SEP Royalties, Investment Incentives and Total Welfare

Prepared for

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION AND SUMMARY

The Fair Standards Alliance ("**FSA**") is an association that contributes to the debate around standard essential patents ("**SEPs**"). FSA advocates for an open and collaborative approach to the licensing of SEPs on a fair, reasonable and non-discriminatory basis ("**FRAND**"). FSA has informed us about concerns brought to their attention that lower SEP royalties might curb upstream incentives for investments in standards and have asked us to prepare an assessment evaluating the economic basis for such concerns. This report presents the assessment, focusing on smartphones and cellular as well as Wi-Fi standards as the main royalty bearing connectivity technologies.

We find that even if lower SEP royalties were to reduce investment by SEP holders upstream, total welfare is likely to increase. This is primarily because lower SEP royalties increase downstream R&D investment incentives. The current level of SEP royalties likely already exceeds the social optimal level, e.g., due to patent hold-up – an issue amplified by end-device licensing. Thus, the increase in welfare from more downstream innovation will likely outweigh any potential decrease from lower upstream innovation investment.

Section 1 of this report demonstrates that **downstream R&D spend in the smartphone sector is substantial and likely materially exceeds R&D spend by upstream SEP holders**. More specifically, we find that around 95% of the total smartphone related R&D is invested by the largest downstream innovators, while SEP holders account for around only 5% only. Using SEP royalties as an upper bound for upstream R&D spend, we find that the contribution of downstream innovators to the total R&D spend is around 80% – compared to only 20% for upstream SEP holders. This shows the importance of downstream investment and highlights that upstream investment must not be assessed in isolation.

We then explain in Section 2 that **SEP royalties are likely set at an inefficiently high level**. First, we clarify that there may exist a trade-off between higher SEP royalties and more upstream investment vs lower downstream investment. However, this trade-off only exists in a licensing environment where a sufficiently large share of SEP holders is not vertically integrated. For SEP holders that are vertically integrated, higher sales downstream imply additional investment incentives upstream (Section 2.1). To evaluate the current level of SEP royalties, we adopt an ex-ante valuation approach and conclude that patent hold-up and end-device level licensing may have contributed to royalty rates that exceed the social optimum (Sections 2.2 and Section 2.3). In particular, we find that end-device licensing likely amplifies the patent hold-up risk by increasing the imbalance in licensing negotiations between SEP holders and downstream innovators (SMEs). Behavioural biases when determining royalty rates based on the end-device value may further contribute to inflated royalty rates. Evaluating the academic literature, we then show that (i) there exists strong evidence that SEP royalties are inflated and (ii) SEP holders are likely engaging in socially wasteful conduct as a result of inflated SEP royalties (Section 2.4).

In the following Section 3 we show that **court enforced reductions in SEP royalty rates and policy shifts towards lower SEP royalty income have not necessarily resulted in lower innovation investments upstream**. In fact, we show that courts have slashed royalty rates for Wi-Fi SEPs requested by SEP holders by in some instances more than 90% in the past, yet contribution to developing new versions of the standard has remained high and if anything increased (Section 3.1). In a similar vein, empirical research studying the effect of policy shifts towards lower royalty income at best suggest mixed evidence for the effect on upstream innovation investment and contributions to developing new standards (Section 3.2).

Section 4 demonstrates how the emergence of the **Internet of Things ("IoT") will result in an increased royalty base in the future, fostering upstream innovation incentives.** We show that the contribution of IoT devices to the cellular royalty base will likely increase substantially in the years to come. Other things equal, this will increase incentives to innovate upstream, demonstrating that concerns about inefficiently low upstream innovation are largely unfounded.

1. UPSTREAM INVESTMENT MUST NOT BE ASSESSED IN ISOLATION – DOWNSTREAM INVESTMENT MATTERS

1. Both upstream and downstream innovations are important in the smartphone total value chain. The relative importance can be illustrated by comparing the respective R&D spend. A closer look reveals that much of the innovation in the value chain is done by downstream innovators, not by holders of SEPs upstream.

2. Downstream innovators' incentives to invest into the development of products implementing a standard depend on the level of (expected) SEP royalties. Inflated royalties can be expected to reduce downstream firms' incentives and ability to invest in product R&D and may even prevent firms from developing new products involving the standard in the first place. By demonstrating that technology contributions of downstream innovators likely far outweigh upstream contributions of SEP holders, we show that while SEP holders should receive a fair remuneration for upstream technologies, royalties must not be too high either.

A comparison of downstream and upstream R&D spend

3. A direct comparison of SEP holders' and downstream innovators' R&D spend for (technologies used in) smartphones would be ideal. However, SEP holders have extensive operations apart from R&D expenditure on technologies contributing to standards used by smartphones. Moreover, connectivity standards are also used for other products, including mobile network equipment and IoT products. Using SEP holders' total R&D spend would materially overestimate their contribution to smartphone-related SEP innovation. Similarly, some of the smartphone OEMs are also selling products other than smartphones. A precise comparison of R&D spend is therefore beyond the scope of our report. However, in the following paragraphs we develop an approach that allows us to derive insights on the order of magnitude of R&D spend upstream and downstream. Based on this, we can then make inferences with respect to the relative size of upstream versus downstream R&D spend.

4. We estimate upstream smartphone R&D by assuming that SEP holders allocate R&D spend to their business segments in proportion to their segments' revenues. The revenue from smartphone related upstream technology development is given by the upstream innovator's SEP royalties. We therefore estimate smartphone R&D spend as an SEP holder's total R&D times the estimated revenue share from smartphone SEP royalties relative to total revenue. Appendix A presents a more detailed discussion of the methodology. For smartphone OEMs we apply a similar approach and estimate

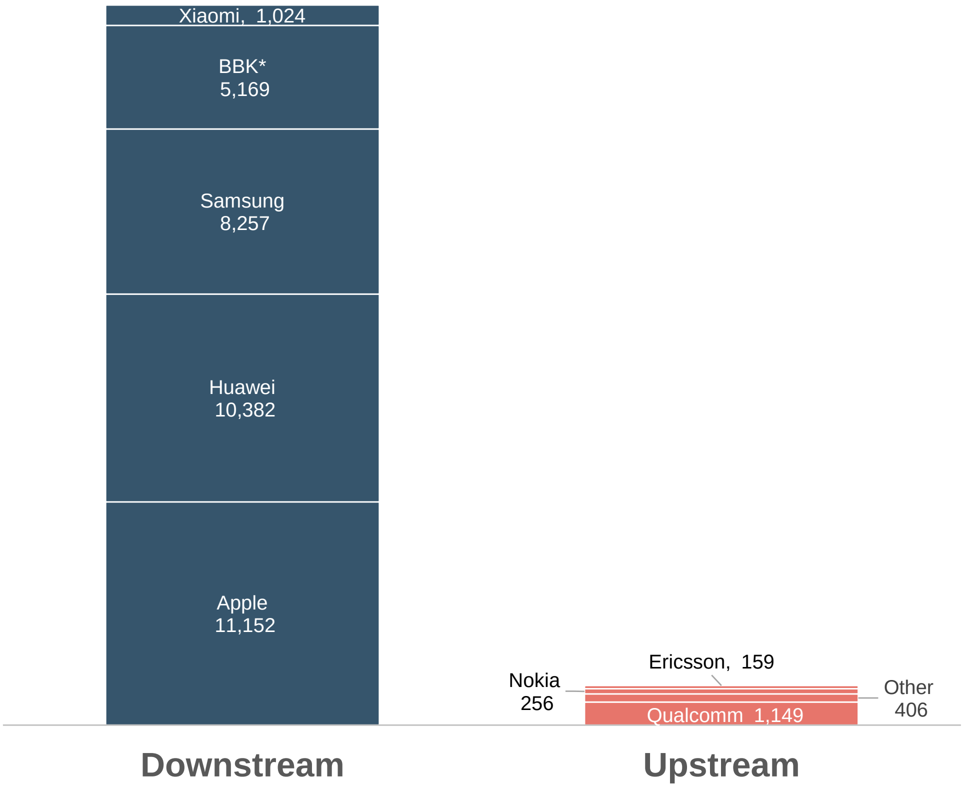
smartphone R&D by multiplying the total R&D by the revenue share accruing to smartphones.

5. Figure 1 below illustrates that downstream smartphone R&D exceeds upstream R&D by far: around 95% of the total smartphone related R&D of approximately $38bn are invested by the largest downstream innovators, while SEP holders account for around 5% only. The five largest smartphone OEMs in terms of 2020 shipment volume (Apple, Huawei, Samsung, BBK[1] and Xiaomi) account for a total smartphone R&D spend of about $36 billion in 2020. In contrast, the estimated smartphone-related upstream R&D spend of SEP holders in 2020 amounted, roughly, to only $2 billion. Upstream firms with the largest estimated smartphone R&D are Qualcomm ($1.1bn in 2020), Nokia ($256m) and Ericsson ($159m). Other upstream innovators[2] are estimated to have invested $406 million in smartphone related R&D.

1 BBK is the provider of Oppo, Vivo, Realme and OnePlus smartphone brands, and currently the largest manufacturer of smartphones.

2 See Appendix A for further details.

Figure 1: Upstream smartphone SEP related R&D vs. downstream R&D, 2020 (USD millions)



Source: CRA analysis of company financial statements and SEP licensing revenue data.

Note: R&D spend of downstream innovators apportioned based on revenues. To calculate R&D spend of upstream SEP holders we first identify a set of 14 licensees which have relevant R&D spend related to smartphone SEP development. We then collect data on total R&D spend and derive smartphone related R&D by multiplying with the SEP royalty share of total revenue. For a detailed explanation of the methodology see Appendix A. * BBK does not publicly disclose figures on R&D spend. BBK's smartphone R&D spend is imputed using the R&D spend of the remaining four OEMs and multiplying with the ratio of BBK total 2020 smartphone revenue over total smartphone revenue of the remaining four OEMs.

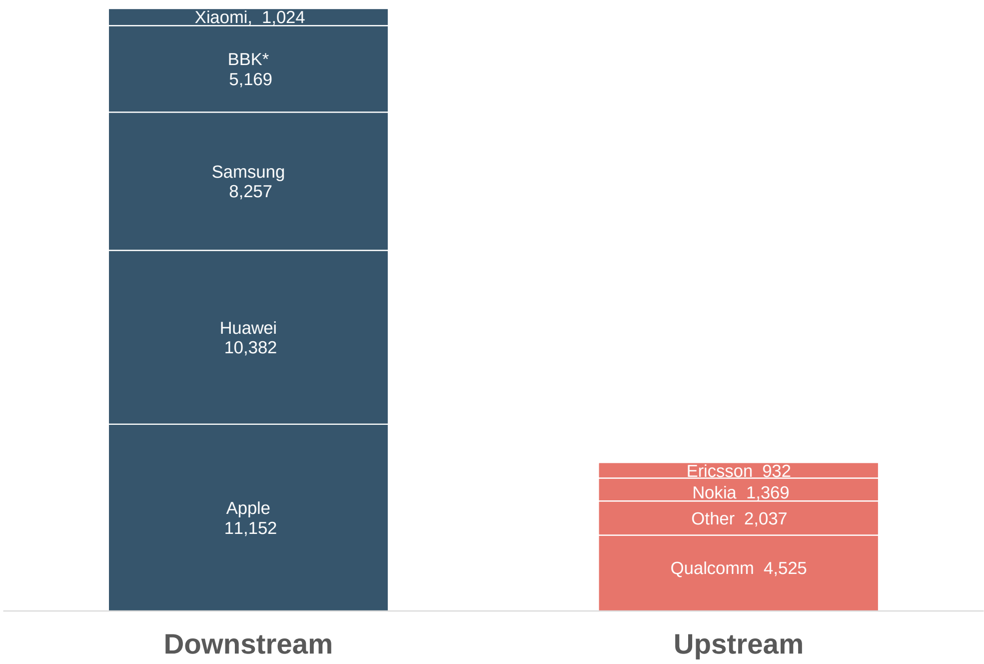
6. To ascertain the robustness of our analysis, we also compare upstream innovators' SEP royalties for smartphone sales with downstream smartphone R&D. SEP royalties can be considered an upper bound for the upstream R&D spend, because the latter is a cost position for IP holders when developing SEPs, and thus normally will not exceed the related revenues – namely, the SEP royalties.[3] A detailed description on how these licensing revenues are compiled can be found in Appendix A.

7. Figure 2 below compares SEP royalty revenues associated with smartphones in 2020 to the R&D spend of the five largest smartphone OEMs in terms of 2020 shipment volume. We find again that the estimated smartphone R&D spend of downstream innovators in 2020

3 Upstream innovators may invest into upstream R&D to obtain IP that is later cross-licensed or used for its own downstream business. As mentioned above, in upstream innovators already receive rewards in the form of cross-licenses or downstream profits, and the SEP royalties can be thought of as a compensation for a portion of the R&D spend that is recouped through licensing out.

materially exceeded the total SEP royalties paid in 2020. The global estimated R&D spend of downstream innovators for smartphones in 2020 amounts to around $36bn, compared to total SEP royalty payments of $8.86bn. The contribution of downstream innovators to the total R&D spend in 2020 is therefore around 80% - compared to only 20% for upstream SEP holders as measured by SEP licensing revenues. The R&D share accruing to these five downstream smartphone OEMs has further been steadily increasing over time, from 54% in 2014 and 61% in 2016 to ultimately 80% in 2020.

Figure 2: Upstream SEP licensing revenues for smartphones vs. downstream R&D, 2020 (USD millions)



Source: CRA analysis of company financial statements and SEP licensing revenue data.

Note: R&D spend of downstream innovators apportioned based on revenues. Upstream licensing revenue is based on the global smartphone SEP royalties of the main smartphone SEP licensors. See Appendix A for a detailed explanation. * BBK does not publicly disclose figures on R&D spend. BBK's smartphone R&D spend is imputed using the R&D spend of the remaining four OEMs and multiplying with the ratio of BBK total 2020 smartphone revenue over total smartphone revenue of the remaining four OEMs.

8. The smartphone R&D spend of downstream innovators likely exceeds the R&D spend of the relevant SEP holders by more than suggested by the assessment above.

- First, we have restricted the analysis to the five largest smartphone OEMs only. Industry wide R&D spend will likely be materially higher. The five largest smartphone OEMs shown account for around 92% of total smartphone revenues. Assuming R&D spend is in proportion to revenues, other smartphone OEMs might add up to around 9% to the downstream R&D spend as identified above.
- Second, for simplicity, the above Figure 2 only captures R&D of OEMs. However, most components in smartphones are procured from suppliers, who also invest into R&D. For the purpose of our assessment, OEMs' suppliers are also "downstream innovators" and hence their R&D in principle is equally relevant.

9. The estimated total SEP royalties exclude the value of cross licenses. Sidak (2016) estimated the implicit value of cross-licenses of large implementers, i.e., the licensing revenue that firms like Samsung, Huawei or Apple would have obtained had they not engaged in cross licensing deals but charged royalties to one another.[4] Sidak's estimates imply an additional $4 billion in non-cash value of cross licenses in 2013 and $3.7 billion in 2014 (roughly one percent of mobile phone sales in each year). Adding these to the estimated R&D spend would not materially change the overall picture.

10. Going forward, as mobile connectivity will be used much more widely in IoT devices and hence many new players will contribute to downstream R&D, it can be expected that the R&D contribution of downstream innovators will further increase compared to that of SEP holders. At the same time, a larger royalty base from IoT will also foster upstream innovation as royalty income and investment incentives increase. We expand on this in Section 4. In any event, we conclude that downstream innovation investment currently amounts to a multiple of upstream investment. The difference between downstream and upstream innovation will continue to persist and if anything, grow in the future. Therefore, the effect of royalty rates on downstream investment requires careful consideration when assessing socially optimal royalty levels.

2. ARE SEP ROYALTIES CURRENTLY AT AN INEFFICIENTLY HIGH LEVEL?

11. Other things equal, higher royalties incentivise upstream SEP holders to develop new technologies. At the same time, royalties are cost to downstream innovators and will curb downstream investment. From a social welfare perspective, SEP royalties should therefore be set at a level that strikes the right balance between incentivising upstream and downstream innovation. This section assesses whether royalties are likely set at socially optimal levels. In particular, we focus on how licensing at the end-device level (in contrast to e.g., component level licensing) may distort upstream and downstream investment incentives away from the social optimum.

12. In Section 2.1, we explain that inefficiently high royalties not only reduce downstream firms' incentives and ability to invest in product R&D but ultimately reduce overall welfare. A key underlying issue resulting in inflated royalty rates and underinvestment is patent hold-up (Section 2.2). Section 2.3 explains that end-device licensing amplifies the risk of inflated SEP royalties. This because the development of end-devices typically involves higher sunk expenditures which increases hold-up potential. More, end-device licensing often goes together with behavioural biases – such as royalties that appear small in relative terms are in fact substantial in absolute terms – that can lead to inflated SEP royalties. Finally in Section 2.4, we present evidence from the academic literature which suggests that SEP royalties may in fact currently be set at inefficiently high level from a social welfare perspective.

4 Sidak, 2016, "*What aggregate royalty do manufacturers of mobile phones pay to license standard-essential patents*?", The Criterion Journal on Innovation, Vol. 1, pp. 701-711.

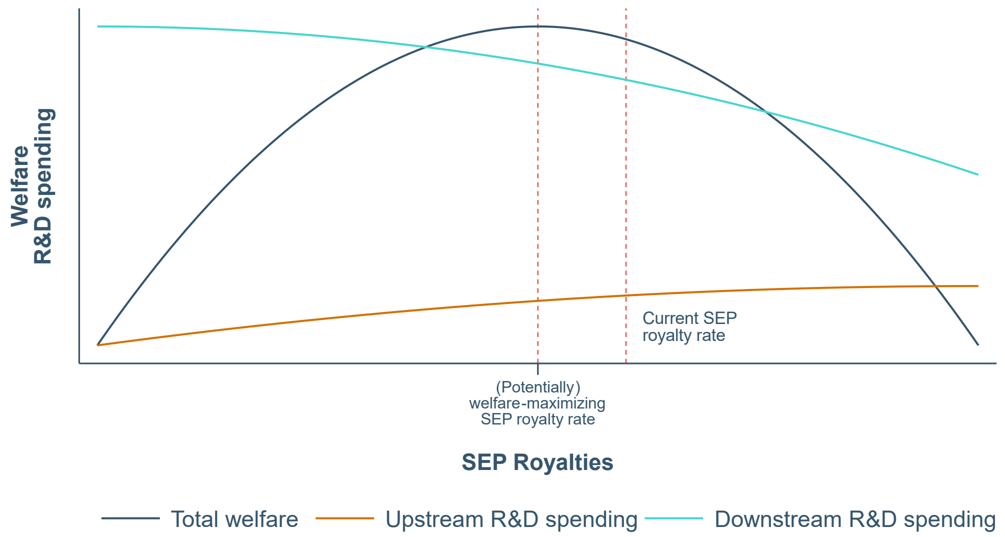
2.1. Socially optimal level of SEP royalties

13. To begin with, higher royalties do not automatically imply more innovation upstream. If SEP holders are vertically integrated, then higher SEP royalties increase cost and thus lead to lower sales downstream. In a similar vein, if SEP holders are vertically integrated, there exist additional incentives to innovate as innovation upstream will lead to higher sales downstream. Therefore, the trade-off between higher royalties and more innovation upstream v. less innovation downstream only exists for standards where a large share of SEP holders are not vertically integrated. Said differently: in industries where most SEP holders are vertically integrated, the welfare maximizing royalty level may well be zero. I.e., royalty free licensing may lead to the socially optimal investment levels upstream and downstream. In Section 3.2 below we introduce empirical studies evaluating the effect of policy shifts towards royalty free licensing. These studies confirm that in certain licensing environments, SEP royalties may be set at zero without distorting upstream innovation incentives.

14. However, even under the assumption that the trade-off does exist and that higher SEP royalties in fact do lead to increased innovation upstream, this effect has to be assessed together with the flip side of the coin: an increase in royalties to SEP holders at the same time means that the royalty burden of downstream innovators goes up. This will reduce the downstream innovators' incentives to invest. Since these effects go into opposite directions, which of these effects dominates depends, inter alia, on the level of royalties.[5] As can be seen in Figure 3, when the current SEP royalty rate is larger than the welfare-maximizing royalty level, a decrease in the royalty rate will reduce upstream R&D spend but also increase total welfare. Again, it is important to emphasise that Figure 3 assume that there exists a trade-off between upstream and downstream investment over the level of SEP royalties because a large share of upstream SEP holders are not vertically integrated. This is a strong assumption and in practice, lower royalties may always be preferrable for upstream investment incentives as explained above.

5 Layne-Farrar and Stark (2020) implicitly assume SEP-holders could be undercompensated if patent hold-up from an excessive royalty base would be reduced. However, this ignores the other side of the coin, namely that SEP royalties are typically associated with reduced downstream investments.

Figure 3: Conceptual illustration of royalty trade-off



Source: CRA.

15. In an ideal world, FRAND royalties could be set to maximise welfare by providing optimal incentives to innovate, both for "upstream" technologies that can be integrated into standards and "downstream" technologies integrated into the final products. Such analysis is complex, and results seem to depend on specific assumptions. Yet, several more general insights can guide this assessment.

16. Value from standard-implementing products typically results from complementary investments.[6] A well-known implication of complementary inputs is that the sum of the marginal contributions of all inputs exceeds the total value.[7] This principle holds for any form of complementary relationship between two inputs but is exacerbated in the case of perfect complements. Rewarding any one contributor with more than the full incremental value of its investment is not desirable because doing so will reduce the reward available to other contributors. The royalties therefore must be balanced to foster both innovations for the standard as well as complementary downstream innovations. The questions arises if current royalty levels strike this balance.

17. For an assessment of FRAND royalty levels, we need an appropriate economic framework. The outcome of a hypothetical negotiation that takes place at the time the SSO is selecting the standard provides a useful benchmark for FRAND royalties of SEPs. Put differently, a FRAND royalty should reflect what would happen as a result of well-informed *ex-ante* technology competition. The European Commission's Horizontal Guidelines also refer to

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6 For instance, for streaming videos on a smartphone amongst others, a video codec, a cellular / Wi-Fi standard as well as a display enabling sufficient resolution is required.

7 The joint value of standard-implementing features and other features of multi-component products is normally greater than the sum of the inputs' values in isolation. An implication is that the sum of the *marginal* contributions of complementary inputs is greater than the total product value. This principle can be illustrated using the example of a smartphone. A smartphone is not worth much without a display. Thus, the marginal contribution of the display almost amounts to the smartphone value. The same applies to a smartphones' battery. The sum of both complementary inputs' marginal contribution thus exceeds the smartphone value.

the *ex-ante* negotiation framework. The Guidelines suggest that royalty rates can be derived by comparing royalties charged "*before the industry has been locked into the standard (ex-ante) with those charged after the industry has been locked in (ex-post), assuming there is a reliable and consistent method for such a comparison*".[8]

18. The SEP holders' *ex-ante* incremental contribution to the product value seems an appropriate upper bound for the FRAND royalty, for three reasons:

- First, if SEP holders obtained more than their incremental contribution in a scenario of complementary inputs, downstream innovators will receive a smaller proportion of their incremental contribution, which may unduly suppress downstream innovation.
- Second, the *ex-ante* incremental value is relevant, as otherwise there would be a risk that upstream innovators are over-rewarded: the ex-post incremental value may exceed the *ex-ante* incremental value because technologies included in the standard in practice cannot be replaced by alternative technologies any longer after standardisation. Of course, from a welfare perspective it would be unreasonable to reward upstream innovators for the loss of competition from standardisation.
- Third, if inventions can be pursued by multiple firms, granting a patent to the first successful firm, and setting the patentee's reward equal to the social contribution associated with the invention (taking competing technologies into account) results in wasteful duplication of effort, and in *socially too strong* incentives to innovate. The lesson from the relevant research is that the reward should be strictly less than the social benefit of an invention in a conventional patent system in which the first firm to achieve the invention receives a reward in the form of exclusive rights.[9] This insight seems to be of particular importance for technologies integrated into standards, which are commonly protected by patents.[10]

8 European Commission, "Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements." 2011, para 289.

9 See Shapiro (2007), p.115-116. Intuitively, the R&D effort of each innovator imposes a negative externality on competitors working on a similar innovation, which each firm individually does not take into account.

10 In contrast, much of the downstream innovation is not patented and the rewards for innovations seem to accrue less often exclusively to firms that are first to discover certain innovations.

19. It follows that the royalty emerging in a hypothetical *ex-ante* negotiation can form a useful benchmark for assessing the SEP royalty levels.[11] The relationship between patent-hold up and inflated royalty rates directly follows from such ex-ante considerations.

2.2. Risk of patent hold-up

20. Patent hold-up in general refers to opportunistic behaviour by the patent holder when licensing negotiations take place ex-post, i.e., after downstream innovators (often also referred to as implementers) have sunk investments into products that use the patented technologies. In the context of standard-setting, patent hold-up also refers to the potentially abusive use of market power conferred to patent holders through standardisation which may result in inflated royalties ("hold-up premium").[12]

21. Baumol and Swanson (2005) pointed out long ago that "*standard-setting exercises normally arise only when there are technological alternatives to select among, and so, almost by definition, are likely to occur in competitive - perhaps very competitive - technology markets*. *Even when conditions are competitive before the selection of a standard, however, the act of selection may lead to increased ex-post market power for owners of the IP necessary to practice the winning standard"*.

22. Indeed, patents that are "essential" to a standard will often be infringed by products implementing the standard, as downstream innovators cannot substitute alternative technologies for the technologies included into the standard anymore. Once the standard is adopted and downstream innovators are "locked in", SEP holders are thus able to negotiate royalty rates higher than those that could have been achieved *ex-ante* when competing with alternative technologies.

2.3. End-device licensing might lead to inflated SEP royalties

23. In the following we assess the relationship between end-device licensing and the level of SEP royalties. First, we find that end-device licensing likely leads to inflated royalty rates as it fosters an imbalance in licensing negotiations to the detriment of potential licensees, increasing the likelihood of patent hold-up. Second, there are behavioural biases in place which may lead to higher royalty rates if the entire end-device value is used as royalty base.

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11 We expect that because of the complementarity of inputs, the IP holder would typically obtain a return of less than the incremental value of its technology in *ex-ante* negotiations. The level of the royalties would depend on the bargaining power of the parties. It has been argued that using an *ex-ante* hypothetical negotiations benchmark when the standard is determined only takes place after the SEP holder has invested in (and borne the risks of) research, development, and patenting of the innovation (e.g. Froeb and Shor (2015), Ganglmair et al. (2012)). Innovation costs are therefore treated as "sunk" in the hypothetical negotiations, but if the SEP holder enjoys a strong bargaining power, it nevertheless can be expected to obtain a high payoff, giving rise to strong incentives to invest into upstream innovations.
Ganglmair et al. (2012) find that if licensees could request courts to impose FRAND rates equalling on average the *ex-ante* negotiation outcome, this may curb incentives to invest into upstream innovations. However, this finding is driven by the artificial assumption that only the downstream innovator, not the SEP holder, can invoke the court to set FRAND rates. The paper also finds that if courts could not be invoked to determine FRAND rates, inefficient patent hold-up may occur, thereby justifying the importance of third-party FRAND setting in the first place.

12 See also Lemley and Shapiro (2007).

End-device licensing may increase patent hold-up and lead to inflated royalty rates

24. End-device licensing likely results in more unbalanced negotiations, primarily as it leads to more SMEs being involved in licensing negotiations with sophisticated SEP holders. This likely increases the degree of patent hold-up. Downstream device manufacturers might lack both the understanding of the FRAND licensing process and the resources to meet SEP holders on equal terms. In addition, they also might not have the necessary technical understanding of the technologies behind the standard needed to evaluate the validity of the SEP holder's licensing claim. For example, in contrast to their component suppliers, start-ups manufacturing smart meters reading on connectivity standards are not likely to have extensive knowledge of mobile wireless technologies (encapsulated in components procured from suppliers) and typically rely on sourcing components for which there are no associated unlicensed third-party IP rights.[13]

25. SMEs – and in particular start-ups - are likely to lack licensing experience, expertise, and resources to properly evaluate and challenge the demands of SEP holders. For this reason, they could be more intimidated by the possible consequences of patent infringement (e.g., facing an injunction) and thus be prone to simply accept non-FRAND royalty demands instead of engaging in further negotiations. Hence, end-device level licensing at the device level might increase the likelihood of patent-hold up. This holds especially for licensing in the IoT arena which has led to continuous entry of new start-ups that implement standardised technologies in their IoT devices.[14]

Potential behavioural biases of end-device licensing may inflate royalties

26. There is ample empirical evidence that cognitive biases may result in an unduly high royalty award if the royalty is only a very small share of the royalty base.[15] One bias, known as "anchoring", is the influence of reference points (or "anchors") on an individual's decision making. For example, the order in which an individual encounters different data points might have impact on the individual's interpretation of the data overall. The first data point with which the individual is confronted might serve as an anchor relative to which the individual will evaluate the remaining data points. Such kind of anchoring bias was found in several experimental studies involving mock juries about personal injury and punitive damage cases with plaintiffs that requests more damages tending to receive a larger award.[16] According to Lemley and Shapiro (2007), U.S. juries tend to award royalty rates that are within the general vicinity of 10 percent, regardless of the size of the base to which that rate is applied.[17] Studies have found anchoring biases also in judges.[18] Thus, there is a risk that royalty awards based on the entire value of the accused multi-component products will

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13 Geradin (2020), p. 17.

14 https://iot-analytics.com/iot-startup-landscape/

15 Cotter et al. (2018), p. 73 et seq.

16 See e.g. Chapman & Bornstein (1996), Hastie et al. (1999) and Campbell et al. (2016).

17 Lemley and Shapiro (2007), finding in a study of 58 patent verdicts awarded between 1982 and 2005 that "*[t]he royalty rate for components is approximately 10.0%, compared with 13.1% for all inventions and 14.7% for integrated product claims*" (85 *Texas Law Review* 1991, p. 2034).

18 See, e.g. Englich et al. (2006), Englich and Mussweiler (2001) and Wistrich et al. (2005).

systematically overvalue patent rights that cover just a fraction of the products' components or features.[19]

27. As we discuss in the following section, empirical findings suggest that SEP holders have been able to extract royalties exceeding the *ex-ante* incremental value of their patents already. In that case, although end-device level licensing might stimulate upstream innovation though higher royalty rates, the associated social benefits would be insufficient to offset the harm from reduced downstream innovation, higher prices and lower quality. A drop in downstream investments triggered by end-device licensing tends to have more severe adverse consequences on welfare, if even in the absence of end-device licensing, more downstream investments would be desirable from a consumer perspective. In the above we have explained that downstream innovations are often complementary, that is, one innovation will have a positive externality on the value of other complementary innovations. Under those circumstances, the level of innovations will generally remain below the socially optimal level. A further reduction in the level of downstream innovations because of SEP holders misappropriating returns from downstream innovators by means of end-device licensing will likely result in consumer harm. This is particularly true in the case of "high value" applications of the standard. Typically, such high value applications require extensive complementary downstream investments into R&D. The risk of SEP holders misappropriating the returns of such investments may undermine the commercial viability of investments into high value products

2.4. SEPs are subject to higher royalty demands than non-SEPs

28. After presenting the economic framework above, we show in the following that (i) there is strong evidence that current SEP royalty levels are inflated and (ii) inflated SEP royalty levels may have triggered SEP holders to engage in socially wasteful conduct.

29. A recent report published by the European Commission's Joint Research Centre finds that "*overall, the remuneration of SEPs – even when it is regulated by FRAND terms – appears to be attractive. Many SEPs are found to generate substantial economic revenues, e.g., through licensing (Stasik, 2010). Pohlmann and Blind (2015) find that firms owning SEPs achieve higher returns on assets than firms owning other patents. The highest returns on assets are achieved by firms owning a mix of declared SEPs and other, non-essential patents. Hussinger and Schwiebacher (2015) study the effect of patents on the market value of a firm's stocks, and find that the number of declared SEPs correlates with a firm's market value, also if controlling for the number of patents in general. These studies suggest that SEPs can generate higher economic returns for their owners than other patents".*[20]

30. One hypothesis for the higher value of SEPs could be that these are inherently more valuable. However, these findings could also indicate that SEP holders may have been able to extract royalties exceeding the *ex-ante* incremental value of their patents.

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19 For instance, the royalties awarded by the court in *In re Innovatio* amounted to 0.01% to 0.16% of the average device values. *In re Innovatio IP Ventures, LLC Patent Litig.*, MDL No. 2303, 2013 WL 5593609 (N.D. Ill. 10.03.2013).

20 Pentheroudakis and Baron (2017), p. 22. Some commentators make the claim that in practice hold-up is of minor importance (Pentheroudakis and Baron (2017), p. 28), which seems at odds with these findings. Shapiro & Lemley (2020) discuss the challenges of empirically identifying hold-up despite its prevalence.

31. As mentioned in Section 2.2 on the risk of patent hold-up, before a standard is set, there typically exist alternatives to the ultimately standardized technology, which limits the value of individual patents *ex-ante*. Because downstream innovators are "locked in" once the standard is adopted, SEP holders are able to negotiate royalty rates that exceed those that could have been achieved *ex-ante* when competing technologies were available.[21] This effect may be aggravated due to implementers facing significant switching costs once investments into the standard-implementing products have been made.[22]

32. In addition, SEP holders normally license their entire portfolio for a standard, regardless of whether the implementer uses all SEPs or only a subset. In Microsoft v. Motorola, the court has therefore noted that "*[A] specific SEP may contribute greatly to an optional portion of a given standard, but if that portion is not used by the implementer, the specific SEP may have little value to the implementer.*"[23] In licensing the entire portfolio regardless, an SEP holder can effectively inflate the royalties for the SEPs used by the implementer.

Have inflated SEPs royalty triggered socially wasteful conduct?

33. Recent findings in the academic literature suggest that potentially inflated royalties may have driven various socially wasteful conducts by SEP holders. Love, Lefouili and Helmers (2021) examined over 1,800 US court dockets related to disputes between SEP licensors and licensees between 2010 and 2019 in an attempt to quantify the extent of patent hold up. The authors reviewed court documents for various categories of "opportunistic behaviour" that can be linked to hold up strategies by SEP holders. In around 75% of cases, some form of opportunistic behaviour could be identified. Although the authors seem to have chosen a rather broad definition of opportunistic behaviour, their findings suggest a wide-spread prevalence of hold up issues and consequently inflated SEP royalty rates.

34. Indeed, inflated SEP royalties following (e.g., following from end-device level licensing) may not only incentivize firms to invest in the development or improvement of a standard, but also to engage in rent-seeking with no value contribution to the standard. In this regard, Dewatripont and Legros (2013) argue that if the contribution of a patented invention to the value of a standard is difficult to observe, FRAND licensing policies induce an over-investment in patenting with respect to the social optimum. Bekkers and West (2008) document a strong increase in the number of patent declarations over time and claim that the obligation to licence SEPs on FRAND terms has proven insufficient to limit this "proliferation" of patents. Simcoe and Righi (2021) observe that continuations, which allow patentees to claim technology developed after the original filing date of a patent, are commonly filed immediately after the standard publishes and are more commonly used when the initial patent examiner is more lenient. The authors interpret the widespread use of continuation procedures as an attempt "*to opportunistically 'invent patents' that are*

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21 To remedy this and to derive a useful benchmark for FRAND, it is therefore common practice to consider the outcome of a hypothetical negotiation that takes place at the time the SSO is selecting the standard. Put differently, a FRAND SEP royalty rate should reflect what would happen as a result of well-informed *ex-ante* technology competition.

22 Federal Trade Commission, March 2011, The Evolving IP Marketplace, Aligning Patent Notice and Remedies with Competition, available at https://www.ftc.gov/sites/default/files/documents/reports/evolving-ip-marketplace-aligning-patent-notice-and-remedies-competition-report-federal-trade/110307patentreport.pdf.

23 Microsoft Corp. v. Motorola, Inc., No. C10-1823JLR, 2013 WL 2111217 (W.D. Wash. Apr. 25, 2013).

infringed by already-published standards".[24] Although the strong proliferation of patents and continuations is not necessarily caused by device level licensing, an increase of the expected SEP royalties through end-device licensing may exacerbate this problem.

3. RESTORING A SOCIALLY EFFICIENT BALANCE OF INNOVATION INCENTIVES

35. In the preceding section we have discussed evidence that the current level of SEP royalties may be too high from a social welfare perspective, resulting in inefficiently strong incentives to innovate upstream, while disproportionally reducing downstream innovation. In the following, we assess past attempts to return to more efficient licensing frameworks. Section 3.1 provides evidence that SEP holders in fact continued to invest in the development of the 802.11 Wi-Fi standard even after several US courts have substantially lowered royalties requested by SEP holders. Section 3.2 shows how policy measures aimed at limiting the scope for harmful patent hold-up can restore the balance between upstream and downstream incentives to innovate.

3.1. UPSTREAM INNOVATION AFTER WI-FI RATE REDUCTIONS

36. The IEEE 802.11 standard, commonly referred to as Wi-Fi standard, was first adopted in 1997 and has since then been continuously improved. New generations of the standard have been continuously adopted over time, for instance in 2008 (802.11n, or Wi-Fi 4), 2014 (802.11ac, or Wi-Fi 5), and 2019 (802.11ax, or Wi-Fi 6).[25] Currently, a new generation is being developed and a final version is expected by early 2024.[26]

37. In 2013 and 2014, royalties requested by SEP holders for patents essential to the 802.11 Wi-Fi standard were slashed in multiple bench trials and jury verdicts in the United States. Table 1 below presents an overview and summaries of the respective litigation cases can be found in Appendix B. The rate reductions were by no means negligible, and in some cases amounted to more than 90% of the rates requested by SEP holders.

Table 1: Litigated 802.11 Wi-Fi RAND royalty rates

Case	Royalty requested by SEP holder	Royalty adjudicated by court or jury	% Reduction
Innovatio (2013)	$3.39-$36.90 per end device	$0.0956 per chip	97.2%-99.7%

24 Shapiro and Lemley (2020).

25 Tim Pohlmann, October 20, 2021, Who's ahead in the WiFi 6 patent race, available at https://www.iam-media.com/article/whos-ahead-in-the-wifi-6-patent-race (last accessed 28 October 2022).

26 Khorov, Levitsky, and Akyildiz, 2020, Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7, available at https://ieeexplore.ieee.org/document/9090146.

Microsoft Corporation v. Motorola Mobility, Inc. (2013)	2.25% of price of end device	*Xbox*: $0.03471 per unit *Other products*: $0.008 per unit FRAND range from $0.008-$0.195 per unit	99.2%-99.7% per Xbox[27]
Csiro v. Cisco (2014)	$1.35-$2.25 per unit	$0.65-$1.38 for Linksys-branded products $0.90-$1.90 for Cisco-branded products	16%-52%
Realtek Semiconductor Corp. v. LSI Corp. (2014)	5% per chip sales price[28]	0.19% per chip sales price	96.2%
Ericsson v. D-Link (2013)	$0.50 per unit	$0.15 per chip	70%

Source: See Appendix B

38. The court enforced rate reductions also lowered expectations of SEP holders on what royalty rates will be considered FRAND by courts in the future. Yet, despite the massive rate reductions and the accompanying decline in expected royalty income, incentives to innovate upstream remained strong and SEP holders continued to improve upon the standard. The Wi-Fi alliance noted that "*Wi-Fi is continuously innovating, providing solutions to meet the growing user demand and maintain quality connections wherever users go.*"[29]

39. The number of submitted standard contributions provides further evidence for continued upstream innovation activities even after courts have slashed requested royalty rates. As shown in Figure 4, the contributions to Wi-Fi 6 and Wi-Fi 7 – whose development begun in 2014 and 2019, respectively, are significantly larger than the contributions to Wi-Fi 4 and Wi-Fi 5.[30]

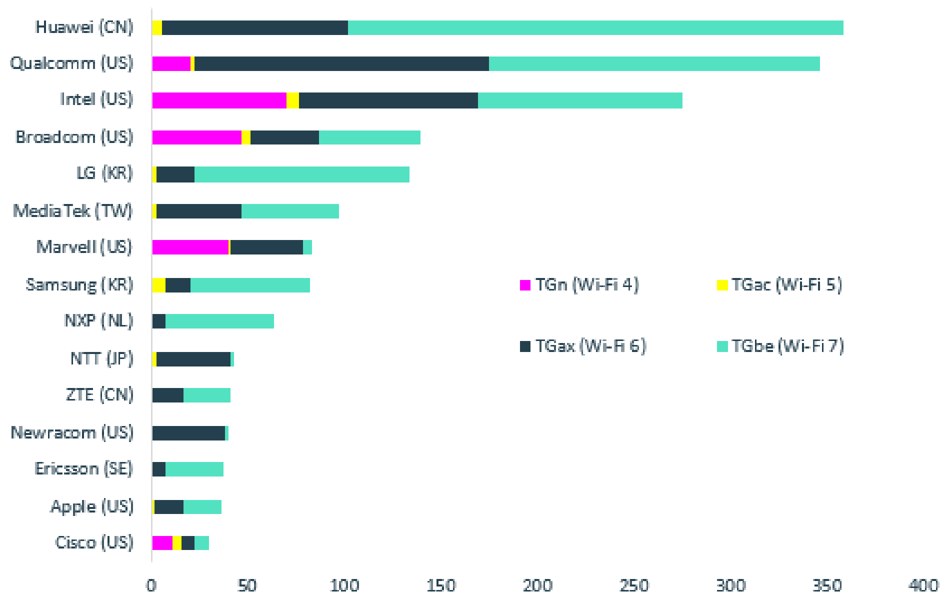
27 Assuming an Xbox price between $199 and $499. See Appendix B.

28 Refers to a license offer in 2002. See Appendix B.

29 Wi-Fi Alliance, September 2021, Global Economic Value of Wi-Fi, 2021-2025, available at https://www.wi-fi.org/download.php?file=/sites/default/files/private/Global_Economic_Value_of_Wi-Fi_2021-2025_202109.pdf (last accessed 7 October 2022).

30 While the number of contributions required to achieve a new standard may increase in the standard's complexity (meaning newer standards may require more contributions), it is shown that these contributions were successfully accumulated despite massive reductions in royalty rates.

Figure 4: Submitted standards contributions to Wi-Fi 4, 5, 6 and 7



Source: IPlytics, available at https://www.iam-media.com/article/whos-ahead-in-the-wifi-6-patent-race.

3.2. Empirical literature on past IP policy changes

40. As explained in Section 2.1, reducing SEP royalty rates does not necessarily lead to lower upstream innovation by SEP holders. This is confirmed by the empirical research on standards setting organisations that have changed their patent policies in ways that could potentially reduce royalty income. Indeed, a review of this empirical literature does not provide convincing support for the hypothesis that these policy changes had negative effects on innovation or participation in standards development.

- Contreras (2011) examines the patent policy change of VMEbus International Trade Association ("VITA") in 2007.[31] Under its revised policy, Vita requires ex-ante disclosure of maximum patent royalty rates. Contreras finds that this policy change had no detrimental effect on the output and participation at VITA. As measures of output and participation, he looked at number of disclosures, the number of new standards-development activities that were initiated, the number of standards that were approved, the average time between the introduction of a draft standard and its final approval, the number of members participating in VITA, and the number of citations for newly approved standards. Further, he conducted an online survey of all then-current VITA members. This study has considerable credibility due to the evaluation of a wide set of outcome variables, the consistency of the results, and the comparison between VITA and other SDOs that did not undergo such a policy change.

31 See also Contreras (2013).

- Simcoe and Zhang (2021) study the 2003 change at W3C from royalty-bearing to royalty-free licensing. According to the study, neither contributions nor patent counts have declined as a result of this policy change. Similarly, Contreras (2016) also studies the W3C policy change and finds that "the RF policy at W3C had largely been a success."[32]
- Stoll (2014) studies the Organization for the Advancement of Structured Information Standards' ("OASIS") 2005 patent policy change from "vague FRAND" to royalty-free licensing. Examining changes in the overall number and the distribution of types of members at OASIS, he finds that the number of new members joining OASIS in the three years before the policy change was about twice as high as in the three years after the change, and that a larger share of these new joiners after the policy change were non-profit organizations.[33] The study also finds that members remained in OASIS for a shorter period of time following the policy change.[34] However, one notable weakness of this study is that it does not report the trend in OASIS membership before the policy change. If the number of new members was already declining before the policy change, the before-after comparison would merely capture an on-going decline in the number of new members.
- In 2015, the Institute of Electrical and Electronics Engineers – Standards Association ("IEEE-SA") changed its IP policy and placed explicit restriction on the access of SEP holders to injunctions.[35] Despite some SEP holders claiming the 2015 policy change would discourage contributions, empirical findings are at best ambiguous. While Gupta and Effraimidis (2018), Katznelson (2018) as well as Bonani (2022) find a rather negative effect of the policy shift on SEP holders' willingness to license their patents, positive Letters of Assurances ("LOAs"),[36] and the number of patent applications, there are several studies finding positive effects. Simcoe and Zhang (2021) find no decline in contributions or patent counts following the policy change. IPLytics (2017, 2018 and 2019) find an increase in Project Authorization Requests ("PARs"), technical contributions, members, published standards, and patent applications for technology classes linked to the 802.11 standard.[37]

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32 Contreras (2016), p. 879.

33 Stoll (2014), Table 5, p. 27.

34 Stoll (2014), p. 28.

35 In September 2022, the IEEE-SA amended its 2015 policy and removed certain language and policy text clarifications to which some SEP owners had objected. See IEEE, September 30, 2022, "IEEE Announces Decision on Its Standards-related Patent Policy", available at https://standards.ieee.org/news/archive-2022/ieee-announces-decision-on-its-standards-related-patent-policy/ (last accessed 26 October 2022). See also the approved updates to the IEEE SA Standards Board Bylaws, available at https://standards.ieee.org/wp-content/uploads/import/governance/bog/resolutions/september2022-updates-sasb-bylaws.pdf.

36 Letters of Assurance are "documents outlining the declaration of patents potentially essential to the standard… and terms under which the submitter is willing to license its SEPs." Gupta and Effraimidis (2018), p.1.

37 "Empirical study on patenting and standardization activities at IEEE" (2017), "IEEE's Empirical Record of Success and Innovation Following Patent Policy Updates" (2018), and "Empirical Analysis of Technical Contributions to IEEE 802 Standards" (2019).

4. THE IOT WILL LIKELY LEAD TO HIGHER UPSTREAM INNOVATION INCENTIVES IN THE FUTURE

41. In the past, connectivity standards served only very specific purposes. For instance, cellular standards had been primarily used in mobile phones. The royalty base of cellular standards was therefore largely limited to phone sales. In contrast, the IoT now provides a myriad of new use cases for cellular connectivity (e.g., smart traffic, smart grids, video surveillance, connected vehicles etc.). As a consequence, the rise of the IoT will increase the royalty base of cellular standards and therefore result in stronger investment incentives upstream, further implying that concerns surrounding inefficiently low upstream investments are largely unfounded.

42. With the emergence of the IoT, the number of royalty-bearing cellular products will grow dramatically. According to estimates by Transforma Insights, the total number of cellular IoT connections is expected to grow from 1.73 billion in 2022 by 19% per year to a total of 2.92 billion connections in 2025.[38] Cellular IoT connections will account for 15% of all IoT connections in 2025.[39]

43. This implies that unit sales and revenues from devices reading on cellular standards can be expected to grow substantially. Whether in the future cellular standards will be predominantly licensed on a per unit basis or based on the end-device value is uncertain. However, in either scenario, the royalty base (in terms of the number of devices sold or revenue generated) will materially increase.

44. Figure 5 below shows forecasts of the cellular IoT market in terms of the number of connected devices based on Transforma Insights. The year-on-year difference gives us a lower bound for total device sales (as it does not account for replacements). The IoT will account for an increasing number of new devices sold in future years and will amount almost to 45% of the number of connected mobile phones by 2027 and around 60% by 2030.[40] At the same time, the smartphone royalty base will likely remain at a relatively constant level, as penetration in the smartphone sector is already very high today and new sales will primarily result from replacements.

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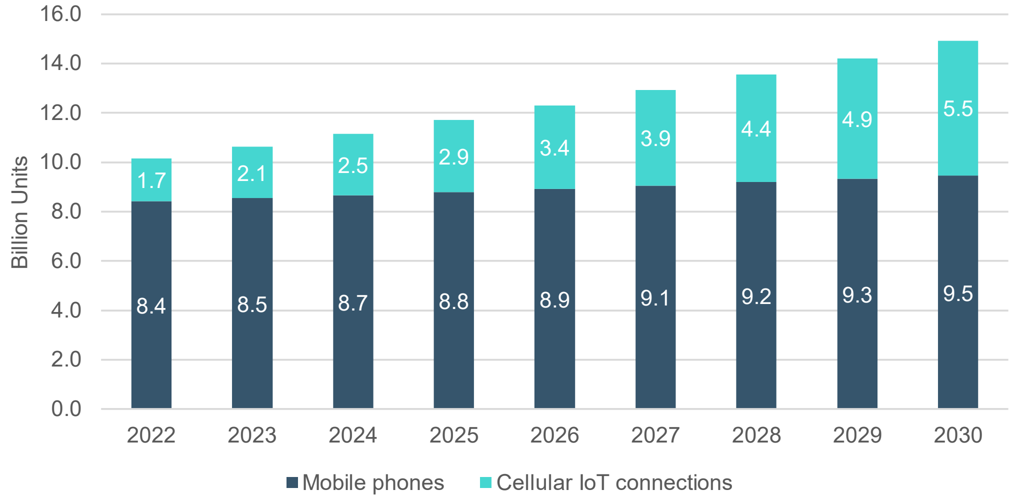
38 Cellular IoT connections include 2G, 3G, 4G, 5G non-mMTC, and 5G mMTC (including antecedent 4G technologies NB-IoT and LTE-M). See Transforma Insights, October 27, 2022, Current IoT Forecast Highlights, available at https://transformainsights.com/research/forecast/highlights (last accessed 28 October 2022).

39 *Ibid*. Total IoT connections are forecasted to reach 19.6 billion in 2025, compared to an estimated 2.9 billion cellular IoT connections in 2025.

40 Mobile phone units are approximated using SIM connections (excluding licensed cellular IoT). See Figure 2.

Figure 5: Total connected mobile phones (units) and cellular IoT units



Source: Mobile phone units are approximated using SIM connections (excluding licensed cellular IoT). SIM connections are reported in GSMA's report "The Mobile Economy 2022", available at https://www.gsma.com/mobileeconomy/wp-content/uploads/2022/02/280222-The-Mobile-Economy-2022.pdf. Cellular IoT units from Transforma Insights (as of October 27, 2022), available at https://transformainsights.com/research/forecast/highlights (last accessed 28 October 2022).

Note: GSMA provides estimates of global SIM connections for 2021 and 2025. Estimates for 2022-2024 as well as 2026-2030 are extrapolated using the cumulative annual growth rate from 2021 to 2025.

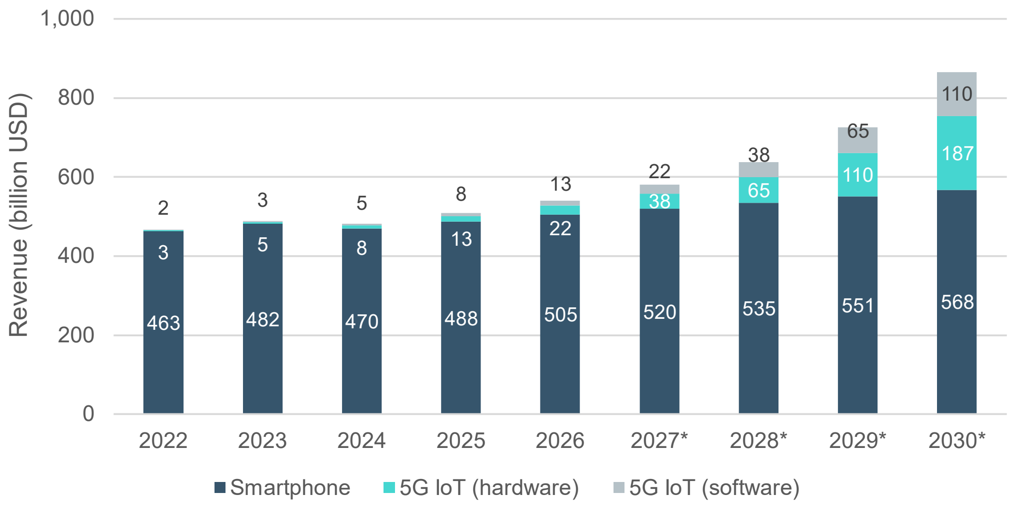
45. Figure 6 below illustrates how the cellular royalty base in terms of value could evolve in the years to come based on third party forecasts. The market value of IoT devices reading on the 5G standard *may* increase from USD 2.5 billion in 2021 (of which around USD 1.6 billion are attributable to the hardware segment) to as much as USD 300 billion in 2030 (of which around USD 187 billion from hardware[41]). Incentives for SEP holders to invest into cellular standards may therefore increase substantially due to the arrival of the IoT. Similarly, while the smartphone share of the royalty base is forecasted to somewhat increase as well – it is expected to increase at a much lower pace.

46. The IoT contribution to the royalty base is restricted to 5G only. Naturally also other cellular technologies add to the royalty base in practice. This means that in particular the contribution of connected vehicles (which due to the high end-device value can be expected to be material) is underestimated – at least in the initial years of the forecast data, where most connected vehicles do not yet use a 5G cellular connection. As 5G adoption increases for high-value vehicles, the royalty base in terms of value will grow (and grow disproportionally when compared to the royalty base in terms of number of connections).[42]

41 According to Precedence Research, the hardware and software segments account for 63% and 37%, respectively, in 2021. We assume the shares remain constant until 2030.

42 Market research firm Transforma Insights estimates that by 2030 "*over 58% of 5G 'non-mMTC' (i.e. excluding the Low Power Wide Area technologies) connections in 2030 will be found in connected cars*."[42] Transforma Insights, June 30, 2022, "Connected cars will hit 2.5 billion connections in 2030, driving cellular IoT and 5G adoption", available at https://transformainsights.com/blog/connected-cars-cellular-iot-5g (last accessed 14 October 2022).

Figure 6: Forecasted annual global revenue from 2022 to 2030



Source: Smartphone revenue from Statista, available at https://www.statista.com/forecasts/1286699/worldwide-smartphone-market-revenue. 5G IoT revenue from Precedence Research, available at https://www.precedenceresearch.com/5g-iot-market.

Note 1: Smartphone revenue is estimated by Statista and available from 2013 to 2026. Smartphone revenues for 2027 to 2030 are extrapolated using the cumulative annual growth rate from 2020 to 2026. 5G IoT revenue is estimated by Precedence Research and available from 2021 to 2030. According to Precedence Research, the hardware and software segments account for 63% and 37%, respectively, in 2021. In the figure, we assume the shares remain constant until 2030.

Note 2: The actual IoT revenue is difficult to predict and forecast about the exact size of the future cellular IoT market vary depending on the source. However, while there are multiple forecasts by different industry observers, they all point towards a significant growth in the coming years. Straits Research estimates the global cellular IoT market to grow with a CAGR of 24.6%, reaching a value of around USD 27 billion in 2030 (available at https://straitsresearch.com/report/cellular-iot-market). Markets and Markets Research (available at https://www.marketsandmarkets.com/Market-Reports/cellular-iot-market-232497754.html) and IMARC (available at https://www.imarcgroup.com/cellular-iot-market) provide similar estimates. Allied Market Research estimates growth at around 70% CAGR and the 5G IoT market value in 2030 at around USD 290bn – close to predictions by Precedence Research shown in this figure (available at https://www.alliedmarketresearch.com/5g-iot-market-A12815).

APPENDIX A METHODOLOGY – R&D SPEND

47. The following annex outlines in detail how the downstream and upstream R&D spend estimates presented in Section 1 are compiled. We first explain how the R&D spend for the five largest smartphone OEMs downstream was estimated. We then present an overview of how (i) the licensing revenue of SEP holders is calculated, and based on this (ii) how upstream R&D spend is approximated.

Downstream R&D spend

48. Our estimation of downstream R&D spend focuses on the largest OEMs making up more than 90% of global smartphone revenues in 2020. These are Apple, Samsung, Huawei, BBK (comprised of brands Vivo, Oppo, Realme and One Plus) and Xiaomi.

49. We then obtain 2020 total revenue related to each firm's smartphone business,[43] as well as total revenue and R&D spend across all business segments from financial statements and annual reports. Smartphone R&D spend for downstream OEMs is calculated by multiplying the revenue share from smartphones with the total R&D spend. BBK is a privately held company and does not publicly disclose revenue or R&D figures. BBK's smartphone R&D spend has been imputed using the R&D spend of the remaining three OEMs and multiplying with the ratio of BBK total smartphone revenue over total smartphone revenue of the remaining OEMs.

Table 2: Revenue and R&D spend by smartphone OEM, 2020 (USDm)

OEM	Total Revenue	Smartphone Revenue	Total R&D	Smartphone R&D (imputed)
Apple	274,515	163,258	18,752	11,152
Huawei**	129,169	65,223	20,562	10,382
Samsung	200,637	92,142	17,980	8,257
BBK*		58,347		5,169
Xiaomi	35,629	27,205	1,341	1,024
Total				**35,985**

Source: Annual reports. Note: * BBK is privately held and does not publish figures on revenues or R&D spend. ** Huawei subsidiary HONOR was sold in November 2020 to Shenzhen Zhixin New Information Technology. 2020 Smartphone revenues are included under the Huawei brand.

Upstream R&D spend

50. In the following, we first explain how smartphone SEP royalties were derived. These are then used in a second step to calculate upstream smartphone related R&D spend.

43 Based on data provided by technology market research company Canalys.

SEP royalties

51. To estimate the level of global smartphone SEP royalties, we use a bottom-up approach: we identify the main smartphone SEP licensors and estimate their respective SEP licensing revenues from smartphones for 2020.[44]

52. We identified 31[45] main smartphone SEP licensors that in total earned around $8.9 billion in smartphone SEP royalties in 2020. As can be seen from **Table 3**, the distribution of these royalties is heavily skewed towards a small number of individual SEP holders with the largest SEP licensor accounting for 51% of the estimated total royalties.

Table 3: Smartphone SEP royalty revenues by licensor - 2020

Licensor	Category	Smartphone SEP Royalty revenue (USDm)	Methodology*
Qualcomm	Individual licensor	4,525	Documented
Nokia	Individual licensor	1,369	Documented
Ericsson	Individual licensor	932	Documented
Huawei	Individual licensor	375	Documented
Interdigital	Individual licensor	312	Documented
Microsoft	Individual licensor	212	Documented
Xperi	Individual licensor	153	Documented
HEVC Advance	Patent pool	134	Calculated
Via Licensing LTE	Patent pool	117	Calculated
Philips	Individual licensor	103	Documented
IBM	Individual licensor	88	Documented
MPEGLA AVC H.264	Individual licensor	77	Calculated
Broadcom	Individual licensor	66	Documented
Via Licensing AAC	Patent pool	62	Calculated
Intellectual Ventures	Individual licensor	60	Extrapolated
MPEGLA HEVC	Patent pool	50	Calculated
Via Licensing WCDMA	Patent pool	48	Extrapolated
Rambus	Individual licensor	32	Documented
Acacia Technologies	Individual licensor	25	Documented
Technicolor	Individual licensor	22	Documented
Blackberry	Individual licensor	19	Extrapolated
Conversant IP	Individual licensor	19	Extrapolated

44 We limit our identification of SEP holders to only those firms that are actively seeking licensing revenues for their SEPs, excluding cross licences.

45 We count the different licensing programmes of patent pools and the company AT&T as separate "licensors". If each patent pool operator and AT&T are only counted once, the number of identified licensors amounts to 26.

Major SEP licensors have been previously identified by Galetovic et al. (2018) who estimate total smartphone SEP royalties for 2016. Galetovic et al. had identified 40 smartphone SEP licensors, eight of which we exclude from our analysis as their royalty revenues are likely negligible (in fact, Galetovic et al. did not provide a royalty estimate for them either). Alcatel-Lucent has been acquired by Nokia in the meantime (i.e. its royalty revenues are included in our estimate for Nokia). Based on our desk research, we find no evidence that additional major smartphone SEP licensors on top of those identified by Galetovic et al. have emerged since 2016.

Licensor	Category	Smartphone SEP Royalty revenue (USDm)	Methodology*
Unwired Planet	Individual licensor	15	Extrapolated
Quarterhill	Individual licensor	15	Extrapolated
ATT MPEG4	Individual licensor	13	Extrapolated
ATT 802.11	Individual licensor	7	Extrapolated
MPEGLA MPEG4	Patent pool	5	Calculated
ParkerVision	Individual licensor	2	Extrapolated
Tivo	Individual licensor	2	Extrapolated
PanOptis-Optis	Individual licensor	1	Extrapolated
VirnetX	Individual licensor	1	Extrapolated
Total		**8,863**	

Source: CRA estimates of 2020 smartphone SEP royalties based on licensors' financial reports, publicly available information and Galetovic et al. (2018).[46]

Notes: * *Documented* licensor revenues are based on annual report filings. *Extrapolated* figures based on adjusted estimates from Galetovic et al. (2018). *Calculated* licensor revenues are based on CRA calculations using available information. ** Microsoft and Philips are members of the Via AAC, MPEG LA MPEG4, MPEG LA AVC and Access Advance pool. AT&T licences its MPEG4 patents through the Via AAC pool. In order to avoid double-counting we have estimated the share of the pools' licensing revenues that accrue to these three licensors and subtracted them from the pools' total estimates revenues.

In estimating smartphone royalties for the 31 identified smartphone licensors, we employ a variety of different research methods.

Licensors with documented licensing revenues

53. Almost 90% of all licensing revenue in 2020 is estimated based on publicly disclosed financial reports. This includes a majority of the largest licensors by licensing revenue – Qualcomm, Nokia, Ericsson, and Interdigital. We estimate SEP royalties for these firms by reviewing their annual reports and extracting the relevant figures – usually this is categorized as licensing revenue or similar. From these figures, we make an assumption regarding what percentage of licensing revenue refers specifically to SEP licensing. We are guided by information provided within the annual reports, which often provide a short note on the components that make up licensing revenue. In instances where it is stated that licensing revenue is made up from more than just SEP licensing, we attribute 95% of licensing revenue to SEPs.

54. Having estimated total SEP royalties from company financial information, we next look to split this SEP revenue between smartphones and all other products. We estimate that in most cases about 90% of the SEP royalties we identify from companies' financial statements are smartphone related.[47]

55. These licensors are referred to as 'documented' in **Table 3** above.

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46 Galetovic et al. (2018).

47 We leverage information on smartphone sales as a proportion of major consumer electronic sales, as well as the fact that smartphones implement most of the standards we identify. See https://www.statista.com/outlook/cmo/consumer-electronics/tv-radio-multimedia/worldwide..

Patent pool revenues

56. For pools where publicly available information regarding licensees and royalty structure is available, we can estimate total royalties attributable to smartphone sales. This is possible for many major patent pools including the MPEG LA pools for MPEG4, AVC, and HEVC, as well as the Access Advance and Via AAC patent pools – all present within the list of 31 identified licensors.

57. In order to calculate pool royalties attributable to smartphones, information on the pool royalty structure, licensees, and the number of smartphones sold by each licensee of the pool is required. The list of licensees and royalty structure are often retrievable from the patent pool website, while for smartphone sales we make use of data from Statista.[48] Combining this information allows us to calculate total smartphone royalties paid by each licensee of a given pool for 2020, thus estimating total smartphone SEP revenue for the patent pool.

The patent pools for which we estimate royalty revenues in this way are referred to as 'calculated' within in **Table 3** above.

All other licensors

58. For a handful of licensors with low licensing revenue below $50m[49], the 2020 royalties are estimated by extrapolating the 2016 estimates by Galetovic et al. assuming their share of total licensing revenue remained constant over time. Each of these extrapolated licensor's 2020 licensing revenue figures is multiplied by 90%, to account for the fact that firms' licensing revenue are unlikely to entirely stem from smartphone SEP royalties.[50]

These licensors are referred to as 'extrapolated' in **Table 3** above.

Smartphone upstream R&D spend

59. To calculate smartphone related upstream R&D spend, we first identify the set of SEP holders which (i) have R&D activities related to smartphone SEP development and (ii) publicly report figures on total R&D spend. This leaves us with a set of 14 licensors, excluding pools and non-practicing entities (NPEs).

60. For these SEP holders, we collect data on total R&D spend and derive smartphone SEP related R&D spend by multiplying with the SEP royalty share of total revenue. This methodology implicitly assumes that upstream SEP holders allocate R&D spend to the various business segments in proportion to each segments' share of total revenue.

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48 Statista is a global business data platform, https://www.statista.com.

49 Based on Galetovic et al. (2018). These cases make up for only around 2.6% of total smartphone SEP royalties in 2016.

50 There are instances where Galetovic et al. attribute zero smartphone SEP royalties to a potential licensor due to a lack of available information. In these instances, unless there is material evidence of licensing revenue being generated, the 2020 figures for these potential licensors are also set at zero. Royalties generated from these licensors are consequently almost certainly underestimated. These licensors include patent pools run by Sisvel (LTE, Wireless, and Wifi), Via (WCDMA), Velos (HEVC), and Vectis (Wifi), as well as private non-practicing entities including IPcom and IP Bridge. Note that some pool operators run more than one pool and a licensee of one standard is not necessarily a licensee of another offered by the same pool operator. For instance, licensees of the Via AAC pool may not be licensed to the Via LTE pool.

The aggregate R&D spend of pool members is derived by first calculating the ratio of pools' SEP royalties over royalties from the 14 SEP holders with relevant R&D activity. This ratio is then multiplied by the total, smartphone related R&D spend of individual SEP holders.

Table 4: Revenue and R&D spend SEP holders, 2020 (USDm)

Licensor	Total revenue	Smartphone SEP royalties	Total R&D spend	Smartphone & SEP related R&D*
Qualcomm	23,531	4,525	5,975	1,149
Nokia	24,945	1,369	4,666	256
Ericsson	25,232	932	4,312	159
Huawei	129,165	375	20,561	60
Interdigital	359	312	85	74
Microsoft	143,015	212	19,269	29
Xperi	892	153	195	35
Philips	22,300	103	2,186	48
IBM	73,620	88	6,333	8
Broadcom	23,888	66	4,968	14
Rambus	243	32	140	18
Technicolor	3,432	22	96	1
Blackberry	893	19	215	5
VirnetX	303	1	9	0
Quarterhill	108	15	2	0
Pool members		513	4,302**	116
Total				**1,970**

Source: Financial reporting, **Table 3**. Notes: * The financial reporting of Xperi and Philips allows for a refined derivation of upstream R&D spend. Xperi reports separately R&D spend related to its IP licensing segment. We assume that 90% of the R&D spend is smartphone related and use this figure as the basis for Xperi's upstream R&D spend. Philips reports separately revenues and R&D spend for "other" segments which include business operations related to "Innovation & Strategy" as well as "IP royalties". In the case of Philips, we derive upstream R&D spend as R&D spend for "other" segments multiplied with the SEP royalty share of revenues related to "other" segments. ** Imputed R&D spend of pool members.

APPENDIX B SUMMARY OF WI-FI LITIGATION CASES

61. This Appendix briefly summarizes the Wi-Fi litigation cases listed in Section 3.1, Table 1.

Innovatio

62. Innovatio IP Ventures, LLC ("Innovatio") has sued numerous commercial users of the Wi-Fi technology for the infringement of nineteen patents owned by Innovatio.[51] Innovatio sought royalties ranging from about $3.39 to $36.90 on each end device, depending on the device type.[52] In 2013, a United States District Court determined the RAND rate to be "9.56 cents for each Wi-Fi chip used or sold by the Manufacturers in the United States". In other words, the Court determined royalty rates that amount to less than 3% of Innovatio's requested royalty rates.

Microsoft Corporation v. Motorola Mobility, Inc.

63. Motorola, owner of patents essential to the 802.11 Wi-Fi standard, offered to license its patents to Microsoft at 2.25% of the price of the end-product.[53] With Xbox prices between $199[54] and $499,[55] Motorola's royalty rate translates into royalty payments between $4.50 and $11.2 per Xbox. After a bench trial in 2012, a United States District Court in 2013 determined the RAND royalty for Motorola's 802.11 SEP portfolio to be 3.471 cents per unit of Microsoft's Xbox products and 0.8 cents per unit for all other Microsoft products. More generally, the Court determined a RAND range starting at 0.8 cents and ending at 19.5 cents per unit. In other words, the Court determined royalty rates for Microsoft's Xbox that amount to less than 1% of Motorola's requested royalty rate.

Commonwealth Scientific and Industrial Research Organisation v. Cisco Systems, Inc.

64. The Commonwealth Scientific and Industrial Research Organisation ("CSIRO") owns a US patent that is essential to the 802.11 Wi-Fi standard. CSIRO filed suit against Cisco, alleging that Cisco's products (including Linksys products) infringe CSIRO's patent.[56] CSIRO demanded volume-tiered royalties ranging from $1.35 (0-1 million units) to $2.25 (>20 million units) per end-product sold. In 2014, a United States District Court determined RAND rates for Linksys ranging from $0.65 (>20 million units) to $1.38 (0-1 million units) per unit. For Cisco, the RAND rates range from $0.90 (>20 million units) to $1.90 (0-1 million

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51 *In re Innovatio IP Ventures, LLC Patent Litig.,* MDL No. 2303, 2013 WL 5593609 (N.D. Ill. 10.03.2013).

52 Around $3.39 per access point, $4.72 per laptop, up to $16.17 per tablet, and up to $36.90 per inventory tracking device.

53 *Microsoft Corp. v Motorola, Inc.*, C10-1823JLR (W.D. Wash. 25.04.2013).

54 David Long, July 31, 2015, Ninth Circuit affirms Judge Robat's RAND decision (Microsoft v. Motorola), Essential Patent Blog, available at https://www.essentialpatentblog.com/2015/07/ninth-circuit-affirms-judge-robarts-rand-decision-microsoft-v-motorola/ (last accessed 13 October 2022)

55 Jordan Crook, 2016, Microsoft slashes Xbox One price to $250 ahead of Slim launch, available at https://techcrunch.com/2016/07/25/microsoft-slashes-xbox-one-price-to-250-ahead-of-slim-launch/ (last accessed 12 October 2022).

56 *CSIRO v Cisco*, 6:11-cv-00343-LED (U.S. District Court, Eastern District Texas, 07.23.2014).

units). The Court determined RAND rates that amount to 48% to 84% of CSIRO's requested rate.[57]

Realtek Semiconductor Corp. v. LSI Corp.

65. LSI through its wholly owned subsidiary Agere owns two US patents essential to the 802.11 Wi-Fi standard. Already in 2002, Agere offered Realtek a license to these patents at a royalty rate of 5% on all 802.11 products sold by Realtek (i.e., per chip). In 2012, LSI made another offer to Realtek, but the content is under seal. In 2014, a United States District Court determined a combined royalty rate of 0.19% per chip sales price for both patents – a mere 4% of LSI's requested royalties.[58]

Ericsson Inc., et al. v. D-Link Systems, Inc., et al.

66. Ericsson filed suit against D-Link, Netgear, Belkin, Acer, Gateway, Dell, Intel, and Toshiba for infringing patents essential to the 802.11 Wi-Fi standard and requested a royalty rate of $0.50 per unit for its 802.11 portfolio. A United States District Court conducted a jury trial in 2013. The jury determined a RAND rate of $0.15 per units – that is, only 30% of the royalties Ericsson had requested.[59]

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57 Across volume tiers, the Court found that RAND rates for Linksys products amount to 48%-61% of CSIRO's requested rates. For Cisco products, the Court found that RAND rates amount to 67-84% of CSIRO's requested rates.

58 Realtek Semiconductor Corp. v. LSI Corp., Case No. C-12-3451 (N.D. Cal.). See Order Granting Plaintiff Realtek Semiconductor Corporation's Motion For Partial Summary Judgement And Denying Defendants LST Corporation And Agere System LLC's Motion To Stay.

59 Ericsson Inc., et al. v. D-Link Systems, Inc., et al., Case No. 6:10-CV-473 (U.S. District Court, Eastern District Texas). See also Essential Patent Blog, August 7, 2013, Rebutting Judge Robart? E.D. Tex. Judge Leonard Davis upholds jury damages award on WiFi SEPs, dismisses RAND-related issues (Ericsson v. D-Link), available at https://www.essentialpatentblog.com/2013/08/rebutting-judge-robart-e-d-tex-judge-leonard-davis-upholds-jury-damages-award-on-wifi-seps-dismisses-rand-related-issues-ericsson-v-d-link/ (last accessed 27 October 2022)

APPENDIX C REFERENCES

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