The Commercial Space Industry: How High-Speed Broadband Satellite Internet Will Affect Rural Consumers

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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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STS Research Paper

CubeSats and the New Space Industry

The rise of CubeSats is partly driving the growing commercial space industry. In the past decade, the global space economy has increased in size by 55%, to an estimated $447 billion USD in 2020 (Space Foundation, 2021). Of that economy, an estimated 80% is now commercial space activity (Space Foundation, 2021), meaning for-revenue commercial activities, as opposed to non-revenue missions such as a NASA launch to the moon. Almost all of that commercial activity, 95%, is in the space-for-earth economy - goods or services produced in space for use on earth (Weinzeirl & Sarang, 2021). The growing space economy, and the new technologies arriving with it, have implications for consumers around the globe. Those implications have the potential to change society by changing the relationships and power balance between different societal groups. The goal of this paper is to investigate those societal changes by answering the question: What are the sociotechnical impacts that rural areas will experience with expanded broadband access? The paper uses Actor-Network Theory (ANT) in order to characterize the relationships among the current players in the satellite broadband market and what that means for rural consumers in the future.

Previous Technologies' History in the US

History of Rural Electricity and Broadband in the United States

Widespread electrification of the rural United States began in the 1930s. Prior to that decade, about 90% of urban residents had electricity, but only 10% of rural residents did (Yang, 2003). However, after the depression the federal government expanded rural electrification initiatives. The Tennessee Valley Authority (TVA) was established in 1933, and in 1935, President Roosevelt established the Rural Electrification Administration (REA) in order to bring rural electrification under government purview. These and other initiatives meant that by 1955 over 90% of farms and ranches had electrical service (Owen, 1998). Electrification had a large positive impact on rural areas, which will be discussed further later in the paper.

The concept of the internet began in the late 1960s as a government research project, and by the 1980s an early form of the modern internet was used to share data between universities and other federally associated organizations. Beginning in the 1990s, the government transitioned control of the internet into the private sector, and by 1995 the internet was run almost completely by for-profit companies. Thus, the internet began spreading within the US under the influence of market forces (Greenstein & Prince, 2006), which do not incentivize building infrastructure for high-speed connections in rural areas (Malone, 2001 and Vogels, 2021). Unlike rural electrification, a widespread government initiative was not made to provide rural internet access. The lack of government support for rural internet has resulted in a so-called "digital divide," where rural and low-income consumers are disproportionately more likely to lack broadband access than those in urban and suburban areas (Vogels, 2021). Recent developments in technology and a push by the federal government to expand broadband access will have widespread impacts on rural areas, and has led to a hope that the digital divide can be narrowed in the near future.

Emerging Broadband Technologies

One of the new technologies that has the potential to bridge the digital divide is faster satellite internet, driven by large "mega-constellations" of low-cost satellites that stay in low-Earth orbit (LEO). Although satellite internet already exists, it uses relay stations that sit in geostationary orbit - an orbit that stays in a fixed position relative to the ground. This orbit is quite far away from Earth compared to LEO, leading to large lag times of up to half a second, making voice and video calls difficult, and multiplayer gaming and high-speed financial training impossible (Harris, 2019). By placing satellites in LEO, the issues with lag time can be remedied, allowing high speed broadband and low latency times. However, in LEO, satellites cross the horizon in 10 minutes, meaning large, globe-encircling constellations need to be maintained in order to ensure continuous coverage. Multiple major companies have announced plans to deploy these types of constellations, and if those plans hold, there could be 50,000 active satellites orbiting within 10 years (Daehnick et al, 2021).

Research Question and Methods

The research question investigated is: What are the sociotechnical impacts that rural areas will experience with expanded broadband access? In order to analyze the research question, Actor-Network Theory (ANT) and historical case studies are used. The historical case studies provide context and examples of how previous advances in technology, both internet and non-internet, impacted rural consumers, while ANT is utilized to analyze the relationships among the current stakeholders in the internet satellite industry. First, the electrification of rural America and its impacts are discussed, and then the impacts of the broadband revolution are discussed. Finally, an actor-network of the different stakeholders in the satellite internet industry is investigated, and the relationships among them are analyzed to categorize the impact emerging technologies will have on rural consumers in the future.

Actor-Network Theory and Rural Broadband

In order to analyze the research question, Actor-network theory (ANT) will be utilized. Actor-network theory was developed in the 1980s by a group of sociologists as a way to analyze social networks. As explained by Cressman (2009), ANT analyzes “networks”, or relationships, among a group of “actors”, or stakeholders within the actor-network. As Latour (1996) explains, an actor-network is not the same as an engineering or other technical network (like a computer network or a train network), which has nodes and clearly defined and stable paths between those nodes. Rather, an actor-network focuses on mapping the way actors “define and distribute roles, and mobilize or invent others to play these roles” (Law & Callon 1988, p.285). Importantly, human and non-human elements are considered actors within an actor-network. Thus, using actor-network theory, the relationships between the satellite companies, consumers, regulators, and the actual technology can be considered equally.

One of the criticisms of ANT is that it is overly broad, and therefore almost everything can be considered a part of an actor-network (Cresswell et al, 2010). Another criticism of ANT is that creating a framework from the knowledge of a network can be difficult, and many times can reduce the scope of a network into a more rigid structure that does not fully evaluate the actors within it (Cressman, 2009). In order to limit the scope of the actor-network, only the major actors within the network will be considered.

Results and Discussion

Impacts of Electrification and Broadband Access

The impact of electrifying rural areas was widespread. Immediate benefits included electric lighting which reduced exposure to kerosene smoke, appliances which reduced time spent on chores (washing machines alone saved 9 hours per week), and pumped water allowing easier water collection (Lewis & Severnini, 2020). Additionally, farm production increased dramatically due to the availability of electric farming equipment. Milk machines, egg heaters and lights helped with dairy and egg production. Water pumps allowed widespread irrigation of fields. Electrification helped rural residents via multiple pathways, allowing higher farm production (Lewis & Severnini, 2020). The higher production in turn had a number of near- and long-term impacts on the economies of local areas.

Lewis and Severini (2020) separate the economic impacts of rural electrification into short-run and long-run impacts. Short run impacts concern the immediate changes resulting from electricity access, while long-run impacts occur after factors have time to adjust to the new technology. They found that short-run impacts of rural electrification included increased farm production and an increase in local property values. Meanwhile, long-run impacts manifested more in counites that had earlier access to electrification. Rural areas both close to and far from metropolitan areas saw population and employment growth as a result of early electrification. In remote areas, this growth was fueled by the agriculture sector, with increasing production allowing increasing local development. In rural counties near metropolitan areas, growth was fueled by suburban expansion, and the population expansion "coincided with decreases in rural production and farmland." These areas also saw higher land values and increases in housing prices (Lewis & Severnini, 2020). The positive economic impacts resulting from electrification led to higher quality of life for rural residents, and allowed rural residents more social mobility.

These impacts support the conclusion that rural electrification helped to encourage suburbanization. Lewis and Severinini (2020) conclude that "by helping to coordinate population and investment flows into particular areas, rural electrification appears to have fostered long-run suburban development." Both the new conveniences associated with the technology and the corresponding increase in investment made rural areas more attractive and accessible to a wider segment of the population. The accessibility of rural areas is important in relation to modern broadband access. Consumers are an important part of the modern satellite broadband actor-network, and it is not unreasonable to expect similar increases in social mobility arising from rural broadband expansion.

The economic impacts of broadband access are similar to the impacts of electrification. As Prieger (2013) points out, “several studies have shown that output and employment are correlated with the deployment of broadband infrastructure,” with gains in employment rates, property values, and economic growth following the development of broadband infrastructure. Kolko (2010) found that areas with one to three broadband providers had 6.4% higher employment growth and 2.4% more population growth compared to areas with no providers. A Deloitte study found that a 10% increase in broadband access in 2016 would have resulted in an additional 806,000 jobs in 2019 (Deloitte, 2021). These findings, along with other studies on mobile telecommunications infrastructure in more rural, developing nations, suggest that the economic development of rural areas would benefit greatly with increased broadband access (Prieger, 2013). As a result, the federal government has recently begun taking a more active role in expanding broadband internet access, with President Biden planning on allocating $65 billion towards broadband infrastructure, the vast majority of it giving subsidies to ISPs to build internet infrastructure in underserved areas (Brodkin, 2021).

The Rural Broadband Actor-Network

There are a variety of companies vying to provide LEO broadband access, with SpaceX’s Starlink, OneWeb, and Blue Origin’s Kuiper being the most prominent. All of these companies are not traditional internet service providers (ISPs), but rather aerospace companies. As a result, they are building not just the infrastructure, but the business model as well, from the ground up. This means that the companies are not just targeting individual consumers for coverage, but other more non-traditional groups as well, such as aviation and cellular backhaul (connections between edge nodes of the network, such as rural cell towers, and the core network) (Foust, 2022). The business models of satellite broadband providers also means that the companies are not aiming to compete with traditional wired ISPs, who have very little current economic incentive to expand to rural areas, with the Starlink website itself saying that the technology "is ideally suited for areas where connectivity has been unreliable or completely unavailable." As a result, ISPs are not a significant part of the rural broadband actor-network.

Other important actors are federal and state governments. The federal government's primary aim is to expand broadband access to all Americans (Foust, 2022), via providing funding and subsidies to ISPs and state governments. That funding includes both federal pandemic relief funding and dedicated infrastructure funding. However, there are a number of factors complicating this goal. Primarily, the FCC lacks accurate maps of broadband access throughout the country, with many current maps vastly overstating existing coverage, making funding appropriation difficult (Hendel, 2021). State governments (and some city governments) meanwhile are seeking to maximize the amount of federal dollars appropriated to them, leading some states to "posture" early in order to gain early access to both the infrastructure and pandemic relief money the federal government is handing out (Hendel, 2021). These factors are leading some to worry that federal funding will be misplaced, given that there aren't strict requirements on what states can spend pandemic relief dollars on (Hendel, 2021).

The federal government is also responsible for regulating the industry, via regulatory bodies like the FCC. The regulators can be categorized as separate actors to the federal government however, given that their aims differ slightly. Although the FCC is also seeking to expand broadband access (Federal Communications Commission, 2021) and receives funding from the federal government, it also has a duty to oversee and manage the communications infrastructure in the country that the legislative branches of the government do not. Other government organizations, such as NASA, have their own agendas as well. NASA recently issued a letter to the FCC outlining concerns about SpaceX's Starlink approval, taking issue with their collision avoidance technology and potential to interfere with science missions (Foust, 2022).

Finally, the other important actors to the network are the consumers themselves, the technology, and scientists such as ground-based astronomers. Consumers are supplying the demand for LEO companies, but may not adopt broadband even if provided access due to price or usability concerns (Rachfal, 2021). The technology itself can be a considered a non-human actor, with a variety of different standards and broadcast frequencies. And lastly, other scientists, especially astronomers, have significant concern that thousands of LEO satellites will interfere with the ability to take astronomical measurements, due to the CubeSats reflecting sunlight (Foust, 2022).

The primary interactions between actors currently are occurring between the broadband satellite providers themselves and government regulators, due to the fact that the technology is nascent, and both the technology itself and regulations surrounding it are evolving quickly. As a congressional research paper states: "As the deployment of LEO satellites accelerates, regulations around deployment rate, frequency allocation, and orbital debris mitigation may continue to evolve" (Rachfal, 2021). The FCC, as the primary actor responsible for regulating the frequencies and licenses that the companies operate on, is at the center of the network. As a regulatory body, they have influence over not just the broadband satellite companies, but over the direction of the technology itself. New regulations on things such as permitted frequency bands, deployment rates, and orbital mitigation all influence how the technology itself evolves. Although the satellite companies are engineering the satellites itself, ultimately the FCC (and to some extent other government agencies like NASA) have a large part in shaping it.

This fact means that satellite companies have a complicated relationship with the FCC. The companies are required to apply for and obtain licenses to operate from regulators, along with coordinating among themselves to ensure that the systems do not interfere with each other (Rachfal, 2021). That means that the companies are both trying to please the FCC and convince it to adopt changes that make it favorable to their respective companies. This is creating friction between the companies as they vie to launch their networks. After SpaceX discussed a proposal to lower the operating altitude of its satellites to the FCC, Amazon gave a statement to CNBC saying:

> "The facts are simple. We designed the Kuiper System to avoid interference with Starlink, and now SpaceX wants to change the design of its system. Those changes not only create a more dangerous environment for collisions in space, but they also increase radio interference for customers. Despite what SpaceX posts on Twitter, it is SpaceX's proposed changes that would hamstring competition among satellite systems. It is clearly in SpaceX's interest to smother competition in the cradle if they can, but it is certainly not in the public's interest." (Sheetz, 2021)

The FCC also acts as the go-between for the federal government and the satellite companies. When the legislative branch enacts new laws and provides funding for rural broadband, it is often up to the FCC to implement that spending. Conversely, the federal government can enact laws new laws that require the FCC to change regulations. Plus, as the primary regulator, other government agencies often petition the FCC with their own goals. During the same Starlink hearing mentioned earlier, NASA sent a letter to the FCC outlining its concerns on the impact the change would have on orbital debris management (Foust, 2022).

Due to the fact that the technology is so new, interactions between consumers and other actors like the satellite companies and FCC are relatively small. So far Starlink is the leading company, having launched about 2,000 satellites already, with only around 145,000 users worldwide (Clark, 2022). However, the company has permission to launch up to 12,000 satellites, and is aiming to launch up to 42,000 in total (Foust, 2022). Other orbital companies have anywhere from zero to a few hundred satellites in orbit. This means that consumer opportunity to shape the technology, via feedback on things like user friendliness and price, has been few and far between. As a result, it is still unknown how consumers will respond if or when they gain access to the technology (Rachfal, 2021).

The satellite broadband actor-network is still evolving as the technology continues to mature. There will be many more regulations developed in order to oversee the network, transforming the technology and changing its impacts. As the historical case studies have shown, early adoption of the technology is critical to local areas for economic development. The areas that adopt broadband earlier are likely going to see the largest gains in employment rates, land values, and overall economic activity. As a result, the actors in the network must work together to ensure a smooth and timely deployment of the technology. There needs to be more coordination among the satellite broadband companies and regulators in the US and abroad, and lasting engineering challenges such as orbital debris management need to be solved in a way that benefits multiple actors, including consumers and scientists. The government could also consider taking a more active role in deploying new technologies, similar to how it did with rural electrification, in order to speed up the process and ensure equitable broadband access.

There are a few limitations to this project. For one, the role of traditional wired ISPs with respect to satellite broadband is mostly ignored. Although the satellite broadband technologies are not competing with wired ISPs, they still have the opportunity to partner with and learn from them. Similarly, how satellite broadband will interact with other emerging technology, such as 5G wireless networks, is ignored. Similar to satellite broadband, wireless 5G networks have the potential to transform how rural areas access and use the internet. Lastly, the interactions between foreign regulators and the primarily US-based companies are not discussed. The technology is by nature a global technology, and foreign governments will have similar powers to regulators within the United States to shape the direction of the technology.

Future research on the subject can take multiple forms. Researches could look into the economic viabilities of satellite broadband in different geographic areas, along with local studies on deployment effects. Future studies should also investigate the evolving nature of regulations, and how best to ensure equitable outcomes for all stakeholders. The specific engineering challenges of orbital debris mitigation and mega-constellations have been and can be further explored as well.

Conclusion

The sociotechnical impacts of rural broadband access include greater economic activity, higher land values, and higher local incomes. However, the current satellite broadband network is young and messy, and has significant regulatory and engineering obstacles to overcome before it has the ability to be deployed more widespread. Those locations that are able to access the technology earlier are more likely to reap better benefits than those that receive the technology later. This means that it is paramount that the technology is quickly and safely deployed in an equitable manner.

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