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The Intellectual Property Rights (IPR) elements of the DIME Network currently focus on research in the area of patents, copyrights and related rights. DIME's IPR research is at the forefront as it addresses and debates current political and controversial IPR issues that affect businesses, nations and societies today. These issues challenge state of the art thinking and the existing analytical frameworks that dominate theoretical IPR literature in the fields of economics, management, politics, law and regulation- theory.

The Effect of Strategic Patenting on Cumulative Innovation in UMTS Standardization

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Abstract

Since the 1990s, intellectual property rights have become increasingly important in the telecommunications sector. In particular, the strategic role of patents played in the GSM standard irrevocably changed the IPR strategies within the sector, increasing both the revenues and barriers provided by telecom patents. The issues raised by GSM foreshadowed comparable impacts of patents upon other ICT standards. These developments parallels broader concerns raised by researchers about the risk that such patents impede the process of cumulative innovation, a problem some have labeled "the tragedy of the anticommons." After reviewing research on the various controversies regarding patents, cumulative innovation and standardization, we review the evolution of the role of patents in telecommunications standards. We then analyze the role of 1227 unique "essential" patents declared in the standardization of Universal Mobile Telecommunications System (UMTS), the third-generation successor to GSM. Using a combination of data sources, we show how differences in the timing, nature and scope of patenting activities relate to firms' business models, competitive position and role in the standardization activity.

From this, we offer broader observations about the limits of existing IPR policies and coordination mechanisms, as well as the likely impact of various policy alternatives on patent proliferation in telecommunications standardization.

Contents

1. Introduction

There has recently been a debate about the actual and optimal role of patents in industrial innovation. This role has changed over the past 25 years, in response to changes in the IPR policy regime in leading countries, industry structure and the strategies used by firms in managing their IPR portfolios. Some have applauded such changes, as with Chesbrough's (2003) advocacy of "open innovation" as a way for firms to maximize their return to innovation investments. Others have deplored the increasing use and impact of patent monopolies, particular as they relate to various forms of cumulative innovation (Heller and Eisenberg, 1998; Scotchmer, 2004; David, 2004). Still others have argued that the patent system (particularly in the US) to reduce the proliferation of questionable patents (FTC, 2003; Jaffe and Lerner, 2004).

A particularly salient example of how such IPRs impact cumulative innovation has been on voluntary product compatibility standards, particularly those related to information communications technology (ICT). Here, the goals of the standardization participants – interoperability and adoption of their respective products — can only be achieved if the IPR does not prevent the implementation of the standard by multiple participants. At the same time, these same participants now use influence and other tactics to their own advantage, both in defining the content of the standard and allocation of its eventual spoils of the collaboration.

Perhaps the best (and best known) illustration of competitive IPR maneuvering in multivendor standardization was in the development of the GSM mobile telephone standard during the 1980s. As documented by Bekkers and others (Bekkers, 2001; Bekkers, Duysters and Verspagen, 2002; Iversen, 1999; Loomis, 2005) the patents provided a key revenue source to a small subset of the standardization participants, while at the same time posing a high barrier to entry by later entrants. The "success" of GSM patent holders in demanding

IPR royalties had a direct impact upon the strategic use of IPR in telecommunications industry.

Here we consider the IPR claims made by 42 firms in the successor to GSM, the third-generation Universal Mobile Telephone Service (UMTS) standard. While there are important differences between the technologies and institutions, the UMTS standard was developed by many of the same European firms and institutions that produced GSM. As such, we believe the contrast in firm IPR strategies between the GSM and UMTS eras suggests both direct learning effects and broader secular trends in the strategic use of patents in industrial innovation.

First, we review prior research on the overall (mis)uses of patents, and their impact upon standardization. Next, we provide a brief summary of the UMTS standardization process, showing how it both paralleled and differed from the earlier GSM effort. From this, we present an original analysis of the "essential" patent claims registered with a key UMTS sponsor, including the increase in the total number of unique patents claimed from 140 in the GSM era to more than 1200 for UMTS. Using the authorship and time of the patent initiation, we draw inferences about the interaction between firm strategies in R&D and standardization activities.

2. Patents and the (Dis)Incentives for Innovation

To provide an incentive for innovative activity, most countries grant temporary monopoly for the creator of inventions that are useful, novel and non-obvious. Besides increasing the likelihood the inventor can appropriate a return from his/her invention, the protection also allows inventors to offer their inventions to the market without risking loss to competitors (Arrow, 1962; Nordhaus, 1969; Gallini, 2002). The monopoly itself is limited both by the scope of the patent grant, and (in most cases) by how determined rivals are to circumvent the patent by "inventing around" (or ignoring) it, as well as the risk that the patent will later be challenged and invalidated.

A longstanding concern about monopolies (however limited) is the effect they have upon the innovation of others. For example, Jaffe and Lerner (2004: 51) recount how after the diode tube was invented and patented, Lee De Forest improved the design by adding a third element to form a triode. But because the triode infringed on the diode patent held by Guglielmo Marconi, U.S. courts ruled that neither De Forest nor Marconi could legally sell a triode without a license from the other (which they refused to grant). Development of the U.S. broadcasting industry was delayed until the stalemate was resolved (Scott, 2001). This case is an example of what Merges and Nelson (1990) term "blocking" patents, in which the earlier patent (e.g., the diode) blocks implementation of the later invention (the triode), but the later patent also blocks the earlier inventor from using a key improvement. The negative effect of such monopolies is particularly a concern for industries or technological developments that depend on cumulative innovation (cf. Scotchmer, 1991, 2004; Murray and O'Mahony, 2005). Advocates have lamented how these individual monopolies amount to "fencing off the commons" (David, 2000) or "the tragedy of the anticommons" (Heller and

Eisenberg, 1998). Specific remedies suggested have included providing a cumulative innovation patent exception for pure research (Merges, 1996; David, 2000).

A variety of factors have increased the concerns about such negative effects. Firms are increasingly pursuing IPR-based business models, in which the returns to innovation are separated from the vertically integrated production of goods that use such innovation (Chesbrough, 2003; West, 2006). Changes in the U.S. patent regime have increased both the number and enforceability of patents granted, including extending patents to previously unpatentable areas such as software (Jaffe, 2000; Graham and Mowery, 2003). And looking at quantity of innovations produced by U.S. firms, other regions (notably Europe) have sought to emulate the American incentives to innovation (European Commission, 1997) — which critics fear will spread the negative impacts of such IP regimes to other jurisdictions.

2.1. Patent Strategies and Innovation

The goal of patents is to provide an incentive to innovation by providing a temporary monopoly to inventors. However there has been a debate over the actual role played by industrial patents. Instead of gaining a temporary monopoly, firms may instead seek to deter rivals from enforcing their own patents, or to extract licensing royalties from the sale of other firms' products.

There is both a positive and normative aspect to this debate over the role of patents. How are they used, and how should they be used? Both the practice and philosophy of industrial patents has evolved over time. One factor has been the changing industry structure. Globalization means that once autonomous national monopolies (or cozy oligopolies) are potentially competing with firms from other countries. Thus, firms seek new and more aggressive strategies to differentiate the firm from a wider range of existing or potential competitors.

Based on a 1994 survey of US manufacturers, Cohen et al (2000: 17-18) identified six major goals for patenting product and process innovations. Allowing for multiple objectives, these six goals were (in decreasing order of importance):[1]

1. *Preserve exclusivity.* This is the traditional role ascribed to patents, allowing a firm a temporary monopoly to profit from its innovation.
2. *Blocking cumulative innovation.* 82% of the product patents and 64% of the process patents were aimed at slowing competitors' efforts to patent in similar areas and build similar products. Such patents would tend to discourage or prevent cumulative innovation, a concern identified by Scotchmer (1991, 2004).
3. *Defensive Patenting.* By winning a patent for their innovation, firms hope that to protect themselves against possible allegations they have infringed upon the patent of another firm. The FTC (2003: 6) identifies the activity creating such patents as one of the major diversions of R&D resources away from creating new innovations.

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[1] The original categories used by Cohen et al were "prevent copying", "blocking" "prevent suits", "for use in negotiations" "enhance reputation" and "licensing revenue.".

4. *Bargaining Chips.* In this model, patents are valuable for negotiating access to rivals patents, and thus "more an instrument for appropriating a share of oligopolistic rents" (Cohen et al, 2000: 26). This is the role of patents recounted by Bekkers (1991) and others for patents in the GSM standard.
5. *Licensing revenues.* Firms may seek to earn royalties from other firms, either as a byproduct of their existing innovation activities or the primary focus of the innovation business models (Chesbrough, 2003). The first approach is consistent Hall and Ziedonis (2001), who noted that during the late 1980s the largest U.S. semiconductor firms began to assert their patents to increase licensing revenues from their patent portfolios. While the second approach is likely underrepresented in Cohen et al (1997) sample of manufacturers, when enabled by IP rights it often allows firms to create a valuable niche in a value network (West, 2006).
6. *Performance benchmarking.* Filing patents provides a way to measure the output of R&D scientists.

A seventh category not covered by the typology of Cohen and colleagues is the "patent troll." This is a disparaging term used by manufacturers to refer to individual inventors (or small firms or investment groups) who do not make products, or even offer prospective licensing terms.

> *"Instead, a troll hides under bridges, metaphorically speaking, waiting for companies to product and market products. ... The ugly, evil troll then leaps up and demands a huge toll, that is a licensing fee settling actual or threatened patent litigation"* (Chisum, 2005: 340).

However, definitions of "patent troll" vary considerably between potential licensors and licensees.[2] The exact definition has significant policy implications, as larger firms seek patent reform to prevent "abusive litigation" (Woellert, 2005).

2.2. Variability in Patent Quality and Value

The inventions represented by patent applications vary considerably in their technical and economic significance. The central trade-off of patent policy is to use the patent grant to maximize the incentive for firms to innovate, while minimizing the deadweight loss that such grant causes to the innovative activities of others.

This loss has been increased by the recent proliferation of patents in the U.S. system, which many have attributed to the failure of patent authorities to enforce the requirements of novelty and non-obviousness. The granting of questionable (or "low quality") patents impairs the innovation of others while rewarding non-innovative patent filing (e.g., FTC, 2003; Jaffe and Lerner, 2004). The problem is exacerbated when the overlapping IPR grants of multiple

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[2] The originator of the term, Intel attorney Peter Detkin, changed his own definition after joining an IP licensing company (Kanellos, 2005).

patents form a "patent thicket," making it difficult for any firm to create actual products without gaining the cooperation of other firms. The number of patents (and tendency towards thickets) is fueled by firms seeking to acquire defensive patents to defend themselves (Shapiro, 2001; FTC, 2003: 6; Clarkson, 2005). According to this analysis, the *ex ante* quality control measures in the US patent system are ineffective while the *ex post* remedies are costly and crude, through use of a lawsuit seeking to invalidate the patent. Graham and Harhoff (2005) estimate that 1-3% of US patents are challenged via lawsuits, with each suit costing $1 million or more. They calculate that if the US adopted the unique post-grant opposition system of the European Patent Office, patent litigation could be reduced by 19-24%, while increasing US patent examination standards could significantly reduce the number of granted and litigated patents.

One of the concerns about the changes in the patent system has been the potential granting of low "quality" patents, i.e., inventions that would not previously been patentable (e.g. Jaffe and Lerner, 2004). Patented inventions differ significantly in their technical innovativeness, commercial value and the degree to which the patent deters potential imitators. Conversely, what is the value of a legitimate patent to the innovator? The distribution of patent values is highly skewed, with only a small percentage of patents holding significant commercial value (Griliches, 1990; Harhoff et al, 2003). The value of the patent is a function of the commercial value of the patented innovation, the impact the patent has on subsequent innovation by others, and how effectively the patent withstands likely attempts at circumvention or challenge. Given both the direct and opportunity costs associated with filing a patent, the decision by an inventor to patent an invention implies a belief that the invention is of above-average importance, but neither the patent application nor award process provide direct evidence of commercial value. Any invention only has a latent economic value until or unless it can be unlocked through a successful business model that innovator to its position in the value chain (Chesbrough and Rosenbloom, 2002).

One proxy for the value of a patented invention is how often the patent is cited by subsequent patents; this is a measure both of the importance of the patent in fueling subsequent innovative activity, and also suggests a potential blocking value for subsequent inventors. Trajtenberg (1990) showed that the number of patents correlated to innovation inputs, while the cumulative number of citations for a patent correlates to the (independently measured) product innovation in the product class. Trajtenberg et al (2002) showed that patent citations captured the high impact of key industry-enabling inventions, such as the Cohen-Boyer recombinant DNA patent and the original patents for CT scanners and pacemakers. However, they concluded that even the most important basic inventions differed in the breadth of their impact — whether limited to the invention's product class or more broadly dispersed among related technologies.

Of course, creating and patenting an invention is no guarantee of commercial value. Given both the direct and opportunity costs associated with filing a patent, the decision by an inventor to patent an invention implies a belief that the invention is of above-average importance. But the value of an invention depends on the degree of intellectual property rights granted and the ability of the firm to appropriate value from those rights (Teece, 1986; Sherry and Teece, 2004). Any innovation has only latent economic value until or unless that value can be unlocked through a successful business model that links the inventor to its position in the value chain (Chesbrough and Rosenbloom, 2002).

Even with IPR rights for a commercially valuable innovation, the innovator faces considerable *ex ante* uncertainty about the actual degree of protection those rights will provide (Sherry and Teece, 2004). A best, the inventor hopes that the patent will deter competitors from circumventing it and will withstand any legal challenges; at worst, the individual patent becomes nothing more than a lottery ticket (Lemley and Shapiro, 2005). The tendency of firms to develop patent thickets is based in part on a desire to reduce the risk of such circumvention or invalidation, and thus increase the certainty appropriating value from the innovation (Shapiro, 2001).

2.3. Coordination and Collaborative Innovation

Patents have recently generated considerable controversy for standards-setting organizations (SSO) establishing voluntary product compatibility standards. Such efforts are a specific example of collaborative innovation, although firms have both collaborative and competitive interests in advancing a standard (Simcoe, 2006). The greater the number of patents that impact a given standard, the more difficult it becomes for firms to legally implement that standard. The issues faced with compatibility standards are a specific case of the "fencing off" or "anti-commons" barriers that patenting pose to inherently cumulative innovation. As the number of patents (and patent holders) increases, the feasibility of alternatives to licensing decreases — and with it the bargaining power of the potential licensee. While individual patent holders of an individual patent have an incentive to reasonable license terms so that it is cheaper for rivals to license the patent than "invent around" it (Gallini, 1992), this incentive is reduced with multiple patents, particularly in the case of patent thickets.

Even if patent holders set an individually reasonable royalty for licensing their patent(s), with patent proliferation the combined effect of a series of such isolated decisions can render implementing a given standard economically infeasible. Such "royalty stacking" by multiple inventors is already considered a serious problem for creating new biotechnology products (OECD, 2002), and is fueled by the presence of questionable patents (FTC, 2003). If high royalty rates prevent sale of a product, this may motivate IPR holders to moderate their licensing demands — unless of course one or more IPR holders have a stake in the success of a competing or substitute technology. For example, a company developing its own proprietary IT standard may have little incentive to license its patents to makers of an open standard developed by its competitors.

Even with reasonable royalties — either through licensor forbearance or through astute use of cross-licensing — a proliferation of patent holders substantially increases transaction costs. Negotiating licenses with multiple licensors entails significant managerial and legal costs, particularly for the inherently complex (and contentious) issues of valuation in cross-licenses.

Patent pools are potentially an answer to all these issues. Subject to the aforementioned legal constraints, a pool can greatly simplify the licensing process by providing a single point of contact for the essential IPR. They also can potentially solve the royalty stacking coordination problems, when patent holders agree to a price cap that guarantees licensees a fixed price by diluting royalties proportionately for each new IPR claim added to the pool. In exchange, licensors may find the effect protection from their patent strengthened if the pool charges fixed (rather than proportionate) royalties for use of any pool patents that reduce the incentive to invent around or legally challenge any one patent.

Despite these theoretical advantages of patent pools in standardization, empirical evidence as to their benefits remains scarce. Possible factors include the rarity of their use, the comparatively recent rise in patent issues in standardization, or even the inevitable secrecy of how patent pools allocate returns to participants. However, even a casual analysis of the patent pool suggests a more fundamental problem: assigning exclusive control of the right to license one's IPRs requires a strong alignment of interests of the IPR holders. When there is competitive heterogeneity between the firms' product and IPR positions, it will be difficult for patent pools to attract (or maintain) broad enough participation necessary to make a significant patent pool. This is demonstrated by their relative unimportance in the case of UMTS standards.

3. An Analysis of UMTS Patents

To consider the impact of patents on cooperative innovation, here we study the 3rd Generation cellular telephone system, UMTS (Universal Mobile Telecommunications System).[3] This is perhaps the largest European effort for cooperative innovation of the past decade,[4] and also one where patents played a highly visible role. We are interested in these research questions:

- How are firm IPR strategies for UMTS similar or different compared to earlier efforts?
- What strategies and policies does this suggest for the future?
- How does the distribution of UMTS patents compare with prior standardization efforts?
- What effect are these patents having or likely to have upon adoption and the allocation of returns?
- What would restrain or limit excesses in the future?

3.1. Development of the UMTS Standard

The UMTS standard was both technically and institutionally a successor to the 2nd generation GSM (née Group Special Mobile). Much of the technical development took place at

[3] UMTS has also been called Wideband CDMA (W-CDMA), DS-CDMA and later 3GSM. For consistency's sake, throughout this paper we use the original UMTS name.

[4] For example, the amount pledged for UMTS radio spectrum licenses in Europe alone exceeds €100 billion.

the European Telecommunications Standards Institute (ETSI), an outgrowth of the GSM standardization effort, and it involved many of the same telecommunications vendors and operators that led the early GSM effort. The standard progressed in three important phases: exploratory research, formal standardization and standard implementation/refinement (Table 1).[5]

Table 1: UMTS development phases

Period	*Time frame*	*Main activities*	*Landmark event concluding this period*
1. Early research into 3G	around 1990 to early 1995	• Explorative R&D only	RACE research programme output shows outline of UMTS technology (though no specific choices yet made)
2. Drafting the UMTS standard and world-wide alignment	early 1995 to late 1999	• R&D • EU induces establishment of UMTS Task Force and UMTS Forum • Japan takes over the lead • Renewal European interest and UMTS technology choice • Worldwide alignment	The so-called Release 99 version of the standard is the full, first stable version and allows developers to design actual equipment
3. Implementation and further development of the standard	from late 1999	• Improving and refining the UMTS standard • License auctions • Product development and network procurement	n/a

There were three significant differences between the UMTS and GSM efforts.

First, while GSM was intentionally a European-only effort, the control of the UMTS standard eventually migrated from ETSI to the Third Generation Partnership Project (3GPP), a consortium that included ETSI and standards bodies from the U.S. , China, Korea and Japan. The latter group — dominated by representatives of the national carrier NTT — was particularly important for both the technical and economic success of the standard. Secondly, the use of a Code Division Multiple Access (CDMA)-derived air interface standard meant that the standardization effort potentially overlapped the sizable patent portfolio developed by the U.S. firm Qualcomm, the originator of the cdmaOne (IS-95) 2nd generation standard that competed with GSM in portions of Asia and the Americas. Qualcomm played a more active role in an overlapping consortium, Third Generation Partnership Project 2 (3GPP2), which developed the rival cmda2000 standard.

Finally, as we will show, the number of patent claims and patent holders in UMTS far exceeded the earlier GSM experience, greatly complicating later implementation efforts (Table 2).

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5 The details of the UMTS standardization are beyond the scope of this paper. For a preliminary assessment of the standardization efforts, see Bekkers (2001) or Hillebrand (2003).

Table 2: Comparison of European 2G, 3G mobile phone standardization efforts

Area	*Issue*	*GSM Era 1988-1991*	*UMTS era 1993-1999*
European Telecommunications Industry	Industry structure	Largely government-owned PTTs	Liberalized with private competitors
	Standardization leadership	Operators	Vendors
Mobile Phone Standardization	Prior adoption	Limited outside Nordic countries	Widespread throughout Europe
	Nationality of participating firms	European and European subsidiaries	European and Japanese
	Locus of standardization	European	Global
	Competing technologies	None – government monopoly	cdma2000, TD-SCDMA; also previous generation
	Expected number of users	~ 100 million	billions
	Perceived role of IPR in standardization	Not considered a problem	Largely unsolvable
IPR Issues	# patent owners	23	73
	# of patents	140	1227
	Estimated total royalty	0-13%	20%
	Strategic patenting	rare	Increasingly common
	Differences in business models	All are manufacturers	Several IPR-only companies
	Opportunistic behavior	Unheard of	Emerging problem

3.2. Patent Data

Our data are derived from UMTS standards-related patent declaration, cross referenced to other patent sources and databases. ETSI requests its members and non-members to provide a written declaration (‘undertaking’) that their essential intellectual property will be licensed for FRAND conditions, and these notifications are usually made public (ETSI, 2004). To identify the patents claimed to be essential for implementing the UMTS/3GPP standard, one may study the appropriate documents and online sources at standards bodies that participate in 3GPP (i.e. ARIB from Japan, ATIS from the US, CCSA from China, ETSI from Europe, TTA from Korea and TTC from Japan); Table 3 presents an overview which firms notified essential UMTS patents at these bodies. The table also includes a column on GSM-related declarations, since most UMTS infrastructures and terminals provide backward compatibility for GSM and thus are affected by such IPR. As shown, the firms adopt a variety of patent declaration policies, which may be partly explained by the fact that firms are not always member of all these standard bodies.

Table 3: Notification of essential UMTS patents to the various 3GPP members, plus GSM patents at ETSI

Notifications at:	*ETSI online IPR database (1)*	*ETSI SR314 (2)*	*ARIB(3)*	*ARIB(4)*	*ATIS(5)*	*ETSI online IPR database (1)*
Concerning (6):	*UMTS*	*UMTS*	*UMTS*	*UMTS*	*UMTS*	*GSM*
1. Aepona	x	x				
2. Alcatel	x	x				x
3. ASUSTeK	x	x				
4. Axalto	x					
5. Bijitec	x	x				
6. Broadcom	x					x
7. BT						x
8. Bull CP8						x
9. Canon	x	x	x			
10. Casio			x	x		
11. CCETT	x					
12. CCL/ITRI	x	x				
13. Cellnet						x
14. Cisco Systems	x	x				
15. Coding Technologies	x	x				
16. DDI				x		
17. De Te Mobil						x
18. Ericsson	x	x	x			x
19. ETRI (Korea Telecom)	x	x				
20. EVOLIUM	x	x				x
21. France Telecom	x	x				x
22. Fujitsu Limited	x		x	x		
23. Gemplus						x
24. Golden Bridge Technology	x		x	x		
25. Hitachi	x					
26. Huawei Technologies	x					
27. Hughes Network Systems	x					
28. Innovatron						x
29. Intel	x					
30. InterDigital	x	x				x
31. IPR Licensing	x	x				
32. Italtel Spa	x	x				
33. KDD			x			
34. Kineto wireless*					x	
35. Kokusai			x			
36. KPN	x					x
37. Lucent/AT&T	x	x			x	x
38. Lupa Finances						x
39. Matra						x
40. Matsushita/Panasonic	x		x	x		
41. Media Farm	x	x				
42. Mitsubishi	x	x	x	x		x
43. Motorola	x	x	x	x		x
44. NEC Corporation	x	x	x	x		x
45. Nokia	x	x	x	x		x
46. Nortel Networks	x	x				x
47. NTT	x		x	x		x
48. NTT DoCoMo						
49. OKI Electric Industry	x	x	x	x		
50. Omnipoint	x	x				x
51. Orange	x					x
52. Philips	x	x				x
53. Qualcomm	x	x	x	x		x
54. Robert Bosch	x	x				x
55. Rockwell						x
56. Salbu Research & Development	x	x				
57. Samsung	x	x	x	x		x
58. Schlumberger Systèmes						x

Notifications at: *Concerning (6):*	*ETSI online IPR database (1)* *UMTS*	*ETSI SR314 (2)* *UMTS*	*ARIB(3)* *UMTS*	*ARIB(4)* *UMTS*	*ATIS(5)* *UMTS*	*ETSI online IPR database (1)* *GSM*
59. Sharp*			x			
60. Siemens	x	x	x	x		x
61. Sony			x	x		
62. Sun Microsystems	x	x				x
63. Tantivy Communications	x	x				
64. Télédiffusion de France	x					
65. Telia	x	x				x
66. Telia Sonera						
67. Texas Instruments	x	x		x		x
68. Toshiba	x	x	x	x		x
69. University de Sherbrooke			x			
70. Vodafone/ Libertel/ Airtouch	x					x
71. VoiceAge	x	x				
72. Voicecraft			x			
73. Wi-Lan	x	x				
Total number of firms notifying	52	37	22	17	2	36

Notes:

(1) IPR in ETSI deliverables, as available from www.etsi.org, as of September 28th, 2005.

(2) ETSI SR 000 314 V1.14.1 (2005-04) Special Report, Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards.

(3) Notifications in document ARIB STD-T63 Ver 1.00 "List of Essential Property Rights (IPRs) for ARIB STD-T63 " IMT-2000 DS-CDMA system" (probably from October 2000)

(4) Notifications in "Japan's Proposal for Candidate Radio Transmission Technology on IMT-2000: W-CDMA", ARIB, June 1998

(5) Notifications in ATIS Patent Information, consulted November 2005 at www.atis.org/tc/patpolicy.asp

(6) GSM refers to any GSM, GPRS or DCS-1800 patents; UMTS refers to any UMTS/3GPP patents

Firms in italics agreed to license via W-CDMA Patent Licensing Programme (cf. 3GPatents 2004)

In addition to these patent disclosures, our primary dataset included the actual UMTS patents themselves, as filed in multiple jurisdictions. Unfortunately, the sources mentioned in Table 2 are not all complete and consistent enough to allow for a detailed analysis. For our analysis, we used the most reliable dataset available (ETSI 2005). This 2,427 page report lists a total of 13,106 patent notifications. Of these, 6,313 of these relate to 3GPP/UMTS standards/deliverables, the other to other ETSI standards (e.g. GSM, TETRA, and ERMES). However, the same innovation is often double counted by this data, when the IPR holder applies for different patents on the same innovation in different jurisdictions. There may also be registrations referring to bundles of patents, such as those applied for by the European Patent Office (EPO) or by the World Intellectual Property Organization (commonly known as PCT patents, and designated by the prefix 'WO'). Also, the same innovation may be listed more than once, at different ETSI projects (all covering UMTS/3GPP). Such double counts have been removed on the basis of the provided patent application number and the patent numbers. To translate such these numbers, usually given in the numbering systems of their respective legislation, we used a variety of sources, including the EPO's MIMOSA patent database. The patent citation dataset developed by OECD proved to be particularly useful to identify of equivalent patents, even though it was originally was designed for another purpose. Its main drawback, however, that it only includes patents up to the year 2000.

We also used several online patent data sources, most notable the Esp@ce service of the EPO and the patent search services of the US Patent Office (USPTO), the WIPO, and those of the Japanese Patent office. The data reduction is not a trivial task, since identical patents may be notified using totally different names while sometimes different patents do share the same name. Also, the data provided is often incomplete, inconsistently coded and contains numerous typographic errors (both in their titles as their numbers). We included all the notified patents, regardless whether they were already granted or still pending. Some individuals have an impressive record as inventors in patents, such as Donald Schilling of InterDigital (225 EPO patents) and Klein Gilhousen (312) and Paul Jacobs (220) of Qualcomm.

Altogether, we have been able to reduce the data to 1,227 unique, essential patents. 801 patents were filed for at the EPO (see Table 4). For those patents that were not filed under the EPO, we tried to find the US or PCT patent numbers, which we found for 276 and 104 patents, respectively. 24 patent notifications were so incomplete that we were not able to identify them.

Table 4: Patents by identifying patent treaty or country

Patent identification	*Claimed number of unique essential patents*
EPO	801
US, no EPO	276
PCT/WO, no EPO	104
Japan, no EPO	8
Canada (no EPO, US or PCT)	5
Germany, Finnish, French, English, Danish or Norwegian patent only (no EPO, US or PCT)	9
Unidentified	24
Total	1227

Source: own analysis of ETSI (2005)

Table 5 provides an overview of the number of unique patents by firm. Nokia, Ericsson, Qualcomm and InterDigital are the biggest players, in terms of patent ownership, followed by eight firms that own between 15 and 86 patents. 20 firms have notified five patents or fewer.[6] Several of these patent portfolios reflected changes in corporate structure during the period 1980-2000, as when AT&T spinoff Lucent assumed patent licensing rights from AT&T (with its 6 GSM patents). Other examples included Qualcomm's acquisition of Snaptrack (and its patents), the InterDigital acquisitions of SCS Mobilecom, and Nokia's purchase of the patent rights of the University of Sherbrooke. A few individuals account for a significant fraction of these patents, particularly Donald Schilling of InterDigital (225 EPO patents) and Klein Gilhousen (312) and Paul Jacobs (220) of Qualcomm.

[6] While the larger patent portfolio implies greater leverage, a firm that owns a single essential patent has the potential of blocking implementation of a standard.

Most firms in our source have provided detailed patent notifications, though six firms note that they believe they own essential patents without specifying the number of patents or their details; there is no way to tell if these firms have one relevant patent or 50. We refer to these statements as 'blanket claims,' but the vague nature of these claims makes it impossible to perform some analyses for these firms. The size of such blanket claims can still be considerable: at least one of the firms issuing a blanket claim is reported to have a portfolio of essential UMTS patents comparable in size and value to that of the four biggest IPR holders that do appear in our list.

Table 5: ETSI notified essential patents by firm

Firm	*Claimed number of unique essential patents*
Nokia	248
Ericsson	244
Qualcomm	228
InterDigital	168
Samsung	86
Motorola	54
Philips	45
Siemens	38
Asustek	23
Alcatel	20
Mitsubishi	18
Nortel	15
Toshiba, *ETRI*, Voiceage, France Telecom, Evolium, Sun Microsystems, OKI, Tantivy communications, IPR licensing, Salbu research & development, Cisco systems, Robert Bosch, Canon, CCL/ITRI, Media farm, Aepona, Bijitec, Wi-lan, Telia	Each claiming 5 or less patents
Coding technologies, Italtel, Lucent, NEC, Omnipoint, Texas instruments	Blanket claim

Source: ETSI (2005). *Firms in italics agreed to license via W-CDMA Patent Licensing Programme (cf. 3GPatents 2004)*

3.3. IPR Impact

In total, 73 firms claim to hold IPRs essential to either UMTS or GSM. This count would be overstated for firms that exaggerated the extent of the IPR. It would be understated the degree to which firms fail to notify essential patents. Firms that are not members of the do not disclose their IPR, particularly for non-member firms which cannot be compelled by UMTS standardization bodies cannot be compelled to disclose patents, suggesting there might be additional firms beyond the 73 that identified.their IPR.[7]

The large number of "essential" patent holders suggests that gaining IPR clearance to build UMTS-compliant hardware would be a complex and time-consuming, with potentially

[7] Based on a sampling of a single patent from 887 patent families of the 3GPP and 3GPP2, Goodman & Myers (2005) estimated that only 21% of the overall 3G patents were essential, while a British consultancy claimed (without verifiable evidence) that as a few as 10% of the patents are "crucial" to implement 3G (PA Consulting 2002). Because we cannot identify which patents are exaggerated or missing, we have chosen to conduct our analysis using the nominal disclosures, adjusted for double-counting as noted above.

some 5,000 bilateral agreements possible among this group. Even more licenses would be required if non-IPR holders were interested in producing products. This might include existing GSM phone makers HP, Palm, Sagem, Sendo, Research in Motion, as well as makers of PDAs, cellular modems, or other products. One possible solution to such high transactions costs would be the formation of a patent pool, allowing a manufacturer to execute many less than the 73 firm licenses. Work on a UMTS- pool entitled 3G Patent Platform started as early as 1998. After receiving positive business review letters from the US Department of Justice and the equivalent European and Japanese competition authorities in 2002, the pool established a joint licensing program in 2004. (3GPatents 2004). The pool currently includes only 7 of the 73 firms (as shown in Table 3) and only 1 of the 10 largest patent holders. As measured by either firms or patents covered, the pool would appear to have a fairly minimal impact on the patenting costs.

Finally, it is important to note that also patents that are not seemed essential to a standard can be very valuable and other manufacturers will feel the need to license those. These patents cover features that are considered valuable by customers (such as the T9 text entry technology for SMS services), or cover technologies that improve the performance of devices or lower their costs, without being strictly essential (i.e., there are other, possibly more expensive implementations that also conform to the standard. These non-essential patents may be owned by firms that hold essential IPRs, but also by firms that do not.

All in all, we conclude that a considerable number of different firms or organizations hold IPR essential to either GSM or UMTS, and both the number of firms and patents are much higher than they were for GSM. For a fair comparison, we look at both standards six years for the standard was frozen (for GSM that was the phase-1 standard, for UMTS the Release-99). This means that the patent portfolios we compare both include the patents essential to the first version, and those essential to later improvements or enhancements added to the official standard. For GSM, six years after the first stable specification, there were a total of 23 essential patent holders and a total of 140 essential patents. With UMTS, also six years after the first stable specification, we find at least 73 essential patent holders and a total of at least 1,227 essential patents, an eightfold increase.

3.4. Differences in Firm Patent Strategies

There are a number of important differences between firms in their patent motivations and output. Below, we will discuss six aspects that reflect firm strategy:

1. Patent intensity (in relation for firm size)
2. Patent timing (with regards to the standard-setting process)
3. Targeting (towards the standards'content)
4. Patent thickening
5. Patent quality
6. Technological diversity of the firm's essential patent portfolio

Intensity. Figure 1 shows, for the twelve major patent holders, the relation between the number of essential patents claimed and the revenue of the firm in question. To provide a consistent definition of telecom industry revenues, we used the revenue categories that ETSI uses as the basis of the contribution of its individual members. For this, ETSI uses the Electronics Communications Related Turnover (ECRT), defined as the worldwide revenue generated by products and services for which ETSI is competent for developing standards. There are incentives to neither understate nor overstate the results, as firms rather closely watch their own and other firm's declarations to ensure the proper payment of dues.

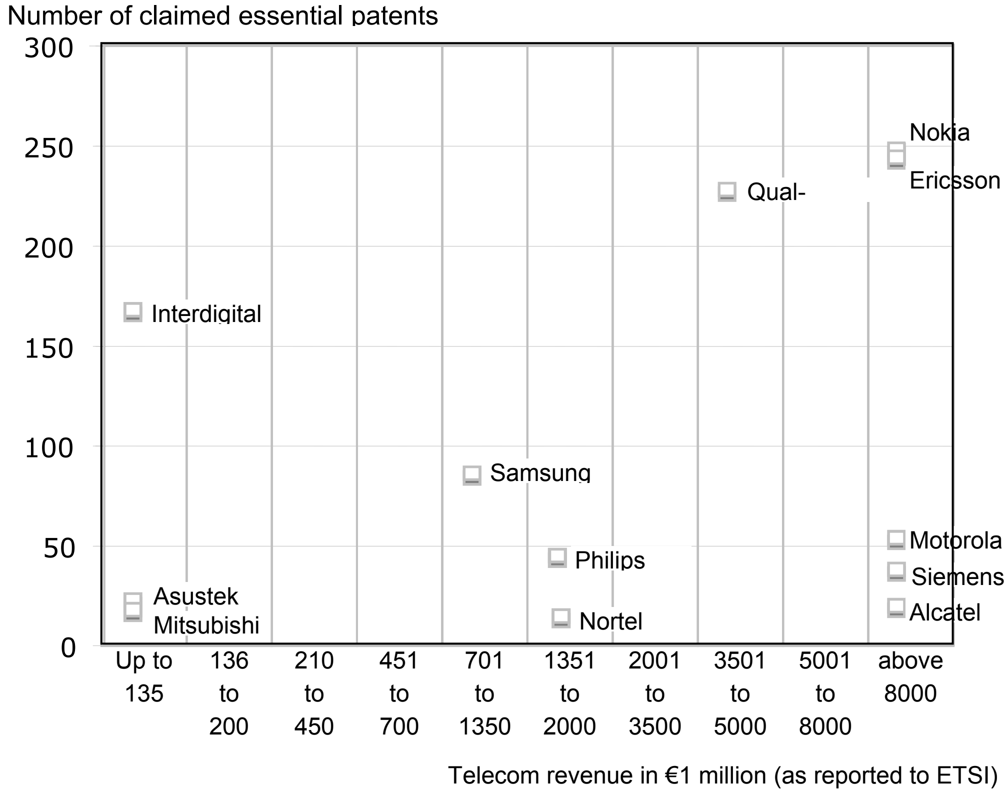

Figure 1: Essential patent portfolio size as a relation of telecom-related

While we might that a firm's patents to be linearly related to its revenue, our data shows exceptions in both directions. With unusually high patent propensity is Interdigital, which has a relatively low telecom revenue (less than €135 million annually), but holds many essential patents. In fact, the remaining three firms with higher patent counts have a revenue that is at least 25 times higher. Also worth to note that Motorola, Siemens and Alcatel all have a relatively small essential patent portfolio in relation to their revenue, even though mobile communications infrastructure and terminal products are key product areas for these firms.

Timing. A key form of standards-related strategic patenting is when a firm deduces the direction that a standardization effort is proceeding and then attempts to create patents to read on that standard. One way such strategic patenting might be evidenced would be if the patents were filed well after the corresponding standardization effort had begun. We analyzed the (earliest) priority dates of the 1203 patents we were able to identify (see Figure 2). More than the patent grant dates, these dates reflect the point in time at which the technology that is covered by the patent has been developed. These priority dates range from 1982 to 2002. There is a clear surge of patenting activities starting from 1990, with a clear peak at 1998/1999.

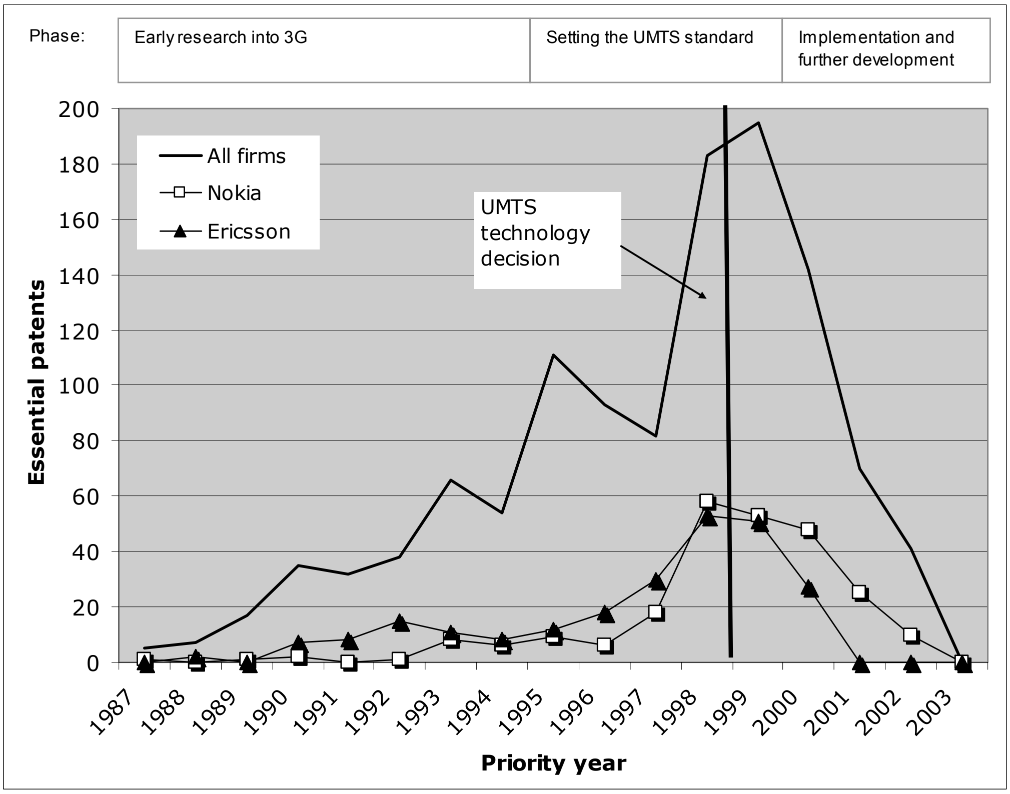

Figure 2: Timing of essential UMTS patents by leading manufacturers

In addition to the all patents, Figure 2 shows separate lines for the priority date for the patents held by Nokia and Ericsson. Both firms have rather identical patterns: there is a clear peak in patenting activity in the years 1998 and 1999, exactly the period in which the basic technology choice was made. Both firms were intensively involved designing their (successful) proposal for that selection, and later in drafting the actual details of the standard within the relevant ETSI Technical Committees.

Interestingly enough, Qualcomm and Interdigital, the two other large IPR holders, show rather different timing patterns (see Figure 3). For Qualcomm, 199 of its 226 claimed essential patents were applied for in 1996 or earlier. That is years before the basic technology for UMTS was selected (in 1999). Although there is usually some delay between the priority date and the moment other parties can see the claims, there is little doubt that at the UMTS technology selection it was clear that Qualcomm owned an extensive portfolio of relevant patents. Also, Qualcomm was not involved in any of the proposals to ETSI (focusing on its competing cdma2000 technology instead) and was relatively absent when the standard was further set and drafted. For the firm Interdigital, we also see that many patents were applied for long before the 1999 technology choice, though this company also shows more patenting activities in 2000 and 2001.

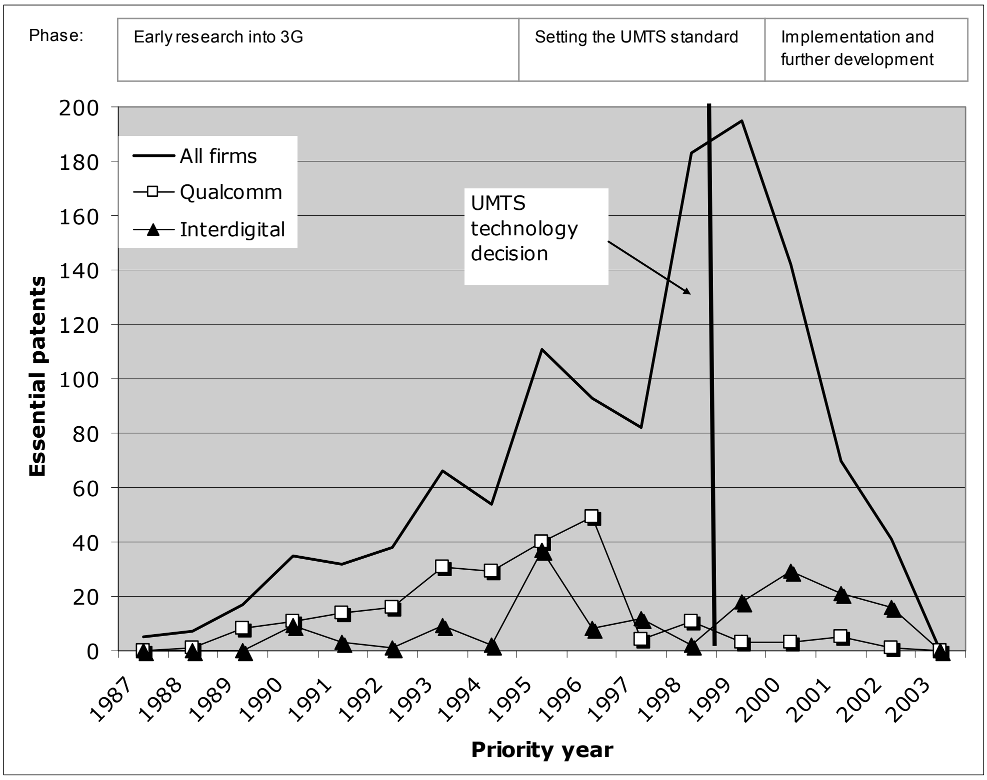

Figure 3: Timing of essential UMTS patents by leading IPR firms

Targeting. Another measure of strategic patenting would be if a firm's patenting is primarily focused at a particular standardization effort (here UMTS) rather than more broadly on mobile telephony or telecommunications. To consider this, we have compared their overall patent ownership in relevant mobile telecommunications categories with the UMTS essential patents that firm owns. We have identified the IPC codes that covered 97% of our essential patent data set, but omitted those IPC classes not specific to telecommunications (covering general electrical computing inventions or musical instruments, for example) which would distort our data for firms that more diversified in product markets. The remaining 11 IPC codes (five at the subclass level, six at the more detailed group level) still cover 85% of all patents essential to GSM, and therefore we consider these patent categories to be a good representation of inventions for mobile telecommunications.

For the 12 firms that rank highest on essential patent ownership (each holding more than 5 patents), we have identified all patents in these categories that were published by the EPO up to March 2005. The results are presented in Table 6, column (2). When we than look at the share of essential UMTS patents among, shown in column (4) then it is immediately clear that there are two clear outliers (marked bold in the table). For Interdigital (93%) and Asustek (92%) nearly all of their mobile telecom patents filed at EPO are disclosed as UMTS essential patents, a strong indication that their patenting activity was specifically directed to inventions that would become implemented in UMTS. The third highest score is for Qualcomm, of which 22% of the patents in this field are essential to UMTS. For all other firms, the ratio is 10% or less. One explanation might be that of a firm's global innovations, only the patents relevant to European use (in this case GSM or UMTS) are patented in Europe. Therefore, we have also analyzed the essential patent in relation to the mobile telecommunications patents held in the US. While this reduces the ratio for Interdigital, nonetheless both it and Asustek remain outliers.

Table 6: Relative specialization in UMTS in relation to all mobile telecom patents, for the 12 most active firms.

Firm	*Unique essential patents notified at ETSI (1)*	*All mobile telecom related patents in EPO (2)*	*All mobile telecom related patents in USPTO (3)*	*ETSI:EPO ratio (4)*	*ETSI: USPTO ratio (5)*	*Fraction of claims with identical titles (6)*
Nokia	248	2,591	2,330	10%	11%	5%
Ericsson	244	2,386	3,672	10%	7%	5%
Qualcomm	228	1,047	1,079	**22%**	**21%**	**27%**
InterDigital	168	181	375	**93%**	**45%**	1%
Samsung	86	1,016	1,317	8%	7%	**20%**
Motorola	54	1,144	4,497	5%	1%	13%
Philips	45	1,493	1,535	3%	3%	**22%**
Siemens	38	2,590	1,719	1%	2%	5%
Asustek	23	25	17	**92%**	**†135%**	0%
Alcatel	20	2,027	1,780	1%	1%	**20%**
Mitsubishi	18	439	814	4%	2%	6%
Nortel	15	921	1,662	2%	1%	13%

Note: Ratio values larger than 0.20 are printed bold. Mobile telecom patents in (2) and (3) are patents in IPC categories G01S1, G01S5, H01Q21, H01Q3, H04B, H04J, H04K1, H04L, H04M, H04N1 or H04Q
(1) Notification filed at ETSI according our analysis based of ETSI SR 000 314 V1.14.1 (2005-04)
(2) Patent filed at the EPO on or after 1 Jan. 1983 and published by 28 Feb 2005.
(3) Patent filed at the USPTO on or after 1 Jan. 1983 and published by 24 January 2006.
† Asustek notified ETSI of 12 patents filed with EPO without an USPTO equivalent.

Thicketing. Finally, firms may seek to deter entry or protect their ability to collect royalties through patent thickets through a web of overlapping patents on a single category of invention (Shapiro, 2001). One indicator of thicketing would be the use of an identical title for two patents; for this, we could conclude the patents are either closely related or even an identical invention. Column (6) in Table 6 shows the fraction of patent claims for which either the patent title or the title used for the notice are identical to that of other patents claimed by the same firms. Again, we observe differences between firms: for Qualcomm, Philips and Samsung the fraction is higher than 20%, whereas the average lies at 11%. For quite a few firms, none of the names are similar. It should be noted, however, that this is only a rough proxy, as some firms might be thicketing but varying the names to make it less identifiable.

Patent Quality It is very difficult to assess the actual value of a patent (cf. Sherry & Teece, 2004), even if we do not take into consideration that the value may become higher if a patent is essential to a standard - hence also increasing the negotiation power of its holder. The difficulty of assessing patent value is also the reason why many firms are reported to conclude cross licenses simply on the basis of the number of patents involved in the deal – not their individual value. Nevertheless, a holder of a patent that is particularly valuable – for instance a radical idea, that is the basis for a whole system – will insist it is worth more than most other patents. For that reason, we are interested to measure the value of the various patent portfolios.

The number of citations that a patent receives is often considered to be a proxy for the value of a patent (Trajtenberg, 1990). For our data set, we have performed an incoming patent citation analysis, using the OECD CitPat data set. This data set includes (outgoing) citations from all EPO and PCT patents, and thus allows us to reconstruct the number of incoming citations for the patents in our data set. It should be kept in mind that the role of patent citations differ per legislation. US applications are obliged to provide the relevant references to other patents or literature, whereas in Europe this is optional. Arguably, a patent citation analysis on the basis of European patents more precisely reveals patent values, because cites are only added if they are relevant, not because of a legal obligation to include a number of citations.

Our citation analysis identifies incoming cites from both EPO and PCT patent. A challenge is that cites often refer to national patent numbers. We have also included those sides by applying a correspondence table from national to EPO (or PCT) patents, and consequently filtering out the redundant routes. Due to this correspondence problem, and because the OECD database includes patents ‘only’ up to 2001, our data may omit some relevant citations, and is also right-censored.

Table 7: Incoming patent citation analysis for 12 most active firms

Firm	*Total number of patents*	*Total number of incoming cites*	*Average number of incoming cites per patent*	*Max received cites per patent*	*Proxy of the patent value*	*Rank*
Nokia	248	83	0,33	6	331	3
Ericsson	244	182	0,75	9	426	2
Qualcomm	228	339	1,49	33	567	1
Interdigital	168	18	0,11	4	186	4
Samsung	86	20	0,23	12	106	6
Motorola	54	103	1,91	13	157	5
Philips	45	32	0,71	9	77	7
Siemens	38	3	0,08	1	41	8
Asustek	23	0	0,00	0	23	11
Alcatel	20	10	0,50	8	30	9
Mitsubishi	18	6	0,33	4	24	10
Nortel	15	8	0,53	4	23	12

Table 7 presents the results of the patent analysis. Motorola and Qualcomm, by any measurement, have the highest scores. The average number of cites to their patents are 1.9 and 1.5 respective, far above the overall average of 0.66 cites per patent. The most valuable single patents seem to belong to Qualcomm; their patent EP0536334 receives no less than 33 cites.

No other firm scores higher than 12 incoming cites for a single patent. Following Trajtenberg (1990), we have calculated a proxy for patent value, that established the value of a single patent to be one plus the number of cites it receives (i.e. the aforementioned Qualcomm patent would receive a value of 1 + 33 = 34). If we would replace our ranking by the total number of patents by the newly calculated value proxy, the most significant change is that Qualcomm would move from the third to the first position, and Nokia vice versa. Thus by these measures, Qualcomm seems to hold the most valuable patents.

Technological Diversity. Another difference between firms is the degree to which patents held by a particular firm relate to many different technical aspects of the standard or whether all patents relate to the same part of the standard. This is a measure of how diverse the overlap is between a firm's patent portfolio and the standard (cf. Granstrand et al, 1997).

To determine diversification, we studied the so-called standards deliverables for which the patents were deemed essential, as indicated in the notifications. The UMTS standard is made up of hundreds of deliverables, classified in 15 main series. These series cover different technical areas, such as radio aspects, (speech) codecs and security (see Table 8). Some series comprise (much) more patents than others, mostly because of differing nature of the technology. Overall, most of the essential patents that are in our database are indicated to be relevant for the 25 series ('radio aspects'; 38% of all patents); the 21 series ('requirements', 25% of all patents) and the 23 series ('technical realization', 13% of all patents). All other series comprise less than 10% of all patents. Our results indicate that Siemens and Nokia are most diversified, whereas the patents of firms like InterDigital, Motorola and Asustek are in one very narrow area (one or two series only).

Table 8: Level of technological diversification

Firm	*Number of different specification series in which patents are notified (1)*	*Diversification measurement (corrected for portfolio size) (2)*	*Main series (3)*
Nokia	11	4,59	25, 23, 26, 24, 29
Ericsson	0	no data	no data
Qualcomm	5	2,12	22, 23, 24, 25
Interdigital	1	0,45	21
Samsung	3	1,55	25
Motorola	1	0,57	21
Philips	2	1,20	25
Siemens	8	5,03	25, 23
Asustek	1	0,72	25
Alcatel	2	1,51	25
Mitsubishi	3	2,35	25, 26
Nortel	3	2,49	25

UMTS specifications series:
21: Requirements
22: Service aspects
23: Technical realization
24: Signalling protocols - user equipment to network
25: Radio aspects
26: CODECs
27: Data
28: Signalling protocols
29: Signalling protocols - intra fixed network
30: Programme management
31: Subscriber Identity Module (SIM / USIM)
32: OAM&P and Charging
33: Security aspects
34: UE and (U)SIM test specifications
35: Security algorithms

Note 1: Column (2) is the total number of series in which a form owns patents (column 1) divided by the log of the size of the patent portfolio of that firm. This indicator can very between 0 (infinitive number of patents, once class) and 12,46 (one single patent in each of the 15 classes).

Note 2: ETSI and 3GPP use different coding for the classifications; for instance, ETSI deliverable TS 125.001 is equivalent to 3GPP deliverable TS 25.001. Although the translation for some deliverables is complex *(especially the older GSM, that are also coded by 3GPP), the concordance for UMTS deliverables is rather straightforward.*

Note 3: Interdigital notified patents for UMTS but indicates them to be relevant for the 3GPP TS41 series. These series, however, are for GSM release 4 and later, not for UMTS. Dealing with this inconsistency, we decided to count these declaration as part of the rather similar series 21 patents; alter all, Interdigital did officially notify these patents for the UMTS project.

4. Discussion

4.1. Impact of IPR on the Telecommunications Industry

We have shown how changes in the patent system, the rise of patent-related business models and larger expectations for the eventual market size increased the number of “essential” patents more than eightfold and tripled the number of firms asserting such patents from the 2nd to 3rd generation mobile telephone technologies.

This explosion of patent claims — and particularly patent claimants — increases the costs of implementing a standard in several ways. First, the increasing number of claims (and claims per firm) reduces the likelihood that any given patent will be challenged, invalidated or invented around. Second, the number of claims is likely to increase the cumulative licensee fees paid by any implementer. Third, each licensee faces increased transaction cost of negotiation a license with each IPR holder. Finally, the increasing number of IP claimants increases the opportunities for individual to block (“holdup”) implementation of the standard through unreasonable licensing terms.

It may be too soon to see the full effect of this IPR explosion upon the implementation and adoption of the UMTS standard. For example, it is possible that some firms are choosing to ship products without taking licenses from firms that hold a single “essential” patent — whether to reduce cumulative royalties, transaction costs or the risk of holdup. Reportedly, licensing contracts for many patents have yet to be signed. However, the cumulative royalties have already proven a problem that contributed to the delayed adoption of UMTS technologies. One estimated placed the total royalties of UMTS equipment at 20% (PA Consulting, 2002), while the leading GSM vendors paid little or nothing due to cross-licensing (Bekkers, 2001; Loomis, 2005). In response, in May 2002 Nokia sought to cap total WCDMA patent royalties at 5%. But in the end, Nokia won only support for “reasonable” licenses from DoCoMo and three European manufacturers. Some other European and Asian manufacturers — as well as some operators — backed the competing 3G Patent Platform Partnership (3G3P). North American participants in WCDMA standardization (Qualcomm, Lucent, Motorola, Nortel, TI) joined neither camp (Tulloch, 2002; Lane, 2003; Salz, 2004).

A patent pool might be expected to reduce the transaction costs associated with implementing a standard, as with the successful DVD and MPEG-4 patent pools. However, patent pools have been shown to fail when the primary motivation is to cap royalties (Bekkers, Iversen and Blind, 2006). In this case, the largest patent holders are outside the 3G3P pool. Although it might be too early to judge, this particular pool seems have failed to make a significant impact on the market. Other attempts to reduce royalties have included seeking a change to ETSI IPR policies, and an attempted European Commission complaint against Qualcomm, which hopes to use the ETSI (F)RAND policies to reduce Qualcomm's UMTS royalty rate. At this point, it is too soon to judge what the results will be (if any) from these efforts.

4.2. Improving Incentives for Cumulative Innovation

IPR licensing can have positive effects on cumulative innovation. For example, if firms aggressively seeking to create and license patents, this can lower barriers to entry by firms without internal R&D capabilities, thus increasing product competition and rivalry. For example, the role of specialized engineering firms in designing and building chemical production plants widely diffused process innovations in the chemical industry in the 2nd half of the 20th century (Lieberman, 1989; Arora, 1997). Similarly, the role of Microsoft and Intel providing components for personal computers greatly increased the number of producers as computing shifted from mainframes to PCs (West, 2006).

We see some influence of this in telecommunications. By licensing CDMA technology from Qualcomm, Korean manufacturers LG and Samsung were able to establish a foothold in the already-crowded global market for mobile telephones (Mock, 2005). However, it is clear that a diversity of business models (and thus misalignment of economic interests) hinders attempts at coordinating collective innovation. Service operators want to pay little or no patent royalties, IPR-only companies want to have little or not limits on royalties, while manufacturers (or at least those with IPR) want to earn enough royalties to recoup their R&D costs. As a result, rather than the constraint that the threat of "inventing around" places on excessive royalty fees, each individual IPR holder has few restraints against aggressively fencing off the rapidly growing anti-commons.

Several remedies have been proposed that seem unlikely to succeed. One proposal is to impose patent licensing restrictions as a condition of participation in standardization, but past experience suggests that a likely impact is that firms which find the conditions unacceptable will not participate in standardization. Another possibility is that the patent system could be modified to discourage trivial or duplicative patents (e.g. Jaffe & Lerner, 2004), but this would seem to have only modest results when at least nine companies have more than 20 patents each.

One approach that has worked in the past has been the formation of a patent pool as part of the standardization process. There are reasons why this apparently failed in the UMTS effort (particularly the number of IPR holders and the diversity of their interests), but there are examples where such pools have been effective in the past. Ultimately, the resolution may require either state compulsion or competitive pressures. One of the most vocal critics of high royalties has been the U.K. operator Vodafone, while two of the greatest beneficiaries of royalties have been the US firms Qualcomm and Interdigital. Thus, attempts by one government to impose compulsory licensing terms would like be resisted by another government, leading to potential trade conflict (as occurred temporarily during the Qualcomm vs. Ericsson disagreement over UMTS licensing terms in 1998-1999).

Market competition could provide another check upon licensing terms. For example, China has used the prospect of its homegrown TD-SCDMA 3rd generation standard to encourage lower royalty rates for deploying UMTS or cdma2000 networks within its borders. The U.S., Japan (and to a lesser degree, Korea) allow both UMTS and cdma2000 technologies to be used within their borders. Another possibility proposed at ETSI is to replace the IPR-laden W-CDMA radio technology of UMTS with another technology that has fewer patents. However, such competing standards are anathema to current European Union industrial policy. Without the credible external threat of a competing technology (as in China), or non-adoption (as happened with MPEG-4), it seems unlikely that a widely disparate group of IPR holders (as in UMTS) could be compelled to overcome their mutual rivalry and distrust to agree upon licensing terms acceptable to potential adopters.

4.3. Limitations and Future Research

This study has examined the IPR issues related to a single (economically significant) example of cumulative innovation. It is situated in a single industry, and largely in a single institutional context (that of its EU/ETSI origins), and thus the findings may not apply to other contexts. In addition, our analysis is missing key information — including specific royalty rates and total income, line of business revenues and the size of the "blanket claim" patent portfolios. Also, there are uncertainties using the self-declaration database we used which could contain both type-1 and type-2 errors. While there may be differences in the legal or economic significance of various "essential" patents, such information is deliberately withheld by IPR holders seeking to maximize their leverage (see Goodman & Myers, 2005 for one attempt to unmask such efforts).

IPR licensing has been effectively coordinated in a number of cases, whether by individual patent holders (the Phillips compact cassette or Qualcomm's cdmaOne), or through cooperative efforts of multiple firms (the aforementioned GSM, DVD and MPEG-4 efforts). An examination of multiple standards (perhaps by aggregating across individual case studies) might suggest what are the necessary pre-requisites for effective collaboration to promote cumulative innovation.

References

Arora, Ashih. 1997. "Patents, licensing and market structure in the chemical industry," *Research Policy* 26 (4-5), 391-403.

Arrow, Kenneth J. 1962. "Economic Welfare and the Allocation of Resources for Invention: Economics and Social Factors." In: Richard R. Nelson (Ed.), *The Rate and Direction of Inventive Activity,* Princeton University Press, Princeton, pp. 609-625.

Bekkers, Rudi. 2001. *Mobile telecommunications standards: GSM, UMTS, TETRA, and ERMES.* Artech House, Boston.

Bekkers, Rudi; Duysters, Geert; Verspagen, Bart. 2002. “Intellectual property rights, strategic technology agreements and market structure: The case of GSM,” *Research Policy* 31 (7), 1141-1161.

Bekkers, Rudi; Iversen, Eric; Blind, Knut. 2006. *Patent pools and standardization: coordination mechanisms for multi-party IPR holders*. Paper for the EASST 2006 conference, Lausanne (Switzerland), 23rd to 26th August, 2006.

Chesbrough, Henry. 2003. *Open Innovation,* Boston, MA: Harvard University Press.

Chesbrough, Henry and Rosenbloom, Richard S. (2002) The role of the business model in capturing value form innovation: evidence from Xerox corporation’s technology spin-off companies. *Industrial and Corporate Change,* 11/3: 529-555.

Chisum, Donald S. 2005. “Reforming Patent Law Reform,” *Marshall Review of Intellectual Property Law,* 4, 336-348

Clarkson, Gavin. 2005. Patent thickets

Cohen, Wesley M. Richard R. Nelson and John P. Walsh. 2000. “Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not),” National Bureau of Economic Research, working paper W7552. URL: http://ssrn.com/abstract=214952

David, Paul A., 2000. “A Tragedy of the Public Knowledge ‘Commons’?” Stanford Institute for Economic Policy Research Discussion Paper No. 00-02, Stanford University.

David, Paul A., “Can ‘Open Science’ be Protected from the Evolving Regime of Intellectual Property Rights Protections,” *Journal of Theoretical and Institutional Economics,* 160 (1): 2004: pp.1-26

ETSI. 2004. “Rules of Procedure of the European Telecommunications Standards Institute,” November 30, 2004, In *ETSI Directives,* December 2004, pp. 16-60,

ETSI. 2005. “Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards,” ETSI SR 000 314 V1.14.1 (2005-04), European Telecommunications Standards Institute, Sophia Antipolis, France.

European Commission. 1997. “Promoting innovation through patents: Green Paper on the Community patent and the patent system in Europe,” June, URL: http://europa.eu.int/comm/internal_market/en/indprop/patent/paten.pdf

FTC. 2003. *To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy.* Federal Trade Commission, Washington, D.C., URL: http://www.ftc.gov/os/2003/10/innovationrpt.pdf

Gallini, Nancy T. 1992. “Patent Policy and Costly Imitation.” *Rand Journal of Economics,* 23 (1), 52-63

Gallini, Nancy T. 2002. “The Economics of Patents: Lessons from Recent U.S. Patent Reform,” *Journal of Economic Perspectives,* 16/2: 131-154.

Goldstein, Larry M. and Brian N. Kearsey, *Technology Patent Licensing: An International Reference on 21st Century Patent Licensing, Patent Pools and Patent Platforms,* Boston: Aspatore Books, 2004.

Goodman, David J. & Myers, Robert A. 2005. "3G Cellular Standards and Patents," *Proceedings of 2005 IEEE Wireless Communications and Networking Conference,,* June 13-16, pp. 415-420, DOI: 10.1109/WIRLES.2005.1549445

Graham, Stuart J.H. and David C. Mowery, 2003. "Intellectual Property Protection in the Software Industry," in Wesley Cohen and Steven Merrill, eds., *Patents in the Knowledge-based Economy.* Washington, DC: National Academies Press, 219-58.

Graham, Stuart J.H.; Harhoff, Dietmar; 2005, "Would the U.S. Benefit from Patent Post-grant Reviews? Evidence from a 'Twinning' Study☐" working paper, Georgia Tech College of Management.

Granstrand, Ove; Patel, P.; Pavitt, Keith.1997. "Multi-technology corporations: Why they have 'distributed' rather than 'distinctive' core competencies." *California Management Review,* 39(4), 8-25.

Griliches, Zvi. 1990. "Patent statistics as economic indicators: a survey." *Journal of Economic Literature* 28 (4), 1661–1707.

Hall, Bronwyn H. and Rosemarie Ham Ziedonis – "The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry, 1979-1995," *RAND Journal of Economics,* 32, 1 (2001): 101-128.

Harhoff, Dietmar, Frederic M. Scherer and Katrin Vopel. 2003. "Citations, family size, opposition and the value of patent rights." *Research Policy* 32 (8), 1343-1363.

Heller, Michael A., and Rebecca S. Eisenberg, 1998: "Can patents deter innovation? The anticommons in biomedical research," *Science,* 280, pp. 698-701.

Hillebrand, Friedhelm (Ed.); *GSM and UMTS: the creation of global mobile communication:* Wiley, Chichester, England.

Iversen, Eric J. (1999). "Standardization and Intellectual Property Rights: ETSI's controversial search for new IPR procedures," *Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology,* Aachen, Germany, September 15-17: 55-63.

Jaffe, Adam B., "The U.S. patent system in transition: policy innovation and the innovation process," *Research Policy* 29 2000 531 – 557

Jaffe, Adam B.; Lerner, Josh. (2004) *Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do about It*. Princeton University Press, Princeton, NJ.

Jaffe, Adam B. Trajtenberg, Manuel. 2002. *Patents, citations, and innovations: a window on the knowledge economy.* MIT Press, Cambridge, Mass.

Kanellos, Michael. 2005. "Companies trying to cash in via licenses, lawsuits." CNET News.com, July 20, URL: http://news.com.com2009-1001_3-5793470.html

Lane, Nick (2003) "Risk of patent poker too high a gamble for Nokia," *3G Mobile*, (January 22), 5/2: 1-2.

Lemley, Mark A.; Shapiro, Carl, "Probabilistic Patents," *Journal of Economic Perspectives,* Spring 2005, v. 19, iss. 2, pp. 75-98

Lieberman, Marvin B. 1989."The learning curve, technological barriers to entry, and competitive survival in the chemical processing industries." *Strategic Management Journal,* 10 (5), 431-447.

Loomis, Tamara, (2005) "Cell Break," *IP Law & Business*, July, URL: http://www.ipww.com/texts/0705/europhony0705.html

Merges, Robert P. 1996, "Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations," *California Law Review,* 84 (5), 1293-1392.

Merges, Robert P, Nelson, Richard R. 1990. "On the Complex Economics of Patent Scope." *Columbia Law Review,* 90 (4), 839-916.

Mock, David, 2005. *The Qualcomm Equation.* New York: AMACOM.

Murray, Fiona and Siobhán O'Mahony, "Reconceptualizing the Foundations of Cumulative Innovation: Individuals, Communities & Institutions," working paper, MIT Sloan School of Management, August 2005.

Nordhaus, William D. 1969. *Innovation, Growth, and Welfare.* Cambridge, Mass.: MIT Press.

OECD. 2002. *Genetic Inventions, Intellectual Property Rights and Licensing Practices: Evidence and Policies.* Organization for Economic Cooperation and Development, 2002.

PA Consulting Group, "Essential patent rights in 3G wireless will win or lose companies millions," press release, September 11, URL: http://www.paconsulting.com/news/press_release/2002/pr_20020911.htm

Salz, Peggy Anne (2004) "Pay by the Rules." *Mobile Communications International*. April, p.109.

Scotchmer, Suzanne, "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*," Journal of Economic Perspectives,* Vol. 5, No. 1. (Winter, 1991), pp. 29-41.

Scotchmer, Suzanne, 2004. *Innovation and Incentives,* Cambridge, Mass.: MIT Press.

Scott, Carol E. 2001. "The Radio Inventor/Entrepreneurs," *Business Quest,* URL: http://www.westga.edu/~bquest/2001/radio.htm

Shapiro, Carl, "Setting compatibility standards: Cooperation or Collusion," In Rochelle Dreyfuss, Diane L Zimmerman and Harry First, eds., *Expanding the Boundaries of Intellectual Property: Innovation Policy for the Knowledge Society,* Oxford: Oxford University Press, 2001.

Shapiro, Carl and Hal R. Varian, *Information Rules: A Strategic Guide to the Network Economy,* Boston: Harvard Business School Press, 1999.

Sherry, Edward F.; Teece, David J. 2004. "Royalties, evolving patent rights, and the value of innovation." *Research Policy* 33 (2), 179-191

Simcoe, Tim. 20006. "Open Standards and Intellectual Property Rights." In Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., *Open Innovation: Researching a New Paradigm*, Oxford University Press, Oxford, pp. 161-183.

Teece, David J. 1986. "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy." *Research Policy,* 15 (6), 285-305.

Trajtenberg, Manuel, 1990. "A Penny for Your Quotes: Patent Citations and the Value of Innovations." *RAND Journal of Economics,* 21(1), 172-187.

Trajtenberg, Manuel, Henderson, Rebecca; Jaffe, Adam B. 2002. "University versus Corporate Patents: A Window on the Basicness of Invention." In Jaffe, Adam B., Trajtenberg, Manuel (eds.) *Patents, Citations, and Innovation,* MIT Press, Cambridge, Mass., pp. 51-87.

Tulloch, James, "Clear as Mud," *Mobile Communications International,* December 2002.

Woellert, Lorraine. 2005. "Washington Outlook: A Patent War Is Breaking Out On The Hill." *Business Week*, July 4, URL: http://www.businessweek.com/magazine/content/05_27/c3941058_mz013.htm

West, Joel (2006) "Does Appropriability Enable or Retard Open Innovation?" In Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., *Open Innovation: Researching a New Paradigm*, Oxford University Press, Oxford, pp. 109-133.