Accelerating innovation in connectivity:

The case for an Open RAN patent pool

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1. Executive Summary

Open Radio Access Networks ("**Open RAN**") technology represents an innovation that has the potential to transform how users and enterprises connect over mobile networks. By fostering greater flexibility and competition, Open RAN has the potential to reshape the market for mobile telecommunications, with greater vendor diversity and lower costs for installing and maintaining network infrastructure. It might also induce further innovation in the industry by, for example, facilitating transition of the network from hardware to cloud-based software. Moreover, Open RAN could help meet the infrastructure needs for wide proliferation of 5G, which allows users to achieve significantly faster speeds on their connected devices. By facilitating interoperability between components of the network, Open RAN may generate new technical solutions and business models that make it possible for operators to overcome physical and financial challenges of rolling out 5G networks. End users and vendors alike could reap the benefits from potential innovations made possible by Open RAN.

This innovation is reliant on heavily patented networking technologies. These patents may lead to challenges in the commercialization of Open RAN. Over the past few decades, increases in the number of patents granted and patent litigation have led to a crowded and complex patenting landscape that has the potential to hinder proliferation of new technologies. The pricing of royalties in this landscape is often obscure with little or no benchmarking information available. Moreover, coordination failures such as royalty stacking threaten to make patents collectively too expensive and limit adoption among those who seek to license the technology. Even if most licensors price their intellectual property ("**IP**") reasonably, any single licensor could act as a "hold-up" and set an excessive price for a patent that is essential for a new technology. Open RAN has encountered questions surrounding its IP that have likely deterred market participants from investing in this infrastructure. Thousands of relevant patents are necessary to incorporate Open RAN, a fact which poses the risks of royalty stacking and expensive litigation. Each of these risks could reduce market participants' expectation of Open RAN's future profitability, leading them to devote fewer resources to the development of its capabilities. These risks also hinder the speed with which 5G technology is adopted.

A patent pool is a mechanism that could encourage investment in and accelerate the spread of Open RAN. The pool can do this by addressing two areas of risk that surround IP for the technology. First, by setting a fixed, reasonable royalty rate, a pool can lessen uncertainty in pricing and combat the royalty stacking problem. Second, a pool can reduce costs associated with the negotiation of licensing agreements and the risk of unpredictable but costly patent litigation. Alium represents a pool created to serve these functions for Open RAN and designed to adhere to best practices.[1] Such a pool could allow Open RAN to bypass the IP bottleneck that may limit vendor diversity by deterring investment and new market entrants.

By conducting a deep analysis of academic research on patent pools, case studies concerning past pools, and interviews about the current state of Open RAN, this paper presents the case that a patent pool for Open RAN could help quicken the development and roll-out of the new technology, allowing customers to realize the prospective benefits of greater connectivity and more diverse product options in mobile networks more quickly.

[1] We discuss Alium further throughout this work. For information on Alium, please see: https://www.alium-llc.com/.

2. Introduction

The provision of a well-functioning patent system is an important driver of the innovation that is fundamental to increases in social and economic welfare. At its core, a patent system is designed to reward individuals or groups focused on innovation. If potential inventors feel there is a sufficient future reward to be gained from their efforts, then it is likely they will invest the needed resources toward the development of new technologies. Patents help serve this role as they are government-granted rights to the inventor that provide protection from others attempting to make, sell, or use the patented technology.[2] The licensing or royalty fees the patent holder charges interested parties to use the patent is the inventor's monetary reward for the time and effort they put into creating the new technology.

Protecting innovators and their resulting new technologies through a functional patent system is necessary for a healthy innovation ecosystem, but it is not fully sufficient. For the resources they expend on innovation to be worthwhile, investors must also believe there is a prospect for sufficient market adoption of the new technology. Major concerns of innovators relate to patent hold-ups:[3] even if they make a valuable invention, other patent holders may pursue litigation or take other steps that inhibit adoption of the technology. These concerns sparked the formation of groups dedicated to the promotion of standards and agreements that enable the implementation of new technologies. The importance of two major types of "innovation facilitators" that fill this need within the innovation ecosystem – standard-setting groups and patent pools – cannot be understated.

One approach to addressing problems that could stifle innovation is the establishment of standards around novel technologies. As we explore further in **4. The value of an Open RAN patent pool** standard-setting organizations help facilitate the adoption of a new technology by outlining in standards how its components and products interact. These organizations also serve to establish the fair, reasonable, and non-discriminatory ("**FRAND**") undertakings that participants must follow when licensing standard essential patents, which are patents determined necessary for the implementation of the standard.[4] These FRAND obligations are intended to prevent patent hold-up by standards development participants. However, as discussed in **Section** Error! Reference source not found.**,** standard-setting organizations are limited in their ability to determine patent licensing.

Patent pools are another type of "innovation facilitator" that often complement standard-setting organizations. Patent pools form when two or more IP owners agree to allow an independent manager known as a patent pool facilitator to license their standard essential patents under one umbrella license agreement. Those forming the pool grant it licensing rights for standard essential patents they own. Once formed, the patent pool licenses these patents under a single license to parties interested in developing or using the standard related technology covered by the pool's IP.[5] These groups have existed in various forms dating back to the 1800s and have helped shape the adoption of some of the most influential technological advances in U.S. history.[6]

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[2] Adam Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It* (Princeton, NJ: Princeton University Press, 2004).

[3] We discuss the hold-up issues in greater detail in **Royalty stacking**.

[4] Joseph Farrell, John Hayes, Carl Shapiro, and Theresa Sullivan, "Standard Setting, Patents, and Hold-Up," *Antitrust Law Journal* 74, no. 3 (2007): 603–70.

[5] Josh Lerner and Jean Tirole, "Public Policy toward Patent Pools," in *Innovation Policy and the Economy*, Vol. 8, (Chicago, IL: University of Chicago Press, 2008), 157 – 186, https://www.nber.org/books-and-chapters/innovation-policy-and-economy-volume-8/public-policy-toward-patent-pools.

[6] Intan Hamdan-Livramento, "The Role of Patents in the History of Aviation," *WIPO Magazine*, December 2018, https://www.wipo.int/wipomagazine/en/2018/06/article_0007.html.

The aim of this white paper is to explore the importance of patents for a healthy innovation ecosystem and the potential impact of innovation facilitators like patent pools on the efficient adoption of new technologies. Specifically, the report will relate these findings to Open Radio Access Networks ("**Open RAN**"), a cutting-edge telecommunications technology currently in the early stages of adoption. Open RAN is focused on transforming how users and enterprises connect over mobile networks. The potential benefits stemming from its adoption include a more diverse supply-chain, more flexibility in the solutions applied to problems in the telecommunications sphere, and increased competition and innovation.[7]

Patents protect the underlying innovation implemented in Open RAN as well as any new innovation that may arise from Open RAN standardization. Full adoption of this technology will require an efficient and standardized framework for licensing those patents. While a detailed discussion of the mechanics underlying this technology is beyond the scope of this white paper, we will apply an in-depth analysis of innovation and patent pools directly to Open RAN and present the case for an Open RAN patent pool.

To achieve this aim, we provide a thorough review of the academic literature related to the rationale behind patent pools. We supplement findings from the academic literature with anecdotal evidence drawn from case-studies of past patent pools and interviews with leading business executives closely tied to development of Open RAN technology. We present the findings in the subsequent sections as follows. **Section 3** delves into Open RAN specifically, outlining potential benefits from the widespread adoption of the technology and IP-related problems that currently limit this cutting-edge technology. **Section 4** outlines the role patent pools could play in overcoming these problems and potentially accelerating widespread implementation of this cutting-edge technology. **Section 5** describes key considerations surrounding patent pool formation and how current efforts at an Open RAN pool work to address these concerns.

3. Open RAN: Benefits and implications for mobile telecommunications

Mobile telecommunications, which allow people to send and receive information across distances using various devices, has witnessed consistent technological advances since the late-1970s. These advances in mobile networks have evolved in generations. First generation (1G) networks only supported voice calls over bulky mobile phones and pagers, but 1G technology has since evolved into fully integrated and widely used 4G networks. This generation offers a range of functions (voice calls, text messaging, internet connectivity, and video streaming, among others) across many types of devices, most commonly tablets and phones. The industry is currently in the midst of another generational shift in mobile networks to 5G, which improves the bandwidth and speed among other benefits through new radio interfaces.

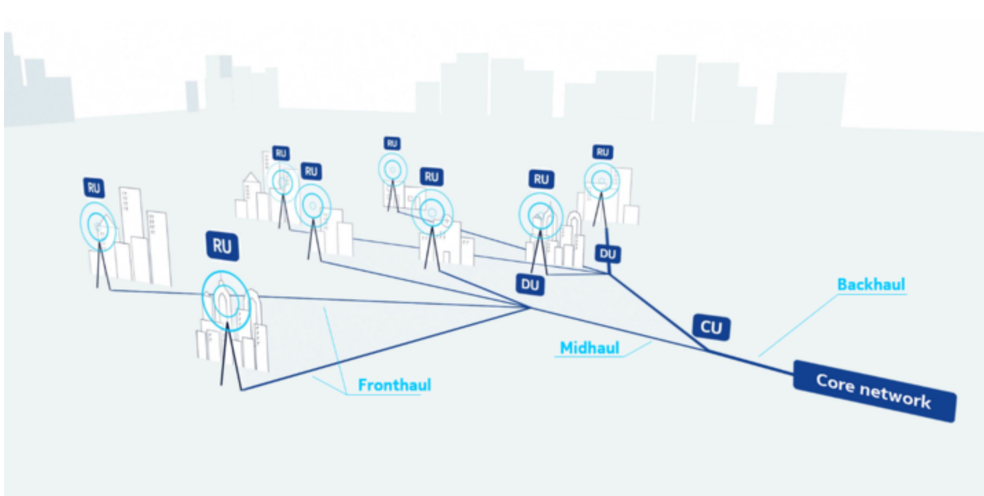
These generational shifts in mobile networks have required a simultaneous evolution in the network infrastructure and operating models that underpin the mobile telecommunications industry. The shift from 4G to 5G is likely no different. There are a number of directions in which the RAN, a major component of mobile networks that facilitates wireless connectivity across devices, might evolve to support the adoption of 5G. Open RAN infrastructure seems to be the likely next iteration of the RAN given its potential to help foster 5G RAN and further generations of mobile telecommunications through automation and densification. This is evidenced by the Federal Communications Commission's recent release on

[7] "Openness, innovation, and flexibility," Ericsson, https://www.ericsson.com/en/openness-innovation/Open RAN-explained.

"Promoting the Deployment of 5G Open Radio Access Networks,"[8] and Congress's $1.5 billion allocation to promoting and deploying Open RAN.[9]

At a high level, mobile networks rely on hardware and software infrastructure that receives and transmits signals to connect devices worldwide. These mobile networks are split into two major components: the RAN, which receives and transmits signals from mobile and other end user devices; and the Core, which manages subscribers and services and connects those digitized signals to the broader network and Internet.[10] As displayed in **Figure 1**, 5G standardization further splits the RAN into three functional units: the Radio Unit ("**RU**"), which transmits, receives, amplifies, and digitizes signals at or near a radio tower's antenna; the Distributed Unit ("**DU**"), which controls the RU and handles computation of those signals; and the Centralized Unit ("**CU**"), which handles computation closer to the Core.

Figure 1: Visualization of the components of a mobile network [11]



The entities that oversee this network are split into two broad categories: vendors and operators. Vendors such as Ericsson and Nokia supply, install, and maintain for the operators both the hardware and software infrastructure of the RAN and the Core components of the network. Operators such as AT&T and Verizon provide end users with wireless services that are dependent on the network infrastructure supplied by vendors. A pivotal aspect of the traditional RAN model is its "closed" nature. Here, the CU, DU, and RU are all fixed, vertically integrated into single base stations, and supplied to an operator by a single vendor. While connections between the base stations and end users are open and based on standards, the connections between base stations themselves are often proprietary. Therefore, an operator that wishes to leverage an interconnected RAN for the provision of services to end users must purchase the necessary

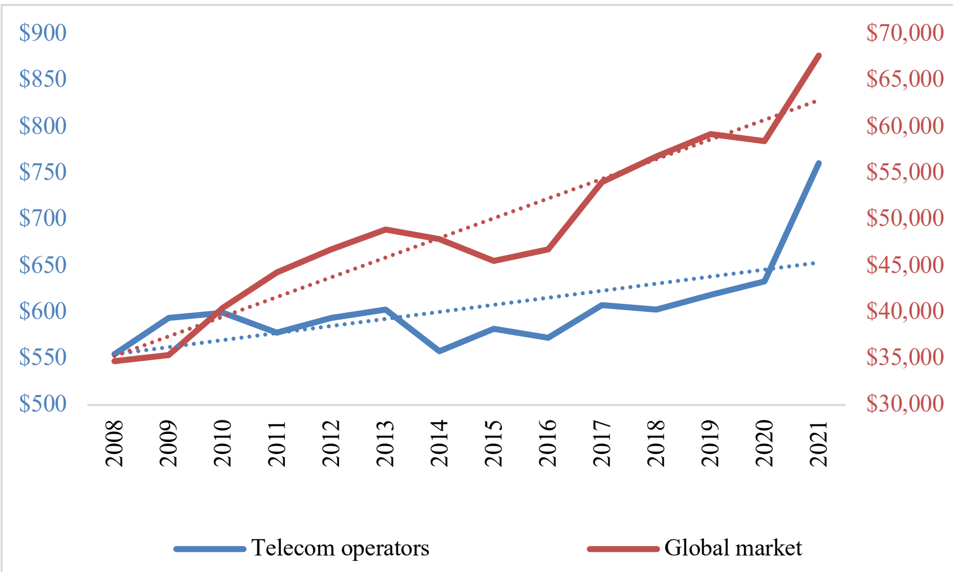
[8] Federal Communications Commission, *Promoting the Deployment of 5G Open Radio Access Networks*, February 24, 2021, https://www.fcc.gov/document/promoting-deployment-5g-open-radio-access-networks.
[9] "FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China." Statements and Releases, The White House, August 9, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/.
[10] "Update: Open RAN Explained," Nokia, March 30, 2022, https://www.nokia.com/about-us/newsroom/articles/open-ran-explained/#:~:text=Open%20RAN%20is%20about%20disaggregated,interfaces%20and%20community%2Ddeveloped%20standards.
[11] Ibid.

RAN equipment and software from a single vendor. This results in a situation where the operator is fully tied, or "locked-in," to a single vendor for all of the necessary RAN components in its network.

This monolithic infrastructure design that locks in operators to a single vendor has the potential to hinder cooperation and competition.[12] Moreover, this system may contribute to a business environment in which operators face higher-than-necessary costs. The total cost of ownership ("**TCO**") for a mobile network breaks down into capital expenditure ("**CapEx**")[13] and operational expenditure ("**OpEx**").[14] Industry commentators have estimated that, over a 10-year period, CapEx represents approximately 30% of TCO and OpEx represents the remaining 70%. While operators do face significant costs outside of RAN, the majority of both CapEx (50%) and OpEx (65%) is directed toward the RAN.[15]

These costs could be especially burdensome given the general context of stagnating revenue and profit margins in the telecommunications industry. **:** compares the combined total revenue of eight top global operators to that of all other industries in the global market. Since the 2008 Global Financial Crisis, revenue for these operators has grown more slowly than that of other industries: between 2008 and 2021, revenue for operators grew by only 37% while the broader market witnessed 95% higher reported revenue. On an annualized basis, this implies that these operators are growing revenue at just 2% per year compared to 5% for all other industries.

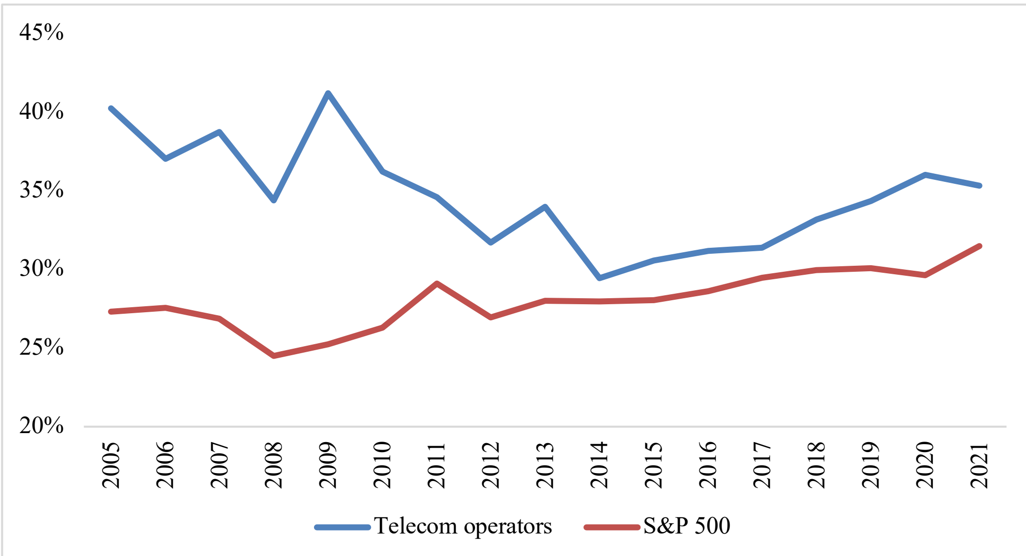
Figure 2: Operator vs. global market revenue over time ($ billions)[16]



[12] Open RAN MoU Group, "Building an Open RAN Ecosystem for Europe," November 2021, https://www.vodafone.com/sites/default/files/2021-11/building-open-ran-ecosystem-europe.pdf.
[13] CapEx is defined as the "funds used to acquire, upgrade, or maintain physical assets such as property, plants, buildings, technology, or equipment."
[14] OpEx is defined as the "costs incurred by a business for its operational activities."
[15] Zahid Ghadialy, "Understanding the TCO of a Mobile Network," *The 3G4G Blog* (blog), October 26, 2020, https://blog.3g4g.co.uk/2020/10/understanding-tco-of-mobile-network.html.
[16] Data from Refinitiv. The global market data aggregates total revenue from business activities for all available public equities, which represents 74,239 companies. The telecommunications data aggregates total revenue from business activities for the following operators: AT&T, Verizon, Vodafone, Telefónica, Orange, MTN, Deutsche Telekom, and América Móvil.

Similarly, operating profits have been stagnant for operators. **Figure 3** plots the average earnings before interest, tax, depreciation, and amortization ("**EBITDA**") margins[17] for operators compared to the average margins of firms currently included in the S&P 500 index. Operators' EBITDA margins have largely increased since 2014 but have yet to fully recover from the sharp decline witnessed in the five years prior. Operators' growth relative to the broader market has also been slow. Over the past ten years, operators' average EBITDA margins increased by 4%, which is considerably less than the 12.5% increase for S&P 500 firms. The stagnant revenues and high TCO (especially concerning the RAN) discussed above are possible factors contributing to the lagging growth in operators' profits.

Figure 3: Capitalization-weighted average EBITDA margin (%) 2005-2021, operators vs S&P 500 firms[18]

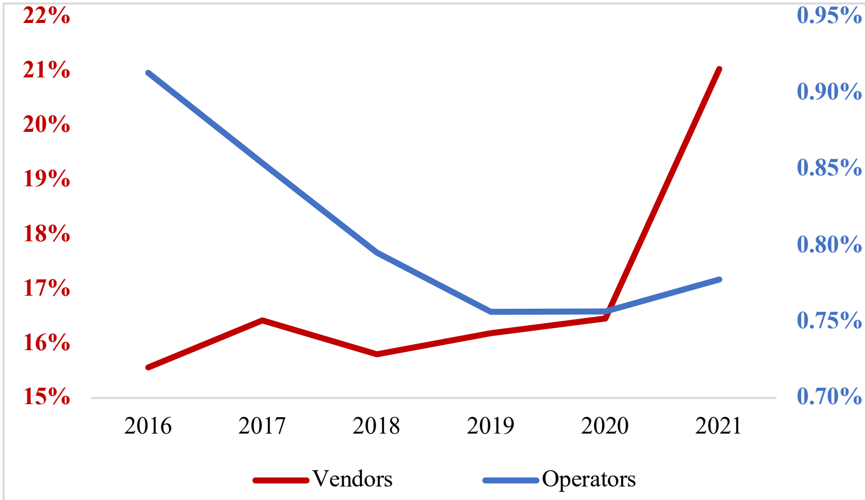


Research and development (R&D) spending among major operators, which is already comparatively low, has decreased further in recent years. **Figure 4** indicates that operators have on average spent below 1% on R&D as a percentage of revenue over the past five years. By comparison, vendors have maintained R&D expenditures above 15% of revenue and significantly increased spending in 2021. This suggests that operators may be underinvesting in R&D and relying instead on vendors to drive innovation in telecommunications. Low R&D spending may be both a symptom and cause of operators' slow growth and stagnant revenues: with flat income, there is little capital available to invest in innovation; and without innovation, operators are unable to generate new revenue streams. As we explore below, Open RAN could alleviate both of these issues by opening up possibilities for operators to pursue innovation through virtualization and automation, generating additional revenue and savings.

[17] The EBITDA margin is a measure of a company's operating profit (measured by EBITDA) as a percentage of total revenue.

[18] Data from Refinitiv. We use weights determined by companies' market capitalization to calculate the average margin for each year. As before, the following firms constitute the telecom operators metric: AT&T, Verizon, Vodafone, Telefónica, Orange, MTN, Deutsche Telekom, and América Móvil.

Figure 4: R&D expenditure / revenue (%) 2016-2021, operators vs vendors[19]



Open RAN proposes to move the industry away from the closed, single-vendor infrastructure and potentially promote more competition in the telecommunications industry by increasing the number of market participants and quickening innovation cycles.[20] At its core, Open RAN opens up the structure of the RAN by allowing components developed by different vendors to interface with each other. As mentioned previously, the traditional RAN infrastructure is monolithic in that its main components are fully integrated – which results in a single vendor providing all aspects of the technology. By comparison, Open RAN provides the ability to modularize all of these RAN components along industry-accepted interface points. This modularization allows for separate vendors to provide different components and software running on these units. In other words, the modularization of the RAN could facilitate an "open" network infrastructure where each component is interoperable with the other, regardless of the vendor providing the equipment.

There are several potential benefits of such a transformation. First, the modularization of the infrastructure and the introduction of interoperability can lead to new entrants in the vendor space. Operators would theoretically be able to source the DU from one vendor, the CU from a second, the RU from a third, and software needed to operate the network from a fourth (or any combination of vendors that results in the lowest cost). New vendors could enter the industry to supply these RAN components, increasing competition in the space and likely lowering the price of upgrading and maintaining the RAN infrastructure. Further, the interoperability of the components allow vendors to produce the these components in a "commercial-off-the-shelf" manner at lower costs and to develop software through open-

[19] Data from Refinitiv and companies' annual reports. We use weights determined by companies' revenue to calculate average R&D expenditure/revenue separately for vendors and operators. We include data on the following operators: The telecommunications data aggregates total revenue from business activities for the following operators: AT&T, BT, Telefónica, Orange, MTN, Deutsche Telekom, and TIM; and the following vendors: Ericsson, Huawei, and Nokia. We exclude operators such as Verizon as they do not report R&D expenses.

[20] National Telecommunications and Information Administration, "Comments of the National Telecommunications and Information Administration Before the Federal Communications Commission," July 16, 2021. https://www.ntia.doc.gov/files/ntia/publications/ntia_comments_-_open_ran_noi_gn_21-63_7.16.21.pdf

source initiatives.[21] The dual impact of new entrants and the ability of operators to mix-and-match components from various vendors could ultimately lead to a reduction in the telecommunication industry's costs.[22] In fact, recent tests by market participants that measure total cost savings from migrating to Open RAN suggest the move could save anywhere between 15% to 42% of TCO, depending on the current RAN infrastructure in place.[23]

Potential cost savings and social benefits concerning the RU for Open RAN

Industry reports suggest that adopting Open RAN could offer large savings for operators of RAN as a whole. But there are also reasons to believe that operators could realize substantial cost savings from the radio unit (RU) component of Open RAN specifically.

The purchase price of an RU varies based on the network's operating band; higher bands provide faster speeds but also cost more. Aside from the operating band, there are few differences across RUs. One framework for thinking about competition among vendors in such a setting is the well-known economic formulation of Cournot competition, in which each vendor sells nearly identical products and therefore competes by increasing or decreasing the quantity they produce. Along with market demand, the quantity that each vendor decides to produce determines the markup, or the portion of the RU purchase price that is greater than the marginal cost of production. Given this model of competition, academic literature suggests the entry of new market participants will reduce the markup and therefore overall RU cost that operators pay. New firms would also likely increase the quantity of RUs sold.[24]

One might believe the benefits of Open RAN are thus primarily associated with savings from lower RU prices: assuming a certain number of RUs will be needed, the total benefit of Open RAN will simply be the price savings per unit multiplied by the number of units needed. However, there may be other economic benefits in such a scenario. For example, wider proliferation of RUs following the adoption of Open RAN could combat the social harm that consumers experience when vendors sell too few units (which economists call "deadweight loss"). Moreover, benefits could accrue from subsequent innovation made possible only with greater adoption of Open RAN RUs, a topic we explore further below. In short, the relationship between the price of RUs sold and economic benefits is not necessarily a simple one. Determining the supply and demand curves to appropriately quantify this relationship would require a significant amount of data, as would a quantitative model capturing the impact of Open RAN diffusion on innovation. An economic model of these considerations is beyond the scope of this paper.

Given these economic realities, the cost savings that operators could experience represents only a fraction of potential social benefits from Open RAN RU proliferation. Nevertheless, we can still provide rough, back-of-the-envelope estimates for cost savings associated with reduced RU prices alone. We begin by using a projection by Dell'Oro that suggests there will be a quantity of 1.2 million Open RAN RUs

[21] Naima Hoque Essing, Jeff Loucks, Kevin Westcott, and Craig Wigginton, "The next-generation radio access network: Open and virtualized RANs are the future of mobile networks," *Deloitte Insights*, December 7, 2020, https://www2.deloitte.com/xe/en/insights/industry/technology/technology-media-and-telecom-predictions/2021/radio-access-networks.html.

[22] "Everything You Need to Know About Open RAN," Parallel Wireless, 2020, https://www.parallelwireless.com/wp-content/uploads/Parallel-Wireless-e-Book-Everything-You-Need-to-Know-about-Open-RAN.pdf.

[23] "Making the business case for Open RAN and Virtualized RAN: How to save money in the radio access network," Intel, https://www.intel.com/content/www/us/en/communications/biz-case-for-open-vran.html.

[24] Rabah Amir and Val E. Lambson, "On the Effects of Entry in Cournot Markets," *The Review of Economic Studies* 67 no. 2 (April, 2000): 235-254.

worldwide by 2025.[25,26] Next, we recognize that a mid-band Open RAN RU currently costs $7,560 on average while a high-band RU costs $12,680 on average.[27] Using these values, if we assume widespread adoption of Open RAN reduces prices by even 1%, the cost savings by 2025 could be $92 million if mid-band RUs are most prevalent or $154 million if high-band RUs are most prevalent (see

Table 1 below). Widespread adoption of Open RAN RUs would likely entail a mix of both mid- and high-band RUs, suggesting the actual savings could be between these two ranges of estimates.

Our simple example of 1% is meant for illustrative purposes only. Cost savings estimates range as high as 30%, according to a recent industry report summarizing the views expressed by operators in various interviews.[28] However, as we are unable to verify or justify such claims due to a lack of empirical data, we instead look to vendor margins as an indication of how much prices could decrease. For instance, the average 2021 network operating margin for vendors Ericsson and Nokia was approximately 15%.[29] We cannot determine the specific margins for the sale of RUs specifically, so we make the further assumption that it is similar to the companies' average overall network margin.

In the event that the entry of new vendors facilitated by Open RAN allows the market to transition from Cournot to perfect competition—a strong assumption made for the purposes of this illustrative example only—one might expect this margin to evaporate completely. Thus, assuming RU purchase prices decrease by 15% under this scenario (representing a 100% reduction in the markup on RUs), the cost savings realized by operators by 2025 could be as much as $1.4 billion if mid-band RUs are most prevalent or $2.3 billion if high-band RUs are most prevalent. Even if RU prices decrease by half of this average network operating margin (7.5%, representing a 50% decrease in the markup on RUs), these savings could be as much as $644 million with mid-band RUs or $1.1 billion with high-band RUs (we reiterate these price drops are meant to be illustrative examples only).

While sizable, these estimates of savings are limited in their usefulness due to the number of assumptions required to derive them combined with a lack of empirical data needed to develop more comprehensive economic models. Moreover, they likely dramatically understate the potential benefits of wider proliferation of RUs under Open RAN. One should thus interpret these estimates with caution and view them as illustrative in nature only. However, these estimates do suggest that if even a fraction of the potential benefits of Open RAN are realized, they could be highly significant.

[25] Dell'Oro Group, "Open RAN Advanced Research Report," August 2021.
[26] We take this estimate as given for the purposes of this example. We did not independently verify the data or assumptions used in the development of these estimates, and our use of them does not imply any endorsement of their accuracy.
[27] Widelity, Inc., "Report: Supply Chain Reimbursement Program Study," Federal Communications Commission Public Notice, March 25, 2021, https://docs.fcc.gov/public/attachments/DA-21-355A1.pdf.
[28] Peter Fetterolf, "The Economic Benefits of Open RAN Technology," ACG Research, May 19, 2021, https://www.delltechnologies.com/asset/en-us/solutions/service-provider-solutions/industry-market/acg-the-economic-benefits-of-open-ran-technology.pdf.
[29] Nokia, "Nokia in 2021", accessed January 1, 2023, https://www.nokia.com/system/files/2022-03/nokia-ar21-en.pdf.; Ericsson, "Ericsson Annual Report 2021", accessed January 1, 2023, https://mb.cision.com/Main/15448/3519770/1545060.pdf.

Table 1: Rough estimates of total cost savings on Open RAN radio units (RUs) by 2025

Band frequency	% decrease in per-unit RU costs	Cost saving estimate (in millions)
Mid-band RUs	1%	$92
	7.5%	$644
	15%	$1,379
High-band RUs	1%	$154
	7.5%	$1,080
	15%	$2,313

Further, the capacity to upgrade or build new RAN infrastructure at a lower cost might catalyze the investment and action necessary to develop a high-speed 5G mobile network. High-band 5G is the form of the technology that operates in the higher-capacity, millimeter wave band (30 – 300 GHz) and allows for the highest speed. Despite the advantages of upgrading to high-band 5G, this technology faces difficulty in widespread adoption due to the high cost of deploying the much denser network it requires. This form of 5G involves signals that do not travel far – in some cases, less than a mile.[30] These signals are also much more susceptible to interference, for example, from buildings, windows, trees, and vehicles. To ensure a high-quality, fast connection for end users, high-band 5G therefore necessitates the installation of a far greater number of RUs located nearer to one another.[31] This largely explains why estimates show that 50 – 70% of 5G infrastructure investment between 2020 – 2025 will be directed to the RAN.[32]

Under the traditional RAN infrastructure, the lack of interoperability between the base stations of different vendors results in an operator relying on a single vendor to handle all the infrastructure upgrades needed to ready mobile networks for 5G adoption. This poses questions as to how quickly and efficiently a single vendor can increase the scale of production and installation of RAN upgrades, if at all. Given that operators are "locked in" with a single vendor for years to come, an incumbent vendor may not view 5G with the same urgency as an operator whose customers might switch network service to a competitor that develops the technology more quickly. As such, the current one-vendor system may slow the mobile network improvements necessary for 5G to come to fruition and, thus, reduce the speed and efficiency of widespread 5G adoption.

Besides promoting vendor diversity to reduce costs, Open RAN could also lower costs through automation. A disaggregated network using Open RAN would rely on a RAN intelligent controller ("**RIC**") to control and facilitate connection between the network components provided by many vendors. Industry commentators have recognized the capacity to incorporate artificial intelligence ("**AI**") and machine

[30] "5G Spectrum Bands Explained — Low, Mid and High Band," Nokia, accessed October 14, 2022, https://www.nokia.com/networks/insights/spectrum-bands-5g-world/.
[31] Craig Thompson and John Morgan, "5G RAN Economics and Licensing," Unified Consulting, February 25, 2021, http://www.unified-consulting.com/webinars/2021/2/25/5g-ran-economics-and-licensing.
[32] Ibid.

learning ("**ML**") into this RIC.[33] This can allow the RIC to automatically gauge network requirements for users in a given time and place, and efficiently meet those users' needs. For example, AI technology might recognize increased activity near a football stadium on game days and adapt the network to meet this greater demand.[34] In this way, Open RAN could engender even greater cost savings by allowing operators to automate functions in optimization and more efficiently allocate network resources.

Beyond the benefits of greater flexibility and lower prices that operators would likely experience, Open RAN also offers potential advantages for vendors through new software applications and service offerings. Opening up the RAN could encourage competition and innovation among vendors with the introduction of new features and software applications.[35] This feature competition might benefit new entrants, but incumbent vendors could also profit by taking advantage of first-mover privileges. Such privileges arise from existing cost advantages, among other factors, that incumbent firms often experience. Academic literature exploring first mover privileges around the introduction of new technologies finds that the "window" for incumbents to capitalize on their advantage shortened considerably during the 20th century, suggesting incumbents in the telecommunications space should act in a timely manner if they are to exploit any existing advantage.[36]

In any case, interviews conducted for this paper suggested market participants view the spread of Open RAN as an imminent reality with the key question not being if the technology is adopted, but how soon. Quicker adoption of Open RAN could allow the vendors most familiar with the technology to get ahead of and adapt to this likely unavoidable shift in the market. As seen in Error! Reference source not found.**,** incumbent vendors have been key in the research and development of Open RAN and could likely leverage this understanding of the technology to expand their product offerings more quickly and efficiently with a range of features.

Both vendors and operators might also benefit from Open RAN's ability to facilitate "virtualization," a process through which elements of the RAN infrastructure once enabled through hardware shift to cloud-based software instead.[37] Virtualization could allow vendors and operators to move away from physical infrastructure. With less hardware maintenance and automation in its software, innovation of the mobile network infrastructure may be less costly and overall easier to manage for vendors and operators alike. While the exact cost savings impact of virtualizing the RAN is dependent on many factors, estimates show that moving components of the RAN to the cloud could reduce TCO by more than 35%.[38] To be clear, Open RAN still supports the use of physical infrastructure, but the new technology

[33] Openness, innovation, and flexibility," Ericsson, https://www.ericsson.com/en/openness-innovation/Open RAN-explained.; "Update: Open RAN Explained," Nokia, March 30, 2022, https://www.nokia.com/about-us/newsroom/articles/open-ran-explained/#:~:text=Open%20RAN%20is%20about%20disaggregated,interfaces%20and%20community%2Ddeveloped%20standards.; "How and Why the RIC Is Key to RAN Modernization," SDX Central, May 10, 2022, https://www.sdxcentral.com/articles/sponsored/how-and-why-the-ric-is-key-to-ran-modernization/2022/05/.

[34] "Update: Open RAN Explained," Nokia, March 30, 2022, https://www.nokia.com/about-us/newsroom/articles/open-ran-explained/#:~:text=Open%20RAN%20is%20about%20disaggregated,interfaces%20and%20community%2Ddeveloped%20standards.

[35] Ibid.

[36] Rajshree Agarwal and Michael Gort. "First-Mover Advantage and the Speed of Competitive Entry." *Journal of Law and Economics*, 44, no. 1 (April, 2001), https://www.journals.uchicago.edu/doi/abs/10.1086/320279.

[37] "Open RAN vs Virtual RAN: Explained," Lanner Whitebox Solutions (blog), August 5, 2021, https://www.whiteboxsolution.com/blog/open-ran-vs-virtual-ran-explained/.

[38] Monica Paolini, "How much can operators save with Cloud RAN?" Senza Fili, 2017, https://www.mavenir.com/wp-content/uploads/2020/01/SenzaFili-Mavenir-TCO-WP.pdf.

could better permit virtualization by permitting operators to shift to software on a piecewise basis rather than all at once.[39]

Virtualization also may help operators increase revenues by allowing them to expand product offerings. These operators could develop applications hosted in the cloud that better utilize finite network resources and target their customer base. For example, the virtualization possible through Open RAN could help enable network slicing, in which the RAN infrastructure splits into multiple networks.[40] These separate "slices" could meet the divergent connectivity requirements of different devices and users, a functionality from which high-traffic venues like stadiums and universities might benefit.

The potential benefits of Open RAN and quicker adoption of high-band 5G extend beyond the utility that consumers might gain from the technology itself. Economists have long recognized that innovations give rise to positive spillovers leading to further innovation.[41] This is especially palpable in the context of Open RAN due to its likely capacity to lower the cost of deploying 5G.[42] With lower deployment costs, automation, and wider 5G adoption, wireless consumers could experience improvements in a broad range of online experiences from streaming entertainment to telehealth.

While the benefits of Open RAN adoption may seem clear, harnessing them requires up-front investments from operators and vendors alike. As is the case with many new technologies, the current risks arising from uncertainty around the future direction of Open RAN have likely discouraged entities from making this investment despite sizable potential benefits. One avenue of risk that may be limiting investment in Open RAN surrounds questions about intellectual property that is material to implementing the technology at a reasonable cost.

While standard-setting organizations and others have made great strides in providing clarity around relevant patents and bringing about the adoption of Open RAN (as detailed further in **4. The value of an Open RAN patent pool**), much obscurity surrounds its IP situation. Major areas of uncertainty on this front include the licensing of Open RAN patents and its cost as well as the potential legal costs needed to resolve IP infringement claims. Vendors and operators have commented on difficulties in the current Open RAN IP landscape. In a 2021 government filing, operator Verizon described access to standard essential patents on fair, reasonable and non-discriminatory[43] terms as important because infringement challenges could delay development of Open RAN.[44] Similarly, operator T-Mobile's networking chief, Neville Ray, referenced "unanswered questions around IP" as a point of concern surrounding Open RAN in 2020.[45]

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[39] Openness, innovation, and flexibility," Ericsson*,* https://www.ericsson.com/en/openness-innovation/Open RAN-explained.
[40] Marcin Dryjański, "Network Slicing in O-RAN," Rimedo Labs (blog), July 2, 2022, https://rimedolabs.com/blog/network-slicing-in-o-ran/.
[41] Adam Jaffe, "Technological Opportunity and Spillovers of R & D: Evidence from Firms' Patents, Profits, and Market Value," *The American Economic Review* 76, no. 5 (December, 1986): 984–1001.
[42] Shelby Hiter, "Understanding Open RAN in the Age of 5G," Enterprise Networking Planet, April 21, 2022, https://www.enterprisenetworkingplanet.com/management/understanding-open-ran-5g/.
[43] FRAND agreements have been an essential aspect of antitrust and standard setting processes for new technologies in the U.S. for decades. For a discussion of the important of FRAND in antitrust, see: Herbert Hovenkamp, "FRAND and Antitrust," *Cornell Law Review*, 105, no 6. https://cornelllawreview.org/2020/09/15/frand-and-antitrust/.
[44] T-Mobile USA Inc., "Comments of T-Mobile USA, Inc. Before the Federal Communications Commission," Federal Communications Commission, April 28, 2021, https://ecfsapi.fcc.gov/file/104280435523172/T-Mobile%20Comments%20on%20Open%20RAN%20NOI.pdf.
[45] Mike Dano, "Open RAN Vendors Cautious on Alium Patent Pool," Light Reading, January 10, 2022, https://www.lightreading.com/open-ran/open-ran-vendors-cautious-on-alium-patent-pool/d/d-id/774464.

Therefore, addressing uncertainty about IP is likely to facilitate quicker and wider adoption of Open RAN. One mechanism to help achieve this could be a patent pool focused on providing clarity for the obscure IP environment. In fact, interviewees even suggested that a patent pool focused on Open RAN could act as a "missing link" that brings Open RAN to the forefront.

4. The value of an Open RAN patent pool

As mentioned previously, new technologies often face considerable risks that may deter market participants from devoting valuable resources to the development and deployment of those technologies. Firms generally make investment decisions based on how much they expect to profit from a given investment in the future. Greater risk surrounding a new technology often lowers expectations of its future profitability and reduces the funding that firms allocate to its deployment. Indeed, despite the potential benefits associated with Open RAN, major areas of risk and uncertainty appear to have deterred vendors and operators from making the up-front investments necessary to implement the technology at a large scale.

Key areas of uncertainty surrounding the maintenance of a multivendor network have likely increased the risk of implementing Open RAN. One common worry among operators surrounds accountability. The current arrangement gives operators only "one neck to choke" because a single vendor is responsible for the supply and upkeep of their network infrastructure.[46] In a multivendor model, however, it may be difficult to pinpoint which among many vendors is responsible for a given issue that seriously impacts the network. Concerns also circulate about the potentially greater susceptibility of a multivendor network to cyber security threats and the feasibility of implementing regulatory mandates such as 911 emergency calls.[47]

The relevant area of uncertainty on which we will focus concerns the IP landscape for Open RAN. Even though a pool may not address non-IP areas of risk, it might ensure that IP is not a main bottleneck to Open RAN adoption and allow firms to focus their efforts elsewhere. A pool may even reduce risk around licensing and patents enough that firms are more willing to invest in solutions to overcome other bottlenecks. Thus, we now discuss two problematic aspects of the IP landscape that have confronted emerging technologies such as Open RAN and discouraged investment: royalty stacking and transaction costs. For both aspects, we delve into the role a patent pool could play in helping overcome roadblocks and accelerate adoption of the technology.

I. Royalty stacking

Patent pools provide a potential mechanism to combat coordination failures among patent holders that may limit or even prevent uptake of new technologies like Open RAN. To understand the central coordination failure of royalty stacking, we briefly outline trends in the current US patenting landscape and describe how these trends present obstacles for the licensing of new technology. We then discuss the role patent pools may play in alleviating this difficult situation, especially as applied to Open RAN.

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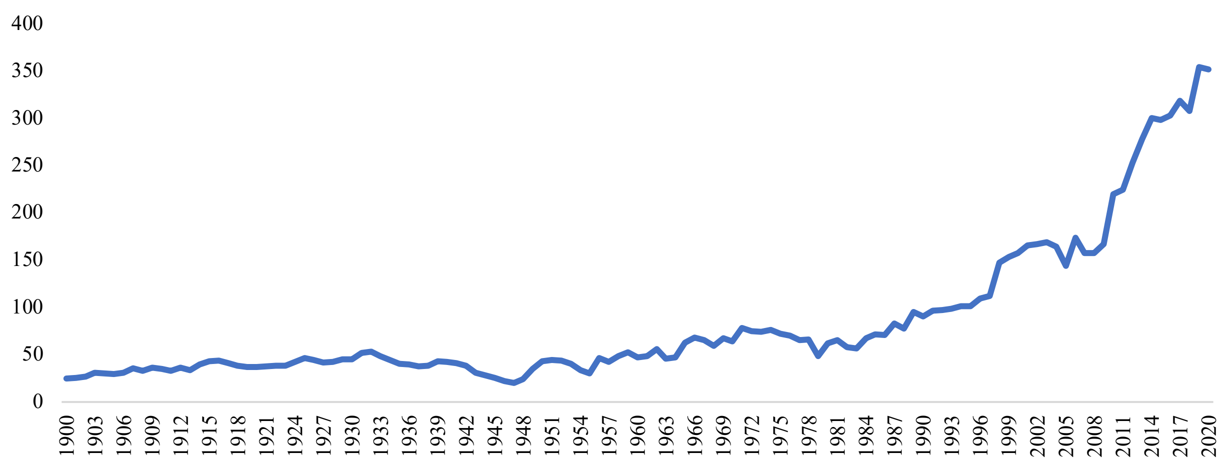
[46] Mike Dano, "Verizon, T-Mobile Outline Their Open RAN Fears," Light Reading, May 3, 2021, https://www.lightreading.com/open-ran/verizon-t-mobile-outline-their-open-ran-fears/d/d-id/769201.

[47] Ibid. Even as uncertainty remains among some operators surrounding cybersecurity, industry participants have outlined the Open RAN security architecture and argue that Open RAN "can be as secure, or even more secure as traditional proprietary RAN systems" due to transparency of open interfaces and competition among vendors in security solutions. Source: Deutsche Telekom, Orange, Telefónica, TIM and Vodafone, "Open RAN Security White Paper, Open RAN Memorandum of Understanding, March 23, 2022, https://cdn.brandfolder.io/D8DI15S7/at/45zqtkzjp4n9ncn77mkqbx8/Open_RAN_MoU_Security_White_Paper_-_FV.pdf.

Beginning in the early 1980s, the United States patent system underwent two major changes that substantially increased the number of patents granted in a given year.[48] First, a significant change in the litigation of patent appeals made it easier for firms to successfully apply for and subsequently enforce a patent in the courts for a significant financial award.[49] This is a fundamental driver behind the subsequent increase the number of patent applications. Second, the fees collected from patent applications became the sole revenue and funding source for the U.S. patent office rather than taxes, incentivizing the office to process more applications at a faster pace. However, this office lacked the resources to quickly and effectively review the increased level of applications, and the dual emergence of more patent applications and less rigor in evaluation opened the floodgates for U.S. patenting activity.[50] As displayed in **Figure 5**, the number of patents granted annually began to grow drastically when the first of the aforementioned changes took hold. This growth has persisted to today – there were 352,000 U.S. patents granted in 2020 compared to only 62,000 granted in 1980.

Figure 5: Annual patents awarded by USPTO, 1900 – 2020 (thousands) [51]



The increases in both patenting activity and litigation have brought about coordination failures that often slow the pace and effectiveness of innovation. The chief coordination failure is royalty stacking, which arises when patent owners fail to account for other licensors' prices when setting the royalties (licensing fees) for their own patent. Due to the aforementioned increase in patenting activity, manufacturers seeking to implement popular technologies in their products must often negotiate and pay for hundreds of potentially relevant patent licenses. For example, any company incorporating wireless 3G technology into a product in 2002 had to navigate over 15,000 patents claimed to be "essential" by over 100 separate companies.[52] In royalty stacking, each of these patent holders sets a price for their patent(s) that might be optimal taken in isolation; however, the overall price of the hundreds of relevant patents taken together may make the technology prohibitively expensive for licensees. Royalty stacking can therefore

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[48] For more detailed discussion on the impact of these changes to the U.S. patent system, see: Adam Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It*, (Princeton, NJ: Princeton University Press, 2004).
[49] Ibid.
[50] Ibid.
[51] Adapted from "U.S. Patent Activity Calendar Years 1790 to the Present," U.S. Patent and Trademark Office, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm.
[52] Ky P Ewing Jr., "United States: EC and DoJ Approval of the 3G Patent Platform," Mondaq, March 10, 2003, https://www.mondaq.com/unitedstates/technology/20207/ec-and-doj-approval-of-the-3g-patent-platform.

diminish the spread of innovation by deterring users from adopting new technologies and discouraging would-be inventors from pursuing ideas that build on existing IP. Instead, a lower aggregate price for a portfolio of patents often proves socially beneficial by allowing for more diffuse spread of the new innovation.[53] Royalty stacking represents a fundamental aspect of wider licensing uncertainty that can hinder the spread of innovation.

As mentioned previously, standard-setting organizations ("**SSOs"**) are one means to combat this problem. SSOs help guide the evolution of a new technology by defining how its components and products must interact. This function can facilitate the spread of new technologies by providing a venue for cooperation between entities involved in developing and adopting the new technology. The main SSOs for Open RAN are the seven 3GPP partnering standards bodies and the O-RAN Alliance, an association of operators, vendors, research institutions, and industry partners working towards wide adoption of Open RAN. Among the group's major aims is publication of "specification[s], aimed at extending RAN standards to include openness and intelligence." [54]

While these SSOs can be useful in overcoming coordination problems, they face limits in their ability to combat royalty stacking. Due to antitrust concerns, SSOs do not establish a licensing fee rate for standard essential patents ("**SEPs**"). As such, SSOs typically rely on the fair, reasonable, and non-discriminatory ("**FRAND**") stipulation required from their participants when they set fee structures for their SEPs covered in the standard. FRAND requirements in SSOs are ambiguous by design as there is no official determination of "fair" and "reasonable" licensing fees for SEPs.[55] This ambiguity often leads to costly litigation which in turn can suppress widespread deployment, the very outcome standards are formed to avoid. Despite attempts to set more solid guidelines around FRAND,[56] it remains a concept fraught with obscurity. **Case discussion 1: Standard essential patents and FRAND** below highlights one such instance where the ambiguity of FRAND resulted in litigation. SSOs can therefore combat coordination failures around how different components of a technology interact with each other but are less effective in addressing coordination failures around pricing of IP.

CASE DISCUSSION 1: Standard essential patents and FRAND[57]

In April 2013, Judge James L. Robart provided the first opinion on a FRAND licensing agreement case offered by a judge in U.S. courts. The case involved Microsoft (plaintiff) and Motorola (defendant), with Microsoft claiming that the licensing fees Motorola charged for patents deemed SEPs by multiple SSOs did not meet FRAND requirements.

The case was originally brought to court in 2010 and stemmed from Microsoft and Motorola's involvement with several SSOs: the Institute of Electrical Electronics Engineers ("**IEEE**") and the International

[53] Josh Lerner and Jean Tirole, "Efficient Patent Pools," *The American Economic Review* 94, no. 3 (June, 2004): 691–711.
[54] Michele Polese, Leonardo Bonati, Salvatore D'Oro, Stefano Basagni, and Tommaso Meldoia, "Understanding O-RAN: Architecture, Interfaces, Algorithms, Security, and Research Challenges," ArXiv, August 1, 2022, https://doi.org/10.48550/arXiv.2202.01032.
[55] Joseph Farrell, John Hayes, Carl Shapiro, and Theresa Sullivan, "Standard Setting, Patents, and Hold-Up," *Antitrust Law Journal* 74, no. 3 (2007): 603–70.
[56] For example, a 2013 court case upheld that a FRAND fee should be set in a way that: (1) promotes adoption of the standard, (2) mitigates the "patent hold-up" and royalty stacking, (3) ensures the patent owner is guaranteed reasonable royalties, and (4) works towards applying FRAND terms to all patented tech needed for the standard; *Microsoft Corp. v. Motorola, Inc*., 871 F.Supp.2d 1089 (W.D. Wash. 2012).; *Microsoft Corp. v. Motorola, Inc*., 696 F.3d 872 (9th Cir. 2012).
[57] Adapted from: *Microsoft Corp. v. Motorola, Inc.*, 871 F.Supp.2d 1089 (W.D. Wash. 2012).

Telecommunications Union ("**ITU**"), that established certain video (H.264, MPG-4 Part 10 or AVC) and wireless local area connectivity ("**WiFi**" or IEEE 802.11) standards. Microsoft engaged with Motorola to license patents owned by Motorola under a FRAND arrangement, as the patents covered video technology and WiFi used in Microsoft's Xbox.

Motorola offered a royalty rate of 2.25% of the price for each Xbox unit produced, which was approximately $4.50/unit. Microsoft strongly felt that the 2.25% rate violated the FRAND requirement and sued Motorola for breach of FRAND. In his deliberations, Judge Robart relied on comparable transactions, many of which were examples of past licensing rates charged by patent pools, to determine the appropriate rate. Ultimately, the judge decided that the FRAND range for Microsoft to access Motorola's SEPs was approximately $0.04 to $0.36 per each Xbox, far below the $4.50 initially demanded by Motorola.

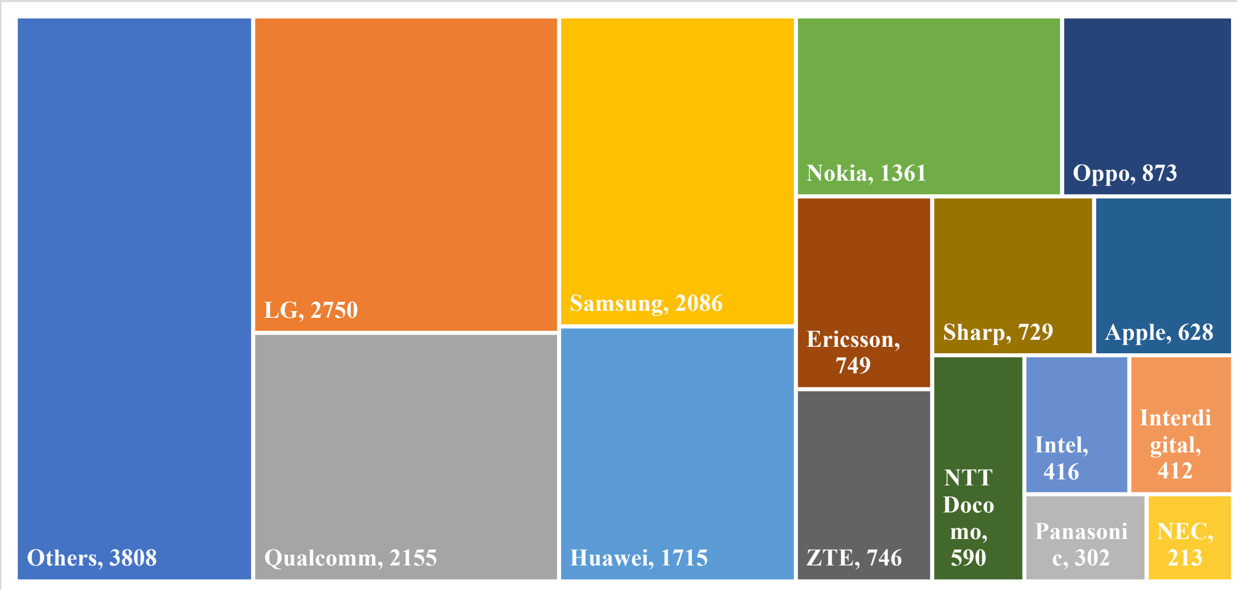
In referencing their use of rates charged by past patent pools, the court stated, "Despite the concerns with using a pool rate as the de facto RAND royalty rate, the court concludes that under certain circumstances, successful patent pools can serve as indicators of a royalty rate that falls within the range of royalties consistent with the RAND commitment." This suggests a pool rate can serve as a "benchmark rate" for licensing.

Patent pools effectively can combat the coordination failure of royalty stacking by working with licensors to establish reasonable prices for access to their collective IP. Ideally, a pool unites every owner of a patent essential for implementing a given technology and determines a single price for licensees to pay for access to all the essential patents. Licensors could theoretically work together to determine such a pricing scheme without the facilitation provided by a patent pool. However, any single firm may act as a "hold-up" in the absence of a patent pool, making the technology overly expensive for licensees by demanding an excessively high fee for its IP. One of the core values of patent pools is that licensors agree to one collective price for all essential patents owned by multiple licensors.[58] Moreover, a well-represented pool's rate can act as a "benchmark" to inform reasonable licensing rates among firms that choose against joining the firm, as discussed in **case discussion 1**. This not only reduces uncertainty in pricing for licensees but often increases profit for licensors. Due to greater proliferation of technology with the elimination of royalty stacking, licensors are often able to realize higher profits by selling far greater quantity of licenses despite lower per-patent prices. In this respect, pools can benefit both licensors and licensees by addressing coordination failures in patent licensing.

This background for how patent pools can combat royalty stacking informs the potential utility of an Open RAN patent pool. As is the case for most modern technologies, ownership of patents necessary to implement Open RAN is diffuse. **Figure 6** illustrates the large number of patents and patents holders for IP concerning the LTE and 5G RAN. This suggests that a large variety of companies hold patents relevant to the implementation of Open RAN, and a single firm holding one of these patents may act as a "hold-up" and slow down adoption of the technology by charging excessively high licensing fees. In the absence of a pool, this "hold-up" concern could manifest when a licensor knows a prospective licensee has already purchased access to every other patent for a given technology. In this situation, the licensor might recognize the hold-up value of its own patents and charge an excessive licensing fee. Buying rights to patents from any individual licensor without guarantees about pricing from other licensors therefore poses a potential risk, especially given the diffuse patenting landscape of Open RAN.

[58] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.

Figure 6: Declared patent landscape for the LTE and 5G RAN, patent holder and number of patents [59]



This royalty stacking problem is especially relevant for Open RAN because the benefits of vendor diversity and greater innovation hinge on the ability of new vendors to enter the market. These entrants will likely need to gain access to the relevant patents as a necessary input to manufacture their products. However, the risk posed by royalty stacking can lower the future reward they expect to attain from entering the telecommunications market and investing in the technology. Research suggests that demand from the downstream market (which consists of both vendors and operators who implement the patented technology) is especially sensitive to patent pricing when widespread adoption remains uncertain.[60] This means that even small distortions that make the price slightly too expensive could dramatically hinder whether novel technologies become popular. By coordinating pricing and increasing volume sold with reasonable royalty terms, a patent pool could allow Open RAN to proliferate more easily as patent holders can increase their return on investment in technology development.

In this context, a patent pool has the potential to curb royalty stacking by facilitating licensing cooperation, committing licensors to a reasonable royalty scheme, and providing a benchmark rate for non-members holding relevant patents. By joining a pool, operators and vendors could lessen the risk surrounding the IP for Open RAN. As outlined previously, this lower risk could accelerate the pace of investment in and expedite the adoption of the technology.

II. Transaction costs – including patent litigation

Another factor that could be limiting investment in Open RAN concerns transaction costs for licensing IP. Following Merges and Mattioli, we define transaction costs to include both negotiation and patent litigation costs.[61] We cover these two sources of costs in turn and discuss the role a pool may play in

[59] Data provided by Alium based on ETSI's IP declaration database as of December 2022.
[60] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.
[61] Robert P. Merges and Michael Mattioli, "Measuring the Costs and Benefits of Patent Pools," *Ohio State Law Journal* 72, no. 2 (2017): 281-347, https://kb.osu.edu/bitstream/handle/1811/81222/OSLJ_V78N2_0281.pdf.

substantially reducing them for both licensors and licensees. We then apply this understanding more directly to Open RAN.

A principal benefit of patent pools is their ability to lower costs for negotiating patent licenses. Without a pool, prospective licensees seeking to implement a given technology often need to expend considerable time and resources determining which patents are relevant and then negotiating the patents' prices with each licensor. Licensors similarly face high transaction costs in arranging these bilateral agreements.[62] By combining relevant patents into a single package for licensing, patent pools can cut down on negotiating costs for both sides of the deal. Further, the distinction between licensor and licensee often blurs as firms holding relevant patents also implement the technology in their own products. For these vertically integrated firms, patent negotiations may prove especially expensive and pools particularly attractive. [63]

Besides negotiating costs, patent litigation can be unpredictable and expensive. Contesting patents in the courts is often costly and distracting to a business. Thus, the prospect of litigation represents a key risk that might discourage market participants from investing in new technology. By reducing the likelihood of litigation among members and potential users, pools can lessen the probability of lawsuits.[64] Moreover, pools mutualize enforcement costs and can help firms defend their IP when non-pool members infringe upon it. This especially benefits smaller firms that face hurdles in reaping the financial benefits of their patents. Other firms are more likely to ignore small firms' patents because the latter are often unable to engage in expensive, time-consuming, and uncertain infringement litigation.[65] Without a pool, the risk that others might ignore their claims might discourage small firms from investing in R&D in the first place.

Both negotiation and patent litigation costs are relevant to the current IP landscape of Open RAN. Legal disputes around IP have proven highly expensive in the past for telecom companies. Largely due to a recent licensing dispute with Samsung, Ericsson's patent licensing revenue dropped from $2.1 to $0.7 billion in the first quarter of 2018.[66] The company behind Blackberry wireless devices, Research in Motion, paid $39.5 million in litigation fees in a single year, which represented 12% of sales in that year.[67] This potential for high legal expenses increases the risk surrounding Open RAN and therefore discourages investment in the technology. This risk is especially pertinent for prospective new vendors that may not be able to afford expensive infringement lawsuits. By reducing the likelihood of patent litigation, pools can address this problem. Similarly, enforcement in a pool could allow new vendors who invested in R&D for Open RAN to potentially increase their ability to reap financial gains from this investment.

Moreover, negotiating costs surrounding Open RAN may prove costly, especially given the high likelihood of new entrants seeking access to relevant patents. A forecast of the savings would be speculative and outside of the bounds of this work, but we can look to past pools to gain an idea of the potential magnitude of savings. **Case discussion 2: Cost savings in MPEG Audio and HEVC pools** and **Table 2**

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[62] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186; Thierry Rayna and Ludmila Striukova, "Large-Scale Open Innovation," *International Journal of Technology Management* 52, no. 3/4 (2010): 447-496.

[63] Robert P. Merges and Michael Mattioli, "Measuring the Costs and Benefits of Patent Pools," *Ohio State Law Journal* 72, no. 2 (2017): 281-347, https://kb.osu.edu/bitstream/handle/1811/81222/OSLJ_V78N2_0281.pdf.

[64] Ibid.

[65] Thierry Rayna and Ludmila Striukova, "Large-Scale Open Innovation," *International Journal of Technology Management* 52, no. 3/4 (2010): 447-496.

[66] Bevin Fletcher, "Ericsson and Samsung Reach Patent License Deal, Ending Litigation," Fierce Wireless, May 7, 2021, https://www.fiercewireless.com/financial/ericsson-and-samsung-reach-patent-license-deal-ending-litigation.

[67] "Legal Bills Pile Up At RIM," Forbes, July 29, 2003, https://www.forbes.com/2003/07/29/cx_ah_0729blackberry.html?sh=252d50fd1d4b.

indicate that cost savings have been substantial for past pools and suggest Open RAN could likely benefit from substantial savings as well. As a note, Alium, the pool for Open RAN, employs a machine learning technique to avoid potentially millions of dollars in standard essential patent review costs, which we discuss further in

5. **Considerations for pool formation and how Alium approaches them** This means the Alium pool may avoid some of the formation and licensor costs faced by other pools such as the MPEG Audio and HEVC pools.

CASE DISCUSSION 2: Cost savings in MPEG Audio and HEVC pools [68]

The MPEG Audio patent pool emerged in the late 1990s to license rights for patents covering the digital distribution and playback of recorded sound under the MPEG Audio standard. Dolby organized this pool and launched a new company, Via Licensing, to handle licensing, collecting royalties, and distributing royalties to patent owners.

To quantify the cost savings of this pool, Merges and Mattioli (2016) gain cost estimates from interviews with participants in the pool's formation at Via Licensing. Accounting for both negotiation and litigation costs, the authors estimate that the MPEG Audio patent pool saved around $628 million after netting out expenses for establishing the pool (**Table 2**). The authors do not break down how these savings split between licensors and licensees, but the often-blurred distinction between the two means pool members likely each saved a substantial amount.

Cost savings are similarly high for another pool that launched in 2014 and licenses patents for video compression technology, High Efficiency Video Coding ("**HEVC**"). The authors estimate cost savings of around $398 million for this pool, a number derived again from interviews with key participants.

Table 2: Estimated transaction costs conserved by patent pools [69]

Description of costs	MPEG Audio Standard	HEVC Standard
Transaction costs devoted to search and negotiations in absence of patent pool	$635,880,000	$402,960,000
Costs associated with establishing patent pool	$7,807,000	$4,600,000
Transaction costs conserved	**$628,073,000**	**$398,360,000**

5. Considerations for pool formation and how Alium approaches them

Given patent pools' potential to combat obstacles facing Open RAN and allow for the realization of its benefits, steps have been taken to make patent pools for this technology a reality. For example, the Alium pool seeks to quicken the adoption of Open RAN and 5G technology.[70] Pools can take many shapes,

[68] Adapted from: Robert P. Merges and Michael Mattioli, "Measuring the Costs and Benefits of Patent Pools," *Ohio State Law Journal* 72, no. 2 (2017): 281-347, https://kb.osu.edu/bitstream/handle/1811/81222/OSLJ_V78N2_0281.pdf.
[69] Ibid.
[70] For information on Alium, please see: https://www.alium-llc.com/.

and key considerations that impact patent owners' decision to join a pool have informed the design of Alium. This section will provide background on Alium and outline its approach to key facets of pool formation. We explore the following considerations in turn: antitrust concerns, royalty distribution, and grant-backs.

Developed by MPEG LA and Unified Patents, Alium seeks to combat problems surrounding the IP of Open RAN and support the technology's widespread implementation. The pool aims to provide "a solution to the uncertainty and risk" surrounding the licensing of Open RAN.[71] Alium focuses specifically on patents for the RU, a component of the RAN central to the network densification necessary for high-band 5G. As of November 2022, this pool includes the operators AT&T, Comcast, SK Telecom, and Verizon and other patent holders including Acer, CableLabs, Meta, Mitsubishi, Pantech, and Philips as members, and is still in the process of attracting RU vendors. The Alium pool is the first pool that addresses licensing for cellular infrastructure equipment.

Antitrust concerns

One primary concern in constructing Alium and patent pools in general is ensuring the pool does not promote anticompetitive collusion. Many early pools operated as price-fixing organizations. These collusive arrangements all but disappeared in the mid-20th century due to antitrust concerns.[72] Antitrust authorities remained skeptical about pools for decades.

However, the Department of Justice ("**DOJ**") and the Federal Trade Commission shifted their stance toward patent pools more than twenty years ago, recognizing that well-designed pools can be a pro-competitive, efficient mechanism for "integrating complementary technologies, reducing transaction costs…and avoiding costly infringement litigation."[73] The DOJ issued guidelines in 1995 that redesigned the modern patent pool to limit its capacity for anticompetitive behavior.[74] For example, these guidelines ensure pool charters do not include any ancillary restraints beyond the aim of the pool, so as to avoid the appearance that the association is a front for price-fixing collusion.[75]

These guidelines restrict a patent pool to license only complementary patents, ensuring the pool does not allow for socially harmful collusion. Complementary patents are jointly essential to implement a given technology, and a customer seeking to use this technology would need to pay for each patent in the

[71] "First Patent Pool for 3GPP Infrastructure Launched to Help Accelerate 5G," Unified Patents, December 6, 2021, https://www.unifiedpatents.com/insights/2021/12/6/first-patent-pool-for-3gpp-infrastructure-launched-to-help-accelerate-5g.
[72] An example of such an anti-competitive pool is the Hartford-Empire Co patent pool, which violated antitrust laws according to the courts by restricting competition between licensors of glass manufacturing patents and charging excessively high prices for these patents. A 1945 court opinion on this pool stated that "there will be further [antitrust] abuses in the future as long as there is a semblance of that system [patent pools] remaining. It is the opinion of the court that this entire system must be abolished." Source: Hartford-Empire Co. v. United States, 323 U.S. 386 (1945).
[73] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.
[74] U.S. Department of Justice and the Federal Trade Commission, *Antitrust Guidelines for the Licensing of Intellectual Property,* April 6, 1995, https://www.justice.gov/atr/archived-1995-antitrust-guidelines-licensing-intellectual-property.
[75] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.

absence of a pool.[76] While selecting complementary, essential patents may sound simple, it is difficult in practice. Participants in pools have invested millions of dollars in legal fees to determine the essentiality of patents in the pool. Fortunately, economic research suggests that the requirement of independent licensing (in which patent owners can license their patents separately from the pool) largely combats anticompetitive patent pools, so regulators need not make any judgements of essentiality.[77] **Case discussion 3: DOJ supervision during patent pool formation** provides an example of a prominent modern patent pool carefully designed to align with these regulations and avoid the anticompetitive tendencies of early pools.

CASE DISCUSSION 3: DOJ supervision during patent pool formation[78]

Given anti-competitive concerns surrounding patent pools, the DOJ has overseen the formation of several modern pools and conducted business reviews to ensure compliance with antitrust law. The first modern-day patent pool was based around MPEG-2, a widely used digital video compression standard featured in products like DVDs and high-definition television. CableLabs, a research and development lab, launched the MPEG-2 patent pool in the mid-1990s. While forming MPEG LA, the company that would handle licensing for the pool, CableLabs worked extensively with the DOJ to avoid anti-competitive practices. They implemented several antitrust safeguards, including:

- The pool could only license essential patents. Firms interested in the MPEG-2 standard employed an independent patent expert to initially determine which patents were essential. Once established, the pool retained an independent technical expert to assess which patents were essential.
- Patent owners were free to license independently and had an obligation to do so. Licensors and licensees were free to use their patents to improve on or compete with the pooled technology.
- The licensing administrator (i.e., MPEG LA) was independent of the pool members.
- Pool members did not receive sensitive market information. Furthermore, the licensing administrator is not given access competitively sensitive proprietary information, such as cost data.

With these rules in place, the DOJ stated that it would likely not initiate antitrust action against the MPEG-2 pool. The DOJ has since applied this framework to several patent pools seeking business reviews, including pools regarding DVD technology, 3G wireless technology, and the recent University Technology Licensing Program in 2021.

[76] Essential patents cannot be perfect substitutes for each other, meaning that no two patents can serve the same purpose. A patent pool that consists solely of perfect substitutes represents a monopolistic arrangement to suppress competition between similar patents and maintain overly high prices. Rather, an ideal pool consists only of complements that serve a purpose together. For further information, see Lerner and Tirole's "Public Policy Towards Patent Pools" cited above.

[77] Under independent licensing, owners of substitutable patents have an incentive to undercut the pool by selling access to a substitute patent at a lower price outside of the pool. Furthermore, independent licensing combats the problem of irrelevant patents unnecessarily driving up a pool's price by allowing customers to license the patents they need at a lower price from the patent owners directly. Independent licensing therefore suggests that any pool largely consisting of irrelevant patents or substitutes would be unsustainable. For further information, see Lerner and Tirole's "Public Policy Towards Patent Pools" cited above.

[78] Adapted from U.S. Department of Justice and the Federal Trade Commission, *Antitrust Guidelines for the Licensing of Intellectual Property,* April 6, 1995, https://www.justice.gov/atr/archived-1995-antitrust-guidelines-licensing-intellectual-property; Michael F. Murray, "University Technology Licensing Program Business Review Request," U.S. Department of Justice Antitrust Division, January 13, 2021, https://www.justice.gov/atr/page/file/1352961/download.

In accordance with DOJ guidelines and common practice for modern pools, Alium is designed to preempt antitrust concerns. The pool permits independent licensing and furthermore seeks to solely license essential patents.

Royalty Distribution

The way a pool divides royalties among its members is an important consideration that often determines whether a patent owner joins. Pools may decide whether to split royalties proportionally based on the number of patents a licensor contributes, the value of each patent, or any number of other relevant metrics. The main advantage of numeric sharing (i.e., dividing royalties equally among all patents in the pool) is the pool can avoid the controversial, costly process of calculating the "value" of each patent. Even an impartial committee of industry insiders would likely struggle in assigning individual values to hundreds of interrelated patents. Further, a minor patent could later become important for a standard, leaving it undervalued due to an outdated, initial valuation. These factors have convinced the majority of pool participants to adopt some type of numeric sharing.[79] When patent claims are relatively similar in value on average across licensors, pools are more likely to form and agree to some type of numeric sharing for a (large) portion of the royalty distribution.[80]

Division of royalties through numeric sharing may drive away firms with especially significant patents.[81] They might view numeric distribution as a disadvantage given the disproportionate importance of their innovations and license independently instead. **Case discussion 4: Lucent's split from MPEG-2** provides an example of such a scenario. Notably, this case suggests that a patent owner "holding out" due to numeric distribution could fail to realize the benefits of such a strategy.

CASE DISCUSSION 4: Lucent's split from MPEG-2[82]

Forming the first modern day patent pool around MPEG-2 video compression and convincing companies to join the pool was difficult. The central issue among the members of the pool was royalty sharing, and disagreements over this topic led to some patent owners withdrawing from the pool. To avoid controversies over assigning value to each individual patent, MPEG LA (the company founded to handle licensing for the MPEG-2 patent pool) chose to distribute royalties numerically based on the proportion of essential patents each licensor owned (in countries connected with the manufacture or sale of royalty products). MPEG LA also promised to not raise the royalty rate unless extreme conditions arose.

Lucent Technologies, a telecommunications equipment company, possessed two patents that it felt were critical to the MPEG-2 standard. Moreover, Lucent wished to maximize the licensing revenues they would receive from their MPEG-2 patents. The company felt that the licensing rate established by MPEG LA was too low and that their patents would be undervalued in the pool. With its large internal licensing department capable of conducting independent licensing activities, Lucent estimated that the higher royalties it could charge would more than offset the slightly smaller market for the technology due to its refusal to join the pool. As a result, Lucent opted to only license its patents independently.

[79] Anne Layne-Farrar and Josh Lerner, "To Join or Not to Join: Examining Patent Pool Participation and Rent Sharing Rules," *International Journal of Industrial Organization* 29, no. 2 (2011): 294–303.
[80] Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.
[81] Ibid.
[82] Adapted from Josh Lerner and Jean Tirole. "Public Policy Towards Patent Pools." *Innovation Policy and the Economy* 8 (2007): 157–186.

However, Lucent profited less from licensing without the pool than initially anticipated. MPEG-2 licensees were generally unwilling to pay Lucent more than the per-patent rate charged by the pool, reflecting a pool's role in helping to set a "benchmark rate."[83] Further, Lucent subsequently faced expensive patent litigation against MPEG-2 that the firm may have avoided by joining the pool.[84] Lucent's MPEG-2 patents were eventually included in the pool as a result of Lucent's merger with Alcatel, which was already an MPEG-2 licensor.

Recognizing common industry practice, Alium shares royalties in part on a numeric rather than value basis. This avoids the controversy and cost of determining the value of the many relevant patents. Further, the failure of value-based schemes to capture how value changes over time is especially relevant for Open RAN given how early the technology is in implementation. Numeric sharing therefore allows Alium to avoid uncertainty in valuation and reduces the risk that a patent owner might fail to realize returns on a patent that only becomes important later. The Alium charter includes a novel approach to impartially approximate whether a patent is likely relevant or not. It uses a machine learning algorithm to make this decision, avoiding the use of expensive third-party evaluations that would otherwise be necessary. [85] This algorithm is less time-intensive and costly than the essentiality determination common among other pools, and patent owners can contest the algorithm's results and seek a second opinion from a more conventional independent party. The patents identified by this algorithm are then used to distribute royalties to the licensors on the basis of their proportional ownership. This royalty scheme therefore represents a low-cost, relatively easy-to-implement option for addressing the often-contentious topic of royalty splitting.

Grant-backs

Licensee grant-back provisions represent another potentially problematic area that those forming a pool must approach carefully. With grant-backs in place, licensees of the pool must agree to license any innovations they develop related to the pool's technology at a reasonable royalty rate. Some earlier pools may have structured grant-backs in a way that necessitated that licensors hand over later-developed patents and discouraged innovation after joining the pool.[86] However, like other pools administered by MPEG LA, grant-backs for Alium are narrow and targeted to the scope of the relevant Open RAN technology that is the subject of the license. In this way, the pool seeks to avoid overreaching and obtaining rights to patents beyond the specific RU component on which it focuses. Moreover, any patent later developed by a licensor that relates to the technology but is beyond the scope of the Open RAN standard covered by Alium would not be subject to the grant-back provisions. Alium has therefore structured its grant-back provisions with the intention to compensate licensors for relevant patents with commensurate royalty rates and still promote subsequent innovation.

Its approach to antitrust concerns, royalty splitting, and grant-backs suggests that Alium has considered these issues when forming its pool. Informed by the outcomes of previous pools, the Alium pool is structured to observe common best practices. Moreover, the pool offers a new approach to a familiar problem with its machine learning algorithm for approximating patent essentiality for purposes of royalty

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[83] Ibid.
[84] Scott M. Fulton, III, "MPEG LA wins major MPEG-2 settlement from Alcatel-Lucent," BetaNews, Inc., March 29, 2010, https://betanews.com/2010/03/29/mpeg-la-wins-major-mpeg-2-settlement-from-alcatel-lucent/.
[85] For more details on the Alium essentiality algorithm, see: https://www.alium-llc.com/blog/hnybywxnf3y9wf1tngjuwif8ybp9w8.
[86] Amol M. Joshi and Atul Nerkar, "When Do Strategic Alliances Inhibit Innovation by Firms? Evidence from Patent Pools in the Global Optical Disc Industry," *Strategic Management Journal* 32, no. 11 (March 14, 2011): 1139–1160.

allocation while granting licenses only to essential patents. In seeking to address the IP bottleneck for Open RAN, this pool might allow market participants to realize the potential benefits of Open RAN more quickly.

6. Conclusions

Beyond a technical change to infrastructure, Open RAN has the potential to contribute to the transformation of the mobile telecommunications market more broadly. By facilitating greater openness in the RAN, this innovation could allow new vendors to enter the market and expand infrastructure options for network operators. This flexibility is likely to facilitate quicker adoption of high-band 5G and promote further innovation in areas such as virtualization of the RAN. Open RAN also may provide opportunities to increase profitability for both vendors and operators alike through lower costs and new revenue streams. Open RAN has the potential to benefit both market participants and their customers with faster speeds on mobile devices and the introduction of a broad range of innovative new services.

While these potential advantages are considerable, risks and uncertainties that accompany new technologies may have the unintended effect of limiting investment in Open RAN. The current IP landscape represents a major area of uncertainty that a patent pool can address:

- First, ownership of IP relevant to Open RAN is diffuse and voluminous, and a great deal of uncertainty may cloud its value. In particular, royalty stacking could make these patents prohibitively expensive for licensees. A pool works to provide clarity in licensing rates by committing pool members to a certain, reasonable licensing fee. The pool rate can also provide a benchmark to guide firms outside of the pool to charge reasonable royalties. This greater certainty in licensing can lower the risk of investing in a new technology, encouraging licensees to increase investment or even enter the market for the innovation.
- Second, costly patent litigation presents a major risk, especially to new entrants in the market. A pool can lessen the likelihood of this litigation and allow smaller firms to rightfully defend their claims with enforcement. Also, pools can reduce the cost of negotiating bilateral contracts between each licensor and licensee.

In these ways, a patent pool works to reduce intellectual property risk and encourage market participants to invest in and adopt the new technology. This could be especially valuable for Open RAN, many benefits of which depend on the entry of new market participants. For new entrants and incumbents alike, a pool represents a potential mechanism to bypass potential IP bottlenecks that might otherwise limit investment in the technology. With the support of a well-designed pool, the benefits of Open RAN and 5G can be widely adopted in a timelier manner.