Broadband Open Access: Lessons from Municipal Network Case Studies

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Abstract

A growing number of communities in the United States and abroad are investing in publicly-owned "last-mile" broadband infrastructure platforms to deliver telephone, video, and broadband data services. In a number of jurisdictions, policy-makers have chosen to insist that municipalities interested in offering communication services over publicly-owned infrastructure must do so on a wholesale-only basis, providing open access to multiple retail service providers. To gain a better understanding of the challenges and implications of open access for broadband services and to provide a foundation for evaluating the advisability of mandatory open access policies, we discuss the lessons learned from a series of case studies of municipal networking in the United States and abroad. In some cases, an open access approach was adopted voluntarily (e.g., Spencer IA or Ashland OR), in others open access was mandated by state law (e.g., Grant County WA), while in many others, no open access is offered (e.g., Braintree MA). These case studies reflect a diversity of approaches that helps elucidate the relationship between open access and the technology/architecture used for the last-mile network, the business strategies employed by municipal communication service providers, and the regulatory environment in which the municipal networks operate. Important differences include the type of open access being provided (e.g., for Internet access v. telephone v. video v. for a bundle of services); whether the open access provider also competes in downstream retail markets; and the choice of technology or system architecture (*e.g.*, HFC or FTTH). A better understanding of alternative open access scenarios is necessary before it is possible to evaluate whether (or how) public policy should promote open access. Additionally, these case studies

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shed interesting light on how future markets for broadband multimedia services may evolve in the future.

I. Introduction

Local access to the Internet has been a bottleneck. Slightly less than half of all U.S. end-users still connect over low-speed dial-up connections that severely limit the quality of multimedia services that can be delivered.[4] To expand the range of services that can be supported via the Internet, ubiquitous broadband access services are necessary. Moreover, for next generation networks, we need broadband access at data rates significantly faster than the 500Kbps to 3 Mbps DSL and cable modem services that are currently available. With 50 Mbps (or more) per home, a broadband access platform could deliver a comprehensive bundle of interactive video, data (Internet), and telephony services to each home. In many cases, the technology of choice will involve significant amounts of fiber optic transmission capacity deployed deep into neighborhoods (FTTx), perhaps all the way to the home (FTTH).[5] Putting the local access infrastructure in place to support the ubiquitous delivery of such services will require upwards of a hundred billion dollars in new investment.[6]

Because fiber optic cables are long-lived assets and installing facilities in "last-mile" networks involves a substantial commitment of fixed costs, it is usually economic to install substantial excess capacity (relative to initial demand). When installing fiber, much of the cost is associated with putting conduit or outside structures in place, and the costs are not significantly increased by placing multiple fibers. This makes it economic to install significant excess capacity in advance of current demand. Additionally, since much of this investment is sunk, the first carrier to deploy fiber may have a significant competitive advantage. While it is certainly possible that in many locales there will be two or more facilities-based providers that are willing to invest in such infrastructure (*e.g.*, the incumbent local telephone and cable television companies), it is also possible that such next generation infrastructure will turn out to be a natural monopoly at least in some locales. For this reason, even if multiple providers do install high-capacity facilities, it is not clear whether effective competition will be sustainable.

In markets where facilities-based competition for next generation broadband access platforms proves unsustainable (or insufficiently robust), last-mile facilities will remain a "bottleneck."[7] In such situations, policymakers will need to consider how best to regulate open access to bottleneck "last-mile" facilities. If there are inadequate facilities-

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[4] Auchard, Eric, “Broadband Passes Dial-up in U.S.” MSNBC.com, August 18, 2004. http://www.msnbc.msn.com/id/5750968/ visited August 26, 2004.

[5] Both incumbent cable television and local telephone providers have been installing fiber deeper into their distribution networks, although it is still rare for fiber to be deployed all the way to the home or curb.

[6] Estimates of the costs for deploying FTTH range from $1,000 to $2,000 per home for 108 million residences in the U.S.

[7] That is, even though technically adequate capacity may exist to support all of the desired services, last-mile access will remain an economic "bottleneck."

based alternatives, then failure to ensure open access will pose a severe threat to competition in all of the upstream and downstream equipment and service markets that depend on access to a digital conduit between the home and wider-area network services.[8]

This paper examines the mix of technical, regulatory, and business strategy issues that arise if one contemplates implementing open access on next generation broadband platforms. Today, there are only limited examples of deployments of local infrastructure that could reasonably be classified as "next generation." A number of these have been undertaken by municipalities, and the only examples of open access over such infrastructure that we are aware of are associated with these municipal deployments. Consequently, our analysis draws on lessons learned from a series of case studies of municipal utilities that have decided to deploy broadband access infrastructure. The cases were selected to reflect a diversity of approaches to open access. Some provide only wholesale access (*e.g.,* the publicly-owned utility in Grant County, Washington, is required by state law to offer communication services on a wholesale-only basis); some provide no wholesale access (*e.g.,* the publicly-owned utility in Braintree, Massachusetts, does not resell access to its platform to any third parties); and some are in between (*e.g.,* the publicly-owned utility in Jackson, Tennessee, provides wholesale access for voice and data services, but not for video services). Only a few of these are deploying what might reasonably be considered "next gen" infrastructure (Grant County, yes; Braintree, no); however, we considered a wider sample of municipal deployments to enable us to more clearly discern what is related to the nature of the infrastructure (is it next generation?), the choice of open access policy (is it open because it is municipally owned?), and the role of public ownership (is the business model adopted an artifact of municipal ownership of the infrastructure?). Teasing apart these separate influences and issues is far from easy, but is aided by considering a mix of cases. Taken together, these case studies provide insight into the challenges and drivers for adopting an open access strategy.

Focusing on municipally-owned infrastructure to better understand the evolution of broadband access infrastructure and open access policies is interesting in several respects. First, as already noted, municipally-owned utilities reflect a diversity of open access strategies while sharing certain common features that may allow us to better focus on how they differ with respect to “open access.” Obviously, for a more complete understanding, it would be useful *also* to study the technology and business choices by investor-owned communication service providers with respect to open access (*e.g.,* AOL/Time Warner’s decision to support unaffiliated Internet Service Providers (ISPs) on their cable network or Verizon’s policies toward DSL resellers).[9]

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[8] These include all of the local and long distance telecommunication and data communication services that depend on a local access connection into the home; the media content and applications that are delivered via electronic communication networks; and the network and customer premise equipment that are used in the networks.

[9] Voluntary adoption of open access among investor-owned service providers is rare. For example, the provision of open access in the two cases cited has been driven by public policy: the FTC required Time

Second, focusing on municipally-owned utilities' "open access" policies is interesting in the context of the larger debate regarding the appropriate role for publicly-owned communications infrastructure. Inspired by fears of unfair or inefficient public-sector competition, a number of states have passed laws prohibiting (*e.g.,* Texas) or limiting (*e.g.,* Washington) public participation in communication services. To fully assess the merits of such legislation, it is necessary to understand the landscape of approaches being employed by municipalities. The fact that municipal utilities that offer telecommunication services typically have *not* adopted open access policies (*e.g.,* provide wholesale access to their networks for unaffiliated telecommunication service providers) suggests that such legislation – when it exists – is very important in influencing the utilities' strategies.

Third, while the share of communities served by municipally-owned telecommunication providers represents a tiny share of the U.S. population, municipal deployments represent a sizable share of the homes served by fiber optic access networks and by new fixed broadband wireless services (*e.g,* WiFi-based networks and precursors to WiMax).[10] Therefore, municipal deployments offer "early-adopter" insight into the technical and associated business strategies that are likely to characterize competition in next generation broadband platform services.

As already noted, the municipal telecom providers reflect an interesting diversity in open access approaches. Whether and how to provide open access is intimately bound up with the choice of technology and network architecture (*e.g,* active star or PON?); the choice of a business model (*e.g.,* which services are offered on a wholesale or retail basis?); and regulatory policy (*e.g.,* who is allowed to share the infrastructure and how are "wholesale" prices for access set?). For example, it appears easier to implement dynamic open access to video services provided over a fiber system that employs an active star rather than a broadband passive optical network (BPON) architecture with an RF video overlay.

The balance of this paper is organized into four sections. Section II defines more fully what we mean by open access to next generation broadband infrastructure, offering a taxonomy for considering some of the relevant choices and issues that arise. Section III provides a descriptive overview of what municipalities are doing with respect to open access in practice. In Section IV we highlight several of the tensions and challenges that

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Warner to open its cable modem networks as a condition of the merger with AOL; Verizon is constrained to provide a form of open access over DSL by FCC rules. The FCC's 2002 Video Competition Report found only two instances of a cable company voluntarily opening its network to competing ISPs (Stern, 2003).

Furthermore, it is worth noting that most of the largest investor-owned utilities operate over geographic areas that are much larger than the areas in which locally-owned infrastructure providers operate. This has important implications for business economics and strategy.

[10] There are about 2000 communities in the U.S. with municipally-owned electric power companies. Only a small share of these offer broadband Internet access, and very few non-municipal-electric companies appear to offer public telecommunications services. See, Gillett, Lehr, and O'sorio (2004), Vos (2004), and Alvarion (2004).

arise with respect to open access. This demonstrates the close connection and complex feedbacks that endogenously co-determine the choice of technology, the business model, and the regulatory framework. We find interesting causality running in multiple directions. For example, the technologies that are used impact business economics which in turn impact the type of competition that may be sustained, and hence the regulatory policy. At the same time, the regulatory legacy shapes the types of markets and institutions that exist, which influences how the future evolves. Finally, the businesses are strategic actors that seek to influence policy, and direct their R&D and technology investments to re-enforce their positions. Section IV concludes.

II. Open access to next generation broadband infrastructure

In this section, we present a taxonomy of open access for next generation broadband infrastructure. The focus of the analysis here is not on the cost/benefit calculus associated with providing enhanced broadband access infrastructure, or in engaging the debate as to the appropriate amount of bandwidth to provide to each home or the best architecture for deploying broadband infrastructure. Rather, we take as a starting point the assumption that such infrastructure *will be* deployed and *will need* to be shared. We then examine the different challenges that arise if one considers getting from where we are today to such a world, what such a world might look like, and the different senses in which the infrastructure might be shared or "open.".

To make this somewhat more concrete, we start by describing in a bit more detail what next generation infrastructure might look like to clarify how it would differ from the current generation of broadband services (so-called "first generation broadband") characterized by today's DSL and cable modem services. And, we suggest why it is at least plausible that access to such infrastructure might have to be shared – that is, that open access may remain an issue in the future.

We then provide some theoretical context for understanding what we mean by ensuring "open access" both from the perspective of industry structure and from the customer's perspective. We then provide a brief discussion of regulatory approaches to promoting open access. This is followed by a discussion of a layered-taxonomy of technical/market/business approaches for supporting open access.

A. What is “Next Generation Broadband Infrastructure”

There are a number of technologies and architectures that may be used to deploy next generation broadband infrastructure (wired or wireless), however to qualify as "next generation" -- as we define it here -- the infrastructure should be able to support multimedia voice telephony, broadband data (at rates in excess of 10 Mbps per household), and multichannel video distribution. This is likely to require 50 Mbps or more per household.

The “next generation” infrastructure is distinguished from the current generation of services provided by local cable television or telephone companies which offer broadband data at rates that are typically significantly below 10Mbps and do not (generally) support all three services (*i.e.,* no video for telecoms, no telephony for cable companies). Of course, both types of carriers are in the process of upgrading their networks to address these issues.

In many cases, fiber optic cables are a critical component in the next generation infrastructure. Fiber optic cables are long-lived and costly to install. Because of the high and largely fixed/sunk costs of local fiber facilities, and the very high transmission rates they support, it may be desirable for multiple service providers to share access to local fiber facilities.[11] This may be necessary either if neighborhood fiber proves to be a natural monopoly, or adequately robust retail-level facilities-based competition proves unsustainable.

Upgrading to "next generation" local access networks will require substantial new investment, and the choice of technology will be heavily influenced by local conditions (*e.g.* terrain and outside plant construction cost factors) and the condition of legacy infrastructure (*i.e.,* telephone and cable television infrastructure in-place). Even if one abstracts from strategic effects (*e.g.,* is it a telephone company or a cable company whose plant is being upgraded?), the choice of technology and architecture are likely to be different if it is a greenfield v. rebuild v. overbuild situation (e.g., new sub-division v. upgrading monopoly legacy plant v. new entry in neighborhood already served by incumbent provider).

Additionally, strategic factors will also prove important. A desire to shape future competitive or regulatory conditions may influence technical and architectural choices. For example, as already noted, it is more difficult to implement full open access on some architectures than on others. A carrier may seek to pre-empt future open access by their choice of last-mile architecture.[12]

B. What is Open Access

Today, last-mile access networks comprise a technical *and* economic bottleneck. After being upgraded, "next generation" networks should no longer present a technical bottleneck that limits the range of service bundles that may be supported. However, if there are not a suitable number of facilities-based alternative access networks serving each home, these may still comprise an economic bottleneck. In economic terms, a "bottleneck facility" is an essential input for production of some service or good for which there is no economically (or technically) viable alternative source of supply.[13]

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[11] Until the 1990s, this was the common practice for undersea transport facilities. Consortia of companies collectively paid for and owned the undersea cables, with indefatigable rights to use (IRUs) point-to-point transmission channels on the cables. In the 1990s, a number of companies installed competing cables, vastly expanding the supply of undersea transport capacity, undermining the traditional cartel, and leading to a precipitous decline in prices.

[12] Banerjee and Sirbu (2005).

[13] See, for example, OECD (1996) for a definition of the essential facilities doctrine in a number of countries, under which access may be ordered to bottleneck facilities. See Lemley and Lessig (2001),

In its most abstract form, open access allows multiple downstream competitors to share a bottleneck facility that is a critical input for the services that are provided. In most cases, the bottleneck facility is owned by one of the firms that also competes in the downstream market. The access is open if it is sufficiently non-discriminatory that all competitors can access the bottleneck facility under equivalent cost and quality terms.[14] This ensures that if the bottleneck provider competes downstream, that it does not realize a significant competitive advantage by virtue of its ownership of the facility.

A shared municipal infrastructure removes the barrier to entry represented by the high fixed costs of outside plant deployment. Nevertheless, each retailer will also have some fixed costs associated with providing service. An ISP retailer will need to invest in servers (email, DHCP) as well as middle mile transport; a video service provider needs a headend, contracts with content providers, operations support and billing systems, etc. The size of these investments imply a minimum market size for retailer viability, and thus a limit on the number of retailers sustainable over a given infrastructure. AT&T is quoted as saying that it needs a minimum market of over 100,000 households to justify its investment as a Utopia retailer. The municipality can reduce these service specific investments by investing in additional capital plant to be shared by competing service suppliers, as Grant County has done by building a shared video headend and by selling ISP's transit over its NOANet investment.

From the customer's perspective, there is effective open access if an end-customer can elect to receive service from multiple service providers offering services that could reasonably be considered substitutes[15] which are provided over a common last-mile infrastructure platform; and if the customer's range of choice is not unduly constrained by the inability of competitors to obtain access services. We explore the customer's perspective more fully below.

In practice, it will be necessary to determine how many and what kind of choices are sufficient.[16] For example, are two to three choices enough, or should it be some larger number? Should customers be able to choose among bundles, or perhaps, different service providers for each service? How dynamic should choice be? For example, should

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Hausman, Sidak and Singer (2001), Bittlingmayer and Hazlett (2002), or Bar *et al.* (2000) for earlier discussions of the case for open access for broadband access, as it applies to cable and telecom facilities infrastructure.

[14] There is some divergence of opinion as to whether access terms need to be equivalent. Some might argue that access is "open" to carrier X if access to the bottleneck facility is available under terms and quality that do not make it uneconomic (although perhaps less profitable) for X to offer the desired service. We adhere to the stricter and less ambiguous notion of equivalent access here.

[15] That is, in the "same market" as an economist would define it.

[16] There may be technical or economic (minimum efficient scale) constraints that limit the number of effective retail competitors. How many is enough may vary from service to service, and market to market. For example, in an earlier era, policymakers debated the viability of sustaining a fourth or fifth national over-the-air television broadcast network; and today, policymakers are debating whether it is viable to sustain more than four mobile service operators.

customers be able to choose video programming on a yearly, monthly, or program-by-program basis? Should the access be dynamically flexible (*e.g.*, video-on-demand)?

C. Regulatory Approaches to Promoting Open Access

The motivation for seeking to promote open access is to facilitate increased competition in the markets that make use of the bottleneck facility. Ensuring that access to the facility is (1) non-discriminatory; and (2) priced at economic cost protects competition and end-users in downstream markets from potential abuse of the market power arising from the monopolization of the essential facilities. The bottleneck owner may seek to exploit its market power either by setting a monopoly price for access, or by discriminating among downstream competitors to leverage its market power into downstream markets.[17] The incentives to engage in such discrimination or monopoly leveraging is greater if the bottleneck owner also competes in downstream markets. Both discrimination and pricing access above cost distort investment incentives in downstream markets which can bias the direction of technical change inefficiently. Because the bottleneck facility is, by definition, an essential input to the production of downstream goods and services, if unconstrained, the bottleneck provider can use its monopoly power to extract whatever surplus is generated in those markets. The threat of such expropriation provides an *ex ante* deterrent to investment in complementary goods and services that depend on the bottleneck facility.

In response to the threat to downstream competition and the efficient operation of downstream markets, policymakers may mandate "open access" rules to regulate access to the bottleneck facility. Such rules may take a variety of forms. At one extreme, policymakers may rely on voluntary open access, under which the bottleneck owner is free to set the terms and conditions for access to the facility. If access terms are unconstrained, the bottleneck facility operator may be content to extract all potential monopoly rents by pricing access at the monopoly level, while relying on effective competition in downstream markets to ensure that all excess rents are captured by the monopolist.[18] If demand for the bottleneck facility is sufficiently inelastic, such monopoly pricing transfers surplus to the bottleneck owner but does not otherwise distort behavior. Policymakers may determine that the cost of regulating open access is greater than any inefficiency that might be avoided. Alternatively, policymakers may be able to induce "voluntary" open access by threatening the bottleneck provider with sanctions of various forms (*e.g*, ordering divestiture or withholding approval for a merger).

More generally, policymakers may seek to ameliorate the adverse impact of monopoly pricing or access discrimination by seeking to regulate the price and terms of access. Regulating the terms for access is necessary to render price regulation effective, because otherwise the price regulation provides an incentive for the bottleneck provider

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[17] For a discussion of incentives and strategies used by a vertically-integrated provider of a monopoly bottleneck facility, see, for example, Economides (1998), Beard, Kaserman, and Mayo (1999), King and Maddock (2001), or Vickers (1995).

[18] See, for example, Sibley and Weisman (1997).

to integrate into downstream markets and to provide discriminatory access in order to bypass the regulatory controls. At the other extreme, policymakers may regulate virtually every aspect of the bottleneck provider's business (what services it can offer, what investments it can make, what prices it can charge for its services, etc.). Public utility regulation of an investor-owned utility provides one model for how this might be accomplished; public-ownership of the bottleneck facility is another.

While there is a wide diversity of regulatory options for enforcing or promoting open access, three key elements include:

- Regulated pricing for wholesale access: absent some constraints on pricing, a bottleneck provider could price at monopoly levels, or if adverse to providing access to a particular provider, could price at a level that makes wholesale access uneconomic for the provider (*e.g.*, to foreclose entry into a market where the bottleneck provider also competes). Price regulation can take many forms ranging from traditional rate of return regulation to price cap to cost-based pricing.[19] The regulation may be direct as in the form of traditional utility rate setting cases, or indirect, as in regulatory approval of negotiated access agreements.

- Establishing the terms and conditions for how access will be provided. This includes defining the forms of wholesale access. The level of technical and business detail required here is often the subject of much dispute.[20] As is discussed further below (regarding layering), the choice of how access is provided is critical in influencing the industry structure and the choice of technology that is used to provide broadband infrastructure.

- Line of business restrictions which may (or may not) limit the range of activities that the wholesale provider of the bottleneck facilities may engage in. As noted earlier, the incentive to discriminate and the cost of regulating access are all greater if the bottleneck provider is vertically integrated into downstream markets. For this reason, access regulation often includes line-of-business restrictions that limit the range of markets in which the provider may

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[19] An example of the latter is the incremental cost-based pricing established for unbundled network elements (UNEs) under the Telecommunications Act of 1996. The cost standard was known as Total Element Long-run Incremental Cost (TELRIC), which was estimated from engineering cost models intended to approximate the forward-looking opportunity cost of incremental facilities.

[20] For example, when the ILECs and CLECs were initially negotiating their interconnection agreements which were to govern the terms under which the ILECs would provide wholesale access to the CLECs, the ILECs typically preferred quite general, relatively short specifications for access terms; whereas the CLECs sought much more detailed terms that carefully defined the precise terms in which access would be provided under each circumstance. This divergence in approach was wholly understandable because the ILECs did not want to provide access, and the CLECs, knowing that to be the case, anticipated having to litigate to enforce compliance and sought to expedite such litigation by providing a detailed record of the points which would be in dispute.

participate, or if allowed, restricts the modes of business organization that are allowed (*e.g.*, accounting separation).[21]

Each of these aspects has important business (*e.g.*, who is enabled to obtain wholesale access under the rules?), technical (*e.g.*, how is the open access provided?), and regulatory features (*e.g.*, what is the legislative/institutional framework for enforcement). These are discussed further below.

D. Open Access and Layering[22]

As noted above, the terms and conditions for how open access is provided have important implications for the industry structure that may be supported. Open access can be provided technically in several different ways, and at several different "layers" of the network architecture (see Table 1). As one moves up the layers, the facilities-based provider – in this case, the municipality -- is providing an increasingly sophisticated and "finished" communications service.

At the most basic level, the municipality can supply conduit and collocation facilities, and competitors can pull their own fiber strands and supply their own electronics. We will refer to this as open access at "Layer 0." This approach minimizes the municipalities' role and allows service providers the greatest degree of flexibility in the broadband access network they implement, but also increases the costs required to become a service provider and minimizes the extent to which infrastructure is shared. This, in turn, may limit the number of facilities-based service providers that will find it economical to compete in the market.

At a higher level of involvement, a community could adopt "Physical Layer" or, equivalently, "Layer 1" unbundling. This also leaves service providers a high degree of flexibility over the broadband network architectures and services that are implemented. For example, the community may deploy dark fiber and lease fiber strands to competitive providers. The community provides the physical infrastructure, but leaves the electronics and other higher-level service provisioning decisions to the service providers that lease the facilities. There are already active markets for dark fiber in local and long-haul transport markets. Such Layer 1 unbundling is analogous to when an ILEC leases copper strands as Unbundled Network Elements.

Layer 1 unbundling in a fiber network may also occur at the optical layer. In one model, each service provider transmits on its own wavelength and multiple suppliers are supported using Coarse Wavelength Division Multiplexing (CWDM). Alternatively, using Dense WDM, each user is served by a unique wavelength per user. Optical layer unbundling is consistent with Passive Optical Network (PON) designs (see Table 2 for a

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[21] See OECD (2001) for a survey of alternative structural remedies used in many OECD countries. See Hubbard and Lehr (2003) for a discussion of structural separation for next generation infrastructure and for cites to a variety of perspectives on this issue.

[22] For a more detailed discussion of open access in FTTH networks see Banerjee and Sirbu (2005).

simplified taxonomy of FTTH architectures). Wholesale services at the optical layer can be found in long haul markets, but have yet to be seen in the access market.[23]

With Layer 1 unbundling, the municipality is assuming responsibility for the longest-lived elements of the local access network: the physical outside plant structures and fiber cable facilities. Meanwhile, the electronics (hardware and software) elements of the network, which are subject to much more rapid economic depreciation, are selected by the service providers.[24]

Layer 1 unbundling reduces the level of capital investment, and especially sunk capital investment, required by a service provider, thereby hopefully reducing the economic barriers to entry in the market. On the other hand, it does require the municipality to assume important business functions as a communications facilities provider, making this substantively different from the minimalist approach implied by Layer 0 unbundling. For example, the municipality assumes responsibility for installing and maintaining the fiber network and outside structures or conduits. Also, the design and implementation of the Layer 1 physical network has important technical implications for how higher services are provided and does require service providers to make substantial complementary facilities-investments in order to deliver services. The higher are these investments that are potentially sunk or co-specialized, the fewer the number of service providers that are likely to be supported in the market.

The most common form of open access in practice (see Table 4 and further discussion below) is at the Data Link layer, or Layer 2. In this case, the infrastructure provider deploys both the fiber and the link layer electronics at either end. Service providers are offered a basic network service which they can use as a platform for delivering a bundle of retail-level services. This can be accomplished using a variety of architectures. For example, where the deployed link layer is based on a packet-based architecture such as Ethernet, each service provider and its associated customers are assigned to a separate Virtual Local Area Network (VLAN). If the operator is providing a link layer service based on Asynchronous Transfer Mode (ATM), than customers are assigned separate Permanent Virtual Circuits (PVCs) which are switched to the designated service provider. This is not unlike what happens in DSL networks today when an ILEC provides DSL service on a wholesale basis to an unaffiliated ISP via an ATM interface to the ISP. While providing the electronics for lighting the fiber, the operator might also provide what is normally viewed as a Layer 1 service: point-to-point circuits, for example using Synchronous Optical Network (SONET) Add/Drop Multiplexors (ADMs).

Finally, open access can occur at the network layer ("Layer 3"). Once again, this may be implemented in a number of ways. For example, in Hybrid Fiber-Coas (HFC)

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[23] See Mindel and Sirbu (2001b).

[24] Although there is also rapid technical progress in optical fiber and other outside plant infrastructure (*e.g.* antenna design, fiber installation technology), the presence of substantial sunk costs associated with installing physical infrastructure reduces the economic depreciation.

networks, the cable modem and cable modem termination system support an IP transport layer (*i.e.* IP Layer 3 service) over the cable. Policy based routers, or Multi-Protocol Label Switching (MPLS)-based Virtual Private Networks (VPNs) are used to separate traffic going to competing ISPs.[25] This is the technology that allows Time Warner cable to provide wholesale service to Earthlink and United as well as to affiliates AOL and Road Runner.

As noted above, the choice of layer at which open access is provided has important implications for the extent of the community's investment and role as a telecommunications service provider. It also influences how many service providers may be supported and what services they may offer. For example, some architectures deliver voice, video, and data services over separate networks implemented over the same physical plant (*e.g.*, video via an RF carrier, voice via circuits, and data in a packet overlay network). With a sufficiently robust (high-speed) IP transport service (Layer 3 unbundling), it is feasible to carry voice, video, and data as applications on top of the IP layer. However, issues like the level of bandwidth delivered to each home and in the shared transport channels in the back-haul network that provides wider-area connectivity will constrain the range of options that can be supported over such an IP Layer. The design of the underlying Layer 2 or 1 networks affect the quality of the Layer 3 network that can be supported. With some physical/network architectures, it may not be feasible to implement a suitably robust IP Layer 3 service to support comprehensive bundles of video, voice, and data services from multiple service providers.

The complex relationship between the choice of open access architecture and unbundling options is best demonstrated via reference to how video services may be unbundled over broadband platforms.

Video services to the subscriber may be provided in one of two ways. In HFC networks, and some PON networks, multiple broadcast channels are frequency division multiplexed to form a broadband (high-bandwidth) radio frequency (RF) signal, which is sent in analog form over a fiber. In an HFC system, this signal is detected at a neighborhood node, and sent the remaining way over coaxial cable to the subscriber's TV or set-top box. In a broadband PON (BPON) FTTH system, a wavelength separate from the data wavelength carries a similar RF multiplex, only the conversion takes place in an Optical Network Termination (ONT) unit on the side of the house. The coaxial cable is used only for in-home wiring. In both the HFC and BPON system, typically, there are not enough channels available on the video wavelength to allow multiple service providers to each send their own package of programming to this group of households.[26] Consequently, open access to video is inconsistent with HFC or BPON architectures.

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[25] Brayley (2003), Sonneson (2004), Flinsenberg and Sijben (2004).

[26] In the HFC or BPON, one or more 6 MHz RF channels may be used to carry digitally encoded video rather than an analog signal, allowing for up to 10 channels in the same bandwidth as a single analog channel. In both HFC and FTTH PON systems, the same optical carrier serves 32-500 households.

An alternative approach to video delivery sends switched video as part of the IP data stream. Only the video program(s) currently being watched is delivered to that household as part of the data stream. An upstream IP message from a settop box sends a request to the switch to deliver a requested video broadcast to the household. With this approach, video is just another form of IP traffic, and multiple video programmers can be accommodated as easily as multiple ISPs. Delivering video in the data stream can greatly increase the amount of data traffic per household. For example, an HDTV signal requires 10-18 Mbps; multiple TV (or DVR) households might easily consume 40-50 Mbps of continuous video transmission. Because Active Star networks typically deliver 100 Mbps Ethernet to the subscriber, open video systems are more often associated with Active Star architectures and always with IP video delivery. [27] Further, in order to minimize middle mile transport costs, switches and settop boxes must efficiently support multicast IP and the associated signaling protocols. Interoperability of settop boxes, switches and video headends for IP video delivery remains limited. Only in the last two years, with the rise of IP video delivery in Asia and Europe, have reliable, inexpensive, and interoperable products become widely available.

To sum up, therefore, the technical choice of how unbundling is implemented (at which layer in the network architecture) has important implications for allocation of costs and responsibilities between the municipality (the bottleneck provider) and the service providers, and for the range of services that can be offered by providers and the type of choice experienced by end-users. While Layer 3 unbundling appears to support the most dynamic range of customer choice and flexible service-level competition, it also requires the municipality to become a full-fledged facilities-based provider of finished wholesale telecommunications services and limits the scope of facilities-based competition.[28] Unbundling at lower layers reduces the municipalities investment and role, and expands options for facilities-based competition for those elements of the local infrastructure that are not "bottleneck" facilities. Identifying where the bottleneck is likely to be in a world of changing technologies, market demand, and industry structure is difficult and uncertain, which helps explain the diversity of approaches.

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[27] By encoding multiple digital video signals in each 6 MHz channel, it is possible to transport more channels than there are subscribers served on a wavelength. This would permit the assignment of at least one channel to each subscriber, allowing for switched video delivery over an HFC or BPON network. This is how VOD is delivered today on HFC networks. A switched rather than broadcast approach would allow for support of multiple video service providers even on HFC or BPON.

[28] That is, to the extent the sale of the bottleneck elements of the access infrastructure are sold in a bundle with other network elements (*e.g.,* network electronics, software, or customer premise equipment), this can distort incentives to invest in competing facilities.

III. Open Access in Practice

The preceding section provided a high-level and largely theoretical discussion of different approaches to open access. In this section, we summarize what we have learned from investigating a number of municipal deployments of last-mile infrastructure. Based on a series of interviews conducted in 2003-4 with representatives from municipal networks and 3rd-party service providers, and supplemented with secondary research sources, we conclude that there is no single definition of open access as it is offered in practice.

In response to varying legal requirements and choices of technology and business model, diverse arrangements have arisen between network operators and 3rd-party service providers. Table 3 summarizes the independent dimensions along which these arrangements vary, presented from the perspective of a network operator defining an open access offering. Table 4 summarizes examples of specific municipalities and their choices within this space; more detailed narrative descriptions of the open access situation in some of these communities can be found in the appendix. With the exception of Braintree MA, which was selected as a control, communities were included in the study because they provide some form of open access. In addition to the cases studied in some depth and listed in Table 2, we are also aware of open access deployments in progress in three Public Utility Districts in Washington (Clallam, Douglas, and Mason Counties) as well as in Provo, Utah.[29]

From Table 4, it is clear that the most common form of "open access" involves Layer 2 unbundling.

In the following sub-sections, we discuss several important ways in which municipal approaches differ (see Appendix 1[30] for additional information.). These include (1) the choice of services offered; (2) the partnership model; (3) diversity in pricing models; (4) responses to changing circumstances over time; and (5) open access beyond the last-mile.

1. Services

A municipality building a telecommunications infrastructure needs to make a number of inter-related decisions. These include deciding what services to offer and choosing a business model for offering those services. The business model will require

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[29] Because data does not appear to be collected on which communities do open access (no doubt partly because of the difficulty of defining the term), we cannot claim to have an exhaustive list. Our knowledge of communities with open access is derived from the list of municipal FTTH deployments provided by the FTTH Council (available at http://www.ftthcouncil.org/dbfiles/techexchange/2004%20-05-19%20OptFiberCommunList.pdf, and personal communications with Ron Lunt, Director of Broadband Services for the American Public Power Association (APPA) and attorney James Baller of the Baller Herbst Law Group.

[30] To simplify distribution of this paper, we have posted the Appendix as a separate attachment on the Web. Please see http://itc.mit.edu/itel/pp.html for the appendix.

choosing which customer classes to serve (residential, business, and/or local government), over what region (ubiquitously in the community or only in specific locations), and which services to offer at a wholesale (*e.g,* to unaffiliated service providers) and/or retail level.

The services that are offered may be different for residential and business customers. Residential services may include Internet access, telephony, and video (including both broadcast video and video-on-demand—VOD). Business services may include dark fiber leasing, point to point circuits (*e.g.* DS1 or OC3) or metro Ethernet.

The range of services or business model may be contrained by state legislation. For example, Public Utility Districts in Washington state may only provide wholesale services to retail service providers.[31]

Open access can be provided to any combination of supported services that the provider chooses (or is required by law to choose), and this choice determines the possible bundling strategies available to third party service providers. Which services to offer and whether to offer them on an open access basis are separable decisions. The decision of which technology to deploy, however, must necessarily be congruent with the choice of services and the business model.

2. Partnership Model

Open access models also vary along regulatory and business dimensions, as shown in Table 1's options for partnership between network operators and 3rd-party service providers. The value proposition for both parties is shaped by whether the operator is a pure wholesaler (analogous to structural separation) or also competes downstream (analogous to vertical integration with a retail affiliate); the level of control the operator exercises over service provider entry; and whether the operator collects revenues directly from customers, or indirectly through regulated or negotiated wholesale prices to service providers. A network operator may have a choice regarding some of these aspects, but state laws may determine others. For example, Washington directly restricts Public Utility Districts to providing wholesale-only services, while Utah imposes burdensome restrictions on municipalities unless they provide only wholesale services.[32]

The communities shown in Table 2 exhibit significant diversity along these dimensions, reflecting differences not only in state policies but also local historical and competitive realities. For example, in the late 1990's when Spencer, IA was developing its plans for a municipal communications utility, HFC was the most economically viable technology. Spencer did not even consider providing open access to video, nor could they have, given the limitations of HFC. They also chose to be the sole retailer of telephony services over the network. However, Spencer was already served by four dial-up ISPs at

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[31] Revised Code of Washington, 54.16.330 available at http://www.leg.wa.gov/RCW/index.cfm?fuseaction=section&section=54.16.330

[32] See APPA (2004) for further details regarding state restrictions on municipal communications.

the time. . The public decision process included a 1997 referendum, required by Iowa law before a feasibility study could be paid for, and a 1998 postcard campaign requested by Spencer Municipal Utilities (SMU) to show continued support once the system's costs were better understood. Both were very successful campaigns, in no small measure because the promise of 3rd-party access by the ISPs brought in its wake political support from the ISPs' customers for the more advanced underlying network.

Once the initial 3-year agreement with local ISPs had expired, however, SMU found itself in a changed competitive environment. The local investor-owned cable TV system had been upgraded to provide broadband by its new owner, an operator with a larger regional footprint. Facing a vertically integrated competitor who could bundle TV and ISP service and could subsidize aggressive price competition based on revenues from other communities, SMU entered the retail ISP business in competition with its partners in March 2004.[33] Representatives of both SMU and open access ISPs in Spencer observed that the ability to sell bundled packages of services was essential to the continued financial viability of the municipal data network. This case demonstrates the challenge of supporting open access in the presence of vertically integrated competition in one or more of the supported services.

The Grant County Public Utility District (PUD) in Washington was one of the first to build an open access FTTH system, a business model dictated, as noted above, by state law. Grant County selected an active star Ethernet architecture that allows them to provide separate VLANs to each service provider. Video and voice are both carried on the system as IP traffic. At the present time there are numerous ISP retailers but only two video and two voice service providers. While this approach offers a significant degree of "open access," it was also quite expensive (in part, because of issues with a "bleeding edge" technical platform) and the extent of voice and video competition does not appear overly robust. This is due, in part, to non-network-related factors associated with competition in video and voice services (*e.g.*, programming and customer-acquisition costs).[34]

Amsterdam has recently announced its intention to build a system with a unique business model. The city will deploy dark fiber. This in turn will be leased to a private provider, with exclusivity for the first ten years. This operator will in turn add electronics to create a layer 2 service which will be marketed on a wholesale basis to competitive Service Providers (SPs) (Figure 1). The city has left itself the option of allowing additional competitors at layer 2 after the initial period of exclusivity expires.

3. Pricing Open Access

Given the absence of regulation, municipalities have been free to adopt a wide variety of approaches to pricing their wholesale services. Some communities, such as

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[33] At the same time, SMU also began providing open access to its partners for business data services, which it had formerly reserved for itself.

[34] See further discussion below on importance of legacy issues on influencing extent of service competition.

Grant and Chelan Counties, have published tariffs; others treat wholesale pricing information as proprietary and require would-be retailers to sign non-disclosure agreements. Jackson Energy is currently negotiating a contract with one retailer based not on prices for specific wholesale services, but on a percentage of retail revenues.

The challenge facing the infrastructure provider is that most of the costs for deploying the infrastructure to a home do not depend on the volume of services offered over it. Shared feeder or central office costs, which may be traffic sensitive, are a relatively small portion of the average cost per subscriber. This has led to wholesale pricing schemes that reflect the small incremental burden that bundled services place on the infrastructure relative to standalone services. Thus, in Grant County[35], a wholesaler who provides telephone service only is charged $10/mo/subscriber line (at the 303 gateway). An ISP only is charged $15/mo/subscriber for 1 Mbps. However, a provider of both voice and ISP service pays the same $15/subscriber to offer ISP and one telephone line. This gives a significant advantage to a provider that offers both ISP and telephone service.

Reflecting the limited impact of traffic on costs, upgrading from 1Mbps/subscriber to 10Mbps plus a phone line increases costs to only $25/subscriber. 10Mbps is sufficient to provide IP video service, though a set-top box, headend, and content represent additional costs. The point is that a provider offering a triple play—and earning the revenues that represents—pays little more for the basic infrastructure than a service provider offering only Internet or only telephony.

Each subscriber served by a retail service provider will be assigned to the service provider's VLAN. The service provider will also need to purchase a high speed interface to the VLAN at the CO, or, pay additional fees for Internet transit, or, in the case of a video provider, for headend services.

4. Responses to Changing Circumstances over time

The communities studied here did not all start their projects at the same time, and the plans reflect changing industry and market dynamics, technological innovation, and experiences learned either from other communities or from earlier phases in the deployment. In some cases, municipalities have altered their views on open access in response to market realities. Kutztown, PA initially set out to build a wholesale-only, open access system. When they were unable to find service providers who were willing to provide retail service over their proposed FTTH network, they chose to provide service themselves. Jackson Energy Authority set out to build a closed system. However, when a lawsuit by a CLEC threatened to delay their financing at a time of rising interest rates, they agreed to settle the suit by allowing the CLEC to offer voice and ISP services over their network. Video service delivery remains closed. Jackson's EPlus network also illustrates diversity in the structure of customer relationships and financial flows: unlike ZippNet, where the retailers bill the end user and pay ZippNet for wholesale service,

[35] ZippNet tariff dated 8/01/03.

Jackson bills customers for EPlus along with its gas and electric services on a single bill, and forwards the revenue, less its wholesale charges, to the retailer.

Dial-up ISP service in the United States evolved under the constraints of Computer Inquiry 2, when "enhanced services" such as the Internet had to be offered by a separate, arms-length subsidiary acquiring basic telecommunications, such as incoming telephone lines, pursuant to tariff. Because the circuits were available through non-discriminatory tariffs, telephone companies exercised little control over who could get into the dial-up ISP business – as evidenced by the large number of companies that did. By the late 1990's there were more than 8,000 ISPs in the U.S.[36]

Not surprisingly given the laws of their states, Grant County in Washington and the Utopia initiative in Utah have the most open access. This is not surprising since the laws in these states prohibit the municipal providers from competing in downstream retail markets. This is in contrast to what happens with telecommunication services offered by the ILEC which is required to provide open access but also is permitted to compete in downstream markets. Interestingly, the municipal providers in Grant County and Utopia – unlike the ILECs – are not subject to price regulations regarding the wholesale prices they set for wholesale access. Instead, the wholesale price that the service provider pays is unregulated and voluntarily negotiated. Furthermore, because of the technical novelty and complexity of FTTH networks intended to carry IP services, the network operator has more control over what kind of service the 3rd-party provider gets. Early ISPs acquired simple telephone circuits and leased lines from the underlying carrier. Municipal wholesalers provide a much more complex service. The Ethernet VLANs offered by Grant County to service providers have different technical and service characteristics than the ATM PON PVCs offered in Chelan County.

The question of how much control the network operator exercises over entry by 3rd parties is still in a great deal of flux. At one extreme, Utopia tried to make a one-year exclusive agreement with AT&T to induce them to provide retail services, but the agreement was invalidated by the Utah legislature. At the other extreme, Spencer, IA simply provided access to all the dial-up ISPs in its community as well as a wireless ISP from a neighboring community that wished to expand into Spencer. In between, Tacoma puts ISPs through a "rigorous" qualification process before it allows them on its network, ending up with three providers. The fixed costs of setting up an ISP are small, and thus, not surprisingly, the greatest number of retailers is typically in the ISP services segment. Over Grant County's ZippNet, for example, there are 18 Internet SPs, 2 Video SPs, 2 voice SPs and one home alarm SP.[37] Until it was revised in July, 2004, ZippNet's wholesale price schedule favored SPs offering bundled services.

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[36] http://www.thelist.com

[37] http://www.gcpud.org/zipp/providers.htm, Visited August 28, 2004.

5. Beyond the Last Mile

Open access can also involve sharing of resources beyond the last-mile network. Voice and data services need to interconnect with the larger telephone and Internet networks, while video services depend on head end systems to collect programming for local distribution. As Table 2 shows, some communities have included sharing of such upstream resources as part of their open access arrangements.

For example, in Tacoma WA the municipal operator manages a backhaul link to nearby Seattle, and shares it with its 3rd-party ISPs. Backhaul to more remote areas is often a large enough challenge to require a cooperative approach among multiple communities. Grant County, located in rural eastern Washington, gets its backhaul from the Northwest Open Access Network, a regional fiber consortium of Public Utility Districts. In Spencer IA, each ISP arranges for its own backhaul, but both SMUNet and some of its 3rd-party ISPs get their traffic to Des Moines via Iowa Network Services, a statewide fiber consortium formed in the mid-1980s to provide equal access from rural telephone cooperatives to competing long-distance telephone companies.

Blacksburg VA provides an alternative model: while it does not provide a last-mile network, it does administer a neutral point of interconnection among local commercial providers, so that less backhaul capacity is needed. The regional approach to backhaul is built into the Utopia initiative, which aims to build interconnected FTTH networks in multiple (14 as of this writing) Utah cities and towns.

Grant County built its own video headend, and leases its use to retail video service providers. Because of the immature state of video IP technology when ZippNet began its deployment, the PUD believed that controlling the headend as well as the ONT and settop boxes would ensure interoperability. Moreover, a video headend represented a large fixed cost that acted as a barrier to entry for would-be service providers in its small market. By contrast, Utopia plans to leave all head end investment to private-sector operators. The difference in approaches may reflect timing; Grant County was one of the earliest adopters of IP video technology, and needed to seed the market for video over IP service providers. When I-Provo sought video SPs, it signed its first contract with a provider that got its start in Grant County.[38]

Finally, Grant County operates a VoIP gateway with a standard GR303 interface to a circuit switch. It is thus able to offer CLECs a virtual loop with a circuit interface, whereas the actual voice traffic travels as IP between the ONT and the gateway. They have even offered to provide wholesale softswitch services, but as yet there have been no takers.

[38] Gubbins (2004)

III. Challenges to Providing Open Access

Several themes emerge from our review of the open access experiments already underway. In this section we highlight preliminary lessons learned and identify challenges that arise in formulating or evaluating an open access strategy. These are organized loosely into issues that arise as a consequence of or are tied to the underlying technology and how that is evolving; those that are an element of or constrained by regulatory policy; or, are associated with the business/industry economics.

A. Technical Challenges

As noted previously, the decision to operate an open access network has implications for the type of technology deployed, and is different for different services. For example, with respect to data access, on an HFC architecture such as in Spencer, open access is provided at Layer 3 because of limitations in the standard technology used to support broadband cable modem services.[39] In contrast, in PON systems which are ATM-based[40] can provide open access at Layer 2 using ATM switching. Many of the Active Star products in the market are based on Ethernet, and thus separate service providers using VLANs. These can be implemented at either Layer 2 or Layer 3 relatively easily in a straightforward manner.

Providing open access for voice is more difficult. One approach is to provide a virtual loop to CLECs, similar to what might be provided to a CLEC by an ILEC. On an HFC system, loop service, until recently, would be provided using circuit-switched or TDM technology. Some FTTH products also break out loops to a TDM interface at the Central Office Optical Line Terminal (OLT), particularly those based on ATM at layer 2.

Other systems simply packetize speech using VoIP standards, and carry voice packets the same as data packets in the access network. This traffic can be converted back into TDM voice by a gateway in the central office, allowing traffic to be handed to a CLEC as though it came from conventional digital loop carrier equipment. Or the packet traffic can be routed directly to the CLEC in much the same way as data traffic is routed to an ISP. Signaling standards and lack of full interoperability of ONTs and softswitches make this a more problematic solution, though Jackson Energy is taking this approach with its EPlus network. Handing the traffic off in packet format, particularly if both caller and callee are on the same network, avoids the cost of two gateway conversions, and so is likely to become more common as standards and interoperability mature.

To the extent that the infrastructure provides low latency "best effort" ISP service, any third party, such as Vonage or ATT Callvantage, can propose to offer telephony service to an existing ISP customer, without the infrastructure provider being able to realize additional revenues when this happens. Thus, a decision to provide open access ISP service may be tantamount to opening voice service to competition as well. However,

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[39] Cable modem services are supported under the industry DOCSIS standard..

[40] That is, PON systems corresponding to the ITU G.983 standards.

when open access voice service is provided as part of the business model, CLECs may benefit from QoS capabilities that are only provided to voice service providers.[41]

As noted earlier, open access video is difficult to deliver in a PON network using a video overlay. Open access for video implies IP video, which in turn implies significantly higher average data rates per household. This has implications for the access network design. Eliminating a video overlay can save money in electro-optics, while raising costs for increased IP transport and switching. The additional data traffic has led open access video providers to prefer Active Star architectures because bandwidth per household growth can more easily be accommodated. We found no examples of open video access over an HFC plant or a PON plant using a video overlay wavelength.

B. Regulatory and market legacy influences open access

The choice of services that are unbundled also owes much to the legacy regulatory and market issues associated with each service. For example, there is legacy of open access for Internet (ISPs), and to a lesser extent for voice (which is different yet again for local and long distance telephone service), but only in a much more limited sense for video.[42] These differences are due in part to the legacy of how the infrastructure for supporting these services evolved. That is, "data" services were an application that shared the Public Switched Telephone Network (PSTN); "voice" telephone services were the principal focus of the PSTN; and "video" (television) services were delivered over separate broadcast over-the-air and, later, coaxial cable networks.[43] The services and the infrastructure were closely coupled, and opportunities for cross-service bundling were limited (*i.e.*, video on PSTN or voice on cable networks). Service-specific and "conduit" (network) specific regulation evolved in each case.

The PSTN was regulated under telecommunications service regulation that focused on the role of these networks as conduits for electronic communications. The core governing principle was common carriage law that imposes responsibilities on network service providers to not discriminate among network users. This common carriage tradition underlies the regulatory legacy for data and voice communication services. In contrast, video services delivered via over-the-air or cable television networks have been principally regulated as content services, where the relationship to the conduit (physical transport network) was not the principal focus of the regulation.

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[41] Cable MSOs who are providing both VoIP and Internet access—even when the latter is open access—limit the use of the DOCSIS standard QoS capabilities to their own voice offerings; they are not available to ISPs.

[42] As will be discussed further below, the principal open access rules for video (television) have focused on content-level regulation. Cable television networks, although heavily regulated, have not been subject to strong open access rules.

[43] Of course, the video broadcasters leased facilities from the PSTN providers for program distribution to their cable head-ends and over-the-air broadcasting stations.

In addition to these historical regulatory factors, there were additional legacy market issues associated with the type of community (*e.g.,* rural v. urban, level of economic development) and whether there was a municipally-owned power utility that affects the extent of and perceived justification for local or other government involvement in provisioning communication infrastructure services. These two are linked in that locally-owned power utilities are associated with two waves of development. The first was associated with municipal lighting companies that were established over a hundred years ago to provide street lighting in a number of early industrialized towns and cities (*e.g.,* Watson was a co-founder of the municipal utility in Braintree). These naturally evolved into electric power distribution companies. The second is associated with the post-Depression-era push for rural electrification and economic development that gave rise to rural electrical cooperatives and additional municipal electric power companies.[44]

As a consequence of these divergent legacies, it is not surprising that unbundling data services appears easiest and is most common. This is true, in part, because there is an existing industry of ISPs who can be counted as customers for a wholesale ISP service. The emergence of the ISP industry is due in part to the legacy of telephone regulation that precluded Incumbent Local Exchange Carriers (ILECs) from restricting ISPs from using dial-up voice circuits to support data traffic. Common Carriage rules and the Computer II decision constrained the ILECs ability to provide discriminatory access to basic telephone transport services.[45]

The emergence of a competitive ISP industry also benefited from the fact that mass market access was initially provided mostly over switched dial-up lines, the provision of which were subject to strong local retail rate and service regulations. This helped create a unified market with low entry costs for ISPs. The highest cost elements were associated with CPE or with the local access infrastructure. The former was under the responsibility of the end-user, while the latter was heavily regulated by PUCs and the FCC.

The promotion of open access in broadband services via telephone networks was initially supported at the logical layer by the Computer Inquiry 3 (1987) rules, and at the physical layer by the FCC's broad interpretation of the TA96's open access rules. The latter enabled the emergence of data-focused CLECs, or "DLECs" such as Rhythms Netconnections, Covad, and Northpoint which provided the infrastructure for emerging DSL broadband services provided over ILEC copper loops. This provided ISPs with a migration path that would not require them to integrate forward into ownership of the underlying data link or physical infrastructure in order to continue to survive in a broadband world.

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[44] For further discussion, see Osorio (2004).

[45] The Computer II (1980) decision required ILECs to provide Comparatively Efficient Interconnection (CEI) wholesale access to telecommunications services that are used to support. See Esbin (1998) for an excellent discussion of the evolution of FCC policy for regulating data services.

Legacy broadcast and cable regulation, as already noted, focused on the role of broadcasters as content providers rather than as conduit providers is quite different. The dominant video service has historically been television which was originally delivered via terrestrial over-the-air (advertiser-supported) broadcast networks. The focus of regulatory oversight for television has been on providing access to RF spectrum for broadcasting networks and on content regulation to ensure adequate programming diversity and to limit objectionable content (censorship). With the emergence of cable television subscription services, a third type of regulation was needed which blended aspects of traditional telephone (*e.g.*, retail rate regulation) with broadcast regulation.

In contrast to telephone regulation, television services have not been subject to significant facilities-level or "conduit" open access regulation. The open access rules that have existed have been associated with "content" regulations that were intended to promote programming diversity and access to content for alternative distribution media. Program access, "must carry," and media channel ownership restrictions were used to ensure open access to content.

With the emergence of cable modem broadband access to the Internet in the mid-1990s, and with AT&T's acquisition of national cable properties (subsequently divested to Comcast in 2002) and the AOL/Time-Warner merger, there was growing concern regarding the need for open access to cable television networks for data services.[46] Although this debate continues, strong open access rules analogous to what has been required for telephone infrastructure have not been mandated.

Additionally, with the growth of alternative distribution media channels in the form of the Internet and direct broadcast satellites (DBS), there has been increased pressure from the industry and from the FCC to relax media ownership rules that would have facilitated the further deregulation of broadcasting and content services. The progress of this trend, however, has been challenged recently by a reaction among the public and in Congress to protect media ownership diversity and to institute stronger content censorship rules, which may extend to the Internet.

With the transition to broadband, the regulatory situation becomes much more complex. The progress of technology makes it feasible today for each of the network platforms to offer similar services, bringing into collision the requirements and concerns of legacy service/network/industry-specific regulation. It is no longer feasible to neatly classify networks, services, or providers as broadcasters vs. cable television providers vs. telephone service providers.

The patchwork of conflicting and diverse regulatory frameworks is illustrated in Table 5, which identifies some of the complexity as it existed in 2001. For example, ILECs had been required to provide facilities-level unbundling of DSL services, but this is no longer required. Cable companies have not been required to unbundle modem service, but the regulatory debate over open cable access continues.

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[46] See, for example, Lemley and Lessig (2001).

Under Chairman Powell's leadership, the FCC has moved to roll back substantially the open access provisions of the TA96. The elimination of line-sharing for DSL was one example, and the FCC's Triennial Review Order ("TRO")[47] anticipated further reductions in UNE obligations, particularly for advanced FTTH networks, for which no unbundling obligation will be imposed. With the First Circuit's overturning of the FCC's TRO, further relaxations are anticipated in the remaining open access rules imposed on ILECs.

Thus, in the near-term at least, it looks like federal policy is moving toward further deregulation of both telephone and cable television local access infrastructure, and away from strong "open access" regulation.

At the state-level and local level, the regulatory picture is more mixed. For example, there is a growing trend towards municipal entry into telecommunication services, as noted earlier. States have adopted divergent policies towards such entry, with some passing legislation to prohibit it. A recent Supreme Court decision leaves this patchwork of divergent state rules intact, at least for now.[48] Whether states or local governments will seek to fill a perceived regulatory void or whether Congress or the FCC will move to preempt additional regulation of last-mile services remains to be determined.

Finally, the uncertain regulatory environment is further aggravated by the growth of Voice-over-IP (VoIP) services. With all types of carriers using IP-based transport to support portions of voice telephone calls and with the growing prominence of Internet-based telephone service providers like Vonage, VoIP services are once again acting as a forcing function for regulatory policy. With improvements in the underlying infrastructure and management of IP networks, it is increasingly feasible to offer VoIP services that have comparable quality to traditional fixed line services. As the services become more similar from a retail customer perspective, it becomes increasingly difficult to retain divergent regulatory treatment for voice telephony that varies based on the type of carrier or network over which a call is carried. The growth of VoIP presents its greatest challenge for intercarrier compensation schemes that set different regulatory rates – typically well-above economic costs – for access (*e.g.,* interstate vs. intrastrate, switched vs. special, interLATA vs. reciprocal compensation). These divergent rates are inconsistent with promoting effective competition and providing appropriate investment incentives for incumbent and new carriers.

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[47] See *In the matter of Review of the Section 251 Unbundling Obligations of Incumbent Local Exchange Carriers, Federal Communications Commission*, CC Docket No. 01-338, *Implementation of the Local Competition Provisions of the Telecommunications Act of 1996*, CC Docket No. 96-98, and *Deployment of Wireline Services Offering Advanced Telecommunications Capability*, CC Docket No. 98-147, "Report and Order and Order on Remand and Further Notice of Proposed Rulemaking," No. FCC 03-36, Released August 21, 2003 (the "Triennial Review Order," or "TRO").

[48] See *Nixon vs. Missouri Municipal League*, which ruled that the Telecommunications Act of 1996 did not pre-empt state laws of this kind which might restrict municipal entry; however, the Court did not address the merits of such laws.

The growth of VoIP helps drive industry convergence and increases the likelihood that, at a minimum, there will be duopoly competition between the incumbent cable and telephone companies, at least with respect to bundled (first-generation) broadband data and telephone services (local and long distance). While both incumbent telephone and cable carriers are continuing to expand access throughout their coverage areas to first-generation DSL and cable modem broadband services, and incumbent cable television companies appear to be moving rapidly to deploy telephony services (sometimes via VoIP and sometimes via other technologies), ILECs face a bigger challenge with respect to offering video services.[49] Delivering video services to homes over ILEC last-mile facilities that are comparable in scope and quality to what cable companies can currently do will require substantial new investment by ILECs.

If the ILECs make the necessary investments, it is unlikely that they would simply replicate the capabilities of existing cable companies. At the same time, the cable companies are continuing to invest and modify their network architectures to expand the range and quality of services they can deliver. As we noted earlier, it remains unclear how intense competition will be among whoever ends up building next generation networks.

Although the precise nature of future regulatory policy remains uncertain, it appears likely – and indeed desirable – that if open access regulation persists in the future that it will need to be more homogenous across access platforms. As the traditional technical, service, and industry classifications have eroded, so has the viability of retaining divergent regulatory treatment across the physical networks.

C. Voluntary Adoption of Open Access Remains Rare

We estimate that 250-300 communities in the U.S. operate a publicly owned network that offers communications services to the public,[50] while only about 25-30 of these offer or intend to offer some form of open access. In other words, around 90% of publicly owned communications systems in the U.S. are vertically integrated and closed to third parties for all the services they offer. The cases we have studied suggest that sustained open access is unlikely to emerge in the absence of regulations requiring it.

Communities have diverse reasons for making public investments in communications infrastructure. If the goal is to jump-start a transition to competition, an

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[49] One approach that has been considered would combine DBS and ILEC services. For example, in April 2002, SBC and Echostar announced a joint venture to market video programming (see, http://www.sbc.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=7500).

[50] Based on an annual survey conducted and validated by the American Public Power Association, 246 public power companies in the U.S. offered some form of communications service to the public as of December 2003; another 323 operate communications networks for their own internal purposes, such as automated monitoring and management of the electrical system; see Gillett, Lehr and Osorio (2004) for further discussion of this data. Systematic data does not appear to be collected about non-public-power deployments, but to the best of our knowledge, these are relatively rare. Utopia is one example, while Vos (2004) also lists 13 U.S. non-public-power communities offering wireless services to the public.

open access strategy may be adopted. The concern of many communities, however, may be less with competition than with getting any local investment at all into advanced communications capabilities, in support of (relatively short-term) economic development. Particularly if the local public utility has a long history of strong public support, open access may simply never be considered as an option. Competition in the last mile may also not seem as urgent if other parts of the value chain (e.g. middle-mile backhaul) are monopolistic bottlenecks as well.

It is conceivable that open access would become more prevalent among emerging municipal FTTH systems. As discussed above, FTTH encompasses a range of technical architectures, some of which make open access relatively easier to support. In addition, the large investments required to deploy all-fiber networks, and the network's ability to support a full range of services, raise political concerns about monopolization of the system and public sector investments competing unfairly with private. Both of these concerns can be addressed by adoption of an open access strategy in which the market in communications services is left to private sector competitors.

Given the nascent state of municipal FTTH, however, it is too early to judge whether open access will actually be more common in these communities. Most public FTTH deployments are still in the planning or early deployment stages, and as the stories of Kutztown PA, Spencer IA, and Jackson TN described above illustrate, eventual open access policies can differ from original intentions.

Not surprisingly, the communities with the most open forms of access are those in Utah and Washington, where state law requires (or essentially requires, in Utah) public operators to restrict themselves to a wholesale-only role. Our case studies suggest that these laws have been essential to holding the public operators to their originally stated intentions. Grant County WA, for example, struggled with lackluster performance from the one CLEC that originally opted to provide telephone service on their system, and if they had the choice would probably opt to provide this service themselves to make the overall system more successful. Utopia seemed to find it necessary to promise a year of exclusivity to AT&T in order to entice them to provide triple play services, but this agreement was invalidated by the state legislature. Iowa has no such law, which allowed Spencer's SMUNet to change its open access policy after several years to compete with its 3rd-party ISPs in retail services. This change in policy reflects a structural incentive that arose because SMU was already vertically integrated into all its other services, and faced serious competitive pressure from the local cable TV and broadband provider with bundled offerings that consumers preferred.

A key rationale for open access is to promote service competition where it would otherwise not be possible, because of natural monopoly in the underlying facilities. However, while it may be true that an all-fiber last-mile network is likely to be the only one in its community and have economic characteristics of natural monopoly, it is almost never the only network when one considers subsets of the supported services.[51] None of the U.S. communities in Table 2 has a triple-play competitor, but all of them have vertically integrated competitors in single services (telephony, cable television or consumer broadband ISP), and some in dual services (e.g. telephony and DSL, or cable TV and cable modem). As Spencer's story suggests, open access limits the flexibility of overall competitive response, for example in the face of bundled pricing for packages of services. Given that access costs per subscriber are relatively fixed and independent of the services carried, a viable wholesale pricing scheme may lead to such a large access cost that only retailers of bundled services can afford the fixed costs of access per subscriber. Alternatively, it may make more sense to sell access separately to the subscriber, leaving retailers to charge only the incremental cost of services. This is not unlike what is happening in the broadband market today where subscribers buy broadband ISP access and pay separately for VoIP or video delivery services over the connection. It has been alleged that open access may have the perverse consequence of making a next generation network financially unsustainable in the face of competition from older and less technically advanced, but vertically integrated, networks.[52] This would especially be true if customers do not find the technical advancements particularly compelling – a distinct possibility in the short term, since given the nature of network effects and the early adopter nature of municipalities *vis a vis* next generation infrastructure, the applications necessary to take advantage of these technical advancements will take some time to emerge.[53]

In this respect, state laws requiring open access may have been essential to seeding the market for advanced services and companies to provide them. Open access can only work if private companies find it in their interest to act as 3rd-party service providers, and as the discussion in the previous paragraph suggests, the competitive viability of the open access arrangement may be enhanced if those companies take innovative advantage of what next generation infrastructure has to offer. For example, Kutztown PA faced no legal requirement for open access. When the national vertically-integrated service providers that serve Kutztown had no interest in acting as 3rd-party service providers, and other providers declined to antagonize large competitors over such a small market, Kutztown simply elected to provide video and data services themselves, while trying harder (and this time succeeding) to find a 3rd-party telephony provider, given the barriers imposed by state licensing rules for CLECs. In contrast, Grant County WA, because of its legal requirement to provide open access in all services, went to some lengths to enable the emergence of a video-over-IP service provider (the Video Internet Broadcasting Corp. or VIB.TV). This firm is now offering services in other communities

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[51] The entire U.S. has access to satellite-based cable television. Aside from Indian reservations, practically every U.S. community has a copper-based telephone network, many of which have been upgraded to support DSL, as well as access to mobile telephony. Most communities also have wired cable television, and a large fraction of those have been upgraded to support cable broadband. A few communities also have wireless broadband providers.

[52] In particular, this criticism has been leveled at Tacoma WA's Click! Network: see Tuerck *et al* (2001).

[53] Further research is needed to illuminate the dynamics and sustainability of competition between open access and vertically integrated providers under different demand scenarios.

as well, including Douglas County WA and Provo, UT, making it easier for them to successfully pursue open access approaches.

IV. Conclusions

Prospects for competitive access to next generation last-mile broadband network services remain uncertain. If facilities-based competition for broadband access turns out to be inadequate, then it seems likely that some kind of mandatory open access framework will be required. However, excess regulatory uncertainty or fear that the policies will be inappropriate can retard investment in next generation infrastructure. Fear that a bottleneck will persevere in the future and market power over the bottleneck may be leveraged into adjacent markets (*e.g.*, CPE, content, or enhanced services) may deter investment in complementary assets (*e.g.*, home networking, interactive media, or VoIP technologies). On the other hand, fear that regulators may implement open access in a way that denies the bottleneck carrier an opportunity to recover its economic costs (including earning a fair return on invested capital) may deter investment in bottleneck facilities. The stakes are high since a failure may preclude the emergence of effective competition and the realization of continued growth in broadband Internet infrastructure and services.

Our review of the issues demonstrates the high degree to which the policy debate is inherently multi-disciplinary and complex. There are a mix of technical, economic, and legacy business and regulatory factors that affect what type of open access is feasible and the cost-benefit assessment of these alternatives. Moreover, these are changing over time with technical progress, the growth of broadband Internet services and applications, and with the learning experiences from early adopters.

We see little evidence that open access would be adopted voluntarily, in the absence of a strong policy framework that encourages its adoption. Arguably, one might suppose that municipalities might be more inclined than investor-owned, profit-maximizing providers to adopt an open access policy, and yet we see few choosing such an approach. The few who have chosen it have been heavily influenced, if not fully constrained, by regulatory policy.

We also do not see wide support for mandatory open access policy at either the federal or state level. Although a number of states have considered mandating structural separation for ILECs, none has yet to do so. Additionally, a growing number of states have adopted legislation that limits or encumbers local government entry into communication services. At the federal level, the FCC appears poised for further deregulation of broadband services, with little appetite for imposing open access on cable television providers or of retaining UNE requirements for services used to support broadband access.

This would suggest that "open access" may be a policy with limited prospects for the future. However, we believe such a conclusion would be premature. The fact that implementing open access is difficult provides a sufficient reason for why it has lost favor among policymakers. On the other hand, the risks of failing to ensure open access if facilities-based competition fails to evolve successfully are potentially also quite large. Additional research into how open access might be effectively implemented and its implications for regulatory policy, technology, and industry structure enriches our understanding of industry economics and prepares for the eventuality where we may find ourselves needing to impose mandatory open access on next generation broadband infrastructure. The analysis presented here demonstrates the importance of past decisions regarding the choice of architecture, regulatory policy, and business models on the costs and success of open access policies. This provides a further justification for prospective analysis to reduce the costs of current and future regulations.

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VI. Tables

Table 1: Open Access and Layering

Layer:	Municipality provides…
0	Conduit and collocation facilities.
1 (Physical Layer Unbundling)	Dark fiber leasing, or perhaps, Optical Layer unbundling (CWDM or DWDM) in PONs
2 (Data Link Layer Unbundling)	Dark fiber and link-layer electronics at each end. For example, Ethernet-based VLAN, or ATM-based PVCs.
3 (Network Layer Unbundling)	Basic network service provided. For example, IP Layer 3 service over cable to support MPLS-based VPN.

Table 2: FTTH Technology Support for Service-Level Competition

Architecture	Description	What's Shared
HomeRun	Dedicated fiber per subscriber (direct connection between subscriber and meet point)	Meet point. Customer chooses how to use fiber and whom/what to connect to.
Active Star	Signals switched at node between user and meet point (e.g. Ethernet)	Between meet point and node.
Passive Star	Signal's power split at node between user and meet point (virtual bus architecture, e.g. FSAN/ATM PON)	Between meet point and user.
WDM PON	Evolving: Dedicated wavelength per … (service, provider, or subscriber)	Depends. Frequency unbundling, maybe.

Table 3: Open Access Decision Points for Network Operators

Open Access …	**Options**
…to which services?	• Voice: Telephone • Data: Internet access (i.e. consumer-oriented ISP services) • Data: Broadband transport (i.e. dark fiber, point-to-point circuits) • Video: Television, video on demand
…at what layer?	• Physical: Ducts, conduits, poles; Dark fibers; RF channels; Synchronous circuits • Data link: ATM PVCs, Ethernet VLANs • Network: VPNs
…with what partnership model for service providers?	• Network operator also competes in retail, or not? • What type of control does network operator exercise over identity and number of service providers? • Who bills customer / who pays whom, and on what basis? • Wholesale prices negotiated or regulated?
…to facilities beyond "last-mile" distribution?	• Voice and data: Shared middle-mile backhaul; shared VoIP Gateways; interconnection point(s) • Video: Shared head end

Table 4: Examples of Municipal Choices *vis a vis* Open Access

Community	Architecture	Services / Layers / Upstream				Partnership Model	VII. Comments
		Voice	Data (ISP)	Data (xport)	Video (TV)		
Braintree, MA (Braintree Electric Light Department)	HFC, 750MHz digital cable plant	Not offered	Closed	Closed	Closed	None	Open access not considered. Competes as second cable operator in community served by both investor-owned telco and cableco with broadband.
Spencer, IA (Spencer Municipal Utilities, SMUNet)	HFC	Closed	Open @ network layer. Independent backhaul for each ISP.	Closed until March 2004; now open	Closed	4 3rd-party ISPs. As of 2004, SMU also competes as retail ISP. For 3rd-party ISPs, customer pays separate charges for network & ISP service (though can be on one bill).	Original commitment to open access helped motivate ISP customers in referendum. 3-year agreement with ISPs, not renewed in face of bundled competition from vertically integrated cableco.
Ashland, OR (Ashland Fiber Network)	HFC/GigE	Not offered	Open @ network layer	Closed	Closed	8 “Certified” ISPs	
Tacoma, WA (Click! Network)	HFC	Not offered	Open @ network layer; Click! manages backhaul to Seattle, shared by ISPs	Closed	Closed	3 ISPs. Click! not a retail ISP. “Rigorous” RFP process for ISP selection. Customer pays ISP, who pays Click! negotiated price based on # customers at different bandwidth tiers.	Governed by Utility Board appointed by City Council. Utility management might prefer reduced managerial complexity and revenues associated with non-open access.
Grant County, WA (GCPUD/Zippnet?)	FTTH, active star with IP video	Open @ L2 (VLANs) shared gateway for CLECs	Open @L2 (VLANs) middle mile services via NOAANet	SONET and Ethernet services	Open @ L2 (VLANs); Provides shared head end for video providers,	wholesale model is mandated, but wholesale prices not regulated. 18 ISPs, 2 video, 2 voice, one alarm service	State law requires wholesale-only for PUDs.
Chelan County, WA PUD	FTTH PON	Open@L2	Open@L2	Dark fiber and leased	Not yet available	Wholesale model is mandated, prices are not regulated	

				circuits	Shared headend for video providers		
Kutztown, PA (Hometown Utilicom)	FTTH, Optical Solutions 2 fiber ATM PON	Open@L2	Closed	??	Closed	Customer pays Conestoga Telephone Co. who pays HU $7.50/8.50 per mo per residential/business customer	Wanted to but claimed could not find 3rd party willing to assume retail functions for data and video. Now that market proven, Conestoga interested in ISP but HU not.
Jackson, TN	FTTH Active Star+PON (Wave7 system)	Open L2	Open L2		Closed		Voluntary to settle CLEC law suit seeking access that was under appeal.
Taunton, MA	FTTH						Trial, being talked about for open access.
“Utopia,” UT (11 communities)	FTTH	Open L2	Open L2		Open L2	Retail service provision severely restricted by state law; wholesale-only models exempt (Utah HB 149) wholesale prices unregulated	Previous exclusive deal with AT&T was disallowed by State legislature.
Amsterdam, The Netherlands	FTTH	Open L1 & L2	Open L1 & L2		Open L1 & L2		Dark fiber leasing and initially an exclusive franchisee for L2 wholesale services, with potential for additional wholesale franchisees in future. Franchisee is also sales agent for dark fiber.
Stockholm, Sweden	FTTBuilding	Open L1	Open L1		Open L1		Carriers and municipality jointly own fiber and multiple carriers integrate L2 and above to offer competing services.
Pasco, Wa	Wi-Fi wireless		Open L2				

Table 5: U.S. Requirements for support of service-level competition (as of 2001)

		Type of Service		
		Voice	**Data**	**Video**
Type of Provider	**ILEC**	UNEs, collocation and resale (TA'96 §251c)	• UNEs, collocation and resale (TA'96 §251c) • Line sharing, DSL UNEs (FCC Report & Orders 3 & 4) • Separate subsidiary: not (merger conditions invalidated by courts; but, watch PA)	3 choices under TA'96 §302 • None ("cable"): just usual broadcast and programming rules • Hybrid: "open video" • VDT: "common carriage video"

	Incumbent cable operator	Allow access to rights of way, don't prohibit resale, etc. ("CLEC" rules: TA'96 §251b)	• Statutory: none
			• Court rulings: none
			  • ATT v. Portland: locality can't require, but FCC can
			  • MediaOne v. Broward County: open access violates 1st Amendment
			• Merger conditions
			  • AOL/TW: FTC consent decree (5 years)
			  • ATT/TCI/MediaOne: none
				None (1984, 92 cable acts; ineffective "leased access")

	Rural telco	None (TA'96 §251f exemptions pre-empt §251c)[54]	None (TA'96 §251f exemptions pre-empt §251c)	None
	Alternative facility provider	Allow access to rights of way, don't prohibit resale, etc. ("CLEC" rules: TA'96 §251b)	None	None
	Municipality (typically through electric utility)	Unclear whether even allowed (differing state laws, pending court cases)	None (although may be locally required, *de jure* or *de facto*)	None (although may be locally required, *de jure* or *de facto*)

[54] Cable-telephone cross-ownership restrictions are also lifted for rural telephone companies. We speculate that companies that are already allowed to provide both video and voice services might be more likely to offer integrated services over a future FTTH network.

Figure 1[55]

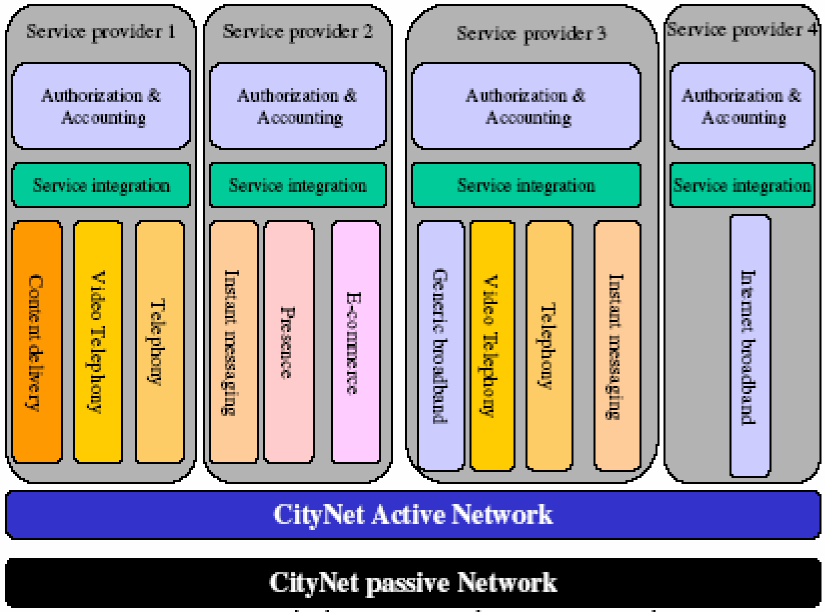

Figure 1. Multiple Service Providers on one network

[55] Sijben (2004)