IEEE Patent Policy Revisions:
An Empirical Examination of Impact[1]

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Kirti Gupta **Georgios Effraimidis**

Abstract

In February 2015, the Institute of Electrical and Electronics Engineers-Standards Association (IEEE-SA) -- one of the largest Standards Development Organizations (SDOs) -- adopted highly controversial changes to its intellectual property rights (IPR) policy. Specifically, the IEEE-SA introduced a specific definition of Fair, Reasonable and Non-Discriminatory (FRAND) licensing terms. The updated policy rules and the position of the Department of Justice (DoJ) -- stated in a Business Review Letter (BRL) -- have attracted much discussion from academic scholars and industry practitioners.

The aim of this paper is to explore how the new patent policy has impacted different aspects of standards development within IEEE. Particularly, our analysis focuses on the IEEE 802 LAN/MAN Standards Committee (IEEE 802 LMSC), whose Working Groups (WGs) have been responsible for the design and development of widely used wireless technologies such as Wi-Fi, Ethernet, and ZigBee. The first part of the analysis examines the submission pattern of Letters of Assurances (LoA), i.e., documents outlining the declaration of patents potentially essential to the standard (commonly referred to as Standard Essential Patents (SEPs)) and terms under which the submitter is willing to license its SEPs. We examine LoA submissions before and after the implementation of the new policy within the 802.11 WG, which covers the Wi-Fi technology. Next, we analyze how the comment resolution process (CRP), that is, the process of resolving comments made by 802.11 voters has changed after the policy update. More specifically, we investigate whether there is a delay in the approval process of 802.11 standards. Finally, we examine how the number of submitted Project Authorization Requests (PARs), or documents that trigger the development or revision of a standard by defining the scope and requirements for a new technical project across all IEEE 802 WGs, has changed after the policy update. PARs can be used as a proxy of new activity related to the development of standards.

The empirical findings suggest a decline in LoAs with several SEP holders reluctant to license under the new IPR policy terms. More importantly, uncertainty on implementers' side has increased, as new standards have been approved under the presence of negative and/or missing LoAs, and other standards are being developed under this "mixed bag" of LoAs. The CRP analysis reveals that the first two rounds of the process last on average longer after the policy change. Such a finding implies that the 802.11 balloting process has become more time consuming, which in turn results in a (potential) delay of approval/publication of standards. We also find that the number of new projects initiated (or PARs) in the IP-intensive IEEE standards (namely the 802 WGs) have decreased, suggesting a potential deceleration of the growth rate of innovation after the policy change.

Keywords: Comment Resolution Process, FRAND, IEEE-SA, Letter of Assurance, Project Authorization Requests, Standards Development Organizations

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1. Introduction

SDOs are an important feature of Information and Communication Technologies (ICT) industry, where firms need to develop interoperable technologies, products and services that meet specific industry requirements. These institutions encourage coordinated innovation by offering a forum for collective decision making. Several studies in the past have established the numerous benefits of cooperative standards development: i) lower transaction costs (Kindleberger (1983)), ii) promotion of intra-industry international trade (Swann et al. (1996)), iii) industry growth and reduced prices of products based on the standard (Spulber (2016)), iv) lower barriers to entry, economies of scale, gains in productivity and efficiency (Tsilikas (2017)). A recent study by Padilla et al. (2016) compares cooperative standards to proprietary technologies from individual firms that then become de-facto standards, or standards dictated by governments. The study finds that SDOs lead to more competition in production, a higher number of specialized research firms, and greater diversity in research. Collaborative standard setting supported by SDOs has an unprecedented record of breakthrough technological achievements as evidenced by widely deployed technology standards: cellular connectivity (3G/4G), Wi-Fi, Bluetooth, USB, JPEG, PNG, and MP3. Some examples of successful SDOs are: the European Telecommunications Standards Institute (ETSI), the IEEE-SA, and the International Telecommunication Union (ITU), which have played a key role in the growth and product differentiation in the ICT sector. [2]

As an incentive to contribute in cooperative standards development, participants are often allowed to retain IPRs for their technical contributions toward the development of standards. The licensing rules for patents that are declared as potentially essential to the implementation of a standard -- commonly referred to as Standard Essential Patents (SEPs) -- lie at the core of cooperative standards development.[3] Several SDOs require their members to commit to license SEPs on what are traditionally referred to as FRAND terms. The objective of a FRAND commitment is to balance the incentives of various parties involved in cooperative standards development and facilitate wide access and deployment of the standards at issue. On the one hand, a FRAND commitment seeks to ensure that technology contributors can reap adequate

[2] IEEE is the world's largest technology association with more than 420,000 members in 160 countries. IEEE plays a key role in the development and advancement of global technologies. IEEE-SA is the SSO that oversees the IEEE standards development process. IEEE-SA brings together a broad range of individuals and organizations from a wide range of technical and geographic points of origin to facilitate standards development and standards related collaboration. IEEE-SA's technology output has transformed the way people live, work and communicate. Some examples of IEEE standards that have enabled key global technologies are: Wi-Fi (802.11), Ethernet (802.3), ZigBee (802.15.4), SystemVerilog (1800), Ampacity (802.35).

[3] Throughout the paper, we use the term "standard" for a standard, revision of a standard, or amendment of a standard.

rewards from their innovations, and on the other hand, allow participants across all levels of the supply chain to have access to standards.[4]

Some commentators have expressed their skepticism about the meaning and completeness of FRAND as a contract, and what that has meant to SDO members (e.g., Farrell et al. (2007)), while others have argued that that since contract incompleteness has been a persistent and historical feature across SDOs, even after taking several antitrust considerations into account, it may be intended as an efficient feature of a competitive contracting process, rationally chosen by the SDOs, to allow for flexible bilateral negotiations between firms (Tsai and Wright (2015)). In the early 2000s, the law and economics literature began to raise the concern that the FRAND commitment was intended but was not enough, to prevent "patent hold-up". For example, Lemley and Shapiro (2007) raise concerns about potential "patent hold-up" when an SEP holder is able to exploit the locked-in position of the standard implementer(s) after they have sunk their manufacturing costs, and potentially extract supra-competitive royalty payments. They therefore imply that the royalties may be higher ex-post (after the standard is set) than what the SEP holder would have received ex-ante, before the incorporation of the patented technology into the standard. Accordingly, if implementers anticipate this possibility, they may reduce their investment level.

In recent years, scholars have argued that hold-up is a two-sided concept and may also arise when implementers refuse to enter into licensing agreements after the inventors or patent owners have sunk their R&D costs. The practice of SEP implementers routinely resisting patent owner demands is defined as "patent hold-out". The newly appointed U.S. DoJ Assistant Attorney General for the Antitrust Division Makan Delrahim has acknowledged that the "patent hold-up" theory exaggerates the risks incurred by standard implementers and completely ignores the "patent hold-out" risk.[5] Froeb and Shor (2015) state that just as implementers invest before knowing what end-product demand will be, so too must innovators make large sunk investments without knowing whether an innovation will be commercially deployed, and therefore, "patent hold-up" is a symmetric problem. Moroever, Heiden and Petit (2018) conduct an industry survey and the findings imply that "patent hold-out" is a significant phenomenon, which deserves as much attention from courts and policy-makers as the "patent hold-up" narrative.

[4] For instance, according to ETSI: "*the ETSI IPR POLICY seeks a balance between the needs of standardization for public use in the field of telecommunications and the rights of the owners of IPRs." (ETSI IPR Policy, Clause 3.1). "IPR holders whether members of ETSI and their AFFILIATES or third parties, should be adequately and fairly rewarded for the use of their IPRs in the implementation of STANDARDS and TECHNICAL SPECIFICATIONS." (ETSI IPR Policy, Clause 3.2). ETSI shall take reasonable measures to ensure, as far as possible, … to be available to potential users in accordance with the general principles of standardization*." (ETSI IPR Policy, Clause 3.3).

[5] https://www.justice.gov/opa/speech/assistant-attorney-general-makan-delrahim-delivers-remarks-usc-gould-school-laws-center

In an attempt to mitigate the perceived risk of "patent hold-up", the IEEE-SA announced an update of its IPR policy in February 2015. IEEE-SA became one of the few SDOs to give a definition of the FRAND undertaking. The most important points of the new policy rules, which became effective on 15th of March 2015, are the following:

- The calculation of reasonable terms should take into consideration the following:
    - The value that the functionality of the claimed invention or inventive feature within the Essential Patent Claim contributes to the value of the relevant functionality of the smallest saleable Compliant Implementation that practices the Essential Patent Claim.
    - The value that the Essential Patent Claim contributes to the smallest saleable Compliant Implementation that practices that claim, in light of the value contributed by all Essential Patent Claims for the same IEEE Standard practiced in that Compliant Implementation.
    - Existing licenses covering use of the Essential Patent Claim, where such licenses were not obtained under the explicit or implicit threat of a Prohibitive Order, and where the circumstances and resulting licenses are otherwise sufficiently comparable to the circumstances of the contemplated license.
- "Reasonable Rate" shall mean appropriate compensation to the patent holder for the practice of an Essential Patent Claim excluding the value, if any, resulting from the inclusion of that Essential Patent Claim's technology in the IEEE Standard.
- The Submitter of an Accepted LOA who has committed to make available a license for one or more Essential Patent Claims agrees that it shall neither seek nor seek to enforce a Prohibitive Order based on such Essential Patent Claim(s) in a jurisdiction unless the implementer fails to participate in, or to comply with the outcome of, an adjudication, including an affirming first-level appellate review…[6]

During the development of this IPR policy, some commentators raised antitrust concerns about the revised IPR policy. For instance, in a letter to the DoJ, Gregory Sidak expressed concerns that the proposed policy update could facilitate buyer collusion – "*amendments posed a serious risk of violating section 1 of the Sherman Act by facilitating tacit or explicit collusion among implementers to suppress the royalties they pay for SEPs*".[7] Furthermore, Ericsson stated that the proposed amendments "*constitute the collective establishment of mandatory, uniform license terms . . . akin to a buyer's-side cartel*".[8] In light of these

[6] See http://standards.ieee.org/develop/policies/bylaws/sect6-7.html.
[7] Letter from J. Gregory Sidak, Chairman, Criterion Economics, L.L.C., to Hon. Renata Hesse, Deputy Assistant Attorney General, U.S. Department of Justice (Jan. 28, 2015).
[8] IEEE-SA Standards Board Patent Committee, IEEE-SA Patent Policy: Draft Comments ID No. 38 (comments of Dina Kallay, Director for IP and Competition, Ericsson).

alleged serious antitrust concerns, IEEE requested a BRL because some comments in response to the proposed IPR policy update "*voiced either vague or specific antitrust concerns," including concerns that revisions "to the term 'reasonable rate' … could amount to 'buyer-side price-fixing*".[9] On February 2, 2015, the Antitrust Division of the U.S. DoJ published its BRL response stating that it has no intention to bring an antitrust challenge against the proposed updates to the patent policy.[10] The DoJ determined that the revised policy would have procompetitive effects by increasing clarity around the meaning of the FRAND undertaking. According to the BRL, this greater clarity would improve the standards development process, foster ex-ante competition among technologies for incorporation into the standard, facilitate licensing negotiations between parties, and mitigate "patent hold-up". The BRL response claimed that any anticompetitive effects were not likely and that even if there were some anticompetitive harms, they would be outweighed by the procompetitive benefits arising from the policy update.

The updated IPR policy rules have attracted much discussion from academic scholars and industry practitioners. In terms of the process adopted by IEEE for the policy revision, Sidak (2016) argues that the new rules have been advanced without respect for the IEEE and IEEE-SA's foundational and core principles of consensus, due process, openness, balance and right to appeal. The revised IPR policy was originally drafted by an ad-hoc committee that was not open to all members. When the draft was opened for comments by all members, Sidak's empirical results based on analysis of publicly available data, reveal a strong negative relationship between an IEEE members' position against the policy revisions and the ad-hoc committee's propensity to accommodate that member's comments in the development of these revisions. The rejection rates of submitted comments were: (i) 85.33% for firms publicly opposed to the revised policy, (ii) 85.71 % for publicly neutral firms, and (iii) 46.36% for firms publicly supporting the IPR policy. The analysis also suggests that the decision making at the IEEE ad-hoc committee was dominated by parties that favor the interests of patent licensees and seek to devalue SEPs. In 2013, for example, firms affiliated with net implementers of SEPs held five of the six voting slots in the ad-hoc committee, and four of the six voting slots in 2014.

Since the new IEEE-SA policy was announced in March 2015, there has been some analysis on the implications and impact of the policy change. For example, Katznelson (2016) examines how the new rules have affected the LoA submission process. First, he empirically demonstrates that the new rules have resulted in a 90% decline in LoAs for IEEE. Second, he discusses how the significant decline in LoAs has

[9] Letter from Michael A. Lindsay, Esq., Dorsey & Whitney, L.L.P., to Hon. William J. Baer, Assistant Attorney General, U.S. Department of Justice 18–19 (Sept. 30, 2014), http://www.justice.gov/sites/default/files/atr/legacy/2015/02/17/311483.pdf

[10] Business Review Letter from Hon. Renata B. Hesse, Acting Assistant Att'y Gen., U.S. Dep't of Justice, to Michael A. Lindsay, Esq., Dorsey & Whitney, L.L.P. (Feb. 2, 2015), *available at* http://www.justice.gov/atr/public/busreview/311470.htm.

negatively impacted the standards development process. For the first time, instead of solely focusing on technical discussions, participants in the standards process spend much more time addressing IP related issues than in the past, which in turn results in a significant delay of the entire standardization process.[11] IPlytics (2016) challenges the findings of Katznelson by presenting an analysis, which indicates an active declaration process shortly after the adoption of the new patent policy. According to the analysis, more LoAs were submitted at IEEE in 2015 than in any prior year in IEEE's history. Moreover, the study claims that new standardization work at IEEE has been at its highest levels ever since the patent update was completed, as the number of approved new PARs -- excluding revision or extension of existing PARs -- reached a historic high in 2016.

In an exploration of how these policy changes would be interpreted against the existing jurisprudence in Europe, Petit (2016) and Zingales and Kanevskaia (2016) present arguments that explain why the new IEEE patent policy may constitute a violation of Article 101 of the Treaty on the Functioning of the European Union (EU). The two papers highlight the disconnect between the DoJ approach in the United States and the jurisprudence in Europe -- whilst SDOs initiatives to refine their patent policies with respect to the licensing rates were endorsed by a BRL from the DoJ, they may trigger findings of antitrust liability in the courts of Europe. According to these two studies, EU antitrust case-law on horizontal coordination under Article 101 creates a risk of antitrust liability for SDO policies that attempt to give substance to the concept of reasonable rates and guidelines on rate-setting factors. Hence, policy revisions such as IEEE's can possibly create an "antitrust trap" for SDOs, as national courts involved in patent litigation may be called upon to assess the validity of the new patent policy.

The aim of this paper is to explore how the recently revised IEEE patent policy has impacted different aspects of the standards development process. Particularly, our analysis focuses on the IEEE 802 LM SC, which designs, produces, and maintains networking standards and recommended practices for local, metropolitan, and other area networks. Widely known and commercially deployed standards developed by the 802 WGs are for Ethernet, Wi- Fi, and ZigBee. The IEEE 802 WGs are the most IP intensive as they account for 1.2% of all IEEE WGs, but almost 80% of the submitted IEEE LoAs – documents that patent owners submit for declaring their commitment to license their SEPs on FRAND terms.[12] Currently, eight different active WGs operate under the IEEE 802 LMSC. Amongst these eight 802 WGs, the 802.11 WG, which develops Wi-Fi technologies, is arguably the most important WG with respect to IP-intensive

[11] Unedited comments collected from attendees at the IEEE 802 Executive Committee Workshop on the perceived impact of the updated patent policy. Compiled by Paul Nikolich, IEEE 802 LMSC Chairman.

[12] So far, there have been 19 802 WGs, active and inactive. The total number of active IEEE WGs is 1507 (http://standards.ieee.org/develop/wg/).

technical work. Particularly, the 802.11 WG accounts for: i) 61.2% of the total contributions across all active 802 WGs, ii) 37.8% of all submitted LoAs across the currently active 802 WGs.[13]

In the first part of the analysis, we place emphasis on the evolution of 802.11 LoA submissions before and after the implementation of the new policy. The LoA analysis allows us to assess how SEP holders have responded to the new patent policy and whether they are willing to license their IP under the new FRAND terms. Next, we explore the duration of the 802.11 balloting process, which begins when the WG (i.e., 802.11) has decided the draft of the standard is stable. The WG forms a balloting group to approve first the draft and subsequently the resolution of negative comments/votes. The process to resolve these negative comments/votes, which is commonly referred to as CRP, consists of a series of recirculation ballots. In this paper, we restrict our attention to the duration of the first two resolution rounds and calculate the average duration of each of these two resolution rounds before and after the policy update. This analysis will allow us to assess whether there is a delay in the approval process of standards after March 2015. In the last part, we examine how the number of submitted 802 PARs has changed after the change of the patent policy. The development/revision of a standard is triggered by a PAR, a legal document that defines the scope, purpose, and expected number of people involved in the project. A PAR is submitted by the IEEE 802 LM SC to the New Standards Committee (NesCom) for review, and subsequently for approval to the IEEE – SA Standards Board (IEEE-SASB). A temporal analysis of the number of submitted PARs gives us the opportunity to assess whether the project initiation activity has changed after the policy update.

Our analysis of 802.11 LoA demonstrates that the adoption of the new IPR policy has had a substantial impact on both positive and negative LoA submissions. A "positive" LoA is a letter in which the submitter agrees to license its SEPs under reasonable terms. A "negative" LoA is a letter in which the submitter explicitly declines to give any assurance regarding its licensing intentions. We find that the number of *new* positive LoA submissions has (significantly dropped) by 91%. We also find that: i) the number of submitted negative LoAs reached an all-time high in 2016, ii) the number of submitted negative LoAs over the period 2015 – 2017 is larger than the number of submitted *new* positive LoAs during the same period. The results suggest that many SEP owners are reluctant to license their patent portfolio on the new FRAND terms. More importantly, the uncertainty on implementers' side has increased, as new standards -- 802.11ah and 802.11ai -- have been approved despite the presence of negative and/or missing LoAs, and the ongoing

[13] The total contributions across the active 802 WGs are broken down as follows (count of contributions in parenthesis): 802.1 (727), 802.11 (52,718), 802.15 (19,435), 802.16 (2,034), 802.19 (2,640), 802.21 (4,228), 802.22 (4,475). In the contribution analysis, we exclude the 802.3, as there is not publicly available contribution data for this WG. The 802 LoAs are classified as follows (LoAs in parenthesis): 802.11 (365), other active 802 WGs (601).

802.11ax standards are continuing to be developed under a similar "mixed bag" of positive and negative LoAs.[14]

With regard to the CRP, we document that, after March 2015, it takes longer for the 802.11 WG to complete this process. The average aggregate duration of the first two comment resolution rounds has increased from 233 days to 332 days (42.5% increase). The increase is broken down as follows: the average duration of the first comment resolution round has increased from 138 days to 197 days (42.9% increase); the average duration of the second comment resolution round has increased from 95 days to 135 days (42.1% increase). Such delays may harm the standards development process and be a waste of private as well as public resources; additionally, standards are not approved on time and this results in slow diffusion of technology standards. Finally, the number of submitted IEEE 802 PARs *under consideration* has declined by 4.2% after the update of the patent policy. Given that the IEEE 802 WGs account for the majority of SEP- related IEEE standards, it is reasonable to claim that the new IPR policy has not boosted the development of IP intensive standards.

A brief outline of the paper follows. Section 2 provides a quick overview of the IEEE 802 LM SC standards process. Section 3 outlines the LoA declaration process. Section 4 describes our LoA counting method and presents several empirical findings on LoA submissions before and after the policy update. Section 5 is concerned with the analysis of the 802.11 CRP. Section 6 uses IEEE PAR 802 data to assess whether the initiation process of new 802 projects has changed after the policy update. The final section 7 provides a general overview of the results and crucial policy implications that emerge from our analysis.

2. IEEE 802 Standards Process

As explained in the previous section, the aim of this paper is to investigate how the standards development process within the IEEE 802 LMSC has changed after the policy update in March 2015. Before we proceed to the main empirical analysis, we first provide a brief description of how the IEEE 802 LMSC is structured and how its standards are developed. A dive in the institutional understanding of this Standards Committee will substantially help us understand the method as well as the results coming from the empirical analysis of the current paper. SDOs have only recently become a topic for analysis and very few studies have described how these institutions operate. Baron and Gupta (2015) describe in detail the organization structure, rules, and procedures followed by 3GPP, which has released successful 3G and 4G cellular standards. Kanevskaia (2016) sheds light on the working procedures of three different SDOs (IEEE, ITU, ETSI) and whether they fall within the scope of global administrative law.

[14] Missing LoAs refer to requests -- made by the WG chair -- to SEP holders to submit LoAs but did not result in a positive LoA.

The IEEE 802 LMSC is directed by the IEEE 802 LMSC Executive Committee (EC), which is the so-called "Sponsor" as defined by IEEE-SA governance. The IEEE 802 LMSC EC sets the rules under which the 802 LMSC operates. The goal of these rules is to encourage compatibility and commonality -- with a minimal overlap -- among the IEEE 802 family of standards.

The development of an IEEE 802 standard is triggered by a PAR, submitted by the IEEE 802 LMSC EC to: i) the New Standards Committee (NesCom) for review and ii) subsequently to IEEE-SA Standards Board (IEEE-SASB) for approval. The NesCom first examines whether the proposed project falls within the scope and the purpose of the IEEE 802 LMSC EC. Upon PAR approval, the 802 LMSC EC assigns the project to the corresponding 802 WG, which in turn gives the project to one of its (newly formed) Task Groups (TGs). The formation of TGs is determined only after the approval of the PAR, and often includes individuals involved in the preparation of the PAR. The largest part of the technical work that results in the development of technical standards occurs in TGs. The draft standard is produced by TG participants via numerous contributions that address various technical issues. Often, hundreds or even thousands of contributions have been submitted by several participants and discussed towards the formulation of the draft standard.

After ensuring (e.g., internal review) that the draft is ready, the output of TGs is presented to the corresponding WG for balloting, which consists of two types of ballots: i) ballot for approval of the draft standard, ii) recirculation ballot(s). For a draft standard to successfully pass the first type of ballot, more than 75 % of the total votes should bear an "Approve". Once the proposed draft has achieved 75% approval (possibly after more than one WG ballot), the subsequent ballots at WG level are referred to as recirculation ballots. The scope of these ballots includes only resolution of comments (that do not affect the approved draft), which were submitted during the first ballot for approval of the draft. Recirculation ballots have the same voting scheme and rules as the first ballot and it is at the discretion of the WG how many recirculation ballots should be held.

Upon approval of the draft and successful completion of the WG recirculation ballots, the draft is forwarded to the 802 LMSC EC, that is, the Sponsor. As at WG level, two types of ballots take place: (i) ballot for approval of the draft standard, (ii) recirculation ballot(s). The content, voting options, and rules are the same as for the WG ballots. Upon successful completion of the Sponsor ballot, the draft is submitted by the Sponsor to the Review Committee (RevCom) for review and next to IEEE-SASB for approval/publication.

Currently, there are eight active WGs and two active Technical Advisory Groups (TAGs) that operate under the IEEE 802 LMSC. As mentioned earlier, the technical work takes place within WGs. On the other hand, the role of TAGs is to provide a pool of technical expertise needed by the multiple 802 WGs. All WGs meet three times per year at plenary sessions. Plenary sessions are held in March, July, and November. Most

WGs hold interim meetings, usually in January, May, and September. The next two tables present the list of the currently active 802 WGs and TAGs.[15]

WG	Standard Technology
802.1	Higher Layer LAN Protocols Working Group
802.3	Ethernet
802.11	Wireless LAN
802.15	Wireless Personal Area Network
802.16	Broadband Wireless Access
802.19	Wireless Coexistence
802.21	Media Independent Handover Services
802.22	Wireless Regional Area Networks

Table 1: List of active 802 WGs.

TAG	Standard Technology
802.18	Radio Regulatory
802.24	Vertical Applications

Table 2: List of active 802 TAGs.

The next pie chart provides the breakdown of contributions by active 802 WG. Based on the analysis, we find that the 802.11 WG is the leading WG, as it accounts for 61.2% of the contributions. It is followed by the 802.15 WG with a 22.5% share. The 802.19 WG comes at a far third position with a contribution share of only 5.2%. These statistics highlight the great significance of the 802.11 WG and substantial amount of effort that has been devoted by its participants toward the development of Wi-Fi standards.

[15] Source: http://www.ieee802.org/.

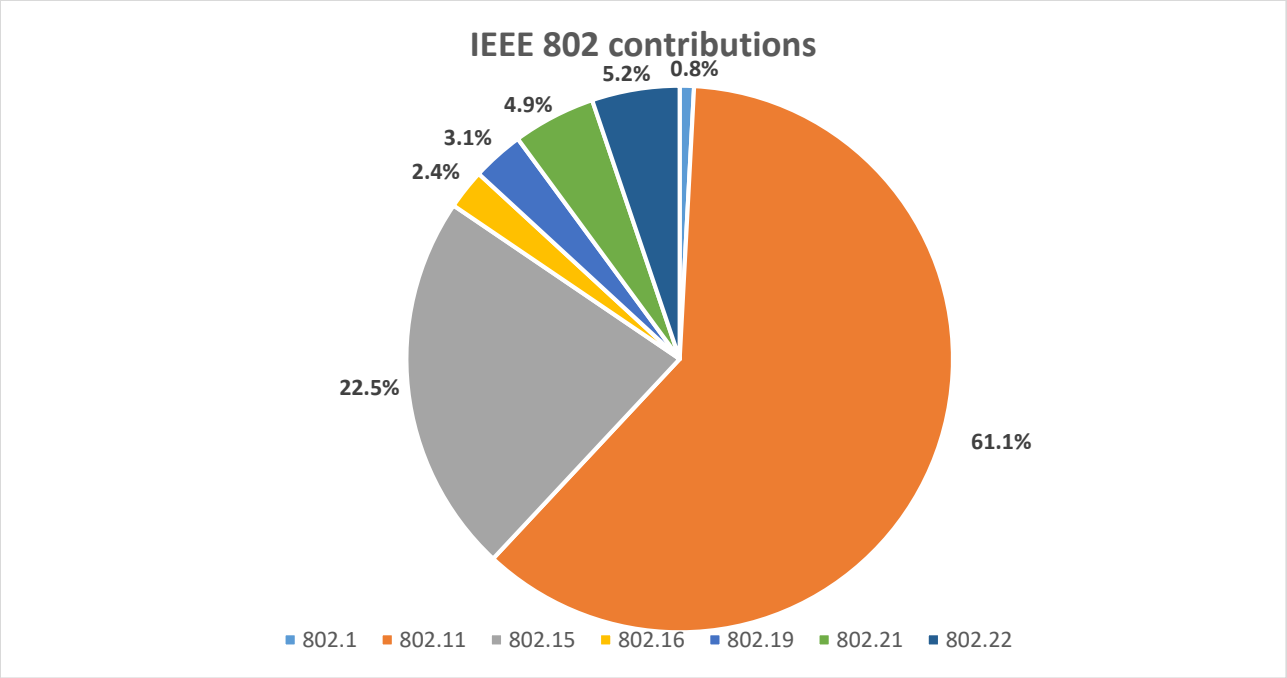

Figure 1: Contribution shares by active 802 WG.

It should be pointed out that the contributions analysis does not consider the 802.3 WG, as there is not publicly available data for this group. However, if we make the (plausible) assumption that the number of contributions is positively correlated with the number of submitted LoAs (and thus higher standards output), it is pretty safe to claim that the above result would not substantially change, as the 802.11 WG is the leading WG in terms of submitted LoAs (see next section).

3. IEEE LoA Disclosure

SDOs provide a platform for industry practitioners to come together and develop technology standards. Given that standards may include patented technologies, SDOs historically have developed IPR policies, which aim to strike a balance between the rights of SEP holders and SEP implementers. Many SDOs accomplish this balance by seeking their members to publicly disclose upfront, that is, prior to the adoption of standard, their patents that are (potentially) essential for the implementation of standards. The American National Standards Institute (ANSI), for instance, states that early disclosure of patents "*is likely to enhance the efficiency of the process used to finalize and approve standards*" and "*provides participants the greatest opportunity to evaluate the propriety of standardizing the patented technology, and allows patent holders and prospective licensees ample time to negotiate the terms and conditions of licenses*…".[16] Disclosures are based on faith of patent owners and SDOs do not perform any verification tests regarding the true

[16] Guidelines for Implementation of the ANSI Patent Policy, Section III.

essentiality / validity of declared SEPs. Furthermore, many SDOs urge patent holders to commit to licensing their essential patents on FRAND terms and conditions. In most of these cases, it is explicitly stated that the meaning of the FRAND undertaking is to fairly reward the contributors and grant implementers access to the technology standard (Layne-Farrar (2016)).

The IEEE-SA encourages participants in the standards development process to disclose their (potentially) SEPs at a relatively early stage of the process. Each WG meeting begins by the statement concerning the IEEE-SA patent policy and a call to identify the holders of patents which the meeting attendees believe that they may be essential for the implementation of the standard in progress. The (potential) patent-holders may subsequently be asked to submit an LoA in which they should state their position with respect to ownership, enforcement or licensing of potential SEPs. Specifically, an LoA submitter has the following five mutually exclusive options: i) state that it will license its SEPs on royalty-free terms, ii) state that it will license its SEPs under reasonable terms, iii) state that it will not enforce its SEPs, iv) state that it is not willing to license under the patent policy terms, v) deny awareness of SEPs. Any submitted LoA is irrevocable once submitted and accepted and applies, at a minimum, from the date of the standard's approval to the date of the standard's transfer to inactive status.[17] Any submitted LoA in which the submitter chooses one of the first four options is either patent-specific or blanket. The former means a document, stating the submitter's position regarding ownership, enforcement, or licensing of certain SEPs for a specifically referenced IEEE standard. The latter means a document, stating the submitter's position regarding ownership, enforcement, or licensing of any potentially SEPs relevant for a specifically referenced IEEE standard.[18]

Although participants in the IEEE standards development process are encouraged to submit LoAs, they are not required to provide such letters as a prerequisite for participation. In case an IEEE-SA participant is requested to submit an LoA and this request does not result in an LoA submission, the respective submission is commonly referred to as "missing LoA". In fact, the IEEE-SASB recently approved the 802.11ai standard under the presence of "missing LoAs". Three companies, IBM, HP, and Blackberry were requested to submit LoAs -- subject to the new patent policy -- but they have not done so far.[19]

The LoA analysis will shed light on how SEP owners perceive the new patent policy and whether this new policy guarantees a proper compensation scheme for their innovations. The pattern of LoA submissions should be of considerable interest to policy makers and industry practitioners, as it will allow us to examine

[17] http://standards.ieee.org/develop/policies/bylaws/sect6-7.html.
[18] See the previous footnote.
[19] See https://mentor.ieee.org/802.11/documents?is_dcn=LoA%20request (Register of LoA requests). The 802.11ai standard was approved in December 2016.

whether the update of the patent policy can (potentially) weaken ex-ante incentives to innovate in critical technology areas.

Before we proceed to the LoA methods/results, we present two figures that largely justify our choice to focus on the IEEE 802 WGs (for the PAR analysis) as well as the 802.11 WG (for the LoA analysis). These figures demonstrate the SEP importance of i) all IEEE 802 WGs compared to the other IEEE WGs, ii) the 802.11 WG relative to the other active IEEE 802 WGs. We begin by noting that, as of October 2017, there were 1,292 submitted IEEE LoAs. The next pie chart gives the breakdown of LoA submissions between the eighteen IEEE 802 WGs (eight active + eleven inactive) and the remaining IEEE WGs. Based on calculations, 77.5% of LoAs are linked to IEEE 802 standards. The striking feature of this result is that the set of IEEE 802 WGs represent only 1.7% of all IEEE WGs (~1,500). These results clearly imply that the vast majority of SEP-intensive IEEE standards have been produced by the IEEE 802 WGs, and consequently any attempt to assess the new patent policy should focus on these WGs.

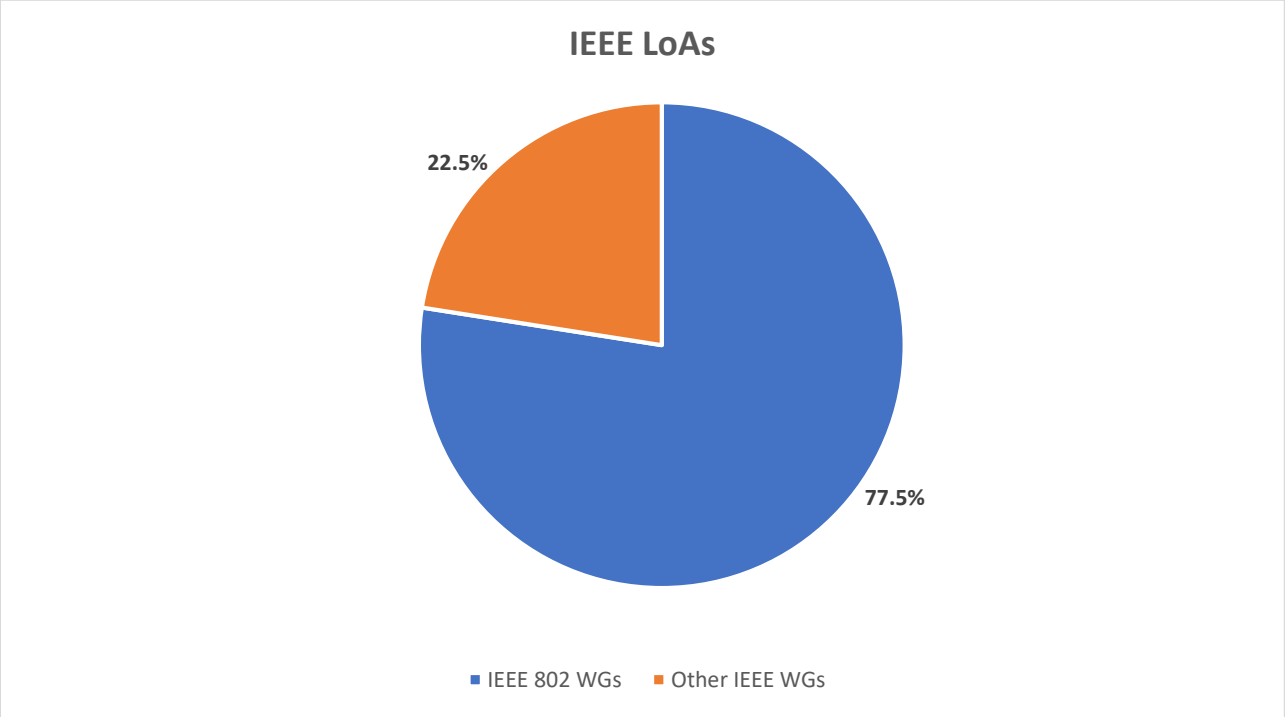

Figure 2: LoA shares of IEEE 802 WGs and the other IEEE WGs (1993-2017).

We now turn to the IEEE 802 LoA submissions. Figure 3 presents LoA shares across the currently active 802 WGs (see section 2 for the complete list of active 802 WGs). As shown, the 802.11 WG is the leader – it is responsible for 37.8% of submitted LoAs across the eight active IEEE 802 WGs.

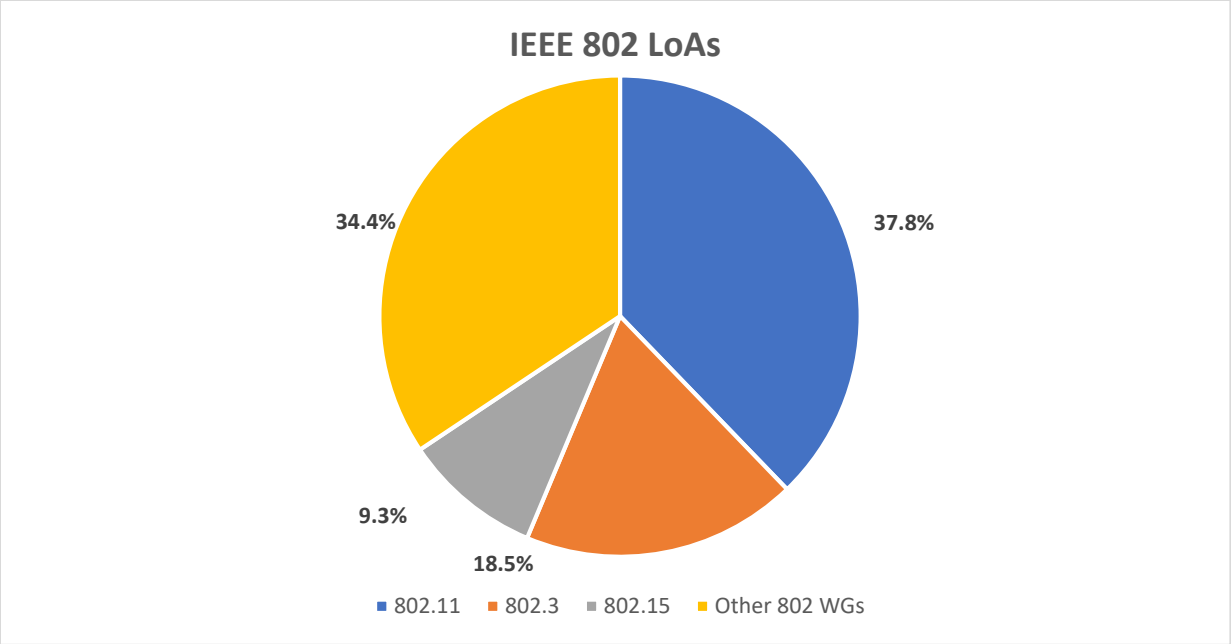

Figure 3: LoA shares of 802.11, 802.13, 802.15, and the remaining five active IEEE 802 WGs (1993-2017).

4. IEEE 802.11 LoA Analysis

4.1 LoA Methodology and Data

To implement the analysis, we have classified LoAs into different categories. Throughout the 802.11 LoA analysis, we will rely heavily on the definition of these different LoA types. We therefore begin with a short discussion of the essential differences between these types. The 80.11 LoA analysis is based on publicly available data on the website of IEEE. The source of data from IEEE is the database "IEEE-SA RECORDS OF IEEE STANDARDS-RELATED PATENT LETTERS OF ASSURANCE FOR IEEE STANDARD 802.11 AND AMENDMENTS".[20] In the analysis, we use LoA submission data, which covers the period 2005-2017. In the LoA dataset, there are few LoA submissions, which reference multiple standards. Accordingly, we count such submissions as multiple LoAs. For instance, on May 31, 2011, Samsung submitted a blanket LoA that references five different standards: 802.11-2007, 802.11n, 802.11c, 802.11ad, 802.11r. In our analysis, we treat that LoA submission as five LoA submissions.

4.1.1 Positive and negative LoAs

Broadly speaking, LoAs are classified as "positive" or "negative". In positive LoAs, the patent holder commits to license SEPs on the new FRAND terms. In negative LoAs, the patent holder declines to license

[20] http://standards.ieee.org/about/sasb/patcom/pat802_11.html.

under the current patent policy. The LoA classification depends on which box the LoA submitter checks in section D.1 of the LoA.[21] Specifically, D.1(b) is defined as positive LoA: "The submitter will make available a license for Essential Patent Claims under Reasonable Rates …", D.1(c) is defined as negative LoA: "The submitter is unwilling or unable to grant licenses according to the provisions…".[22] Below, we present examples of positive and negative 802.11 LoAs.

- **Positive LoA – Examples**
    - 802.11- 2007 patent - specific LoA submitted by Nokia (Jun-07)
    - 802.11ai blanket LoA submitted by Broadcom (Oct-15)
- **Negative LoA – Examples**
    - 802.11ax blanket LoA submitted by Ericsson (Sep-16)
    - 802.11z patent – specific LoA submitted by Nokia (Sep-17)

The next table gives information on the number of positive and negative LoAs over 2005-2017.

Year	All LoAs	Positive LoAs	Negative LoAs
2005	23	23	0
2006	36	36	0
2007	44	44	0
2008	18	18	0
2009	20	20	0
2010	15	14	1
2011	34	34	0
2012	10	10	0
2013	36	36	0
2014	43	43	0
2015	24	24	0
2016	10	3	7
2017	6	1	5

Table 3: Yearly count of positive and negative LoAs.

4.1.2 Duplicate and repeat LoAs

Next, we introduce two additional -- mutually exclusive -- LoA categories: "duplicate" and "repeat". We will use this classification in subsection 4.4.2 to assess how the update of the patent policy has affected the 802.11 LoA submission pattern. Duplicate LoAs are multiple LoA submissions for a certain standard by

[21] An LoA can be found here: https://development.standards.ieee.org/myproject/public/mytools/mob/loa.pdf.
[22] Note that the wording in the previous LoA format was different. It is beyond the scope of the paper to discuss whether these differences are significant from a legal perspective.

the same patent holder under the same policy. Repeat LoAs are LoA restatements filed -- under the new policy -- for standards for which a blanket LoA was accepted from the same patent holder under the old policy. We should point out that several submitted LoAs do not fall into either of these two categories. Duplicate submissions commonly arise because some companies have submitted multiple patent-specific LoAs under the same policy for the same standard.[23] Repeat submissions arise because in some cases a company has submitted two LoAs -- one before and one after the policy change -- for the same standard where the first LoA is blanket positive. Note that the definition of repeat does not specify the type of the second LoA submission: patent-specific or blanket. As shown later, there are cases of repeats where the second submission is blanket LoA and other cases where the second submission is patent-specific LoA.

In either case -- duplicate or repeat -- the respective LoA submission should not be considered as new. Consequently, when someone counts unique assurances to standards provided by each company, the duplicate and repeat submission (NOT the original submission) should be removed from the analysis. Next, a few examples of duplicate and repeat 802.11 LoAs are given. We also list an example of LoA that it is neither duplicate nor repeat.

- **Duplicate LoA – Examples**
    - 802.11 patent –specific positive LoA submitted by Thomson Licensing (Aug-14). Thomson Licensing had submitted patent – specific positive LoA for 802.11 (Jul- 14).
    - 802.11ad patent –specific negative LoA submitted by Nokia (Jun-17). Nokia had submitted patent – specific negative LoA for 802.11ad (Jan-16).
- **Repeat positive LoA – Examples**
    - 802.11ai blanket LoA submitted by Intel (Mar-15). Intel had submitted blanket positive LoA for 802.11ai before the policy change (May-13).
    - 802.11n blanket LoA submitted by Samsung (July-15). Samsung had submitted blanket positive LoA for 802.11n before the policy change (May-11).
- **Neither duplicate nor repeat LoA – Example**
    - 802.11ax blanket positive LoA submitted by KAIST (Mar-17). KAIST has not submitted any other LoA for this standard.

[23] Another example of a duplicate submission is when a company submits first a patent-specific LoA and next it submits a blanket LoA.

Hence, when we focus on counting unique LoA submissions (subsection 4.4.2), we will remove the following LoAs: 802.11 (Aug-14) from Thomson Licensing, 802.11ad (Jun-17) from Nokia, 802.11ai (Mar-15) from Intel, and 802.11n (July-15) from Samsung. Note that the corresponding original submissions associated with these four LoAs (e.g., 802.11n (May-11) LoA from Samsung) will be considered for the counting of *unique* LoA submissions. The next table gives information on the number of positive and negative LoAs over 2005-2017. [24]

Year	All LoAs	Duplicate	Repeat	No duplicate/no repeat LoA
2005	23	2	0	21
2006	36	8	0	28
2007	44	4	0	40
2008	18	3	0	15
2009	20	6	0	14
2010	15	5	0	10
2011	34	7	0	27
2012	10	1	0	9
2013	36	3	0	33
2014	37	8	0	29
2015	30	4	23	3
2016	10	0	0	10
2017	6	2	0	4

Table 3: Yearly count of duplicate, repeat, no duplicate/ no repeat LoAs.

4.2 Distribution of LoA submitters

We start by presenting our results for the distribution of 802.11 LoA submitters. The next figure plots the LoA shares for a set of companies, which have publicly stated their concerns/opposition about the recent amendments to the IEEE-SA patent policy. These eight companies are: Nokia, Blackberry, Interdigital, Qualcomm, Panasonic, Orange, Ericsson, and Siemens. These companies, which have made significant contributions to the development of wireless technologies, are responsible for almost one third of 802.11 LoA submissions.

[24] Nokia is a company, which has submitted multiple (positive) patent-specific LoAs. Particularly, it has submitted 23 LoAs for the 802.11 standard. In subsection 4.4.2, where we count unique LoAs, all these LoAs are removed from the analysis, as the first LoA was submitted before 2005 and the subsequent 802.11 LoAs are duplicate.

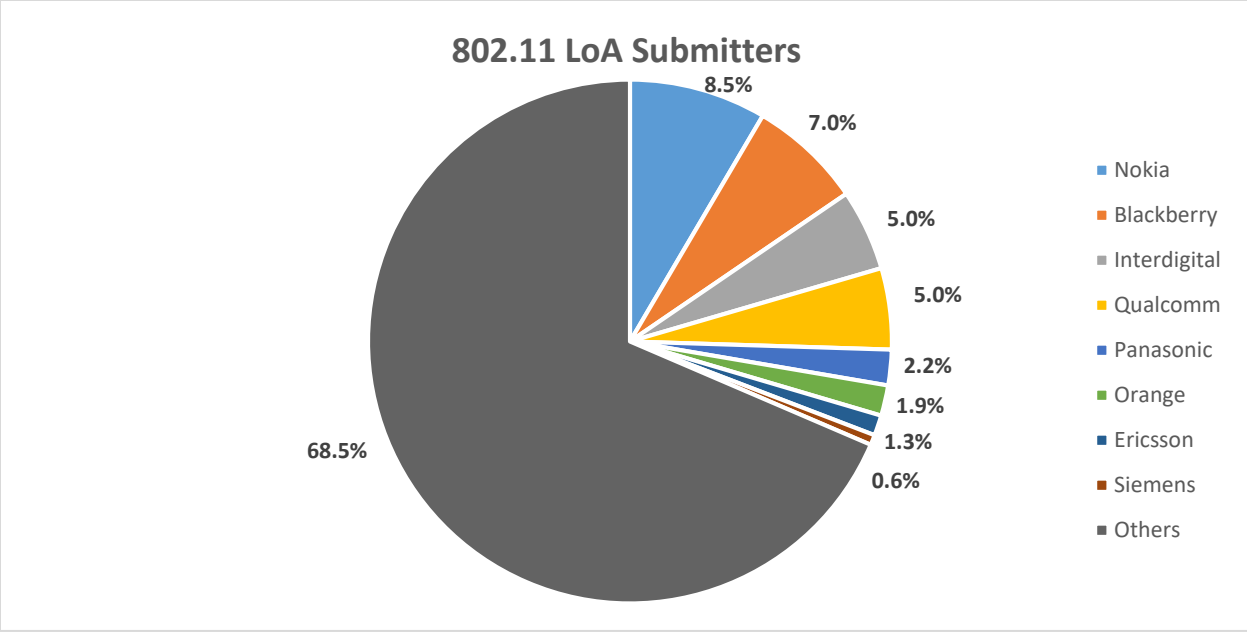

Figure 4: 802.11 LoA submission shares of companies, which have publicly opposed the new patent policy (1993-2017).

4.3 Patent-specific vs blanket LoAs

In this subsection, we show that the share of submitted patent-specific 802.11 LoAs has increased after the update of the patent policy. Recall that in a patent-specific LoA the submitter states its position with regards to certain patent numbers, whereas in a blanket LoA the submitter states its position with regards to any SEPs relevant for the standard at issue.

The next two graphs break down 802.11 LoA submissions by company and type of LoA: patent-specific vs blanket. Specifically, 27% of the 802.11 LoAs submitted before March 2015 were patent- specific. On the other hand, the share of patent-specific 802.11 LoAs after the policy update climbed to 38%. These statistics reveal that SEP holders' behavior has changed, as they are less willing to provide blanket patent declarations under the new patent policy rules. One interesting case is Samsung, which has submitted six LoAs during the period 2005-2015 and four LoAs after March 2015. Only one out of the six pre-March 2015 LoAs was patent-specific, while all post-March 2015 LoAs are patent-specific. What is even more interesting about Samsung's LoA submissions is that three LoA submissions before March 2015 and three LoA submissions after March 2015 reference the same standards: 802.11ac, 802.11ad, 802.11n; however, the pre-March 2015 LoAs are blanket, while the post-March 2015 submissions are patent-specific.[25]

[25] The number of patents being declared in the post- March submissions are (the corresponding standard in parenthesis): 1(802.11ac), 1(802.11ad), 6(802.11n).

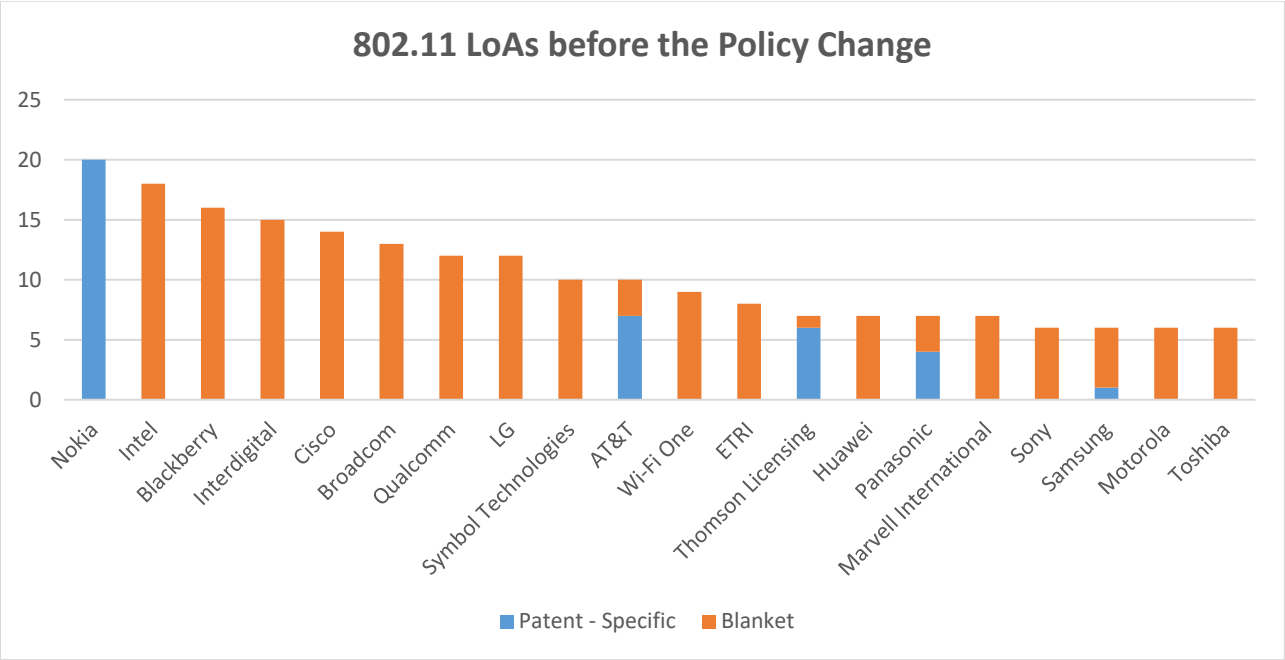

Figure 5: 802.11 LoA submissions by company broken down as follows: patent-specific vs blanket (2005 - 2015). The above histogram includes the top-20 802.11 LoA submitters.

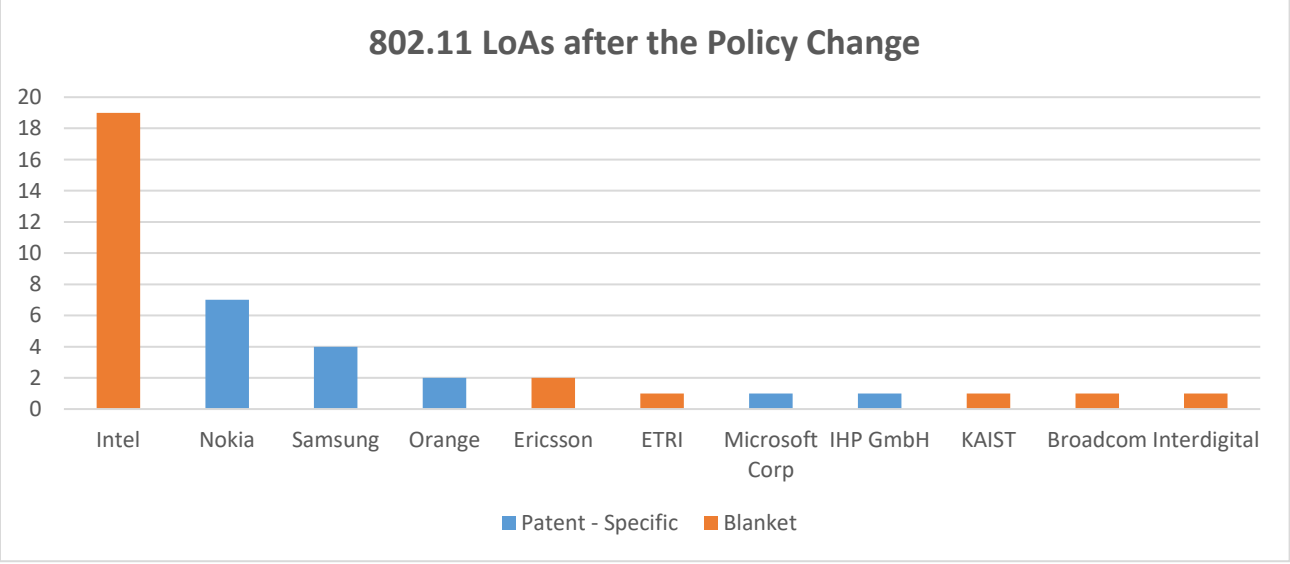

Figure 6: 802.11 LoA submissions by company broken down as follows: patent- specific vs blanket (2015 - 2017).

4.4 Temporal Analysis of LoA Submissions

The objective of this subjection is to assess the effect of the new IEEE-SA policy on 802.11 LoA submissions over time. We begin by examining how the number of submitted 802.11 LoAs (positive + negative) has evolved over the period 2005-2017. Next, we move forward to the analysis of positive and negative LoA submissions after removing duplicate and repeat LoAs.

4.4.1 Cumulative Count of LoAs

Figure 7 displays the quarterly count of all 802.11 LoAs during the period 2005 – 2017. The chart below shows a spike of all 802.11 LoA submissions shortly after the adoption of the new policy by IEEE-SA. The number of submitted LoAs in the second quarter of 2015 increased by 200% (compared to the first quarter of 2015). However, as shown later, this steep increase should be attributed only to repeat positive LoAs. Recall that these LoAs refer to restatements for standards for which a blanket LoA had been already accepted under the old policy. Furthermore, our analysis reveals that multiple LoAs submitted during 2016-2017 are negative, that is, the LoA submitters are unwilling to license on the new terms and conditions.

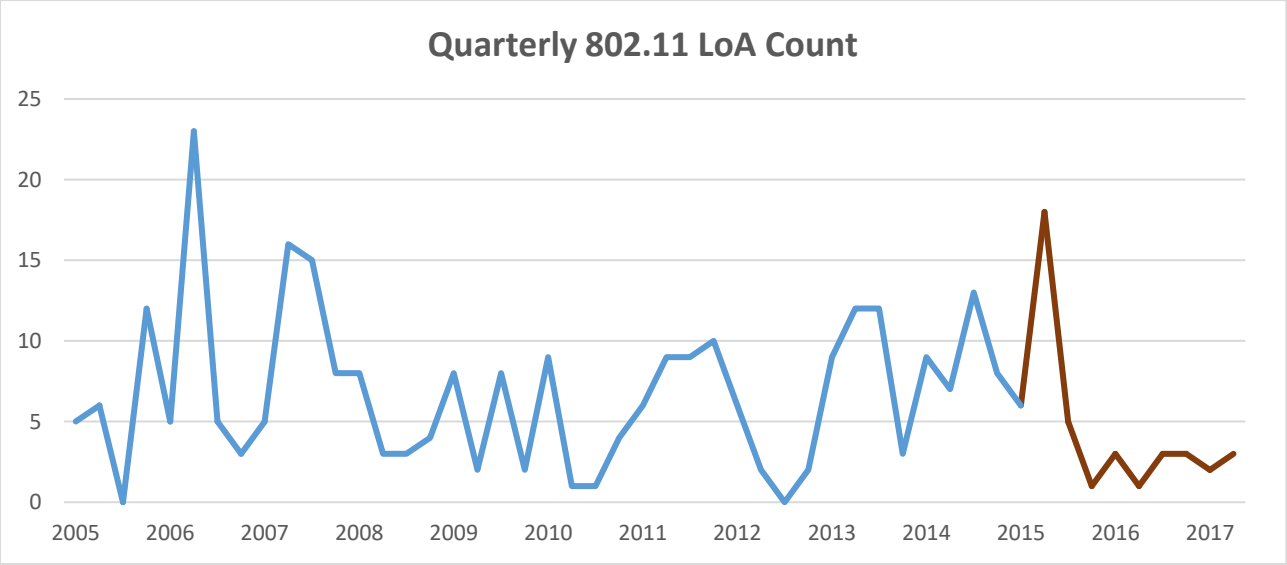

Figure 7: Quarterly count of 802.11 LoAs (2005-2017). The blue line reports the quarterly count under the old policy; the brown line gives the quarterly count under the new policy. To identify the effect of the new policy, the first quarter of 2015 is assumed to last until 14th of March 2015.

Our aim is first to show that gross counting of LoAs severely overestimates the number of new positive LoAs. We have created three quarterly time-series below that plots the value of three different variables after the policy update: total count of LoAs, count of repeat positive LoAs, and count of negative LoAs.

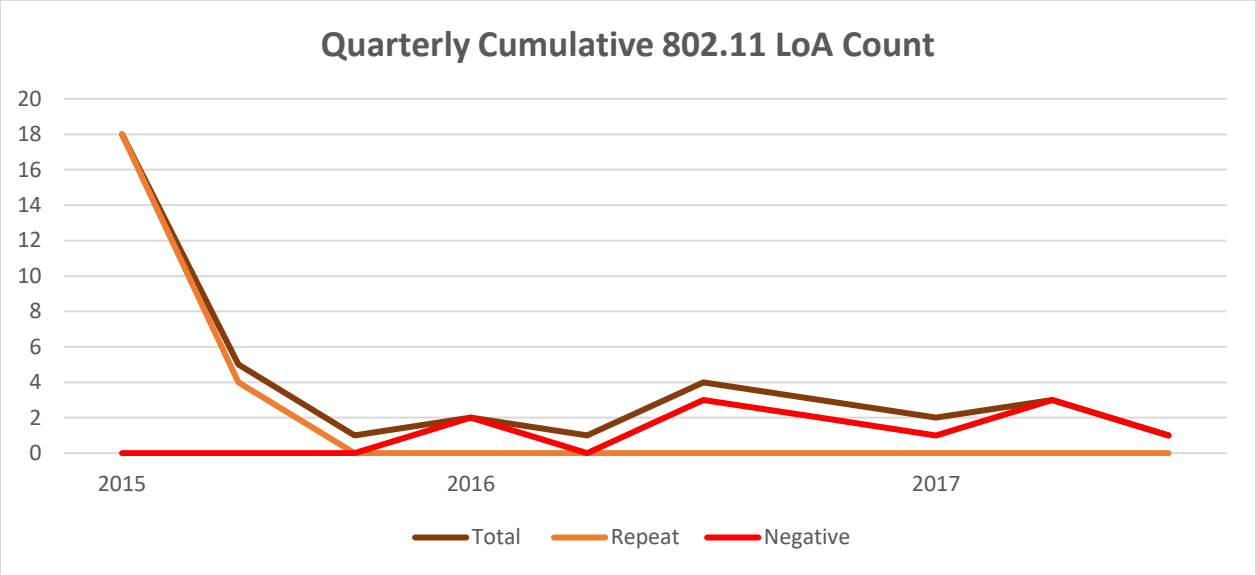

Figure 8: Quarterly count of submitted 802.11 LoAs after the policy update. The brown line reports the total count of submitted 802.11 LoA submissions. The red line reports the count of negative LoAs. The orange line reports the count of repeat positive 802.11 LoAs. To identify the effect of the new policy, the first quarter of 2015 is assumed to last until 14th of March 2015.

We find a considerable and significant share (85%) of the submitted 802.11 LoAs to be either repeat or negative. For instance, all eighteen LoAs submitted during the period 15 March-30 June are repeats, that is, these LoAs are NOT *new* submissions. In fact, these repeat LoAs were submitted by the same company: Intel. Similarly, three LoAs submitted by Samsung and one LoA submitted by Intel in July 2015 are repeats. Last but not least, twelve 802.11 LoAs are negative. In summary, forty LoAs were submitted after March 2015: only seven LoAs are *new* positive LoA submissions. In the Appendix, we provide a list of all 802.11 LoAs submitted after the policy update and identify whether they are repeat positive or negative.

4.4.2. Count of positive and negative LoAs

To assess the effect of the new policy on LoA submissions, a proper LoA counting approach should: i) distinguish between positive and negative LoAs, ii) remove repeat LoAs as well as duplicate LoAs. The next Figure plots the count of positive and negative LoAs after having removed repeat positive and duplicate LoAs.

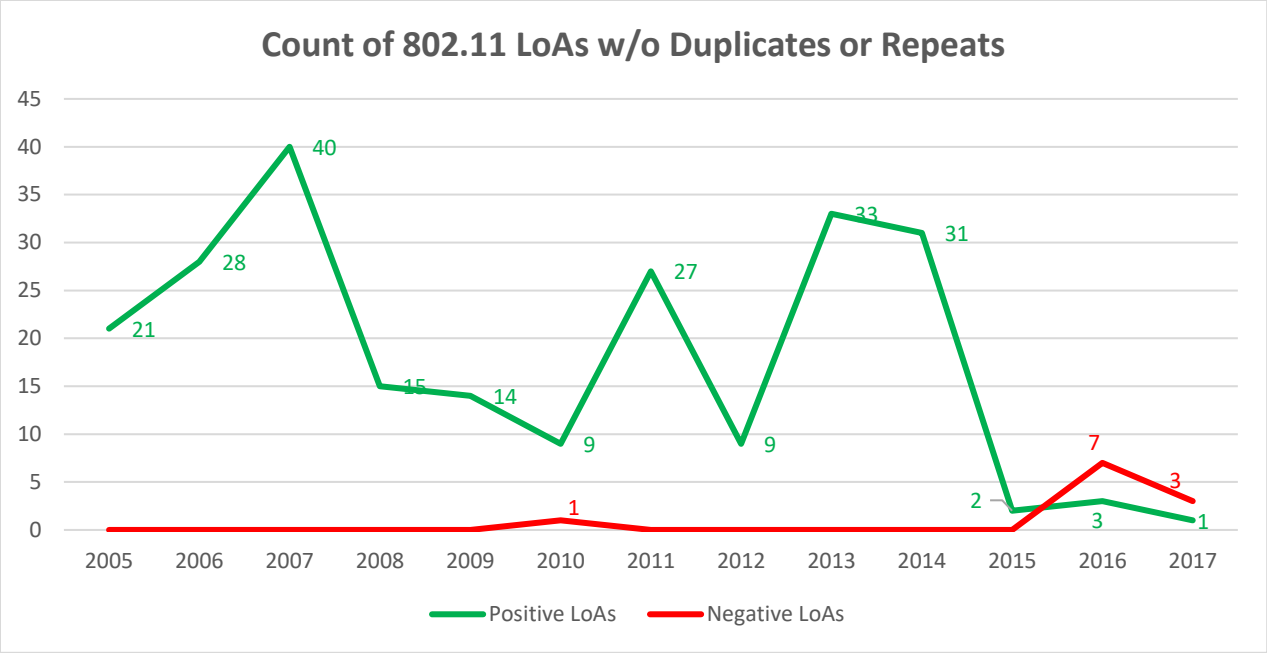

Figure 9: Yearly count of submitted 802.11 LoAs after the policy update. The green line reports the count of positive LoAs w/o duplicates and repeats. The red line reports the count of negative LoAs w/o duplicates. To identify the effect of the new policy, the period 1st of January - 14th of March 2015 is part of 2014. [26]

The results are indicative of the significantly negative impact of the new policy on the submission of *new* positive LoAs. The striking feature of these results is that the average yearly count of *new* positive LoA submissions has dropped by 91%. Our result is almost identical to the result of Katznelson (2016). However, in contrast to Katznelson, we do not net out negative LoAs to derive this figure. If we follow the same approach as his, then the negative effect would be 100%. More specifically, the number of negative LoAs is larger than the number of new positive LoAs after the policy update, which results in an average number of *new* LoAs less than zero. In view of this comparative analysis, we can argue that the effect of the new policy on 802.11 LoA submissions is more profound than the remaining IEEE (802) WGs. Regarding negative LoAs, the analysis establishes that there is a substantial upward trend in the submission of such letters after the implementation of the new policy. Our calculations reveal that the number of negative submissions hit a historic high in 2016; seven negative LoAs.[27]

5. IEEE 802.11 CRP Analysis

[26] This assumption is rather innocuous as only two positive LoAs – after removing duplicates—have been submitted during this period. Hence, the assumption neither overestimates the LoA count in 2014 not underestimates the LoA count in 2015.
[27] In the previous subsection we stated that the number of submitted negative LoAs post-March 2015 is 12. However, when we count negative LoAs w/o duplicates the number reduces to 10, as there are two duplicate negative LoAs after March 2015. Orange has submitted two negative LoAs for 802.11n. Similarly, Nokia has submitted two negative LoAs for 802.1ad. In both cases, the second submission is considered as duplicate.

As explained in section 2, once a PAR is approved, the 802.11 WG assigns the underlying project to one of its (newly formed) TGs. The draft standard is generated by combining a large number of contributions submitted by the corresponding TG participants. After ensuring (e.g., internal review) that the draft is ready for balloting, the TG sends it to 802.11 members for balloting. The 802.11 balloting process consists of two types of ballots: i) ballot for approval of the draft standard, ii) recirculation ballot(s), which constitute the 802.11 CRP.

The first step in the WG balloting process is the approval of the draft standard. The 802.11 voters have three choices: “Approve”, “Disapprove”, and “Abstain”. For the ballot to be valid, the “Abstain” rate must be less than 30%. The minimum return rate for 802.11 ballots to be considered valid is 75%.[28] The ballot for approval of the draft is successful if and only if more than 75 % of the “Approve” and “Disapprove” votes bear an “Approve" vote. In addition, “Disapprove” voters should provide an explanation for their choice and attach specific comments on what must be done to change their vote to "Approve".

Upon approval of the draft, the so-called CRP (at WG level) commences. The 802.11 CRP can be briefly summarized as follows. Once the proposed draft has achieved 75% approval (possibly after more than one ballot), TG participants should respond to the comments raised by the “Negative” voters. TG participants should try to resolve the negative comments and accordingly incorporate the changes into the draft of the standard. The proposed changes –based on the negative votes – are brought to the 802.11 WG for an approval– known as “recirculation ballot”. The above process is iterative, as more than one recirculation ballot may be required for the successful resolution of the “Negative” comments. It should be pointed out that the scope of these recirculation ballots includes only resolution of comments and not revision of the draft. They have the same voting scheme and rules as the corresponding WG ballots. It is at the discretion of the WG how many recirculation ballots should be held. Below, we give a summary of the entire 802.11 balloting process for the 802.11ah standard. As can been seen, the first ballot for approval of the draft was not successful, as the approval rate was less than 75%. The draft of the standard was approved on the second ballot followed by four recirculation ballots.

Date	Ballot Type	Outcome
Oct-13	Approval of the draft	Draft standard was not approved, approval rate = 73%
Jun-14	Approval of the draft	Draft standard was approved, approval rate = 83%
Oct-14	Recirculation ballot	Recirculation ballot, approval rate = 90%
Feb-15	Recirculation ballot	Recirculation ballot, approval rate = 90%
Apr-15	Recirculation ballot	Recirculation ballot, approval rate = 93%
Sep-15	Recirculation ballot	Recirculation ballot, approval rate = 98%

[28] Note that the requirement for the return rate is not identical across all IEEE 802 WGs. For instance, the 802.22 WG has set the minimum level requirement to 75%.

Table 4: Balloting process at 802.11 level for the 802.11ai standard.

In this article, we focus on the duration of the first two comment resolution rounds. Ideally, we would compare the average duration of entire CRPs initiated/completed *before* the policy change to its counterpart of entire CRPs initiated/completed *after* the policy change. However, only one CRP falls into the second category and thus it is not possible to make a proper statistical inference. Furthermore, a gross comparison of all resolution rounds before March 2015 to all resolution rounds after March 2015 would not be robust, as most of the post-March 2015 rounds are late (e.g., 3rd round) and thus such an analysis would lead to an underestimation of the CRP duration of these rounds.

Before we proceed, we should introduce some notation that will be used throughout the rest of this section. For each standard/project, we calculate: the duration of resolution round 1 (DR1) and the duration of resolution round 2 (DRR2). In mathematical notation, we have

- **DRR1**= # of days between closing date of successful ballot for draft standard approval and opening date of first recirculation ballot.
- **DRR2**= # of days between closing date of first recirculation ballot and opening date of second recirculation ballot.

Our dataset for the CRP analysis spans the period 2010 – 2017.[29] There are eight 802.11 standards for which the first two rounds of the CRP were initiated and completed before March 2015: 802.11aa-2012, 802.11ad-2012, 802.11ac-2013, 802.11ae-2013, 802.11af-2013, 802.11-2016, 802.11ai-2016, 802.11ah-2016. On the other hand, there are three 802.11 standards for which the first two rounds of the CRP were initiated and completed after March 2015: 802.11aj,802.11ak,802.11aq. The next two tables display the value of the variables DRR1 and DRR2 for these eleven standards.

Standard	DRR1	DRR2	Aggregate Duration
802.11aa	136	63	199
802.11ad	148	42	190
802.11af	158	53	211
802.11ae	99	52	151
802.11ac	107	114	221
802.11mc	215	223	438
802.11ah	97	97	194
802.11ai	145	118	263

Table 5: Duration of the first two comment resolution rounds before March 2015.

Standard	DRR1	DRR2	Aggregate Duration

[29] http://www.ieee802.org/11/LetterBallots.shtml

802.11ak	294	286	580
802.11aj	147	46	193
802.11aq	151	74	225

Table 6: Duration of the first two comment resolution rounds after March 2015.

The figures reported in tables 5 and 6 highlight the fact that the 802.11 CRP lasts longer after the change of the patent policy. The average aggregate duration of the first two comment resolution rounds has increased from 233 days to 332 days (42.5% increase**)**. Specifically, i) the average duration of the first comment resolution round has increased from 138 days to 197 days (42.9% increase**)**, ii) the average duration of the second comment resolution round has increased from 95 days to 135 days (42.1% increase**)**.

IEEE 802 PAR Analysis

The submission of a PAR is the first step in initiating a standards development project. A PAR is a legal document that specifies the (technical) requirements as well as goal of the project, and an approximate number of WG members, who will work on this project. Every 802 PAR that is submitted to the NesCom and IEEE–SB for review and approval, respectively, is "sponsored" by the 802 LMSC EC. The role of the 802 LMSC EC (i.e., the Sponsor) is to supervise and take responsibility for the scope and content of a proposed standard.[30] Usually, 802 LMSC EC forms a Study Group (SG) to examine the new idea, technical feasibility and eventually draft the PAR. A SG may operate under an existing 802 WG or under the 802 LMSC EC depending on whether the new suggested work falls within the scope of any active 802 WG. SGs are expected to last for a limited period of time (~ 6 months), and must be authorized to continue at each plenary session if they have not accomplished their work.

Officially, a standards project does not exist until a PAR is approved. The PAR's date of approval also starts the clock running on the standards project. According to IEEE-SA rules, the first draft of a standard should be created (not necessarily approved) within four years after the PAR approval.[31] If by the end of the fourth year, the WG needs extra time to revise/improve the draft, the 802 LMSC EC should request an extension of time to finalize the project. It is thus very common to have PARs, which request the extension or revision of existing previously approved new PARs. According to IEEE-SA rules, the maximum allowed duration between the approval of a *new* PAR (i.e., not extension or revision of existing PAR) and the approval of a standard by the 802 LMSC EC is eight years.

The 2016 IPlytics study claims that the approval rate of new PARs is rather strong after the recent amendments to the patent policy. According to this study, the number of approved PARs reached a

[30] Other examples of Sponsors in IEEE are Technical Societies such as Antennas and Propagation Society, Computer Society. Also, the IEEE-SASB can serve as a Sponsor.
[31] https://standards.ieee.org/develop/par.html.

maximum historical level in 2016, which can be potentially interpreted as a sign of positive impact of the new policy on the standards development. However, one may argue that the estimated increase in the number of approved PARs comes from projects that do not embody patented inventions. The IEEE-SA consists of hundreds of WGs whose function is merely to develop standards of little or even none IP value that just enable interoperability between systems and/or devices.

In this paper, we investigate whether the number of 802 PARs has changed after the update of the new policy. We restrict our attention to 802 WGs, as they have produced an overwhelming majority of SEP-intensive IEEE standards. As discussed in section 3, almost 80% of submitted LoAs reference IEEE 802 standards. Thus, any attempt to assess whether the new policy has an impact (if any) on the initiation of new projects should in principle focus on the 802 projects, which are obviously associated with significant IP value and not just compatibility and interoperability.

In the statistical analysis below, we use "Under Consideration" PAR data of 802 WGs. The data is provided by the IEEE LMSC on its website.[32] Similarly with the IPlytics study, we look at *new* PARs, i.e., not revision or extension of previously approved PARs. The data spans the period 2009 to present. In total, there are 148 PARs under consideration from 2009 through 2017.

The histogram below gives the annual count of 802 PARs under consideration. On an annual basis, the average count of 802 PARs before 2015 is16.7, whereas the average count of 802 PARs after March 2015 is 16. These figures imply that the average count has dropped by 4.2% after the policy update. In fact, if we restrict out attention to the period 2012-2017, the decline is even higher. Specifically, the annual average count of 802 PARs during 2012-2014 is 16, which translates to a 16% decline after 2015.

[32] http://www.ieee802.org/PARs.shtml.

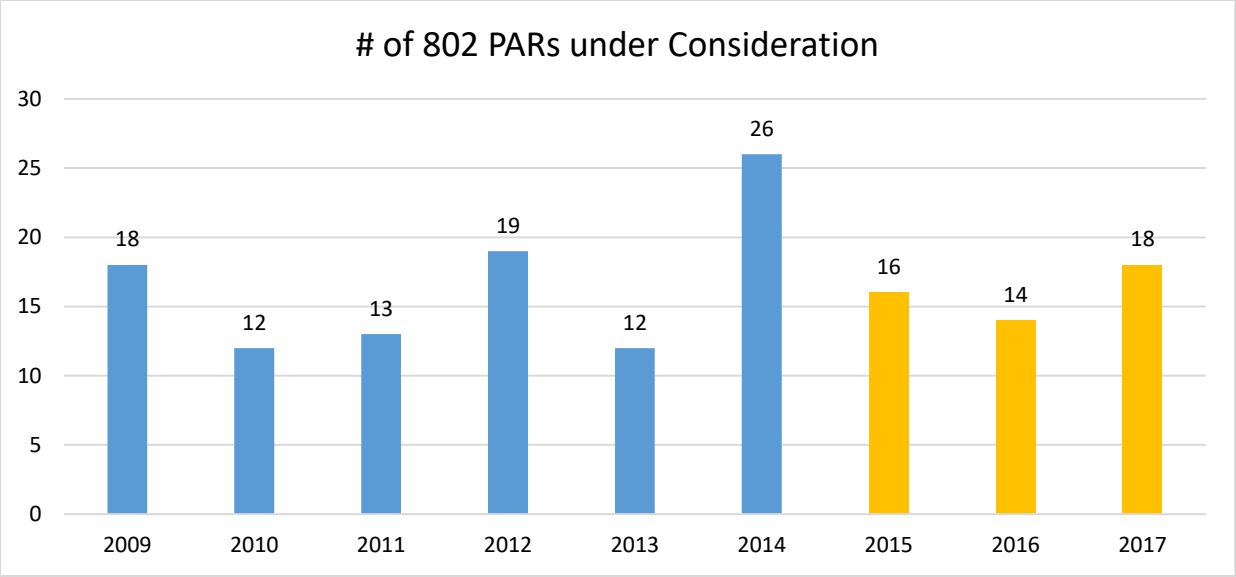

Figure 10: Yearly count of 802 PARs (2009-2013). The blue columns report the count of 802 PARs before the policy update. The yellow columns report the count of 802 PARs after the policy update.

6. Conclusions

The IEEE-SA, one of the world's leading technology standards-setting organizations, significantly amended its patent policy in 2015. IEEE's revised patent policy includes the following four provisions: (1) prevent patent owners from seeking an injunction until after an affirmative appellate decision; (2) royalty calculations should be based on the value of the "relevant functionality of the smallest saleable compliant implementation that practices the essential patent claim."; (3) prohibit reference to existing licenses -- obtained under the explicit or implicit threat of injunction -- in determining a reasonable rate; and (4) exclude any value resulting from a patent's inclusion in the standard.

Since the new patent policy became effective, there has been a tremendous interest from industry practitioners, and academic scholars in whether any aspects of the IEEE standards process have changed after the update of the patent policy. The literature provides mixed evidence, with some studies finding support for the suggestion that the new policy has a negative impact on the standards development process (Katznelson (2016)), and others finding the opposite (IPlytics (2016)).

In this paper, we unpack the discrepancy between the two empirical studies, and enhance the analysis by exploring the impact on the balloting process as well as new initiated projects. In the first part of the analysis, we show that the new patent policy has a significant effect on LoA submissions for the commercially popular 802.11 standards (Wi-Fi standards). The results suggest that multiple SEP owners are not willing to license under the new terms: the number of new positive LoA submissions has decreased by 91%, while the number of negative LoA submissions has dramatically increased by hitting a historic

high in 2016. Such unwillingness from SEP holders can have a potential adverse impact on the standards development process. The uncertainty on the SEP implementers' side will increase, as it will not be clear to them whether the SEPs at issue should be licensed under the new or old policy. As a consequence, the licensing negotiations between SEP holders and implementers will be distorted resulting in a highly inefficient negotiation process. The second part of the analysis demonstrates that the average aggregate duration of the first two comment resolution rounds during the 802.11 balloting process has increased by around 43% -- from 233 days to 332 days. The implication of this result is that the balloting process has become longer and therefore there is a substantial delay in the approval of 802.11 standards. Finally, we show that the new patent policy does not have any positive influence so far on the initiation of new IEEE projects. In contrast to the IPlytics study, we restrict our attention to IP- intensive projects, as only these projects will be *possibly* affected (either positively or negatively) by the patent policy amendments.

Designing IPR policies that achieve their goal, that is, to strike a proper balance between the rights of innovators and implementers, is a necessary requirement for an SDO to be successful. There is a need to identify how all SDO participants -- upstream and downstream -- are incentivized to actively participate in the development of standards. A properly designed IPR policy should enhance incentives of technology contributors to innovate, while ensuring unlimited access to the new technology standards. It is in the economic interest of all SDO participants that the underlying IPR policy will lead to significant gains in consumer welfare, in the form of higher quality products and services as well as more consumer choices.

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Appendix

In this Appendix, we list all 802.11 LoAs submitted after the update of the patent policy. We also provide the corresponding links on the IEEE website. The highlighted in orange LoAs are repeat, whereas the highlighted in red LoAs are negative. Recall that when we count unique LoA submissions (subsection 4.4.2), we remove repeats and duplicates. In the list below, the only duplicate LoAs are the following: the 802.11ad LoA submitted by Nokia (Jun-17) and the 802.11n LoA submitted by Orange (May-17). [33]

Std No.	Patent Owner	LoA Type	Letter date	Letter_link
802.11 - 2012	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11-intel-27Mar2015.pdf
802.11	Intel	Blanket positive	6-Jul-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11-intel-06Jul2015.pdf
802.11k	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11k-intel-27Mar2015.pdf
802.11n	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11n-intel-27Mar2015.pdf
802.11n - 2009	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11n-2009-intel-27Mar2015.pdf
802.11n	Samsung	Patent - specific positive	15-Jul-15	https://standards.ieee.org/about/sasb/patcom/loa-802_11n-samsung-15July2015.pdf
802.11n	Nokia	Patent - specific negative	18-Mar-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11n-nokia-18Mar2016.pdf
802.11n	Orange	Patent - specific negative	19-May-17	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11n-orange-part1-19May2017.pdf
802.11n	Orange	Patent - specific negative	19-May-17	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11n-orange-part2-19May2017.pdf
802.11r	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11r-intel-27Mar2015.pdf
802.11s	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11s-intel-27Mar2015.pdf
802.11u	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11u-intel-27Mar2015.pdf
802.11v	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11v-intel-27Mar2015.pdf
802.11w	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11w-intel-27Mar2015.pdf
802.11y	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11y-intel-27Mar2015.pdf
802.11z	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11z-intel-27Mar2015.pdf

[33] Recall that, by definition, repeat LoAs are post-March 2015 LoAs. On the other hand, the vast majority of duplicate LoAs have been submitted before March 2015. There are only two duplicates LoAs after March 2015: the negative 802.11ad LoA by Nokia and the negative 802.11n LoA by Orange.

802.11z	Nokia	Patent - specific negative	19-Sep-17	https://standards.ieee.org/about/sasb/patcom/neg-loa-802_11z-nokia-19Sep2017.pdf
802.11aa	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11aa-intel-27Mar2015.pdf
802.11ac	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11ac-intel-27Mar2015.pdf
802.11ac	Samsung	Patent - specific positive	15-Jul-15	https://standards.ieee.org/about/sasb/patcom/loa-802_11ac-samsung-15July2015.pdf
802.11ad	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11ad-intel-27Mar2015.pdf
802.11ad	Samsung	Patent - specific positive	15-Jul-15	https://standards.ieee.org/about/sasb/patcom/loa-802_11ad-samsung-15July2015.pdf
802.11ad	Nokia	Patent - specific negative	13-Jan-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ad-nokia-13Jan2016.pdf
802.11ad	Nokia	Patent - specific negative	20-Jun-17	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ad-nokia-20Jun2017.pdf
802.11af	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11af-intel-27Mar2015.pdf
802.11af	Samsung	Patent - specific positive	15-Jul-15	https://standards.ieee.org/about/sasb/patcom/loa-802_11af-samsung-15July2015.pdf
802.11af	Nokia	Patent - specific negative	13-Jan-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11af-nokia-13Jan2016.pdf
802.11ah	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11ah-intel-27Mar2015.pdf
802.11ah	Ericsson	Blanket negative	27-Sep-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ah-ericsson-27Sep2016.pdf
802.11ah	Nokia	Patent - specific negative	7-Oct-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ah-nokia-07Oct2016.pdf
802.11ai	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11ai-intel-27Mar2015.pdf
802.11ai	Broadcom	Blanket positive	29-Oct-15	https://standards.ieee.org/about/sasb/patcom/loa-802_11ai-broadcom-29Oct2015.pdf
802.11ai	Microsoft	Patent - specific positive	12-Apr-16	https://standards.ieee.org/about/sasb/patcom/loa-802_11ai-ms-12Apr2016.pdf
802.11ai	Nokia	Patent - specific negative	7-Oct-16	https://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ai-nokia-07Oct2016.pdf
802.11.2	Intel	Blanket positive	27-Mar-15	http://standards.ieee.org/about/sasb/patcom/loa-802_11_2-intel-27Mar2015.pdf
802.11ax	Interdigital	Blanket negative	15-Mar-17	http://standards.ieee.org/about/sasb/patcom/neg-loa-802_11ax-IPH-15Mar2017.pdf
802.11ax	Ericsson	Blanket negative	27-Sep-16	http://standards.ieee.org/about/sasb/patcom/negative-loa-802_11ax-ericsson-27Sep2016.pdf
802.11ax	ETRI	Blanket positive	23-Aug-16	http://standards.ieee.org/about/sasb/patcom/loa-802_11ax-etri-23Aug2016.pdf
802.11ax	KAIST	Blanket positive	3-Mar-17	http://standards.ieee.org/about/sasb/patcom/loa-802_11ax-KAIST-03Mar2017.pdf
802.11az	IHP GmbH	Patent - specific positive	10-Nov-16	http://standards.ieee.org/about/sasb/patcom/loa-802_11az-IHP-10Nov2016.pdf

Table A1: List of 802.11 LoAs submitted after 15 March 2015. Highlighted in red: negative LoAs; highlighted in orange: repeat positive LoAs.