Innovation in Telecommunications

DEFINITION

"The word 'telecommunications,' a twentieth century amalgam of Greek and Latin roots, literally means the art of conveying information 'from a distance.' . . . Today, although precise definitions differ, 'telecommunications' is broadly defined as the transmission of information by means of electromagnetic signals: over copper wires, coaxial cable, fiber-optic strands, or the airwaves."[1]

INTRODUCTION

Telecommunications technology touches every aspect of our lives. It affects the way we do business, the way we govern ourselves, the way we keep in touch with those we love, and the way we build the collective human experiences we call culture. Altogether, the telecom sector accounts for about fifteen percent of the U.S. economy.[2]

As outlined in Table 1 below, this paper explores one particularly dynamic area of change in the telecommunications industry: the ongoing broadband revolution in residential and mobile communication.[3] The nature of the telecommunications products and services that Americans use has changed dramatically over the last twenty years as a consequence of significant, sustained, and rapid innovation. This paper reviews these shifts, and then explores how the underlying innovation has come about, and in particular whether it has tended to follow proprietary or commons-based models. Have telecommunications innovators been driven to discovery by the promise of ownership over their discoveries, monetized through licensing revenue or by the exclusive sale of knowledge embedded products? Or have companies been driven to innovate in pursuit of a different set of rewards? If the latter, has the result been a commons in telecommunications technology available for harvest by others?

There are no simple answers. Different companies have adopted different models, and indeed a single company or academic institution may take different approaches depending on its strategic interests in particular negotiations. It is possible, however, to at least catalog the major approaches, and identify the forces that are shaping innovators' strategies.

Part I of this paper provides a brief overview of the major ongoing changes in residential telecommunications driven by the rise of broadband. Part II connects these changes to areas of technological innovation, providing just enough background on network design to show what

1 Jonathan A Neuchterlein & Philip E. Weiser, Digital Crossroads: American Telecommunications Policy in the Internet Age (2007), at 1-2.
2 Nicholas Lemann, *The Chairman,* New Yorker, Oct. 7, 2002, at 48.
3 This focus should not be taken to diminish the importance of enterprise telecommunications. In fact, company reports indicate that enterprise services are a larger share of revenue for the major telecommunications operators than residential services.

technological developments led to the rise of residential and mobile broadband. Part III reviews the basic value chain in telecommunications, describing the major players that have contributed to this innovation. With these background pieces in place, Part IV turns finally to the core questions of the paper, asking what incentives motivate the key players in telecommunications and how they manage their innovations. Finally, Part V concludes with proposals for further research.

THE BROADBAND REVOLUTION

The major network owners that are the front line in the broadband revolution historically provided four distinct consumer-facing products: home telephony, mobile telephony, cable television, and internet access. In the residential market, these historical divisions are disappearing. Cable and telephone companies have each refashioned their networks to provide general-purpose high speed data transmission capacity. Using ever-growing and improving networks, both now compete to provide the dominant "triple play": telephony, television, and internet access. Municipalities and other new actors are building their own residential broadband networks, offering the same basic services.

Cell phone companies are also racing to become broadband providers. Cell phones have become much more than just phones, and data is rapidly overtaking voice as the dominant source of revenue in the industry. Mobile services offer lower bandwidth than residential service, and as a result, cellular networks will not be able to support robust wireless video for any substantial fraction of their users, and will not be able to support the same kind of “triple play” as residential broadband. But what mobile networks lack in speed, they make up for in ubiquity. Many analysts see the rise of mobile broadband as the most important and dynamic area in telecommunications in the short and medium term.

As Internet speeds and penetration increase—on both wired and wireless platforms—a new group of actors has also become increasingly important: so-called “over the-top” providers of communications services. Over-the-top providers are companies that compete with traditional telecommunications products and services over the public Internet—from the perspective of the traditional operators, these companies provide services “over the top” of basic consumer telecommunications, rather than as a component of the consumer package. Internet telephony companies like Skype and Vonage are the classic examples of this type of service, to which we also add makers of other innovative products and services used primarily for communication—things like email, online gaming, and virtual worlds.

The figures above and below demonstrate the revolutionary transformations ongoing in telecommunications based on the public operating data of the major U.S. carriers. Figures 1.1 and 1.2 show the growing role of cable companies in voice service and—more recently—of telephone companies in video. As of the first quarter in 2009, Comcast announced that is the now the United States’ third largest phone company, passing regional giant Qwest. Meanwhile, telephone companies have seen a rapid decline in the number of residential access lines they serve—more the result of losses to wireless subscribers who are “cutting the cord” than of losses to cable—but nevertheless a marked contrast with the rapid subscriber growth of the new entrants. On the video side, the rise of Verizon and AT&T as television providers is more recent and therefore less far along than the entry of cable into voice service. Thus Figure 1.2 shows only the last five quarters of video subscriber data as compared to the four years of changes in voice depicted in Figure 1.1. In this short time Verizon has not yet quite taken over the number five spot from Cablevision, but as in the voice market, the trendline is striking. Both Verizon and AT&T are quickly adding video subscribers while the largest cable companies have all been slowly shrinking or holding steady.

Figure 2.1 illustrates the effect that the convergence in service offerings, along with the growth in demand for high speed Internet, is having on companies’ revenues. Just five years ago, video service accounted for four fifths of the subscription revenue received by Comcast, the largest U.S. cable provider. By 2008, the share was down to two thirds. The large phone companies do not break out their revenue in a way that makes a similar comparison possible, but based on the rapid decline in voice subscribers combined with steady growth in video and voice subscribers, we can surmise that they are seeing a similar diminution in the share of their residential subscription revenue realized from their legacy business.

Meanwhile, the mobile sector is also changing rapidly. Figure 2.2 illustrates the rise of mobile broadband. The share of revenue from data services realized by AT&T and Verizon (the two largest U.S. mobile providers) has grown from just 5% to over 25% in the last 4 years. This figure is somewhat overstated because cell phone companies count text messaging fees as data revenue—but even excluding these lucrative charges, analysts agree that the growth in the data side of the mobile business has been large and rapid.

Although all the above statistics are from U.S. companies, telecommunications providers worldwide are experiencing similar, fundamental shifts in their businesses.

FOCUS AREAS OF INNOVATION

For our purposes, the study of innovation in telecommunications is the study of the transformations described above. Technically, the various providers of new broadband services all offer some variation on the same very general network design. Fiber optic lines—by far the dominant modern telecommunications technology—form the high bandwidth core of any network. These glass cables can carry a quantity of information that is virtually limitless for all practical purposes. Backbone providers specialize in just this highest bandwidth segment of the network, in long runs between cities or underneath the sea. Other providers specialize in getting data from the backbone to end users, and some providers do both. Residential networks come in several varieties. In the case of a fiber-to-the-home (FTTH) network, fiber optic lines run all the way to the home. In fiber-to-the-node (FTTN) networks, the fiber cable is stopped at a cabinet that serves a neighborhood, and data is carried from there to each individual home over legacy wires, typically twisted-pair copper telephone wires. Cable broadband networks are built on a similar design, with a few significant differences: the legacy infrastructure is coaxial cable, which is a higher bandwidth medium, but which is shared among the served houses. (In a telco-built fiber to the node network, each house has its own copper wire to the local fiber node.) In addition, each fiber node in a cable network generally serves on the order of 500-2000 homes, whereas each node in a telco FTTN network may contain a few hundred homes. Whatever the technology used to reach the home in a residential broadband network, the last leg within the home is often wireless, at least for the Internet portion of the broadband service. Cheap and widely available WiFi routers operate at low-power on open frequencies to provide this capability.

Although we often think of them as a fundamentally different technology, commercial cellular networks are not all that different from residential broadband networks: they are also just wired networks with a wireless last leg. Like residential networks, cellular networks are built with fiber at the core. This fiber extends all the way to many cell towers. The remaining towers are connected by legacy copper and coax links. Sitting at the end of these wired links, each cell tower is the equivalent of a WiFi base station, but with coverage up to at least ten miles depending on the location and network design. No doubt, digital cellular technology differs in important ways from home WiFi technology: it is optimized for a combination of voice and data rather than pure data, it includes complex systems to support communication with fast-moving devices (e.g. a cellular handset being used in a car), it is designed to reuse radio frequencies more efficiently, and it is engineered to allow the wireless link to be seamlessly “handed off” as customers move between one cell and the next. The bigger differences are regulatory rather than technical, however: cell towers are able to cover a much greater geographic range then a WiFi router because they are operated at much high power. High power operation is possible because the towers transmit and receive data on frequencies where the operator has purchased an exclusive license to operate from the federal government.

Table 2 provides an overview and comparison of the basic fixed and mobile network designs. As the table implies, the three broad areas of innovation necessary for the deployment of residential and mobile broadband have been:

1. the development of fiber optic communications technology;
2. the development of new network standards to coax greater speeds and two way capacity from legacy cable and telephony systems; and
3. the development of new high speed wireless communication systems for both high-power licensed and low-power unlicensed frequency bands.

At the same time, a fourth area of innovation has both fueled and been fed by these other innovations, as discussed in the introduction. Namely:

4. the development of new “over the top” communications systems offered by independent companies over the public Internet.

The remainder of this overview focuses on these four areas of technological change. Although our focus is on the residential sector, the same basic areas of innovations are driving enterprise services.

INNOVATION FLOWS IN TELECOMMUNICATIONS

Figure 3 illustrates a highly simplified value chain for residential broadband providers. Component manufacturers provide the basic optical and electrical building blocks for telecommunications systems—things like lasers and chipsets. Equipment and subsystem manufacturers assemble these items into complete network components—things like cell tower radios and switching systems. Finally network operators build and manage complete networks, selling services to consumers and businesses. In addition, over-the-top service providers sell further products and services that operate over the Internet and supplement or substitute for those services offered by the network provider itself. Table 3 list examples of major actors in each category along with their 2008 revenues from telecommunications-related divisions.

The first three major areas of innovation described at the end of the previous Part—each in different segments of the physical network—emerge from the complex interaction between system operators and their upstream suppliers. These relationships are dynamic and situation dependent. Innovation is neither simply manufacturer-driven nor operator-driven. Rather, operators have a set of market imperatives and competitive pressures that lead them to seek specific capabilities from manufacturers. These needs may be communicated in informal interactions, in formalized requests for proposals, or collectively through various industry associations. At the same time, equipment manufacturers constantly strive to develop new products that anticipate coming needs or give providers new capabilities. To a certain extent, network operators also do their own R&D, in part through collaborative consortia. The industry advances through the interaction of this push and pull.

The relationship between vendors and operators is also heavily shaped by standards processes. Operators want assurance that they will be able to buy interoperable equipment for different parts of their network from different vendors, and vendors want the large markets and economies of scale that come from building to broadly accepted standards. For obvious reasons, different pieces of network technology have to interoperate to a greater degree than do different components in most other technology-intensive industries. Thus, all parties have significant incentives to support standardization. Once a technical standard is adopted, it imposes a profound, durable effect on the industry, determining the specifications that vendors build to, and the capabilities that system operators offer to end users. A number of different organizations lead standards efforts, each with a different membership and focus that shapes its work. Table 4 lists examples of major industry associations, research consortia, and dedicated standards bodies, along with basic membership information and standards activity.

Innovation in over-the-top Internet-based services occurs somewhat differently than for in-network technology. In particular, innovation on the Internet can be driven more by freestanding actors, because inventions are embodied in software code running on general purpose machines rather than in integrated, special purpose systems. Often, the same company engineers a piece of software and uses that software to provider consumer-facing services (e.g. Skype). For this reason, Internet-based providers to some extent compete with both network operators and equipment manufacturers. There is creative friction in this competition, but also the potential for mischief on the part of network operators (who, as Internet access providers, are providing the platform for their own competitors). This tension is the source of high profile policy debates over mandatory unbundling of broadband services and "net neutrality" regulations.

Finally, as for all highly innovative industries, public sector research contributes substantially to telecommunications R&D. Military and university research constantly feeds the innovation pipeline. Table 5 lists examples of significant technologies that have emerged in part from the public sector. In a 1993 MERIT/SESSI survey of large firms in the EU, 70% (17 of 24) respondents reported that publicly funded research in electrical engineering was extremely important or very important to their unit's technological base.[4] This figure was somewhat lower than for comparable public sector inputs in other industries (for example 85% of pharmaceutical industry respondents indicated that public sector biomedical research was extremely or very important, and 78% of computer industry respondents indicated that public sector electrical engineering research was extremely or very important).[5] Nevertheless, the public sector contribution to telecommunications is indisputably quite large in absolute terms.

THE ECONOMICS OF INTELLECTUAL PROPERTY IN TELECOMMUNICATIONS

We can now turn back to the questions posed at the outset. It is worth pausing briefly to present the issues in a slightly more systematic fashion. At the highest level, we are interested in two closely related questions: (1) Analyzing innovations as *outputs*, are telecommunications companies motivated to innovate because of proprietary control that they can exercise over these innovations, or by other benefits that do not depend on restricting access to the fruits of their ingenuity? And (2) Analyzing innovations as *inputs*, is access to new discoveries difficult to come by, or are new discoveries readily available to those who would seek to utilize or build on them? In each case, the former possibility reflects a proprietary innovation environment, the alternative is commons-based.

In general, there are three basic ways in which a company taking a proprietary approach to its innovations may limit access in the pursuit of profit (or, from the perspective of a downstream innovator, there are three basic ways in which the use of preexisting innovations may be

4 Arundel et al., Innovation Strategies of Europe's Largest Industrial Firms, at Table C-12 (1995).
5 *Id.*

limited): a company may restrict *who* may use its innovations, it may restrict *how* the innovation may be used, or it may charge *fees* for access to the innovation. We label these dimensions as "openness," "regulation," and "cost." Closedness and high cost characterize proprietary models, whereas openness and low cost characterize commons-based models. The regulatory dimension is more complex, because regulation of the use of innovations may be used to extract value in proprietary models, for example where a patent owner restricts licenses by use in order to protect certain markets for its product. But regulation may also be used in commons-based models to sustain the commons itself, in the way that traffic rules maintain the utility of the roads. Such is the well-known approach of open source licenses like the GPL.

In telecommunications literature, openness and cost are the major foci of concern. Regulation is less widely discussed, presumably because innovations, where available, are not restricted in their use, or at least not in ways that inhibit development or downstream innovation. Following the existing literature, the analysis below also focuses on the dimensions of openness and cost. Is access to innovation in telecommunications restricted? And is it expensive?

The answers to these questions differ somewhat between in-network technologies and over the top technologies, so the next two sections address each in turn.

A. In-Network Technologies

Telecommunications equipment manufacturers patent heavily.[6] Telecommunications system operators also patent, but apparently somewhat less so. Table 6 shows the total number of 2007 U.S. patents granted to leading system operators and equipment companies compared to biotech/pharmaceuticals companies and computer systems and software companies. These data must be read with due caution because some companies have units that fall into more than one category and because many factors affect the number of patent grants that have little to do with the extent of actual legal protection acquired—but the counts at least provide a rough indicator of the degree of patenting activity. One reason that system operators may patent less than equipment manufacturers is that operators achieve their margins by being in extremely capital intensive industries rather than through intellectual property. They exist in monopoly or oligopoly environments thanks to the economics of fixed costs, not because of government-granted rights to restrict use of their inventions.

A more systematic look at patenting activity in telecommunications is provided by Cohen et al.'s report on the comprehensive 1994 Carnegie Mellon Survey on Industrial R&D in the United States. Directors of research labs for telecommunications equipment manufacturers that participated in the survey reported that they filed patents on 60% of all product innovations, well

6 Software copyrights and rights in semiconductor designs, a *sui generis* form of IP, may also be important in certain instances, but patents are the most contested forms of legal protection in the industry and the focus of the most active legal and policy debate.

above the cross-industry average (49%).[7] Using data from the 1993 MERIT/SESSI survey of large European firms mentioned earlier, Arundel and Kabla reached a similar result. Weighted by total sales volume, communications equipment manufacturers reported that they patented on average 47% of product innovations, as compared to a cross industry average of 36%.[8] Although the specific percentages differ between the two surveys, the qualitative finding of above-average patenting is consistent. Again, the story may be somewhat different for system operators, but unfortunately Cohen et al. do not report data for telecommunications service providers, and Arundel and Kabla report data only aggregated with providers of physical transportation providers.

Notwithstanding high levels of patenting, makers of telecommunications equipment did not see patents as the most important means of protecting or monetizing innovations in either the Carnegie Mellon or MERIT/SESSI surveys. In fact, respondents to the Carnegie Mellon survey rated patents as the least effective among the specific surveyed means of appropriating value from new innovations, scoring behind lead time, secrecy, complementary sales, and complementary manufacturing. Patents scored low across all the industries surveyed, but telecommunications stood out even in the context of this general finding: the importance of patents was rated as far lower in telecommunications than in the cross-industry mean. Table 7.1 reproduces these data with comparisons to selected other industries.

As in other industries where widespread patenting activity accompanies a low perception of patent value, the primary cause is the prevalence of overlapping patent claims. Multiple patents, generally owned by different companies, are required to assemble a finished product. For example, the 3G Patent Platform Partnership estimates that over 100 companies own patents that are essential to implement 3G mobile telephony standards.[9] In such an environment, companies must patent widely at a minimum to protect their own freedom to operate: a strong patent portfolio allows a company to deter infringement with the threat of countersuits, but a company without a defensive portfolio is at the mercy of would-be litigants.

Because companies hold a mutual litigation threat, cross-licenses are common. Fourteen or fifteen (74-79%) of the nineteen communications equipment industry respondents in the Carnegie Mellon survey reported that they used patents in negotiations, to prevent infringement suits by other companies, and to block other firms from patenting related inventions. One respondent interviewed by the study's authors described the situation this way: "Mostly your patents are used in horse trading. . . . In our industry things all build on each other. We all overlap on each other's patents. Eventually we come to some agreement: 'You can use ours and we can

7 Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not)*, NBER Working Paper 7552, at Table A1, http://www.nber.org/papers/w7552.
8 Anthony Arundel & Isabelle Kabla, *What Percentage of Innovations Are Patented? Empirical Estimates for European Firms*. 27 Research Policy 127, 133 (1998).
9 Ky P Ewing, Jr, *EC and DoJ approval of the 3G Patent Platform*, Global Competition Review 12, Feb. 2003, *available at* http://www.3glicensing.com/articles/03%20-%203G%20(p12-14)%20f.pdf

use yours.'"[10] Table 7.2 shows the full survey results with comparisons to other industries. Arundel et al. report qualitatively similar findings from the MERIT/SESSI survey.[11]

Standards processes also heavily influence the handling of IP, increasing the pressure to license broadly. As described in the previous section, standardization activity is central in telecommunications. Standards bodies generally require that participating companies disclose all intellectual property they own that is necessary to implement any new standard, and that the companies commit to license all such IP on "reasonable and non-discriminatory" (RAND) terms. (European standards bodies often add an additional obligation of "fairness"—making the acronym FRAND—but it is unclear whether this change actually adds any legal content.) Unlike patents that are only made available in the context of cross-licensing negotiations, patents that are subject to RAND obligations are available to companies that wish to enter the market even if they do not bring their own IP portfolio. Especially where only a small number of companies own the core IP, cross-licensing regimes can effectively perpetuate oligopolistic market structures. RAND commitments preclude such barriers to competitive entry. Accordingly, RAND licensing commitments provide some assurance to system operators that they will not get locked into just one or two suppliers. Meanwhile, equipment manufacturers are willing to submit to these requirements because of the huge scale advantages of having their IP included in a widely adopted standard. Indeed, if a company's IP is left out of an industry standard process that subsequently achieves dominance, its innovation is likely to fade to irrelevance.

The principle criticism of RAND agreements is that they are often vague and therefore difficult to enforce. As two lawyers with experience in licensing litigation put the issue:

> Standards bodies which make use of FRAND declarations—ie a promise that the licensor will make specified technology available on fair, reasonable, and non-discriminatory terms—rarely, if ever, give any guidance as to what those terms mean. . . . Nor will most standards bodies intervene in bilateral disputes between members (or between members and non-members) to set a FRAND royalty, or even to give any guidance on the meaning of the commitment, not the least because most standards bodies are little more than the sum of their members, with inevitably disparate commercial views. As discussed above, there is a significant risk that [FRAND or RAND] can mean all things to all men. In consequence, the obligation risks becoming toothless.[12]

Ambiguity in the meaning of RAND commitments leads to high transaction costs and lower transparency in the handling of IP, since each license must be individually negotiated (albeit often after a product is on the market, not before). Demonstrating the effect of these problems on downstream innovation, some industry players blame the failures of RAND licensing in part for limiting the spread of wireless technology to gaming consoles, smart energy meters, parking

10 Cohen et al., at 19.
11 Arundel et al., at Table C-19a.
12 Pat Treacy & Sophie Lawrence, *FRANDly Fire: Are Industry Standards Doing More Harm Than Good?,* J. Intel. Prop. L. & Practice , Dec. 5, 2007, at 22.

meters, and other new devices. As one executive at Intel stated the problem in 2008, "We haven't seen a broad proliferation of cellular technology in anything other than handsets because the model is closely held and restrictive."[13]

Responding to the limitations of RAND agreements, some industry players are increasingly seeking to push IP policies towards greater openness, either by seeking specificity in the commitments made by standards contributors or by forming patent pools with standard in- and out-licenses. For example, several of the major players in the high speed WiMAX standard have formed a patent pool in an effort to "stimulat[e] a larger WiMAX industry that supports innovation through broader choice and lower equipment and service costs."[14] Similarly, many players in the various 3G mobile standards have banded together to form the 3G Patent Platform, a system for standardizing licensing terms designed to make licensing of 3G related patents simpler and more predictable.

The fact that telecommunications patents tend to be licensed broadly—whether through cross licenses, RAND commitments, patent pools, or otherwise—does not mean that these innovations are free in the economic sense. Nine of the nineteen communications equipment industry respondents in the Carnegie Mellon survey (47%) saw licensing revenue as a motivation to patent. Across all industries, only 28% of firms cited licensing revenue as a motivation for patenting. In other words, licensing revenue in telecommunications is substantially less important than the defensive motivations described above, but it cannot be ignored. In addition, many industry observers report that telecommunications companies have increased their emphasis on licensing revenue in the fifteen years since the Carnegie Mellon survey.[15]

The pursuit of licensing revenue varies greatly among component and equipment equipment manufacturers depending on the balance of their own IP and the IP of other players that goes into the products they produce (or whether they produce products at all). Qualcomm is a well known example of a company that assembled a sufficiently strong and free-standing patent portfolio to demand significant royalties in licenses for early digital wireless standards, and constructed a business strategy with a heavy emphasis on licensing. In 2008, Qualcomm reported $11.1 billion in revenue, of which $4.0 billion (36%) derived from licensing and royalty fees. An even more dramatic example is InterDigital communications, also a significant patent holder in advanced digital wireless technologies. InterDigital's 2008 Annual Report listed $229 million in total revenue, of which $217 million (95%) came from patent royalties. In contrast, licensing revenue does not merit its own line in the annual reports of companies like Cisco and Alcatel-Lucent, and these reports mention IP-litigation risk in the context of concerns that the company may be sued for infringement, rather than the possibility that a lucrative patent will be invalidated. Notwithstanding these generalizations, the interests of companies shift in different circum-

13 Marguerite Reardon, *WiMax Patent Alliance Announced*, CNET NEWS BLOG, June 9, 2008, http://news.cnet.com/8301-10784_3-9963352-7.html.
14 http://www.openpatentalliance.com/.
15 *See, e.g.*, KEVIN G. RIVETTE & DAVID KLINE, REMBRANDTS IN THE ATTIC: UNLOCKING THE HIDDEN VALUE OF PATENTS (1999).

stances. For example, Alcatel-Lucent became infamous in 2006 and 2007 for its aggressive enforcement of MP3 patents against Microsoft, winning a $1.5 billion jury verdict before having the judgement overturned by the court of appeals.

System operators seem to have a more uniform position towards IP than their upstream manufacturers. As they do for openness, operators generally appear to pull in the direction of lower prices. IP factors into their economic equation primarily as a cost rather than as a means to thwart competitive pressure, and therefore their usual goal appears to be to push prices down. The PacketCable specification developed by CableLabs, a consortium of cable system operators, demonstrates this dynamic. PacketCable specifies standards for IP-based voice services on cable networks. In conjunction with certifying the standard, CableLabs set up a royalty-free licensing pool for related IP. (As this example perhaps suggests, the interaction of standards-setting and pricing concerns creates complicated competition policy issues.[16])

Of course, there remain circumstances when system operators change their approach to IP, just like equipment manufacturing companies. For example, Verizon, Sprint, and AT&T each sued Internet telephony provider Vonage for patent infringement in 2006 and 2007, extracting combined settlements of $240 million.[17] Then, in early 2008, Verizon sued two cable companies, Cox and Charter, over the same eight voice-over-IP patents that it had successfully asserted against Vonage.[18] Charter appears to have been better armed for battle than Vonage, however, and in December it fought back against Verizon, suing for infringement of four video and data transmission patents of its own.[19]

Figure 4 summarizes the discussion thus far, charting the basic licensing models used for in-network technologies in telecommunications on the dimensions of openness and price. Patent pools and other forms of standardized agreements are more open than IP licensed subject to RAND commitments, which in turn are more open than cross licensing arrangements. All these approaches can vary broadly in terms of the attendant pricing strategy. Figure 5 charts illustrative examples of some of these different strategies, many of which have already been mentioned.

From a policy perspective, the variation in licensing models means that different companies—or the same companies in different circumstances—have varying degrees of interests that turn on having strong patents in telecommunications. Many innovative telecommunications companies license their IP widely with zero or near-zero royalties (willingly or unwillingly), thereby adopting an essentially non-proprietary model and contributing to a commons in telecommunica-

16 Indeed, the fear of running afoul of antitrust rules is in part the reason that standards bodies long opted for general RAND obligations rather than specific commitments on pricing and other competitive terms. *See, e.g.*, Peter Grindley, Mark Bezant & Daniel Ryan, *Patent Licensing and Standards Setting — IP Collides with Antitrust, in* Licensing in the Boardroom 2008 (2008), *available at* http://www.iam-magazine.com/issues/Articles.aspx?g=68b-b21ce-9dc8-488c-98be-c4986ef63921.

17 *See* Dan Frommer, *Vonage (VG), AT&T (T) Finalize Patent Settlement*, Business Insider, Dec. 21, 2007 http://www.businessinsider.com/2007/12/vonage-vg-att-t-finalize-patent-settlement.

18 *See* Victoria Slind-Flor, *Charter Communications, GM: Intellectual Property*, Bloomberg.com, Jan 8, 2009, http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aucTsLbHm5w8.

19 *Id.*

tions innovation. But there are also significant counterexamples, companies that may ultimately be pleased to see their innovation used broadly, but that seek significant compensation in return. Because they extract revenue based on a proprietary approach to their discoveries, these companies have interests in strong IP rights in telecommunications innovation.

A final caveat to these results is that what makes a company money ex post and what motivates it to innovate ex ante are related but not identical questions. Suggestively, 95% of telecommunications respondents in the MERIT/SESSI survey (18 of 19) reported that the desire to create new products was “extremely” of “very” important in “influencing the types or magnitude of innovative activities undertaken,” while only 4% (1 of 25) reported that the desire to “earn revenue from licensing products” was that important.[20] This result is likely distorted by the fact that the MERIT/SESSI survey focused on large firms and is now over 15 years old. But it is nevertheless striking.

B. Over the Top Services

Internet-based communications services are relatively new, at least on the timescale of major cross-sectoral studies of innovation, and rarely studied as a distinct industry sector. Consequently, it is difficult to draw generalizations about the way intellectual property is used by the various companies that provide services in this category. Nevertheless, it is possible to at least note the areas of major public focus and controversy—namely, software patents and software licensing by software-as-service companies—and to make some anecdotal observations.

As the multiple lawsuits against Vonage (described above) demonstrate, patents can be very important for over the top service providers just as for more traditional providers of communications services. The Vonage example also suggests that some Internet-based providers—especially newer or smaller players—may not be aggressively patenting themselves, and therefore may be poorly prepared to defend themselves from patent suits. Larger players, like Google and Microsoft, are known to patent widely. It is less clear how these patent portfolios are being used. There are fewer high profile examples of these companies adopting aggressive licensing strategies as compared to certain vendors of in-network technologies, but quantitative data is unavailable.

Because the innovations of over the top service providers are frequently embodied purely in software running on general purpose computers (rather than physical equipment or embedded microprocessors, for example), there has been substantial controversy regarding whether or not they should be patentable at all.[21] In the United States, so-called “software patents” are generally permissible. In Europe, the situation is more complicated, and proposals to strengthen protection for software patents have met strong resistance.

20 Arundel et al.

21 *See, e.g.*, http://stopsoftwarepatents.org/.

The reason that the patent debate has taken on an added degree of importance in the software context is that the barriers to entry are otherwise so low. Becoming a manufacturer of telecommunications equipment requires substantial economic and social capital. In contrast, a handful of programmers with very few resources and pre-existing relationships can launch a new online service company. Witness the success of Facebook, for example. Facebook was started by four Harvard undergraduates in 2004, and built in under five years into the number one social networking platform on the Internet. Early in its life cycle, this sort of enterprise almost certainly does not have the resources to invest heavily in patenting. Opponents of software patents fear that if building a strong defensive patent portfolio becomes a prerequisite to release of innovative software, including innovative online communication services, the rapid innovation that has been the hallmark of the Internet to date will be dramatically slowed.

Significant attention has also focused the copyright and trade secret policies of online communications providers. In general, the free software and open source movements have proven very successful in recruiting companies to contribute to open source products. But the open source model is unsettled as applied to software-as-service companies, which includes many Internet-based communications providers. Until recently, the requirement in "viral" open source licenses that users of open source software contribute improvements back to the commons was triggered by distribution of new versions. As a result, companies like Google and Facebook, whose custom software runs exclusively on their own servers and is never released to the public, were historically not bound by the obligations of open source licenses. But some members of the free software and open source communities began to feel that these companies are unjustly taking advantage of free and open source software (which they build upon) without contributing back. From the perspective of advocates, software as service companies have adopted closed, proprietary models of software development, albeit protected by secrecy rather than copyright or patent.

In 2007, the Free Software Foundation released a new variant of the Gnu Public License (GPL), called the AGPL, aimed at this concern. The Free Software Foundation "recommend[s] that developers consider using the GNU AGPL for any software which will commonly be run over a network." Any company that builds upon software licensed in accordance with the AGPL to provide online services is required to release the source code for its improvements, allowing others to adopt and build further upon those changes, but perhaps undercutting its own competitive advantage. Understandably, the desirability and viability of this new requirement have been subjects of widespread debate.

Because they are so young, the business models of Internet communications services are still undergoing rapid change. As in the telecommunications sector as a whole, there are forces pushing both towards closedness and openness, towards proprietary models for the management and exploitation of innovation and towards commons-based models. It is still far from clear where a stable equilibrium exists.

NEXT STEPS

This paper has sought to provide a broad overview of innovation in telecommunications. But it is necessarily just a beginning.

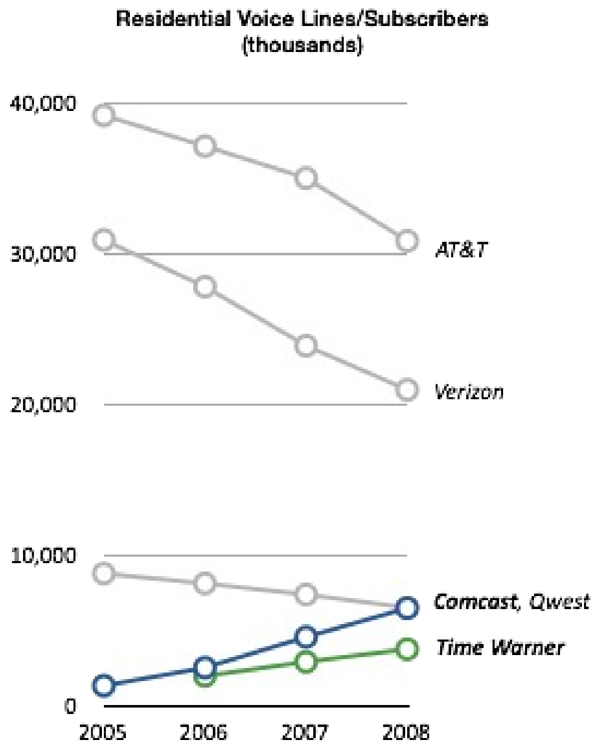
The most immediate next requirement is a series of telecommunications case studies to explore different examples of innovation in action. Ideally one would seek examples of representative innovations in each network segment and at each network layer: for example one might seek case studies in each of the fiber optic, legacy infrastructure (phone/cable), and wireless network segments, and at the physical, logical, and software/service layers. Candidates might include erbium doped fiber amplification, a critical contribution to long-haul fiber networks; discrete multitone, a breakthrough that allowed efficient use of legacy telephone networks for DSL service; code division multiple access technology (CDMA), a transmission technology that revolutionized mobile data services; and Google Voice, an aggressive entry into telephone service by one of the largest Internet-based telecommunications companies.

Further research is also needed to add a political dimension to the analysis. What position have various telecommunications companies taken on the major intellectual property battles of the day—for example in Federal Circuit and Supreme Court cases governing patent standards or the availability of injunctions, or in legislative negotiations over patent reform? How have trade associations engaged in these debates? Are smaller companies that cannot afford (or choose not to invest in) individual political representation having their interests well looked after in centers of power? Placing an analysis of these questions in dialog with the economic research presented here and proposed for future case studies would allow a comparison of how companies perceive their self interest against what the economic data predicts.

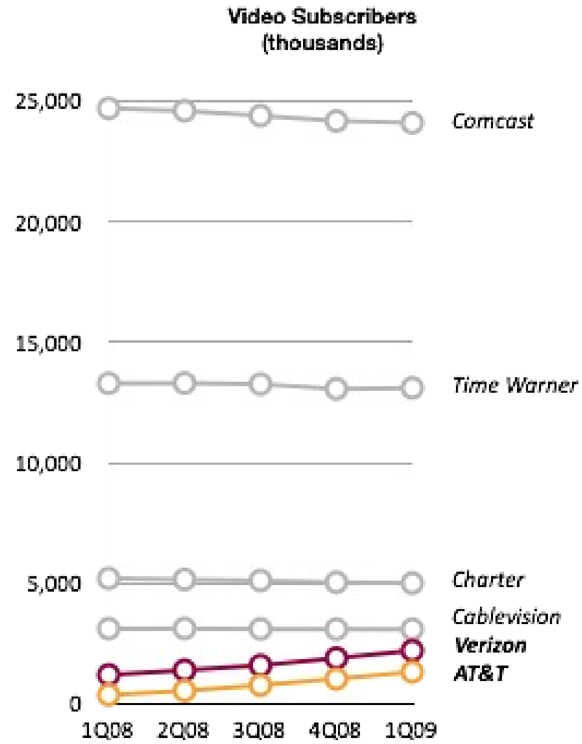
Given the central role of telecommunications in the global economy and in the lives of humans worldwide, an understanding of innovation in telecommunications is critical to understanding the global dynamics of innovation generally. The technical, economic, and political dynamism of the sector means that there could be no better time for this work.

Table 1: Field Definition		
Focus Industry Segments	**Other Industry Segments**	**Excluded From Definition**

• Wireline (Fixed Access Telephony)
• Cable
• Commercial Wireless (Cell Phone)
• Unlicensed Wireless Data (esp. 802.11)
• Internet-Based Communications Platforms
(e.g. Skype, email)
	• Broadcast TV
	• Satellite TV
	• Broadcast Radio
	• Satellite Radio
	• Other Wireless
	(e.g. public safety radios, maritime radios, cordless phones, etc.)
		• Pure Content, including:
		  • Television and Radio Programmers
		  • Online Content Platforms (as distinguished from Communications Platforms) (e.g. Hulu, iTunes, Netflix)

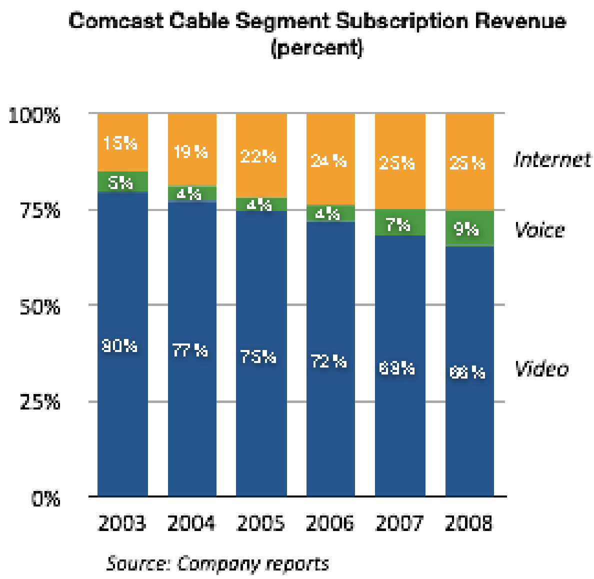


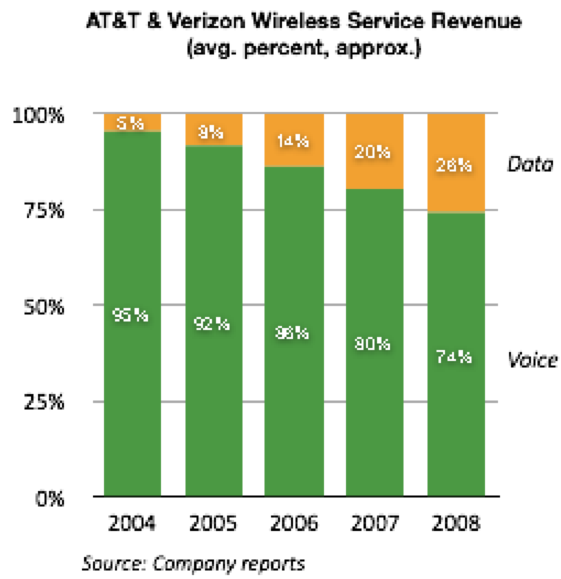
Source: Company reports
Note: 2005 and 2006 AT&T totals include BellSouth for accurate comparison (AT&T and BellSouth merged in 2006). Cable and phone company numbers may not be exactly comparable because cable companies report "subscribers" while phone companies report "access lines," so customers with two lines may be counted differently.



Source: Company reports
Note: Cox, the third largest cable operator, is privately held and does not publicly disclose subscriber data. AT&T includes only U-Verse subscribers, not resale of satellite service.

Figures 1.1 & 1.2: Voice and Video Subscribers





Figures 2.1 & 2.2: Cable and Wireless Revenue Sources

Table 2: Basic Network Components			
	Fiber	**Legacy**	**Wireless**
Telco FTTH **(e.g. Verizon FiOS)**	to every home	in-home coax or telephone wiring (using MoCa, HPNA, or another standard)	in-home WiFi
Telco FTTN **(e.g. AT&T U-Verse)**	to a "node" (a node typically serves ~500-2000 households)	telephone wiring (using VDSL)	in-home WiFi
Cable	to a "node" (a node may serve a few hundred households)	coax cable wiring (using DOCSIS)	in-home WiFi
Cellular	in some cases, directly to towers, otherwise to multiple-tower aggregation points	"special access" lines to some towers from aggregation points	various digital cellular standards, depending on the network

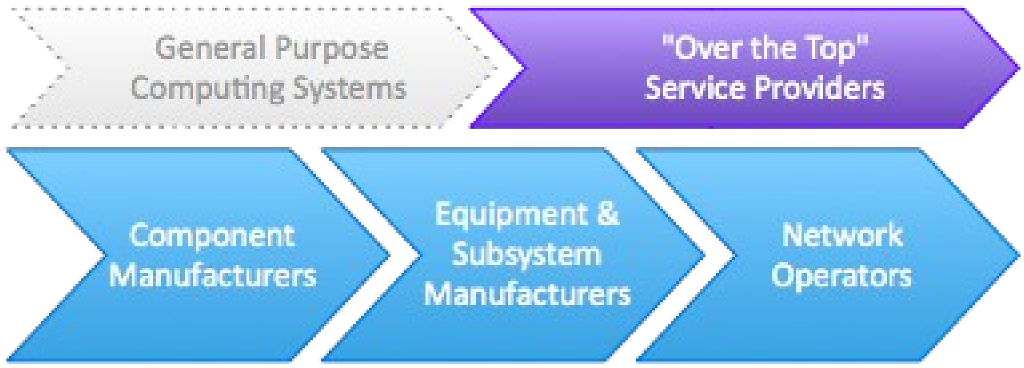


Figure 3: Basic Telecommunications Value Chain

Table 3: Examples of Large Actors

	major telecom products/services	2008 revenue from specified activities/division
Component Manufacturers		
Qualcomm	mobile chipsets	$ 7.5 B (QCT & QWI divs.)
Broadcomm	chipsets	$ 4.7 B (all divs)
Intel	wireless chipsets	$ 4.2 B (Mobility Group chipset revenue)
CommScope	cables, cabinets, antennas, electrical components	$ 3.8 B (all divs)
Texas Instruments	wireless chipsets	$ 3.4 B (Wireless div.)
Corning	optical fiber, cable, and components	$ 1.8 B (Telecommunications div.)
ADC Telecomms.	various components	$ 1.4 B (all divs)
Equipment & Subsystem Manufacturers		
Nokia	mobile devices, networking systems	~ $ 69 B (Devices and Services, Networks divs.) (50.4 B euros)
Cisco	routers, switches, networking systems	$ 38.0 B (all divs.)
Alcatel-Lucent	various networking systems	~ $ 24 B (all divs) (17.0 B euros)
Motorola	mobile handsets, consumer premises equipment, networking systems	$ 22.2 B (Mobile Devices, Home and Networks Mobility divs.)
Huawei	various networking systems	~ $ 18 B (all divs) (press accounts)
Network Operators		
AT&T	U.S. fixed & mobile networks	$ 124.0 B (all divs.)
NTT	Japan fixed & mobile networks	~ $ 109 B (all divs) (10.7 T yen)
Verizon	U.S. fixed & mobile networks	$ 97.4 B (all divs.)

Table 3: Examples of Large Actors		
China Mobile	China and Asia mobile networks	~ $ 60 B (all divs) (412 B yuan)
Sprint	U.S. primarily wireless network	$ 35.6 B (all divs.)
Comcast	U.S. fixed cable network	$ 32.4 B (Cable div.)

Over the Top Service Providers		
Vonage	Internet telephony	$ 900 M
NewsCorp	MySpace social networking site	~ $ 500-700 M (analyst estimates)
eBay	Skype Internet telephony and chat	$ 551 M (Communications div.)
Yahoo	#1 webmail provider, chat	*communications revenue not separately reported*
Microsoft	#2 webmail provider, online gaming	*communications revenue not separately reported*
Twitter	short text messaging	*privately held (but revenues thought to be small)*
Linden Labs	SecondLife virtual world	*privately held*

Sources: Yahoo Finance, http://finance.yahoo.com/; Company reports; Hitwise, *Top 20 Websites*, http://www.hitwise.com/datacenter/main/dashboard-10133.html (webmail rankings); Debra Aho Williamson, *Social Network Revenues Down: Here's Why,* eMarketer.com, (Dec. 23, 2008), http://www.emarketer.com/Article.aspx?R=1006825 (MySpace revenue estimate).

Table 4: Examples of Significant Standards-Setting Bodies

	description/membership	examples of important standards/ areas of important standards activity
European Telecommunications Standards Institute (ETSI)	ETSI is an officially recognized but independent organization responsible for standardization of information and communication technologies within Europe. Its standards can have quasi-legal force. Its membership includes network operators, manufacturers, and some government bodies.	• GSM European mobile phone standard • part of 3GPP group developing third and fourth generation mobile standards
International Telecommunications Union (ITU)	The ITU is a longstanding UN body. Membership in its standardization activities consists of UN States along with companies as "sector" or "associate" members. The ITU sometimes originates standards activity, but also often approves standards after they have been first adopted by another industry body in order to give them international credibility.	• Passive Optical Networking (PON) • Synchronous Digital Hierarchy (SDH) • wavelength-division multiplexing (WDM) • Digital Subscriber Line (DSL)
Institute of Electrical and Electronics Engineers (IEEE)	IEEE is an international non-profit professional organization with a large standards-setting arm. IEEE allows both individual and corporate memberships, with standards processes following different paths depending on which class of membership is voting.	• Ethernet (802.3) • WiFi (802.11) • WiMAX (802.16)
Bellcore/Telcordia	Created after the 1984 breakup of AT&T, Bellcore provided joint R&D and standards-setting for its co-owners, the Regional Bell Operating Companies. The companies later sold the enterprise, which changed its name and now operates as independent private company. Telcordia still performs standards-like functions under the name of "generic requirements" specifications.	• Synchronous Optical Networking (SONET) • Digital Subscriber Line (DSL)
CableLabs	CableLabs is a non-profit research and development consortium that was founded in 1988 by cable television operating companies to help them match the systems innovation capabilities of Bellcore. Its members are all cable operators.	• DOCSIS (Data Over Cable Service Interface Specification) • PacketCable managed voice-over-IP standard

Table 4: Examples of Significant Standards-Setting Bodies		
Internet Engineering Task Force **(IETF)**	The IETF is has no formal membership or corporate status, but consists of individual participants organized into working groups and discussion groups that focus primarily on core Internet standards.	• email (SMTP/POP/IMAP) • domain name resolution (DNS) • network configuration (DHCP)

Table 5: Examples of Important Public Sector Innovations

	public sector contributor	description
erbium doped fiber amplifiers	Southampton University	EDFAs are a technology for amplifying optical signals, critical to long-haul fiber optic cables (e.g. for undersea use). The first EDFA was demonstrated by David Payne at Southampton University in 1987.
RSA cryptography	MIT	A cryptographic algorithm first published in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman at MIT, RSA is used in numerous settings where secure communication is required. For example, RSA is used in the DOCSIS standard to ensure privacy on shared cable networks.
code division multiple access	U.S. military	CDMA allows multiple radio devices to efficiently and robustly share the same radio frequencies in the same physical location. Developed by the military during World War II to frustrate jamming, CDMA was aggressively developed and popularized for commercial mobile use in the 1990s by Qualcomm.
discrete multitone	Stanford University	DMT is a technology to allow high speed communication over legacy copper telephone lines of varying length and quality, incorporated into the DSL standard. It was developed by John Cioffi of Stanford University, who founded a startup around the technology in 1991 and then sold the business to Texas Instruments six years later.
Internet Protocol	DARPA, Stanford University	The basic idea of a very simple but universally interoperable networking protocol gave birth to the Internet and has revolutionized telecommunications. It was first formulated by Robert E. Kahn of DARPA and Vinton Cerf of Stanford in a famous 1973 paper.

Table 6: 2007 Patenting Activity by Telecommunications Companies, With Comparisons

Company/Organization, Country	2007 U.S. Patents
Telecom Equipment & Services	
1. Siemens, Germany	1305
2. Nokia, Finland	730
3. AT&T, U.S.	705
4. Alcatel-Lucent, France	696
5. Cisco Systems, U.S.	660
6. Motorola, U.S.	631
7. Qualcomm, U.S	284
8. Telefonktiebolaet LM Ericsson, Sweden	277
9. Nortel Networks, Canada	274
10. NTT, Japan	228
Biotech & Pharmaceuticals	
1. Roche, Switzerland	515
2. Johnson & Johnson, U.S.	476
3. Genentech, U.S.	283
4. Pfizer, U.S.	226
5. GlaxoSmithKline, U.S.	200
Computer Systems & Software	
1. IBM, U.S.	3149
2. Microsoft, U.S.	1649
3. Hewlett-Packard, U.S.	1466
4. Fujitsu, Japan	1490
5. NEC Corp., Japan	972

Table 6: 2007 Patenting Activity by Telecommunications Companies, With Comparisons

Source: Patrick Thomas & Anthony Breitzman, *Patent Prowess*, IEEE Spectrum Online, Dec. 2008, http://www.spectrum.ieee.org/dec08/7023.

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7.1 *Mean percentage of product innovations for which each mechanism was reported effective in protecting "the firm's competitive advantage from those innovations" during the prior three years...*

	N	Secrecy	Patents	Other Legal	Lead Time	Complementary Sales/Svcs.	Complementary Mfg.
Communications Equipment	34	47%	26%	20%	66%	42%	41%
Drugs	49	54%	50%	21%	50%	33%	49%
Medical Equipment	67	51%	55%	29%	58%	52%	49%
Computers	25	44%	41%	27%	61%	40%	38%
Semiconductors and Related Equipment	18	60%	27%	22%	53%	42%	48%
ALL	1118	51%	35%	21%	53%	43%	46%

7.2 *Percentage of respondents indicating each reason as motivating their most recent decision to apply for a product patent…*

	N	To Measure Performance	For Licensing Revenue	For Use in Negotiation	To Prevent Suits	To Prevent Copying	To Block Related Patents	To Enhance Reputation
Communications Equipment	19	11%	47%	79%	74%	84%	79%	63%
Drugs	36	14%	44%	61%	67%	100%	97%	69%
Medical Equipment	60	5%	22%	58%	65%	95%	93%	57%
Computers	20	0%	30%	80%	90%	85%	65%	40%
Semiconductors and Related Equipment	12	0%	42%	67%	67%	92%	75%	33%
ALL	765	6%	28%	47%	59%	96%	82%	48%

Source: Cohen et al., at Table 1, Table 8.""

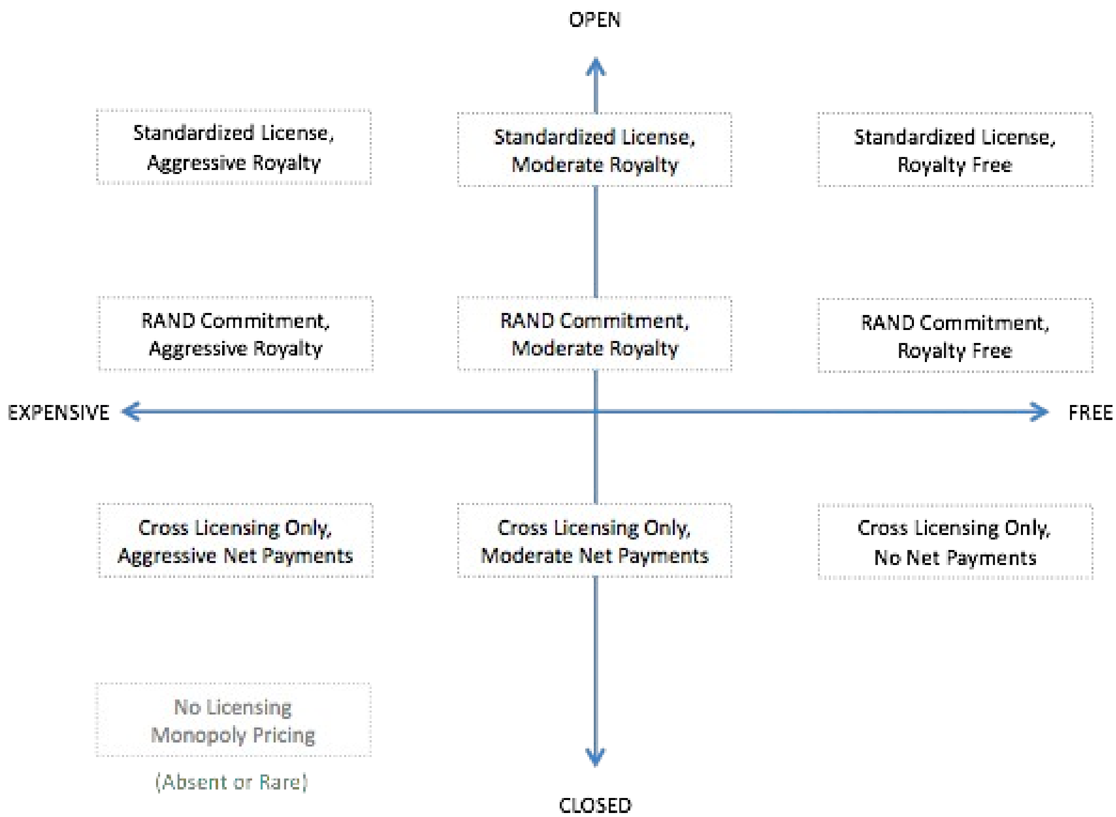
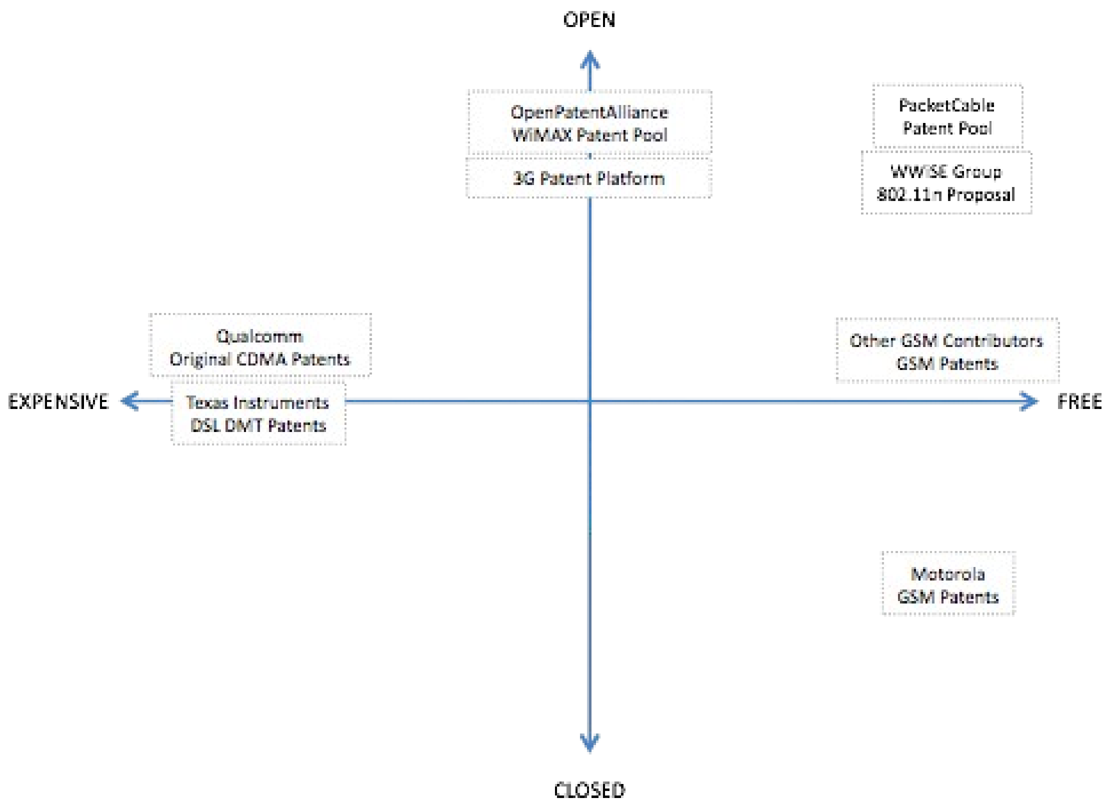


Figure 4: Licensing Paradigms in Telecommunications



Sources: RIVETTE AND KLINE, REMBRANDTS IN THE ATTIC: UNLOCKING THE HIDDEN VALUE OF PATENTS (1999), at 125, 146 (Texas Instruments, DMT); DAVID MOCK, THE QUALCOMM EQUATION: HOW A FLEDGLING TELECOM COMPANY FORGED A NEW PATH TO BIG PROFITS AND MARKET (2005); http://www.openpatentalliance.com/; Department of Justice, Antitrust Devision, Business Review Letter on 3G Patent Platform, available at http://www.usdoj.gov/atr/public/busreview/200455.htm; Cable Labs, *PacketCable Royalty-Free IPR Pool Created*, Press Release, Oct. 30, 1999, *available at* http://www.cablelabs.com/news/newsletter/SPECS/specnewsoct/news.pgs/leadstory.html; WWise, *802.11n WWiSE Alliance Forms*, Press Release, Aug. 12, 2004, *available at* http://www.unstrung.com/document.asp?doc_id=57680; Rudi Bekkers, Bart Verspagen, Jan Smits, *Intellectual Property Rights and Standardization: The Case of GSM*, 26 TELECOM. POL. 171 (2002).

Figure 5: Licensing Examples in Telecommunications