Convergence Through Solution Interoperability: Case Study of Integrated Telecommunication Design and Incremental Deployment

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Abstract

Researchers have cogently presented the technical case for converged telecommunications systems. However, it is not clear how market-based telecommunications providers are embracing this technical argument as they design new telecommunication systems. This paper uses a case study approach to examine market and policy influences on achieving converged networks in a mixed commercial and residential environment. Specifically, the article presents the overall telecommunications design and then analyzes several implementations (and alternatives) proposed for a major urban redevelopment project in the greater Denver metropolitan area. Based on this review, the paper analyzes the role of interoperability as a mediating condition between a converged design and incremental solutions to this design. Finally, the paper addresses public policy implications for encouraging adoption of fiber-IP based networks in metropolitan areas. These implications are compared to recent findings from a national research council study on broadband deployment.

1. Introduction

In his 1983 book, *Technologies of Freedom,* Ithiel de Sola Pool described the "blurring [of] the lines between media" where a "single physical means… may carry services that in the past were provided in separate ways" as the "convergence of the modes."[1] Today, with emerging digital technologies, the advent of the Internet and its associated communications protocols, and the merging of multiple electronic services onto single delivery platforms, network convergence has become a technological reality. Chatterjee and Byun define this new reality as "…the integration of several media applications (e.g., data, voice, video, images) onto a common packet-based platform provided by Internet Protocol (IP)."[2] Several researchers have cogently articulated the technical justifications for technological convergence, such as the end-to-end (e2e) argument and the more efficient use of bandwidth. Applications that enable converged services have traditionally been considered in accordance with end-to-end design principles as proposed by network architects Saltzer, Reed and Clark (i.e. Voice over IP) [3,4,5]. These packet-based end-to-end systems have been demonstrated across a number of platforms and market conditions and there continues to be a push for the e2e argument in network design [3,4,5]. However, Internet design is evolving away from a classic e2e approach as new and changing stakeholders in the Internet demand and implement technologies that allow for robust, scalable solutions that do not sacrifice quality of service [5]. This current trend is expanding the technical options of what is considered a "converged network." But, from a level of service point of view, the technical claim is clear: delivery of highly reliable and scalable bandwidth can facilitate a range of voice, video and data services over IP [6].

Mansell and Steinmueller support the technical argument for convergence, but add that there is an additional dimension. They explain that a second part of convergence is the "industrial and market implications of this technological potential."[7] Technical convergence cannot be achieved simply by introducing new technology, but rather must mesh with the social and economic milieu. Noam elaborates: "Technological change has provided the precondition for change but is not a sufficient condition."[8] Policy and market conditions, in combination with new technologies, are all conditions that shape the acceptance and implementation of technical convergence into the marketplace. For example, there are many unanswered questions in relation to how convergence is being embraced by market-based communications providers

The telecommunications environment currently, and for the past few years, has been extremely turbulent due to two underlying factors. The first is the economic "ripple effect" of the "dot bomb" bubble implosion. Several events within the telecom industry took place surrounding

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the Internet explosion that caused difficulties later on. This included rapid expansion of fiber supply in anticipation of accelerated telecom demand, aggressive vendor financing of dot.com enterprises, including telecom co-location and switching facilities, and investment forays into building-centric services (e.g. Broadband Office).

The second underlying factor relates to the first, but deserves separate mention. This concerns the public policy debate surrounding the "deregulation" of telecommunications networks and services, how the debate relates to the current economic turmoil, and what needs to be done to end an industry wide standoff so that acceptance of broadband services can continue to move forward. One ostensible objective of the "Telecommunications [Deregulation] Act of 1996" was to foster broadband deployment by encouraging competition among providers. Yet, as evidenced by the recent actions and debate to modify the Act (e.g. the Tauzin-Dingell Bill of 2002), there is still widespread disagreement as to how well the current telecommunications environment is encouraging competitive providers (CLEC's) to deploy broadband services, particularly in residential and small business environments.

Given these conflicted technical and socio-economic conditions, it is not surprising that a recent National Research Council report found several barriers to local (last mile) entry into the broadband market. As will be taken up in the discussion section, their recommendations can provide a general template for considering steps at the local level. First, however, come the details of the present case study.

This paper explores a recent effort by a community master-planned developer to encourage competition in a high tech corridor, high profile development. The driving research question is to what extent are converged systems being pursued within the context of an urban mixed-use (e.g. commercial, residential, retail) community development. In particular, the case examines how service providers are responding to the current economic and regulatory environment, particularly as relates to the types of "converged" networks that are being built in new, opportunity rich communities. As will be taken up in the final concluding section, the case provides some insight into the regulatory influences, the economics of convergence, and the need for local public policy to encourage convergence through interoperability.

2. Case Study: Urban Mixed-use Development

The case study in this paper is a mixed-use community development in the Denver metropolitan area. The community encompasses 19 city blocks, including approximately 900,000 square feet of office and hotel space, 1 million square feet of retail space, and 1,300 residential units. The construction began with the demolition of an existing mall. Before construction began, the community developer designed an overall vision and described how a telecommunications plan related to the scope of the project. The developer envisioned implementing a robust and state of the art system to support current and emerging needs for commercial retail providers, office tenants, residents, and community service providers. The developer intended to have a high-bandwidth capable network implemented in the community and therefore hoped to receive high bandwidth, converged, end-to-end IP voice, video, and data offerings from service providers. The network services would extend from service providers' owned or leased physical facilities and would include services over packet-based delivery protocols. These service provider facilities would then interconnect with the public switched telephone network (PSTN) when referring to telephone operators, the Internet via an Internet point of presence (POP), or other long distance or cable operator backbone that intersects with the PSTN, Internet POP, cable head end, or any combination of the three. This high-bandwidth network would ideally extend the entire "last mile" to the end customer, or subscriber.

The developer planned for the system to include a full-array of "voice, video, and data" capabilities including telephony, high-speed data, business services, entertainment, energy management, security management, and community Internet access. Pursuant to the community's vision for a converged system, the developer sought partnerships with as many telecommunications providers as necessary to provide the highest quality services available. In addition, it was expected at the outset that the partner would be responsible for the associated capital investment to achieve this objective for the residential portion of the project.

2.1. The Partnering Process

In late January 2002, an Invitation to Partner (ITP) document was prepared and sent to several service providers. The ITP contained information about the community and described the developer's telecommunications and business goals. Written responses to the ITP document were received from several entities. The responses were analyzed in terms of the proposed network infrastructure, services offered, revenue share and joint venture options, and other types of business implications. A series of follow-up discussions were held to further understand service provider proposals and implications for the development. A final group of provider's consisted of the Incumbent Local Exchange Carrier (ILEC), a competitive cable operator and multiple services operator (MSO), two

Competitive Local Exchange Carriers (CLECs), and two alternative solution providers. It is important to note that only "landline" based providers offered solutions. No wireless solutions were offered by any provider.

A detailed description of each network, such as specific hardware, software, and engineering specifications is not discussed in this paper, as it is outside the scope of this paper. A general, very high-level description of network and services offerings is described below (and summarized in Table 1) for each of the service provider options.

Table 1. Telecommunication service provider options

	Option I	Option II	Option III	Option IV
Network	Centralized SONET ring, copper	Decentralized Fiber-to-the-Curb, copper to the building	Decentralized Fiber-to-the-Community, fiber-to-the-building upon demand	Centralized, Fiber-to-the-building
Services	POTS Telephony, high-speed data/Internet	Cable TV, IP Telephony, high-speed data/Intern	POTS telephony, high-speed data/Internet	Converged IP Services (telephony, video, high-speed data/Internet)
Markets	Residential and Commercial	Residential and Commercial (Small Business only)	Commercial	Residential and Commercial
Business Model	Regulated Services	Cable Franchise	CLEC pricing and access, developer support	Developer support and funding
Revenue Share Options	None	After exclusive mktg. agreement	After developer investment	Developer/ owner determines access fees

2.2. Option I: The Incumbent Local Exchange Carrier Option

As a regulated telephone company, the ILEC is obligated to provide subsidized plain old telephone service (POTS) to all residents within the community. Under normal circumstances, it is expected that the ILEC will build a copper infrastructure to every building. However, the ILEC proposed to build a combination fiber optic and copper infrastructure. Under this option, fiber optic cabling would extend to the edge of the community from the ILEC central office (CO) facilities. From the community edge, a synchronous optical network (SONET) (or SONET capable network) would be built in a ring topology throughout the community. SONET equipment would be dispersed in exclusive telecom closets in various locations in the community each connecting to another closet with fiber optic cabling. Copper wiring would then run from each cabinet to resident dwellings and small business locations. Large businesses would have fiber pulled directly to their location.

Besides providing POTS to all residents and businesses, they offered to provide enhanced telephony services to residents and enhanced and channelized services to businesses (T1, T3, ISDN-PRI/BRI, Centrex). A wide range of hosting services, private data networking, and Internet access for businesses and ISP's were also included in the ILEC's list of services.

The ILEC could not confirm if digital subscriber line (DSL) services would be offered to residents and businesses. Ironically, while the ILEC is regulated to provide basic high-speed residential broadband (e.g. ADSL), the relatively dire financial circumstances surrounding the telecommunications sector generally hampered the ability of the ILEC to commit to DSL at a time certain basis. The ILEC did not propose a competitive cable TV offering as some ILEC's have done in other communities either through business partnerships or using DSL technology [9].

2.3. Option II: The Cable Operator Option

A competitive cable operator/multiple services operator (MSO) proposed to build a "fiber-to-the-curb" infrastructure to residential dwellings. From the competitive cable operator/MSO head end facilities located within the city, fiber optic cables would extend to a series of network aggregation points until finally reaching an optical node located less than 400 feet from each of a maximum of 250 subscribers. The optical node would then split a dual hybrid fiber coax (HFC) and Ethernet network into separate (but copper) transmission mediums. The 100 mbps symmetrical Ethernet network would utilize category 5 cables that would extend to the subscriber to provide voice and data IP services. The HFC network would consist of coax cable extending to the subscriber to provide analogue and digital TV. A network interface device (NID) would be installed near the perimeter of a subscriber's dwelling for those customers subscribing to voice, video, and data services. If voice over IP services are not subscribed to, the coax cable would run directly to a set top box for digital TV while the Ethernet cable would extend directly to a computer's Ethernet card. The company planned to fully fund the project and build, own, and service the network indefinitely.

This private company offered voice, video, and data services to all residential and small business customers. There were no solutions for medium to large businesses. According to the proposal, both the voice and data services would utilize IP technology, meaning that the voice services would be considered "secondary" phone services. However, both long distance and local calls would be billed at a flat rate. The company's voice

transport is provided by a partners' worldwide IP network. The data speeds offered ranged from 1 megabit per second (Mbps) to 1 gigabit per second (Gbps). The network would be open to any ISP willing to lease 10 Mbps lines. Customers could choose between a variety of ISP's, digital and analogue cable TV packages, and Video On Demand (VOD). The company also offered to provide local intranet content and hosting services for a community intranet. This entity expected a firm revenue share agreement with the developer in exchange for exclusive marketing agreements. However, shortly after proposing this option, the company announced financial difficulties and has not been able to commit to a date certain for implementation.

2.4. Option III: The Competitive Local Exchange Carrier Option

There were two competitive "converged" offerings by CLEC's as will be discussed below.

The first CLEC did not offer to build infrastructure in the community. Instead, they encouraged the developer to contact them once the ILEC had finished their build-out. The CLEC planned to use all three basic modes of entry into the CLEC market as they were created by the current deregulation policy. They would: 1) lease unbundled network elements (UNE's) from the ILEC, 2) resell ILEC services, and 3) collocate their voice switches and DSL equipment at the ILEC central office, thus "sharing" the regulated companies' controlled facilities and plant, while providing services over the ILEC funded network [10].

The second CLEC owned and operated a nationwide IP backbone as well as facilities in major metropolitan U.S. cities, including the Denver area. They proposed to run fiber optic cables from their facilities to the development. The proposed infrastructure was based upon a partnership and revenue share agreement with the developer. Under the agreement, the CLEC would extend its fiber plant to the "edge" of the development using its own capital. From the "edge", the *developer would fund* and build a conduit ring through the business sector of the community. In this way, the CLEC could access medium and large business customers with its fiber optic cables through the conduit at low cost. In exchange for building the conduit infrastructure, the CLEC would share a percentage of its revenues. A network cabinet that includes the necessary communications equipment would be located at a centralized location designated by the developer. In order to access small business customers, the CLEC planned to make use of existing telecommunications deregulation policy, specifically the "Essential facility doctrine," as in the case with the first CLEC.

The first CLEC would provide basic and enhanced telephony services to residents. Both the first and second company proposed to provide basic and enhanced voice and data services to businesses that compete with the ILEC services. Private data networking, ISP services, hosting, and Internet access as well as data services to ISP's were all included in the ITP responses.

2.5. Option IV: The Interconnected and "Open Access" Option

Two companies proposed a converged "fiber-to-the-subscriber", also known as fiber-to-the-home (FTTH), last-mile network. Both proposals consisted of building a fiber-to-the-subscriber/Ethernet-to-the-subscriber (ETTS), point-to-point IP network (star topology). All subscriber lines would terminate at equipment located in a developer designated central office (CO) location. The network would be fully scalable and adaptable to the number of subscribers and desired Ethernet network speeds (10/100/1000 mbps). The CO would be an "open access" facility that would allow interconnection by any voice, video, or data provider. Any provider could simply collocate and "plug in" their equipment at the CO and utilize the existing fiber plant infrastructure to service their customers. Although the "last mile" would be a converged digital network, the central office would contain interconnection equipment capable of accepting uplinks from numerous types of service providers and their related technologies. Telephone companies, cable operators, multiple services operators (MSO's), DSL providers, ISPs, or any other landline based telecommunications provider would be responsible for running their own (or leased) lines from their facility to the community CO. From that point, the "last mile" to the subscriber would be based on a packet switched delivery platform for all voice, video, and data traffic.

Two companies offered a similar scenario that would utilize very similar converged telecommunications equipment. The difference between the two companies being that one offered only to build the network. The second company offered to build *and manage* the network upon completion. Both options put ownership into the hands of the developer and neither company offered to use any of its own capital to fund or help fund the project. The entire capital expenditure was reliant upon the developer.

2.6. Public-Private Partnerships to Achieve Convergence

The solution-set that emerged out of process was 1) an incumbent (e.g. ILEC) backbone system that provides basic telephony and a scalable background, yet no commitment of converged services, 2) an aggressive but unfunded (or not reliably funded) converged option from competitive providers, and 3) an emerging realization that

some form of public-private partnership might be needed to supplement (not substitute) a backbone system to facilitate deployment of converged systems.

The developer had built a relationship with the city and secured public funds for the purpose of "infrastructure build out". These public funds were designed to cover the costs of building water, electricity, and sewage infrastructures. As a consequence of the telecommunications options proposed and reviewed, it was determined that the costs of financing parts of high-speed converged telecommunications network were eligible under this public fund, and the developer could therefore support a high-speed network while avoiding the capital expenditure. However, other concerns became evident. City and county organizations and entities were already in place to own and operate water, sewage and electricity infrastructures. However, no such public entity existed to own and operate a publicly funded telecommunications infrastructure. Who will own the infrastructure? Who would manage the infrastructure on an ongoing basis? What would be done with the revenues or debt (if any existed)?

It became clear to the developer that, while it had no intention of becoming a telecommunications provider, utilization of public infrastructure funds could be justified to ensure fiber connectivity throughout the community (e.g. fiber conduit system) and to ensure interoperability at key points in the network (such as the Central Office location). The developer then set about implementing this hybrid solution, an incremental approach that utilizes ILEC backbone systems but enhances them to provide ubiquitous broadband availability and interoperability through a public-private partnership.

3. Discussion

While the case study could stand on its own as a cautionary tale about the ability to realize converged and funded telecommunications solutions, its main purpose is to exemplify several issues that have been discussed generally in the literature but seldom documented in terms of actual implementation experiences. Three issues surrounding convergence are regulatory influences, the economics of convergence, and the need for local public policy.

3.1. Regulatory

The Telecommunications Act of 1996 (TA96) was designed to "promote competition and reduce regulation" to secure "higher-quality services for… consumers" and "encourage the rapid deployment of new telecommunications technologies."[11] The result of the act has been an increase in the number of competitive service providers and a more rapid deployment of new technologies [12,13]. However, with introduction to regulation policies largely supported by ILEC's (especially regional bell operating companies (RBOC's)), the regulation landscape faces a change in a different direction. It is unclear whether regulation will support further dismantling of RBOC's, or dismantling of TA96 requirements on ILEC's [10,12,14]. Based on proposals as well as discussions with the case's telecommunication providers, there is no clear incentive (from a regulatory point of view) for deploying broadband services where the market is not clearly established. In general, there has been a large amount of regulation that has discouraged new investment by both incumbent carriers and competitors that have the finances and technical ability to build out new broadband networks and develop facilities-based competition [10].

As discussed previously, current law forces ILEC's to open their networks to competition. Competitive carriers argue that the RBOC's continue to display anticompetitive behavior by not fully complying with current regulation and continue to make it difficult for competitors to gain access to UNE's and equipment space at ILEC CO's [14]. As Noam has argued in his recent book *Interconnecting the Network of Networks*, "Control of interconnection by any entity, whether by government or by private firms, is the key to the control of the telecommunications system and its market structure."[8] And CLEC's argue that the RBOC's continue to exercise anticompetitive control over interconnection at these bottleneck CO facilities. In addition, CLEC's argue that current ILEC-backed regulation has contributed to the financial devastation of the CLEC industry. They claim that current legislation backed by ILEC's, such as the Tauzin-Dingell bill, "stand squarely in opposition to competition and deregulation. The result for consumers will be less choice, higher prices and poorer quality."[14] In addition, the ILEC's resistance to TA96 regulatory laws and the threat of laws changing the implications of TA96 have discouraged venture capital finance in their businesses thus discouraging future broadband network expansion [14].

However, the mid 2001 wave of CLEC bankruptcies and shutdowns called into question the unbundling strategy contemplated in the TA96 [15]. The general argument ILEC's make against unbundling policy is that it is discouraging ILEC's from investing in new broadband networks, as they naturally do not want to invest in expensive broadband networks on behalf of interconnecting competitors [10]. The RBOC's argue, "what was supposed to be orderly deregulation has become a spiral of regulation piled on more regulation" that has discouraged any investment in new broadband networks [10]. In addition, ILEC's argue that current pricing structures that regulate how much ILEC's can charge competitors for services is below actual costs. They state that the intent of TA96 was for CLEC's to eventually construct their own facilities-based operations,

but that flawed pricing structures have kept them from doing so. This regulatory "standoff" has discouraged investment by venture capital firms and the normally financially robust RBOC's.

The above regulatory standoff could be observed in the case study. One example was in relation to the strategic placing and access of telecom equipment in the community. The ILEC, who was also an RBOC, would not allow access or interconnection to their plant by any competitive entity through manholes. In addition, the RBOC would not cooperate in leasing their neighborhood fiber to any competitors. These interconnection requirements were non-negotiable in order to prevent competitive carriers from gaining closer access to customers. Competitors would have to interconnect at their CO facilities located over 3 miles away. The RBOC decided they would place interconnection equipment in small cabinets throughout the community. For the purpose of aesthetics, the developer wanted to negotiate a centralized telecom closet for all telecommunications equipment. The RBOC was cooperative in these discussions, however they required unobstructed access to those facilities at any point in time.

The ILEC/RBOC in this case played a significant role in the development of a "basic communications infrastructure." For one, the company was obligated to provide services and two; they were able to afford a large capital expenditure, unlike their competitive counterparts. The company owned facilities and plant in the vicinity and had a long-standing relationship with the city. In the telecommunications environment during this case study, competitive carriers did not have the scalability and robustness that the regulated phone company had and could not build their own facilities-based converged high-speed networks. Although the ILEC played a significant role in the development of a "basic infrastructure", it remained uncertain as to whether they would build the more advanced SONET ring infrastructure or otherwise have any commitment to a "converged" solution. The final result has been that neither the ILEC nor the CLEC's offered to build a truly advanced and converged network or to provide converged voice, video, and data services.

3.2. Economic Issues

The telecommunications industry has been in a financial freefall for the last 12-24 months, with major players in the industry teetering on or into bankruptcy (e.g. Global Crossing, PSINet, Worldcom). Venture capital firms significantly reduced investment from 2000 to 2001 in CLEC's, Internet access services, and Internet backbone infrastructure [16,17]. The coming of broadband services has not yet materialized. Wall Street has lost much of its enthusiasm for the "dot.coms", Internet service providers (ISP's), and builders of broadband networks, and for the many manufacturers of hardware and software that depend upon them [10,15]. According to the ALTS 2002 annual report, more than 50 CLEC's filed for bankruptcy over the last two years, and several others have disappeared without notice [17]. In addition, "some observers count only 70 facilities-based CLEC's in operation today, down from more than 300 two years ago."[17] Both of the CLEC's discussed in this case study were among those that filed for chapter 11 bankruptcy in the past year.

Besides a lack of venture capital funding and an uncertain regulatory environment, there has also been a drop in consumer demand for broadband services resulting from the economic downturn. This has left broadband consumers with fewer choices and, ultimately, higher monthly prices [13,15,17]. The uncertain demand is one of the biggest impediments to investing in telecommunications infrastructure [18]. From January to December 2001, the cost of broadband services rose approximately $5, and broadband subscriber growth dropped from 39.5% in the first quarter of 2000 to 14.2% in the third quarter of 2001 [17]. ARS consulting expects that this trend of increasing prices will hamper the widespread adoption of broadband services [17].

Reaction to the market drop by observers has been mixed. An added market barrier may be that it is unclear why the CLEC's have failed so miserably, which makes it difficult to know how to proceed in terms of economic and policy decision-making. The National Research Council, Committee on Broadband Last Mile Technology explain:

> It is unclear whether the CLECs' apparent woes were due to the better engineering and operational practices of the incumbents, to unrealistic undercapitalization, intrinsically flawed business models, poor management, anticompetitive practices, failures of their business partners, or insufficient added value relative to the incumbent, or to some combination of these factors [15].

Despite the dismal market atmosphere, this case study provides for some interesting market implications. The first market implication had to do with an attractive customer base within the community. The 900,000 square feet of office space influenced both the ILEC and CLEC's interest. The cost for the ILEC to build a SONET ring rather than a strictly copper infrastructure through the community could be justified due to the large projected financial returns from potential medium and large business customers. Both of the CLEC's were also primarily interested in the business sector. It is safe to say that neither of the CLEC's would have considered an investment in a strictly "residential" community as an aggregation of residences and small businesses have historically been less likely to attract investment than the fiercely competitive medium to large business sector [15, 19]. Despite a shrinking of the CLEC industry in 2001,

the CLEC market continued to grow and expand in terms of access lines and revenue. This is largely attributed to the CLEC's expanding their services to business customers [17].

The business models advanced in this case study provided a means for observing the CLEC financial environment. Unlike the RBOC and cable operator, the CLEC's could not justify a business case to build fiber infrastructure prior to securing large revenue generating tenants. The conduit infrastructure provided by the developer would save the CLEC's in infrastructure build out costs. With the savings and easy access to customers, they could justify making their services immediately available to new building tenants and thus share revenues with the owner of the conduit. The benefit to the developer would be revenue generated through the revenue share agreement with this entity as well as any future competitive carrier that wished to utilize the conduit. As a final benefit, tenants would be provided with more than one immediate choice in service providers, thus enhancing competition.

It should be noted that such revenue partnerships represent a dramatically different economic environment than just two years hence. At the height of the dot.com bubble, building centric telecommunications providers (e.g. Broadband Office, Onsite Access) were offering to pay for the capital costs of the infrastructure throughout commercial locations, as the potential economic value of providing converged services to tenants and residents was believed to be very high [20,21]. These types of partnerships have all but vanished from the telecommunications landscape, and have been replaced with a much more cautious expectation of converged value and consequently, a much reduced willingness by market-based providers to finance the infrastructure to deliver the services.

The "open access" central office model offers the most innovative, yet most costly option. The motive for this "open-access" business model is to provide a cost savings for service providers to enhance competition and consumer choice [16,22]. The reduced cost of infrastructure build-out should act as an incentive for service providers to utilize the existing infrastructure rather than build their own proprietary (or shared) networks. Tenants and residents would ideally have numerous choices in service providers and be allowed a wide range of services and bandwidth capabilities. Hypothetically, the developer could potentially earn large revenues depending on the type of partnerships and arrangements made with interconnecting service providers at their facilities. However, the dramatic uncertainly surrounding telecommunications demand dampened developer enthusiasm for investment in an open telecommunications system.

Besides FTTH being considered a cost prohibitive investment [22], the developer was also introduced to several other concerns. The leading concern had to do with whether the developer wanted to enter into the telecommunications business, an industry that stands well outside the core business and focus of the developer. It was clear the developer did not want to become a telecom provider. In addition, the economic temperature of the telecom sector indicated that there might not have been any telecom companies with the necessary capital or desire to purchase the facilities upon completion if the developer decided against becoming a service provider. A final concern with the proposal was that there was no assurance that the large and financially robust service providers (ILEC and Incumbent Cable Operator) would utilize the facilities and forego building their own physical networks.

3.3. Public Policy

Much has been written on the challenges of the "last mile" and various local demonstration projects exist on overcoming the market barriers to deliver "last mile" converged services in the residential environment (For a more elaborate discussion, see [18,22,23]). Less understood is how synergy can be achieved between commercial and residential services so that a higher level of convergence can be delivered to the last residential mile, riding on the backbone of commercial services.

Perhaps the most interesting public policy issue in this case pertains to the public infrastructure funds that could be used to support a fully robust and advanced converged network. While at the outset the developer did not contemplate the use of such funds for telecommunications, the "gap" in the ability of market-based solutions to deliver a robust system has changed their posture toward these funds. The developer's present intent to utilize these infrastructure funds to enhance broadband services is, however, typical of several actions that have been taken at the local level.

In this sense, considering telecommunications as an infrastructure subject to local policy, new options for local financing and development could help to foster public and private investment for new infrastructure options. Increasingly there are communities, public entities and public-private partnerships that are including telecommunications infrastructures as part of city/community telecommunications initiatives [23]. Some of these utilities are supposed to work much in the same way as the deregulated electric utilities market. A city authority maintains "last mile" infrastructure while a myriad of energy providers "compete" for that city/community business. A partnership limits public liability as in the case with the Palo Alto FTTH project. Palo Alto Utilities Crews have strung fiber optic cables into participating neighborhoods. Public funds are being used to build the underlying network while private companies will provide video, telephony, and Internet

services to residents over the leased lines. The City projects this public-private partnership will ensure a return on the public investment in 2.5 years [24,25]. As another example, Carnegie Mellon University researchers and 3 Rivers Connect, a Pittsburgh-based non-profit have launched a joint venture to create an "affordable" broadband network for the 12-county southwestern region of Pennsylvania. Carnegie Mellon and 3 Rivers is promoting the creation of a new public/private authority with the ability to assume debt and build, manage and lease telecommunications infrastructure to competing service providers [26].

3.4. Municipal Telecom Solution: Interoperability/Interconnection as a Policy

As alluded to above in terms of Noam's thesis, in the policy arena, convergence has a strong relationship with interoperability. This is because in a deregulated environment, the latter is often required to bring disparate services to the end user; the net effect of which is a converged set of services. Interconnection is "…the construction of vertical and horizontal business relationships implemented through interoperable technological linkages in the information and communication infrastructure."[7] Interoperability could be the policy analog to convergence. But interoperability where no service providers exist poses an obvious problem and barrier to convergence.

The developer in this case study wanted to facilitate interconnection while the ILEC resisted the notion. Two of the network infrastructure options discussed designated a central office in the community that would allow for interconnectivity by any service provider to plug into the last mile network. But to make it an economic and technical reality, the developer needed to work with the local community to implement policies to ensure broadband coverage and interoperability.

In sum, with convergence, voice, video, data, everything – "has become a digital stream that can be transported across the Internet. But an important stage of this evolution is to first initiate broadband connectivity."[15] The convergent nature of broadband will permit, but not necessarily foster, industry convergence and consolidation across traditional industry lines [15]. Consequently, as can be seen in this case study, an important incremental step toward such convergence is to allow for competition. And, "successful competition in the telecommunications industry relies critically upon interconnection policy."[27]

4. Conclusion

The technical argument for telecommunications convergence is clear and persuasive [2,3,6,7,8]. This case study provides a "grounded" illustration of the challenges to implementing this vision under current market and policy environments. The widespread failure of competitive telecommunications providers (as well as ILEC's and cable providers) is generally perceived as a setback for converged systems.

As noted in this articles introduction, such concerns were voiced in a recent publication by the National Research Council. Their Committee on Broadband Last Mile Technology made several recommendations for enhancing broadband access and these recommendations provide a useful concluding coda on the national implications of the case study findings:

NRC Recommendation: Structure Regulation to Emphasize Facilities-Based Competition and to Encourage New Entrants. In the long term and in the case of investment in new facilities, policies should favor facilities-based competition over mandated unbundling.

The paper has discussed the confusing and difficult regulatory environment that has fallen short of the goals of the Telecommunications Act of 1996. Policy-makers should look to new ways of encouraging facilities-based competition to encourage new entrants into the industry to more effectively compete with incumbents. Particular to this case study, where two or more service providers are located in the vicinity, interconnection policies to promote competition is an important prelude to convergence. To help foster interconnection, public-private partnerships could be formed between cities/communities and as many service providers as possible.

NRC Recommendation: Defer Development of a Universal Service Policy for Broadband Until the Nature of Broadband Services, Pace of Deployment, Distribution of Access, and Social Significance Become Clearer.

This recommendation alludes to the importance of policies that advance existing and proposed local access systems in a manner that supports incremental deployment and subsequent incremental upgrades and provisioning [22].

Every community will have different economic and social requirements in relation to converged networks. A single policy will likely not work for every location. The case study in this paper gives an example of how a local infrastructure financing policy could effect the deployment of a converged network and how local policies need to take into account the current economic and regulatory environment of each locality.

NRC Recommendation: Take Active Steps to Promote Increased or Accelerated Deployment, Including at the Local Level.

Local public institutions can play a key role in creating digital places at the community level by creating public-private partnerships with telecommunication and digital technology companies to enhance regional competitiveness [28]. The case study illustrates that the local level may be an effective place to enhance interconnection, competition, and thus move closer towards convergence. The emergence of a public-private partnership suggests that advancing convergence may involve forms of public policy and partnerships beyond the relative focus of public policy to date. Palo Alto and others provide examples of this development.

NRC Recommendation: Support research on economic, social, and regulatory factors.

This paper has attempted to address a research question relating to the economic, social and regulatory issues surrounding convergence. One area of future practical research would be to track the successes and/or failures of public-private telecommunications partnerships and other local community initiatives whose intent is to provide affordable, converged services to community members in a competitive environment.

To conclude, this paper has confirmed that convergence is not just a technical challenge, but also an economic, social and policy challenge and consequently, the solution set needs to include these elements. The case study has served as a validating local example of this multi-dimensional dynamic and provided specific illustration of the occurrence of these broader trends at the local level.

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