# Managing the Wireless Communication Commons at Multiple Scales

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## INTRODUCTION

When I began this investigation, I sought to understand the Internet commons. I found a 1996 paper by Charlotte Hesse of Indiana University that examined the Internet as not one commons, but four – the Internet technology infrastructure commons, the Internet budget commons, the networked information commons, and the Internet community commons – applying Margaret M. Polski's and Elinor Ostrom's Institutional Analysis and Development framework to each (Hesse 1996; Polski and Ostrom 1999). The Internet technology infrastructure commons was the most obvious of the four: Much like a highway, as more people use the infrastructure, congestion makes it less usable. Citing Hesse in a 2000 paper, Gerald Bernbom, also of Indiana University, analyzed that commons extensively. The responses to congestion that he describes, namely increasing provisioning, restricting access with acceptable use policies, and introducing innovations such as differential service and end-to-end congestion control, have been successful at sustaining the Internet technology infrastructure commons over the last two decades (Bernbom 2000). However, I chose not to focus on that commons because, though successful, the responses are largely technical, not social, and have historically been exogenous to the users. For example, the acceptable use policy of a monopoly Internet service provider in rural Parsons, Kansas literally states that it "determines in its sole discretion what constitutes a reasonable use of bandwidth" (Acceptable Use Policy). Furthermore, I came across a compelling 2013 article by Mark Raymond in the Georgetown Journal of International Affairs that criticized the notion that the Internet is even a commons. Invoking Ostrom's language, Raymond argues that over time, the Internet has proven to be excludable and nonsubtractable for most people, and that it "generates positive returns for all users as more individuals adopt it" – the antithesis of a commons (Raymond 2013).

While Raymond's arguments are effective, he neglects to consider an increasingly important aspect of the Internet that I will show is indeed a commons: Wireless communication. The aforementioned monopoly Internet service provider uses wireless technology to connect its customers to the Internet. Since the wireless communication medium is shared, why must the residents of Parsons, or any community, subscribe to an Internet service provider over which they have no control? In this paper I apply the first few steps of Polski's and Ostrom's framework to analyze the wireless communication commons at multiple scales.

## TECHNICAL BACKGROUND

Wireless communication is based on electromagnetic radiation. Humans observe electromagnetic radiation as visible light, but the gamut of colors that we can see is a small fraction of the electromagnetic spectrum (Petruzzello). (In fact, the spectrum is infinite!) The gamut of colors corresponds to a range of frequencies, with blue having the highest visible frequency (about 750 THz), and red having the lowest visible frequency (about 429 THz). Frequencies above that of blue and below that of red have common names: Ultraviolet is above blue (hence the name), above which are X-rays, above which are gamma rays; infrared is below red (hence the name), below which are microwaves, below which are radio waves (Nassau). The former set with higher frequency is called shortwave radiation, and is capable of damaging DNA, which can cause cancer and disqualifies it as a suitable means of wireless communication. The latter set with lower frequency, on the other hand, is called longwave radiation, and it is not capable of damaging DNA. Longwave communication is ubiquitous: For example, TV remotes use longwaves to transmit commands, Wi-Fi routers use them to transmit content to mobile devices, and radio stations use them to transmit audio to vehicles. The longwaves in each of these examples have a particular frequency, as do the longwaves used by the monopoly Internet service provider.

The commons problem arises from the fact that frequency is nonexcludable and subtractable. It is nonexcludable because any entity with the appropriate transmission equipment can use it. It is subtractable because there is a limited number of viable frequencies, and if multiple appropriators simultaneously use the same frequency on the same scale, that frequency will become unusable. Rules exist to prevent such a tragedy.

## HISTORICAL BACKGROUND

According to Nobuo Ikea of the Research Institute of Economy, Trade and Industry, the earliest regulation of the radio spectrum in the United States was the Radio Act of 1912. Prompted by the failure of the Titanic to communicate SOS signals to nearby ships, the Act limited radio communications to military and marine use, and it was revised in 1927 to allow private companies to use radio waves for business purposes. As a compromise between industry, which wanted open spectrum, and the federal government, which opposed open spectrum, the Federal Radio Commission – established by the 1927 revision – created a licensing system to permit specific uses of specific frequencies (Ikeda 2002). The Communications Act of 1934 replaced the Federal Radio Commission with the Federal Communications Commission, but kept the licensing system created by the former. Even after an overhaul by the Telecommunications Act of 1996, the licensing system remains in place (Telecommunications Act of 1996).

## OBJECTIVE: PREVENT AND CONTROL INTERFERENCE

The main goal of managing the wireless communication commons, as articulated by the International Telecommunication Union, is to “prevent and control Interferences” (Restrepo 2013). This is most easily understood by analogy: Consider a building with several rooms, and many pairs of people in conversation. It would be impossible to give each pair of people their own room in which to converse, so many, if not all, rooms will have multiple independent, simultaneous conversations going on. That is not an issue if the pairs of people are talking quietly enough relative to the distance between pairs – for example, speaking softly when pairs are in close proximity – but if the pairs of people are talking loudly relative to the distance between pairs, their conversations will interfere, and no pair will be able to communicate. This explains why parents impose the “indoor voice” rule on their children, and scold them if they do not obey (at least in my experience).

Connecting the analogy back to wireless communication, the building is the radio spectrum, and each room is a frequency. The pairs of people are wireless communicators, and their conversations are radio signals. The volume of a conversation is the transmission power, and the distance between pairs is geographic separation. Altogether, if a frequency has multiple independent, simultaneous radio signals with significant transmission power relative to geographic separation, all of the signals will be destroyed. A common example is Wi-Fi in a crowded room. Routers operate at a particular frequency, and devices that are capable of connecting to Wi-Fi must operate at the same frequency to communicate with them. Therefore, in a crowded room, many devices will “talk over” each other, and communication with the router will become nearly impossible. The situation only gets worse as the number of devices in the vicinity increases, which explains why public Wi-Fi can be unbearably slow.

### Multiple Scales

The Wi-Fi example is small-scale, but the same problem exists at larger scales. The scale of a wireless communications commons is determined by the transmission power. Perhaps the largest scale is satellite communications. There are currently almost 2,000 satellites orbiting the Earth, and they would be useless if we could not communicate with them (Andy 2019). That would be a very real possibility if all the satellites operated on the same frequency, since their transmission power is high, and therefore their radio signals would interfere. Moreover, even if there were only one satellite, if the terrestrial receiver is near a low-power transmitter on the same frequency, the satellite and terrestrial radio signals would interfere locally, resulting in the same destruction of the commons.

At the regional scale, radio stations would face the same problem. In my hometown, one can listen to a Long Island radio station such as WBLI at 106.1 MHz, and one can also listen to a Connecticut radio station such as WKCI at 101.3 MHz. If these frequencies were the same, my hometown would receive neither pop hits nor the Elvis Duran and the Morning Show. Parallel to the global scale, even if there were only one radio station, if the receiver were near a Wi-Fi router that operated on the same frequency, the radio station and Wi-Fi radio signals would interfere locally, again resulting in the destruction of the commons.

Finally, the same problem exists at the local scale. The aforementioned wireless monopoly Internet service provider in Parsons, Kansas would have a serious problem if another wireless provider popped up and used the same frequency. The commons would be destroyed, and Parsons would be knocked off the Internet. These multi-level concerns were the impetus for the development of national and international rules to sustain the wireless communication commons.

## HIERARCHAL GOVERNANCE

Recalling the building analogy, who are the "parents" that impose the "indoor voice" rule, and what is that rule? It will help to first identify the "grandparents." They are the aforementioned International Telecommunication Union, a specialized agency of the United Nations and the highest authority on radio spectrum allocation (About International Telecommunication Union). The United States has been a member since 1908, and 193 other countries are members (List of Member States). Its Radiocommunication Sector is the division responsible for maintaining the

Radio Regulations, an international treaty governing the use of spectrum, which is revised and updated during the World Radiocommunication Conferences every 3-4 years. Revisions and updates are proposed at Radiocommunication Assemblies by six Study Groups, which are collectively comprised of more than 5,000 specialists from International Telecommunications Union member states, Radiocommunication Sector members, associates, and academia throughout the world, and each Study Group has subgroups called Working Parties and Task Groups that study specific questions (ITU-R Radiocommunication Study Groups).

The part of the Radio Regulations most relevant to this paper is Volume I, Chapter II, Article 4, “Assignment and use of frequencies” (Radio Regulations Articles). Essentially, member states must conform to the international Table of Frequency Allocations, which divides the radio spectrum into bands by allowed use (FCC Online Table of Frequency Allocations). The International Telecommunications Union makes enforcement recommendations, but leaves execution to the member states.

It is now possible to identify the “parents.” Unlike the “grandparents,” in the United States, they are not one, but two federal bodies: The National Telecommunications and Information Administration, and the aforementioned Federal Communications Commission. The former is an operating unit of the Department of Commerce and manages spectrum for federal use, and the latter is an independent regulatory agency and manages spectrum for non-federal use (Radio Spectrum Allocation). Federal use includes that by the military, the Federal Aviation Administration, the Department of Justice, the Department of the Interior, and the National Science Foundation, while non-federal use includes that by individuals, businesses, and state and local governments.

Like the superintending International Telecommunications Union, the Policy and Rules Division of the Federal Communications Commission's Office of Engineering and Technology maintains a Table of Frequency Allocations for federal and non-federal use that is consistent with the international Table. However, allowable frequency is not sufficient for frequency use – that is, allowable does not mean allowed. As mentioned earlier, the licensing system created by the Federal Communications Commission's predecessor is still in place, and the requirement is taken seriously. To prove it, the Commission publicly posts infractions with levied penalties, many of which are monetary forfeiture orders of several thousand dollars (Unauthorized Broadcast Stations). The effect of this is twofold: Not only does it show that the requirement is heavily enforced, but it introduces public shame to the calculus of potential violators.

The list of infractions is a testament to the success of mutual monitoring. The Federal Communications Commission cannot monitor all frequencies all across the country all the time, so it accepts complaints. This works well in theory because frequency is scarce throughout the country, so proper users will not tolerate infractions and be incentivized to report violators – and potential violators know that. The theory is borne out in practice: In just the last few years, there were several hundred infractions posted. However, most of the penalties were only warnings, evidence of graduated sanctions.

## Conclusion

While there is disagreement among scholars about whether or not the Internet is a commons, it is clear that a related technology, wireless communication, is. As the technology proliferates, more and more entities want to use the radio spectrum, but there are relatively few frequencies, and none can support multiple independent, simultaneous uses on the same scale without collapsing. To avoid such a tragedy, rules have been instituted to allocate frequency at multiple scales. Now that the key features of this action situation have been distilled, in my next paper I will apply the remaining steps of Polski's and Ostrom's framework.

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# Managing the Wireless Communication Commons at Multiple Scales

# Part II

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## INTRODUCTION

In my previous paper, I applied the first few steps of Margaret M. Polski's and Elinor Ostrom's Institutional Analysis and Development framework to wireless communication (Sussman 2019; Polski and Ostrom 1999). I showed that the means of communication, radio spectrum, is both nonexcludable and subtractable – nonexcludable because anyone can transmit with the appropriate equipment; subtractable because frequencies are finite and single-use – and therefore wireless communication has a commons problem. I explained that national and international bodies were formed to manage the wireless communication commons, namely by allocating bands of spectrum.

In this paper I focus the analysis on the amateur radio community, which depends on the wireless communication commons. Polski and Ostrom emphasize the importance of rules in use, which need not be written down, and may conflict with written rules. Guided by their framework, I will show that the rules in use by amateur radio operators have allowed them to sustain the wireless communication commons for over a century. I will further illustrate the patterns of interaction among amateur radio operators, their interest group, and government by analyzing an ongoing case that has divided the amateur radio community.

## AMATEUR RADIO

The United Nations International Telecommunication Union (ITU) allocates bands of spectrum by purpose (Radio Regulations). For example, some bands are reserved for industrial, scientific, and medical (ISM) applications, while other bands are reserved for marine use. This makes sense: Hospital equipment should not be compromised by, say, FM radio, and maritime SOS signals should not be drowned out by intercontinental wireless communication. Indeed, the latter example was the original motivation for spectrum allocation (Ikeda 2002).

Figure 1. An amateur radio operator in action (What Is Ham Radio).

In this paper I focus on one type of spectrum use called the amateur service, which the ITU defines as “a radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons in radio technique solely with a personal aim and without pecuniary interest” (Radio Regulations). The amateur radio community includes an estimated 2 million people worldwide (Fig. 1), and since it depends on the wireless communication commons, its primary policy objective is two-pronged: Preserve the amateur service bands, and prevent interference on those bands (Technical Relations Office).

## INTERNATIONAL REGULATION

The ITU allocates several bands for the amateur service, but otherwise largely leaves regulation to the member states. It requires administrations to “verify the operational and technical qualifications of any person wishing to operate an amateur station” and provides “guidance for standards of competence” (Radio Regulations), but member states could legally block amateur radio operation by setting standards unattainably high. Therefore, to preserve the amateur service bands, the amateur radio community must lobby not only the ITU, but administrations as well.

### National Regulation

Title 47 of the United States Code of Federal Regulations covers telecommunication, and is administered by the Federal Communications Commission (FCC). An entire Part of the Title, number 97, is devoted to the amateur radio service. The regulations in Part 97 lay out the licensing process, rights, and responsibilities of amateur radio operators (47 CFR).

### Licenses and Rights

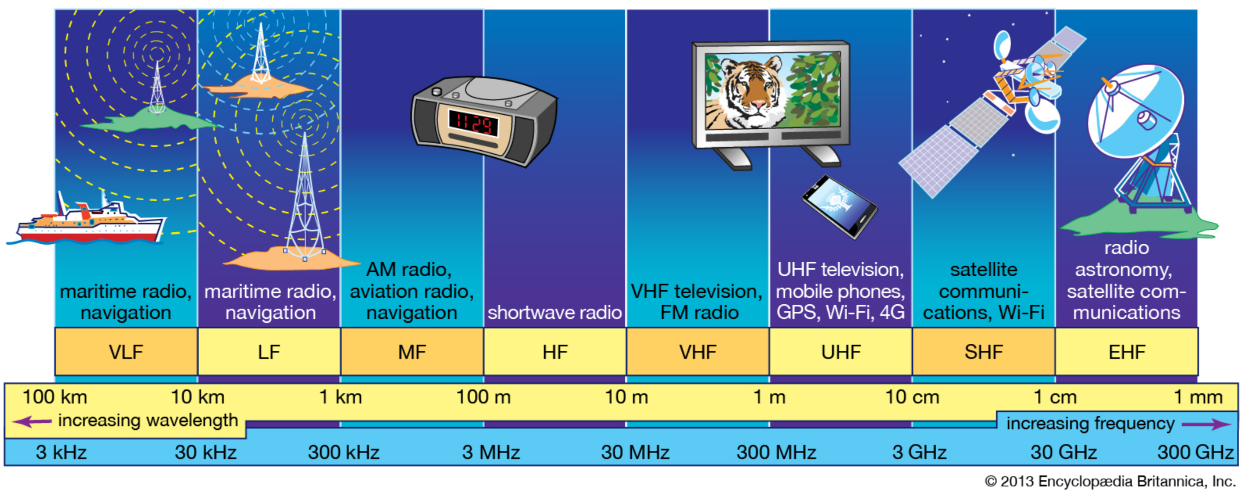


Figure 2. The radio spectrum (Encyclopædia Britannica).

To qualify for an amateur operator license, the FCC – in accordance with the ITU requirement – regulates that one must prove possession of "the operational and technical qualifications required to perform properly the duties of an amateur service licensee" (47 CFR §97.503) by passing an examination. There are three tiers of license, each with its own prerequisite examination on the rights and responsibilities of the tier (47 CFR §97.501). The entry-level license, called Technician Class, can be obtained by correctly answering 26 out of 35 questions on the corresponding examination, and gives an amateur radio operator the right to transmit on all very high frequency (VHF) and ultra high frequency (UHF) amateur service bands (Fig. 2), on which domestic communication and limited international communication is possible (Getting Your Technician License). A Technician can similarly upgrade to a General Class license by correctly answering 26 out of 35 questions on the corresponding examination, giving the amateur radio operator the right to transmit on most high frequency (HF) amateur service bands (Fig. 2), on which worldwide communication is possible (Upgrading to a General License). The top-tier license, called Amateur Extra Class, can be obtained by correctly answering 37 out of 50 questions on the corresponding examination, and gives an amateur radio operator the right to transmit on all amateur service bands (Ham Radio Licenses). Regardless of tier, licensed amateur radio operators are required to follow certain rules and are expected to follow certain norms that support the two-pronged policy objective of amateur service band preservation and interference prevention.

RULES

The most obvious rule is that one cannot transmit on a band without the appropriate license. For example, one cannot transmit on any band – amateur service or otherwise – without a license; one cannot transmit on HF bands with just a Technician Class license; and one cannot transmit on marine bands with an amateur operator license, regardless of tier. What stops inadequately licensed operators from disregarding the rule and illegally transmitting anyway? The amateur radio community calls this "bootlegging" or "pirating," and the license manual answers that "first of all, it's quite apparent to [amateur radio operators] who has and who hasn't passed a license exam. You'll find yourself attracting the attention of the FCC, but more importantly, you won't fit in and you won't have fun" (Ham Radio License Manual). I disagree about the relative importance. Since the rule is a legal requirement, the FCC has the power to issue forfeiture orders for noncompliance. One such order, not uncommon, was in the amount of $25,000, and its publication shamed the perpetrator (Forfeiture Order). The threat of such costly and shameful forfeiture orders helps prevent tragedy of the wireless communication commons.

Another rule was exhibited in the film *The Incredibles*. Fans will recall a scene in which Mrs. Incredible pilots a plane. They may not recall, however, the first thing she says when missiles approach the aircraft: "India-golf-niner-niner, transmitting in the blind guard" (The Incredibles). "India-golf-niner-niner" is the ITU-recommended way of saying "IG99," the fictional plane's identifier (and presumably an homage to the director's 1999 film *The Iron Giant*), and the rest of the sentence is a distress signal (Communicating with Other Hams). The identifier is termed a call sign, and the FCC assigns one to every licensed amateur radio operator, much like the Department of Motor Vehicles (DMV) assigns a license plate to each motor vehicle. Unlike license plates, however, call signs are entered into a public database called the Universal Licensing System, which anyone can search to find out about licensees. The FCC requires that "each amateur station, except a space station or telecommand station, must transmit its assigned call sign on its transmitting channel at the end of each communication, and at least every 10 minutes during a communication, for the purpose of clearly making the source of the transmissions from the station known to those receiving the transmissions. No station may transmit unidentified communications or signals" (47 CFR §97.119). The law inherits from the ITU regulation that "during the course of their transmissions, amateur stations shall transmit their call sign at short intervals" (Radio Regulations). In the face of danger, Mrs. Incredible complies with federal and international law!

Failure to transmit a call sign is an indication of unlicensed transmission, so the rule is important, and the FCC can issue forfeiture orders for noncompliance. Call signs are not just proof of licensed transmission, though: They are also a means of accountability. Recall that the ITU definition of the amateur service explicitly prohibited "pecuniary interest." Seemingly inconsequential, the prohibition is paramount for the preservation of the amateur service bands. The service is called amateur because business is strictly prohibited (Ham Radio License Manual). That's the point – the amateur service bands are set aside as the only noncommercial and nongovernment bands. Call signs allow amateur radio operators to report pecuniary activity to the FCC, which can in turn issue forfeiture orders. Without such mutual monitoring, the amateur service bands would be overrun with business communication.

Related to the preceding rules is the prohibition on encrypted transmissions. If a transmission is encrypted, it would be impossible to determine if it is nonpecuniary and if the amateur radio operator is appropriately licensed. Encryption is thus itself prohibited, and subject to FCC forfeiture orders. However, there is considerable debate within the amateur radio community over the definition of encryption, since all transmissions must be encoded in some way. According to the license manual, "as long as the protocol is published and available to the public, that transmission is acceptable. The general rule to remember is that no [amateur radio operator] should be prevented from receiving the communications of another [amateur radio operator] because the necessary information has been withheld" (Ham Radio License Manual). In other words, since Morse code is a public protocol, amateur radio operators can use it without penalty – many do. Berkeley code, on the other hand, is not a public protocol, so its use would be prohibited.

NORMS

Even when all the rules are followed, interference could still occur. In fact, it is common. Changes in ionospheric and atmospheric conditions can make noninterfering signals suddenly interfere. Furthermore, an amateur radio operator might think a frequency is not in use when another operator was just silent. The license manual provides the following guidance:

> What should you do if harmful interference occurs to your contact? Can you change frequency a little bit or change antenna direction? Common courtesy should prevail, but remember that no one has an absolute right to any frequency. Be flexible – it's one of [amateur] radio's greatest strengths! What should you do when you cause harmful interference? If it's your fault, apologize, identify and take the necessary steps to reduce interference – change frequency, reduce power, or re-aim your antenna. (Ham Radio License Manual)

This attitude, in conjunction with the rules, has enabled the amateur radio community to sustain the wireless communication commons for over a century. The rules and norms have remained basically unchanged over time thanks in part to an interest group that has served the amateur radio community from the beginning.

## Interest Group

The United States began licensing amateur radio operators in 1912, and by 1914 there were thousands. An inventor and industrialist in Hartford, Connecticut named Hiram Percy Maxim "saw the need for an organization to unify this fledgling group of radio experimenters" (Ham Radio License Manual) and founded the American Radio Relay League (ARRL) to meet that need. Over a century later, ARRL – still headquartered near Hartford – has approximately 167,000 members, and is "the standard-bearer in amateur affairs" (Ham Radio License Manual).

While ARRL's stated mission is "to advance the art, science, and enjoyment of amateur radio," (Ham Radio License Manual), its actual mission is to pursue the aforementioned policy objective by advocating for the preservation of the amateur service bands and promoting norms that minimize interference on those bands. Indeed, the organization states that "ARRL represents US radio amateurs to the Federal Communications Commission and other government agencies in the US and abroad" (Ham Radio License Manual), and it publishes the license manual that explains the rules and norms of amateur radio. Its five pillars – public service, advocacy, education, technology, and membership – each support the actual mission.

### PUBLIC SERVICE

It may be a cynical analysis, but the public service pillar of ARRL is, at its core, leverage. Public service is the main reason the FCC makes amateur operator licenses attainable. Indeed, in the "basis and purpose" section of the amateur radio service regulations, the very first point acknowledges "the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications" (47 CFR §97.1). ARRL created the Amateur Radio Emergency Service (ARES) in 1935 to provide communication support during natural and man-made disasters, and it has remained vital through the modern era. For example, when hurricanes Harvey, Irma, and Maria knocked out mobile and landline telephones, electrical power, cable TV, and internet service in Texas, Puerto Rico, the US Virgin Islands, and across the Caribbean in 2017, ARES volunteers worked closely with the National Weather Service and the National Hurricane Center to report on local conditions, and they were put to work at Emergency Operations Centers (EOCs) and Red Cross shelters in the affected areas (Ham Radio License Manual). The FCC would be foolish to inhibit the amateur service.

### ADVOCACY

Before undertaking this investigation, I was unaware of the size and public service of the amateur radio community. Policymakers may be similarly unaware, which is why the advocacy pillar of ARRL exists. The organization claims to have thwarted "repeated attempts to restrict [amateur radio's] growth" (Ham Radio License Manual) by advocating to the FCC and the ITU.

### EDUCATION

The education pillar of ARRL is fairly straightforward: Amateur radio operation requires specialized knowledge, so to maintain the amateur radio community, that knowledge must be shared. That is why they publish the license manual, and they encourage experienced amateur radio operators to be an "Elmer," or mentor, to new entrants. (A mentor named Elmer inspired the jargon.) ARRL also publishes numerous resources on its website, including a tool to find upcoming examinations nearby, which ARRL members volunteer to administer. The organization made it so easy to sign up that I did!

### TECHNOLOGY

It is ironic that to preserve the wireless communication commons, the amateur radio community must increase the number of appropriators. However, the technology pillar makes this sustainable. New technologies developed by amateur radio operators have allowed the community to grow without overcrowding the amateur service bands.

### MEMBERSHIP

The final ARRL pillar, membership, goes hand-in-hand with education. A large community is only influential if it is unified, so ARRL not only trains new amateur radio operators, but recruits them into the organization. Membership also serves a practical purpose: Funding. One must pay to become a voting member, which is how the organization funds its work. Why would amateur radio operators want to be voting members? ARRL leaders are determined by election, and those leaders decide which policies to support and oppose.

### ONGOING CASE

It is now possible to analyze an ongoing case that has divided the amateur radio community. The story begins on November 15, 2013, when the ARRL submitted a petition for rulemaking to the

FCC requesting that the symbol rate limit be replaced with a bandwidth limit (Imlay 2013). The details are not important, but the organization claimed that "the proposed rule changes would…permit greater flexibility in the choice of data emissions" (ARRL News 2013), meaning new encoding techniques would be permitted. The petition was put on public notice for comments.

As requested, on July 27, 2016, the FCC issued a notice of proposed rulemaking, but instead of proposing to replace the symbol rate limit with a bandwidth limit, it proposed to just eliminate the symbol rate limit (Dortch 2016). Again, the details are not important, but the proposal was crafted as a compromise to balance the concerns expressed in public comments on the ARRL petition. The ARRL formally reiterated its position on October 11, 2016 (Imlay 2016).

Then, on October 9, 2018, an amateur radio operator from Lincoln, Nebraska named Ron Kolarik exercised his right to "file a statement…in opposition to a petition for rule making prior to [Federal Communications] Commission action on the petition" (47 CFR §1.405), claiming that there was "overwhelming opposition" among amateur radio operators to both the ARRL's and the FCC's proposals, and he petitioned instead for regulatory modifications that would block new encoding techniques as well as some that were already in use (Kolarik 2018). He argued that the ones already in use were generating effectively encrypted signals that cause interference, and warned that the new techniques would only make matters worse.

Kolarik's petition ignited a fierce debate within the amateur radio community. Those aligned with him believed that the new encoding techniques threatened to destroy the wireless communication commons, but others believed the so-called threat was actually an opportunity to create new services like Winlink, an over-the-air email system run by Amateur Radio Safety Foundation, Inc. (ARSFI). On November 15, 2018, Prof. Theodore Rappaport (Fig. 3), a wireless expert at New York University, submitted comments to the FCC in support of Kolarik's petition.

He wrote that "the reason why amateur radio works reasonably well in discipline with very limited FCC involvement and enforcement is because of its self-policing nature of monitoring content over the airwaves, from peer pressure, which is made possible only by open and unobscured transmissions over the air" (Rappaport 2018), an argument consistent with the findings of this paper. He went on to call Winlink a "threat to our national security," which prompted the ARSFI President, Loring Kutchins (Fig. 3), to submit his own comments to the FCC challenging Rappaport's claims and explaining that Winlink enhances emergency communications (Kutchins 2018).

Figure 3. NYU Prof. Theodore Rappaport (left) and ARSFI President Loring Kutchins (right) (IEEE Spectrum).

Hundreds of comments were submitted on either side, including increasingly heated ones from Kolarik, Rappaport, and Kutchins. The ARRL stepped in to mediate, but a compromise could not be reached, so the organization formed a committee to address the issue (ARRL News Aug. 2019). The committee has not yet completed its study, but on November 4 and 5, 2019, an ARRL delegation led by the organization's President visited FCC Headquarters in Washington, DC to lobby for ARRL's original proposal to replace the signal rate limit with a bandwidth limit (ARRL News Nov. 2019). The delegation argued that ARRL serves the amateur radio community at large, and that the organization's proposal best conforms with long-standing ITU regulation.

## Conclusion

It remains to be seen what the ARRL committee will recommend and what the FCC will ultimately decide, but the particular result is less important than the democratic process by which it comes about. It is clear that individual amateur radio operators, the ARRL, the FCC, and the ITU all have important roles in the wireless communication commons. The rules and norms that define their interaction have sustained amateur radio for over a century. Whatever happens, I am confident that the community will survive.

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