organizations - based in Europe, the United States, Japan, China, and Korea – in the two partnership projects. There are 239 individual members of 3GPP and 75 individual members of 3GPP2. The partnership projects and their constituent standards organizations encourage individual members to "declare" patents and patent applications that they believe are "essential" to implementing third generation cellular standards. The official definition of essential is formulated in negative terminology:

> "ESSENTIAL" as applied to IPR means that it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the time of standardization, to make, sell, lease, otherwise dispose of, repair, use or operate EQUIPMENT or METHODS which comply with a STANDARD without infringing that IPR. [9]

Lists of patents declared essential to WCDMA appear at the web site of the European Telecommunications Standards Institute (ETSI)[10]. Lists of patents declared essential to CDMA2000 appear at the web sites of the Association of Radio Industries and Businesses (ARIB)[11] and The Telecommunication Technology Committee (TTC)[12], ARIB and TTC are Japanese standards organizations. At the beginning of 2004, we identified 6,872 patents declared essential to WCDMA and 924 patents declared essential to CDMA2000.

This paper reports the results of a study of these 7,796 patents and applications and the standards to which they are declared essential. Section III describes the standards documents that define WCDMA and CDMA2000. Section IV explains that the 7,796 declared patents are clustered in 887 "families". All the patents in a family cover the same invention. Section V describes the distribution of the patent families across several technology categories and among companies that own rights to the patents. In Section VI, we report the results of a preliminary technical assessment of each patent family in order to estimate the number of inventions that are actually essential to the two sets of standards. Section VII summarizes our main findings and their implications.

III. THIRD GENERATION CELLULAR STANDARDS

Among the many types of standards, the ones considered in our study are in the category of "compatibility specifications"[13]. Their purpose is to insure that different types of conforming equipment (for example cellular telephones and base stations) will operate correctly when they interact. The technologies covered by 3G cellular standards reside in three domains: core network, radio access network, and user equipment. These categories are only partly reflected in the organization of the two standardization projects: 3GPP and 3GPP2. Both projects have assigned the formulation of specifications to Technical Specification Groups (TSG). However, the definitions of the TSGs are different in the two projects. The TSGs in 3GPP are concerned with core network, radio access network, terminals, and service and systems aspects[14]. In 3GPP, the TSGs are titled access network interfaces, CDMA2000, services and systems aspects, and intersystem operations[15].

Although the technologies in the two projects cover the same ground, there are several differences in working methods. One salient difference is that 3GPP periodically produces a complete current version of its specifications in a sequence of Releases. At the beginning of 2004, the current specifications were components of Release 5, consisting of 386 Technical Specifications in four categories. This number excludes the specifications published by TSG GERAN, covering the latest versions of GSM, GPRS, and EDGE. It also excludes TS21.101[16], which contains a list of all the Technical Reports and Technical Specifications published by 3GPP.

By contrast, 3GPP2 does not periodically publish a new release of the entire CDMA2000 standard. Instead, each TSG in 3GPP2 publishes a new version of one of its specifications, when the specification is approved. At the beginning of 2004, the documentation of 3GPP2 included 100 approved Technical Specifications in six categories.

The disparity in number of specifications produced by the two partnership projects is a consequence of the fact that 3GPP divides the standardization effort into smaller tasks than 3GPP2, 3GPP also publishes a large number of specifications devoted to project organization and management as distinct from definitions of technologies. Beyond this difference in style, there are different definitions of technology categories. 3GPP2 considers codecs and security technologies to be part of the radio access network (TSG-C), while 3GPP groups them with services (TSG-SA) at the application layer of a protocol stack. 3GPP classifies interfaces between the radio access network and other networks to be part of the radio access network. In 3GPP2 these interfaces comprise a separate category of standards. Access network interfaces, the responsibility of a separate TSG in 3GPP2 (TSG-A) are considered part of the radio access network (TSG-RAN) in 3GPP.

The pie charts in Figures 1 and 2 summarize the classifications of standards by the two projects.

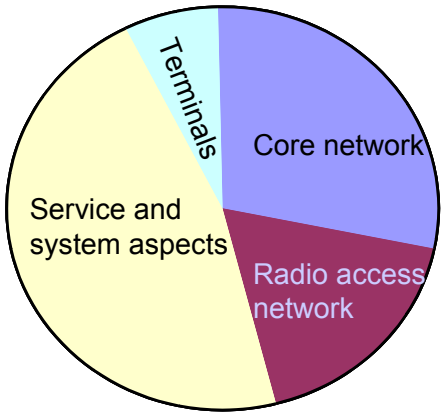

Fig. 1: 3GPP Technical Specifications

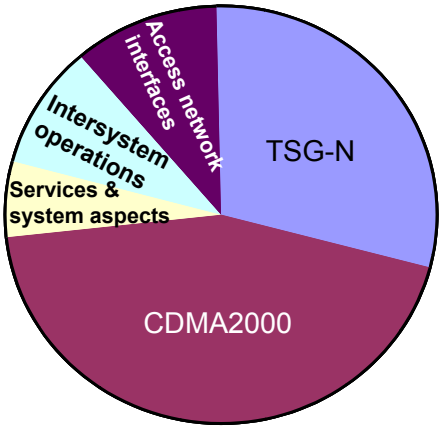

Fig. 2: 3GPP2 Technical Specifications

IV. Declared Patents

Our sources for patents and patent applications declared essential to 3G technology are the web sites of three standards organizations. ETSI lists declarations of patents declared essential to 3GPP[17], as well as declarations of patents declared essential to other technologies standardized by ETSI including GSM. The web sites of the Japanese standards organizations ARIB[18][19], and TTC[20] contain information about patents and patent applications declared essential to both third generation technologies. The ARIB notation for 3GPP standards is T63. The TTC notation is 3GA. For 3GPP2, the respective notations are T64 (ARIB) and 3GB (TTC). In the United States, the web site of the Telecommunications Industry Association contains statements by companies that have agreed to license essential patents on a non-discriminatory basis[21] but it does not contain lists of individual patents and patent applications.

Our study of WCDMA intellectual property is based on the ETSI list containing 6,872 patents and patent applications declared essential. For CDMA2000, we used both ARIB and TTC, which together identify 924 items. We analyzed these 7,796 items in order to cluster patents and applications into "patent families". The members of a family are patents obtained in different countries for a single invention. We determined that for WCDMA, there were 732 patent families with patents issued prior to January 1, 2004. There were 527 patent families for CDMA2000 with patents issued prior to February 5, 2004. There is considerable overlap in the declarations for the two technologies: 372 inventions were declared essential to both technologies.

It is important to remember that we examined only patents explicitly declared as essential to 3GPP and 3GPP2. Many companies, as a matter of policy, do not participate in setting standards nor do they declare any of their patents to be essential and thus agree to license them for a reasonable and non-discriminatory royalty. It is also important to note that the backward compatibility aspects of 3G standards means that patents declared as essential to an earlier standard such as GSM, TDMA or EDGE may also be essential to 3GPP or 3GPP2.

After clustering the patents into families, we chose one patent from each family for further analysis. To select a patent declared essential to WCDMA, we first looked for a patent issued by the European Patent Office. If there was no European patent in the family, we selected a United States patent if one was present. Our next choice was a Japanese patent. In the case of CDMA2000, our first priority was a United States patent. Our second choice for CDMA 2000 was a European patent, followed by a Japanese patent. There were only three families with no European, United States or Japanese patent. For those inventions, we analyzed a German patent, a British patent, and a Swedish patent.

V. PATENT CATEGORIES AND OWNERSHIP

After examining one patent from each patent family, we sorted the patents into 17 technical categories, covering key aspects of CDMA cellular communications such as CDMA fundamentals (including spreading codes, physical channels, and modulation), radio resources management (including power and rate control), location management (including location determination and mobility management), layer 2 (including media access control, error detection, and retransmission), source coding, channel coding, core network operations, call management, and synchronization. Table 2 shows the categories and the number of WCDMA and CDMA2000 patents in each category. With a few exceptions the ratios of patents in each category are similar for the two technologies. The biggest difference is the large number of electronic circuits patents declared essential to CDMA2000 (11%), compared to only 3% for WCDMA.

Table 2: Technical categories

Technical category	Patents declared Essential to WCDMA		Patents declared Essential to CDMA2000	
	number	percent	number	percent
antenna	20	2.7	17	3.2
call management	24	3.3	14	2.7
cdma	113	15.4	86	16.3
channel coding	50	6.8	30	5.7
electronic circuits	21	2.9	59	11.2
data	13	1.8	12	2.3
fax	3	0.4	3	0.6
handover	80	10.9	49	9.3
layer 2	29	4.0	22	4.2
location	40	5.5	21	4.0
network	59	8.1	32	6.1
radio resources	119	16.3	80	15.2
security	22	3.0	17	3.2
source coding	79	10.8	49	9.3
synchronization	40	5.5	21	4.0
tdma	4	0.5	1	0.2
terminal	7	1.0	6	1.1
not related to 3G	9	1.2	8	1.5
Total	732	100.0	527	100.0

In addition to the names of inventors, it is customary for a patent to state that the rights to the patent are "assigned" to a certain organization, usually the employer of the inventors. Although the patents in the study are assigned to 41 different companies, four companies own the rights to three quarters of the patents declared essential to the two systems: Qualcomm, Nokia, Ericsson, and Motorola. Twelve companies account for more than 90% of the patents. Figures 3 and 4 are pie charts showing the distribution of patent ownership for patents declared essential to 3GPP and3GPP2.

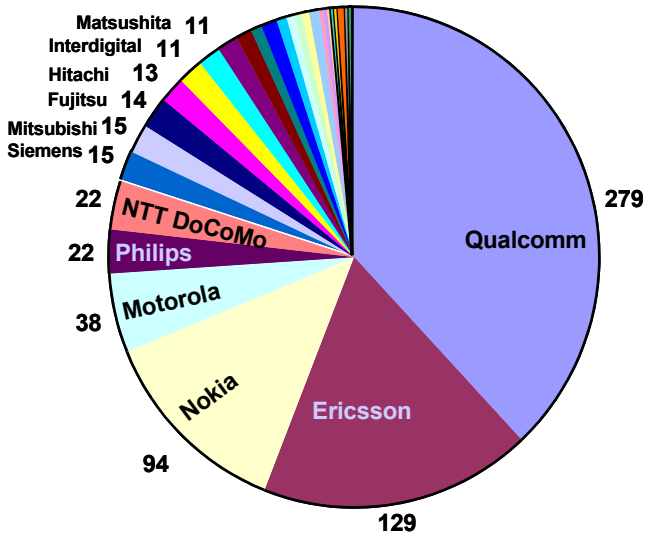

Fig 3: 3GPP Ownership of declared IP

VI. PATENT EVALUATION

Fairfield Resources International, an intellectual property consulting and licensing group headquartered in Stamford, CT, USA assembled a panel of technical experts in the United States, Canada, the United Kingdom, France, and Germany to perform a preliminary evaluation of the patents in the study. Each patent was assigned to one panelist according to the technical area of the patent. The panelists examined the independent claims of each patent and spent on average one hour comparing the content of the independent claims with the relevant part of the standard to which the patent was declared. Based on this evaluation, the panelist formed a preliminary judgment as to whether the content of at least one independent claim is necessary to implement the relevant part of the standard.

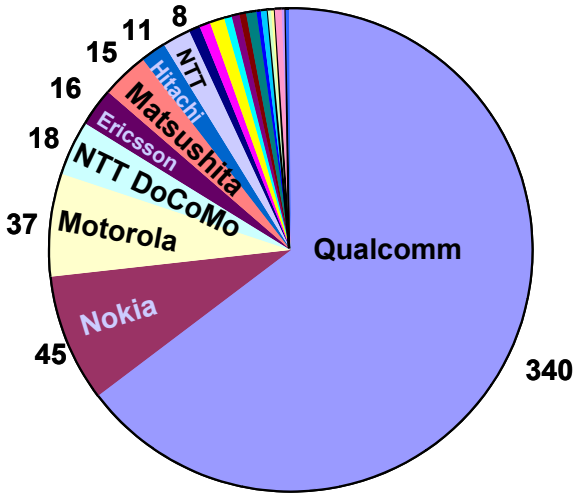

Fig 4: 3GPP2 Ownership of declared IP

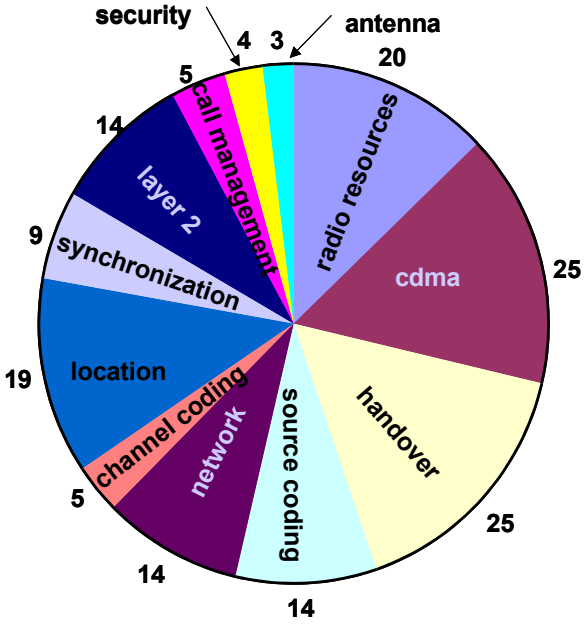

Fig 5: IP judged essential, 3GPP categories

This preliminary evaluation uses the narrow definition of essential quoted in Section I, i.e., every element of at least one claim must be practiced in order to implement the standard. The experts judged that 157 of the 732 of the patents (21.4%) declared essential to 3GPP are probably essential in the narrow sense of the definition and the others are probably not essential. For 3GPP, the experts estimated that 108 of 527 patents (20.5%) are probably essential. Figures 5 and 6 display the distributions of patents judged to be essential by patent category for the two technologies. Figures 7 and 8 show the distributions by patent ownership.

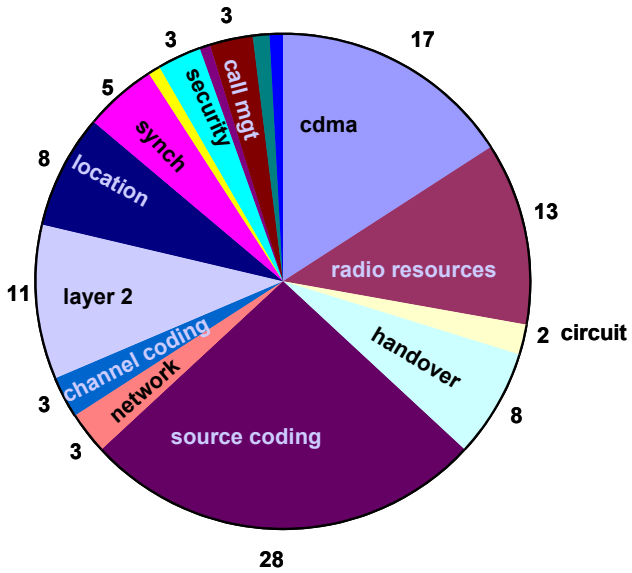

Fig 6: IP judged essential, 3GPP2 categories

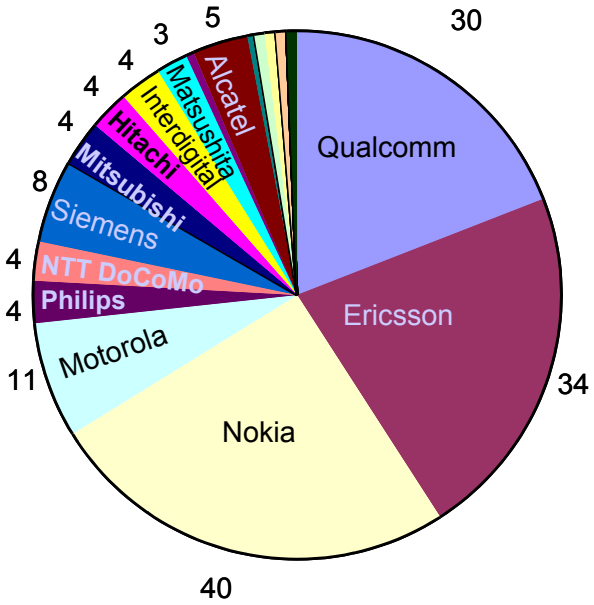

Fig 7: IP judged essential, 3GPP ownership

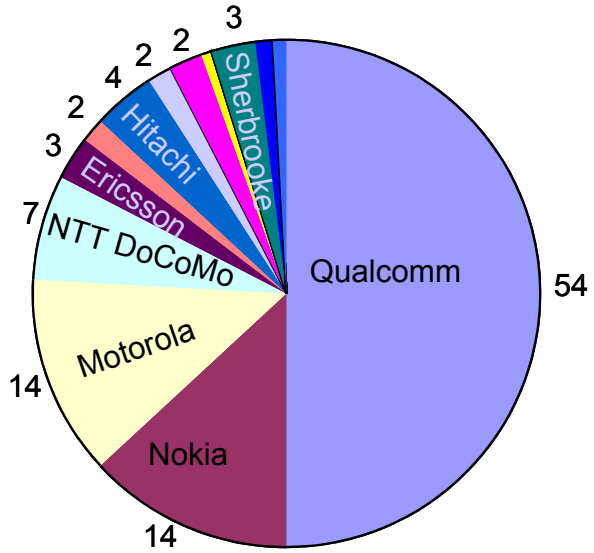

Fig 8: IP judged essential, 3GPP2 ownership

VII. Discussion of Results

A salient outcome of the patent study is that the evaluation panel estimates that nearly 80% of the patents declared essential are probably not essential for practicing the standards under the narrow definition of essential adopted by the standards organizations. Nevertheless, a company that creates equipment or services for third generation cellular systems still faces a formidable task obtaining rights to patented technology. Even with the narrow definition of essential and the low ratio of essential patents to declared patents it may be necessary to acquire rights to several dozens of patents,

depending on the equipment or service to be produced. In addition to the patents that are *technically* essential, there are probably many other patents that are *commercially* essential because they contain the best (albeit not the only) possible implementation of the standard. For example, while very few electronic circuit patents were judged essential, there may be many others that cover compelling implementations.

Although the patents declared essential are assigned to 41 companies, the patents judged to be essential by the panel are assigned to 20 companies. Of the 13 companies with patents judged essential to 3GPPP2, twelve companies have patents judged essential to 3GPP. Nineteen companies have patents judged essential to 3GPP technology. It is clear that the companies with major patent holdings can benefit from bilateral cross-licensing agreements containing rights to practice a group of patents. The alternative is for two companies to pay royalties to each other based on individual products produced.

In addition to the patents and patent applications in our study there may be others that are essential. For example, Nortel Networks has declared to the TIA that it owns technology essential to CDMA2000[21] and there may be other companies with essential patents that have chosen not to declare them to the standards organizations. As another example, Lucent Technologies, a major manufacturer of cellular infrastructure equipment, has apparently not declared any of its intellectual property to be essential to practicing the standards.

Concluding this paper, it is necessary to point out several limitations to our study. For example, with regard to patent ownership, we are aware that it is not unusual for a company to acquire the rights to patents invented by outsiders. Such acquisitions are only rarely in the public domain. As a consequence our pictures in Figures 3,4,7 and 8 are not precise indicators of who owns declared and essential intellectual property. The actual ownership distribution would take into account agreements that transfer patent rights from the company identified on the patent to another company.

It is also important to address the status of the essentiality data. In practice, the value of a patent depends on several *legal* and *commercial* factors. By contrast, the evaluations performed by the panel in this study are *preliminary technical* assessments, based on an average of one hour of analysis per patent. Determining the scope of a patent and its commercial value, if any, requires several days of effort by lawyers and engineers, and sometimes weeks or months of adjudication by judges and juries. In addition to the relationship of a patent to practical equipment and services, it is also necessary to consider patent *validity*. It is common for a company to assert that a competitor's patents are invalid and therefore unenforceable, either due to flaws in the patent itself or due to the fact that the claimed technology existed elsewhere when the inventor filed the patent application.

Another factor is the dynamic nature of both standards and intellectual property. By necessity, the standards cover existing proven technology, while patent applications describe novel techniques. Many of the patents were declared to be essential to technical specifications that were under consideration but not yet published when the patent applications were submitted. Both 3GPP and 3GPP2 continue to refine and enhance the standards. They regularly publish new and revised Technical Specifications, so that some of the patents that were judged not essential to specifications published before 2004 may be essential to present-day specifications or specifications to be published in the future. In addition, inventions that appeared in the databases in early 2004 as patent applications may now be embodied in published patents that are essential to 3G technology.

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