Mending the Fabric: the Contentious, Collaborative Work of Repairing Broadband Maps

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In 2011, the United Nations declared Internet access to be a basic human right. Achieving universal Internet access has been a longstanding goal of governments around the world. In the United States (US), provision depends primarily on decisions made by Internet Service Providers (ISPs) driven essentially by commercial market concerns. To encourage deployment in underserved regions, the US federal government has recently allocated unprecedented funding, with distributions guided by the information in *broadband maps*, spatial representations of current Internet access and quality published by the Federal Communication Commission. Yet, these maps are known to be inaccurate, especially for populations that are marginalized, such as tribal and rural residents. We are interested in the collaborative and contentious efforts to *repair the data* contained in broadband maps, and particularly by the efforts of citizen groups and local government to counter claims made by ISPs. In this paper, we study these efforts via interviews of 14 individuals involved in various local and regional roles, in policy, IT, advocacy, and research. We draw upon frameworks of repair and of data activism to ask who does this work and why; what tangible and intangible tools are brought to bear; and how the structural context simultaneously empowers and burdens repair workers. In doing so, we make three contributions: (i) we critique the process and system for broadband map repair for the burdens it places on historically marginalized groups to demonstrate how they have been left out of expansion and how their experiences are otherwise silent in official records; (ii) we bring together analytical concepts from repair and data arenas to examine repair work that is substantially shaped by socio, political, and economic context; and (iii) we illustrate how viewing broadband data workers as activists reveals the inadequacy of current tools and the opportunity for better support for their long-term, contextualized, and mediated efforts.

CCS Concepts: • **Human-centered computing** → **Empirical studies in collaborative and social computing**; • **Social and professional topics** → *Broadband access*; Governmental regulations.

Additional Key Words and Phrases: broadband, repair, mapping, data politics

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1 INTRODUCTION

> "*You can easily dispute, or challenge, information shown on the map that you believe is inaccurate. An accurate map helps identify the unserved and underserved communities most in need of funding for high-speed Internet infrastructure investments.*"
> – Federal Communication Commission, United States, retrieved July 2023[1]

The passage of the 2021 Infrastructure Investment and Jobs Act in the United States (US) and the subsequent Broadband Equity, Access and Deployment (BEAD) program have brought unprecedented federal funding to improve Internet access across the country. Yet understanding where high speed ("broadband") access is available, and at what quality (e.g., upload and download speed), remains a challenge. In the US, the Federal Communication Commission (FCC) requires that Internet Service Providers (ISPs) submit information about their current coverage using a specific form (Form 477). Using this information, the FCC publishes maps of broadband coverage. However, these maps are well understood to be inaccurate, with both over and under reporting of coverage [2, 20, 26, 32, 33]. Because the distribution of funds for broadband expansion prioritizes areas with inadequate service (i.e., "underserved" [50]), inaccuracies in the maps have a direct bearing on allocation of funds and the possibility of better future access. Communities lacking in Internet access and reliable broadband coverage data are often rural, tribal, and/or economically marginalized.

Towards improving the quality of Internet access, citizens and citizen advocacy groups have embarked on their own Internet measurement activities, often to defy the claims of ISPs about coverage. For example, on Deer Isle off the coast of Maine, the town manager rallied residents to provide data on Internet coverage after the incumbent provider published maps showing far more coverage than citizens experienced [5]. The accuracy of the Deer Isle maps mattered, because the incumbent was attempting to block a competitor from funds to expand coverage on the island, arguing that the island was well-covered already. This is not the only instance where ISPs may have a financial interest in the (in)accuracy of maps, e.g., claiming coverage to prevent funding to competitors in a region [3, 45]. The FCC has attempted to leverage citizen measurements through crowdsourcing, but the level of participation has been low [3]. Citizen and government-led efforts to improve mapping are highly uneven, depending on skills, motivation, and resources of individuals and organizations. In the case of Deer Isle, the town manager had a doctorate in urban planning.

Thus, the work of producing maps that document Internet coverage and coverage quality is, in practice, an uneasy collaboration between citizens, organizations, government at different levels, and ISPs. Figure 1illustrates the relationships among these actors, which determine the way each of them may use and/or populate official broadband maps. Independent efforts to dispute or *repair* the official maps have accelerated in recent years in anticipation of federal funding. Recently, the FCC established a mediation framework for data repair efforts via a structured process that dictates what makes a "cognizable" challenge by independent groups [16]. Despite the characterization as "easy" in our opening quote, the FCC document which describes the requirements for mobile broadband challenges exceeds 150 pages. The need to repair and the rules imposed by authoritative actors have created alliances among people with common goals, yet who span a diverse set of roles. Here we group the local government, nonprofits, and citizens involved as "people working in broadband" (a term coined by one of our interview participants) or *broadband workers* for short.

In this paper, we seek to understand the collaborative and contentious efforts to create accurate maps of broadband Internet access, and specifically the role of those closest to ground truth — broadband workers — as they seek to repair the data contained in official maps. By framing this effort as repair, we are able to draw upon and expand the understanding of repair work in the CSCW and HCI research communities, in an arena of politics, exclusionary policies, and capitalism.

[1]https://www.fcc.gov/BroadbandData/consumers

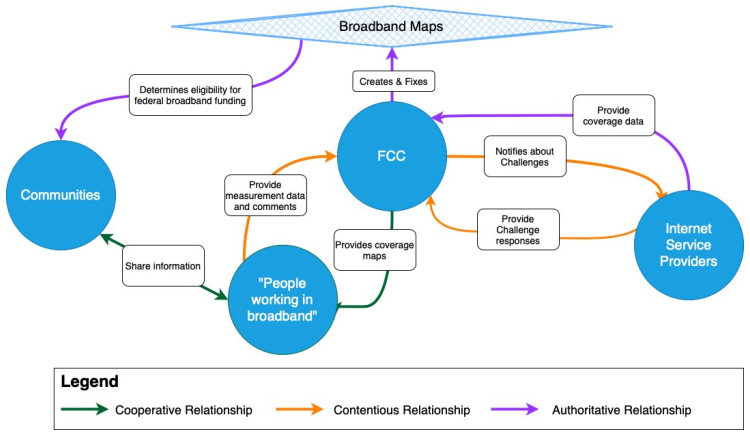


Fig. 1. The contentious, cooperative, and authoritative relationships between ISPs, the FCC, and "people working in broadband" informs how national broadband maps are created and mended, ultimately determining how communities are (dis)empowered to access funds for broadband deployments.

Because of the complex context of the repair, we also draw upon recent work in *data arenas* [54] that casts data as a social good that "mediates relationships and constitutes the position of the actor" and highlights uneasy or contentious collaboration. We also document remarkable creativity and empowerment, as well as opportunities to make repair work easier. We ask the following research questions:

RQ1. Who is doing the work of data repair in broadband and what are their motivations?
RQ2. What are the tools (tangible and intangible) of data repair in broadband?
RQ3. How does the structural context of broadband data simultaneously empower and burden individuals and communities in repair work?

We offer three contributions: (1) We critique the process and system of broadband map repair for the burdens it places on historically marginalized groups to demonstrate how they have been left out of expansion and how their experiences are otherwise silent in official records. The result is an example of cartographic silence in the realm of provision of critical infrastructure. (2) We bring together ideas from repair and data arenas to examine repair work that is substantially shaped by socio, political, and economic context. This context affects nearly all aspects of the repair work, from the definition of what is to be repaired, to how repair work is recognized as legitimate, to what constitutes repair completion, to how repair work and workers can have influence when their work is part of long-term resource allocation and infrastructure deployment processes. (3) We illustrate how viewing broadband data workers as activists reveals the inadequacy of current tools and the opportunity for better support for their long-term, contextualized, and mediated efforts. An alternative view — that of broadband measurement work as akin to citizen science — is implicitly suggested in current tools and reveals their limitations.

2 BACKGROUND

Internet connectivity is a resource that has become fundamental to participate and survive in the 21st century. Recent political discourse has placed Internet access and availability on the forefront of infrastructure planning [3, 4, 49], yet the constantly evolving reach and definition of broadband Internet poses a unique set of obstacles unlike other established infrastructures. This section will illustrate a handful of such obstacles through an overview of recent broadband mapping

and expansion efforts in the US. First, we will describe the basic technological characteristics of Internet connectivity and their relationship to existing policy (Section 2.1). Then, we will outline the socio-political climate of Internet access in the US with a description of federal efforts to document the availability of broadband in this country (Sections 2.2 and 2.3).

2.1 Broadband Technology

Legislatively, Internet connectivity is most often characterized by its speed—in the download and upload directions—and the technology used to access the Internet. The FCC has historically used the term "broadband" to denote a high-speed Internet connection that is "always on and faster than the traditional dial-up access," an increasingly anachronistic reference to the provision of Internet access over traditional telephone lines [15]. The most common broadband Internet technologies today include those used in fixed locations such as in the home or office building (e.g., fiber, cable, fixed wireless, and satellite) and those used for mobile access (predominantly cellular). Wifi supports limited mobility, confined to the reach of an access point, which is typically on the order of tens to a few hundreds of meters. Thus, Wifi is generally considered part of an otherwise fixed location deployment. The speed of fixed Internet access is associated with the street address of service, while the speed of mobile Internet access is associated with geographic coordinates. Both types of access technology require measurements to ascertain achieved performance, which can differ from provider-advertised performance. Mobile performance is especially challenging to characterize completely because performance is highly dependent on local conditions such as line of sight, distance between the base station and end device, congestion, and weather.

Since 2015, the FCC has officially considered 25 Megabits per second (25 Mbps) download speeds and 3 Mbps upload speeds (25/3 for short) as the minimum benchmark for "advanced telecommunications capability" of a fixed broadband service [15, 41]. However, ever-growing online tools and services with increasing bandwidth demands prove that a 25/3 connection is insufficient and disruptive for daily tasks, such as remote work or education, or for essential services, such as telehealth. Indeed, the FCC released an announcement in July of 2022 outlining their Chairwoman's proposal to increase the 25/3 standard to 100/20 to better reflect modern conditions [41].

2.2 Broadband Maps

As a response to the Broadband Deployment Accuracy and Technological Availability (DATA) Act passed by the US Congress in 2020, the FCC manages and releases annual maps describing the availability of broadband throughout the US [16, 51]. These maps employ two complementary data sets. First, the FCC *Broadband Serviceable Location Fabric* ("the Fabric") dataset contains "locations (or buildings) in the US and Territories where *mass-market*[2] fixed broadband Internet access service is or could be installed" [18, 19]. A private company generates and licenses this dataset, which relies on a variety of sources, including aerial and satellite images, address databases, as well as tax and vendor records [19]. Second, the FCC *Broadband Availability* dataset includes a series of maps and lists, which specify broadband availability attributes for a given location. Each datapoint must include (among other metrics) the technology type, such as 3G, 4G, or 5G in the case of mobile, or fiber, cable or wireless for fixed; as well as the minimum speeds for mobile, or the maximum advertised speeds for fixed. ISPs are required to self-report their fixed and mobile coverage data to the FCC each year for these maps.

[2]The Fabric has a separate representation for facilities with custom, enterprise-grade Internet services, such as schools, libraries, and most other community anchor institutions.

Public concern on the veracity of the FCC maps is multifold. On one hand, the locations used to map connectivity should be accurate not only in terms of their physical coordinates and service attributes (i.e., is it considered "serviceable" by FCC standards), but also on the broader context they represent. For instance, a location may not always be associated to a street address, or it could involve a multi-family dwelling. Such locations may be misrepresented or missing entirely from the Fabric. Furthermore, claims to the availability of connectivity in each location may raise questions with regards to the quality and the lived experience of a service. For example, *are the advertised speeds actually achievable at a certain location? What is the quality and reliability of the service over short and medium timescales?*

2.3 FCC Procedures

Following the creation of the first broadband maps, the FCC updated their data collection specifications in 2022 to include challenge, verification, and crowdsourcing processes [16]. The new procedures enable government entities, ISPs, third parties, and individuals to dispute and possibly correct both Fabric and Broadband Availability data. Our work is mainly concerned with the challenges to the Broadband Availability data. We will henceforth use "Challenge Processes" as a shorthand for the official crowdsourcing procedures outlined by the FCC to improve the quality of broadband data.

While the Challenge Processes appear promising, the complex requirements to carry out a "cognizable challenge"[16] may impose considerable barriers to participation. In order to be accepted for a Mobile Availability Challenge, for example, measurement speed test data must be collected within a particular set of parameters, including restrictions on the time of day and duration of the tests. A sufficient density of measurements must be collected, and a set of specific metrics must be gathered. Although recent updates to the FCC Speed Test App [17] may guide users through the initial stages of collecting *mobile* measurements for a challenge, everything that happens *after* submitting these data remains obscure. For instance, once enough measurements have been collected in a particular space, the FCC *might* file a challenge on behalf of the data collectors. After a challenge has been made, ISPs have 60 days to rebut the challenge with their own measurement data. At the time of this writing, it is unclear how many have measurements led to challenges, how many challenges have corresponded to actual changes in the Fabric, or how many ISP rebuttals are successful.

3 RELATED WORK

Our work relates to two major bodies of CSCW literature. The first is that of repair work, which examines the processes, motivations, and consequences of work that seeks to mend objects and systems. The second relates to data politics and contentious collaborations. Additionally, we engage with work on marginalized communities to contrast official definitions in federal policies against CSCW research terminology.

3.1 Repair Work

There is a long history of attention to repair work in CHI and CSCW, often examining sites in ICTD or HCI4D contexts [10], that present unique constraints not typically considered in the more privileged, resourced, and/or sterile environments in which technology is designed. In his seminal 2014 essay, *Rethinking Repair*, Steven Jackson proposes a "broken world" perspective where two paradoxical realities exist: one in seemingly constant and tumultuous collapse, and another under hopeful and persistent restoration [48]. This view allows us to consider the instabilities created and left behind by rapid innovation, as well as the "resilience, creativity, and sheer magnitude of the work represented in the ongoing maintenance and reproduction of established order" [48].

While correcting data on official broadband maps can be likened to counter-data efforts [9], repair provides an analytical lens which is better suited for the *ongoing* efforts of broadband workers. In our findings we will provide examples for how broadband workers negotiate arbitrary standards and collaborate with actors of various interests to restore order within their communities–in the context of policy and digital equity [39].

The scope of broadband work is twofold: first, there is the push for broadband *expansion*, followed by the labor to accurately document (i.e., *map*) the gaps that remain. Filling these "cartographic silences" [21, 47] requires extraordinary effort. In particular, we draw inspiration from the three key themes Jackson identified in repair work: the *innovation* exuded while using and re-purposing tools for repair; the *knowledge/power* dynamics that become transparent due to breakdown; and the *ethics of care* that embody a moral responsibility towards the objects of repair [48]. These three themes helped frame the discussion in Section 6.

Literature on repair often looks at the work involved in tinkering with discrete physical objects, e.g., fixing a broken screen on a phone [23], repairing a variety of analog electronics [27], or maintaining rural networks [24]. This type of work may take place in specialized shops by trained individuals, or collaboratively and distributed across multiple sites based on need and available skills. There are many works from around the world focusing on *broadband infrastructure repair*, with prominent elements of care and creativity [1, 13, 22, 25]. This paper highlights similar themes, yet focuses on the data collection and coordination efforts that broadband workers conduct *in preparation for* subsequent broadband buildouts. Of particular interest to us are the discussions around collaborative and negotiated repair work. Rosner and Ames coined the concept of *negotiated endurance* to describe the processes where various actors "drive the ongoing use, maintenance, and repair of a given technology through the sociocultural and socioeconomic infrastructures they inhabit and produce" [44]. Related to negotiated endurance is Jung et al.'s concept of *negotiated repairedness*, which refers to the contingent stability of artifacts under repair and the temporary conclusiveness of repair work [27]. Importantly, Jung et al. surface the ephemerality of repairedness as new situations render artifacts in need of new repair. Indeed, repair work can be iterative, where it is up to actors of repair to negotiate new definitions of repairedness in light of new circumstances. This renders repair work as a continuous and contingent process, rather than a process with a clear ending. By examining such negotiations, we are able to distill the complex relationships at play in broadband work. Especially in the case of Internet connectivity these negotiations are challenged by power and knowledge imbalances.

More recently, repair, data, and civic involvement are coming together in interesting ways to bring citizens into the process of documenting and deciding on what to repair and how. For example, Meng et al. consider a collaborative setting for gathering and acting on data about urban repair that centers community members and their ability to draw upon care [37]. Cooney and Raghavan evaluate original prototypes for a tool that enables citizen-led city planning and design in an effort to support urban repair projects [7]. They use citizen science as a starting point for thinking about how citizens can use tools, appropriately designed, to have legible influence. Similar to how the FCC's Challenge Processes seek to improve broadband mapping data to better inform future broadband expansion efforts, the goal of the urban planning tool is to use the citizen-made design inputs to better inform future city planning projects.

3.2 Data Politics and Contention

When repair work becomes a negotiation among distributed and diverse actors, there is room for contention: *what is worth repairing and to what extent? Who gets the privilege/burden of repairing? Who decides what qualifies as repair?* Scholars in CSCW and beyond have borrowed the term of *arenas* from the social sciences to characterize these kinds of contentious spaces [28, 54]. In

describing the relational nature of data, Ślosarski introduces a theory of *data arenas* [54]. Ślosarski argues that "attention should be paid to the data itself as a social good that mediates relationships and constitutes the position of the actor." In their analysis of the varying identities in the space of "security research" at hacking conventions, authors Korn and Wagenknecht describe the spectrum of interests between the hacking/research community and industry on an *arena of repair*, where mutual concerns meet and differences in values must be recognized and negotiated [28]. In other words, an arena–particularly a *data arena*–embodies a space where interactions between actors are inevitably contentious, yet cooperation still takes place, and all actors involved are focused on "solving a case-specific problem using data as a symbolically meaningful resource" [54]. Data arenas, thus, become a useful theoretical framework to characterize the various actors involved in the work of broadband in the US. Furthermore, contrasting forces of contention and cooperation are helpful as a way to analyze the work of repair that further supports Jackson's view on broken worlds. Our critique of the FCC procedures, especially as these prioritize provider data, is a direct answer to Ślosarski's call to further study "incumbents in the data arena" [54].

Contention in arenas becomes critical when the context involves policy. A particularly rich area of study on contentious work relates to *data politics*. One example is Singh and Jackson's ethnographic study on a national identification project in India, where the authors identified key challenges and pitfalls in the modernization and digitization of governance [46]. Singh and Jackson call for taking on the perspective of an infrastructure (i.e., "seeing like infrastructure") to better understand the roles and limitations of data when it is used to represent real-world people and phenomena [46]. This approach illustrates how ascribing data categories to citizens can distort or fully erase their lived experiences. Yet, some may find this kind of representation useful or even accurate, which could positively influence subsequent policy outcomes. Furthermore, the authors utilize *resolution* as both a metaphor and a guiding theory to signify the visibility of citizens and their activities to infrastructures. In other words, low resolution refers to lower visibility or the absence of data; whereas high resolution implies higher availability of data [46]. This metaphor also serves the context of broadband where certain citizens, such as tribal members, have been left out of official datasets, and rendered invisible [46] to the broadband infrastructure, due to inaccurate or insufficient data [14].

Fortunately, there is a body of work that suggests ways with which actors in these roles might (re)claim power in arenas fraught with incumbents. In their investigation of outsourced machine learning data work in Latin America, Miceli and Posada leverage the Foucauldian notion of *dispositifs* to conceptualize the ensemble of discourses, actions, and objects that are oriented towards producing knowledge and power relations in data and labor [38]. Importantly, they make suggestions about how data workers can reorient components of the data-production dispositif to render themselves more visible. These suggestions include making data pipelines more visible to data workers, encouraging interrogation of preconceived labeling taxonomies, and investing in the experience and expertise of workers. Similarly, our work seeks to attend to broadband workers to better understand the affordances required by tools and policies to enhance the visibility of incumbent actions and to support citizens and policymakers while they ensure that communities are amenably rendered visible in data and to services.

The work of reclaiming visibility through data work has long been a theme in Indigenous data sovereignty [29]. Specifically related to the work of mapping, Kukutai et al. describe an approach that they used to "repatriate and harmonise historic land data," tracing the history of the 45,500 acre Opuatia Block–Indigenous Māori land that had been confiscated by settler colonizers in 1866 [30]. Specifically, the authors devised a methodology that allowed them to synthesize historic records of land alienation (transfer of land away from Māori control) with Opuatia maps to identify and quantify the alienation of land. In devising this methodology and doing this work, Kukutai

et al. elucidated how Indigenous data sovereignty might allow disenfranchised people to speak truth to power, though the authors describe how accessing Indigenous data can be a substantial burden of labor for analysts. It also demonstrates that mapping relationships between people and land at a finer scale of granularity can reveal more exacting truths about disenfranchisement. In Section 6.1, we comment on how the responsibility of broadband data repair often falls unevenly on disenfranchised and marginalized groups.

3.3 Marginalized Communities

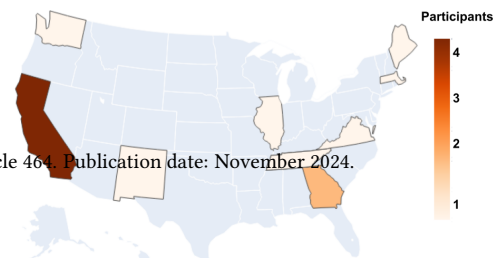
Evolving from the FCC classifications on broadband speeds (Section 2), the Infrastructure Investment and Jobs Act (IIJA) defines an "unserved" location as one without any broadband service at all or with Internet service offering speeds below 25/3 Mbps. It defines an "underserved" location as one without broadband service offering speeds of 100/20 Mbps [50]. These definitions are agnostic to the type of Internet broadband technology and strictly serve to prioritize areas in need of federal funding. However, not all federal programs use the same benchmarks for broadband speeds as the FCC and IIJA. Moreover, each state in the US has the authority to either defer to a specific agency's definition or to define their own classification for "unserved" and "underserved" depending on their needs. For instance, some state broadband offices have drafted definitions based on the number of providers in an area and population size, regardless of Internet speeds [50]. Broadband workers carefully employ these terms by distinguishing between the FCC-prescribed definitions and those of their local offices. Though slight variability exists, these definitions identify areas which lack appropriate broadband services.

In HCI and CSCW, we have the concept of "underserved users" or those who are not typically taken into consideration during the design process of today's technology. This user category includes "low-income, gendered, ethnic, and racialized populations, [as well as] the unique needs of people with disabilities" [11]. Dillahunt et al. caution that traditional HCI methods in this context may perpetuate existing power imbalances [11]. Asset-based design is one of several efforts to better support underserved groups, particularly those facing more critical instances of oppression, such as the case with vulnerable populations [52]. Work that centers the agency of underserved or vulnerable groups resorts to terms like "minoritized" to critique systems of oppression that historically uphold racialized and gendered hierarchies, or in the case of Crooks and Currie, to more broadly "foreground power relations" [8].

Perhaps the terms with the closest parallels to the context of broadband are those of "hard-to-reach" or "hidden" populations, as described by Xu et al. [53], who borrowed the concept from the field of nursing. These describe "the socially disadvantaged groups who face barriers with transportation, digital literacy, and financial access" [53]. Across these terms for marginalized communities in HCI and CSCW literature rises a common goal for establishing better methodologies to engage with these populations in ethical, effective, and sustainable ways. We use the term "marginalized" to encompass larger societal issues that communities face. Our references to "underserved" and "unserved" allude to the Federal definitions referring to broadband Internet access. Our interviewees used these terms in a similar manner.

4 METHODS

We conducted semi-structured interviews with 14 professionals working in broadband mapping and expansion efforts in North America, who are particularly involved in local, city-run, or state-run organizations. The purpose of the



interviews was to understand the different responsibilities of broadband workers, their individual motivations and concerns, and the collaborations that take place in their work. We have categorized interviewees by their role in Table 1, and identified them with anonymous labels. Our Institutional Review Board approved the interview protocol and every participant consented to take part in the study.

Label	Current Role(s)	Past Role(s)	Gender	Community Type
P1	academic researcher	academic, television production consultant	M	rural
P2	academic researcher	student	M	urban
P3	volunteer and IT specialist	advocacy group member, industry technologist	M	rural
P4	code developer, IT specialist, educator, data analyst	code developer, industry technologist	M	rural and tribal
P5	program manager, advisory board member	advocacy group member	M	urban
P6	county-level CIO	city-level CIO	M	urban
P7	city planning and mapping specialist	advocacy group member	M	urban
P8	regional policy representative and advocacy group director	regional policy representative and advocacy group director	M	tribal
P9	community engagement specialist, educator	consultant	F	urban
P10	IT specialist, strategic planning manager, network engineer	consultant	M	urban and tribal
P11	geospatial analyst	community development analyst	F	rural
P12	regional policy representative and advocacy group director	regional policy representative and advocacy group director	M	tribal
P13	public executive officer	journalist	M	rural
P14	public executive officer	business owner, advocacy group member	M	rural

Table 1. Interview participant demographics and relevant roles.

4.1 Participants

We recruited half of the interview participants
by advertising our study on active newsletters related to broadband access and digital inclusion in the US. Thus, half of our participants were self-selected. We also reached out to our network

and sought participation from broadband actors, making sure to recruit participants representing a variety of roles (e.g., IT, mapping, policy). These contacts also provided suggestions, allowing for some snowball sampling. Finally, we attended several broadband deployment webinars, and recruited two participants by contacting the main speakers of said events.

All the participants had either direct or indirect involvement with policy work. However, it is worth noting that most participants fulfill multiple roles. As we will explain in our findings, this work rarely allows anyone engaged in broadband to focus on any particular role. We highlight both current and past roles to demonstrate the perseverance of individuals who engage with broadband work as well as the diverse expertise that their roles demand. Only one of the participants (P3) became involved with broadband by chance, and actively volunteers on broadband maintenance in their community, despite it not being related to their day job. All other participants maintain professional roles related to broadband, either directly, such as managers or IT directors within programs dedicated to broadband efforts, or indirectly, such as city planners or contractors who actively partner with broadband mapping projects.

One interview participant identified as Native American and another as Hispanic/Latino. All other interview participants identified as White. Because this work is highly contextual, we note the participants' current locations or main communities of involvement, which we show in Figure 2. In the interest of privacy, we have decoupled this information from Table 1. Table 1 does report the types of communities with which participants currently engage. We characterize these communities as rural, urban, and/or tribal. In the context of this work, tribal communities are those governed by US federally recognized tribes, and the rural/urban distinction is based on the US Census criteria[3].

4.2 Interview Data and Analysis

We asked participants open-ended questions about their experience collecting, analyzing, and/or mapping broadband data. Our initial set of research questions focused on how broadband workers *conceptualize* and *use* broadband data. The first author led all the interviews. Each interview was recorded and transcribed with permission from the participant. The interviews lasted between 25 and 71 minutes, with an average of 40 minutes in length and a grand total of 8.5 hours of recordings. Participants P9 and P10 were interviewed together because they are collaborators on at least one project related to broadband.

Using a grounded theory approach, the authors reviewed different transcripts, and highlighted relevant text pertaining to the use, collection, and analysis of broadband data, as well as any comments on federal procedures or other information on what the participants do in their work. We used this text to generate our own personal sticky notes about potential themes that we observed. Then we used these sticky notes for live discussions and affinity mapping.

Our thematic mapping sessions took place in five major steps. (1) First, we conducted one initial round of thematic analysis collaboratively via Zoom. Each author described the themes that emerged from the subset of transcripts they reviewed. In an effort to consolidate these preliminary themes, we considered *infrastructuring* as a possible framework. Singh and Jackson provide an analytic framing on "seeing like an infrastructure," which includes questions such as who does the work and when/how/why is the work done. We found this helpful for refining our research questions from focusing on data uses to examining the *work* of improving the data. This led us towards literature on repair work. Then, (2) the third author revised the themes based on this initial discussion and the sticky notes on the shared board. Drawing inspiration from reparative justice work [6], the third author sought a model that could reverse the current power dynamics in the

[3]https://www.federalregister.gov/documents/2022/03/24/2022-06180/urban-area-criteria-for-the-2020-census-final-criteria

Challenge Processes: *what would it look like to focus on supporting overburdened communities that we already know have needs to be repaired?* (3) After a clearer focus emerged around "repair," all the authors discussed relevant questions we could ask from the interviews (e.g., who repairs? why repair?). (4) Next, the first author sketched diagrams to group the themes into categories answering these relevant questions. (5) Finally, the authors read other transcripts (different from the first round) to corroborate the key themes.

4.3 Limitations

When recruiting participants, our goal was to cover a wide range of roles, location, and community type represented. However, our pool of interview participants was not as diverse as we would have hoped in terms of gender and race. One issue is that historically disenfranchised communities working towards broadband access or expansion may be especially short on time and/or resources. It is pertinent to seek their input, while also respecting their time and compensating them fairly. Thus, while this work represents an important exploratory perspective on the nature of broadband repair work, there is a need for sustained, iterative characterizations that more thoroughly probe the nuances of this work in marginalized communities.

4.4 Statement of Positionality

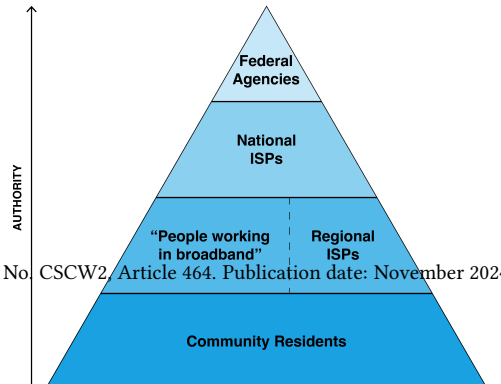
The first author is a PhD student at an R1 institution, advised by the fourth author. She was born outside the United States in a region of political instability. She has collaborated with tribal and rural communities on broadband expansion efforts in the US. All four authors have substantial experience as collaborators and have over three decades of combined experience in community-based broadband research, often in partnership with people working in broadband and operating community ISPs. Through this work, they have developed a nuanced perspective on the broadband arena, both as it exists at present and how it has evolved through decades of policy and practice.

5 FINDINGS

Broadband mapping and expansion efforts require those involved to sustain continuous efforts while managing an array of information and systems. We seek to position this process within a data repair context. Our findings are organized into six themes, grouped into three sections: Section 5.1 presents the *roles* of broadband workers and their *motivations* (towards RQ1, who does the work and why); Section 5.2 describes the tangible *hardware and software tools* used in the work and the intangible elements of *care and creativity* (towards RQ2, what tools are utilized in the work); and Section 5.3 characterizes the *contentious relationships* and *structural barriers* to broadband data work (towards RQ3, how does the socio-political structural context empower and burden the repair workers).

5.1 Who and Why

5.1.1 Roles in Broadband. As we introduced in Section 2.3, there are a variety of groups who may interface with the FCC Broadband Data Collection procedures, namely, government entities, advocacy groups, ISPs, third parties, and individuals. Access to and availability of broadband services spans a variety of social, political, and technical infrastructures. Because of this, broadband workers manage complex and highly collaborative projects. For example, P12



explained that broadband is typically *"co-built"* with other utilities, such as power, water, and sewer, because you can place fiber conduit in tandem with those efforts. He noted that broadband often becomes *"interwoven"* with other funding:

> *"I'm talking to Treasury, I'm talking to the White House, I'm talking to NTIA [(National Telecommunications and Information Administration)], I'm talking to RUS–Rural Utilities, FCC; and I'm constantly working on angles that are supportive of broadband, but from multiple aspects of other utilities as well."* -P12

Some broadband workers may become overwhelmed by the number of proverbial "hats" they must wear in order to fulfill the variety duties associated with their roles. This is especially true for those newer to the broadband sphere. Some participants lamented falling behind on a handful of projects because they feel inundated with the amount of information they manage: *"there's so much input – right now it's a firehose for me"* (P1).

We wish to differentiate broadband workers as a sug-group of people within an already diverse system. While we represent the complex, cooperative, contentious, and authoritative relationships involved with the FCC Challenge Processes in Figure 1, the general authority afforded to each sub-group can also be simplified into a pyramid structure (see Figure 3). We characterize broadband workers by noting the organizations with which our participants interface. From P12's quote above, we know that he is constantly in conversations with *federal* agencies, which we exclude from our definition of broadband workers given the level of authority they hold over our participants. Participants such as P9 and P10 mostly engage with city-level offices and local community-based organizations. We include these under the umbrella of broadband workers for they represent the same level of authority and engagement within the community. Participants with more technical capacities, such as those who work in code development or IT offices, may also work closely with ISPs. We do not consider ISPs broadband workers themselves for their status as outsiders:

> *"They [the ISPs] are part of the ecosystem, but not part of the community, and it's a completely different engagement."* -P10

Thus, we conclude that broadband workers act as a bridge between authoritative powers and community needs, and are themselves active members or close allies[4] of the communities with which they work.

5.1.2 Individual Motivations. Participants' motivations spanned multiple levels. The first and most straightforward is to *become involved* in their local community. For instance, P6 brought his prior experience in the technology industry into his policy work, and became excited at the prospect of an IT department having a more visible role:

> *"Rarely does an IT department get to actually touch the public. And this was one opportunity I thought would be really be a lot of fun. How can an IT person make a difference in a community?"* -P6

[4]Some of our participants work with tribes, but are not tribal members themselves, or may work with tribes outside of their own.

The next motivating factor comprises the education and advocacy efforts required to *correct* the inaccurate data in federal broadband maps because *"good policy is only possible with good information"* (P8). Most participants were galvanized into the work of broadband when they noted the unreliability or the lack of information on the areas where they lived, especially for those in rural and tribal communities.

Although improving broadband data is a significant portion of the work, the end goal is to actually set up and maintain a quality connection to the Internet in their region. In particular, the term *quality* alludes to more substantial issues beyond the simple binary of whether a connection exists or not. For example, P8 expressed his frustrations at how the oversimplified data on the FCC maps is essentially *"meaningless"*:

> *"What we really should be looking at, in my opinion, is all the indicators of digital equity. So do you have that connection? Is it a sufficient enough connection to do what you need to do to be safe and successful online? Do you have the skills, knowledge, and experience to be safe and successful online? Do you have a device that's quality enough to do what you need to do online? In there, there's digital literacy, there's cybersecurity[...] A lot of people who remain offline could have access if they wanted to have access. They just don't see the benefit to it. They don't see what's in it for them. So the other piece of the puzzle is, is there relevant content online?"* -P8

5.2 Tools

5.2.1 Software and Hardware Tools. Participants' data collection efforts involved both qualitative data, in the form of surveys, community events, and focus groups, and quantitative data mostly through Internet speed tests. A unifying sentiment across interview participants is that commercially available tools are insufficient for their organizations' needs. Custom tools are preferred for a crucial feature: detailed, contextual data in a time-sensitive (near-real time) manner.

> *"You can actually see that what you've been doing as research is getting populated into the database and that's, that's high value for me."* -P12

For instance, P4 developed a custom web tool for residents to take Internet performance measurements, which appends an optional community broadband survey after the measurement completes. The site uses a commercial license, obtained by P4's state, which incorporates Ookla's proprietary Speedtest software. This survey includes quantitative questions (e.g., household income) as well as qualitative questions (e.g., satisfaction with Internet service). The utility of such a tool is that it allows the community to tie an individual Internet measurement with to an individual survey response for a more comprehensive data point.

Importantly, our participants rarely perform direct data collection themselves. Instead, broadband workers manage and coordinate such efforts, spending a significant portion of their time on tools for data *analysis*, such as GIS mapping software or dashboards with statistics on the connectivity in their region. In order to populate the database for such tools, participants will resort to their social networks. Sometimes broadband workers require simple, sporadic measurements. For example, P4 occasionally asks his wife, a schoolteacher, to send her students to one of the major Internet performance sites so they may share screenshots of their results. For more substantial efforts, such as with the surveys described above, participants will engage with local groups to encourage widespread participation.

5.2.2 Care and Creativity as Tools. The intricate and "interwoven" nature of broadband mapping requires an extended commitment, which may span several months at a time. P10 stressed that *"an issue with data collection is that it never ends."* Several of the interview participants have been working in the broadband space for years, even decades, some of which have engaged in multiple

iterations of FCC data collection procedures. For instance, when asked to describe his involvement with broadband, P12 jokingly asked, *"do we have five hours?"* While describing his myriad of (notably, ongoing) projects, one dedicated participant explained:

> *"I failed at retirement many years ago [...] I think I'm on 12 years now."* -P4

The vast amount of data required to gather a complete picture of the digital divide has inspired participants to draw from multiple sources. P4's work in different (yet adjacent) industries allowed him to think about broadband data from more practical and indirect sources. Instead of thinking about the traditional Internet performance tests, he wondered about alternative sources of information for deducing the quality of connectivity in his region:

> *"One could argue that – like we're doing a Zoom meeting right now – does Zoom then have data on people that are having difficulties? And I'm sure they do."* -P4

In addition to innovative strategies for collecting data, some participants provided examples on how they actually *use* their own data in order to work around limitations. For instance, P5 and P6 complained about outdated cable contracts, which forbids them from talking to their service providers about broadband services. Existing regulations inadvertently render communities powerless and dependent on old cable fund revenue in order to fulfill their broadband-related duties. Yet, this has not deterred them from seeking conversations with providers in order to create better contracts for broadband:

> *"When the cable providers see you do that [collecting data], it gets their attention[...] And it's not what [they're] telling you is happening, but you're going to go verify it yourself. It does mean that they know you're serious about it, and they respect you when you pick up the phone and make a call."* -P6

5.3 Obstacles

5.3.1 Contentious Partnerships. The relationships between folks working in broadband, the FCC, and the ISPs are riddled with conflicting interests and tensions. Some participants have been nicknamed or self-described as *"warriors"* or *"champions,"* demonstrating perceptions of the relationships as so contentious as to be combative. Many years of sustained frustration, e.g., due to those in power ignoring (and occasionally *harming*) communities, has led some participants towards cynicism and apprehension. For instance, P3 complained about the federally-sanctioned monopoly that ISPs hold, despite their neglect towards less populated areas:

> *"Year by year, decade by decade, they've been given forbearance [from the government] because of the cost. And so those of us who live in these rural areas don't get connected."* -P3

This type of neglect yields to misrepresentation and erasure of marginalized communities on official datasets. In Section 2.2 we described how the FCC maps are populated with ISP self-reported data, which P12 described as *"marketing data."* P4 argues that *"it's sort of the fox watching the chicken coop"* because when communities run analyses on their own regions they can easily disprove ISP claims.

Many participants voiced their concerns over how the FCC represents their availability data using census blocks. P3 mentioned that it was somewhat of an improvement from previous iterations, which used a coarser-grained representation, the census tract. P4 explained that this is still undesirable because if a single person has Internet within a census block, then the entire block is considered to be connected. P4 argues for an *"inverse"* approach:

> *"I've got people that don't have Internet in that census block, therefore, everybody doesn't have Internet [in the block]–or if they do, they're lucky."* -P4

These types of inaccuracies sustain the digital divide because if a block is wrongly considered connected, then the local community would have limited funding opportunities (if at all) for a new Internet deployment in that area.

This is not a purely contentious setting; some collaboration occurs, although reluctantly at times. For instance, although P6 shares a similar worry as P3 with regards to ISPs being allowed to stop servicing an area due to high costs, he has taken it as an opportunity to start conversations about possible partnerships for new deployments:

> *"I'm going to go create a broadband relationship with everybody, and they're going to notice it[…] Without being mean, or pushy, or being a bully, just being on point, technically, can get their [the ISPs'] attention."* -P6

Indeed, some participants have been able to work through these conflicting interests in order to find opportunities with ISPs. Rural communities often struggle to reach favorable agreements – if they can get these conversations to happen in the first place. In such cases, participants such as P12 became their community's own ISP.

5.3.2 Structural Barriers. The FCC Challenge Processes were created with the alleged purpose of bridging the tensions between the business interests of the ISPs, the lived experiences of the public, and the credibility of the FCC's data and policies. Some participants expressed their hope and positive attitude towards the Challenge Processes, yet the majority are skeptical. For participants like P10 who was already familiar with FCC procedures, these processes came as a welcome change, *"even if the process may not be perfect, it's really nice to be able to provide feedback"* (P10). Yet even P10's collaborator, who feels just as optimistic as he, highlighted the ambiguity and complexity of the Challenge Processes:

> *"I only understood it because I watched like two or three webinars and read a ton of articles. So, it took a lot of my time to self-inform."* -P9

The Broadband Availability Challenges place a significant and oftentimes insurmountable onus on communities. When asked about their opinions on the Challenge Processes, participants described them as being essentially *"flawed"* and *"unreasonable"* due to lack of transparency, lack of guidance, and capricious deadlines, among other issues. Participants were especially concerned with the structure and distribution of information:

> *"It's troubling that the FCC is kind of taking this approach of like trust, but don't verify with the ISPs."* -P2

At the time of the interviews, most participants were still in the throes of conducting their own challenges to broadband data, thus, we have no accounts on the outcomes of the most recent iteration of this process. However, some had heard about the outcomes to challenges to the Fabric (location) data. For instance, P5's city was organizing their own "bulk challenge" to the Fabric because of the significant discrepancies another large metropolitan city uncovered:

> *"I want to say it was in the range of 20 to 30 percent of addresses in [their] city were missing or mislabeled on the original draft FCC map."* -P5

The Challenge Processes are highly criticized in particular by those working with marginalized communities. For instance, P12 explained that the changes in favor of finer-grained data (which P3 thought was a step in the right direction since it allows for a more detailed information) is actually hurtful to tribes:

> *"It is essentially the old 477 data* [5] *cut up into little teeny chunks so that now tribes have to challenge every single little cut up census block, where versus before they used to be able to challenge a region."* -P12

Although the process was not easy before, these most recent changes make it an even larger and more complex burden on tribes, which must also contend with the challenge of "checkerboarding" or situations where contiguous portions of land belong to different jurisdictional powers [34]. Tribes have already *"been fighting those types of battles"* (P12) for decades: they are historically excluded from the language in policy, and often must grapple with being hastily added onto policies, post hoc, via loopholes.

Furthermore, some of the participants consider the Challenge Processes to be futile because they do not consider those who are entirely unserved:

> *"They don't have even a methodology – how can I get online and complain if I don't have an online [connection]?"* -P4

P4 further expressed his disappointment with the fact that the FCC only outputs their data and tools in English (and not in any other language spoken in the US, such as Spanish) by suggesting that *"somebody should get really big in trouble for that [sic]."* These examples further illustrate the perils of exclusionary policies, which disproportionately neglect marginalized communities.

6 DISCUSSION

We will situate our research questions and contributions within the repair themes described in Jackson's *Rethinking Repair*[48]. Towards answering **RQ3** –*how does the structural context of broadband data empower and burden individuals and communities?* – we highlight broadband workers' remarkable and unwavering feats of *innovation* to endure the burden of repair (Section 6.1). In addressing **RQ2** – *what are the tools (tangible and intangible) of data repair in broadband?* – we note the gaps in existing tools at supporting or subverting the *knowledge and power* dynamics within broadband data arenas (Section 6.2). To answer **RQ1**–*who is doing the work of data repair and why?*– we reflect on the acts of *care* and resistance that depict broadband workers as activists (Section 6.3).

6.1 The Burden of the Challenge Process

Much of the repair literature in computing focuses on physical objects, repaired by individuals, guided by valuing the work and the promise of repaired capability, and where the goal is to restore well-defined operation or, sometimes, to create new functionality [23, 24, 27, 44]. In contrast, our work examines the repair of data, to correct the inaccuracies contained in official maps of broadband access by contributing on-the-ground measurements. Initially, broadband data repair may not appear to be any different from existing repair efforts. Historically, the phenomena of breakdown and repair are invisible to the more dominant sites of technology design and development [48]. For instance, the situated, collective effort required to accurately map broadband in a given community is rendered invisible by ISPs' claims to coverage in an area—claims which remain largely unquestioned by the FCC. The *need to repair* is imposed from one more powerful group of people onto another, which is a reality shared among past repair work and broadband data repair.

Past examples on repair work demonstrate ways in which individuals and communities may organize around repair efforts. For instance, negotiations exist within communities with regards to what is deemed worthy of repair [44] as well as the stability of an artifact upon repair [27]. In other words, negotiations revolve around both the *object* and the *output* of the repair process. However,

[5]Referencing the 477 form, which was used in the previous Broadband Data Collection process for the FCC https://www.fcc.gov/economics-analytics/industry-analysis-division/form-477-resources

even though some collaboration may arise in practice, there is an overall distinction that those who carry out repairs possess a certain level of expertise [44], and therefore may define the ways in which they fulfill repairs. Despite their undeniable domain expertise, *broadband workers may not be able to exert authority over the data repair process*. Indeed, not only are broadband workers carefully carrying out the "privileged practice" [44] of repairing broadband data—requiring specific materials and expertise—but they are also navigating the imposed parameters within which they may repair. Recall in Section 5.3.2 where P9 complained about spending a lot of her time to "self-inform" on the intricacies of the FCC processes. This compounds the burden on marginalized communities who, explained in Section 5.3.2, may already be fighting for inclusion in policy. For instance, broadband workers within tribal lands must comb through a lengthy technical document to even determine if existing land jurisdictions will even allow them to comply with the FCC's onerous expectations.

There is something paradoxical about how the Challenge Processes have chosen to render "unserved" and "underserved" communities more visible. While the change requiring ISPs to report their coverage per street address rather than per census block seems to address a longheld critique that census-block reporting failed to adequately reflect on-the-ground realities of broadband access, it presents an immense repair burden on communities that tend to be misrepresented. This is because the process initially assumes that ISP coverage data represents the de facto status of coverage, and then requires broadband workers to identify all the individual addresses or geolocations where this is not the case. This process puts a massive burden on communities where coverage has historically been overstated by ISPs (often tribal and rural communities [33]), aggravating longstanding cartographic silences [21, 47].

The FCC Challenge Processes privilege ISPs by assuming their data is correct until sufficiently challenged; it also disempowers broadband workers by rendering descriptions of the Challenge Processes as complex and asserting timelines for repair that are unrealistic for even the most well-prepared communities. However, as argued by Miceli and Posada, there are significant opportunities to re-dispose data systems towards citizen and community empowerment through the addition of transparency and interrogation of data taxonomies [38]. Thus, our work poses a critical question: *How can we have transparent policy and allow for the Challenge Processes to become more accessible?* Lin and Jackson's perspective on "*artful living with* error" suggests that there is room for improving current policy towards mitigating the burden on broadband workers, for instance, by embracing existing and nascent structures of collaboration which remain "unseen or underappreciated" [31]. What would a fair partnership between ISPs and community organizations look like? What would happen if ISPs were required to conduct *some* targeted measurement efforts in order to report data, instead of relying entirely on the invisible labor of broadband workers to keep ISP data accountable?

As we observed in Sections 5.1.1 and 5.2.2, there is substantial resistance to disenfranchisement that is manifested in the endurance, care, and creativity shown by broadband workers. Those involved in broadband data repair seek to represent the reality that they and their communities experience, in contradiction to versions of reality put forth by ISPs. Repairing the data can be personally satisfying, but the material change in the future comes about when more accurate maps are used as part of resource allocation and decision making around expansion of Internet access. That is, the data repair contributes to what might be viewed as system repair, ensuring that underserved regions are accurately visible to those with the power and capability to provide service. The indirectness of realizing the material value of repair requires that those involved practice a remarkable level of persistence and faith in change. Broadband workers are exemplary *innovators*, and their work a feat of distributed expertise [48].

As noted in Section 5.1.1, there is a longevity associated with broadband workers—particularly in tribal communities. It was common for individuals working with tribal communities to report decades of experience focusing on broadband work. This durability points both to the complexity and

contingency [27, 44] of repair work as well as the resilience of broadband workers. This resilience is a hallmark of Indigenous knowledge about how to recover from and survey through adversarial challenges [36] and it exemplifies the optimism expressed in spite of heavy burdens of repair. One reason for optimism is that the Challenge Processes open pathways whereby communities can take action. For tribes, this broadband data repair work constitutes what Kukutai describes as Indigenous data sovereignty [29] and it is the "site of activism [30]." While the burden of repair can be substantial, it provides a "literal path to decolonization [30]" and self-determined solutions, such as network sovereignty [12].

6.2 Relational Tensions in the Broadband Data Arena

The partnerships formed between broadband workers and ISPs play an important role in realizing a community's repair goals. Although these partnerships are generally perfunctory and face constant negotiations that are often tense and contested [28], it is these kinds of alliances that have the highest possibility of creating an impact.

The FCC is seemingly leveling the playing field of broadband, while–inadvertently or purposefully—rendering the richer contextual data of quality of broadband in each community invisible. Similarly to Ślosarski's case study on environmental activism, where the "dominant decision-making actors" hold "high-quality" data that meets international standards [54], ISPs are the only actors who provide broadband data to the FCC maps. The Challenge Processes are used by interested parties (in our case, broadband workers) to contest any given region on the FCC broadband maps. Yet, ultimately, any subsequent iterations or revisions to the FCC broadband data will always originate from the ISPs themselves—using FCC-imposed data standards.

Successfully *correcting* broadband data poses a critical question: *how does collaboration actually take place in this data arena and what are the outcomes?* In a data arena, there is a shared understanding among the diverse actors that "data are the primary means of perceiving, communicating and managing [a] problem" [54]. Indeed, broadband workers have the means to communicate the availability of connectivity in their region through data they have collected about themselves. Yet legitimate participation in the Challenge Processes requires their data meet the FCC standards. However, in Section 5.1.2 we saw that these standardized data are insufficient at documenting and addressing the major challenges that communities face, whether they are holistic equity needs in rural regions, such as P8 described, or quality issues in urban areas such as in P6's county. The more holistic data that broadband workers may have of their communities is extraneous to FCC procedures—despite its potential to complement the gaps left by official datasets. This further exemplifies the ways in which power and knowledge imbalances are revealed through breakdown, as described by Jackson [48].

Nevertheless, our participants have found creative ways to document and address the experiences within their communities, even if this means circumventing FCC procedures and "allowing" inaccurate or incomplete data to prevail in the broadband maps, in favor of actually solving the connectivity issues elseway. Ślosarski explains that the critical role of data in data arenas positions it as both a tool to uphold the status quo, as well as a tool for disempowered groups to seek legitimacy or even alter the dominating perspectives [54]. For instance, the ways in which P6 used self-collected data to put pressure on ISPs "without being a bully" (see Section 5.3.1) may well be an example of "good" politics in *frictional* data repair, where cooperation can be effective despite differences, or better yet, "productive *through difference*" [28]. We note that participants who successfully found workarounds with existing ISPs were White–like the majority of our interviewees–and represented particularly wealthy counties.

Jackson posed a question: "Can the fixer know and see different things—indeed, different worlds—than the better-known figures of 'designer' or 'user'?" [48] With the previous examples we argue: absolutely, yes. In fact, sometimes there does not need to be a direct interaction with the data for this friction to prove fruitful. For instance, starting partnerships with *many* ISPs can prove to be an effective way of opening new opportunities in the same space where the interactions were once intransigent (Section 5.3.1). Furthermore, some broadband workers end up becoming ISPs themselves (Section 5.3.1), effectively taking on a "hybrid" identity within the data arena [28], and taking up the infrastructure repair work (in addition to the ongoing data repair work) into their own hands. We wish to highlight that the participants who most actively worked towards fulfilling this hybrid role of becoming local ISPs were mainly working with tribes. This supports Duarte's framing of tribal ISPs as infrastructures that fulfill unmet needs for connectivity, while simultaneously strengthening sovereignty [12]. If we refer back to Figure 1, we could argue that some of our participants are paving a new and promising–albeit contentious–relationship between broadband workers and ISPs, which is not traditionally supported by the Challenge Processes or the affordances of national broadband maps.

Remarkably, the arena of broadband data repair, as enabled by the FCC procedures, does not currently equip broadband workers with many *tangible* tools for repair. Broadband workers are self-empowered via intangible tools for repair, namely partnerships with diverse actors and a resolve for creative problem-solving (Section 5.2.2). Publicly available tools such as the FCC Speed Test App [17] appear to be a positive step towards offering more tangible tools for repair, although it suffers from lack of transparency given the intricacies of the process it serves.

There is room for designing more forthright tools to better support broadband workers as they interact with ISPs, especially for those who like our participants may feel frustrated or stuck with existing FCC procedures. Perhaps such a tool could allow some semblance of transparency by taking on an "infrastructural inversion" approach [48]. Jackson explains that the practices and politics behind a technology become invisible when these are elevated to the level of infrastructure, and that through instances of breakdown, these practices and politics return to the forefront as possible agents of change. Thus, instead of allowing the intricacies of the Challenge Processes to hide behind the veil of a seemingly simple—yet obscure—multi-purpose Speed Test app, a tool for broadband data repair should explicitly communicate which parts of the process are FCC-imposed. Given the ingenuity of broadband workers, we believe that highlighting these points of friction could further support communities as they seek alternative solutions to the Challenge Processes that may more effectively address their needs. Drawing inspiration from work on supporting rural networks [40, 42, 43], we see an opportunity for future work on managing these contentious relationships in favor of productive action.

6.3 Broadband Workers as Activists

It is important to attend to the motivations of these individuals and organizations so that their work is well supported. However varied their routes into the broadband arena, our findings in Sections 5.1.2 and 5.2.2 demonstrate that participants were all connected by remarkable levels of care towards the *meaning* of broadband data in their communities—beyond the strictly "functional"—which undeniably *sustain* continuous repair efforts [48]. At the outset of our interviews, we considered framing broadband data workers as "citizen scientists," given that a key task was measuring/sensing an artifact at specific locations using accepted and authorized tools, as the FCC presents its Challenge Processes to citizens. However, this framing lacked depth and did not encompass all of the roles individuals embodied in their work–including those of educator, story collector, and engineer.

As we untangled the connections between the (many) roles, relationships to organizations and communities, and individuals' motivations for working in broadband–a particular characterization

emerged. *Broadband workers are activists.* Their efforts center on empowering communities by working towards digital equity across social and infrastructural dimensions. Some are intentional and would resonate with this description; their work is a deliberate campaign to change power dynamics in their community. We observed this in how some of the participants self-described as champions and warriors (Section 5.3.1). Others, like P4 and P10, are incidental activists who do work that advocates for their community in a more subtle manner, such as through research and the creation of new software and hardware tools that can assist with repair (Section 5.2.1). By framing broadband workers as broadband activists, it becomes clear that there is a need for repair tools that can do the work of activism. Specifically, there is a need for tools that enable connections between the communities and broadband data, clarity around the relationship between repair work and the impact on broadband infrastructure, and transparency into the contentious relationships that might thwart community repair efforts. Interestingly, Cooney and Raghavan find citizen science to be a valuable reference point for their work on enabling citizen participation in urban planning [7]. There may be fruitful work to understand why broadband data repair and urban repair differ on this point.

Currently, the tools provided by the FCC for data collection that can be used to repair the National Broadband Map are relatively simple [16]. They are oriented around transactional, individual effort and do not provide mechanisms to support collaborative repair efforts (or even data sharing). However, this individualistic perspective is contrary to what P12 characterized as the fundamental "interwovenness" of broadband infrastructure in Section 5.1.1. It is also contrary to the motivation that several participants shared in Sections 5.1.2 and 5.1.1, which centers on bringing people in communities into greater connection with each other, either through teaching digital literacy, enabling digital representation, or illuminating each other's lived experiences with data.

As stated by McCaffertey in a critique of digital activism, "activism has always been–and will always be–about people [35]." *Consequently, to best support the activism of broadband data repair, it is necessary that repair tools center people and the connections between them.* This can be accomplished by providing mechanisms for coordination and collaboration between new and existing repair workers. Especially in the case of marginalized or minoritized communities—from where our more *combative* participants emerge— framing broadband workers as activists allows us to borrow from work on *agonistic data practices* [8]. Such literature appeals to the emotional and story-telling abilities of data, via the combination of qualitative and quantitative data, in order to galvanize action against systems of oppression. For instance, in order to focus mobilization towards a specific underserved neighborhood, broadband workers could include their intimate community knowledge alongside Internet speed test data. To our knowledge, P4's custom survey site (Section 5.2.1) is the only tool available to broadband workers that couples quantitative and qualitative data in this fashion. However, this tool is meant for strictly one-way communication: it collects data from residents for broadband workers to analyze. We believe there is room for more collaborative features in this space. We know that broadband workers care for broadband data in "more than a trivial way" [48]. Should other community residents care as well? Should ISPs?

At the time of writing, broadband data repair tools do not provide particular insight into whether a community or particular geographic location is close to mounting a cognizable challenge and there is no way for tool users to view their own data in the context of the data collected by others. If a challenge does get filed, communication about the status of that challenge is done on a per-individual basis rather than as a community-based announcement. This forces ad hoc coordination to ensure that contentious relationships with ISPs do not circumvent earnest repair efforts as part of what Miceli and Posada characterize as a "disposition" of data systems towards incumbent power. *Supporting broadband activists requires repair tools that illuminate the arena so that efforts can be concentrated on spaces where it is of most value to conduct repair work.*

Finally, existing tools do not attempt to connect the action of repair to the ultimate and ongoing impact on broadband infrastructure. As noted by P10 in Section 5.2.2, the need for data collection never ends. Even as new broadband infrastructure is deployed, the demands on the infrastructure are dynamic. Populations shift, grow, and shrink; broadband services require more bandwidth with less latency. Thus, the fitness of broadband infrastructure in any particular place is something that will need to be constantly monitored–and states of repairedness will need to be constantly renegotiated [27]. Rosner and Ames state that there is an element of endurance that is fundamental to repair [44]. However, as shown in Figure 1, the relative distance between the action of broadband data repair and the action of broadband deployment and investment stretches endurance over time across many actors. *Thus, sustaining the perpetual work of broadband data repair requires new tools that draw clearer connections between repair and action.*

7 CONCLUSION

The work to repair broadband data maps in the US happens in a complex context of competition and collaboration mediated by the government as a continually negotiated balance between ISPs (with their data and power), and people working to improve broadband (with their creativity, care, and persistence). The value of accurate, repaired maps has been heightened by the promise of substantial investment to extend the infrastructure whose reach and limitations is documented by the maps, in a dramatic example of how the value of repair can change over time. The work of repairing the maps bears resemblance to repair of other electronic or digital objects, where care and creativity feature prominently, yet it differs in ways we find better understood by acknowledging the data arena, with its many actors and relationships. Our contributions call out the process of broadband map repair as another example where the burden falls on those who are misrepresented to correct official record; illustrate the analytical value of bringing together the concepts of repair and data arenas/activism; and highlight the need for better tools to support persistent, long term, data-driven activist efforts.

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