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FirstNet: An Economic Analysis of Opting In vs. Opting Out

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Executive Summary

Congress created FirstNet to provide modern, reliable, secure, and interoperable communications for first responders during times of national and local crisis. FirstNet is charged with overseeing the construction, operation, and maintenance of the country's first interoperable, nationwide public safety broadband network (NPSBN). This new network is intended to support the needs of first responders in all states and territories in a fiscally efficient manner.

States must decide to either opt in and be fully part of the FirstNet system, or opt out and build a portion of this interoperable public safety network on their own—specifically, the towers and related equipment to access FirstNet's nationwide core network, referred to as the "radio access network" or RAN. If a state decides to opt out of FirstNet, it assumes the responsibility to construct, operate, and maintain a wireless public safety broadband RAN for at least 25 years. In order to do that, states would incur costs that include expenses associated with maintaining interoperability with the FirstNet core network; expenses associated with deploying, operating, managing, and maintaining the network, including staying in compliance with national network policies, as well as conducting ongoing upgrades; and expenses for the expert staff needed to manage the public safety state radio access network program. A state that opts out must also pay FirstNet to lease the spectrum needed to operate its RAN, as well as recurring fees to access the FirstNet core network. Finally, the federal government has to review and approve the state's network plan before it can be built to ensure that it will be technically compatible with the network FirstNet is building.

Two economists have suggested that a state that opts out of FirstNet can avoid the cost and financial risk of funding its own RAN by simply deploying a spectrum exchange to raise revenue. This paper finds that such an approach is illusory and would actually expose states to financial risk with no benefits for first responders.

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On the other hand, states that opt in to the FirstNet system will minimize financial and operational risk. They will also be providing a superior solution to their first responders. FirstNet's solution takes advantage of the scale of existing, nationwide LTE network infrastructure to deliver coverage that will likely far exceed any state-based network solution. States that opt in will also likely provide their first responders with access to new public safety broadband network technologies faster than otherwise.

Suggestions that a spectrum exchange can somehow bring states the revenue they need to build, operate, and maintain a RAN are founded on a series of incorrect assumptions and incomplete analysis. The exchange itself is risky and the benefits are illusory. Such suggestions should therefore be avoided as a basis for a state deciding whether to opt in or opt out of FirstNet.

Introduction

In February 2012, Congress passed the Middle Class Tax Relief and Job Creation Act,[1] which, *inter alia*, created the "First Responder Network Authority," otherwise known as "FirstNet." FirstNet, housed within the National Telecommunications and Information Administration (NTIA),[2] is tasked with overseeing the construction of the country's first interoperable, nationwide public safety network (NPSBN) the primary function of which is to give first responders primary access to a high speed mobile broadband network in all 50 states and six territories.

As part of its mandate to roll out the network expeditiously and efficiently, FirstNet is obliged to leverage existing telecommunications infrastructure and use commercially available equipment.[3] Going forward, it is also required to generate the funding necessary to operate, maintain, and improve the network. To do so, FirstNet is allowed to collect network user fees (e.g., from public safety entities) and lease fees from entities that seek to interconnect with its network as well as from public-private arrangements. In the latter, a commercial entity would construct, manage, and operate the network under the auspices of FirstNet, and the commercial entity would have access to network capacity on a secondary basis to provide commercial services.[4] Importantly, the fees collected by FirstNet "shall not exceed the amount necessary to recoup the total expenses of the First Responder Network Authority in carrying out its duties and responsibilities described under this subtitle for the fiscal year involved."[5]

The legislation that gave rise to FirstNet affords states the opportunity to either opt in or opt out of fully participating in FirstNet's nationwide network. States that opt in will have a dedicated, first responder network built, operated, and maintained in their state without having to incur the cost and financial risk to do it on their own. The costs to build, operate, and maintain will be shouldered by FirstNet.

States that decide to opt out of participating in FirstNet must still construct a dedicated public safety RAN in their state but will have to cover much of the cost to build, operate, and maintain it. Specifically, if a state seeks to opt out of FirstNet, the state has 180 days to develop and complete requests for proposals for the construction, maintenance, and operation of its RAN. The state must then first submit its proposal to the FCC for review and approval of the technical merits.[6] If the FCC approves, then the state must satisfy additional criteria at the NTIA.

If a state's plan to build its own first responder RAN is approved, the state may then apply for a grant from the NTIA to help offset some, but not all, of the costs to build. Further, if the state builds its own RAN, it will have to pay fees to FirstNet to interconnect its RAN with FirstNet's core network.[7] In addition, the state will have to apply to the NTIA to lease spectrum from FirstNet on which the state network must operate.[8]

Another factor of concern to the opt-out states is the fact that some read the statute mandating the establishment of FirstNet as placing limits on these states' disposition of their revenue by potentially requiring that any revenues in excess of costs be put back into the network.[9] This limitation would prevent states that opt out from earning a return on their investment.

The structure of this paper is as follows. In Section II, I briefly state my findings with regard to the technical and financial risks of opting out of the FirstNet network. In Section III, I provide an analysis of the proposed revenue raising mechanism some have suggested can be used by states to cover the costs of building their own RAN, instead of opting in to FirstNet. In Section IV, I dissect the alleged benefits this untested revenue raising mechanism is projected to produce. I then offer my concluding observations.

Synopsis of the Risks and Costs States Will Incur by Opting Out of FirstNet

Participating in FirstNet is beneficial to the states and territories that opt in because it eliminates the significant technical and financial risks a state or territory would face by opting out; that is, the states and territories would not incur any direct costs.

The technical risks of opting out flow from the need to build, operate, and maintain an up-to-date network over the initial 25-year term when radio access technology evolves very rapidly and needs continual upgrades and specialized technical knowledge to operate. The technical risks also include the need to maintain network security (i.e., cybersecurity) that satisfies the standards of the nationwide network throughout the term.

The financial risks flow from the costs of financing the opt-out states' and territories' radio access network (RAN) in the face of uncertainty about how much the NTIA would provide by way of grant dollars, and how much FirstNet will charge for leasing its spectrum and interconnecting a state RAN to its nationwide core network. Professors Peter Cramton and Linda Doyle have drafted a proposed solution to the financial risks opt-out states will face but, as explained below, the proposal is premised on a series of flawed assumptions that render it useless as a viable revenue-raising solution for states that opt out of FirstNet.

An Assessment of the Cramton-Doyle Revenue Generating Idea

The General Proposition

Radio spectrum is an integral part of any mobile wireless network, as it provides the means for subscribers to connect wirelessly to the network, a nearby base station in particular. International best practices allocate radio spectrum on the basis of spectrum licenses. These licenses provide the license holder (typically a mobile wireless network service provider) with the exclusive right to the spectrum covered by the license subject to its terms and conditions. Spectrum is often allocated through an auctioning mechanism. The FCC has allocated spectrum through ascending simultaneous multi-round auctions for the last two decades. Spectrum licenses in the United States are defined by their geographic coverage and their bandwidth. The geographic coverage ranges from nationwide licenses to regional licenses, which limit the area covered to Economic Areas (EAs) or Cellular Market Areas (CMAs).[10] Because spectrum is a finite resource, the FCC allocates spectrum blocks when a band becomes available. Consequently, spectrum is sold infrequently and in bulk. Recognizing these two basic traits of current spectrum allocation, Rivada Networks retained Professors Cramton and Doyle to devise a market design that "use[s] wireless spectrum and networks more efficiently."[11] In response, Cramton and Doyle proposed an "open wireless market," which mandates that network capacity unused by first responders (spare capacity) be made available on the open market and auctioned in forward and spot markets. As described by Rivada:

> Dynamic Spectrum Arbitrage allocates LTE network resources to wholesale buyers of wireless bandwidth, while its Open Access Market allows bidders to buy that bandwidth a year out, a month out, or in real time in response to projected demand and market conditions. The Open Access Market, modeled on the successful and proven markets for electricity supply, radically lowers the barriers of entry into the wireless market by ensuring that supply and demand are matched every hour of the day, on every cell site on a network. This in turn makes possible a wide range of new business models to take advantage of that bandwidth.[12]

Cramton and Doyle argue that such a proposal, if implemented, would provide a revenue stream for the network owner (i.e., a state that decided to opt out and construct its own RAN), create additional competition, and improve social welfare overall. It is important to note that the Cramton-Doyle market design proposal does not seem to be limited to spectrum but also includes the physical network infrastructure. As such, the proposal resembles more of a structure sharing agreement than a spectrum exchange program.

Although Cramton and Doyle argue that their spectrum exchange market proposal "is suitable in all countries," the authors emphasize that "[i]n the United States, public safety provides an avenue for open access," where the term "open access" is used to refer to the market exchange proposal.[13] In short, Cramton and Doyle advocate the use of spectrum exchanges in the form of forward and spot markets in allocating spare capacity on the RAN portion of FirstNet. My review of this proposal is therefore limited to the proposal's application to the NPSBN RAN. As the new design suggests a particularly strong upside to state-owned RANs, I further focus on this specific scenario.

The Spectrum Exchange Proposal as Applied to State-Owned RANs

Cramton and Doyle propose that the nationwide public safety network be operated as an open access network. As it appears unlikely that FirstNet will operate in that fashion, Cramton and Doyle suggest that the states and territories should opt out from FirstNet, build their own cell towers and signal backhaul (a RAN), and organize a capacity market run by an independent system operator (ISO). A state-built RAN would give public safety preemptive access rights in emergencies, but the state could also offer access to the network to commercial wireless service providers on a wholesale basis. Under the Cramton-Doyle proposal, the ISO runs the network,[14] manages the physical delivery (by interconnecting with other networks), and "plans and executes network development and performs network upgrades."[15] A state-appointed board consisting of stakeholder-affiliated and independent directors would oversee the ISO.[16] The state would also designate a "market monitor" independent of the ISO. This monitor would observe the market, identify problems, and suggest solutions to the ISO.[17]

The Cramton-Doyle proposal also describes how states would be able to raise the revenue required to cover their operating expenses, incremental capital expenditures for network upgrades, and payments for the use of FirstNet's core and spectrum. The proposal also permits for the possibility of profits to be generated from a state-run RAN. To raise revenue, the ISO could conduct three types of auctions to determine the "sale of network throughput": yearly and monthly auctions in forward markets and hourly auctions in spot markets.

Yearly and monthly forward markets

As implied by the name, forward markets are future contracts that sell network capacity a year or a month in advance. The Cramton-Doyle proposal envisions that the state ISO would determine the yearly and monthly spare capacity on the RAN and offer this capacity to third parties through an auction mechanism, a simultaneous ascending clock auction in particular. For example, if the ISO for the State of California anticipates 35% spare capacity for the upcoming year, it would offer this capacity on the yearly forward market. Third parties acquire the spare capacity through an auction. Similarly, if after the yearly auction, the same ISO determines that additional network capacity is available for an upcoming month, it would sell this spare capacity via the same mechanism.

Hourly spot markets

The spot market envisioned by Cramton and Doyle is hourly and sells spare capacity "on the spot" for an upcoming hour. The authors propose that the spot capacity also be sold via an auction process, albeit a sealed bid auction. To stay with the example above, if after selling the yearly and monthly spare network capacity, the California ISO determines that it has additional spare capacity for an upcoming hour, it can sell such capacity by soliciting sealed bids (i.e., one-time purchase offers) from third parties.

The market clearing prices for spare network capacity in both the forward and spot markets are a function of demand. If demand for the capacity exceeds the supply, the potential purchasers' maximum willingness to pay will determine the market clearing price. Cramton and Doyle refer to this scenario as "congestion pricing."[18] Naturally, not all network capacity will be in high demand. Thus, in instances where supply exceeds demand, Cramton and Doyle propose a "price floor."[19] Although the details of the proposed price floor remain unknown, the price floor functions as a reserve price below which the ISO would not sell the spare capacity. Interestingly, Cramton and Doyle propose, "[t]he price floor ideally is a nominal amount at or near zero."[20] The authors also posit setting the reserve price at long-run marginal cost.

Cramton and Doyle aver that the proposed spectrum exchange markets represent a superior solution to the current auction-based licensing model and that it would offer significant consumer benefits. First, the authors claim that it corrects the alleged "challenge" that "the spectrum auction model inevitably creates an oligopoly where the regulator has a constant fight to maintain competition and promote innovation."[21] The authors assert that their proposal would "substantially enhance competition and efficiency in mobile broadband."[22] With respect to the NPSBN RAN, the authors further assert that spectrum exchanges would "provide a secure, robust, wide-coverage platform for mobile communications supporting public safety and universal service."[23] Finally, the authors state that their proposal "provides a natural remedy for mergers, allowing operational efficiency gains while increasing competition."[24]

In support of their spectrum exchange proposal, Cramton and Doyle compare it to electricity markets. Their proposal claims that wholesale electricity markets have successfully operated on this basis for more than a decade. It further maintains that the wireless communications market setting "is much *simpler*" than the wholesale electricity market, mainly due to the fact that the latter has "lumpy" resources (power plants) that are expensive to turn on and not speedily adjustable.[25]

Cramton and Doyle further claim that the main reason such access markets do not already exist is that until recently both the underlying network technology and the wireless handsets were not sufficiently advanced to accommodate spectrum exchanges.[26] There is no existing wireless spectrum exchange in operation. In fact, according to Cramton and Doyle, only Mexico, where the dominant incumbent (Telcel) has a 71% market share and the top two service providers (Telcel and Movistar) together have a 92% share, is in the process of implementing a shared wholesale network. Cramton and Doyle do not indicate if pricing in this network would be based on a spectrum-exchange auction model.[27] A recent presentation suggests that the wholesale network in Mexico, called Red Compartida, "can freely determine both the tariffs and the services and capacities offered, which will allow it to respond to the different demands of operators in terms of quality, coverage, and capacity, among others."[28] Mexico selected a consortium to build the network in November 2016 with the goal of reaching 92% of the country in seven years. Initial operations are to start in April 2018.[29]

The Cramton-Doyle Proposal Is Likely to Create Substantial State Deficits

There have been indications that certain states are considering using the opt-out process in which the state would be responsible for building and operating the RAN and backhaul portions of the public safety network. It is my understanding that Alabama, Arizona, and New Hampshire have issued RFPs and that Colorado will issue one in March 2017,[30] California has released a Request for Information (RFI),[31] and New Hampshire has given Rivada Networks the exclusive right to negotiate a RAN buildout agreement in case New Hampshire decides to proceed with its opt out.[32]

Here I evaluate the business case of a state-owned RAN. If positive, then state taxpayers could benefit indirectly, assuming that profits are not limited to reinvestment in the RAN. Conversely, if negative, then taxpayers stand to pay for the related losses. It is important to highlight that the states have the opportunity to obtain the RAN at no direct cost to the state by opting for the FirstNet program instead of opting out and provisioning a state-run RAN. Thus, unless the indications are that the business case will be positive, not opting out is the economically rational decision.

RAN coverage and capacity revenue will likely be de minimis

A closer examination of the potential profit that the states could earn from opting out from the FirstNet program demonstrates that demand will likely be weak, leading to low revenue expectations and thus negative profits. First, the deployment of a state-owned RAN is costly. Roughly, the costs fall into several categories: (a) initial capital investment,[33] (b) operating expenses, and (c) upgrading or incremental capital expenses. To illustrate the level of investment that is required on the state level, consider the following illustrative estimates.

The overall cost of building a public safety nationwide network is not trivial; one estimate puts it at "40 billion dollars or more to build, maintain and upgrade the system" over the next 25 years. The Government Accountability Office (GAO) has cited estimates for the upfront deployment cost, ranging from $7 to $18 billion, with the top end amounting to significantly more than the $7 billion that Cramton and Doyle state Congress has allocated. These same sources estimated total costs (consisting of upfront costs as well as maintenance and operations) over the first 10 years at $12 to $47 billion.[34] I conducted my own calculations and found that $40 billion over 25 years is a realistic amount. I estimate that the initial deployment would cost approximately $16 billion, and the cost including maintenance and operating expenses would reach $35 billion over a 25-year period. There are no estimates available for the cost of technological upgrades, such as overlaying 5G on the 4G LTE network. Three states have already put out RFPs: New Hampshire, Alabama, and Arizona. I estimate that these three states can expect to pay as much as $48 million, $269 million, and $524 million, respectively.

Against these high levels of cost, the states run a high risk that capacity in both the forward and spot markets would sell at a nominal price, thereby offsetting costs only minimally. Demand for RAN capacity generally falls into two categories: coverage and capacity. Purchasers of coverage purchase the RAN throughput so they can offer coverage in a certain geographic area (e.g., a rural area in which the purchaser has no capacity). Because the four national carriers already cover much of the nation and because the smaller regional carriers, if not already affiliated with a national carrier, have roaming agreements, it is unclear that there would be sufficient demand for such coverage at prices significantly greater than nominal. Similarly, in capacity markets (e.g., Manhattan, New York City), purchasers obtain spectrum to vaccinate against temporal spikes in demand. Because the congestion pricing envisioned by the Cramton-Doyle proposal is expected to essentially cover the costs of building, maintaining, and upgrading the public safety network (i.e., all the costs not covered by the nominal prices), it is not realistic that a mobile wireless service provider would expend such large amounts on solutions that are not permanent. As described earlier, a much more realistic investment for a service provider would be to split its cell towers into smaller territories, which is currently the practice in spectrum-constrained areas. In addition, when there are foreseeable temporary spikes in demand for capacity such as those generated by major sporting events or political conventions, service providers can accommodate by using mobile cell sites.[35] Thus, realistically, a state-owned RAN can expect only modest revenues. Importantly, congestion pricing, which is the only scenario where the state makes a profit, will be rare. This means that although there will be some revenue to offset a state's costs it will likely not be sufficient to cover all of the costs. Hence, states will incur substantial deficits, which they will only be able to cover by an increase in taxes.

Additional risk factors

A state opting out faces a number of additional financial risks. These flow from both the Act itself (as well as FirstNet's interpretation of its mandate) and from the theories put forward in the Cramton-Doyle proposal. As described earlier, the Act requires that within 90 days after receiving notice of the FirstNet RAN provisioning plan for the state the "Governor shall choose whether to participate in the deployment of the nationwide, interoperable broadband network as proposed by [FirstNet] or conduct its own deployment of a radio access network in such State."[36] If a state decides to opt out, it has 180 days to "develop and complete requests for proposals for the construction, maintenance, and operation of the radio access network within the State."[37] Both FirstNet and the FCC interpret this to mean that a state must issue an RFP, receive the responses, and award a contract to a provider within this 180-day period.[38] This period is so compressed that some states have issued RFPs/RFIs prior to receiving the finalized FirstNet plans for their states.[39] Even after the FCC and the NTIA approves a state's rollout plan, the state will still be missing important information because it is at that point that it must apply for a grant from the NTIA.[40]

The Act and FirstNet's final RFP also "require deployment phases with substantial rural coverage milestones as part of each phase of the construction and deployment of the network." The FirstNet Final RFP calls for achievement of 20% of the project contractor's proposed coverage in rural areas within 12 months and 60% within 24 months. The FCC described the FirstNet buildout schedule as "aggressive."[41] Thus, a potential risk is that although the NTIA is expected to provide funds for the buildout the level is not set ahead of time and the buildout will likely occur prior to revenue flowing in any significant quantity. As part of a state's expectations regarding the level of funding that it would receive from the NTIA, it would have to consider that it would not benefit from "FirstNet plans to leverage its buying power as a nationwide network serving millions of public safety users."[42] A single state buying equipment on its own (even through a vendor) would not receive the economies of scale benefits that a buyer on the national level would.

An additional risk is that, as part of its mandate, FirstNet will charge the states for both the spectrum and the part of the network that is not state built, in particular, the network core.[43] The states will not know the level of the charge ahead of time. In addition, as reported in the trade press, FirstNet has issued a decision (legal interpretation) that requires opt-out states with high density, revenue-generating areas to contribute to FirstNet just as they would if they were part of FirstNet.[44] Thus, high revenue states could not keep any alleged "reward." This model creates little possibility for upside gain but retains the downside risk of opting out because the state would be required to maintain the RAN and be responsible for the upgrades necessary to remain interoperable with the NPSBN.[45] Thus, although the current network is going to be a 4G LTE network, forecasts predict that the next few years will see the introduction of a 5G network.

The Rivada Mercury proposal to FirstNet, which relies on Rivada Networks' dynamic-spectrum-access wholesale broadband marketplace revenue model,[46] if applied to the states, would add significant uncertainty. Not only does the Rivada revenue proposal have the issues that I previously discussed, applying it only to the selected states that may opt out would result in additional problems. In particular, it is not clear that all states could even theoretically rely on congestion pricing as, for example, the highest prices in the FCC's auction of broadcast TV spectrum for mobile wireless use were limited to broadcasters based in major metropolitan areas, such as Chicago, Los Angeles, and New York City.[47]

Crucial Details Missing from the Cramton-Doyle Proposal Confirm Its Flaws

The lack of crucial details in the Cramton-Doyle proposal severely handicaps any evaluation of the state-owned RAN concept. I discuss only a few examples of missing information required before a state can make a sound decision with regard to opting out. For instance, the proposal does not address the amount of the "nominal fee" and provides no details as to whether the authors find that demand will exceed supply (congestion), thereby resulting in auction revenues that exceed this nominal fee level. It also does not address how a state-based standalone RAN would resolve the spectrum capacity limits in the FirstNet spectrum allocation. Similarly, the proposal does not discuss how opt-out states using spectrum exchanges would integrate into the nationwide public safety network. In addition, while the proposal discusses forward auctions of one year, it provides no information on how the states would fund the necessary long-term investments needed for upgrading the public safety network.

First, the Cramton-Doyle proposal does not discuss how to define "congestion." Congestion in a mobile wireless network is not a simple yes/no situation because these networks have redundancy built into them. Recall that a mobile wireless network consists of many different components, not just the RAN. A mobile wireless user usually can reach multiple towers, which allows for dynamic routing. It is unclear from the Cramton-Doyle proposal when a single cell site would qualify as congested. Without a definition of congestion (and thus congestion pricing), it is unclear how the "nominal fee" would cover the necessary costs to maintain and upgrade the public safety network.

Second, the structure of a mobile wireless network also severely complicates defining the region to be auctioned in real time. Note that the Cramton-Doyle proposal envisions auctions of "gigabytes of data throughput in a small geographic area in a particular hour," but a geographic area is not a static concept in mobile wireless markets.[48] Cramton and Doyle recognize, "[i]n practice, however, such extreme granularity would not lend itself well to the efficient realization of the market," but they do not resolve how a geographic area would be defined.[49] In addition, in the case of opt-out states, the geographic areas would be affected by political boundaries that do not currently affect network design.

Third, the FirstNet structure allocates 20 MHz of spectrum to the first responder network. While 20 MHz of spectrum is a significant amount of capacity it still represents only about 457 simultaneous calls on a cell tower, assuming that there is no data traffic at all.[50] Since, for example Rivada, does not operate its own wireless network, the state's network would operate as a standalone, without the ability to transfer excess traffic to its own commercial network. The Cramton-Doyle proposal does not discuss how such a potential occurrence during a major first-responder event would be resolved.

Fourth, the Act requires the states that build their own RAN to integrate fully their networks into the nationwide public safety network. The Cramton-Doyle proposal, on the other hand, does not discuss how commercial transactions would work between the states that opt out and use spectrum exchanges and those that are part of an integrated public safety network covering the remaining states. Traffic between an opt-out and a FirstNet state flows in both directions. These two types of states will have completely different management and pricing structures. The ISO of an opt-out state network will manage the network but not set prices, whereas the operator of the FirstNet network will manage the network and set prices. The opt-out state's prices can range from "nominal" to "congestion pricing." Full integration of the networks is impossible until FirstNet and an opt-out state negotiate a commercial "roaming" agreement.[51] Because the roaming cost on an opt-out state's network can vary drastically for commercial users depending on many factors, for example, traffic congestion, it is not clear how the parties involved could successfully negotiate a roaming agreement. The inability to place a call outside the opt-out state would make the opt-out network one of very low value to its subscribers.

Fifth, the Cramton-Doyle proposal posits three auction periods: real-time (hourly) markets, monthly forwards auctioned before the start of each month, and yearly forwards auctioned before the start of each year.[52] Cramton and Doyle argue that the yearly auction is appropriate because "[i]n general service providers think of longer-term usage trends on a yearly basis. It therefore makes sense to offer forward products on the open access market that allow the purchase of capacity for yearlong periods."[53] This overlooks the fact that mobile wireless service providers build their networks based on a much longer horizon. For example, current spectrum auctions generally offer spectrum for 10-plus years.[54] This is to allow a service provider to make the necessary infrastructure investment and to recover that investment. The initial term for the FirstNet network extends even longer, for 25 years.[55] The Cramton-Doyle proposal offers no solution on how to bridge these differing time horizons. The electric system experience clearly demonstrates that long-term investment incentives are important. According to a Cramton paper dated April 2015, the "most challenging component of the wholesale electricity market has proven to be the long-run investment market."[56] The same paper concludes that despite proposed reforms to encourage long-term electric capacity investment: "With the exception of New England's pay-for-performance design adopted in 2014, all capacity markets suffer from performance incentives that were too weak."[57]

Without answers to the questions and other necessary information, Cramton and Doyle do not offer the states enough detail to properly evaluate their proposal for state-owned RANs as part of the NPSBN.

The Proposal Is Experimental and Exposes States to High Risk

Auctions can offer a good approach to allocating resources efficiently, as shown by the current FCC auctions of wireless spectrum. On the other hand, the Cramton-Doyle proposal is experimental and risky. The FirstNet network is specifically to support first responders in an emergency. The Cramton-Doyle paper does not highlight the fact that a state-operated RAN likely will face other costs, such as the need to maintain high levels of network reliability, quality of service, availability, and cybersecurity.[58] As Cramton and Doyle admit, their proposal is unrelated to the rollout of a public safety network, they view it simply as an opportunity to introduce their spectrum exchange proposal, that is, "[i]n the United States, public safety provides an avenue for open access."[59] The Cramton-Doyle proposal also states that only Mexico, which faces special circumstances (i.e., "[t]he chief motivation for Mexico is addressing a serious competition problem in mobile communications"),[60] has recently begun implementing a shared wholesale network although, as I discussed earlier, Cramton and Doyle do not indicate that its pricing will be based on a spectrum exchange auction model. In any case, no country has a working spectrum-exchange system.

The Revenue Projections Based on Cramton-Doyle Spectrum Exchange Are Illusory

As described, the Cramton-Doyle proposal states that significant benefits will flow from the introduction of spectrum exchanges. Specifically, that it solves a problem with the current spectrum licensing model, improves competition and innovation, ensures the secure and robust deployment of the NPSBN RAN, and allegedly "provides a natural remedy for mergers." Importantly, the proposal suggests to the states that choose to opt out of FirstNet the possibility of generating profits from selling the spare network capacity of their RAN. In this section, I review the accuracy of each of these claims.

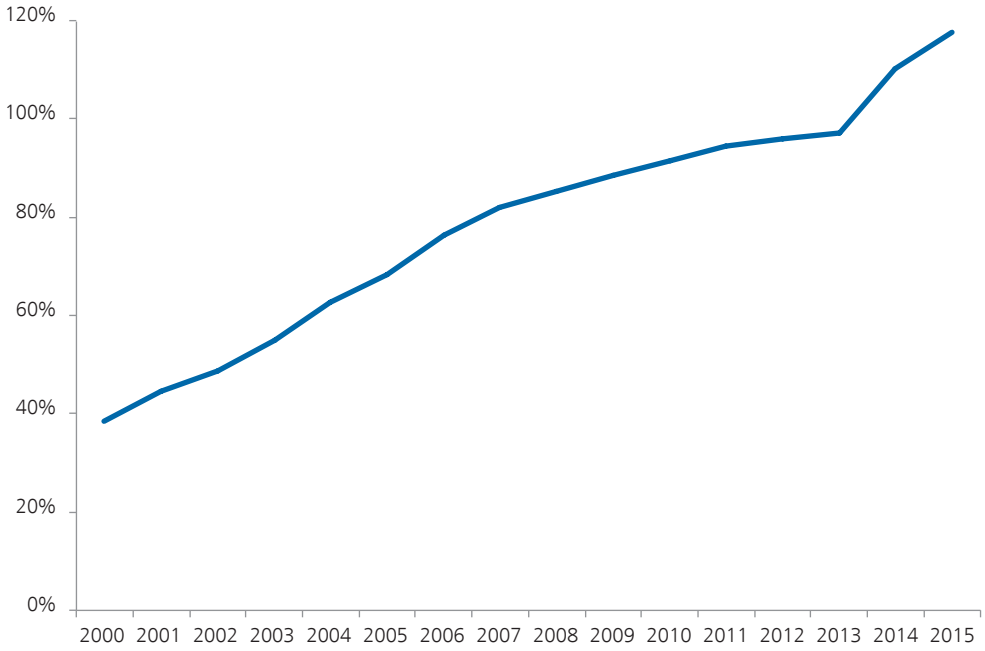
Spectrum Exchanges Will Not Increase Competition

The central impetus for the Cramton-Doyle proposal is the assumption that the current spectrum licensing model "has serious shortcomings." Specifically, the authors find:

> The main challenge is competition in the market for wireless services. Typically, there are two or three carriers that dominate the wireless market due to the enormous economies of scale in network infrastructure. A robust wireless network covering much of the US requires an investment of tens of billions of dollars for spectrum licenses and tens of billions more for physical infrastructure. As a result, the spectrum auction model inevitably creates an oligopoly where the regulator has a constant fight to maintain competition and promote innovation.[61]

The spectrum exchange model proposed by Cramton and Doyle will not increase competition for the simple reason that the U.S. mobile wireless market is already competitive at both the wholesale and retail levels. The alleged serious shortcoming of creating an oligopoly structure is incorrect. The FCC has repeatedly declared the market "effectively competitive" and has never concluded the opposite.[62] In fact, the FCC has long exempted wireless services from most regulation and used regulation only as a backstop. This approach has paid off as consumers have benefited enormously from the current wide-ranging availability of mobile wireless telephone service at competitive price levels. As Figure 1 shows, mobile wireless penetration rates have increased significantly, reaching over 100% penetration as of 2016, whereas prices have decreased sharply (see Figure 2).

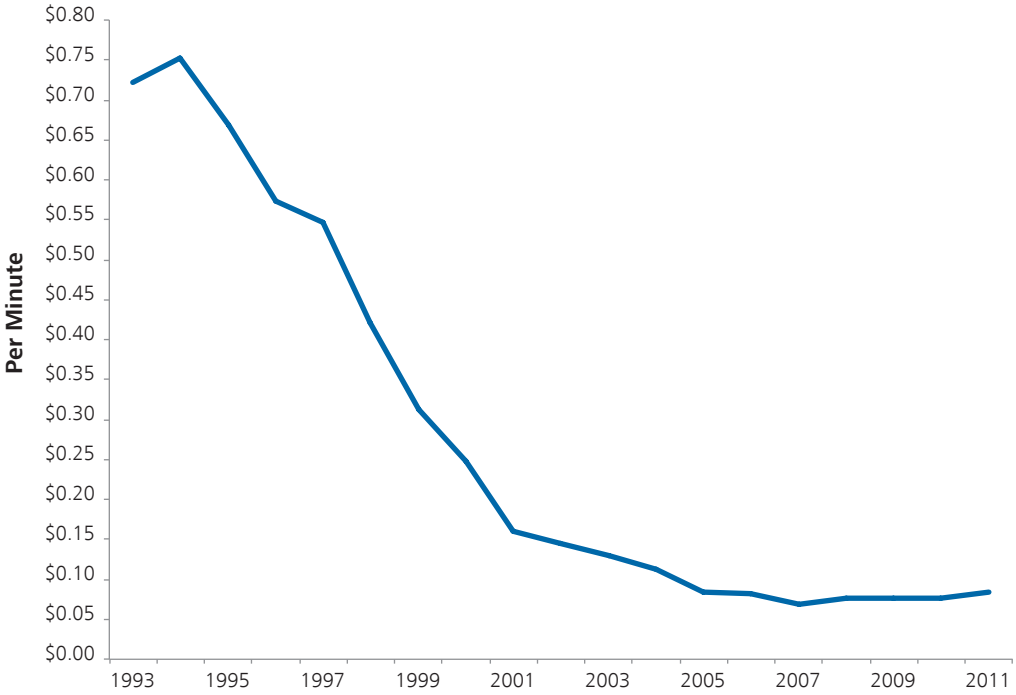
Figure 1. **U.S. Mobile-Cellular Telephone Subscriber Penetration**



Source: ITU Mobile-cellular telephone subscriptions.

As mobile wireless penetration has increased and retail prices have decreased (Figure 2), mobile wireless service providers have invested heavily in their respective networks. As shown in Table 1, cumulative capital expenditures and the number of cell sites deployed further illustrate the fierce competition in the U.S. mobile wireless market.

Figure 2. **U.S. Mobile Retail Price Levels**



Note: Retail rates include both voice and data.
Source: Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services, *Fifteenth Report*, 26 FCC Rcd 9665 (2011), Table 20 and *Sixteenth Report*, 28 FCC Rcd at 3836 (2013), Table 38.

Table 1. **U.S. Subscribers, Capex and Cell Cites**
1995 to 2015

Date	Estimated Total Subscriber Connections	Cumulative Capex ($000)	Cell Sites
	(1)	(2)	(3)
1995	33,785,661	$24,080,467	22,663
2000	109,478,031	$89,624,387	104,288
2005	207,896,198	$199,025,327	183,689
2010	296,285,629*	$310,014,852	253,086
2015	377,921,241	$462,605,007	307,626

Notes and Sources:
*Previously Restated CTIA Annualized Wireless Industry Survey Results – December 1985 To December 2015 (2016)

Additionally, U.S. service providers have deployed a series of technical improvements, often called by their generational name 2G, 3G, 4G LTE, and in the near future 5G. The 3G and 4G LTE generations in particular have significantly improved data speeds. Curiously, the Cramton-Doyle proposal acknowledges the success of the current spectrum-licensing model by stating that the current "'spectrum auction model' provides outstanding investment incentives for the carriers," yet still concludes that the resulting market is not competitive.[63]

Cramton and Doyle are also incorrect in their claim that "a chief weakness of the current mobile communications market" is the "extreme version of the 'walled garden' approach to competition" where "users face enormous switching costs to move from one garden to the next, and there are few gardens to choose from."[64] Again, this statement is simply incorrect. As shown above, the U.S. mobile wireless market is fiercely competitive—a fact that industry data strongly support and that regulators and industry participants have accepted for a long time. Similarly, the walled garden claim is contradicted by the data as there is extensive evidence that customers can and do easily switch carriers. The ability of wireless customers to take advantage of these trends is apparent from customer switching data (called "churn" in the industry). For example, the FCC reported that for 2015 the average monthly industry churn rate was 1.96%, meaning that on an annual basis 23.5% of all wireless subscribers in the United States moved from one wireless provider to another.[65]

The Cramton-Doyle proposal seems to acknowledge the competitive nature of the U.S. wireless market when it notes that unlike in Mexico where there has been a competition problem, "the key motivation for the open access network [in the U.S.] is public safety."[66] Yet, other than suggesting to the states the possibility of generating profits from a state-owned RAN, the study does not explain what problem spectrum exchanges would solve in the U.S. mobile wireless market. The Cramton-Doyle proposal attempts to solve a problem where no problem exists.

Spectrum Is Already Deployed Efficiently

One of the fundamental premises of the Cramton-Doyle spectrum exchange proposal is that spectrum is used inefficiently because it is purchased in bulk at infrequent auctions.[67] Rivada Networks, the sponsor of the Cramton-Doyle proposal, summarizes this premise in its slogan: "We can't make any more wireless spectrum but we can use it better. Much better."[68] This is an extremely overstated claim because secondary markets for spectrum are strong and thriving. Given the high cost of acquiring radio spectrum, firms (which are under investor pressure to maximize profits) have a strong incentive to use the acquired spectrum efficiently. Hence, although it is true that the licensing of spectrum is bulky and infrequent, this does not imply that firms that acquire the spectrum are not seeking to deploy and use it in the most efficient manner. A mobile wireless service provider's incentive to use spectrum most efficiently manifests itself in both network design and the use of secondary markets.

Network dimensioning addresses much of spectrum's bulkiness

As the FCC has stated repeatedly, "[m]obile wireless service providers also compete for customers on dimensions other than price, including capacity and investment, network coverage and technology, service quality…."[69] In terms of network design, mobile wireless service providers dimension their networks for busy-hour peak demand, among other things. This competitive strategy ensures that sufficient network capacity is available at each location in the network during the busiest times. If network service providers were to dimension for less than the busy-hour peak demand, subscribers would experience network congestion in the form of unsuccessful call attempts (i.e., network busy responses) and dropped calls. Furthermore, in high traffic areas, a strong inverse correlation exists between the amount of spectrum held by a mobile wireless service provider and the number of cell sites required. Generally, the more spectrum bandwidth in such areas, the lower the amount of cell sites required to meet the demand. Thus, mobile wireless service providers carefully balance the number of cell sites with the spectrum holding, thereby addressing much of the bulkiness problem described in the Cramton-Doyle proposal.

Secondary markets are active and working

Given the high cost of acquiring spectrum, mobile wireless service providers have every incentive to use it efficiently. As explained, this is done in part by dimensioning the network in accordance with the spectrum portfolio. Secondary markets further help in dealing with the bulkiness of spectrum sales and the infrequency with which spectrum is sold. Secondary markets are wholesale spectrum exchanges and exist in four general forms: (a) selling or swapping of spectrum licenses, (b) leasing network capacity to mobile virtual network and machine-to-machine (M2M) service providers, (c) leasing network capacity to facilities-based service providers, and (d) leasing network capacity from third parties with only a spectrum license.

Selling and swapping of spectrum licenses

Spectrum holders may sell or swap their spectrum to realign their holdings, subject to FCC approval. Most straight purchases are smaller service providers or spectrum holders selling to larger service providers, but there have also been larger spectrum purchases. For example, in December 2011, AT&T received FCC permission to purchase spectrum held by Qualcomm,[70] a semiconductor chip manufacturer. In August 2012, the FCC gave Verizon permission to acquire SpectrumCo holdings. SpectrumCo was a joint venture of Comcast and other cable companies. As part of the spectrum sale to Verizon, these cable companies acquired the option to sell Verizon's wireless service acquired on a wholesale basis under their own brand, that is, as a mobile virtual network operator (MVNO).[71]

The national service providers also use a combination of selling and spectrum swapping to realign their holdings. According to the industry publication *FierceWireless*, "[s]uch spectrum swaps are relatively common among the nation's wireless carriers…."[72] For example, in November 2011, Verizon and Leap Wireless announced an exchange of spectrum in which Verizon would acquire spectrum covering a population of 18.7 million (POPs) and Leap would acquire the 11 million Chicago area POPs.[73] This swap was accompanied by a separate sale of spectrum by Leap to Verizon.[74] In April 2012, Verizon "announced plans to conduct an open sale process for all of its 700 MHz A and B spectrum licenses in order to rationalize its spectrum holdings."[75] As part of that rationalization, Verizon entered into a deal with T-Mobile in June 2012 in which T-Mobile would receive spectrum in 15 of the top 25 markets covering 60 million POPs in return for Verizon receiving spectrum covering 20 million POPs as well as a payment of $2.37 billion.[76] In January 2013, Verizon entered into a deal with AT&T in which AT&T would receive spectrum in 18 states, including spectrum in Chicago, Miami, and Los Angeles, covering 42 million POPs in return for Verizon receiving spectrum in western markets as well as a payment of $1.9 billion.[77]

Leasing network capacity to mobile virtual network and M2M service providers

MVNOs also absorb network capacity of the incumbent service providers as they do not own any spectrum or other network facilities but instead purchase mobile wireless services wholesale from facilities-based providers and in turn resell these services to consumers under their own brand. Although the FCC does not currently report estimates of the number of MVNOs, there were at least 60 operating in 2010. The largest of these was TracFone with over 14 million subscribers.[78] In 2015, it had grown to 26 million subscribers, making it the fifth largest wireless provider in the United States.[79] In 2015, total MVNO subscribers were estimated at 45.1 million.[80] This compares to 59 million subscribers for Sprint and 63 million subscribers for T-Mobile.[81] TracFone absorbs spectrum from every major service provider in the United States, having deals with AT&T, Verizon, Sprint, T-Mobile, and U.S. Cellular.[82] These service providers also have MVNO deals with others. For example, Sprint has deals with Kajeet and Ting.[83] In addition, the two largest cable companies in the United States, Comcast and Charter (now called Spectrum), have activated MVNO arrangements with Verizon.[84]

Google also has a presence in the MVNO industry. Unlike TracFone where a customer's handset is linked to a particular wireless provider, Google's "Project Fi" is an MVNO in partnership with two providers—T-Mobile and Sprint—which switches Google Fi subscribers' signals between the two networks depending on which one offers the better signal.[85]

Wholesale services for M2M communications provide yet another avenue for spectrum license holders to ensure the most efficient use of spectrum. Like MVNOs, M2M service providers do not own any network facilities but instead purchase wholesale wireless data services from facilities-based providers and resell them to business customers. The service providers often report M2M and MVNO connections together. In 2013, M2M connections for AT&T, Sprint, and T-Mobile were already approximately 50% of their wholesale connections.[86] Between 2011 and 2014, the last year it broke out the detail, T-Mobile's M2M connections grew by over 80%.[87]

The current shift to the Internet of Things (IoT) applications, including a rise in smart meters and connected cars, has increased wireless service providers' M2M wholesale connections and will continue to absorb spectrum.[88] According to one of Cisco's 2016 white papers, "M2M connections will be the fastest-growing category, growing nearly 2.5-fold during the forecast period, at 20 percent CAGR, to 12.2 billion connections by 2020."[89]

Leasing network capacity to facilities-based service providers

A facilities-based provider may complement its own service offerings by buying wholesale capacity and reselling it to gain customers outside of its network coverage area or to add additional service offerings, which would otherwise not be available on its own network. For example, prior to Sprint's acquisition of Clearwire, the two companies had a wholesale relationship starting in 2008 in which Sprint provided spectrum, which allowed both companies to offer WiMAX under the Clearwire name.[90]

Leap is another example of a facilities-based reseller. In August 2010, Leap (Cricket) entered into a wholesale agreement with Sprint Nextel that allowed Cricket to offer "enhanced products and services and to strengthen and expand our distribution."[91] Although AT&T has now taken over Leap,[92] Leap's wholesale agreement with Sprint exemplifies market forces; there is a working secondary market for spectrum, which is accessible to facilities-based resellers and which ensures that spectrum resources are used efficiently. A current example is Shenandoah Telecommunications (ShenTel), which leases network capacity to Sprint.[93]

Leasing network capacity from third parties with only a spectrum license

The Cramton-Doyle proposal claims that a spectrum exchange "easily accommodates the inputs of nonservice providers. For example, a company with a spectrum license may offer some or all its spectrum to the market. This allows companies to make pure-spectrum plays and receive competitive returns on that spectrum asset without making any infrastructure investment."[94] Such an approach is already envisioned without the need to involve public safety-related spectrum. DISH Network and- its affiliates in recent years have made investments of about $15 billion in wireless spectrum, making it at this point a pure-spectrum entity.[95] Analysts view one option for this spectrum being "a wholesale deal" by which a service provider in need of spectrum enters into a leasing agreement for all or part of the spectrum.[96]

As the above facts demonstrate, the view in the Cramton-Doyle paper that there are great inefficiencies in the current spectrum-licensing model is at best overstated and likely mistaken. A working secondary market for network capacity already exists. In fact, the secondary market is a spectrum exchange, much as the one envisioned by Cramton and Doyle, albeit the result of market forces instead of a state policy directive. Most important, these secondary markets evolved and continue to evolve naturally without risking the safety network or state finances.

The Cramton-Doyle Proposal Does Not Benefit First Responders

Interestingly, Cramton and Doyle list no specific benefits from the introduction of spectrum exchanges on public safety networks. Cramton and Doyle state, "Congress has allocated $7 billion for network build. The set-aside spectrum and funds would go a long way to initiate an open access network. Major network builders and tower vendors with dominant inventory, stand ready to execute the FirstNet build. Sharing agreements with existing carriers may further speed the initial deployment of a network with unrivaled coverage."[97] Cramton and Doyle further concede, "[t]o be clear, neither public safety nor universal service are needed for the open access market,"[98] but they claim without support that structuring it as an open access network "provides funds to build, operate, and maintain a much more robust network."[99] They argue that this is so because "[t]raditional public safety networks have long suffered from poor funding."[100] However, their own statements make it clear that FirstNet will benefit from both a large public investment and the fact that a sharing agreement with an existing network provider will guarantee that, at a minimum, it will operate as a robust network because it will have to meet the commercial standards of that provider. This is already envisioned in the Act because one of its important requirements is that "to the maximum extent economically desirable, existing commercial wireless infrastructure [be used] to speed deployment of the network."[101] There is no evidence offered that the network would be more robust under a spectrum exchange structure.

The Analogy to Electricity Markets Is Misleading

Although discussed briefly before, it is important to focus on Cramton and Doyle's analogy to the electricity market. Cramton and Doyle state that their proposal is not new because "[w]holesale electricity markets have operated on these principles for more than a decade with great success."[102] Although the subject of the present study is not to fully examine the accuracy of this analogy, it is nevertheless informative to compare the electricity market with the wireless market to examine whether they operate similarly. As it turns out, the analogy between electricity markets and wireless communications markets is misplaced for a number of reasons. I focus on four main reasons; however, an in-depth exploration of the differences would include many more.

Differences in competitive dynamics

Open access to electric systems solved a particular problem: geographic dominance of the wires by incumbents at a time when the United States wanted to start competition in electric generation. The electric system connects each generator to the network and connects each electricity user directly to the network or, more often, to a monopoly utility that delivers electricity over a distribution network. This network has tremendous economies of scale such that it is usually uneconomic to have more than one in a given geographic area and although interconnected there is little geographic overlap between networks. Open access through an ISO cedes operating control of these networks to a central planner who, in addition, gives continuous orders as to which generators will be allowed to generate power at any time. By creating a fair process for running this network and prioritizing generation decisions, open access enables competition between generators.

In contrast, there are few similar economies of scale in wireless transmission. Spectrum is split between competitors so that geographic dominance by a single entity has never characterized the market. Thus, the historic impetus for equal access in electricity, fostering a transition from monopoly service to competition, is irrelevant.

Unlike a communication packet, electricity is not user-specific

The Cramton-Doyle proposal also claims that a "key difference is that the wireless communications setting is much *simpler*" than that of the electricity market.[103] In an electricity network, generators generate power into the grid and end users take power from the grid. There is no physical matching of which generators supply power to individual customers. Rather, the network is one-way (from generators to end users), ambiguously traversed (there is no directed allocation of generators to loads), unswitched (power simply flows according to voltage differentials), globally dependent (what can be generated at A or withdrawn at B is a function of the entire network and all generation and load patterns), and synchronous (the amount of power input and withdrawn must balance at all points in time). All of the financial flows are simply conventions: generators are paid based on where and when they put power into the grid (when allowed to do so) and end users (or their distribution utility) are charged a different price based on where and when they take power from the grid. The algorithms to calculate these prices are made to roughly balance. Because the ISO has no resources of its own, complicated procedures after the fact impose a strict balance that also recovers the costs of the ISO itself. Although running the transmission system and honoring numerous constraints is a difficult technical task, where the electricity flows is determined almost entirely by physics.

In complete contrast, a wireless network is two-way (senders and receivers alternate), unambiguously connected (the sender's message must arrive at the intended receiver), switched (messages pass through switches that *choose* where to send a message), globally independent (switches route around local bottlenecks), and not synchronous (messages can encounter substantial delays before reaching their destinations). A message that originates at one node of the network must actually arrive at a specific destination. The path the message takes is dynamic (depending on the specific congestion on the network) and the specific protocols employed by the switches. A message from A to B need not (and often does not) take the same path as a message from B to A. Messages routinely traverse networks owned by many different competitors with a payment structure having been determined in advance. Thus, electric and wireless networks do not operate similarly.

Timing has different meanings for the two networks

Cramton and Doyle also posit, "[a]s in electricity markets, it is necessary to assign and price network resources at each time and location to make sure that gains from trade are maximized and supply and demand balance at every time and location. This means that a time and locational 'real-time' market is the backbone of the market, standing on the foundation of open access."[104] The real-time prices that electricity generators are paid to generate and the prices that consumers (or their distribution company) pay are determined well after the moment, often days later. The reason this is feasible is that there is very little dynamic choice in the system: specifying the pattern of generation and the pattern of consumption specifies the utilization of the network, and we can work out after the fact the price signals that would exactly support that pattern of flows.

Such prices in wireless switched networks are useless. The *point* of prices in such a network is to encourage the use of less utilized facilities in *real time*. The electricity network can be run on an *ex-post* basis because it is simple: it has very little dynamic ability to adjust in real time. The wireless network has *already* been designed to adjust in real time, so using the sort of calculations used by electricity networks would be a step backward.

Unlike in the wireless sector, the ISO is a required function in an electric network

Cramton and Doyle explain their procedure: "The independent system operator (ISO) runs the network, manages physical delivery, and conducts the real-time, monthly, and yearly auctions. In addition, the ISO plans and executes network development and performs network upgrades."[105] The complex interdependence of the electricity network *requires* a central planner to authorize all network changes. Without this, changes to make the network more reliable in one place can easily make it less reliable in another without the network upgrader being responsible for the diminution in value. In other cases, a network improvement in one place creates higher reliability elsewhere in the network but because the benefits do not go to the entity upgrading the network this makes it likely that beneficial upgrades will be foregone. The ISO attempts to prioritize and select those network upgrades whose benefits most exceed costs and to allocate the costs of those upgrades to all of those who benefit.

This sort of central planning is unnecessary in wireless networks (because there are very few such obvious externalities) and would take investment decisions out of the hands of those who seek to profit from them. This would violate the clear economic principle that decisions should be put in the hands of those who have the proper incentives. We hand electricity network operations and investment decisions to an ISO not because we think it best but because we have no alternative. The same is simply not true in a competitive mobile wireless environment. Thus, Cramton and Doyle's analogy to the use of "open markets" in the electricity sector is misleading as it misses crucial differentiators between these two very different networks.

Conclusion

Relying on a spectrum exchange to raise the revenues needed to fund a state RAN is a very risky proposition for any state considering it. If the spectrum exchange idea does not work as I have suggested here, and revenues are not raised, a state that opts out will likely not be able to afford to build its own RAN. This creates a gap in the NPSBN and defeats the purpose of FirstNet, which is to ensure the creation of a nationwide, interoperable public safety broadband network in all 50 states and in the territories. It also exposes the state to additional liabilities because the legislation that created FirstNet also made it impossible for a state to simply do nothing.

Because opting in to FirstNet affords a state all the benefits of a robust network for its first responders without the financial and operational risk incurred by opting out, a cost benefit analysis leads one to the conclusion that opting in to the FirstNet system is the better choice.

About the Author

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Notes

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1 Middle Class Tax Relief and Job Creation Act of 2012, Public Law 112-96 (Feb. 22, 2012) (hereafter the Act), Sec. 6204, https://www.congress.gov/112/plaws/publ96/PLAW-112publ96.pdf.

2 Act, Sec. 6204(a).

3 Act, Sec. 6001(10) and FirstNet, About, http://www.firstnet.gov/about.

4 Act, Sec. 6208 and FirstNet, About, http://www.firstnet.gov/about.

5 Act, Sec. 6208(3)(b).

6 FirstNet, "State Decision on FirstNet's RAN Plans," http://www.firstnet.gov/consultation/state-decision-on-firstnet-ran-plans.

7 FirstNet, "Funding the Build-out," http://www.firstnet.gov/consultation/funding-the-build-out.

8 FirstNet, "Licensing FirstNet Spectrum," http://www.firstnet.gov/consultation/licensing-firstnet-spectrum.

9 Donny Jackson, "FirstNet's latest legal interpretations make opt-out less appealing to states, territories," *UrgentCommunications*, Oct. 20, 2015, http://urgentcomm.com/blog/firstnet-s-latest-legal-interpretations-make-opt-out-alternative-less-appealing-states-territory.

10 FCC, "Accessing Spectrum," https://www.fcc.gov/general/accessing-spectrum.

11 Rivada Networks, "Our Technology," https://www.rivada.com/#our-technology.

12 Rivada Networks, "Our Technology," https://www.rivada.com/#our-technology.

13 Cramton-Doyle, p. 4.

14 The state may designate a third party to conduct the buildout.

15 Cramton-Doyle, p. 5.

16 Cramton-Doyle, p. 6.

17 Cramton-Doyle, pp. 5–6.

18 Cramton-Doyle, pp. 1, 3.

19 Cramton-Doyle, p. 27.

20 Cramton-Doyle, p. 27.

21 Cramton-Doyle, p. 3.

22 Cramton-Doyle, p. 3.

23 Cramton-Doyle, p. 1.

24 Cramton-Doyle, p. 1.

25 Cramton-Doyle, p. 4 (emphasis in original).

26 Cramton-Doyle, p. 6.

27 Cramton-Doyle, pp. 29–30.

28 Wilson Rojas Sifuentes, "Red Compartida in Mexico: The Role of Government," CPR LATAM Conference, Mexico, June 22-23rd, 2016 in conjunction with CLT2016, June 20-23rd, 2016, p. 136.

29 Jude Webber, "Mexico selects winning tender for national wholesale mobile network," *Financial Times*, Nov. 17, 2016, https://www.ft.com/content/9383453f-ef0b-3745-8b77-181140ed8ae1. Rivada Networks (a bidder) was disqualified for being "non-solvent" for not submitting the bid bond in the required manner. Rivada Networks is currently suing the Mexican government. [See SCT, "The Ministry of Communications and Transportation (SCT) of the Mexican Government Announces the Result of the Evaluation of the Technical Proposals of the Tender of Red Compartida and Opens the Economic Proposals"; see also "Rivada Networks condemns the SCT's decision on the award of the Red Compartida contract," *Business Wire*, Nov. 22, 2016, http://www.businesswire.com/news/home/20161122005567/en/Rivada-Networks-condemns-SCTs-decision-award-Red.]

30 Donny Jackson, "Alabama issues RFP for public-safety LTE RAN network, says it has not made opt-out decision," *UrgentCommunications*, Sept. 20, 2016, http://urgentcomm.com/public-safety-broadbandfirstnet/alabama-issues-rfp-public-safety-lte-ran-network-says-it-has-not-mad; Donny Jackson, "Arizona becomes third state to issue RFP for statewide public-safety LTE network," *UrgentCommunications*, Sept. 28, 2016, http://urgentcomm.com/ntiafirstnet/arizona-becomes-third-state-issue-rfp-statewide-public-safety-lte-network; Donny Jackson, "New Hampshire gets five RFP bids for a public-safety LTE system, but no opt-out decision has been made," *UrgentCommunications*, Feb. 22, 2016, http://urgentcomm.com/public-safety-broadbandfirstnet/new-hampshire-gets-five-rfp-bids-public-safety-lte-system-no-opt-out; Sandra Wendelken, "Colorado to Release Public-Safety LTE RFP in Coming Weeks," *Mission Critical Communications/RadioResource International*, March 7, 2017, http://www.rrmediagroup.com/Features/FeaturesDetails/FID/728.

31 Donny Jackson, "California releases RFI for statewide public-safety LTE system," *UrgentCommunications*, Nov. 17, 2016, http://urgentcomm.com/public-safety-broadbandfirstnet/california-releases-rfi-statewide-public-safety-lte-system.

32 Donny Jackson, "New Hampshire approves contract with Rivada Networks, but state official insists no FirstNet opt-out decision has been made," *UrgentCommunications*, Sept. 8, 2016, http://urgentcomm.com/ntiafirstnet/new-hampshire-approves-contract-rivada-networks-state-official-insists-no-firstnet-opt.

33 At least a portion of the state's initial capital investment is expected to be covered by a grant from the NTIA.

34 Donny Jackson, "RFP competition should improve chances that FirstNet vision can become a reality for public safety," *Urgent Matters*, July 2016; GAO, Public-Safety Broadband Network Report, GAO-15-407: FirstNet's Public Safety Network (April 2015); Cramton-Doyle, p. 5.

35 David Steele, "AT&T Outline Plans to Use Drones for Mobile Cell Sites," *AndroidHeadline*, July 13, 2016, http://www.androidheadlines.com/2016/07/att-outline-plans-use-drones-mobile-cell-sites.html.

36 Act, Sec. 6302(e)(2).

37 Act, Sec. 6302(e)(3)(B).

38 In the Matter of Procedures for Commission Review of State Opt-Out Requests from the FirstNet Radio Access Network, *Report and Order and Notice of Proposed Rulemaking*, PS Docket No. 16-269, rel. Aug. 26, 2016, ¶ 51 (hereafter the Opt-Out NPR).

39 As explained by the State of Alabama: "Delaying the release of the RFP until that point in time is expected to be a major risk, since it is unlikely that the State would have the essential details of the Alternative Plan developed in the statutory 180 day period. Therefore, this forces states to conduct an RFP process prior to the opt-out decision. The State of Alabama has already issued its RFP due to this circumstance." (In the Matter of Procedures for Commission Review of State Opt-Out Requests from the FirstNet Radio Access Network, *Response of the State of Alabama*, PS Docket No. 16-269, undated, p. 3.)

40 "There are additional funding implications if a state receives approval to build its own RAN: … NTIA will determine eligible costs of the grant program, whether a match will be required, and funding levels." (FirstNet, "Funding the Build-out," http://www.firstnet.gov/consultation/funding-the-build-out.)

41 Opt-Out NPR, ¶ 40.

Notes

[42] FirstNet, "Guiding Principles," http://www.firstnet.gov/principles.

[43] FirstNet, "Funding the Build-out," http://www.firstnet.gov/consultation/funding-the-build-out; Licensing FirstNet Spectrum, http://www.firstnet.gov/consultation/licensing-firstnet-spectrum.

[44] Donny Jackson, "FirstNet's latest legal interpretations make opt-out alternative less appealing to states, territories," *UrgentCommunications*, Oct. 20, 2015, http://urgentcomm.com/blog/firstnet-s-latest-legal-interpretations-make-opt-out-alternative-less-appealing-states-territor; see also Donny Jackson, "Rivada's Ganley calls on FirstNet to share revenues with states, provide free service to public safety," *UrgentCommunications*, Nov. 4, 2016, http://urgentcomm.com/public-safety-broadbandfirstnet/rivada-s-ganley-calls-firstnet-share-revenues-states-provide-free-se.

[45] FirstNet, "Funding the Build-out," http://www.firstnet.gov/consultation/funding-the-build-out; Licensing FirstNet Spectrum, http://www.firstnet.gov/consultation/licensing-firstnet-spectrum.

[46] Donny Jackson, "Rivada's Ganley calls on FirstNet to share revenues with states, provide free service to public safety," *UrgentCommunications*, Nov. 4, 2016, http://urgentcomm.com/public-safety-broadbandfirstnet/rivada-s-ganley-calls-firstnet-share-revenues-states-provide-free-se.

[47] Richard Marsden and Jonathan Pike, "US 600MHz Incentive Auction Forward and Reverse Auction Rules," NERA Economic Consulting, Oct. 29, 2014, p. 4.

[48] Cramton-Doyle, p. 4.

[49] Cramton-Doyle, p. 18.

[50] A typical cell tower houses three sector antennas. Since each sector antenna is directionally separate from the others it cannot move excessive traffic to another sector antenna on that tower.

[51] Cramton and Doyle state, "Critical funding is provided through efficient congestion pricing that balances supply and demand at every time and location." (Cramton-Doyle, p. 1) "[S]pot market pricing reflects congestion. Only a nominal fee is paid for throughput at times and locations without congestion; however, during congestion throughput is priced at the value of the marginal demand." (Cramton-Doyle, p. 3)

[52] Cramton-Doyle, p. 1.

[53] Cramton-Doyle, p. 17.

[54] For example, the Advanced Wireless Services (AWS-3) auction that concluded in January 2015 had an initial license term of 12 years. (FCC, Auction 97, http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=97).

[55] FirstNet, "Arizona becomes third state to issue RFP for statewide public-safety LTE network," Sept. 28, 2016, http://urgentcomm.com/ntiafirstnet/arizona-becomes-third-state-issue-rfp-statewide-public-safety-lte-network.

[56] Peter Cramton, "Market Design in Energy and Communications," April 2015, p. 6 (hereafter Cramton Market Design).

[57] Cramton Market Design, p. 7.

[58] Donny Jackson, "FirstNet cybersecurity demands just one area that potential opt-out states should weigh carefully," *UrgentCommunications*, Dec. 20, 2016, http://urgentcomm.com/blog/firstnet-cybersecurity-demands-just-one-area-potential-opt-out-states-should-weigh-carefully.

[59] Cramton-Doyle, p. 4.

[60] Cramton-Doyle, p. 4.

[61] Cramton-Doyle, p. 3.

[62] In its *Eighth Mobile Wireless Report* through *Thirteenth Mobile Wireless Report*, the FCC included a specific finding that there was effective competition in the provision of CMRS service without defining the term "effective competition." (See, e.g., Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993; Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services, *Thirteenth Report*, 24 FCC Rcd 6185, 6310, ¶ 274.) In its most recent report, the FCC did not reach an overall conclusion or formal finding regarding whether or not the CMRS marketplace was effectively competitive but rather provided an analysis and description of the CMRS industry's competitive metrics and trends. (See FCC, In the Matter of Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services, *Nineteenth Report*, WT Docket No. 16-137, rel. Sept. 23, 2016.) Although the agency has withdrawn its explicit statement due to the complexity of the market, the agency has never found the market not to be competitive.

[63] Cramton-Doyle, p. 3.

[64] Cramton-Doyle, p. 7.

[65] Nineteenth Mobile Wireless Report, ¶ 18.

[66] Cramton-Doyle, p. 7.

[67] Cramton-Doyle, p. 7.

[68] Rivada Networks, https://www.rivada.com/.

[69] Nineteenth Mobile Wireless Report, ¶ 94.

[70] Phil Goldstein, "FCC approves AT&T's 1.93B purchase of Qualcomm's 700 MHz spectrum," *FierceWireless*, Dec. 23, 2011, http://www.fiercewireless.com/wireless/fcc-approves-at-t-s-1-93b-purchase-qualcomm-s-700-mhz-spectrum.

[71] FCC, Verizon Wireless SpectrumCo and Verizon Wireless Cox, https://www.fcc.gov/proceedings-actions/mergers-transactions/verizon-wireless-spectrumco-and-verizon-wireless-cox.

[72] Mike Dano, "Verizon and Leap trade spectrum for LTE, EV-DO buildouts," *FierceWireless*, Nov. 30, 2011, http://www.fiercewireless.com/wireless/verizon-and-leap-trade-spectrum-for-lte-ev-do-buildouts.

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[77] Dan Meyer, "Verizon Wireless completes 700 MHz spectrum sale; AT&T bolsters holdings," *RCRWireless News*, Jan. 28, 2013, http://www.rcrwireless.com/20130128/carriers/verizon-wireless-completes-700-mhz-spectrum-sale-att-bolsters-holdings.

[78] Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services, *Fourteenth Report*, 25 FCC Rcd 11407 (2010), ¶ 33.

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98 Cramton-Doyle, p. 5.

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100 Cramton-Doyle, p. 7.

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102 Cramton-Doyle, p. 4.

103 Cramton-Doyle, p. 4 (emphasis in original).

104 Cramton-Doyle, p. 15.

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