# IMPROVING BROADBAND ACCESS IN RURAL VIRGINIA

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The United States currently faces a digital divide in information accessibility, as rural communities have less access to broadband Internet services than urban communities (Prieger, 2013, p. 484-497). This disparity places rural regions at an economic disadvantage. A study by the United States Department of Agriculture (2009) found that increased broadband availability in rural counties improves employment rates and income growth (p. 21-22). Thus, without broadband access, rural communities can experience reduced economic development. The technical project and STS research present two distinct methods that aim to narrow the digital divide and reduce this economic disadvantage.

The technical project provides a proof of concept for techniques improving reliability in the Internet of Things (IoT), the network of connected devices (International Telecommunication Union, 2017, Volume 1, p. 99). The result is a prototype for a fleet tracker system that uses two emerging technologies, solar energy harvesting and a frequency modulation scheme called LoRa (Semtech, 2015). The prototype demonstrates that these two techniques can improve resilience in the IoT. In the context of the digital divide, the technical project shows that LoRa-based wireless communications can transfer information without broadband service, enabling independence from broadband access.

The STS research analyzes the factors contributing to the limited broadband availability in rural Virginia from a sociotechnical perspective. The analysis uses Michel Callon and John Law's (1989) Actor-Network Theory framework, with a focus on the interactions between the global and local networks. The research aims to reveal that, in order to ensure the success of broadband initiatives across the United States and in Virginia, an established actor must moderate communications between the two networks.

The technical and STS solutions, although distinct, share a common goal to narrow the digital divide. Together, the technical project and STS research present a technical and sociotechnical solution to the digital divide. There is loose coupling between these two projects. Although the research topic does not address the LoRa technology specifically, it answers why such a technique is necessary in rural environments. Additionally, an analysis of the factors contributing to low rural broadband access can help engineers ensure that new communications methods are reliable in all environments.

## IMPROVING BROADBAND ACCESS IN RURAL VIRGINIA

Broadband Internet availability in rural regions is often much weaker than in urban areas, creating a digital divide in information access (Prieger, 2013, p. 484-497). In Virginia specifically, this divide is large. The Federal Communications Commission (FCC) defines fixed broadband as services with a minimum download speed of 25 Mbps and a minimum upload speed of 3 Mbps (U.S. Federal Communications Commission, 2018). According to these guidelines, 97.2% of urban Virginians have access to rural broadband, compared to only 71.1% of rural Virginians (Virginia Association of Counties, 2018a). This digital divide is evident in Figure 1 on page 3, which shows the regions in Virginia that lack access to broadband Internet.

Such a disparity hinders economic progress in rural Virginia. The United States Department of Agriculture (2009) has found a positive correlation between broadband availability and economic success in rural regions (p. 21-22). For example, according to Virginia's Secretary of Commerce and Trade, the lack of broadband access has kept businesses

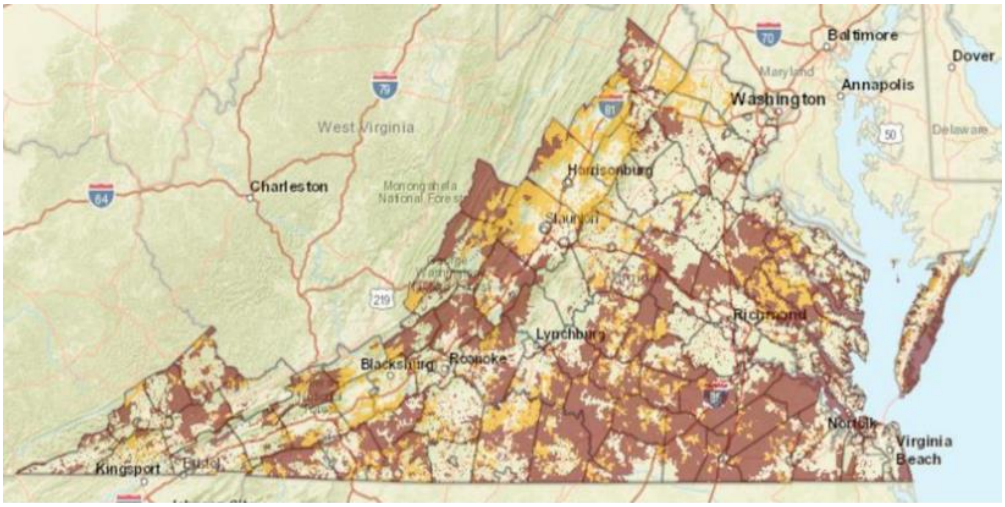


Figure 1: Broadband Coverage in Virginia: A large portion of Virginia communities lack broadband access (Adapted by Vivian Lin from Virginia Association of Counties, 2018b).

out of Virginia's rural areas (as cited in Virginia Office of the Governor, 2019, para. 5). This trend places rural communities at a natural disadvantage compared to urban populations.

Understanding why rural broadband access is so limited can help to close this divide and reduce economic disparities. One way to perform this analysis is through Michel Callon and John Law's (1989) Actor-Network Theory (ANT) framework. By applying the ANT framework, such an analysis can illuminate a solution to the rural broadband problem, helping to bring broadband to rural Virginia.

## APPLYING THE ACTOR-NETWORK THEORY FRAMEWORK

The rural broadband problem involves several parties influencing and acting upon each other, such as the broadband technology itself, local communities adopting the technology, Internet service providers, and government regulators (Ali and Duemmel, 2019, p. 384; Cramer, 2016, p. 998, 1003-1004; Galaviz, 2017, para. 3; Martin, 2018; Utility Facilities Act, 2016). These actors and actants fall into two categories. One network of actors and actants creates the supports and blockades, legal or financial, for rural broadband service. The other network uses this scaffolding to implement the rural broadband service.

Michel Callon and John Law's (1989) Actor-Network Theory (ANT) provides a fitting framework for understanding this structure of actors and actants. According to Deborah Johnson, a professor of Applied Ethics at the University of Virginia, ANT "takes as its unit of analysis the systems of behavior and social practices that are intertwined with material objects... [It] emphasizes the presence of many actors, human and nonhuman" (Johnson, n.d.-a; Johnson, n.d.-b, p. 1792). Additionally, Actor-Network Theory can consider both a global and a local network of such actors. The global network constructs the supporting conditions in which the local network implements a technology (Law and Callon, 1998, p. 289). In the rural broadband problem, the actors and actants include the broadband technology, local communities, Internet service providers, and government regulators. These parties split into a global network and a local network. The global network creates supports and blockades for rural broadband service, while the local network implements the rural broadband service.

## PRIOR LITERATURE USING ACTOR-NETWORK THEORY

Prior research has used some element of Actor-Network Theory to analyze the factors contributing to limited rural broadband access. In 2016, Benjamin W. Cramer, a researcher at the College of Communications at Pennsylvania State University, considered the interactions between federal government policies, telecommunications service providers, and the American legal system (p. 996-997). Ali and Duemmel (2019), researchers at the University of Virginia Department of Media Studies, similarly analyzed the role of federal government regulators in supporting rural broadband access. They treated these regulators as a polycentric regulation regime, or a network of interdependent actors (pp. 381). The works of Cramer, Ali, and Duemmel modeled rural broadband access as a single global network. Existing research has also considered local networks, which affect the implementation of broadband infrastructure. For example, Durban Institute of Technology researchers Andrew and Petkov (2003) outlined key networks that can influence telecommunications infrastructure, including technical, local cultural, and political networks (p. 79-80, 82-84). Unlike Cramer, Ali, and Duemmel's research, the work of Andrew and Petkov acknowledged the presence of a local cultural network. Together, these prior analyses define a global network and local network in the general rural broadband problem.

Combined with additional research, prior literature also helps to establish the networks of the broadband problem in Virginia, specifically. As Ali and Duemmel (2019) discussed, actors in the global network include federal government agencies and federal policies. They introduced federal agencies, such as the Rural Utilities Service, as actors in the global network. These agencies provide financial support for actors in the local network to implement rural broadband services (p. 384). The Virginia state government and its policies are also global actors. The

Utility Facilities Act (2016), outlined in the Code of Virginia, enacted roadblocks to municipal broadband service. A Virginia General Assembly bill similarly placed several restrictions on approval for municipal broadband facilities (Galaviz, 2017, para. 3). Thus, the Virginia state government and its policies support private broadband providers over public providers in the implementation of rural broadband services.

Actors in the local network of rural Virginia broadband access include service providers, local governments, local communities, and cultural perceptions of local communities. According to Cramer (2016), outdated government regulations have allowed telecommunications providers to neglect universal service obligations and ignore their legal responsibility to implement rural broadband services (p. 998, 1003-1004). This has pushed local governments in Virginia to establish their own municipal broadband services (Galaviz, 2017, para. 8; Martin, 2018, para. 4, 7). Finally, local views, grounded in a respect for culture and heritage, have slowed progress in implementing broadband service in rural Virginia. For example, residents and administrators in Albemarle County, viewing the County's lands as both historic and scenic, have opposed the physical infrastructures often necessary to establish broadband service (Albemarle County, 2000; Martin, 2018, para. 15-16).

Although existing literature allows for insight into the local and global networks, it does not provide a wholistic view of the rural broadband problem in Virginia. Figure 2 on page 7 illustrates this, showing an aggregate framework that combines the methods of prior analyses, and applying it to the actors in Virginia's rural broadband problem. As seen in Figure 2, existing literature treats the global network and local network as independent, ignoring the relationship between them. Cramer, Ali, and Duemmel considered only the global actors, such as federal government policies and agencies. Additionally, although Andrew and Petkov discussed a local

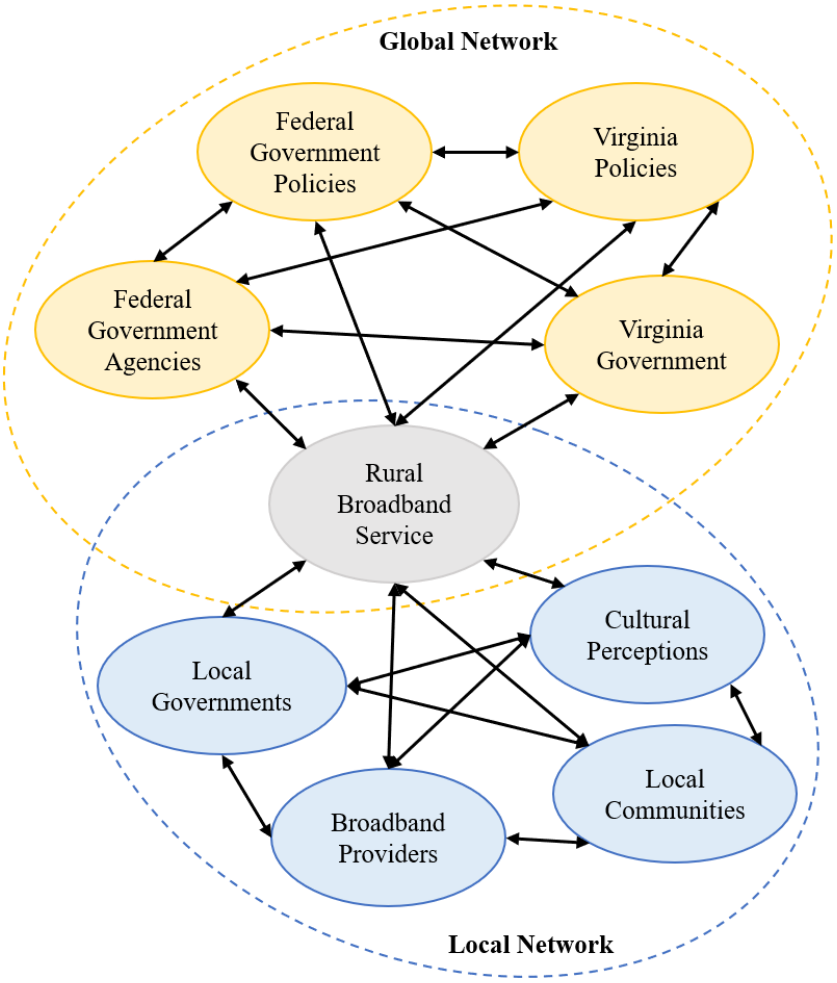


Figure 2: Actor-Network Theory Analyses in Prior Research: Existing literature treats the global and local networks as independent, without any interaction between the two (Lin, 2020a).

cultural network, they failed to consider how the relationship between the local and global networks, in addition to the networks themselves, influence the spread of telecommunications technologies. The STS research aims to fill this gap in existing methods. To do so, it is necessary to develop a model for the interactions between the two networks.

## MODELLING INTER-NETWORK INTERACTIONS

Understanding how the global and local networks best interact can answer why past universal broadband initiatives have failed and how future initiatives can be more successful. Two case studies using the Actor-Network Theory (ANT) have explored such interactions between the global and local networks. In 1998, Law and Callon applied ANT to a failed British military aircraft project and considered the flaws in the network that led to the project's cancellation. Jolivet and Heiskanen (2010) similarly used ANT to understand the factors that

created major delays in a French wind energy project. In both analyses, the authors stressed the need for an actor that moderates interactions between the global and local networks. Specifically, this moderating actor must receive ideas from one network, reinterpret them relative to the language and expectations of another network, and pass the translated message on to this other network. In other words, the moderating actor must bridge the contexts of the global network and local network to ensure the smooth transmission of ideas from one network to the other.

In their discussions of the military aircraft project, Law and Callon (1998) introduced their version of the moderating actor, the "obligatory point of passage" (p. 290). The obligatory point of passage must work within a "negotiation space," or an "area of relative autonomy" from external influences. In this negotiation space, the obligatory point of passage constructs the local network according to the global network's needs (p. 289). In the case of the military aircraft project, the global network, consisting of the British Treasury, the Royal Navy, and the Royal Air Force, established the technical specifications of the aircraft (p. 286). Besides these high-level directions, the global actors played a minimal role in the construction of the aircraft. Instead, they designated two firms as project managers, who oversaw the implementation of this technology. The project managers chose the designers and subcontractors, creating a local network, that would build the aircraft. Ideally, the project managers were to act as the obligatory point of passage between the global network and local network. Given the freedom from the global network to guide the project, the local managers selected local actors to construct the aircraft according to the global actors' specifications. In Law and Callon's terms, the global network provided the managers a negotiation space, in which the managers were able to autonomously construct a local network (p. 289-290). However, neither of the firms appointed as project managers were able to establish their own authority as the obligatory point of passage,

often facing interference from a number of outside agency committees (p. 290-291). With the failure to establish an obligatory point of passage, and with the project managers lacking the autonomy afforded in a negotiation space, the aircraft project ended prematurely.

Jolivet and Heiskanen (2010), researchers from the University of Toulouse I Capitole and Helsinki School of Economics, respectively, also emphasized the importance of a moderating actor that bridges contexts. They called this bridging by another name, "framing" (p. 6748). When a global network presents new ideas to a local network, some moderator must first reinterpret these ideas to align with the needs and desires of the local network. The result of an inaccurate framing is "overflow," in which negative consequences occur from local actors behaving unexpectedly and outside the bounds of the framing (p. 6749-6751). In the wind energy project, such a conflict in framing between the project manager and local communities caused major delays. While the manager pushed to frame the project location as a symbol of emerging technologies and the future of energy, local officials wished to frame a nearby town as a historical site. Ultimately, this difference led to deviation from the original project plan and long stalls in progress (p. 6749-6751).

Although Law and Callon's ideas differ slightly from those of Jolivet and Heiskanen, there is a common key argument. Law, Callon, Jolivet, and Heiskanen's works agreed that an actor must bridge the contexts of the global network and the local network. The actor can accomplish this in one of two ways. According to the guidelines of Law and Callon (1998), the actor can construct the local network to align with the global network's existing framing (p. 289). Alternatively, along Jolivet and Heiskanen's (2010) suggestions, the actor can construct the framing to align with the existing local network (p. 6749-6751). In the case of the rural broadband problem, there is a pre-existing local network. Thus, the moderating actor must frame

the project according the local network's context. Wihlborg and Soderholm (2013) called this moderating actor, who constructs the framing, the "mediator" (p. 268).

While Law and Callon (1998) and Jolivet and Heiskanen (2010) argued for the necessity of a mediator, Elin Wihlborg and Kristina Soderholm (2013) introduced a model that concretely qualifies the role of the mediator. According to Wihlborg, a researcher in the Department of Management and Engineering at Linkoping University, and Soderholm, a researcher in the Department of Business Administration at the Lulea University of Technology, a successful mediator must fulfill four requirements. Mediators must

1. translate rather than transfer specific knowledge,
2. function as a single entrance for knowledge,
3. support the selection process through their interpretative competencies, and
4. bridge knowledge in unforeseen ways (p. 270).

The works of Jolivet and Heiskanen and of Law and Callon support Wihlborg and Soderholm's model, and they provide specific methods for mediators to fulfill these requirements. Wihlborg and Soderholm's (2013) model first required that a mediator translate knowledge to fit the context of the receiving actor, rather than simply transferring it unaltered (p. 269). In their analysis, Jolivet and Heiskanen (2010) discussed a method, framing, that can accomplish this translation (p. 6749-6751). Wihlborg and Soderholm (2013) also argued that there should only be a single mediator through which the global and local networks pass ideas (p. 269). Law and Callon (1998) similarly noted the importance of having a lone mediator. Analyzing the military aircraft project, they found that "the autonomy of the negotiation space was eroded because no one agency was able to impose itself as an obligatory point of passage between the global and the local network" (p. 292). As this case demonstrates, having a single mediator is necessary to preserve autonomy within the negotiation space and successfully construct a local network. Finally, Wihlborg and Soderholm's (2013) final two points asserted

that the mediator must select an appropriate method to bridge contexts, and the mediator can do so in potentially unpredictable ways (p. 269). Law and Callon (1998) introduced the negotiation space, which can allow mediators the freedom to accomplish this (p. 289). The negotiation space affords mediators isolation from outside influences, which is necessary to perform this bridging in such a way that will truly satisfy the local network.

Wihlborg and Soderholm's model delineates what is necessary for mediators to successfully bridge the local and global contexts, while the works of Jolivet and Heiskanen and of Law and Callon demonstrate how mediators can accomplish this in practice. Combining these ideas, an adjusted model for optimal inter-network interactions emerges. A mediator must fulfill Wihlborg and Soderholm's four requirements using Jolivet and Heiskanen's idea of framing and Law and Callon's concept of a negotiation space:

1. The mediator must translate ideas by framing them according to the contexts of the receiving local network (Jolivet & Heiskanen, 2010, p. 6749-6751; Wihlborg & Soderholm, 2013, p. 269).
2. The mediator must be the only point of access for interactions between the global and local networks (Wihlborg & Soderholm, 2013, p. 269).
3. The mediator must bridge contexts appropriately and sometimes unexpectedly within the autonomy of a negotiation space (Law & Callon, 1998, p. 289; Wihlborg & Soderholm, 2013, p. 269).

Applying this model to the rural broadband problem provides insight into why previous rural broadband initiatives have failed and how future initiatives can be more successful.

## THE CURRENT STATE OF RURAL BROADBAND INITIATIVES

Past and current initiatives have provided tools for the global network and local network to interact. However, the two networks do not interact correctly, as defined by Wihlborg and Soderholm's model. Considering previous efforts to bring broadband to rural communities, two

problems become clear. The first problem is the reliance of global actors on subsidies. The second is the failure of mediators to satisfy Wihlborg and Soderholm's model.

**Reliance on Subsidies**

Actors in the global network primarily rely on subsidies to promote rural broadband service (Jayakar, 2017, p. 18-19). This use of subsidies violates Wihlborg and Soderholm's (2013) requirement that the mediating actor translate ideas. Evaluating this choice in the context of the actors' ethical justifications, the violation of the model becomes clear. For example, in supporting universal broadband access, the FCC has used ethical justifications consistent with rule-utilitarianism. According to Mike W. Martin and Roland Schinzinger (2010), professors at Chapman University and the University of California, Irvine, respectively, rule-utilitarianism is the theory that ethical actions should follow rules that maximize good (p. 56). In its 2019 Broadband Deployment Report, the FCC cited motivations for universal broadband service that aligned with these views of rule-utilitarianism. The communication agency declared, "Modern society is an increasingly digital one, and accessing advanced services is essential to ensuring that all Americans can participate and thrive. We remain committed to ensuring that all Americans... have the benefits of a high-speed broadband connection" (U.S. Federal Communications Commission, 2019, p. 2). In other words, the FCC aims to improve the lives of all Americans through broadband access, maximizing the good of the public.

However, utilitarianism allows for subjectivity in defining what is "good" (Martin & Schnizinger, 2010, p. 55). The FCC can choose to define "the good of the public" in multiple ways. For example, the agency can associate public good with enabling traditional providers to supply rural broadband service. The FCC can also define public good as finding alternative

means to bring broadband to rural areas. By using subsidies, the FCC has chosen to support traditional providers rather than more unconventional approaches, and it defines maximized good as maximized benefits to private Internet service providers. The FCC therefore, in attempting to carry out the global network's plans for universal broadband access, only reinterprets these plans to fit the needs and desires of the Internet service providers. It ignores the other local actors in the rural broadband problem, the local governments, local communities, and cultural perceptions. The FCC's use of subsidies, justified by rule-utilitarianism, violates Wihlborg and Soderholm's (2013) requirement that some actor translates ideas from the global network to fit the contexts of a local network (p. 269).

**Failure to Fit the Model**

Current interactions between the global and local networks also fail because mediators have not satisfied all four requirements of Wihlborg and Soderholm's model. Ali and Duemmel (2019) introduced three global actors who could have acted as mediators between the broadband networks. However, none of these actors fulfilled all of Wihlborg and Soderholm's (2013) four requirements for a mediator.

Ali and Duemmel (2019) first identified the Rural Utilities Service (RUS) as a potential but unsuccessful mediator. According to Ali and Duemmel, the RUS faced constant criticism for the way it handled its broadband initiatives (p. 386-387). To preserve its reputation, the RUS attempted to redefine its role from policymaker to bank. This uncertain role only made the RUS less successful in implementing rural broadband initiatives (p. 387, 391). Additionally, the RUS's initiatives were intertwined with the FCC's Connect America Fund (CAF). Any changes to the CAF affected the RUS (p. 386-387). These factors in the RUS's failure to bring broadband

to rural America are symptoms of the absence of a negotiation space. The RUS, open to the outside influences of its critics and the FCC, lacked the autonomy available in a negotiation space necessary to implement its initiatives.

Ali and Duemmel (2019) also named the FCC as a potential mediator. However, the FCC was similarly unsuccessful because it lacked a negotiation space. The RUS had a large influence on the FCC's policies, "a consistent voice before the [Federal Communications] Commission... It positioned itself as a major stakeholder in [the FCC's Universal Service Fund]... RUS went to pains to remind the FCC of its legislative authority in this domain" (p. 389). With the RUS attempting to exercise authority over the FCC's policies, the FCC did not have the autonomy that is available within a negotiation space. Additionally, since the RUS and the FCC had similar responsibilities, both potential mediators violated Wihlborg and Soderholm's (2013) requirement that there be a single mediator.

Finally, according to Ali and Duemmel (2019), state governments were potential mediators. The RUS once argued that "the [Telecom Act of 1996] calls for a coordinated federal and state universal service support system where state support mechanisms were intended to augment federal support mechanisms" (as cited in Ali & Duemmel, 2019, p. 389). This statement implies that state governments should act as mediators between their respective state-wide local networks and the global networks, translating global policies to fit the local context. However, once again, state governments have not had the autonomy and negotiation space necessary to fill this mediating role. For example, in 2016, the FCC claimed authority to preempt laws in Tennessee and North Carolina (Fisher, 2016, para. 1-3). In attempting to interfere with state broadband policies, the FCC has stripped state governments of their negotiation spaces.

**Unsuccessful Mediators**

The reliance on subsidies and failures to satisfy Wihlborg and Soderholm's model expose why mediators have been unsuccessful. Together, the two problems violate each of Wihlborg and Soderholm's four requirements for a mediator. In relying on subsidies, the FCC fails to translate ideas from the global network according to the needs of individual local networks. Additionally, actors have not had the negotiation space necessary to be a mediator, or too many actors have attempted to act as a mediator. Figure 3 illustrates the current state of interactions between the global and local networks of the rural broadband problem. Multiple mediators, influencing each other, transfer ideas between the global network and the local network.

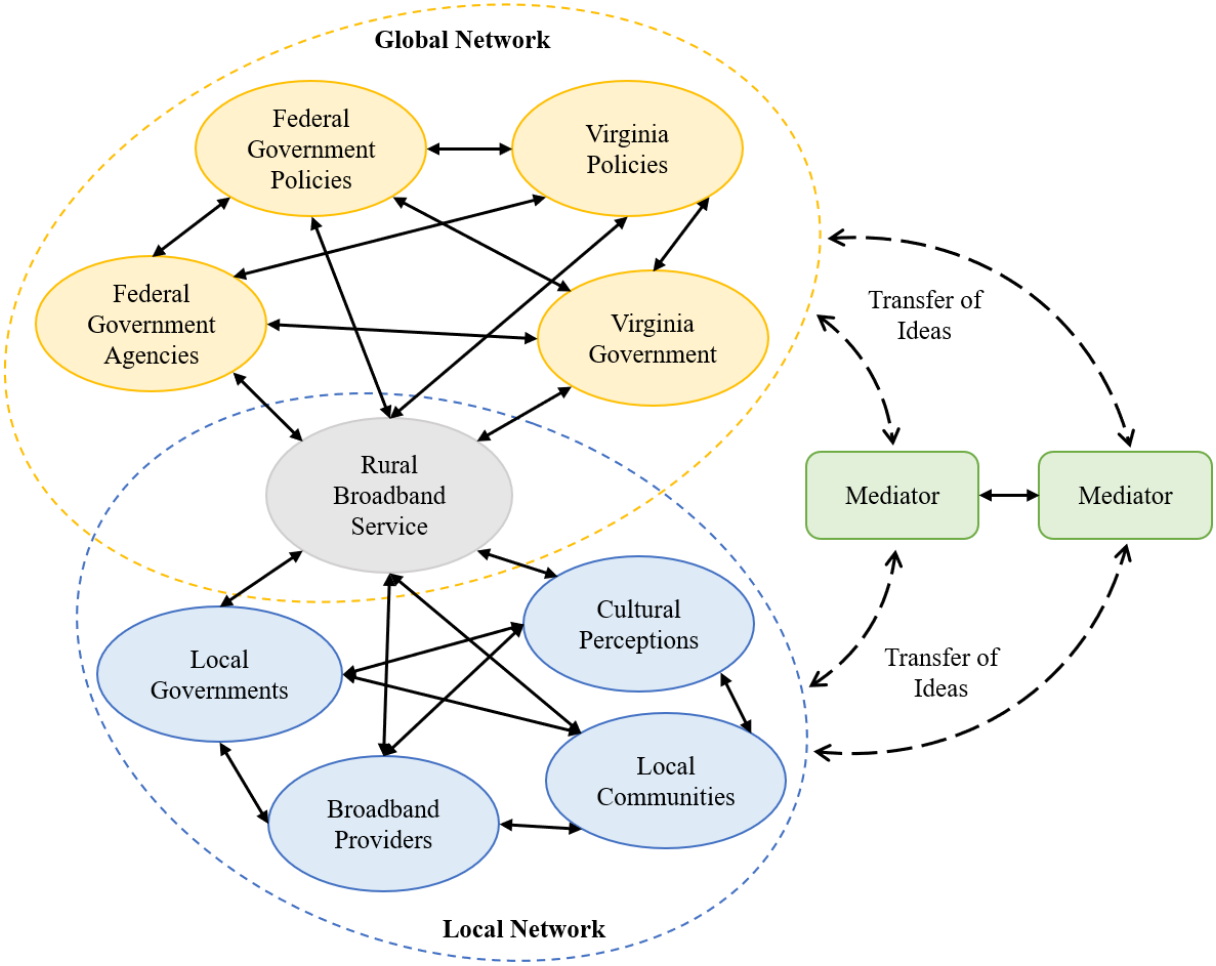


Figure 3: Actor-Network Visualization of the Rural Broadband Problem: Multiple mediators exist between the two networks, influencing each other and transferring ideas rather than translating them (Lin, 2020b).

## IMPROVING RURAL BROADBAND INITIATIVES

From Wihlborg and Soderholm's (2013) model, as well as the research of Jolivet and Heiskanen (2010) and of Law and Callon (1998), an adjusted model dictates that a mediating actor must satisfy three requirements:

1. The mediator must translate ideas by framing them according to the contexts of the receiving local network (Jolivet & Heiskanen, 2010, p. 6749-6751; Wihlborg & Soderholm, 2013, p. 269).
2. The mediator must be the only point of access for interactions between the global and local networks (Wihlborg & Soderholm, 2013, p. 269).
3. The mediator must bridge contexts appropriately and sometimes unexpectedly within the autonomy of a negotiation space (Law & Callon, 1998, p. 289; Wihlborg & Soderholm, 2013, p. 269).

Considering this adjusted model, as well as past and current rural broadband initiatives, two solutions for improving future broadband initiatives emerge.

First, in order to satisfy the first requirement of the model, a mediator should seek alternative methods to subsidies for rural broadband support. Subsidies maximize the good of private service providers, but do not consider other local actors within the local network. Thus, subsidy-based policies do not translate global ideas to fit the needs of certain local contexts.

Second, state-level agencies should act as mediators between the global network and their respective state-wide local networks. In the United States' three layers of government, the state government sits between the federal government and local government. Thus, it is in a natural position to create independent agencies mediating between the global and local networks. This idea of establishing a state-level mediator is not new. The RUS argued that state governments should play a role similar to a mediator, adjusting federal policies to fit state-specific needs (Ali & Duemmel, 2019, p. 389). That is, state governments must translate ideas from the global network to fit the context of the local network. However, to reduce influence from outside forces, state governments should establish independent agencies to act as these mediators, instead of

acting as mediators themselves. Such agencies must have a negotiation space and act as the sole mediator between the global network and its respective local network. Figure 4 illustrates this solution applied to the rural broadband problem in Virginia. The Virginia state agency acts as a single mediator between the global network and the local network, uninfluenced by other mediators and translating ideas between the two networks.

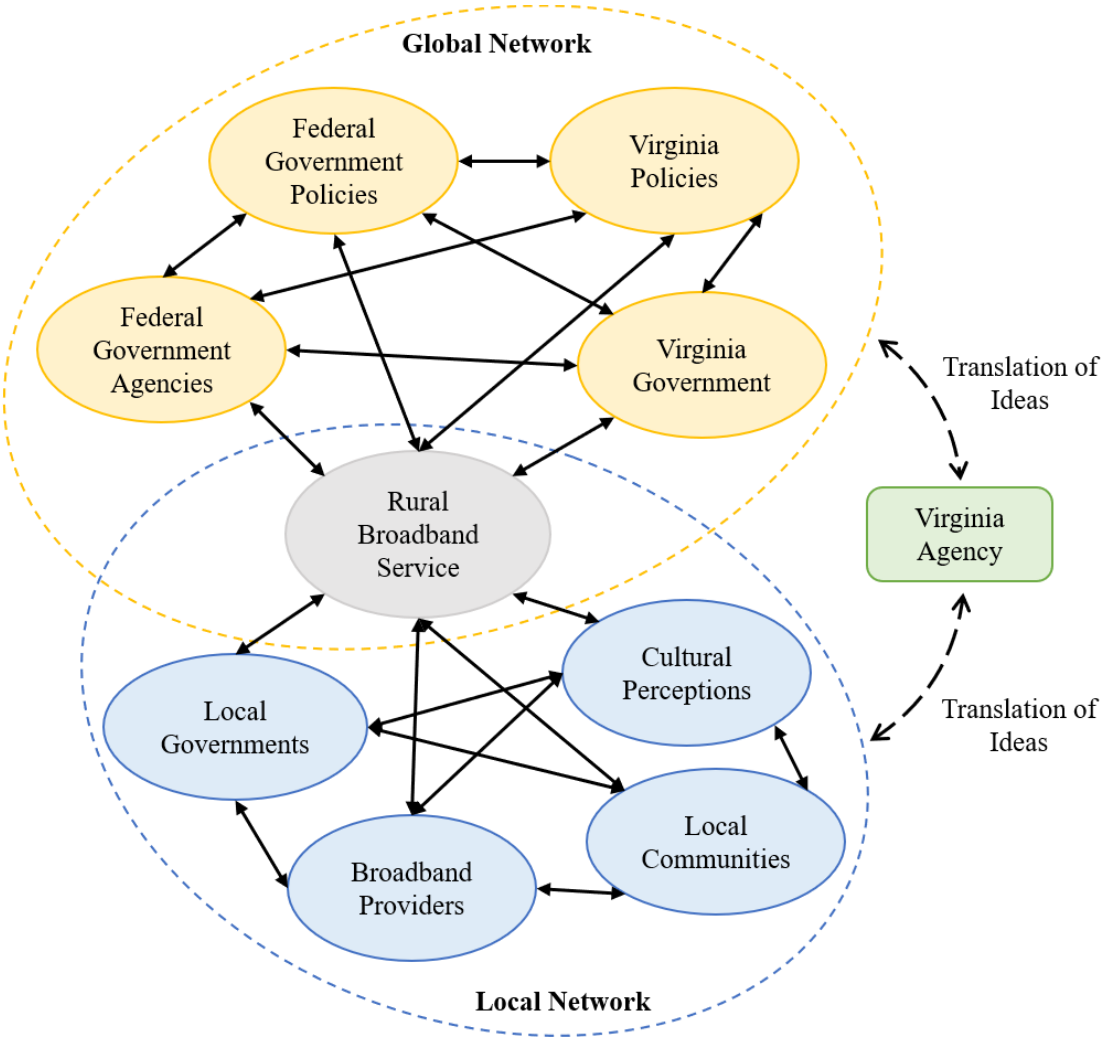


Figure 4: Actor-Network Visualization of the Rural Broadband Solution: A Virginia state agency serves as a single autonomous mediator, translating ideas between the two networks (Lin, 2020c).

## THE FUTURE OF BROADBAND SERVICE IN VIRGINIA

Due to the economic impacts of the broadband access disparity in Virginia, it is important to determine the factors that have caused past and present rural broadband initiatives to fail and the techniques than can help future initiatives to succeed. Callon and Law's (1989) Actor-Network Theory (ANT) framework, which divides actors into a local network and a global network, was a fitting model for analyzing the rural broadband problem in Virginia. Specifically, understanding the interactions between the two networks provided insight into how global actors can adjust their ideas to fit local needs.

The works of both Law and Callon (1998) and Jolivet and Heiskanen (2010) suggested the need for an actor to moderate inter-network communications, bridging the contexts of the local and global networks. Wihlborg and Soderholm (2013) introduced a model for evaluating such actors, which they called "mediators" (p. 268). Their model provided four requirements for a successful mediator, while Jolivet and Heiskanen (2010) and Law and Callon (1998) provided concrete methods for satisfying these requirements. Combining Wihlborg and Soderholm's (2013) four requirements for a successful mediator with Jolivet and Heiskanen's (2010) idea of framing and Law and Callon's (1998) concept of a negotiation space, an adjusted model for a mediating actor emerged.

Applying Wihlborg and Soderholm's model to the rural broadband problem revealed that previous rural broadband initiatives have had mediators that violated at least one of the four requirements, leading the initiatives to fail. From this analysis of previous rural broadband initiatives and the adjusted model for a mediating actor, two suggestions for future broadband initiatives appeared. First, mediators should support rural broadband service through methods alternative to subsidies. Second, the Virginia state government should establish an independent

agency to act as the sole autonomous mediator between the global network and the Virginia local network.

Through the development of a new model and the analysis of past rural broadband initiatives, this research demonstrated a need for new universal broadband policies and organizational changes within broadband initiatives. However, it did not specify what these new policies and organizational changes should be. To supplement this work, future research should approach the rural broadband problem from a policy and government perspective, using this STS research as a justification. Such future research must make more specific suggestions for new policies and organizational changes. These insights can help further narrow the digital divide in Virginia.

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