Emerging Global Satellite Network: The Barriers to Connect the Unconnected

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring 2022

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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Abstract

Internet, a global network of devices that connect humans and non-humans, is a basic need in the 21st century, however, an estimated 4 billion people still do not have access to it (Udoewa et al., 2016). As part of the solution, a significant expansion of the satellite Internet sector is taking place, bringing with it big hopes for social and economic growth. Satellite Internet has resurfaced in recent years as a viable alternative to laying thousands of miles of fiber optic cable, a practice that is time and energy-intensive and associated with high operating costs. In order to compete with broadband service, new Silicon Valley-associated companies such as SpaceX, OneWeb and Amazon are developing innovative constellations of small satellites in non-synchronous orbits. The constellations reduce production costs and improve signal delay, allowing them to provide cheap, high-speed Internet access around the globe (Graydon et al, 2019). The Actor-Network Theory (ANT) methodology is applied in this study to explain the increasing popularity of commercial satellites, as ANT highlights how linkages and their dynamic result in the emergence of new entities, for example the new emerging organizations and the uncertainties they face, which is core part of this paper.

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Methodology: Actor Network Theory (ANT)

In this paper, I use Actor Network Theory (ANT) to explore the renewed interest in satellite connectivity and what are the non-human actors that pose challenges to the industry? ANT is a unique approach in that it seeks to redefine actors as entities -human or nonhuman- that impact or perturb the behavior of a socio-technical system (Crawford, 2020). Non-human actors can take different forms like artifacts, concepts, rules, etc., and it's essential to look at how human actors are outlined as well. In Latour's 1996 "On actor-network theory: A few clarifications", he describes an actor as "something that acts or to which activity is granted by others. It implies no special motivation of human individual actors, nor of humans in general. An *actant* can literally be anything provided it is granted to be the source of an action" (Latour, 1996). Hence, according to Latour, when analyzing a network, humans and non-humans are treated no differently. This concept is essential to forming this paper because it will examine the agency of non-human actors, such as technology, costs, regulations etc, that would impact the lives of human actors i.e. the users.

ANT's broad definitions allow it to be used in a wide range of contexts, but there are certain drawbacks. Nonhuman performers, according to critics, lack the ability to act since they do not possess the capacity for self-awareness and self-control (Whittle & Spicer, 2008). The actors forming the network in this paper consist of corporates, government, civil/military clients, astronomers, regulation agencies, satellite/telecommunication technology, and non-human actors as having enough funding and strategies. Understanding the relationships and interactions between these actors will allow us to determine how satellite communications came back into mainstream interest. If we have that knowledge in hand, we can then use it to predict which technologies will be used in the future based on similar interactions in different networks.

Background

According to the United Nations Space Department, more than 11,139 objects have been launched into Earth's orbit since the beginning of modern space endeavors, and numbers are expected to increase significantly in the foreseeable future (Mohanta, 2021). Several private companies are planning to send tens of thousands of satellites into space to provide internet access to clients. Under SpaceX's Starlink fast broadband project, Elon Musk has announced their intentions to deploy 42,000 satellites by mid 2030s (Mann et al, 2022). If this occurs, SpaceX will hold five times the number of the satellites as currently exist in the orbit. Technically, a satellite is an object in space that orbits a larger object, but this paper I use the term “satellite” for the artificial objects sent to space by humans to achieve specific purposes. Now to look back in time, Sputnik, the first man-made satellite that launched into space was about the size of a basketball and it was launched by the Soviet Union in 1957 (National Geographic). The launch of Sputnik signified the start of the modern space saga and since then, humans have launched an increasing number of satellites into orbit by the time.

Actors like SpaceX, Amazon, Telesat, and OneWeb are now attempting to deploy thousands of satellites to create their own mega-constellations. According to Airbus, a mega-constellation is a network of hundreds or thousands of satellites orbiting and operating together as a complete system in Low Earth Orbit (LEO), a lower altitude than traditional satellite orbits (Airbus SE, n.d.) . There are two main reasons why these corporations are currently chasing these networks. The hardware for these kinds of satellites has become significantly less expensive and smaller in overall size and there is a growing need for data throughout the world.

As a result, the ability to provide fast broadband data to any location on the planet is becoming increasingly important (Petrova, 2019).

How are these Networks Established?

Satellite internet access is not a new concept. With the help of enterprises such as Viasat and Hughes Network Systems, rural areas throughout the world have been getting access to the internet since 2012 (Paul, 2022). Even so, more than half of the world's population is still unable to access the internet. Additionally, these are the customers that have been targeted by traditional satellite providers in the past and network latencies have long been a problem with existing satellite networks. Latency is the network's ability to respond quickly to the users’ request, so low latency means a network with less delay. Now there are a lot of distances to cover when it comes to traditional satellites and that distance adds to the network's total delay. Streaming online is all about how quickly or smoothly anything loads or operates. The 'low Earth orbit' (LEO) satellites are those that operate within merely hundreds of miles above the earth's surface, and those proposed by SpaceX, OneWeb, Amazon, and Telesat will operate in low earth orbit. So technically, LEO satellites can have speeds up to 20 times faster than existing high-altitude satellites and are expected to reduce signal delay difficulties (Iridium, 2018). However, the number of LEO satellites required to provide the same level of coverage is far higher. In order to communicate with Earth, satellites still require a receiver on the ground. These firms will have to invest a significant amount of money in-ground infrastructure in addition to the satellites they create for these massive constellations. To receive the satellite signal and transmit it to users on the ground, will require tens of thousands or possibly millions of communication base stations all over the world. Additional actors or companies like Google and Facebook have previously discussed the development of satellites that may provide internet access from orbit but haven't shared any progress recently (Wired, 2018).

Essential Actors with Agency

i. SpaceX

SpaceX has already launched 1,469 of its Starlink satellites and plans to launch many more in the near future, making them the frontrunner in this category (Barret, 2022). For SpaceX, the utilization of its reusable Falcon rockets significantly cuts the cost of orbiting satellites. According to records filed with the Federal Communications Commission (FCC), SpaceX anticipates Starlink is expected to become fully operational by the end of 2022 (Cooke, 2022). According to Elon Musk, at Tesla's annual shareholder meeting in 2019, Starlink will provide "low latency, high bandwidth access to sparse and relatively sparse areas", like relatively low-density areas, and it should serve approximately three to five percent of the global population (Elon Musk, 2019). SpaceX's original plan was to launch 12,000 small satellites in a single mission. However, in 2019, the corporation sought an extra 30,000. In the proposal to the FCC, SpaceX has also requested that it be allowed to deploy up to one million Earth stations for use by its satellite clients (The Guardian, 2022). Starlink has also flown satellites for the US Air Force with satisfactory results, in addition to civilian clients. SpaceX is considered one of the biggest potential actors in the network that would provide to most of the remote areas on the earth including distressed networks as recently, they have been providing internet access to Ukrainians seeking shelter.

ii. OneWeb

OneWeb, which has already launched few hundred satellites so far, is just behind SpaceX. Starting with smaller number of satellites, they eventually want to build up to a total of

2000 over time (OneWeb, 2021). OneWeb, like SpaceX, has a slew of high-profile supporters, including Softbank and Richard Branson. Each OneWeb satellite is estimated to cost $1 billion to build. While SpaceX uses American-built Falcon 9 rockets to deploy its satellites, OneWeb had to rely on Russian-built Soyuz rockets, until recently which changed due to the Ukraine war (Reuters, 2022).

iii. Amazon

While OneWeb and SpaceX have already launched satellites, Amazon is in the early stages of developing its Kuiper Network, which is currently awaiting regulatory permission. For Amazon's Project Kuiper, a net of more than 3000 satellites are planned to be launched into low-Earth orbit (LEO). With its ground infrastructure in place, Amazon has an advantage over its competitors. And in 2019, Amazon announced the creation of a new business unit, AWS Ground Station, which would develop twelve satellite facilities across the world (Estes, 2021).

Failure in the Network

Launching hundreds of batches of satellites sounds like a harmless way to connect people across the world. But in 2019 many astronomers were shocked when the first batch of SpaceX's Starlink appeared in the astronomical images captured by the telescopes in Chile. Astronomers have shown that they are unhappy about overwhelming long trails of satellites. And the real challenge they brought to attention is not only the number of satellites in orbit but the brightness of the solar reflection of the satellites to the earth, which saturates the detectors during the astronomical observations.

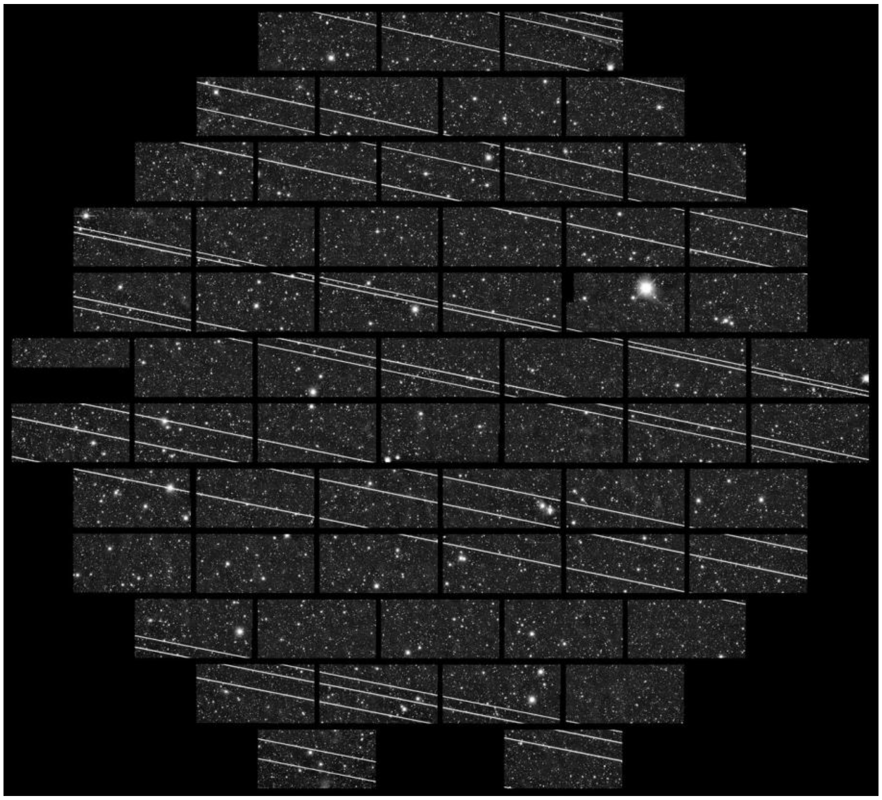

Image from Noir Lab, 2019

The image above, acquired in November 2019 from an observatory in Chile, demonstrates the astronomers' worries regarding the reflections (O'Callaghan, 2019). The detectors have captured trails of Starlink satellites instead of long-distance galaxies. Following SpaceX's satellite deployment in May 2019, some astronomers directed their worries to Elon Musk on Twitter. As a result of these concerns from astronomers, SpaceX CEO Elon Musk stated in a tweet that his business will investigate ways to dim the reflectivity of their satellites. Gwen Shotwell, SpaceX's president, also informed reporters in December 2019 that the company was working on resolving the issue (Clark, 2019).

Astronomers anticipate the problem will deteriorate further as SpaceX and its adversaries compete in launching mega-constellations of satellites, thousands to say in numbers. Thus far, only a small percentage of the entire number of projected satellites have been put in orbit, and cosmologists are concerned that the satellites that are set to be launched in future will also reflect light in the same way as the existing Starlink satellites. And from a general viewpoint, all of this is part of a gold-rush to deliver fast broadband internet access to billions of people who have never had it before. Regardless of whether a professional scientist or a casual observer, the magnitude of the potential turnover to our night sky is quite alarming. According to Patrick Seitzer, a scientist at the University of Michigan, prior to the Starlink missions, approximately 200 artificial objects were visible from Earth's orbit and with the ever-growing number of these celestial bodies, it's difficult to envision a different night sky. If big LEO satellite players do not dim their constellation reflections, the sky will be different forever. In the beginning of this saga, astronomers were hopeful that maybe authorities would prioritize the night sky over the potential benefits of the internet for economic opportunities. But the general opinion is that access to the internet is a basic human right in the 21st century, just like water and sanitary needs; ironically, in a world where billions of people worldwide lack access to clean water. As a result, it's difficult to battle the issue from a western political standpoint. According to Anthony Tyson, another scientist at the University of California, the big industry players should be able to darken satellite reflections by a factor of 100. However, being practical, this is unlikely to occur. A more plausible estimate might be 10-20 times dimmer, that will enable astronomers to mitigate most of the scientific impact of trailing lights through vastly enhanced data-processing and the associated analysis techniques when they are observing the universe (Hadhazy, 2020).

With the shock of the Starlink's effects, astronomers began performing simulations to determine how their observations around the world would look like with a larger number of satellites. For a full constellation of 12,000 Starlink satellites, the approximate estimates indicated that 200 of them would be visible in the taken images at any given time. Although not every satellite will be visible in the observed pictures, a considerable percentage of images will certainly be impacted, with their data potentially being unfruitful. If SpaceX expands its constellation to its maximum of its projected satellites as they have envisioned to do so and if other entities launch their own mega-constellations, Tyson predicts that up-to 70% of observations would be lost to the trailing lights caused by satellite reflections (Hadhazy, 2020).

On the other hand, these satellites may also have an effect on radio astronomy. The International Astronomical Union (ITU) summarized their concerns following the first launch of Starlink's satellites, stating that “despite significant efforts to avoid interfering with radio astronomy frequencies, aggregate radio signals emitted by satellite constellations can still threaten astronomical observations at radio wavelengths” (CNBC, 2019). This is important to mention, since with the help of radio astronomy technology, scientists took a picture of a black hole for the first time in history, which signals that there is no tolerance in case commercial satellites interfere with study of the origins of the universe using radio waves.

The next significant issue is debris. This is described by the Kessler Syndrome Theorem, which states that when two things collide in space, they produce further debris, which further collides with other objects, generating even more shrapnel and trash until the entire earth's lower orbit becomes impassable (NASA, 2016). This hypothetical situation became a reality in February 2009, when an inactive Russian communications satellite Cosmos 2251 collided with an operational commercial communications satellite owned by the US-based Iridium Satellite Communications. Around 2,000 pieces of debris were generated during the incident (Weeden, 2010). Debris is especially critical in light of the fact that SpaceX, OneWeb, and Amazon have all said that their satellites would have a lifespan of approximately 5-7 years, almost half compared to that of traditional satellites. When the corporations are through with the satellites or they fail in orbit, they de-orbit them, which means they will be deliberately driven back into the earth's atmosphere, where they will burn up on reentry.

Another long-term concern for mega-constellation operations lies in the fate of satellites that malfunction and will be unable to alter their own orbits by firing thrusters, or simply age and no longer function. It is possible that such defunct satellites could collide with active satellites or with each other, as well as obscure astronomical views, especially if their orbits decayed. Thus, the only way forward is to have as many satellites disappear into space as possible (Hadhazy, 2020).

Legislative Guidelines

Regulatory oversight of these mega-conglomerates is one of the key challenges facing this industry. And there's no clear guidelines on this problem. According to Michael Newman, UN office for outer space affairs, there is no international “mandate to approve or reject any space activity of any sovereign government or of any company” (CNBC, 2019). Generally, the Federal Communications Commission is responsible for regulating satellites in the United States. In addition to radio spectrum distribution, the FCC is responsible for minimizing any debris that may result from satellite deployment. During Ajit Pai's tenure -the chairman of FCC 2017 to 2021-, the FCC has been eager to work with the mentioned companies. In 2019, at the US chamber of commerce, Mr. Pai stated that FCC is trying to make sure that their regulation keeps up with rapidly changing satellite technologies which some of these modern satellites are built in a matter of months and days (Federal Communication Commision, 2019). In his speech, Pai promised to review FCC rules on orbital debris in light of recent changes in the market. Along with the FCC, other United States regulators include the Air Force, the Federal Aviation

Administration, and, sometimes, the National Oceanic and Atmospheric Administration (NOAA).

Conclusion

The gradual integration of the internet into all aspects of life has resulted in the emergence of new sorts of remote communities living off-grid that challenge the traditional concepts of using fiber optic technology networks. Actors with a strong financial background like big corporations are introduced through high-risk liability investments with a hope to receive a share of the market with potential growth. Although their hopes are valid, at the end of the day, their lack of inclusivity from the scientific community would hurt the network in general. It is vital to have big players with agency to collaborate with astronomers instead of doing otherwise. Other actors, some who are familiar with the network and do not have influence over other actors, interact with the network to control, dominate and influence regulations. In response to these interactions, actors in a network will be compelled to compete and collaborate on ethics for the health of the network. As long as the actors are in interaction, the actor-network would look stable. This study has unique implications, especially for the interaction between corporations and governments, as well as for the development of new technologies. Can it be seen if other governmental agencies have enough influence over the corporations? Are there scenarios that actions of corporations to do good marginalize some actors that are not intended to marginalize? What are the factors that impact success in a developing hardware technology industry? Are there other older technologies that can be used to tackle modern problems? The answer to the questions above will enable industries to gain a competitive advantage by creating products that complement re-emerging technologies that incorporate the benefits of older technologies and different actors of the network would have more insight to interact with the network.

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