Dynamics of Technological Mediation: A Case of Television White Space Deployment

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ABSTRACT

Technological mediation provides a model for analyzing the role that internet service providers (ISPs) play in translating technologies from the "technological frontier" to their particular commercial context. Although its original conception defined three obstacles mediators encounter during this process (technical, commercial, and structural), how these obstacles unfold during mediation has yet to be fully investigated. Through an ethnographic case study with a small rural ISP, we deepen our understanding of this model, in particular the complex interplay between the dynamic technological environment and the experiences of the mediator. While innovation scholars know that commercial markets mature over time, this study illuminates how this process impacts the organizations who must adopt and localize these technologies.

CCS CONCEPTS

• **Social and professional topics** → **Socio-technical systems**; *Broadband access*; • **Networks** → *Network management*;

KEYWORDS

Television white space, TVWS, internet service provision, ISP, technological mediation

ACM Reference Format:
Richard N. Caneba and Carleen F. Maitland. 2019. Dynamics of Technological Mediation: A Case of Television White Space Deployment. In *Proceedings of ACM International Conference on Information and Communication Technologies and Development (ICTD'19).* ACM, New York, NY, USA, Article 4, 5 pages. https://doi.org/10.475/123_4

1 INTRODUCTION

The popular discourse on novel network technologies often focuses on the early phases of technological development: news sources trumpet 'latest breakthroughs,' patents are issued, standards may be developed, and policies formulated to enhance market penetration. From there, successful diffusion of technology is perceived as an inevitability. *But what happens in the middle?* This question is addressed in studies of technological mediation: the process whereby participants in the network supply chain work together to bring new network technology to market.

ICTD'19, January 2019, Ahmedabad, India

ACM ISBN 123-4567-24-567/08/06.
https://doi.org/10.475/123_4

Television white space (TVWS) has been touted as a network technology advance that stands to impact rural internet service provision due to its robust signal transmission properties in limited line-of-sight conditions (LoS) and relatively inexpensive infrastructure requirements. TVWSs are the "large portions of spectrum ... which became available in the United States on a geographical basis" following the industry switchover from analog to digital television spectrum [17]. The opening of the TVWS spectrum to private enterprises was overseen and continues to be managed by the Federal Communications Commission (FCC) [3, 4] with a certain degree of controversy. The still evolving regulatory and technical state of TVWS technology have resulted in a fluid technological environment.

In this paper, we focus on one such organizational mediator tasked with bringing TVWS to commercial reality: the small, rural, nonprofit internet service provider (ISP). This ISP, Tribal Digital Village (TDV), operates in the reservations of San Diego County, CA and made the decision to extend their network with TVWS technology. The interaction between the fluid TVWS technological ecosystem (e.g. regulation) and the developing experiences of the mediator produce a dynamic environment with implications for those seeking to bring this technology to their commercial context. We sought to explore this dynamism by answering the following question: *how do the dynamic conditions of TVWS impact the experiences of mediating firm?*

2 BACKGROUND AND THEORY

2.1 Technological Mediation

Technological mediation as a singular concept originates from Greenstein's industrial organization research which examined internet markets and the central role ISPs play in bridging emerging internet technologies with their commercial contexts [7–9]. 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, 24]. Technological mediators are organizations that work to adapt technologies from engineering, lab-based settings to a particular commercial context.

Greenstein presents three empirical predictions about observable challenges that 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", e.g. policy considerations [8]. Mediational behaviors are defined by how technological mediators overcome these challenges.

There have been empirical examinations of technological mediation, most notably Van Gorp et al. examination of technological mediation in ISPs and their broadband service markets via mixed-methods approach (national case study and international survey) [24]. A common thread through empirical approaches within the mediation literature is a 'black-boxing' of the mediation process. In some cases, this is a byproduct of method, e.g. survey methods (e.g. [10, 24]), cross-sectional interviews (e.g. [26]), and industry-level data analyses (e.g. [12, 15] largely mask the mediation process. While illuminating, a static focus may not go far enough towards capturing the socio-technical aspects of the mediation process itself.

2.2 TVWS in Rural and Developmental Contexts

One such element of socio-technical systems is the experiences of social actors, and how time dependent factors influence those experiences. There are at least two factors likely to have dynamic elements: 1) the evocative impacts of accruing experience with a technology, and 2) the evolution of regulatory conditions surrounding that technology. While these temporal notions are somewhat represented within the Van Gorp et al. model of technological mediation via 'experience' as a firm-specific factor, this concept was operationalized via a single survey item measuring the number of years providing internet access service [24] and is a shallow notion of experience. The lack of primacy to this dimension limits the ability for the model to take into account the dynamic nature of technological mediation.

Socio-technical scholar Sherry Turkle has explicitly identified the "evocative" nature of machines, describing the way they provoke self-reflection [22, 23], a process with strong experiential connotations as well as deserving of analytical depth. Using an ethnographic approach, we seek to lend depth to the model of technological mediation by examining how temporally dependent conditions of technology impact the experiences technological mediators adopting these technologies.

2.3 TVWS Technology in Development and Rural Contexts

The challenges encountered in network service provision in development contexts also parallel challenges encountered in rural areas, where TVWS technology has been touted to make an impact. Limitations to traditionally established commercial networking technologies in these contexts make robust, relatively inexpensive technologies like TVWS are attractive. For example, the Philippines made TVWS a central component of their "Internet for All" initiative within the broader Philippine Digital Strategy [21], and as a nation have explored TVWS to reach "far-flung" regions [1].

There have been several technical studies of TVWS in rural and development contexts, e.g. explorations of channel saturation in Kenya [14] and explorations of novel TVWS platforms [18, 19]. Similarly, there have been studies in the rural UK evaluating the regulatory environment [5] or spectrum availability and market factors surrounding the technology [13]. These studies that have focused almost exclusively on technical or economic aspects of TVWS do not engage the social characteristics of TVWS diffusion, while those that do have not presented operator perspectives. What is missing from these accounts are explorations of the process of mediation itself.

3 THE STUDY

3.1 Site Selection

The site selection was influenced by the ongoing relationship of the research team with SCTCA and TDV. TDV traces its origins to the High Performance Wireless Research and Education Network (HPWREN) at the University of California - San Diego (UCSD), and has since evolved from a small-scale project into a fully-fledged ISP. The research team secured a grant to enable TDV to trial TVWS technology, aiding in selecting the equipment vendor. The TVWS deployment was on the Santa Ysabel Indian reservation, so the bulk of our TVWS related findings are drawn from that region.

3.2 Methods and Data Collection

Our study of technological mediation took a qualitative, ethnographic approach including semi-structured interviews, participant-observation, and active participation in daily work practices to gain an embodied perspective [16]. A member of the research team was embedded with the TDV staff for a 2-week field study period in June 2017, working closely alongside TDV's field technicians and office staff. During this time, field notes, interview data, and supporting technical documentation were collected. Following the field study, the research team spoke to representatives from the TVWS vendor. In summary, observational data was collected from principally 7 TDV employees (4 field technicians, 2 administrative staffers, and TDV's manager), interviews were conducted with 3 of the 4 field technicians and representatives from 3 of the 4 households receiving the TVWS-based network service.

3.3 Data Analysis

Greenstein's taxonomy of technological mediation challenges and how TDV perceived and/or surmounted them were used to frame the analysis process. Following each day, the researcher consolidated the field notes into a digital format and shared with the rest of the research team via a secured online file repository. Regular telephone discussions during the 2-week period supported an organic identification of topics, ensuring that key subjects and questions were being explored. Analysis continued once the researcher returned to his home university. This analysis was conducted in a qualitative grounded theory coding style [2, 6, 25].

4 FINDINGS

The TVWS deployment required several steps, spread over several days. These included 1) relocating the TVWS base station to a new location in accordance 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; and 5) installation of the TVWS devices at the client sites. Standard network maintenance activities were conducted simultaneously.

4.1 Technical Challenges

4.1.1 Challenging Installation Requirements. Working with the vendor, the TDV team received specific recommendations for optimal conditions for the client-site TVWS equipment: a minimum 500 meters from the base station, a minimum 5 meters above ground level to minimize ground interference, and a minimum 9-12 meters distance to the treeline. TDV staff expressed skepticism of these recommendations because they appeared to conflict with common conditions in their region, e.g. the density of foliage at installation sites commonly makes the 9-12 meter distance to the treeline unrealistic. Of the new client sites, the fourth stood out as having particularly poor LoS conditions.

Despite the questionable conditions at a few of the sites, connections were ultimately achieved at each, successfully integrating four new customers into the TDV network with TVWS. This included the successful installation at the fourth location, contrasting the aforementioned pessimism about the client site and surprising the TDV staff.

4.1.2 Signal Interference. While television channels were moved off of the analog signal spectrum in 2008 in the United States, Mexico still uses that spectrum for analog television. That fact combined with high powered analog television signal projection from Mexico introduces signal interference into San Diego County, especially noticeable at higher elevations. While "height-above-average-terrain" (HAAT) regulations limit the elevation of TVWS base stations relative to the surrounding terrain, the vendor pointed out that the signal interference at high elevation is significant enough that it's preferable to install at lower elevation regardless. Despite TDV's significant experience with wireless broadband networking, mediation of TVWS introduced a new spectrum that carried with it a new set of technical considerations.

TDV technicians noted however that TVWS is at least beneficial as an additional option in an increasingly saturated wireless environment:

> 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.

4.2 Commercial Challenges

4.2.1 Equipment Costs. TDV acquired enough equipment to connect 9 client sites with TVWS technology at a cost of about $11,000 USD (about $1,222 USD per client site). This was significantly more expensive than the fixed terrestrial wireless broadband technology that comprised the core of their network. Additionally, it was noted by TDV staff that the devices required a lot of energy to operate: the TVWS devices operated at 60 Watts, several times more than what is currently deployed (a comparable device on their network has a maximum power consumption of 7.5 Watts).

4.2.2 Opportunity Costs. The tasks of TDV's technician roughly fall into one of two categories: maintenance of the existing network and expansion of the network. During the TVWS deployment, TDV staff worked along these two goals simultaneously, conducting visits to client sites and tower locations to maintain and expand the network. Maintenance activities consisted of providing at-home customer support or tower maintenance, and TDV's staff noted that coordinating this work with the TVWS installations carried costs in time and energy:

> 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.

Significant time was dedicated during the two-week field study towards TVWS: 4 of the 10 business days were dedicated to TVWS relocation, field testing, and client site installations. This does not include the time spent before the field study installing the TVWS base station at an erroneous location and poring over simulations and directions with the TVWS vendor.

4.2.3 Oversubscription Limitations. Despite the eventual success of the installations, the maximum throughput of the TVWS base station was decidedly limited: the observed total download rate was 20 Mbps. TDV technicians noted this as significantly less their current terrestrial fixed wireless broadband base stations, presenting a limitation to "oversubscription": the practice of connecting multiple clients to a single base station and assuring more bandwidth than mathematically possible (e.g. offering 5 Mbps speed for 5 clients connected to a single 20 Mbps base station) with the assumption that not all customers will be stressing the internet at the same time.

4.2.4 Technological Skepticism. The new customers connected via TVWS technology to the TDV network were decidedly non-dependent upon internet offered by TVWS by their own admission. The interviewed customers described themselves as having low internet needs with limited streaming and other high-data applications. Regardless, there was evidence of internet use playing a role in their lives, e.g. one resident interviewed had been given a tablet by his healthcare provider for regular biometric monitoring (the tablet used their cellular service).

4.3 Structural Challenges

4.3.1 Regulation by FCC Geo-location Database. The TDV technicians had previously attempted to install the TVWS base station at a site of high elevation in order to maximize LoS to as many client sites as possible, as is standard for their fixed wireless broadband technologies. The practice is based on sound reasoning: the rugged terrain reinforces a 'higher is better' attitude. However, this location was in violation of the FCC's HAAT restriction, and thereby not allocated spectrum for use. Every TVWS device must interface with an external geo-location database that enforces FCC regulations and manages spectrum use automatically (this check is hard-coded directly into each TVWS device), including the HAAT restriction. In addition to managing the new, private users of the TVWS spectrum, these measures are also designed to protect 'incumbents': those users of the spectrum who remained following the FCC-mandated switch from analog to digital broadcasting. TDV technicians did not realize how the geo-location database functioned and simply followed existing practices, and it is only through close work with the vendor that TDV was ultimately able to correct this.

These frustrations with the regulatory environment pointed to larger structural challenges that the TVWS vendor was aware,

and similarly pessimistic. According to the vendor, this database is flawed:

> 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.

In this case, "overly optimistic" refers to an overestimation of propagation range, leading to an underestimation of available spectrum in the interest of protecting incumbents and other parties using the TVWS spectrum. Additionally, database issues were compounded by a state of regulatory 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 [11]. The representative did not mince words when describing the current structural state:

> 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.

Reflecting on this new regulatory environment in which control over technology use was ceded to a database, TDV's manager expressed that up until now they existed in a "play-nice" atmosphere. Spectrum is managed through direct contact with competing parties and negotiated directly with an assumption of mutual respect. The FCC's regulation of TVWS spectrum through a remote database that had little connection to the local context was perceived as contradictory to this relationship-based approach.

5 DISCUSSION

This case study reveals the intertwined nature of Greenstein's tenets of mediational challenges: FCC regulations have introduced structural obstacles that impact the commercial and technical viability of TVWS [35]. This non-static view of mediation taken here via an ethnographic approach identifies the evocative nature of mediation, and the entanglement of uncertainty that comes with technological mediation of emerging technologies. Providing a dynamic account deepens our understanding of tech mediation by incorporating these evocative impacts into the model.

5.1 Deepening Technological Mediation: The Dynamic Context

Our findings indicate that the entwinement of mediator's accruing experience and the evolution of regulatory environments have interdependent effects on mediation, provoking evocative impacts. Of these impacts, trust was a common thread: mistakes driven by unfamiliarity with TVWS, the introduction of additional regulatory reach via geo-location database, and conflict with established work practices sowed mistrust on the mediator's personnel.

These findings also suggest a latent temporal structure: while the FCC's structural conditions lead to the trust-related experiential impacts, they also formed the foundation of commercial and technical issues encountered, most apparent being the opportunity costs presented by the HAAT enforcement. Future research should seek to examine this temporal structure, and lend a depth to what is currently a 'flat' triad of mediational challenges.

While self-reflection (in Turkle's sense of "evocative objects" [22, 23] was not explicit during the TVWS deployment, the perspectives of TDV's staff reflected the stressors of handling an unfamiliar technology. In defining a "sociable" technology, Turkle implicitly defines an unsociable one: "when technology has been designed without human fulfillment in mind" [22]. The forced interaction between the conditions of the TVWS ecosystem and the mediator's established work practices, e.g. the 'play-nice' mode of spectrum management, was revealed through this ethnographic focus on the mediator, painting the TVWS technology in an 'unsociable' light.

6 LIMITATIONS

This examination of the process of technological mediation utilized cross-section interviews with key stakeholders, including TDV staff, customers receiving TVWS service, and a representative from the TVWS vendor. Future work on dynamic conditions of technological mediation would benefit from a longitudinal examination.

7 CONCLUSIONS

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. By focusing on the experiences of an ISP as a technological mediator and the dynamic conditions of the process of mediation as emergent technologies are incorporated into their stable of network technologies, we have opened the 'black box' of mediation, exposing the entanglement of regulatory fluidity and mediator experiences. In doing so, we connected an in-situ account of mediation to the speculated challenges facing TVWS commercial maturation [20]. The dynamic state of TVWS produces a multi-layered 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, a character that has been under-examined in mediation literature.

8 ACKNOWLEDGMENTS

We would like to thank the wonderful staff of Tribal Digital Village and Southern California Tribal Chairman's Association for conducting this study with us. The authors gratefully acknowledge the grant from NSF (Award #1562613).

REFERENCES

[1] Marife Carpio. 2015. TV White Space for Development Programs in the Philippines: Implications and Challenges. In *Asia Conference on Society, Education, and Technology*. https://papers.iafor.org/wp-content/uploads/papers/acset2015/ACSET2015{_}18915.pdf

[2] K Charmaz. 2002. Qualitative Interviewing and Grounded Theory Analysis. In *Handbook of Interview Research*, Jaber F. Gubrium and James A. Holstein (Eds.). SAGE Publications, Inc., Chapter 32, 675–694.

[3] Federal Communications Commission. 2008. *FCC Adopts Rules for Unlicensed Use of Television White Spaces.* Technical Report. Federal Communications Commission, Washington, DC. 382–388 pages.

[4] Federal Communications Commission. 2015. *FCC Adopts Rules for Unlicensed Services in TV and 600 MHz Bands.* Technical Report.

[5] Michael Fitch, Maziar Nekovee, Santosh Kawade, Keith Briggs, and Richard MacKenzie. 2011. Wireless Service Provision in TV White Space with Cognitive Radio Technology: A Telecom Operator's Perspective and Experience. *IEEE*

Communications Magazine 49, 3 (2011), 64–73. https://doi.org/10.1109/MCOM.2011.5723802

[6] Barney G. Glaser and Anselm Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research.* AldineTransaction, New Brunswick (USA) and London (UK).

[7] Shane Greenstein. 2000. Building and Delivering the Virtual World: Commercializing Services for Internet Access. *The Journal of Industrial Economics* 48, 4 (2000), 391–411.

[8] Shane Greenstein. 2000. Technological Mediation and Commercial Development in the Early Internet Access Market. *Policy* (2000).

[9] Shane Greenstein. 2000. Understanding the Evolving Structure of Commercial Internet Markets. In *Understanding the Digital Economy: Data, Tools and Research*, Erik Brynjolfsson and Brian Kahin (Eds.). MIT Press, Cambridge, Massachusetts, and London, England.

[10] László Gyarmati and Tuan Anh Trinh. 2016. Investigation of the Impacts of User Behaviour on Pricing Competition of Internet Service Providers: Empirical Evidence and Game-Theoretical Analysis. *Access* March (2016).

[11] Adam Jacobsen. 2017. NAB Steps Up Its White Space Fight Against Microsoft. *Radio & Records* (2017), 1–6.

[12] Riitta Katila and Gautam Ahuja. 2002. Something Old, Something New: A Longitudinal Study of Search Behavior and New Product Introduction. *The Academy of Management Journal* 45, 6 (2002), 1183–1194.

[13] Santosh Kawade, Maziar Nekovee, and Richard MacKenzie. 2012. Is Wireless Broadband Provision to Rural Communities in TV Whitespaces Viable?: A UK Case Study and Analysis. *IEEE International Symposium on Dynamic Spectrum Access Networks* 147 (2012), 461–466. https://doi.org/10.1109/MCOM.2011.5723802

[14] Kenneth Kimani, Kibet Langat, and Vitalice Oduol. 2017. TV White Spaces Opportunistic Spectrum Access for Wireless Regional Area Networks . May (2017).

[15] Kayvan Miri Lavassani and Bahar Movahedi. 2014. Broadband Internet Adoption Challenge: An Investigation of Broadband Utilization in the United States. *Transforming Government: People, Process and Policy* 8, 4 (2014), 620–644.

[16] Bronislaw Malinowski. 1922. *Argonauts of the Western Pacific: An Account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea.* Routledge and Kegan Paul, London.

[17] Maziar Nekovee. 2010. A Survey of Cognitive Radio Access to TV White Spaces. *International Journal of Digital Multimedia Broadcasting* (2010), 1–11. https://doi.org/10.1155/2010/236568

[18] Veljko Pejovic, David L. Johnson, Mariya Zheleva, Elizabeth M. Belding, and Albert Lysko. 2014. VillageLink: Wide-area wireless coverage. In *2014 6th International Conference on Communication Systems and Networks, COMSNETS 2014.* IEEE. https://doi.org/10.1109/COMSNETS.2014.6734868

[19] Veljko Pejovic, David Lloyd Johnson, Mariya Zheleva, Elizabeth M Belding, and Albert Lysko. 2015. VillageLink: A Channel Allocation Technique for Wide-Area White Space Networks. In *White Space Communication.* Springer, 249–280.

[20] Ramachandran Ramjee, Sumit Roy, and Krishna Chintalapudi. 2016. A Critique of FCC's TV White Space Regulations. *GetMobile* 20, 1 (2016), 20–25. https://doi.org/10.1145/2972413.2972421

[21] Republic of the Philippines: Department of Information and Communications Technology. 2018. *TV White Space (TVWS) Technologies Adoption.* Technical Report. Republic of the Philippines. http://dict.gov.ph/major-programs-and-projects/national-connectivity/tv-white-space-tvws-technologies-adoption/

[22] Sherry Turkle. 2002. Sociable Technologies: Enhancing Human Performance when the Computer is not a Tool but a Companion. In *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, Mihail C. Roco and William Sims Bainbridge (Eds.). National Science Foundation, 150–158. http://kr.ibrea.org/bbs/ftp/NBIC{_}report.pdf{#}page=164

[23] Sherry Turkle. 2005. *The Second Self: Computers and the Human Spirit.* The MIT Press, Cambridge, Massachusetts, and London, England. https://monoskop.org/images/5/55/Turkle{_}Sherry{_}The{_}Second{_}Self{_}Computers{_}and{_}the{_}Human{_}Spirit{_}20th{_}ed.pdf

[24] Annemijn F. Van Gorp, Carleen F. Maitland, and Heidemarie Hanekop. 2006. The broadband Internet access market: The changing role of ISPs. *Telecommunications Policy* 30, 2 (2006), 96–111. https://doi.org/10.1016/j.telpol.2005.05.009

[25] Diane Walker and Florence Myrick. 2006. Grounded Theory: An Exploration of Process and Procedure. *Qualitative Health Research* 16, 4 (2006), 547–559. https://doi.org/10.1177/1049732305285972

[26] Lawrence E. Wood. 2008. Rural broadband: The provider matters. *Telecommunications Policy* 32, 5 (2008), 326–339. https://doi.org/10.1016/j.telpol.2007.08.004