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A DYNAMIC PERSPECTIVE OF INTERNET SERVICE PROVIDER ADOPTION OF EMERGENT NETWORK TECHNOLOGY

A Case Study of Tribal Digital Village

Richard Canevez, Carleen Maitland, and Matthew Rantanen

ABSTRACT

Technological mediation describes the process where internet service providers (ISPs) translate telecommunications network innovations from the "technological frontier" to their particular commercial context. Although the original conception defined three obstacles during this process (technical, commercial, and structural), how these obstacles unfold has yet to be fully investigated. Using a qualitative case study with a rural ISP, we identify extensions to the model, in particular emotional response during mediation and their relationship to the dynamic elements mediation process. This illuminates how commercial market maturation impacts the organizations adopting these technologies, and the impacts of experience on the dynamic nature of technological mediation.

Keywords: television white space, TVWS, internet service provision, ISP, technological mediation

The popular discourse on novel telecommunications network technologies often focuses on the early phases of technological development. News sources trumpet the latest breakthroughs, patents are issued, standards may be developed, and policies formulated to enhance market penetration. From there, technology is expected to smoothly diffuse throughout the market. In some cases, such as global diffusion of mobile telephony, it occurs faster than expected. In others, such as with digital television, the transition is far longer than expected. Society's collective attention is

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often focused on the invention and its eventual use. But what happens in the middle? This question is addressed in studies of technological mediation, the process whereby participants in the telecommunications network supply chain work together to bridge gaps in order to bring a new network technology to market. Previous research in technological mediation has examined market and firm-specific determinants of mediation behaviors,[1] and static mediation models of industry internet adoption.[2] However, to date there has been limited scholarship on the temporally dependent, dynamic elements in technological mediation by internet service providers (ISPs), as well as how those elements affect the social aspects of the process of technological mediation. Within the context of this study, "dynamic" is meant to denote how various elements of the mediational process evolve over time, and how these shifts are in tension with each other. Examining these elements and their effects opens the black box of the network technology diffusion process.

Television White Spaces (TVWSs) have been touted as a technological advance that stands to make an impact in rural internet service provision due to its robust signal transmission properties in limited line-of-sight conditions and relatively inexpensive infrastructure requirements.[3] TVWSs are the large portions of electromagnetic spectrum, often in the ultra-high-frequency (UHF)/very-high-frequency (VHF) bands, which became or are becoming available across the globe following the transition from analog to digital television.[4] Within the United States, the opening of the TVWS spectrum to private enterprises has been overseen and continues to be managed by the Federal Communications Commission (FCC), which has implemented and enforced a system of regulation of spectrum and devices[5] with a certain degree of controversy. While the technical potential of TVWS technologies has motivated initial deployments, in contexts as diverse as Europe, Africa, and Asia, due to the still evolving regulatory and technical environments, the TVWS ecosystem faces challenges.

In this article, we examine an "organizational mediator" taking up the challenge of bringing TVWS to commercial reality. The small, rural,

1. Gorp, Maitland, and Hanekop.

2. Greenstein, "Technological Mediation and Commercial Development."

3. Horvitz.

4. Nekovee.

5. Federal Communications Commission, "FCC Adopts Rules for Unlicensed Use"; "FCC Adopts Rules for Unlicensed Services."

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nonprofit ISP, known as Tribal Digital Village (TDV), operates in the reservations of member communities of the Southern California Tribal Chairmen's Association (SCTCA) in San Diego County, California. Using a qualitative case study analysis of the deployment process, we answer the following questions: (1) how are dynamic elements, particularly *experience* and *evolution,* expressed during the process of mediation of emergent network technologies? and (2) how do these dynamic elements impact the experiences of the mediating firm?

We first present the background literature on technological mediation, examining the dynamic aspects of these activities. We then present the study design and findings with a focus on these dynamic aspects. This is followed by a discussion and brief conclusion. As TVWS technologies diffuse across the globe,[6] this study provides practical insights into deployment challenges potentially faced by rural ISPs as well as the impact of policy on the diffusion process. Furthermore, by focusing on the experiences of the mediator during mediational processes, it extends the technological mediation model by providing social and psychological factors that are reflective of dynamic forces acting upon and within these organizations in order to better explain and predict technology diffusion.

Background and Theoretical Framework

Technological Mediation

Technological mediation as a singular concept originates from Greenstein's industrial organization research that examined internet markets and the central role ISPs play in bridging emerging internet technologies with their commercial contexts.[7] These new technologies often offer a host of potential benefits, yet those benefits are in need of "translation" to the commercial context, a task fulfilled by "technological mediators."[8] Mediation involves two relationships: the "upstream" relationship between the adopting organization and the vendor, and the "downstream" relationship with their customers.

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6. Microsoft.

7. Greenstein, "Building and Delivering the Virtual World"; "Technological Mediation and Commercial Development"; "Understanding the Evolving Structure."

8. Greenstein, "Technological Mediation and Commercial Development"; Gorp, Maitland, and Hanekop.

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Greenstein presents three empirical predictions about challenges mediators will encounter: (1) technical challenges, which arise when organizations uncover technological features that are "mismatched to commercial needs," (2) commercial challenges, which occur when adopted technology does not "translate profitably to commercial environments," and (3) structural challenges, which rather broadly speak to "impediments to commercialization," for example, policy considerations.[9] "Mediational behaviors" are enacted to overcome these challenges.

Central to this model is adaptive behavior, when organizations respond to market demands by "tailoring [a] new technology to the user's needs."[10] General notions of mediation and adaptive behavior in technology adoption have been explored from many angles, including technology's role in mediating experiences in day-to-day life[11] and in supporting collaborative work.[12] However, of interest here is the mediation role played by organizations specifically involved with deploying technology to meet customer needs, and is therefore a distinct form of technological mediation.

This specific form of technological mediation has been investigated in the provision of broadband services by ISPs.[13] Based on data collected through a mixed methods approach (national case study and international survey), they identified three market-specific factors that shaped mediation behaviors: (1) policy environment, (2) market structure, and (3) competitive pressures. This research operationalized mediation activities as customer support procedures (e.g., providing on-site technical support). By collecting data on these activities through the international survey of ISPs, the researchers identified organization size as a crucial firm-specific factor governing mediating behaviors. Specifically, smaller ISPs engaged in higher numbers of technological mediation activities.

In addition to these studies focusing specifically on technological mediation, there are more general studies of up- and downstream relationships that provide insight into mediation. For example, the upstream relationship between mediating firms and technology vendors has been explored by the closely related research stream on adaptive practices in technological trajectories. These studies focus instead on the role of contextualization

9. Greenstein, "Technological Mediation and Commercial Development."
10. Greenstein, "Understanding the Evolving Structure."
11. Dosi and Nelson, "Technical Change and Industrial Dynamics"; Gyarmati and Trinh.
12. Driskell, Radtke, and Salas; Geisler and Rogers; Tjora.
13. Gorp, Maitland, and Hanekop.

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in the design and development of technologies,[14] and therefore on the vendor–organizational adopter relationship. One such practice, localization, generates a set of shared practices, design concepts, and shared understandings,[15] a process of "learning-by-doing" that is transferred to the design and production of technology.[16] For example, this framework has been used to examine the balance of search scope (search for new technology) and search depth (reuse of existing knowledge about technology) in technology adoption by firms in Katila and Ahuja's examination of the robotics industry.[17] That study's findings indicated that firms orient toward depth as opposed to scope because of the increased cost associated with an extensive scope search, as well as the possibility that human tendency to minimize uncertainty plays a role in depth orientation. Concerns about cost and uncertainty may therefore orient firms toward a reliance on depth, despite the limitations that this tendency imposes, in particular the limitations of those technological trajectories.[18]

Knowledge of mediation behaviors also can be gained from the numerous studies of downstream relationships. Several studies have examined the conditions of customer loyalty within the ISP marketplace,[19] or the game theoretic aspects of competition related to ISP operations in regards to their customer base.[20] Further, a study by Wood examined the effects of provider characteristics on broadband service provision in rural areas. The study found small ISPs operating in rural contexts are more likely to explore more advanced technologies in order to remain competitive, in contrast to their larger telecommunications counterparts.[21] This study offers some insight into decision-making concerning advanced networking technology in rural areas. However, it does not focus on the dynamic process of the deployment as influenced by the features of the technology.

Key aspects of relevant literature on technological mediation are summarized as follows. Smaller telecommunications firms are more likely to

14. Dosi, "Technological Paradigms and Technological Trajectories"; Dosi and Nelson, "Technological Paradigms and Technological Trajectories."

15. Dosi and Nelson, "Technological Paradigms and Technological Trajectories."

16. Ibid.; Dosi and Nelson, "Technical Change and Industrial Dynamics."

17. Katila and Ahuja.

18. Dosi, "Sources, Procedures, and Microeconomic Effects."

19. Cheng, Lai, and Yeung; Chiou; Sanchez-Franco, Ramos, and Velicia; Thaichon, Lobo, and Mitsis.

20. Gyarmati and Trinh.

21. Wood.

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explore novel technological solutions in their commercial environments.[22] Findings from Katila and Ahuja[23] showed that, while firms may have a preference for exploring their own internal, familiar technologies before considering novel solutions, this may be as much a result of a desire to avoid uncertainty as it is to lower costs, indicating that psychological factors play a role in decision-making about mediational activities. Bringing new technologies into use hinges upon these firms' relationships with vendors, as "learning-by-doing" with these new tools is a shared experience of adaptation to the commercial context.[24] Learning-by-doing is a fundamental component of the mediational process. In general, mediational behaviors are shaped by policy, market, and competitive pressures.[25] Providing computer support for customers at the ISP's location is one of the most prevalent practices. These service-oriented practices in turn serve to maximize the mediating firm's competitiveness,[26] promoting their ongoing use in an often crowded market environment.

Throughout these varying approaches to mediation, an overall lack of focus on the actual process of mediation in the empirical literature leads to a black-boxing of the mediation process. In some cases, this is a by-product of method. For example, to date, survey methods,[27] temporally cross-sectional interviews,[28] and industry-level data analyses[29] have largely masked the mediation process. This is particularly true when the focus is placed on postadoption outcomes as opposed to the process of adoption itself. These research approaches implicitly contribute to a "build it and they will come" mentality toward technological diffusion. This approach, while illuminating static implications of mediation, provides only limited insight into the socio-technical aspects of the adoption process itself. This more granular insight is needed to better understand the forces affecting successful technological diffusion.

22. Gorp, Maitland, and Hanekop; Wood.

23. Katila and Ahuja.

24. Dosi, "Technological Paradigms and Technological Trajectories"; Dosi and Nelson, "Technical Change and Industrial Dynamics"; "Technological Paradigms and Technological Trajectories."

25. Gorp, Maitland, and Hanekop.

26. Cheng, Lai, and Yeung.

27. For example, Gyarmati and Trinh; Gorp, Maitland, and Hanekop.

28. For example, Wood.

29. For example, Katila and Ahuja; Lavassani and Movahedi.

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The Evocative Nature of Technological Mediation

Evocative Impacts of Organizational Actors and Technology

One such element of socio-technical systems is the experiences of social actors, in particular how different time-dependent factors interact to influence these experiences. There are at least two factors likely to have dynamic elements: (1) the evocative, or emotional, impacts of accruing experience with a technology, and (2) the evolution of regulatory and structural conditions surrounding that technology. Mediators are always evolving, connecting current practices with previous experiences, personnel turnover, and accrued additional knowledge, a process that is likely to elicit an evocative response that can shed light on social and psychological factors that influence mediation.

The spotlight on the emotional or evocative nature of technology was prominently explored by socio-technical scholar Sherry Turkle, motivating examinations of adopters interacting with technologies beyond merely their instrumental value, as a space to express their own deeper sentiments (e.g., personal or political).[30] In her description of the "evocative" nature of machines, Turkle describes how inanimate technologies can provoke self-reflection,[31] a process with strong experiential connotations. Turkle's analysis of the relationship between "man and machine" depicts the anthropomorphic effect of technologies upon human actors within socio-technical systems. As technologies evolved, Turkle's work has explored technologies with humanoid appearances and behaviors, for example, research on cyber-companions that speaks to the differences that exist between users' relationships with robotic technology.[32] These more recent analyses reinforce earlier insights into the ways humans develop relationships with technologies, beyond the instrumental value those technologies serve. In this way, technological adoption can be akin to starting a new relationship, a process that involves personal, emotional investment. Scholars in sociomateriality have explicitly illustrated some of these

30. Turkle, "Computer as Rorschach."

31. Turkle, *The Second Self: Computers and the Human Spirit*; "Sociable Technologies: Enhancing Humas Performance."

32. Turkle et al.

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emotional phenomena, for example, faculty frustration with forced adoption of a Faculty Productivity (FP) system.[33]

Emotional responses to technologies in adoption processes are also subject to (as well as in dynamic tension with) management activities, where the managerial control of adopter behaviors can promote or dispel certain emotional responses to information technology diffusion.[34] In this way, we expect emotional responses from individuals who are forced to use a technology through controlled activities, particularly when it operates either suboptimally or in an obfuscated manner. However, an emotional response from a technician when installing technology to be used by others is less expected, if not surprising. Understanding technological diffusion processes undertaken by technicians motivates a holistic view that captures the social, psychological, and technical conditions of deployment, and in particular factors the emotional into these processes.

Dynamic Elements of Technological Mediation

The extant scholarship on technological mediation has underserved the dynamic nature of mediation. First, the environment of mediation is itself dynamic: the policy environment, market structure, and competitive pressures are all constantly shifting, and especially so with emergent technologies. Additionally, these environmental factors are in dynamic tension with the experiences of the mediator, where the conditions interact with the previously established practices and knowledge that mediators have accrued, and in doing so affect those experiences as well. The model proposed by Van Gorp et al.[35] captured the notion of experience in the technological mediation literature, operationalizing it as a firm-specific factor, but its relatively simple treatment as a single survey item assessing the number of years providing internet access service does not adequately capture the dynamic nature of technological mediation. Here we expand the concept of technological mediation by incorporating both the emotional elements as well as the broader social elements of policy, the latter discussed in the following, attending to the dynamic elements of each. We likewise elect a qualitative case study approach using observations and interviews due to its strength in identifying individual emotional impacts on people, and in

33. Stein et al., "Coping with Information Technology: Mixed Emotions, Vacillation and Non-Conforming Use Patterns."

34. Murungi, Wiener, and Marabelli.

35. Gorp, Maitland, and Hanekop.

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doing so lend crucial insights through examining how temporally dependent conditions impact the organization tasked with adopting emergent technologies to meet their commercial needs, in particular the interactions and impacts of this process upon experience.

TVWS in Rural and Development Contexts

TVWS technology is expected to play a significant role in increasing the overall reach of broadband. These expectations are based on the claim that it is an economically efficient and relatively inexpensive solution to internet service provision in areas of lower population density,[36] providing higher range and signal propagation in limited line-of-sight conditions.[37] For example, the Philippines made TVWS a central component of its "Internet for All" initiative within the broader Philippine Digital Strategy,[38] and as a nation has explored TVWS to reach "far-flung" regions.[39]

To support commercialization, extant scholarship surrounding the TVWS technology has focused on specific technical aspects,[40] simulation and modeling-based analyses,[41] and prospective analyses within a particular social context.[42] In the United States, where our study is conducted, commercialization of TVWS broadband internet was made possible by the reallocation of spectrum from television broadcasters,[43] where the opening of the TVWS spectrum has been overseen and continues to be managed by the FCC. As with many (but not all) uses of public spectrum, the FCC implemented a system of regulation of TVWS spectrum and its devices,[44] and, abiding by these regulations allows private enterprises to leverage this newly available spectrum for commercial use. While the development of TVWS technology for internet service provision is more of a "cumulative" development with strong conceptual similarities to commonly used

36. Singh, Naik, and Kumar; Kumar et al.

37. Horvitz; Townsend.

38. Republic of the Philippines: Department of Information and Communications Technology.

39. Carpio.

40. Pejovic et al.; Masonta, Johnson, and Mzyece; Hadzic, Phokeer, and Johnson; Kimani, Langat, and Oduol.

41. Fitch et al.; Kawade and Nekovee.

42. Ndlovu et al.

43. Horvitz; Stirling.

44. Federal Communications Commission, "FCC Adopts Rules for Unlicensed Services"; "FCC Adopts Rules for Unlicensed Use."

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fixed terrestrial wireless broadband solutions, FCC policies are nonetheless remarkably distinct in this regulation system, which can have significant impacts on the innovation and diffusion process.[45]

These policies themselves have been subject to scrutiny: Ramjee, Roy, and Chintalapudi[46] took a critical approach to US FCC regulations, interpreting a set of regulatory obstacles from evidence that the TVWS market is in a state of arrested development. The authors make a point of comparison between the FCC and the UK equivalent Ofcom: the latter's more flexible approach, utilizing a tiered system of spectrum access based on the bandwidth needs of the device (e.g., higher bandwidth needs require more stringent operating parameters) supports a wider range of operators. By comparison, the FCC's "one-size-fits-all" approach to spectrum regulation, which requires all TVWS devices to adhere to the same stringent operating parameters (e.g., electrical power) regardless of their bandwidth needs or other finer-grained contextual factors, is crucially limiting. Additionally, the FCC's "height-above-average-terrain" (HAAT) restrictions mandating a maximum antenna height relative to the surrounding terrain were criticized, due to its limiting of TVWS use in hilly areas. This is particularly true when a TVWS base station is at a higher elevation than TVWS receivers connecting to that base station. Although not based on ISP perspectives, the authors argue that structural challenges have hamstrung TVWS in the United States, and that policy reform must be taken to support the development of a healthy TVWS ecosystem.

On the one hand, the earlier studies focusing on technical aspects of TVWS do not engage the social characteristics of TVWS diffusion, and in turn the development of this healthy TVWS ecosystem. On the other hand, the studies that do address the TVWS ecosystem do not present operator perspectives. As with the current state of technological mediation literature, what is missing from these accounts are explorations of the process of adoption and mediation, in this case with a focus on the mediation behaviors, emotional or evocative responses to the technology, the policy context, and the dynamic aspects overall.

Technological Mediation in Deployment of TVWS

In order to better understand the role of technological mediation in diffusion, the model of mediation must better account for mediational

45. Dolfsma and Seo.

46. Ramjee, Roy, and Chintalapudi.

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behaviors. These behaviors are those undertaken by employees of mediating firms that address the mediational challenges outlined by Greenstein[47]: technical, commercial, and structural obstacles that stand in the way of an effective commercial deployment. Engagement with these obstacles will elicit emotional responses in those employees tasked with overcoming them. These employees undertake mediational behaviors within dynamic technological and market contexts, where the specifications of a technology and the space of competitors are constantly shifting. These experiences are likewise shaped by a regulatory context that in some cases is still evolving. How organizations manage the social uncertainties presented by this process is deeply contextual, as governed local operating environment considerations,[48] interacting dynamically within broader technological and regulatory conditions. The challenges are particularly pronounced in emergent technology diffusion, and early adopters of these technologies will likely have different experiences than those mediating firms adopting technologies at mature stages and with more mature markets and settled regulations.

Therefore, given the relative immaturity of TVWS, we address the following questions:

- *How are dynamic elements, particularly in overcoming technical, commercial, and structural challenges, expressed during the process of mediation of emergent technologies?*
- *How do these dynamic elements impact the evocative experiences of the mediating firm?*

The Study

Site Selection

Our site selection was influenced by the ongoing relationship of the research team with the SCTCA and its ISP, TDV. TDV operates on the outskirts of San Diego County, principally servicing the residents of the American Indian reservations in that region. Tracing its origins to the High-Performance Wireless Research and Education Network (HPWREN) at the University of California–San Diego, it has since evolved from a

47. Greenstein, "Technological Mediation and Commercial Development."
48. Hall, Matos, and Martin.

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small-scale project to a fully fledged ISP. TDV primarily operates as a non-profit organization, with revenues generated from subscriptions, grants, and support from its parent organization SCTCA. Its network covers over 80 linear miles from the Pala Indian Reservation to the Campo Indian Reservation approaching the United States–Mexico border. As of 2015, TDV has provided internet access at some point over the organization's lifetime to over half of the approximately 3,000 homes located in partner communities of the SCTCA, although at that time only 354 houses were receiving TDV internet coverage.[49]

The region that TDV operates in is noted for its jagged and rugged terrain, occasionally extreme temperature conditions, and disparate population density.[50] This region and its network have also previously been the site of several other studies, including technical approaches to rural internet connectivity,[51] social media traffic,[52] digital cultural archiving practices,[53] and the history and day-to-day life of the organization itself.[54] To support the TVWS trial for this particular study, we secured a grant to cover the up-front costs of the TVWS devices, aiding in selecting the equipment vendor. TDV's TVWS deployment was on the Santa Ysabel Indian reservation, so the bulk of our TVWS-related findings are drawn from that region.

Methods and Data Collection

For our study of technological mediation, we took a qualitative approach including participant observation and active participation in daily work practices to gain an embedded perspective[55] on TDV's mediational role between emergent TVWS technology and their customer. To enable this, we embedded a member of the research team with the TDV staff for a two-week field study period in June 2017, where he worked closely alongside TDV's field technicians and office staff. During this time, field notes from participant observation and active participation in work practices, as well as supporting technical documentation was collected. This entailed the

49. Vigil, Rantanen, and Belding.
50. Sandvig.
51. Schmitt, Raghavendra, and Belding.
52. Vigil, Rantanen, and Belding; Vigil, Belding, and Rantanen.
53. Srinivasan, Allain, and Ellis; Strathman.
54. Sandvig.
55. Malinowski.

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researcher shadowing members of the team throughout their full workday, commonly from 8:00 a.m. to 5:00 p.m., for the full time throughout the weeks. Additionally, the researcher spent time outside of work hours with the technicians socializing, which helped to maximize comfort with the researcher's presence and promote honest appraisal of the mediation process, as well as simply build relationships between the research team and the organization.

We also conducted semi-structured interviews with TDV technicians and a small cadre of customers receiving the TVWS service connection to supplement the findings from the participant observation and active participation components of the research. Interviews conducted with TDV staff were done during breaks in work, for example, over lunch or in the TDV office. Interviews were both organized around certain topics when formal interviews were conducted, as well as in the field in response to observations made by the researcher, allowing for an organic exploration of themes as they emerged with the TDV staff. This resulted in a single group interview with TDV technicians, a single interview with the TDV field coordinator (each taking approximately 20 minutes), and numerous smaller question-based interactions, all to support the participant observation and active participation data collection of the researcher.

TDV's technicians had received technical education in varying degrees with regards to networking technologies, but their day-to-day lives were driven primarily by on-the-job experience, as befitting a "blue-collar" workforce. Work approaches and networking technology knowledge were heavily pragmatic and based on applied experience, as opposed to technical understanding or centered around strict preparation. Each technician had multiple years of experience working with TDV's network, with the longest tenured being the TDV field coordinator who had worked off and on for TDV for over a decade, starting from the organization's time as an exploratory endeavor at HPWREN.[56]

Community members who would receive the TVWS upgrade for TDV's pilot were identified by the Tribal Chairman of the Santa Ysabel Reservation, who pointed us toward a group of homes awaiting internet service that were both (1) difficult to reach by previous terrestrial wireless broadband technologies, and (2) geographically close to each other. Prior to interviewing, each household was notified of the interview several days in advance, and invited to participate. This resulted in three interviews

56. Sandvig.

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with community members that were conducted at their homes during the TVWS installation, each taking approximately 20–30 minutes, and centered on topics of information and communication technology (ICT) usage habits and devices they regularly use in the household, as well as overall perceptions of the prospective enhanced service of TVWS.

Finally, following the field study, we also spoke to key stakeholders from the vendor providing the TVWS technology to the ISP, focusing on their impressions of the state of TVWS in the United States and the effects of regulatory context on their operations and experiences.

Data Analysis

Throughout the course of the two-week field study period, we used the obstacles that pertain to Greenstein's taxonomy of mediational challenges to frame the analysis of the data, focusing on these obstacles as well as how TDV approached them. The embedded researcher would consolidate the day's field notes into a digital format and share with the rest of the research team via a secured online file sharing repository. This combined with regular telephone discussions allowed for our analysis of data to begin in the field and support an organic identification of topics of investigation, ensuring that we explored key subjects and questions.

Once we concluded the field study portion, we continued the analysis once the researcher returned to his home university, combining field notes with interviews conducted both during and after the field study (poststudy interviews were conducted via teleconference or email), as well as supporting documentation and technical readouts acquired during the field study. We analyzed this data using a combination of inductive and deductive coding, identifying themes from the various data according to Greenstein's taxonomy of challenges.

Findings

Timeline of TVWS Installation Activities

Our field study followed TDV staff during their installation of the TVWS equipment. As is typical with wireless networking systems, the equipment included the TVWS base station as well as customer premises equipment. The TVWS deployment required several steps, spread over several days, and included:

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1) Relocating an incorrectly installed TVWS base station to a new location to comply with FCC regulations
2) Testing the base station at the new location
3) Testing simulated client site connections at nearby locations
4) Conducting site surveys of the potential new clients serviced with TVWS
5) Installation of the TVWS devices at the client sites

TDV staff conducted standard network maintenance activities simultaneously. This timeline is provided as a reference, while our analysis in the following follows the technical, commercial, and structural framework.

Technical Challenges

TVWS Performance

We observed the technical challenges of TVWS in the last three phases of installation: testing simulated client site connections, site surveys, and client site installations. In advance of the actual installation at client sites, once TDV confirmed that the TVWS base station location and operating parameters were in accordance with FCC operating requirements, TDV conducted field tests to verify not only the establishment of connections in differing environmental conditions, but also to evaluate that performance was up to a serviceable threshold, for example, signal strength, bandwidth (as designated by the TDV technicians). TDV conducted the field tests in two stages: establishing connectivity from the base station to client site hardware and field surveys of actual client sites identified as prospects to receive the TVWS internet service. The connectivity tests first examined the links between the base station and client hardware operating from the back of a pickup truck. TDV conducted the tests along a road adjacent to where the tower holding the base station was located. Using the pickup truck allowed the technicians to test several locations, at different distances and with varying line-of-site characteristics.

Working closely with the vendor, the TDV team received specific requirements for optimal connection settings. The client premise equipment had to be a minimum 500 m from the base station, set at an elevation of 5 m above ground level to adequately simulate installations (e.g., on a roof), and a minimum of 9–12 m between the antenna and the tree line. TDV staff were somewhat skeptical of these requirements because they appeared to contradict conditions at their potential clients' homes (e.g., establishing the minimum tree line distance). Once these requirements were

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communicated, TDV set up the initial testing rig so the TVWS antenna was attached to the rack of a pickup truck, at a height of approximately 5 ft above the ground, connected to the radio that sat in the bed of the truck, powered by a portable gas generator. However, this configuration failed to establish a connection, prompting TDV to contact the vendor once again. The vendor quickly identified that the radio elevation was too close to the ground and was introducing fatal signal interference. The TDV team readjusted their configuration, this time installing the antenna at the top of a 6-m (~20 ft) pole, which was then propped on the truck bed, bringing the antenna elevation to roughly 7.32 m (~24 ft). While driving around with this pole upright brought concerns and humorous observations about dodging power lines, this configuration ultimately resulted in connections with the base station, which were verified at multiple locations.

Following the successful field tests, the TDV team proceeded with client site selection and site surveys (actual single-family homes) and, ultimately, TVWS service installation. To identify ideal candidate homes, the TDV team visited the tribal administrative office and spoke directly with the Santa Ysabel Reservation tribal chairman. The chairman identified four households from a list of those awaiting internet connectivity from TDV deemed ideal for this first pilot installation. TDV then visited each of the four potential sites, evaluating them for general line-of-sight conditions and tree lines, elevation differences, and distance from the base station to the tower. The fourth site stood out as having particularly poor line-of-sight conditions that would have likely prevented consideration with standard wireless network technologies. The TDV staffers were pessimistic.

Despite questionable conditions at a few of the sites (including limited line-of-sight conditions or being unable to meet vendor recommended tree line distances to devices), TDV ultimately established connections at each. Thus, the TDV staff successfully integrated four new customers into their network, effectively leveraging the TVWS performance advantages. This included the fourth installation location, where TDV measured speeds at 11 Mbps download/16 Mbps upload. These results stood in contrast to the aforementioned pessimism about the client site, surprising the TDV staff.

Signal Interference

While the FCC moved television channels off the analog signal spectrum in 2008 in the United States, as of 2017 Mexico still used that spectrum for analog television. That fact, combined with high-powered analog television signal projection, introduced signal interference into San Diego County. The interference is especially noticeable at higher elevations. During testing

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of the relocated TVWS base station at the both shorter and lower (elevation-wise) tower on a customer's private property, the TDV technicians noticed signal interference in the TVWS frequencies. Representatives from the vendor guiding the reinstallation process identified the source as a local television broadcaster, just over the border in Mexico. Signal interference near the border is a known issue[57] due to two separate regulatory bodies needing to coordinate, as well as the state of TVWS spectrum regulation being at two different stages of development between the two nations.[58]

Additionally, while HAAT regulations limit the elevation of TVWS base stations, the vendor pointed out that the signal interference from television sources is significant enough at high elevations to warrant installations at lower elevations, regardless of the HAAT regulation. While TDV has significant applied experience with wireless broadband networking, adoption of TVWS introduced a new spectrum band that carried with it a new set of technical considerations.

TDV technicians noted however a particular benefit of TVWS spectrum for their network: TVWS represents an additional option in an increasingly saturated wireless environment. Although saturation is typically less of an issue in rural environments, TDV already used the 900 MHz, 2.4 GHz, and 5 GHz frequency bands. Signal robustness combined with a more "available" frequency range was perceived as a plus, as one TDV technician noted: "It's another option aside from the 900 MHz . . . it seems like a better option. I mean, we're getting the speeds through the trees, so that's a positive."

Indeed, increasing frequency saturation was cited by TDV's field coordinator as a concern that would only increase in relevance going forward, as more small devices use the open wireless spectrum, for example, Internet-of-Things networks. At the very least TVWS could be an additional frequency option available to TDV.

Commercial Challenges

Equipment Costs

TDV acquired enough TVWS equipment to connect nine client sites. The total cost of these devices was approximately $11,000 USD (about $1,222 USD per client site). TDV staff noted that this was significantly more expensive than the fixed terrestrial wireless broadband technology that comprised the core of their network. Initial impressions of the TVWS

57. Kolenc.
58. Franca et al.

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equipment also identified energy consumption concerns, with TDV's field coordinator remarking "that is a lot of required power": these devices operate at 60 W, several times more than the network equipment currently deployed (TDV technicians cited comparable devices on their network that consume 6–8.5 W by comparison[59]).

In reference to this issue (as well as the opportunity cost discussed in the next section), TDV technicians observed that, were financial structures different, TVWS adoption may have been commercially infeasible, its potential benefits notwithstanding:

> I don't know if it's because we're kind of [both] a nonprofit and a for-profit, so this company isn't solely dependent on customers to make ends meet financially, so we do have a lot more flexibility to use new technologies and mess up, and kinda have wasted days, but I think [TDV Director] is always keeping up with, I mean, we do too, but [TDV Director] keeps [up], is always pushing us to try the new technologies, and you know, he's not afraid to try something and have it fail, or try something and have it work, know what I mean.

Opportunity Costs

The tasks of TDV technicians roughly fall into one of two categories: maintenance of existing network installations both at client sites and tower locations, and expansion of the network through the establishment of new relay locations or installations at new client sites. During the TVWS deployment, TDV staff worked toward these two goals simultaneously, conducting several site visits to clients and towers to both maintain and expand the network. Illustratively, TDV technicians conducted a visit to an elderly couple having trouble connecting to their modem over Wi-Fi, which ultimately just needed to be reset. On the last day of the field study, TDV technicians visited a client site to give them an extended Ethernet cable, and another site to replace a broken radio-dish combo. A more complicated project involved upgrading and expanding a tower site to order to reach more customers in the southernmost locations of the network. This included both maintaining the current towers at the location (TDV technicians had to replace the batteries of a smaller tower located in the desert) as well as overseeing the construction of a new, larger scale tower

59. For formal specifications of the comparable devices, see: https://www.ui.com/airmax/powerbeam/

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nearby. Also, a major backbone location needed maintenance, requiring the replacement of solar panel arrays, upgrading power management software, and basic hardware relocation.

The small staff of TDV noted the stress that the TVWS adoption placed upon their time and energy, especially as a nonprofit entity with essential financial support from their parent organization, the SCTCA:

> Say we were an independent company, it would be a lot harder to employ this technology. It would be, you know, this whole week, it would have been hard to make ends meet. We would have to do installs and make money off of it. Luckily, we're not that way. Like [independent competitor]? I don't think they would have been able to do it.

TDV staff dedicated significant time during the two-week field study toward the TVWS deployment of the ten business days, four of those days were dedicated to the process of TVWS base station relocation, field testing, and client site installations. This does not include the time spent on the initial base station installation, as well as the amount of time TDV technicians spent poring over simulations and directions with representatives from the TVWS vendor over the phone and in emails. Adoption of unknown technology appeared to incur opportunity costs that hampered its commercial potential with serious implications for small operations like TDV.

Oversubscription Limitations

Despite the eventual success in establishing connections at the customer locations, the maximum throughput detected at the TVWS base station was decidedly limited: the observed total download rate was ~20 Mbps. TDV technicians noted this is significantly less than their current wireless broadband base stations. Commercially, this creates a limitation to the use of "oversubscription": the practice of connecting multiple client's sites to a single base station, and promising greater bandwidth availability than is mathematically possible (e.g., offering 5 Mbps speed for five clients connected to a single 20 Mbps base station). Clearly, this practice is based on the assumption that not all customers will be using the internet at the same time. According to TDV staff, this is a common industry practice. This limitation was an explicit point of consternation during follow-up interviews with TDV staff:

> I don't see, even with 20 Megs, being able to oversubscribe an access point like you would typically do, because there's not enough

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> Megabytes to hook up 20 homes or something like that. You would have to be limited to 5 or 6 homes, depending on what you're offering in terms of your bandwidth, speed.

In a conversation with TDV's field coordinator about the changes, he experienced during his time with the organization (he had worked off and on with TDV since its beginnings at the University of California–San Diego [UCSD]), he pointed to a constant push for network improvement to keep up with "increasing data intensity." The throughput limitations of the base station in effect either limit the number of subscriptions served by an access point, or lower the promised bandwidth to those customers. This creates a challenge in meeting the aforementioned increasing data intensity.

Customers' Technological Skepticism

The new customers TDV connected via TVWS technology, although they had been on a waiting list for TDV broadband internet for some time, were not dependent on technology by their own admission. The first resident interviewed (64 years old) was notably proud of an "old-school" mentality with regards to technology:

> I'm old school. I haven't got into it at all. [As a truck driver] on my diesel truck, they wanted [to attach a device] that let me Google where I needed to go. Or they wanted to give me one of those big, square phones where they can text me all the time. I said "call me." And I don't need Facebook. I need a [paper] Thomas Brothers map and I can get anywhere I need to go. I'm not into the technology.

The pride in lower internet (and technological) needs was echoed by the second resident, likewise describing himself as "old-school" (40 years old). This resident's living situation had changed since the request for an internet upgrade had been made, with his smartphone sufficing for connectivity:

> I'm by myself now. When I ordered this stuff, I had my whole family here. We had laptops, tablets, we had all that stuff. Now I just got my phone. Now it's just me.

The third resident interviewed (72 years old) was a regular if rather low-intensity user. Despite no reported usage of streaming, social media, or even information seeking (e.g., news), this resident was a regular gamer (puzzle and casino games):

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> It's something to do, because I don't go [to] that many places. I'm a home person. My games keep me company.

Her ability to remain in contact with her family was also stressed, primarily over her cell phone (a nondata feature phone from Verizon):

> I have 4 kids, so everybody has their problems. Just because they're adults doesn't mean mom goes away.

All of the residents described themselves as having lower internet needs, with limited use of streaming and other high data usage applications. Regardless, there was evidence of internet connectivity playing a crucial role in their lives, including by others within the household. The first resident interviewed had been given a tablet by their healthcare provider to allow for regular biometric monitoring (the tablet used their cellular service). Additionally, this resident's spouse was described as being a more regular user of both email and social media (Facebook) via satellite internet. The second resident interviewed was principally engaged with sports and news via an unlimited data plan through his smartphone, regularly streaming this content. The third resident interviewed, as previously described, was a gamer, although the games were of relatively low data usage (e.g., casino games), also serviced by satellite connection. Through these residents, each household could be directly observed or explicitly self-described as regularly partaking in some form of internet-based activity. In the absence of TDV's broadband internet, the customers interviewed had made do with competing services, either via satellite internet or cellular data on their smartphone. Thus, there are additional commercial challenges in this unique environment, presented by the lower data needs and interests (existing use notwithstanding) and competing network technologies and providers.

Structural Challenges

Regulation by FCC Geo-Location Database

As was the practice for their 900 MHz, 2.4 GHz, and 5 GHz wireless technologies, TDV technicians at first attempted to install the TVWS base station at a site of significant elevation. This practice maximizes line-of-sight opportunities to reach as many client sites as possible. This initial base station location was one of the primary backhaul sites of the Santa Ysabel Indian reservation, located on one of the mountainsides near the

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summit, and theoretically would have reached many of the residents in the valley below. The technician who made this choice had significant experience working with TDV's wireless networks, having been with the organizations for over five years. The reasoning was sound: the rugged terrain of Santa Ysabel and the history of standard work practices had reinforced a "higher-is-better" attitude when it comes to installing new devices and locating tower sites.

However, TVWS is significantly different in that it is a "managed access" wireless technology, where protecting incumbents on the spectrum requires range of use be restricted by locational factors, including HAAT and, in turn, propagation distance (a function of power and elevation). Managed access requires that each piece of network equipment is "checked" to assess its likelihood of interfering with current spectrum users. This "check" occurs in the actual physical location at which the equipment will be used. This process requires the TVWS base station access a geo-location database, a functionality hard-coded into all FCC approved TVWS devices. Several database companies exist, competing for the business of TVWS equipment vendors.

Through this required interfacing with an external geo-location database, TDV's TVWS initial base station installation location was found to be in violation of the FCC's HAAT restriction. The tower was simply too high relative to the surrounding terrain. In this situation, the base station radio became inoperable as the database is designed to enforce the HAAT requirement by refusing to "allocate" TVWS spectrum for use. The TDV field technicians did not anticipate this outcome, and it resulted in significant frustration due to being unable to predict this requirement, as well as what was perceived as a lack of clarity surrounding restrictions in the use of the TVWS technology.

The mistake was a result of two factors. First were the superficial similarities of TVWS with the current stable of wireless networking technologies used in TDV's network. Second was a lack of understanding of this new technology. TDV technicians did not realize how the geo-location database functioned by checking for elevation, and thus simply followed existing operating protocols. It was only through close collaboration with the TVWS vendor that TDV was ultimately able to correct the situation and find a viable location. Although this was time and energy spent on the part of the vendor, it was viewed as part of an investment:

> The process of learning and understanding, it's an investment on our part, to get the payoff later. We actually try very hard to invest in our customers if we think they are good customers and are going to grow.

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Hence, the TDV team was forced to relocate the TVWS base station to an established tower lower down the mountainside, nestled within the actual Santa Ysabel community. Theoretically, and in accordance with the FCC database, they could have chosen a location at an intermediate elevation, providing wider coverage than this final base station location. However, that option would have required construction of an additional tower at great expense. So, in the end TDV opted for an existing tower at a lower elevation identified as valid through the FCC database, as relayed by the TVWS equipment vendor. Continuing to work directly with the vendor over the phone during the reinstallation process, the TDV team was able to verify that the new location was indeed acceptable as per the database, and therefore allocated the required spectrum allowing the base station to function.

Reflecting on this new domain, in which authority and control over technology use was ceded to a database, TDV's manager expressed that up until now they existed in a "play-nice" atmosphere. As such, signal interference is avoided through direct contact with competing parties and negotiated directly with an assumption of mutual respect. He recounted a story where a contractor running a wireless device at a very high-power level blocked out other wireless signal transmissions, including TDV's wireless internet radios. At first this hired contractor refused to budge but was eventually persuaded to adjust his devices when TDV offered to bring the tribal chairman into the discussion, by whom the contractor was employed. The FCC's regulation of TVWS spectrum through a remote database, which had little connection to the local context, was immediately perceived as being contradictory to this relationship-based approach.

Many of the frustrations that TDV encountered during the installation (e.g., the HAAT restriction, up-front cost) pointed to larger commercial and structural challenges. The vendor itself was aware of these challenges and was similarly pessimistic. Part of this pessimism stemmed from models of signal propagation being used by the FCC to restrict access to protect incumbents via the geo-location database. According to the vendor, this database is flawed in its current state:

> The database, as it stands, is based on flawed analysis right now. The propagation models they use are overly optimistic, and because they are overly optimistic, it actually reduces the amount of spectrum that is available. So, it does not reflect the reality of how it's being used. So [the] database for TV white space, it's very early, it's immature, it needs a lot of work.

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In this case, "overly optimistic" refers to an overestimation of propagation range, which in turn leads to an underestimation of available spectrum in the interest of protecting incumbents and other parties using the TVWS spectrum. The vendor pointed to the current TVWS regulation instability: in 2017, the National Association of Broadcasters (NAB) was squaring off against Microsoft Inc. over the use of the available TVWS spectrum by privately owned devices. In July 2017, Brad Smith, the President of Microsoft, announced his company's goal to use TVWS to serve rural areas with high-speed internet access. NAB responded critically to this, charging Microsoft with "arrogance" and circumventing the FCC incentive auction created for bidders to purchase spectrum rights.[60] Thus, at the time of this study, lobbying forces from the NAB were pressuring the FCC to prevent Microsoft from using TVWS spectrum for rural broadband internet connectivity, the outcome of which would strongly affect the activities of ISPs seeking to use TVWS for their networks.[61] The representative from the vendor did not mince words when discussing the current unstable state of FCC regulation of TVWS in the United States:

> You [have] the regulatory body in the FCC being lobbied by the NAB to choose rules that make it as tough as possible. The way it stands right now with the database, with the rules, [TVWS] is designed to fail.

An interview conducted with a representative from another US-based ISP client of the vendor echoed many of the concerns. However, he also reiterated some of the reasons for optimism TDV had encountered during their deployment. Although they were also able to leverage external funding sources to acquire TVWS equipment, it was still cited as an economic concern: "how much will it cost to put in the network?" As he noted, Microsoft had been attempting to reach school-age children with TVWS connectivity in rural areas of the state of Virginia. However, at a cost of $500 per child, he assessed the economics at that time were "prohibitive."

Yet, he still considered rural areas the ideal place to exercise the potential of TVWS, reiterating that "the beauty of white space" is its ability to increase reach through poor line-of-sight conditions by increasing the power level of each device. Although the FCC caps the maximum operating power, the potential benefit was noted by this ISP. He noted this potential

60. Jacobsen.

61. Ibid.; National Association of Broadcasters.

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existed especially outside urban/suburban areas with their increased congestion and lack of white space availability. In his mind, "white space is a better connectivity [option]" for rural internet service provision.

Together, the experiences of TDV, its vendor, customers, and a fellow ISP provide evidence of the technical, commercial, and structural challenges faced by TDV as a technological mediator. These findings provide further support to the established taxonomy provided in the technological mediation model. Our findings also provide new evidence by which the model can be expanded. The two new dimensions are (1) the evocative aspects of new technology adoption inherent to mediation as well as (2) mediation's dynamic aspects. These are discussed in detail in the following.

Discussion

The Evocative Elements of Technological Mediation

Through our findings, we demonstrated the role that emotional responses played across the mediational behaviors. Each actor in the mediational process (vendor, mediator, and customer) displayed their own set of emotional responses to the sale or use of the technology (in this case TVWS). These actors illustrated differing perspectives, histories, and knowledge, informing their perceptions and opinions of the emergent technology. These emotional responses were also illustrative in some cases of personal attitudes held toward technology, which likewise have impacts across mediational behaviors. These attitudes, meaning a manner, disposition, or feeling toward a person or thing, typically provide both a background for emotional responses as well as are shaped by these emotional responses over time. We illustrated here that the process of mediation evokes emotion, which in turn reveals more deeply held attitudes about technology. While we do not claim that these particular findings are necessarily representative of the whole of their communities (whether they be employees of the mediator or of the customers), we take these findings as evidence of attitudes that may likely be encountered during mediational processes, and that these factors can influence the success or failure of such projects.

To categorize the type of emotions we observed during the field study, we draw on Robert Plutchik's theory of emotional types, which provides

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a taxonomy of emotions for analyzing our observations.[62] Plutchik places emotional response within a feedback loop that consists of a stimulus event, which, in turn, leads to an emotional state, and ultimately an overt behavior on the part of the subject. In our study, while the relevant stimulus events that generate emotional responses vary from person to person, each of the responses ultimately is the result of an introduced relationship with the TVWS technology. Plutchik[63] developed a visual aid representing a range of emotions. From a core set, including ecstasy, admiration, terror, amazement, grief, loathing, rage, and vigilance, more moderate emotions appear in flower-like petals, decreasing in intensity with distance from the center. In Table 1,[64] we present the actor(s), stimulus, inferred cognition, and emotional response. The emotions primarily are drawn from the visual aid and the states are a subset of those elaborated in Plutchik's full feedback loop.[65] We also offer observed attitudes (either through participant observation or explicated during interviews) where they could be gleaned from the case data.

From the perspective of the mediator, being forced to relocate the TVWS base station, in light of not realizing the FCC operating requirements, served as an early stimulus, prompting annoyance and anger in TDV technicians and staff. As the staff gradually came to terms with what was required by the FCC for TVWS use, the awareness that these requirements may conflict with previously established work practices (e.g., elevation of base station locations) likewise prompted frustration. Additionally, pessimism was the response when subideal technical and commercial features of TVWS were identified. Despite these inauspicious beginnings to the deployment, successful tests and eventually successful client site connections prompted a more optimistic view of what TVWS could offer. These feelings transformed into some form of acceptance, based on a realistic notion of TVWS derived from their experiences and learning.

Upstream of the mediator, the vendor's engagement with the mediator's staff during the deployment was illustrative of their optimism with regards to the mediator. This, in turn, was indicative of their attitude toward TDV, which they perceived as long-term customers. According to the vendor, the amount of time and energy dedicated to TDV is not always offered to all

62. Plutchik, "The Circumplex as a General Model"; "The Nature of Emotions."
63. Plutchik, "The Nature of Emotions."
64. Appendix 1.
65. Plutchik, "The Nature of Emotions."

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firms, but is typically reserved to those perceived as serious and capable. It is an investment on the part of the vendor, one that seeks to maximize the efficiency of their time and energy in service to their own objectives.

On the other hand, the awareness of the FCC's policy on TVWS generated a mix of negative emotions, including pessimism (TVWS is "designed to fail"), together with annoyance and anger in the form of frustration. The vendor's broader international experience (e.g., underpinning comparisons with the UK's Ofcom policy) lent credence to these negative emotional responses, and is a sentiment that is shared by many other industry representatives and operators.[66] Feeding into these emotions, as well as shaped by them, was the vendor's caution, pointing to the need to manage their customers' expectations and carefully monitor deployments in the United States, given the challenging regulatory context.

Downstream of the mediator, the customers stressed a general lack of need for high bandwidth internet connectivity. Having made do with the speed either satellite or their own mobile phones offered, the prospect of TVWS supported broadband internet access was perceived as a bit of a contrivance. The stated "old-school" attitude of minimal technological needs provided a background to understand this apathy and indifference (which most closely resembles boredom within Plutchik's emotions taxonomy) to the advancing broadband technology being offered to them now that it was available to reach their homes.

While skepticism, "luddite" pride, and general technological agnosticism were explicitly stated by these customers, their actual use of the internet and data as a household appeared to contradict these attitudes: families kept in touch through social media, health was remotely monitored (albeit over the cellular network), and households enjoyed gaming and recreational internet use. Furthermore, previous research has illustrated the various uses of relatively high data consumption activities of TDV's customer base, including social media mainstays like Instagram, media services like YouTube, as well as gaming and shopping.[67] So while these customers' usage habits did not regularly stress their current networking technology (prior to TVWS access), they and their communities undeniably had a foothold in the internet society. Just as access to internet technologies and services had enabled these facets of their day-to-day lives,

66. For example, Schatz.

67. Vigil, Rantanen, and Belding.

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it stands to reason that enhanced internet connectivity through TVWS could likewise bring additional changes as well.

While related scholarship has emphasized adaptability and "learning-by-doing" as essential practices during technological diffusion and mediation,[68] these practices speak more to the cognitive aspects as opposed to the emotional. Given the ubiquitous nature of emotional responses in mediational behaviors, as elicited by the relevant stakeholders, designers and producers ought to pay more explicit attention to these emotional responses, as they often reflect motivations for rejecting technologies, and ultimately contributing to failed diffusion projects. Novel, emergent technologies can fail just as much as succeed not just by virtue of their level of advancement or production characteristics, but also by social and psychological factors. These factors are also not necessarily confined to simply the end-user customer bases, but also those responsible for engineering, manufacturing, and mediating these technologies. As mediating firms like ISPs are servicing their own customers, they must monitor their own emotions, especially negative ones, in order to prevent conveying that negative message to their customers. In this regard, mediating firms like ISPs have a practical reason to account for these emotional responses in their mediational activities.

Dynamic Elements in Mediational Behaviors

One dynamic element of mediation is related to the evocative components presented in the preceding section. The dynamic nature of emotion was on full display with regards to the mediator, whose staff experienced shifting and evolving emotions throughout the two-week deployment period. Starting from the frustration, distrust, and annoyance—anger spurred by the significant opportunity cost that relocating the TVWS base station incurred, the mediator's emotional states experienced shifts throughout the process influenced by the events of the deployment, how they perceived these events, and their own histories and work practices. Although scholarship on emotional responses has focused on end users of a technology within the context of organizational studies,[69] our findings show that what is relevant to understanding technological diffusion is not just

68. For example, Dosi and Nelson, "Technological Paradigms and Technological Trajectories."

69. For example, Stein et al., "Coping with Information Technology: Mixed Emotions, Vacillation and Non-Conforming Use Patterns"; Murungi, Wiener, and Marabelli.

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the experiences of end users, but also those who comprise the middle step between the technological frontier and those end users. In particular, we see that the emotional responses evoked by mediating of those who comprise the middle step shift over time.

The other dynamic element consists of those directly tied to mediational behaviors. Downstream of the mediator, we observed customer living situations change that affected their connectivity needs, for example, changes in household membership. Upstream of the mediator, we observed the establishment and evolution of a relationship that was in the process of shifting from a close instructional partnership to a more traditional business one based on the mediator's future purchasing of the vendor's offerings. Each of these evolving relationships hinged on the interactions with, as well as affected, the mediator's experiences and work practices, for example, decisions about which new customers to reach in light of technological capabilities and know-how, or decisions about which technologies to use to extend or maintain the network given their current stable of options as well as novel, unfamiliar ones. The practice of mediation changes the key elements of the actors and their situations involved, pointing to this process being a continuous feedback loop. Incorporating the new networking technologies like TVWS changes the topology of their network, granting them access to customers that would otherwise be outside the physical reach of their network. Acquiring access to additional consumers can prompt network expansions in directions previously thought impossible, lending to the company's growth.

During the TVWS deployment, we witnessed the growing understanding of the TVWS technology, shifting from the initial confusion that evoked the negative emotional responses to a gradual understanding and begrudging acceptance of what the technology could realistically offer their network. We as researchers likewise came to a greater understanding of the TVWS technology through practice, for example, how the geo-location database functions in attempting to manage the spectrum in an automated manner. Although many of the challenges we observed were cited in extant literature and speculative essays, our firsthand experiences during the research illustrated our own shared gaps in understanding with the TDV staff. This growth impacts the way TDV conducts their mediation of this technology, most obviously with the upstream vendor: a firmer grasp of the technology means less hand-holding is required by the vendor, and so strongly observable mediational behaviors attenuate, although the quality of the relationship itself is not decreased. This is a goal explicitly echoed by the vendor: working closely with a mediating firm, should they

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determine that firm to be worth this activity, is an investment that hopefully yields a reliable diffuser of their technology with minimal required oversight on the part of the vendor going forward.

Implications of Evocative Responses to Mediation

In defining a "sociable" technology, Turkle[70] implicitly defines an unsociable one: *when technology has been designed without human fulfillment in mind*. Through our findings, we show that this sociability has direct impacts on the mediational process itself, and that producers and mediators must take these evocative impacts into consideration when producing and selecting technologies to fit certain commercial needs. For technological producers, failure to account for these impacts insofar as they are experienced at the local levels (a challenge when technologies are produced to fit broader national or global contexts) can hinder the usability of these emergent technologies beyond simply their technical characteristics, so the need for clear communication and close interaction with mediators ought to be imperative in order to maximize the chances of a successful diffusion process. At the same time, mediating firms must monitor their own emotional states, as outright rejection of a technology on the basis of the initial stressors and frustrations can inadvertently close off organizations to broadening commercial opportunities that these technologies may offer, or convey a negative impression to customers. The attitudes and emotions that could be evoked by their customer base as a result of technological diffusion ought to be considered by these operating firms as well, as these attitudes and sentiments ought to play a role in selecting the appropriate technology to service customers, both in the present and future as customer situations and demands change.

By opening the black box of mediation, we expose the entanglement of evocative impacts and a dynamic adoption and diffusion environment, connecting an in situ account of mediation to the speculated challenges facing TVWS commercial maturation.[71] Reflecting back on the TVWS literature, the multitude of technical and modeling-based studies[72] do not necessarily capture the reality of turning "frontier technology" into commercial reality, and our study provides empirical support to the critiques

70. Turkle, "Sociable Technologies: Enhancing Human Performance."

71. Ramjee, Roy, and Chintalapudi.

72. Fitch et al.; Hadzic, Phokeer, and Johnson; Masonta, Johnson, and Mzyece; Pejovic et al.

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levelled at the FCC approach,[73] as well as aversion toward adopting unfamiliar technologies as an attempt to avoid organizational uncertainty.[74] The negative evocative responses elicited by the staff were the result of the assumptions that the FCC approach makes about the spectrum: that it is, or will be, crowded, necessitating an automated approach due to the infeasibility of scaling a personal, context sensitive style of spectrum management that TDV had become accustomed to, given their rural, sparsely populated context. Additionally, it was FCC "regulation by database" that forced the more thorough use of simulations to examine different base station locations, which would have incurred significant financial expense to TDV. In essence, the FCC approach biases the TVWS technology: automated, contextually unaware regulations appear more oriented toward densely populated areas (and the increased spectrum use that comes with it), as well as to more financially powerful ISPs that have the resource backing to adjust to shifts in their operations as a result of broad-scale regulations that don't consider their unique contexts. The focus on evocative impacts in this analysis reveals this bias. As Hall et al.[75] notes, policymakers such as the FCC need to be aware of local contexts, and provide active support mechanisms to support innovation and diffusion and mitigate uncertainties, mechanisms that appeared to be relatively lacking during the TVWS deployment.

Thus, although scholars have hypothesized about the influence on tech mediation by organizational experience,[76] our account lends depth to this construct, presenting how mediating emergent technologies impact the emotions and experiences of the mediating firms, as well as uncovering the potential sources of obstacles to successful technological diffusion. Although this case closed with a positive working relationship between the TDV staff and the TVWS technology, it is not always the case that emergent technologies succeed in diffusing across prospectively identified commercial environments. This unpacking of technological mediation provides an account of emotion and relationships in diffusion processes. These factors almost certainly play a role in an operator's decision to incorporate emerging, unfamiliar technologies into established work practices. Policymakers and industry professionals ought to heed the impacts

73. Ramjee, Roy, and Chintalapudi.
74. Katila and Ahuja.
75. Hall et al.
76. Gorp, Maitland, and Hanekop.

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of emergent technological ecosystem instability on firms considering incorporating these frontier technologies, or risk "poisoning the well" of technological advances and diffusion processes.

Future Directions and Limitations

The TDV staff noted and were concerned with the increased power requirements of TVWS. With much of TDV's telecommunications towers off-grid and powered by their own solar panels and batteries. New technologies, such as TVWS, with higher levels of power consumption can generate subsequent demand for innovations in power supplies. This suggests, in some circumstances, mediation processes may have a cascading nature. Future research might investigate the nature of these interdependencies and their effects on ongoing mediational processes.

Methodologically, our examination of the process of technological mediation used cross-section interviews with key stakeholders, including TDV staff, customers receiving TVWS service, and a representative from the TVWS vendor. While our contributions focus on taking a dynamic, overtime perspective on mediating emergent technologies, we still collected data from within a relatively concentrated time span, in conjunction with these cross-sectional interviews. Future work would benefit from a longitudinal examination to more clearly elicit the time-dependent factors of the process of mediation.

As an interpretive study, it is principally defined by the impressions of the individual coder who performed the analysis of the collected data. Although the qualitative nature of this study is embraced by the authors (and indeed the findings and contribution hinge crucially upon this approach), it is nonetheless limited insofar as it represents a limited number of possible perspectives on the observations and collected data. As a result, it would be of great benefit to this study's direction as well as the field that there be more studies that seek to explore the social impacts of information technology infrastructure development in difficult environments (e.g., rural or developmental). As an example, scholars have explored how TVWS infrastructure development has affected education and teaching practices in Africa.[77] Our study explores similar notions of

77. Masonta, Ramoroka, and Lysko; Lysko et al.

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consequences of TVWS on practice, but focused on the ISP as adopter, and should be conceptualized as contributing to this area of scholarship.

Additionally, since we focused our observational and interview data collection efforts on the staff of TDV, our number of interviews with TDV customers was very small, and limited only to a subset of the customers receiving the TVWS-based broadband internet service (we interviewed representatives from three of four households). Future work within this domain ought to flesh out the "downstream" portion of the mediational relationship by contributing additional data to understanding this relationship, including interviews, surveys, or even deeper observational research focusing on the role small, rural ISPs play in disparate and underserved regions like the American Indian reservations in San Diego County.

Finally, further exploration into the digital divide that exists on tribal land must be explored, as a result of the fact that these sovereign nations are often times left to establish and maintain their own infrastructures, and this includes persisting issues of digital divide.[78] This study ought to be conceptualized within this push, as providing a tribal operator-centered account of infrastructure development on reservation land, and connecting regulatory factors and technological features with the circumstances both organizationally and geographically that tribal operators must navigate. Even with our contribution, scholars must continue to explore novel and emergent technologies to bridge these divides, and shed light on how to maximize their chances of success.

Conclusion

While the recent scholarship on TVWS has probed technical challenges in largely rural or low-income country contexts, illustrating technical capabilities, the current technical focus has lacked the social and psychological elements of technological adoption and diffusion. The experiences of networking professionals portrayed in this study illustrate the tensions and challenges of this process, complementing this gap in the literature as well as offering broadly generalizable findings to the process of diffusion by professionals wrangling with unfamiliar technologies like TVWS. By focusing on the experiences of an ISP as a technological mediator and on the dynamic conditions of the process of mediation as emergent technologies

78. McMahon et al.; McMahon; Wang.

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are incorporated into its stable of network technologies, we have opened the black box of mediation, exposing the entanglement of regulatory fluidity and mediator experiences. Thus, our study broadly contributes to our understanding of the construct of technological mediation by moving beyond depicting mediation as merely a role to be played by firms and presents an empirical account of behaviors and the limits to the mediation process as they occur. Our account of mediation through the ISP's perspective illuminates the psychological risks and costs of the diffusion process, contributing to scholarship on mediation, adoption, and commercialization of frontier technology. The dynamic state of TVWS produces a multilayered character to mediation, where the ISP is just as much coming to terms with commercially developing technology as they themselves are deploying it to serve their customers. Technological mediation as dynamic is shaped by an ongoing state of evolution, conditions that have been underexamined in adoption and mediation literature.

Appendix 1

TABLE 1 Taxonomy of Emotional Responses and Attitudes to TVWS Technology

Taxonomy of Observed Emotional Responses and Attitudes				
Actor(s) within Mediational Process	**Stimulus Event(s)**	**Inferred Cognition**	**Emotional Response**	**Attitude**
Mediator	• Forced relocation of the TVWS base station due to HAAT violation	• Perception of the opaque nature of the TVWS technology • Perception of regulatory overreach	Annoyance–anger (Frustration)	• Desire for consistency, clarity • Confidence in their own understanding of network technology
	• TVWS requirements conflicting with established work practices		Distrust/ disgust	

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Taxonomy of Observed Emotional Responses and Attitudes				
Actor(s) within Mediational Process	**Stimulus Event(s)**	**Inferred Cognition**	**Emotional Response**	**Attitude**
	• Confirming TVWS good performance in poor line-of-sight conditions	• Awareness of potential for TVWS to reach new customers • Awareness of TVWS as an additional spectrum option	Surprise	
			Optimism	
	• Observation of low overall data throughput of the TVWS base stations • Calculating the financial burden that TVWS presents • Calculating the power requirements of TVWS	• Concretizing awareness of TVWS limitations	Disapproval/ pessimism	• Caution with new technologies
	• Successful deployment and connection of homes using TVWS technology	• Understanding of TVWS technology's fit in mediator's network (e.g., as a targeted tool for special cases)	Acceptance	

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Taxonomy of Observed Emotional Responses and Attitudes				
Actor(s) within Mediational Process	**Stimulus Event(s)**	**Inferred Cognition**	**Emotional Response**	**Attitude**
Customer	• Received ostensibly faster, more reliable internet access through the TVWS technology	• Consideration of prior and current use of internet connectivity	Boredom (**a**pathy)	• Technological skepticism • "Luddite" pride
Vendor	• Building and maintaining business relationship with mediator	• Positive impression of the mediator	Optimism (toward TDV)	• Receptive to firms perceived as potential long-term customers
	• Building and maintaining a business offering TVWS technology	• Awareness of long-term implications of FCC's current TVWS policy	Disapproval/ pessimism	• Caution with expectations, deployments in the United States
			Annoyance–anger (frustration)	

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