# The Value of a Standard Versus the Value of Standardization

J. Gregory Sidak*



*Chairman, Criterion Economics, Washington, D.C. Email: jgsidak@criterioneconomics.com. 

## I. INTRODUCTION

The Federal Circuit said in *Ericsson, Inc. v. D-Link Systems, Inc.* that a jury instructed to determine a fair, reasonable, and nondiscriminatory (FRAND) royalty for standard-essential patents (SEPs) "must be told to consider the difference between the added value of the technological invention and the added value of that invention's standardization."[1] The court emphasized that a FRAND royalty "must be premised on the value of the patented feature, not any value added by the standard's adoption of the patented technology."[2] The Federal Circuit reasoned that "[t]hese steps are necessary to ensure that the royalty award is based on the incremental value that the patented *invention* adds to the product" and is not based on any value that the standardization of that technology adds to the product.[3]

The Federal Circuit's phrase "the value of standardization" is abstract and ambiguous. Restated in more direct and more intuitive terms, the phrase appears to denote *the value from making a collective decision to conform to a standard*—that is, the value that arises when inventors and potential implementers agree that they will comply with a standard to solve a particular technological challenge. That agreement to create a standard does not imply that a feasible technology already exists to become the standard, nor does it indicate that the required technology (if it does not yet exist) will be straightforward to develop. The standard-setting organization (SSO) cannot simply hypothesize that an available and acceptable technology exists for the standard because the SSO would like to have a standard.

Consequently, in patent litigation after *Ericsson v. D-Link,* it is essential to disaggregate "the value of standardization" from the value of the technologies incorporated into the standard. "The value of standardization"—that is, the value of the agreement to implement a unified standard—can arise from (1) a reduction in transactions costs for implementers of the standard and for SEP holders and (2) the network effects generated by interoperability between standard-compliant products. The value of the technologies incorporated into the standard comprises the rest of the total value of the standard.

[1] 773 F.3d 1201, 1233 (Fed. Cir. 2014).

[2] *Id.* at 1232.

[3] *Id.*

## II. DISAGGREGATING THE VALUE OF A STANDARD INTO THE VALUE OF STANDARDIZATION AND THE VALUE OF THE TECHNOLOGIES INCORPORATED INTO THE STANDARD

Standardization through an SSO creates interoperability through private collective action. Depending on the circumstances affecting the industry and the standard, this kind of collective action might be the most efficient way to create interoperability, because it obviates the web of bilateral negotiations that inventors and potential implementers would otherwise need to undertake to ensure technological compatibility. When a standard results from an SSO's collective action, each SEP holder and each implementer still will need to negotiate bilaterally the prices, terms, and conditions for use of the SEPs in question. (It is doubtful, for example, that the SEP holder would give away its valuable SEPs for free or put them in a patent pool and be content to receive a share of the pool's posted royalties.) That is, standardization economizes on the transactions costs of achieving interoperability, but it does not replace bilateral negotiation as the method of price formation for the SEPs in question.

This paper examines the network effects resulting from the interoperability that a collective standard creates. Those network effects increase the value of the products that implement the standard. Value in this sense corresponds to the economic understanding of willingness to pay.[4]

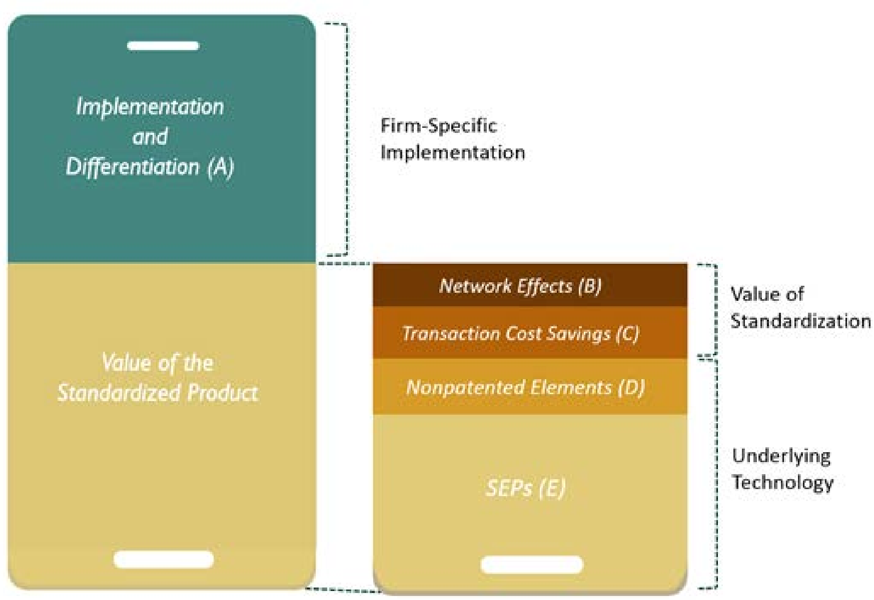
Standardization enables better interoperability between devices and network elements produced or operated by different parties. For example, a mobile phone made by Foxconn, sold by Apple, and operating on AT&T's network can connect to a base station, made by Ericsson and operated by Verizon, and send a text message to a phone sold by Samsung operating on Sprint's network, through a base station made by Alcatel-Lucent and operated by T-Mobile. In markets in which network effects are present, consumer demand increases as the number of other consumers participating in the market increases. That is, as more consumers use mobile phones, the demand curve for mobile phones (or for mobile phone usage) will shift outward, indicating a higher willingness to pay for any given quantity demanded. Standardization enables different device manufacturers (or retailers or network operators) to internalize some of the network

[4] *See, e.g.*, JACK HIRSHLEIFER, AMIHAI GLAZER & DAVID HIRSHLEIFER, PRICE THEORY AND APPLICATIONS: DECISIONS, MARKETS, AND INFORMATION 204 (7th ed. 2005) ("For any individual the demand price for good *X* is equivalent to [the marginal value of that good], a person's willingness to pay . . . for an additional unit of commodity *X*.").

externality created by additional users of a competitive product. Thus, a consumer's first purchase of a mobile phone will, on the margin, increase the willingness to pay of all current mobile phone users (albeit by a tiny amount). "The value of standardization" will include both the reduced transactions costs associated with achieving interoperability and the network effects unleashed by that interoperability.

Figure 1 graphically represents the various sources of the value that consumers derive from a mobile device: firm-specific implementation, the collective decision to conform to a standard, and the technology (both standard-essential and unpatented) that forms the standard.

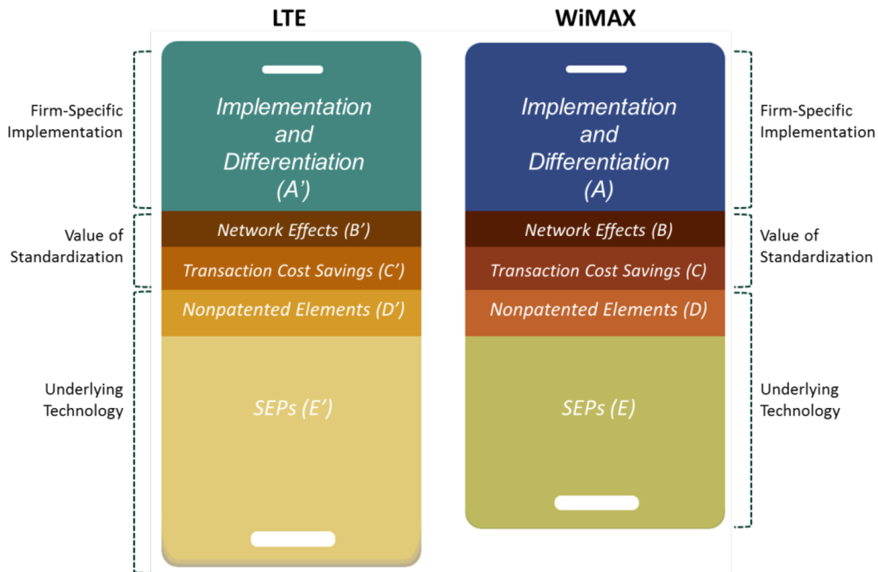
FIGURE 1: VALUE TO THE CONSUMER OF A MOBILE DEVICE




Mobile devices are highly differentiated products, even within the set of products that practice the same standard. The value of a particular device will include both the value of the standardized functionalities ($B + C + D + E$) and the value of differentiating features ($A$). Differentiating features might include nonstandardized elements such as high-resolution cameras, whereas standardized functionalities include voice calls, text messaging, or data transfers. One can further separate the value of the standardized product into identifiable components. Areas *B* and *C* in Figure 1 represent "the value from making a collective decision to conform to a standard," corresponding to the area labeled "Value of Standardization." Areas *D* and *E* represent the value of the underlying technologies incorporated into the device that are required to implement the standard. Those technologies include both SEPs (*E*) and nonpatented elements (*D*). These nonpatented elements might consist of SEPs that have expired. Identifying the components of the value of a standard-compliant device enables one to perform the rigorous economic apportionment that the Federal Circuit evidently envisioned in *Ericsson v. D-Link*. In Parts II and III, I present two straightforward methodologies for identifying *E*, the value of the SEPs. However, I first identify a common methodological error concerning the process of identifying and quantifying that value.

Suppose that there are two candidate technologies competing to become the prevailing 4G standard: WiMAX (Worldwide Interoperability for Microwave Access) and LTE (Long-Term Evolution). Adopting WiMAX as the standard creates a value of $(B + C + D + E)$, as represented in Figure 1. Within the language of the Federal Circuit's opinion in *Ericsson v. D-Link*, *E* is "the value of the patented feature," which is equivalent to WiMAX itself. Analogously, adopting LTE as the standard creates a value of $(B' + C' + D' + E')$. ($B'$, $C'$, $D'$, and $E'$ correspond to *B*, *C*, *D*, and *E* in Figure 1, with the symbol ′ denoting that the values for LTE differ from the values for WiMAX.) Thus, $E'$ is "the value of the patented feature" when that feature is LTE. We observe that consumers (and mobile network operators) all eventually have chosen LTE instead of WiMAX—which is compelling evidence that $E'$ exceeds *E* (if, as explained below, $B + C + D = B' + C' + D'$). Figure 2 compares the distributions of value across the different sources of value (that is, *A*, *B*, *C*, *D*, and *E*) for an LTE-compliant mobile device with the distribution of value for a WiMAX-compliant mobile device.

FIGURE 2: COMPARISON OF THE DISTRIBUTIONS OF VALUE FOR AN LTE-COMPLIANT DEVICE AND FOR A WIMAX-COMPLIANT DEVICE




Implementers claim that the FRAND royalty offered by the SEP holder combines both ($B' + C'$) and $E'$ for LTE, the technology chosen for the standard. In other words, the royalty includes the network effects and transactions-costs savings from standardization in addition to the value of the LTE standard itself. Those implementers argue that the sum ($B' + C' + E'$) exceeds a genuinely FRAND royalty because such an offer includes ($B' + C'$)—which is "the value of standardization." It is important to note that "the value of standardization" differs from "the value of the standard" that the SSO has actually chosen: the latter equals ($B' + C' + D' + E'$). Implementers argue that the ratio $E'$ / ($B' + C' + D' + E'$) is small—that is, the technology incorporated in the SSO's chosen standard (in this case, LTE) supposedly contributes a tiny proportion of the value of the standard. Instead, implementers claim that the value of the standard arises primarily from the industry's having collectively agreed to adopt *any* common standard. This narrative by implementers suggests that the SSO's selection of a particular technology (such as LTE) for the standard is akin to a miracle that turns water into wine.

It is possible to determine the contribution of patented LTE technology net of both the value of standardization and the value of the next-best noninfringing substitute technology for the LTE standard (which, in this example, is WiMAX). The difference in value between the LTE patented technology and the WiMAX patented technology is equal to ($B' + C' + D' + E'$) minus ($B + C + D + E$). The value of the SSO's having selected a standard is common to the value of both of the SSO's technologies when adopted—that is, $(B + C) = (B' + C')$—such that taking the difference between the values of the two standards nets out the value of the SSO's having selected any standard at all. (As I will explain in Part II.A, it should be the case that $B = B'$ and that $C = C'$. To the extent that LTE or WiMAX did not cause the number of mobile subscribers to increase, there is no reason to believe that the transactions-costs savings or network effects varied between WiMAX and LTE—two standards that were developed nearly simultaneously.)

Suppose, for the sake of this example, that the value of nonpatented elements is equal for the LTE standard and the WiMAX standard—that is, $D = D'$.[5] For reasons that I have previously explained, the FRAND royalty for LTE in this example is not merely $(E' - E)$, which is the difference in value between the chosen technology for the standard and the first runner-up technology.[6] It bears emphasis that it is incorrect to assert (1) that $(E' - E)$ is the measure of the FRAND royalty for the chosen technology, and (2) that $(E' - E)$ converges to zero because of competition between the rival suppliers of technology for adoption into the standard. Both assertions are fallacious. Implementers do not get $E$ as an increment of value for free—$E$ might be a patented technology that the implementer would need to pay to use, or it might be a design-around that requires investment in research and development before it can support implementation. By choosing LTE over WiMAX, implementers receive the underlying value that WiMAX would create, $E$, plus the incremental value of LTE's technological superiority over WiMAX, $(E' - E)$. In other words, implementers receive a benefit equal to $E + E' - E = E'$. Because $E'$ exceeds $E$, it necessarily follows that a royalty equal to either $E$ or $(E' - E)$ would be less than the FRAND rate for LTE. Examining only the difference in benefits between the two best

[5] The value of the nonpatented elements will differ across standards. I examine that difference in value in Part III.

[6] J. Gregory Sidak, *The Meaning of FRAND, Part I: Royalties*, 9 J. COMPETITION L. & ECON. 931, 994 (2013).

alternative technologies for the standard (that is, $E' - E$) is thus certain to undervalue the benefits of standardized technologies.

## III. DETERMINING THE VALUE OF THE TECHNOLOGIES INCORPORATED INTO THE STANDARD

The Federal Circuit's statements in *Ericsson v. D-Link* raise[7] but fail to answer a fundamental question: what economic methodology may an economic expert on damages properly use to calculate a FRAND royalty? In *Ericsson v. D-Link*, the Federal Circuit articulates a vague requirement for apportioning damages to the value of the patented technology.[8] If one interprets that requirement as some implementers and their expert witnesses have recommended—so as to assume that competition among firms to have their patented technology to be adopted into the standard forces the FRAND royalty to converge to zero—the result would be an absurd hypothetical *ex ante* valuation detached from and contrary to what occurs in the real world.[9] Moreover, such an approach would require the finder of fact to engage in analysis that has never been done and, put simply, cannot be reliably accomplished. In lieu of that unworkable approach, the analysis that follows develops a coherent framework that satisfies the Federal Circuit's requirement about apportionment.

### *A. Using the Value of Standardized Products to Identify FRAND Royalties*

Taking the economic approach to FRAND price determination that I have previously explained and applying it to the incremental improvements in mobile communication standards yields a tractable and intuitive method by which the finder of fact can reliably apportion the value of the patented technology.[10] Consider Figure 3, which shows how the number of patented inputs affects the cumulative value of the patents incorporated into a standard.[11]

[7] 773 F.3d at 1228 n.4.

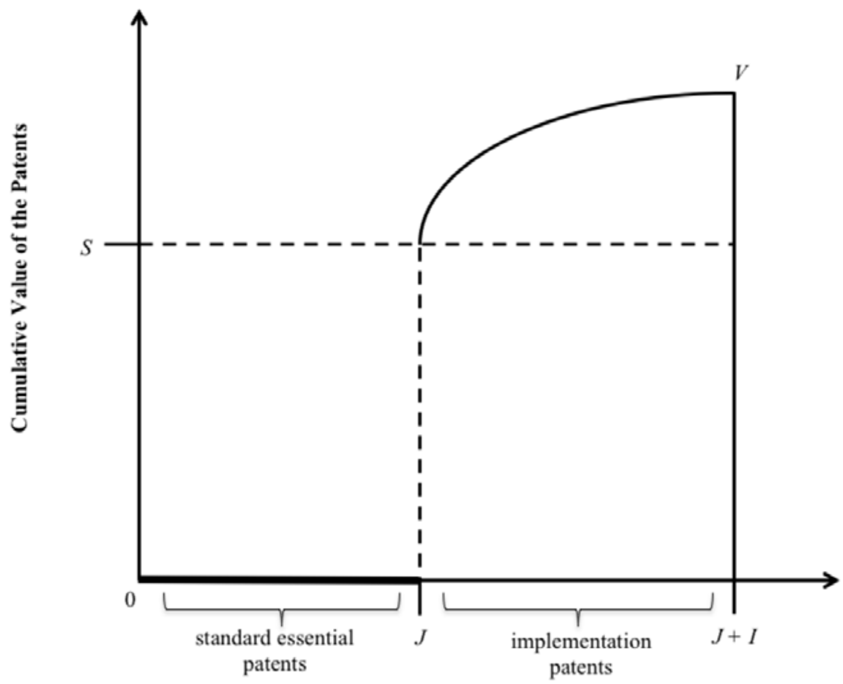
[8] *Id.* at 1228.

[9] As an aside, this specious economic argument assumes a critical fact not in evidence—that empirical evidence establishes that many, rather than only one or two, substitute technologies compete to be included in every given standard.

[10] *See, e.g.*, Sidak, *supra* note 6, at 953–63.

[11] *Id.* at 957.

FIGURE 3: THE VALUE OF THE DOWNSTREAM PRODUCT COMBINING STANDARD-ESSENTIAL AND STANDARD-NONESSENTIAL (IMPLEMENTATION) PATENTS




In Figure 3, *J* SEPs contribute to generate a value *S* that is the value of the intellectual property included in the "standardized" product (ignoring for simplicity nonpatented elements). Implementation patents will then differentiate the standard-compliant products that appear in the market. However, even as products are differentiated, the value of the "standardized" product is a common building block upon which all standard-compliant products are based. For that common building block, entry into the market is facilitated by the existence of the standard and the FRAND commitment that SEP holders have made. Low barriers to entry will generate vigorous competition in the market for the standardized product. A market that approaches perfect competition tends to include many relatively homogenous products sold for similar prices. Consequently, a distribution of prices charged for different products in that market will show an easily identifiable cluster of data points (one data point representing the price of one of the products) around the price of a standardized product that lacks any extra features that differentiate it from the rest of the products in the market. One can analyze that identifiable price for the standardized product so as to identify the value of the SEPs incorporated into the product.

For purposes of illustration, suppose that the values are approximately $20 for the most basic 2G phones, $40 for 3G phones, $80 for WiMAX phones, and $120 for LTE phones. The price of a commoditized phone will reflect the benefits of standardization and the underlying technology. Competition should drive profits for those products down to a normal rate of return on investment, for which one can use a measure of the weighted average cost of capital (WACC) as a proxy. The remaining portion of the device's price will include the costs of production and any costs of licensing patented inputs. The per-unit operating profit (price minus the cost of inputs and assembly, not including licensing costs) will include the aggregate royalty stack (*E*) that the implementers collectively pay for the use of the SEPs plus the value of standardization, represented by area *B* + *C* in Figure 1, but it will not include any licensing cost of incorporating nonpatented elements (*D*), whose licensing cost is zero. (For the sake of example, assume a profit margin of 50 percent, leaving a value for area *B* + *C* + *E* of $10 for 2G, $20 for 3G, $30 for WiMAX, and $40 for LTE.)

The value (*B* + *C*) includes the value of network effects and the value of decreased transactions costs. There is no reason to believe that (*B* + *C*) varies between 2G devices and later devices. Customers who value only interoperability do not need to switch from 2G to 4G, as the 2G standard already provides sufficient interoperability. However, many customers prefer 4G over 2G because of the more technologically advanced features (such as faster data transmission) that the 4G standard supports. Because mobile saturation of the adult population has occurred (or is occurring) worldwide with 2G devices, purchases of 3G and 4G devices have generally replaced older devices already in use. Thus, the introduction of later standards (3G and 4G) has not necessarily increased the value of standardization already attained or attainable with 2G. Likewise, the developers and implementers of earlier standards have continued to interact with each other in later standards. Although some parties have exited the market and others have entered, the majority of the leading SEP holders are the same between 2G and later standards. Consequently, there is no reason to believe that 3G or 4G standards generate more significant transaction costs savings than do 2G standards. The effect of this relationship is that ($B + C$) should be roughly equal across standards.

Therefore, the maximum value of ($B + C$) is bounded by the per-unit operating profit for manufacturers of 2G devices. Under the conservative assumption that $E$ = \$0 for standardized 2G devices and ($B + C$) = \$10, the aggregate royalty stack for SEPs, $E$, would be \$10 for 3G devices, \$20 for WiMAX, and \$30 for LTE. The aggregate royalty stack can then be apportioned to SEP holders using any of several methods. Note that this methodology will generate a per-unit royalty that is constant across implementers. The royalty rate, measured as a percentage of the price of the downstream product, will vary from device to device. Continuing with the example above, if a given SEP holder is responsible for creating 25 percent of the value of the LTE standard, then a reasonable per-unit royalty for any LTE device would be \$7.50, or 25 percent of \$30. One can combine this approach with the analysis that I will explain below to generate a robust estimation of a reasonable royalty. This approach is the most direct approach and probably the most intuitively understandable method for the finder of fact.

### *B. Directly Comparing the Incremental Improvements Between Standards to Estimate the Value of the Underlying Technology Independent of the Value of Standardization*

A reliable and cost-effective method for evaluating the value of the underlying technology independent of the value of standardization is to compare incremental improvements *between standards*. This method returns an incremental value for LTE similar to that described in Part II.A, and it serves as a check on that estimated incremental value. Comparing the value of two competing standards allows identification of the value attributable solely to the technologies incorporated into the standards. The value of standardization should be similar across alternative new standards for the same type of product (in particular, LTE and WiMAX for 4G mobile devices), such that any difference in value between the standards should focus exclusively on the difference between the underlying standardized technologies.

WiMAX—which Intel, Samsung, Sprint, and other market participants sponsored—was an alternative standard to LTE. Consumers and network operators nonetheless chose LTE. The two standards offer the same level of interoperability. The difference in value between the two standards is therefore attributable to their respective technologies. Thus, an incremental comparison of two competing standards can isolate the effects of changes in the patented technologies on the value of the downstream product. In the remainder of this part, I show that one can examine changes in technology to estimate the incremental value of the technology that the LTE standard uniquely embodies.

With sufficiently identified technological differences between standards, one can use hedonic demand estimation to compare the value of LTE with contemporaneous next-best noninfringing alternatives, such as WiMAX, 3G standards, and perhaps even 2G standards. Although one can readily identify the incremental value of switching from one standard to another, it is more difficult to estimate the value of the *original* standard. By estimating the incremental value of consecutive standards, one can estimate a lower bound on the value of the 3G and 4G standards.[12] (As more 2G patents expire and enter the public domain, the incremental value of more recent standards will increase, such that this lower bound on the value of the 3G and 4G standards will likely approach the value of the respective standards.)

One can value the improvements over those previous cellphone standards using hedonic demand estimation. Economists have developed hedonic demand estimation to standardize prices when technology is changing.[13] The methodology is distinct from conjoint analysis or other survey-based approaches to valuation. Under hedonic demand estimation, standard units for computers could include, for example, the number of CPU cycles or the number of bytes of memory, just as standard units for a house could be the square footage or the distance from desirable amenities. One can then use hedonic demand analysis to estimate separately the value of each feature and the combinatorial value of multiple features. For example, a large house may be more valuable than a small house, and a house that is in a more desirable location may also be more valuable; but the increase in the value of a larger house from being in a more desirable location might exceed the sum of the increase in the value of the individual features (a condition that economists call "superadditivity").

For those hedonic demand comparisons, one would measure the improvement in features not across time, but rather across different

[12] As more 2G patents expire and enter the public domain, the incremental value of more recent standards will increase, such that this lower bound on the value of the 3G and 4G standards will likely approach the value of the respective standards.

[13] *See* Matt Monson, *Valuation Using Hedonic Pricing Models*, 7 CORNELL REAL EST. REV. 62, 62 (2009).

technologies. One can estimate the difference in the valuation of features at the time of standard formation, generating an *ex ante* estimate of the unique value of the technologies incorporated into the standard. Additional insight comes from examining different pricing levels for access to the same technology, on the basis of customer demand. For example, some mobile network operators (MNOs) might cap data access to LTE networks at some level each month. If the affected consumers wish to continue using the LTE capability, they might need to pay a supplemental fee to access more data. For example, an MNO might offer a basic data plan that includes 2 gigabytes per month of mobile data through the MNO's LTE network for $30 per month. A consumer who wishes to use more than 2 gigabytes of LTE mobile data per month can purchase another 2 gigabytes for an additional $10 (that is, such a consumer would pay $40 for 4 gigabytes per month of LTE mobile data). Examining the price that this subset of 4G consumers is willing to pay for access to LTE service (in the example, $10 for 2 gigabytes per month) will yield an estimate of the value of that access. Such an analysis will isolate the benefits of the LTE standard for accessing data—that is, it will not include the value that consumers derive from standards other than LTE. Such analysis does not violate the entire market value rule (EMVR) because it identifies the value of a feature of LTE (more efficient data usage) that arises from the technological improvements that the standard embodies.

Spectrum auctions provide additional data. The price of spectrum will reflect its value to an MNO—a value that the MNO passes on to consumers who use its network. This analysis will enable one to estimate the effect that the constraint of limited bandwidth imposes, and the price that companies would be willing to pay to loosen that constraint. Economists call this price the "shadow price" of the constraint.[14] A technical feature that causes an MNO to need to spend less in spectrum auctions than it had before decreases the MNO's cost of operation. More efficient spectrum use reduces the cost to the MNO of each LTE subscriber (relative to a WiMAX subscriber or a 3G subscriber), holding constant the amount of mobile data use per subscriber. That cost saving informs the economic value of that technical feature to the MNO and thereby approximates the MNO's

[14] *See, e.g.*, ANDREU MAS-COLELL, MICHAEL D. WHINSTON & JERRY R. GREEN, MICROECONOMIC THEORY 563 (Oxford Univ. Press 1st ed. 1995). The "shadow price" of a constraint represents the gain in terms of profits or utility that an economic actor receives when one marginally relaxes the constraint. That is, the shadow price of the bandwidth constraint shows how much additional profit the MNO gains when there is a marginal relaxation in the constraint.

maximum willingness to pay for that feature. Because LTE enables more efficient bandwidth use than older mobile standards, the prices paid for spectrum bands that can service an LTE network and the prices paid for spectrum bands that can service 3G or WiMAX networks will provide an estimate of the cost savings that LTE enables for MNOs. An MNO's cost of spectrum will include its purchase price for the spectrum, plus any upfront or annual license fees. Using those values and expected spectrum usage per subscriber, one can calculate an MNO's spectrum cost per new phone purchaser. For example, suppose that, given spectrum costs and average expected data usage, it will cost an MNO $50 less to service a new subscriber purchasing an LTE smartphone than to service a new customer purchasing a WiMAX smartphone on the same service contract. The incremental cost savings that the LTE standard offers over the WiMAX standard will approximate the MNOs' maximum willingness to pay for the technologies incorporated in the LTE standard.

In a sealed-bid auction, participants typically have an incentive to bid an amount that approximates their valuation of the object being sold. In a second-price sealed-bid auction, all bidders have an incentive to bid an amount that is equal to their valuation of the object being sold—that is, their expected value of the benefit from the object. In a first-price sealed-bid auction, all bidders have an incentive to bid an amount that is slightly below their valuations of the object being sold, but, as the number of bidders participating in the auction increases, they will have an incentive to bid amounts that increasingly approximate their valuations of the object. Consequently, the bid amounts of all participants will approach their maximum willingness to pay for the object.[15] The MNOs' willingness to pay for the technologies incorporated in the LTE standard is one estimate of the incremental value of the LTE SEPs. Again, this methodology does not violate the EMVR because it helps identify the value of a particular patented feature of the standard-compliant device—specifically, more efficient mobile data usage.

For purposes of this analysis, one needs to calculate the price paid for spectrum bands in terms of the present value of the expected spectrum usage by a new subscriber. Using only the absolute dollar amount paid for a

[15] *See* Lawrence M. Ausubel, *Auction Theory for the New Economy*, *in* NEW ECONOMY HANDBOOK 123, 130, 132–34 (Derek C. Jones ed., Elsevier Science 2003); *see also* PAUL MILGROM, PUTTING AUCTION THEORY TO WORK 10 (Cambridge Univ. Press 2004) ("The second-price sealed-bid auction . . . . presents each bidder with a simple strategic bidding problem: each merely has to determine his reservation value and bid it.").

band of spectrum might overlook either differences in the number of mobile users in the area on a particular mobile network or differences in data usage across users of different mobile networks. Mobile users who pay for access to the LTE network might have a higher demand for mobile data than mobile users who only uses 3G or WiMAX networks. Consequently, an MNO might still bid a higher absolute amount for an LTE spectrum band so as to accommodate those high-demand users, even though the LTE standard offers greater spectral efficiency. In addition, the winning bid for a 3G or WiMAX spectrum band, in absolute terms, might exceed the winning bid for an LTE spectrum band because fewer mobile users have devices capable of using the LTE network. Calculating the price paid for spectrum bands in terms of dollars per MHz per capita will filter out these potential biases and more accurately indicate the economic benefit that the LTE standard provides MNOs.

In Appendix I, I identify three measurable differences between LTE and WiMAX that allow one to estimate the incremental value of the LTE standard. Table 1 presents those differences, their advantages to the LTE implementer, and their relationship to willingness to pay (WTP).

TABLE 1: COMPARISON OF LTE AND WIMAX WIRELESS FEATURES

| **Identifiable Difference** | **Advantage to LTE Implementer** | **Identifiable Relationship to WTP** |
|---|---|---|
| Backward compatibility | Single radio in device | Cost savings to device maker |
| Spectrum usage | Better penetration, fewer towers | Cheaper for operator; higher operator WTP |
| Download speed | Better consumer experience | Higher consumer WTP |

The advantage of an approach based on actual consumer prices (compared with an approach based on survey data) is that the former will be more reliable, more precise, and more cost effective than conducting a survey-based analysis. From an evidentiary perspective, an analysis of actual consumer prices is a methodology that one can apply to the observed facts and data.

In contrast with WiMAX, LTE is backward-compatible. The cost to a device manufacturer of making a non-backward-compatible device will exceed the cost of making a backward-compatible device. This cost difference is a proxy for the cost of designing around the LTE standard. When combined with the value of other differences, it generates an estimate of the willingness to pay for LTE technology.

For many standard-compliant mobile devices, the wholesale consumer is an MNO. An increase in spectral efficiency will decrease the usage cost of a mobile device, increasing the MNO's expected profit from a particular device and thus increasing the MNO's willingness to pay for that device. The value of spectrum to an MNO is observable through prices that it has paid in spectrum auctions. An increase in the MNO's willingness to pay for a more spectrally efficient mobile device will increase a manufacturer's willingness to pay for the technology that enables that greater spectral efficiency.

In addition, faster download speeds will increase a consumer's willingness to pay for a mobile device. Consequently, an MNO's profit on the sale of a mobile device will increase, thereby increasing the operator's willingness to pay for the device. The increase in the MNO's willingness to pay for the mobile device will increase a manufacturer's willingness to pay for the patented technology. Hedonic estimation of a consumer's willingness to pay for certain features will identify the incremental value of a patented feature. One can gather data for this estimation using actual pricing plans that mobile network operators offer. Those pricing plans will reveal a consumer's valuation of faster download speeds. Taken together, faster download speeds and more efficient spectrum usage will each increase an MNO's willingness to pay for an LTE device (relative to a WiMAX device). Combined with the cost savings to a manufacturer from using LTE as opposed to WiMAX to manufacture a backward-compatible mobile device, one can calculate a lower-bound estimate of the incremental value of LTE to a device manufacturer. This estimate will be a lower bound because it is based exclusively on feature differences that one can easily identify and quantify. One can analyze additional qualitative differences to show how this incremental value is a conservative estimate.

Ultimately, one should determine the FRAND royalty for a standard by quantifying (1) the incremental increase in consumer benefits over the next-best alternative standard's technology and (2) the consumer demand for the improved technology. To estimate those benefits, one must answer the following technical question: "What improvements does the standard's technology provide that the next-best alternative standard does not?" After one answers that technical question, the economic analysis of calculating the increase in value of these features and the determination of a FRAND price for the relevant SEPs is straightforward. The calculation of a FRAND royalty will ideally use data on the market prices that consumers would be willing to pay for the enhanced features at the time of standard formation.

## IV. CONCLUSION

I have outlined a tractable and intellectually rigorous methodology by which one can calculate a FRAND royalty for SEPs incorporated in the LTE standard by using publicly available data to reveal the incremental value of the LTE standard. Table 2 summarizes my two approaches. Each approach serves as a robustness check on the other.

TABLE 2: METHODOLOGIES FOR CALCULATING A FRAND ROYALTY FOR THE LTE STANDARD

| **Competitive Standardized Product Analysis (Part II.A)** | **Feature-Specific Incremental Value Analysis (Part II.B, Appendix I)** |
|---|---|
| • Identify the market price of the standardized product | • Identify the technical differences between two standards (for example, LTE and WiMAX) |
| • Identify the profit margin of the standardized product (to reveal the value of the aggregate SEP royalty stack) | • For each identified technical difference, calculate the incremental value of the improved feature |
| • Subtract from the estimated profit margin the equivalent value for the next-best standard (to reveal the incremental value of the patented technology for that standard) | For example:<br>▪ Spectrum auction prices that MNOs pay and consumer pricing plans that vary by download speeds will reveal an increase in MNOs' willingness to pay manufacturers for devices<br>▪ Backward compatibility will reduce the cost to manufacturers of manufacturing or servicing a device |

To calculate a FRAND royalty for a single SEP holder's portfolio for a given standard, one must apportion the incremental value of the patented technologies among all of the SEP holders for that standard. The preferred method for apportioning that incremental value among the SEP holders is to identify approved contributions. If sufficient data are available, a feature-specific incremental-value analysis might facilitate more precise estimation of a FRAND royalty by estimating the incremental value of specific feature improvements associated with specific releases of a given standard.

## APPENDIX 1: COMPARISON OF LTE TO PREVIOUS STANDARDS FOR MOBILE COMMUNICATIONS

In this appendix, I analyze the technical differences between the LTE standard and previous standards for mobile communications. First, I compare LTE to WiMAX, a competing 4G standard that was commercially available in the United States before the launch of LTE. This comparison is the basis of the analysis that I propose in Part III.B. Next, I compare LTE to HSPA+, a 3G standard that Apple products used before the launch of LTE. HSPA+ is a valuable benchmark with respect to Apple products, because Apple never introduced a WiMAX-compatible product and sometimes identified an HSPA+ connection as "4G" for customers using iPhones on AT&T's HSPA+ network. Because that labeling might have caused some consumers erroneously to ascribe the features of LTE to HSPA+-compatible products, estimates of the incremental value of LTE based on HSPA+ benchmarks are conservative.

### *A. Preliminary Comparison Between LTE and WiMAX*

The LTE standard and the WiMAX standard are both mobile communication standards for high-speed data transfer for mobile devices. Although they were widely marketed as "fourth generation" standards, neither met the technical specifications of a 4G standard that the International Telecommunication Union (ITU) had established (that is, a minimum speed of 1 gigabit per second for low-mobility communication and a minimum speed of 100 megabits per second for high-mobility communication).[16]

WiMAX became the first 4G wireless communication standard to be implemented when Sprint began in 2008 to sell products implementing the WiMAX standard.[17] The ITU did not approve the LTE standard until December 2008, after Sprint already had implemented the WiMAX

[16] Igor Bartolic, *WiMAX vs. LTE – What Is a Better 4G Technology*, THEBESTWIRELESSINTERNET (Mar. 4, 2014), http://thebestwirelessinternet.com/WiMAX-vs-lte.html; Rob Triggs, *4G vs. LTE – Key Differences Explained*, ANDROID AUTHORITY (Oct. 4, 2013), http://www.androidauthority.com/4g-vs-lte-274882.

[17] Sascha Segan, *WiMAX vs. LTE: Should You Switch?*, PCMAG (May 16, 2012), http://www.pcmag.com/article2/0,2817,2403490,00.asp; *see also* Sascha Segan, *Sprint XOHM (Mobile WiMAX)*, PCMAG (Oct. 1, 2008), http://www.pcmag.com/article2/0,2817,2331479,00.asp.

standard.[18] Despite WiMAX's first-mover advantage, which tends to be crucial in industries with network effects or learning-curve effects,[19] LTE became the 4G standard of choice in the United States and in western Europe for three primary reasons: (1) Sprint was slow in building out its WiMAX network, and it was the only major U.S. carrier to adopt WiMAX on a large scale,[20] (2) to a greater extent than WiMAX, LTE offered backward compatibility with 2G and 3G standards, such as GSM, CDMA, UMTS, and WCDMA,[21] and (3) LTE enabled higher speeds.[22] Sprint and some mobile virtual network operators (MVNOs) have continued to implement the WiMAX standard in the United States.[23] However, Sprint announced in 2014 that it would cease operating its WiMAX network in November 2015.[24]

### *B. Feature Comparison Between LTE and WiMAX*

LTE and WiMAX use similar methods of encoding digital data that are based on orthogonal frequency division multiplexing (OFDM).[25] However, the two standards differ in their technical origins and practical performance. One can use these differences to identify the relative value of each technology.

#### 1. Technical Origins and Differences

One point of comparison between the LTE and WiMAX standards is backward compatibility. The LTE standard updates the existing 3G UMTS

[18] Segan, *WiMAX vs. LTE*, *supra* note 17.

[19] *See, e.g.*, DENNIS W. CARLTON & JEFFREY M. PERLOFF, MODERN INDUSTRIAL ORGANIZATION 370–71 (4th ed. 2005).

[20] Segan, *WiMAX vs. LTE*, *supra* note 17; Brad Reed, *LTE vs. WiMAX*, NETWORKWORLD (Nov. 2, 2011), http://www.networkworld.com/article/2182390/wireless/lte-vs—WiMAX.html.

[21] Bartolic, *supra* note 16.

[22] *See* Triggs, *supra* note 16 (explaining that Sprint's WiMAX network could offer speeds of only 3 to 6 megabits per second, which disappointed consumers); Bartolic, *supra* note 16.

[23] *See* Phil Goldstein, *Sprint to Shutter WiMAX Network Around Nov. 6, 2015*, FIERCEWIRELESS (Oct. 7, 2014), http://www.fiercewireless.com/story/sprint-shutter-WiMAX-network-around-nov-6-2015/2014-10-07; Rob Pegoraro, *4G Me Not: WiMAX Isn't LTE and Is Going Away at Sprint Resellers*, USA TODAY (Dec. 7, 2014), http://www.usatoday.com/story/tech/columnist/2014/12/07/WiMAX-4g-sprint-wireless/19917605.

[24] Goldstein, *supra* note 23.

[25] Bartolic, *supra* note 16.

standard.[26] Developed by the 3rd Generation Partnership Project (3GPP), which had developed the 2G GSM standard and the subsequent 3G standards, LTE is backward-compatible with the previous generations of digital wireless communication technologies. In contrast, the WiMAX standard (IEEE 802.16) belongs to the IEEE 802 family of standards and extends the WLAN (or Wi-Fi) standard.[27] WiMAX thus is not backward-compatible with the 2G and 3G standards.[28]

To implement both the WiMAX standard and the 2G and 3G standards, a mobile device must include a dual-mode radio that can access both the 2G and 3G networks and the WiMAX network. In contrast, a mobile device that implements the LTE standard and the 2G and 3G legacy standards requires only one LTE radio that is backward-compatible.[29] Even so, major players, such as Intel and Nokia, initially backed the WiMAX standard.[30] Some attribute WiMAX's slow adoption to the high cost of building its necessary infrastructure,[31] but others say that deploying a WiMAX network is less expensive than deploying an LTE network.[32] Those statements imply that it is possible that, where a 3G network infrastructure already exists, an LTE network is cheaper to deploy than a WiMAX network, and that, where no wireless network infrastructure exists, WiMAX is cheaper to deploy than LTE (because the latter presumably would require building a network that can also implement the 2G and 3G legacy standards). In the United States, where extensive 3G infrastructure already exists, deploying an LTE network is less costly than deploying a WiMAX network. That fact increases the MNO's maximum willingness to pay for LTE-compliant mobile devices.

A second point of comparison between the two standards is spectrum usage, which also affects operating costs for all MNOs. LTE uses spectrum around the frequency of 700 MHz.[33] In the United States, WiMAX typically

---

[26] Jose Vilches, *Everything You Need to Know About 4G Wireless Technology*, TECHSPOT (Apr. 29, 2010), http://www.techspot.com/guides/272-everything-about-4g.

[27] *Id.*

[28] Bartolic, *supra* note 16.

[29] *See* Reed, *supra* note 20.

[30] Segan, *WiMAX vs. LTE*, *supra* note 17.

[31] *See, e.g.*, Vilches, *supra* note 26.

[32] *See, e.g.*, Bartolic, *supra* note 16.

[33] Vilches, *supra* note 26. The LTE-Advanced standard, the successor to the LTE standard, uses spectrum from 1.4 MHz to 100 MHz. Bartolic, *supra* note 16.

uses spectrum at the frequency of 2.5 GHz.[34] The choice of spectrum bandwidth puts WiMAX at a competitive disadvantage relative to LTE. LTE's 700-MHz signals have better range and propagation, as they can penetrate buildings more effectively than can WiMAX's 2.5-GHz signals, all other factors being equal.[35] Because LTE is more cost-effective than WiMAX for the MNO with respect to spectrum usage and the number of base stations necessary for network coverage, economic analysis implies that MNOs in the United States have a higher maximum willingness to pay for LTE-compliant mobile devices than for WiMAX-compliant mobile devices. As the MNO's maximum willingness to pay for LTE-compliant mobile devices increases, the value of patents essential to implementing the LTE standard also increases.

### 2. Performance in Practice

Although LTE and WiMAX might offer the same maximum data speeds in theory, LTE outperforms WiMAX in terms of speed in field tests conducted in the United States.[36] To the extent that LTE offers faster data speeds to consumers than WiMAX does, the consumers' maximum willingness to pay for LTE-compliant mobile devices will increase. Again, as the maximum willingness to pay for LTE-compliant mobile devices increases, the value of patents essential to implementing the LTE standard also increases. As Table 3 shows, LTE's download and upload speeds exceed those of WiMAX.

[34] *See* Vilches, *supra* note 26.

[35] *Id.* ("Some experts have said that 700MHz will require as few as one-quarter as many base stations to offer identical coverage to 2.5 GHz.").

[36] *See* Reed, *supra* note 20.

TABLE 3: COMPARISON OF VARIOUS MOBILE COMMUNICATION STANDARDS ON THE BASIS OF DATA SPEEDS

| | | Average Actual Data Speeds | | Average Theoretical Speeds | |
|---|---|---|---|---|---|
| **Generation** | **Technology** | **Download** | **Upload** | **Download** | **Upload** |
| 2.5G | GPRS | 32–48 Kbps | 15 Kbps | 114 Kbps | 20 Kbps |
| 2.75G | EDGE | 175 Kbps | 30 Kbps | 384 Kbps | 60 Kbps |
| 3G | UMTS | 226 Kbps | 30 Kbps | 384 Kbps | 64 Kbps |
| | WCDMA | 800 Kbps | 60 Kbps | 2 Mbps | 153 Kbps |
| | EV-DO Rev. A | 1 Mbps | 500 Kbps | 3.1 Mbps | 1.8 Mbps |
| | HSPA 3.6 | 650 Kbps | 260 Kbps | 3.6 Mbps | 348 Kbps |
| | HSPA 7.2 | 1.4 Mbps | 700 Kbps | 7.2 Mbps | 2 Mbps |
| Pre-4G | WiMAX | 3–6 Mbps | 1 Mbps | 100 Mbps | 56 Mbps |
| | LTE | 5–12 Mbps | 2–5 Mbps | 100 Mbps | 50 Mbps |
| | HSPA+ | – | – | 56 Mbps | 22 Mbps |
| | HSPA 14 | 2 Mbps | 700 Kbps | 14 Mbps | 5.7 Mbps |
| 4G | WiMAX 2 (802.16m) | – | – | 100 Mbps (mobile); 1 Gbps (fixed) | 60 Mbps |
| | LTE Advanced | – | – | 100 Mbps (mobile); 1 Gbps (fixed) | – |

***Source*: Vilches, *supra* note 26.**

In a 2011 speed test in the United States, downloads over Verizon's LTE network had an average speed of 6.5 megabits per second (Mbps), which exceeded Sprint's WiMAX network's download speeds of between 3 Mbps and 6 Mbps.[37] Data speeds depend on the quality of the operator's network infrastructure as well as on the quality of the mobile communication standard itself.[38] Nonetheless, because LTE has become the dominant 4G standard,[39] it is unlikely that any firm would deploy a WiMAX network infrastructure to the extent necessary to outperform the existing LTE networks. Although the four major U.S. mobile network operators will largely cease to implement mobile WiMAX altogether by the

[37] *See id.* Sprint's WiMAX network also was not available on a consistent basis, although that drawback might have been due more to Sprint's network coverage than to the quality of the WiMAX standard. *Id.*

[38] *See* Segan, *WiMAX vs. LTE*, *supra* note 17.

[39] *See* Reed, *supra* note 20 ("[I]t's pretty fair to say [as of November 2011] that WiMAX is dead as a technology for consumer handsets in the United States.").

end of 2015,[40] other industries, including the smart-grid industry, might continue to use WiMAX to transmit data on private networks.[41]

### *C. Examples of Feature Comparisons Between the LTE and HSPA+ Standards*

One can compare features of the LTE standard with the features of the Evolved High Speed Packet Access (HSPA+) standard. Although the HSPA+ standard sometimes receives the "4G" moniker,[42] like the LTE standard, it does not meet the technical specifications of a 4G standard that the ITU established.[43] The HSPA+ standard builds on the 3G UMTS standard (also known as WCDMA). AT&T and T-Mobile began to implement the HSPA+ standard in 2010.[44] A commercial LTE network first launched in the United States in October 2010,[45] and Verizon Wireless was the first major U.S. carrier to offer LTE service, starting in December 2010.[46]

#### 1. Technical Origins and Differences

Backward-compatibility is an important starting point in the comparison of the LTE and HSPA+ standards because it affects the implementation

[40] *See* Goldstein, *supra* note 23 ("Sprint (NYSE:S) confirmed it will shut off service on its mobile WIMAX network on or around Nov. 6, 2015 . . . ."); Reed, *supra* note 20 ([A]lthough major U.S. wireless carriers such as AT&T and Verizon have chosen to deploy LTE over 700MHz spectrum . . . .").

[41] Reed, *supra* note 20 ("WiMAX will still find a home delivering data for a wide variety of U.S. industries including airports, oil and gas companies and the burgeoning smart grid industry.").

[42] Ankit Banerjee, *HSPA+ vs. LTE: Which One Is Better?*, ANDROID AUTHORITY (May 6, 2012), http://www.androidauthority.com/hspa-vs-lte-which-one-is-better-78120/ ("A hotly debated issue is the 4G tag offered by cellular network companies to advertise their HSPA+ networks (T-Mobile and AT&T), while most accept that it should be considered, at most, a 3.75G network.").

[43] *See id.*; Bartolic, *supra* note 16.

[44] Caroline Gabriel, *AT&T Reverses "Straight-to-LTE" Strategy*, RETHINK WIRELESS (May 18, 2010), http://www.rethink-wireless.com/2010/05/18/att-reverses-straight-to-lte-strategy .htm; Caroline Gabriel, *T-Mobile USA Prepares for HSPA+*, RETHINK WIRELESS (Mar. 12, 2010), http://www.rethink-wireless.com/2010/03/12/t-mobile-usa-prepares-hspa.htm.

[45] Segan, *WiMAX vs. LTE*, *supra* note 17.

[46] Jeffrey Nelson, *Verizon Wireless Launches the World's Largest 4G LTE Wireless Network on Dec.5*, VERIZON WIRELESS (Nov. 30, 2010), http://www.verizonwireless.com/news/ article/2010/12/pr2010-11-30a.html.

costs of the MNO or of the mobile-device manufacturer. Both the LTE and HSPA+ standards were developed by the 3GPP, which had developed the 2G GSM standard and its subsequent 3G standards (including UMTS or WCDMA). However, LTE uses OFDM[47] to encode digital data, whereas HSPA+ builds on the existing 3G UMTS (WCDMA) standard and thus uses code division multiple access (CDMA).[48] Consequently, the LTE and HSPA+ standards differ with respect to the degree of backward-compatibility with the previous generations of digital mobile communication technologies. Although implementing the LTE standard is relatively less expensive than implementing the WiMAX standard,[49] HSPA+ is even more cost-effective, because it does not require any additional construction of infrastructure.[50] To implement both the LTE standard and the 2G and 3G standards, a mobile device must include an LTE radio that can access both the 2G and 3G networks and the LTE network.[51] In contrast, implementing the HSPA+ standard does not require such a hardware change.[52]

Spectrum usage is another basis of comparison between the LTE and HSPA+ standards because it heavily influences an MNO's operating costs. LTE uses spectrum bandwidth around the frequency of 700 MHz,[53] whereas HSPA+ uses the bandwidth for the existing 3G UMTS network.[54] LTE's superior spectral efficiency relative to the existing 3G network and the HSPA+ network increases an MNO's maximum willingness to pay for LTE-compliant mobile devices and therefore increases the value of LTE SEPs.

[47] Bartolic, *supra* note 16.

[48] Alastair Brydon, *Facts and Figures on HSPA+, LTE and LTE-Advanced*, UNWIRED INSIGHT (June 17, 2013), http://www.unwiredinsight.com/2013/evolved-hspa-lte-advanced-overview.

[49] Vilches, *supra* note 26 ("The reason behind LTE's strong industry support lies in the relative ease of upgrading from the current 3G networks worldwide over to LTE mobile broadband, compared to the significant infrastructure build out that WiMAX has taken thus far.").

[50] *See* Banerjee, *supra* note 42.

[51] *See id.*

[52] *See id.*

[53] Vilches, *supra* note 26. The LTE-Advanced standard, the successor of the LTE standard, uses bandwidth from 1.4 MHz to 100 MHz. Bartolic, *supra* note 16.

[54] *WCDMA / HSPA / HSPA+ Technology*, ROHDE & SCHWARZ, http://www.rohde-schwarz.us/en/technologies/cellular/wcdma-hspa/wcdma-hspa-hspaplus-technology/wcdma-hspa-hspaplus_55946.html (last visited Jan. 23, 2016).

### 2. Performance in Practice

HSPA+ offers a higher maximum data speed than LTE in theory,[55] but LTE generally outperforms HSPA+ in terms of data speed in tests. In a 2012 study, LTE had faster download and upload speeds and lower latency than HSPA+.[56] HSPA+ might lag behind LTE in part because MNOs that implement it artificially limit its speed for network reliability reasons.[57] However, in one speed test in the United States in 2012, T-Mobile's HSPA+ network outperformed AT&T's and Verizon Wireless's LTE networks in terms of speed in some areas.[58] With respect to spectral efficiency, LTE is nearly twice as efficient as HSPA+.[59] To the extent that the LTE standard, relative to the HSPA+ standard, offers consumers faster data speeds and provides MNOs superior spectral efficiency, the maximum willingness to pay of consumers and of MNOs for LTE-compliant mobile devices increases, which in turn increases the value of LTE SEPs.

---

[55] *See* Banerjee, *supra* note 42.

[56] Brendan McWilliams, Yannick Le Pézennec & Grahame Collins, *HSPA+ (2100 MHz) vs LTE (2600 MHz) Spectral Efficiency and Latency Comparison*, XVTH INT'L TELECOMM. NETWORK STRATEGY AND PLANNING SYMPOSIUM (NETWORKS), Oct. 2012, at 3–6.

[57] *See* Jessica Sims, *HSPA+ Details Emerge*, HIGH SPEED EXPERTS (Sept. 13, 2014), http://www.highspeedexperts.com/hspaplus-details-emerge.

[58] Sascha Segan, *Fastest Mobile Networks 2012*, PCMAG (June 18, 2012), http://www.pcmag.com/article2/0,2817,2405641,00.asp.

[59] *See* Brydon, *supra* note 48.