Universities as Hubs for Next-Generation Networks

A model for universities to spur 21st century Internet access and innovation in their communities

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Summary

Based on a request for information (RFI)[1] submitted to The University Community Next Generation Innovation Project (Gig.U), the paper describes a model for universities to develop next generation broadband infrastructure in their communities. In our view universities can play a critical role in spurring next generation networks into their communities through use of their physical infrastructure to extend high-speed Internet access and sharing their expertise and resources to support engagement and participation by community members, businesses, and institutions. We propose a network model that integrates both high-capacity fiber deployments to community anchor institutions along with community-driven wireless mesh deployments, a device-as-infrastructure network architecture that operates using commonly available WiFi equipment, to create connectivity for local neighborhoods. The model enables universities and communities to 1) provide affordable, scalable broadband access to end-users; 2) empower and engage community members through a collaborative deployment process; and 3) create a sustainable ecosystem of connectivity to further drive community development. In addition to expanding next-generation high-speed Internet access, the model allows for the creation of a community-wide intranet to develop local applications and serve as a platform for community data collection and research to better understand challenges relating to mobility, health, safety, urban management, and education. The paper also provides recommendations for universities to engage and identify local stakeholders and needs, build and finance network infrastructure, and for engaging community members in the build-out of wireless mesh networks.

[1] Benjamin Lennett, Sarah Morris, Greta Byrum, Preston Rhea, "Gig.U Request For Information," New America Foundation, December 2, 2011, http://oti.newamerica.net/publications/resources/2011/gigu_request_for_information [accessed April 10, 2012].

Introduction

The U.S. is falling behind in technological innovation and broadband infrastructure. According to a September 2011 global download report from Pando Networks, the U.S. ranks 26th in the world in terms of average consumer download speed, with an average of 4.93 Mbps.[1] As comparison, South Korea ranked 1st in the report with an average speed of 17.62 Mbps.[2] Critics of such rankings often point out the unfairness of the comparisons to nations like South Korea, given that other nations' much higher population densities makes broadband deployment theoretically less costly. Yet even America's most densely populated cities lag behind their global peers.[3] As this gap continues to widen, it will present an increasing challenge to maintaining U.S. economic competitiveness and fostering digital innovations in healthcare, education, and government that require ubiquitous access to high-speed Internet communications.

Gig.U, the University Community Next Generation Innovation Project, was created to "accelerate the deployment of world-leading, next generation networks in the United States in a way that provides an opportunity to lead in the next generation of ultra high speed network services and applications"[4] Gig. U's model puts universities at the center of next generation networks.[5] Universities in particular require robust connectivity to ensure competitiveness in research and education as well as to increasingly facilitate collaborative research across the country and the world.[6] We also see universities as catalysts for the deployment of next generation communications infrastructure in their communities. Research shows a strong association of positive externalities with the presence of educational and cultural networks within a community.[7] Universities and their knowledge networks of researchers, faculty, and students create hubs of innovation and productivity at the center of regional and urban developments.[8] They serve as "catalysts for stimulating the spillover of technology, talent, and tolerance into the community,"[9] and provide a foundation for economic growth, as communities surrounding the universities become more attractive for individuals with new ideas and talents.[10] Because of the positive spillover effects of education for communities, it is essential to develop robust policies to drive the expansion of knowledge and innovation. These studies provide a strong argument that universities can and should play a significant role in fostering local economic development, innovation, and knowledge-sharing.

The paper begins with an introduction to next-generation networks and their impact on the community. It follows by highlighting two existing approaches currently utilized by university communities and providing an overview of our proposed network model for fiber and wireless mesh deployment. The paper then provides recommendations for universities to engage and identify local stakeholders and needs and how to collaboratively build and finance network infrastructure. Finally, it concludes with a detailed explanation of a community-driven process for deploying wireless mesh infrastructure.

Fostering Innovation and Economic Development through Next-Generation Community Networks

Many communities and local governments are creating foundations for economic development and innovation through investing in next-generation networks. High-speed Internet access has become a basic requirement for all businesses. As a recent report from the Commerce Department on U.S. competitiveness noted:

> Small and medium-sized enterprises (SMEs), in particular, have benefited from the Internet. SMEs with a strong web presence have been found to grow faster and export more than those that had minimal or

no presence. One survey found these firms also created more than twice the number of jobs as firms without an Internet presence, creating 2.6 jobs for each one eliminated.[11]

Investment in next-generation Internet connectivity has already substantially benefited the city of Santa Monica. The city extended its gigabit fiber infrastructure to commercial buildings over the past several years, offering service at a fraction of the cost of other providers, and spurring a cluster of film production firms to set up shop in the city.[12] Similarly, the communities of Chattanooga, Tennessee, and Lafayette, Louisiana, have also invested in gigabit network infrastructure[13], attracting new businesses and creating testbeds for new innovative applications in health-care and education.[14]

Beyond these leading cities, nationwide there remains a persistent "chicken-and-egg" problem, wherein communities ask providers to invest in higher-capacity infrastructure, and the providers reply that there is not a sufficient business case for expansion based upon the existing base of businesses, institutions or residents. Moreover, the problem extends more broadly to the business case in general for high-bandwidth Internet connections where providers argue that there is no broad consumer demand for substantially faster connections as few if any Internet applications require such levels of connectivity. Of course, if the vast majority of consumers have access to slower and more limited Internet connections, then such applications will likely never have the space to develop in the first place.

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Indeed, the recent announcements from Verizon and AT&T that they will stop deploying FiOS and U-Verse throughout the rest of the country[15] make it unlikely that there will be a rush of private providers willing to invest in next generation broadband networks except in the most lucrative markets. In many cases, the public sector may need to lead the private sector by developing its own broadband deployment solutions. For economically depressed communities and areas where a business case for private providers may not materialize without community-wide mobilization and investment, universities can play a more active role in communities by leveraging their technological expertise and, increasingly, access to world class communications infrastructure. Research networks such as Internet2 and National Lambda Rail currently facilitate broadband speeds up to 40 Gpbs and are scaling up to 100 Gpbs.[16] However, with a few exceptions use of the infrastructure has been limited to university campuses and has not benefited surrounding communities. As this paper demonstrates, universities can serve as primary anchor institutions offering both robust physical infrastructure that can be leveraged to extend high-speed Internet access into communities and the capacity to facilitate community engagement to foster local investment and participation.

Spurring Next-Generation Community Networks

Case Western Reserve University (CWRU) and the University of Illinois at Urbana-Champaign are two examples of universities spurring next generation connectivity in their communities. CWRU's focus has been on the gradual but deliberate deployment of fiber to the home, with additional city-driven deployment of wireless mesh network infrastructure into public areas on the university's campus and in downtown areas. Champaign-Urbana's deployment includes both fiber and wireless mesh, with its wireless mesh network (CUWiN) actually preceding the University's fiber rollout. Fiber deployment is currently underway as a result of a Broadband Technology Opportunities Program (BTOP) infrastructure award through a project called Urbana-Champaign Big Broadband or "UC2B."

Building on these examples and our work in the development of wireless mesh networks in communities, OTI provides a model and recommendations for universities to work in partnership with local governments, businesses, and community leaders to deploy fiber and wireless infrastructure to spur local economic development and connect city services. Our approach recommends the deployment of high-capacity fiber to community anchor institutions such as schools, libraries, and community centers ("CAIs"). The CAIs can then serve as points of presence ("POPs") for wireless mesh nodes to spread connectivity into surrounding communities. By incorporating wireless mesh architecture into existing and future fiber deployment, universities and their surrounding communities can leverage high-capacity fiber infrastructure deeper into neighborhoods to 1) provide affordable, scalable broadband access to end-users; 2) empower and engage community members through a collaborative deployment process; and 3) create a sustainable ecosystem of connectivity to further drive community development.

The **key objectives** of the approach include:

- Construction of a high-capacity, reliable fiber optic backbone network interconnecting university and municipal buildings with community anchor institutions (CAIs);
- Expansion of fiber connectivity through local government investment and public-private partnerships to enable high-capacity fiber connections as available infrastructure for low sunk-cost investments by competitive service providers in order to spur local economic development;
- Utilization of open-source mesh wireless technologies to create participant-driven neighborhood networks, provide low-cost Internet access to area residences and businesses, and to leverage fiber infrastructure deeper into communities;
- Support for community Intranet applications, including community data-gathering and storage services.

Overview of Network Model

Our approach recommends leveraging both fiber and wireless mesh infrastructure to create robust, next generation community networks. A high-capacity fiber backbone is essential to connecting government buildings, schools, libraries, and hospitals, as well as community anchor institutions and public housing. Fiber should be extended beyond the backbone to well-located community and commercial sites deeper into the community.

Open access to fiber build-out is critical to the success of a wireless mesh deployment and allows a multitude of public and private services to prosper using the infrastructure. Thus, any mechanism for building fiber to anchor institutions and other points of presence in communities should include an open access requirement that permits wireless nodes to interconnect with wired infrastructure at points along the network. If the wired portion of any broadband deployment is designed as a closed network without interconnection points, wireless build-out will be hampered by a lack of access to the infrastructure.

"When deployed in a community-driven, collaborative and participatory way, mesh wireless networking also provides a framework for community learning and is an effective option for spreading existing connectivity deeper into neighborhoods."

For example, UC2B's fiber rollout uses a "ringed" approach, with an initial deployment of two on-campus nodes that supply fiber connectivity to seven overlapping rings. Each ring in the network connects to both nodes, and each strand of fiber on a given ring can be connected to any strand on any ring in either node.[17] The rings encircle several neighborhoods with high-capacity fiber, connecting businesses, anchor institutions, and community residents. These ringed areas can then serve as foundations for wireless mesh networks, which in turn push connectivity outward into surrounding neighborhoods.

Once CAIs and other community buildings are connected with fiber, they can then also serve as points of presence for both wireless backhaul that provides point-to-point wireless connectivity to additional locations, and wireless mesh, which can be used to blanket neighborhoods with high-capacity connectivity spread via wireless devices. Mesh wireless is a device-as-infrastructure network architecture that operates using common standards such as 802.11n Wi-Fi on 2.4 GHz and 5GHz WiFi frequencies and modified but easily accessible hardware components. Using these components, users build the network out over time both by obtaining access to Internet connections and hosting nodes to create a more robust and scalable network. Wireless mesh can add exponential use value to fiber installed to the premises of CAIs. Mesh networking deployed over a high-bandwidth foundation ultimately turns the network into a platform for next-generation, high-speed wireless

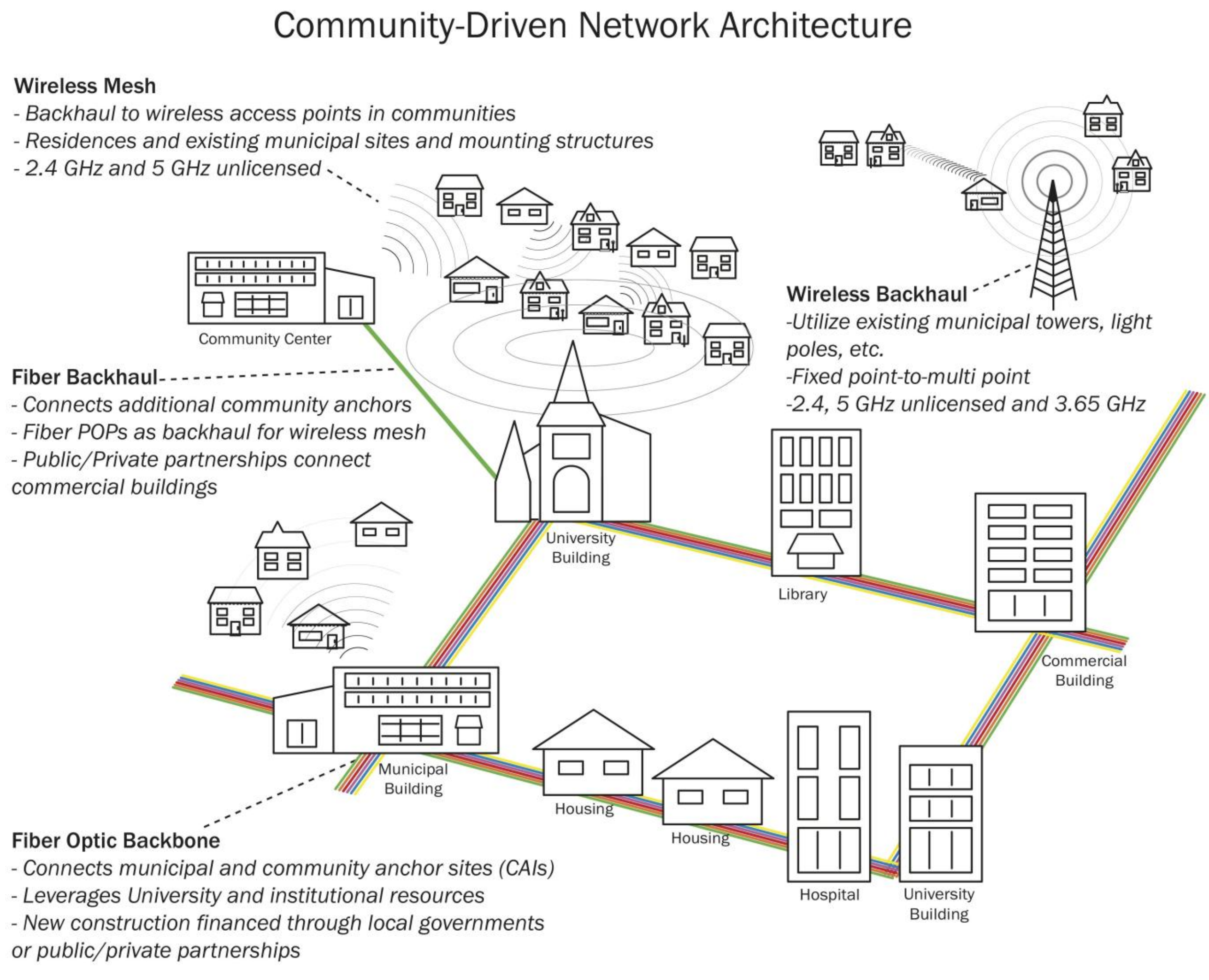

Figure 1: Example of Fiber and Mesh Wireless Network

communications.

When deployed in a community-driven, collaborative and participatory way [the process for which is explained in *Model Rollout Strategy for Wireless Mesh*, below], mesh wireless networking also provides a framework for community learning and is an effective option for spreading existing connectivity deeper into neighborhoods.[18] In addition, it enables municipalities and universities to share the benefits of fiber infrastructure with the broader community by leveraging buy-in from local residents. Studies have shown that without a sense of local ownership, well-intended attempts to bring new technology to communities may fail.[19] Mesh wireless creates this sense of ownership, as residents and local businesses contribute directly to the build-out and maintenance of the network.

Moreover, communities deploying wireless mesh technology can incorporate additional service offerings into their networks. Mesh facilitates the use of a community-wide intranet, allowing all users connected to the mesh to access content and applications from local schools, universities, libraries, religious establishments, social service agencies, local governments, and local anchor institutions.[20] To the extent that each of these components is also connected to the mesh, the intranet component of the network would be functional even without Internet backhaul connectivity, and might actually run faster than Internet connections. For example, CWRU included a local public services platform for education, health and wellness, public safety, and energy monitoring and conservation. These services include high-definition video conferencing and smart health applications available to each house in the network's Beta Block.[21]

In addition, wireless mesh allows users flexibility in how and where they access a network – as long as they are in range of an available node and have appropriate software installed on their device of choice, they can connect to the mesh.[22] Home installations can be as simple as using readily available and relatively inexpensive WiFi hardware. By installing a mesh router in their home, individuals are not only able to obtain access, but they also have the ability to expand the network by simply maintaining a mesh node.

Figure 2 depicts the various components of wireless mesh infrastructure and helps visualize how the install process for the home could interact with devices at other community buildings and the underlying fiber backbone. Municipalities and other community stakeholders can help expand the mesh by incorporating their own devices on various other buildings and structures. In addition to installing omnidirectional routers in and around anchor institutions and public spaces, adding point-to-point links atop high structures can make the wireless layer of the network more resilient and create faster connections between, for example, two anchor institutions several miles apart. If there are connectivity problems in an area, these links can help alleviate the problem until connectivity is restored. These links are also useful for connecting hospitals, schools and libraries directly to one another.

Community Engagement to Identify Stakeholders and Needs

Universities should pursue a community-driven, participatory planning process when extending connectivity into surrounding communities. Although this type of process may take longer than a private provider-led build-out, the end result is a more affordable, more resilient network that is beneficial for the local government, anchor institutions, residents, and business owners. A community-driven process fosters collaboration and leverages community-wide investment. Moreover, participants in a community-driven network ultimately become engaged stakeholders who have an interest in the way the network is built and used.[23]

Often, networks are constructed based on corporate business models and are heavily influenced by expected rates of return. While that system has financial advantages, it leaves behind many geographic areas and demographic populations that do not fit tightly into the model. As a result, it tends to deliver broadband on an "as (economically) demanded" rather "as (actually) needed" basis. Conversely, our approach seeks to also facilitate long-term systematic and comprehensive planning for fiber deployment, taking into account public-interest and public-goods considerations. By using an alternative model that closely examines community needs and relies on community stakeholders and buy-in to guide the planning process, the networks will be better suited to meet actual community needs and more effective in delivering robust but inexpensive broadband connectivity to a wide swath of residences and businesses. The wireless mesh component, relying much more heavily on direct community member participation for both planning and installation, allows long-range planning to nimbly adapt to needs at the hyper-local, neighborhood level.

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On a process level, the first step toward a community-driven build-out is beginning the process and identifying stakeholders and partners. The impetus for starting the process can stem from nearly any corner of the community, but for large-scale deployment, university and municipal participation from the beginning ensures that the

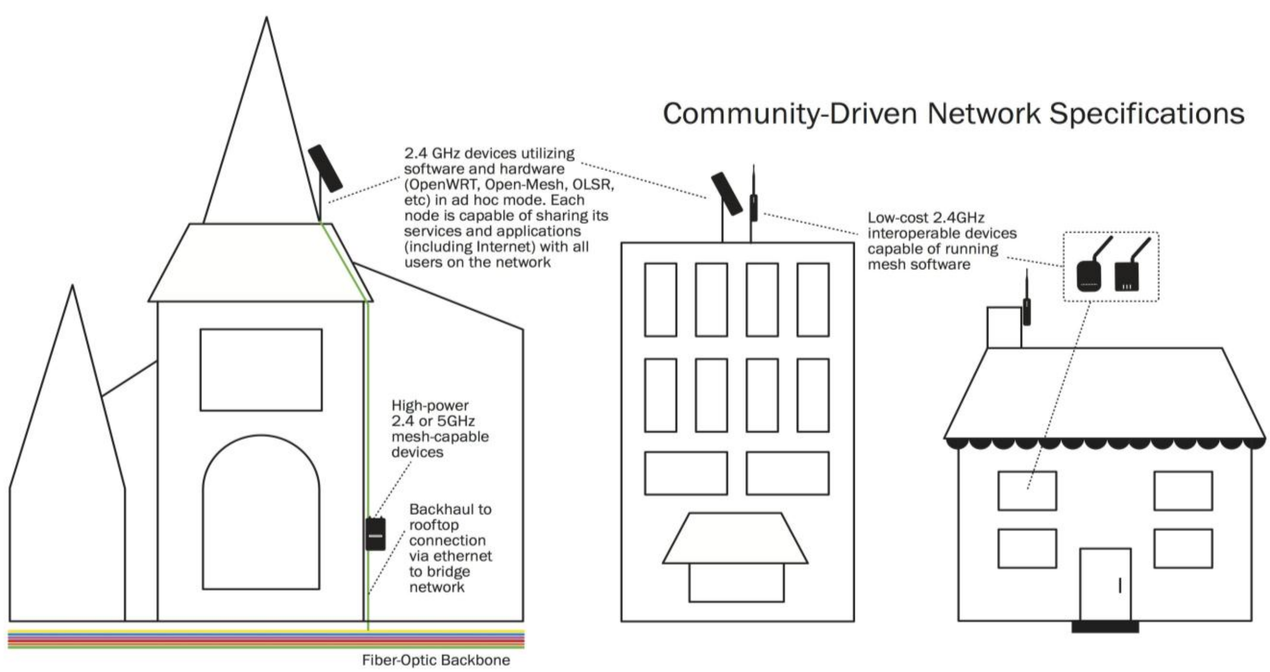

Figure 2: Community-Driven Network Specifications

community's largest broadband resources are identified and longer-term planning is conducted with community-wide assets in mind. Universities and municipalities may be best suited to define fiber expansion goals and establish funding streams for the installation of additional fiber where needed. However, fiber and wireless build-out in the community can and should occur concurrently, driven by goals identified by residents and community-based organizations. The community can begin to leverage even limited fiber resources to establish surrounding wireless networks, and those networks can be adapted or replaced by fiber infrastructure when it becomes feasible.

Stakeholder-driven meetings with working groups should be ongoing throughout the deployment process in order to coordinate the planning, finance, and execution of build-out, the maintenance and documentation of the network, and the development of applications. Stakeholder groups should also facilitate technology and media production training and distribution programs to enhance the community-based media ecosystem. Ongoing outreach efforts also allow stakeholders to ascertain how the network can be used and/or adjusted to add value to the work of municipalities, CAIs and universities. At the onset, pioneering community members should identify a collaborative team to facilitate the process. The team could include university, community, and municipal government representatives and should ideally include both members with technical backgrounds to provide support for installation and network maintenance, and members without technical backgrounds to ensure the network is designed to fit the community's existing social networks and goals.

We also recommend interagency cooperation at the municipal level to ensure maximization of public resources and comprehensive strategic planning. This cooperation could occur, for example, through resource sharing among public works, power, and transportation agencies, as well as through comprehensive asset mapping and coordinated planning in order to maximize returns on investment and minimize traffic and construction disruptions. In addition, municipalities that pool IT funds and leverage any existing dark fiber assets can very quickly achieve improvements in efficiency and savings. For all of these reasons, collaboration among municipal agencies is recommended. For municipalities that wish to deploy a city-run wireless mesh network like the one deployed in the CWRU project, there will need to be coordination for any wireless equipment installations on utility poles in the proposed coverage area. For the CWRU wireless network, for example, the wireless mesh network included 167 wireless transmitters mounted on utility poles and other public structures, which connect to OneCommunity's fiber-optic network, and also involved the installation of 15 transmitters, creating a 10-block wireless downtown network.

Incentive-based strategies emerging from local government can facilitate this cooperation, as multiple sets of stakeholders sharing capacities and resources can create greater efficiencies across a range of town and municipal initiatives. For example, the City of Philadelphia has developed a groundbreaking model for cooperative infrastructure development. Faced with aging sewer wastewater infrastructure that was flooding regularly -- and with a budget shortfall that precluded building a whole new sewer system -- last year the City approved a 25-year plan to integrate a comprehensive "green" infrastructure system to ease the burden on sewers citywide. The plan combines enforceable requirements for the replacement of non-porous surfaces with tax incentives and subsidies for "green" infrastructure elements at multiple scales. These include green roofs, porous pavements, roadside plantings, and pocket parks managed at various levels by City departments, businesses, community organizations, CAIs, and individuals. The Streets Department has begun building porous streets, and the Water Department is working on streamlining codes, ordinances, policies, and interagency procedures to resolve any barriers to implementation. Meanwhile, an outreach program run through schools, libraries, and with apps that use open data is helping residents learn how to contribute to the program. The result is a reduction of 80-90% of stormwater flowing through the City's system, a huge decrease in water pollution, and enormous infrastructure cost savings, in addition to a more educated and engaged public.[24]

Incentive-based collaboration in this model is a form of resource-sharing. Universities can offer resources in terms of human capital and research and development capacities, as well as infrastructure and service capacities, and can facilitate relationships with community anchor institutions. Municipalities have data and records on existing infrastructure and land use plans, as well as oversight of public utilities, rights-of-way, and municipal IT networks, and transportation departments, all of which must be coordinated for infrastructure build-out and mesh deployment. Communities can provide deep local knowledge and a base for economic and entrepreneurial activity, in addition to human capital.

Building and Financing the Network

In many cases, universities or communities have already invested in fiber infrastructure. Initial coordination among these stakeholders can identify fiber assets and guide future investments. Additional fiber build-out to businesses, government institutions and CAIs can be funded through a variety of means, such as:

- Bond financing through public works authorities
- Public/Private partnerships through business improvement districts
- IT funds pooled from city agencies

Multiple funding streams based on a broad range of partners can help fund the network and leverage multiple local, state, and federal funding sources of support. For example, a fiber network that connects community anchor institutions such as schools and libraries could potentially receive federal E-rate funding. Annual cost savings for local government communications could justify municipal investment in the network through a bond issue, which would then also create a revenue stream for the municipality as private providers lease infrastructure. A robust fiber network can also facilitate public/private partnerships to further support the network such as working with local businesses to fund the upfront building costs to connect commercial areas and buildings.

The municipal network developed by Santa Monica, California, noted above, is one example of successful community investment in fiber infrastructure. Santa Monica’s approach was unique in part because the build-out of its network occurred gradually, focusing first on serving communications needs of local governments and CAIs such as libraries and the local university and then extending over time by installing fiber whenever a road project occurred. The city further leveraged its fiber network to support local businesses by working with commercial buildings and property managers to cover the up-front costs of build-out to those locations. The Santa Monica City Net now offers up to 10 Gbps broadband service to at least 14 commercial buildings. Businesses in these buildings can choose from over 160 Internet Service Providers (“ISPs”), providing a range of services – including IP transit, virtual private networks, and cloud services – that are interconnected to the Santa Monica network internet exchange point in Los Angeles.[25]

Mesh Wireless

As discussed above, building fiber to community anchor institutions offers several key benefits. Equipped with fiber, community anchor institutions can serve as valuable, connected meeting places for the three overlapping groups of stakeholders we have discussed (municipalities, universities, and communities), as they also serve as gathering-places and hubs of social activity within communities. Moreover, using CAIs as access points has the potential to enhance broadband adoption and the development of a local business presence, as CAIs can amplify the community-building effects and local applications of mesh networking. CAIs that serve as hubs in the network can also provide spaces for face-to-face community engagement and skill-sharing sessions on digital literacy, digital entrepreneurship, and network-build-out and optimization processes.

Unlike traditional deployment models, where build-out is dependent upon a single entity, wireless mesh requires a certain level of responsibility on the individual participant – but, more importantly, it is driven by larger community collaboration. For example, universities can offer backhaul and interconnection to research and education networks. They can also contribute by sharing their technical knowledge and encouraging student groups and/or classes to assist with mesh deployment to foster skill-sharing and real-world learning labs along with network and application development. Municipalities can assist the deployment of the network by facilitating access to rights-of-way, towers, light poles, and other infrastructure. Moreover a variety of non-governmental community organizations can contribute to the network. Local businesses can supply and maintain network connections. Community groups (including school groups and hobbyists) can work with other partners to facilitate build-out or provide resources for underserved residents to organize their parts of the network.

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Most of the funding needed for build-out of the wireless mesh emerges in the initial phases of the process (laying fiber to CAIs and placing initial gateway routers on roofs and light poles). The expansion of a mesh network is incremental, as the equipment costs are minimal (and often user-financed), and most of the labor cost associated with build-out can be absorbed by CAIs and universities, which can treat the build-out activities as part of a "living lab" program to better understand community issues related to mobility, health, safety, urban management, education, etc. Indeed, by nature, this process allows investment in the wireless mesh to be performed by a variety of stakeholders in any number of configurations, with those stakeholders investing in as much or as little of the mesh infrastructure as is appropriate for the community. The local government could, for example, invest in some of the initial, higher-powered routers and related hardware on top of the CAIs and other POPs within the university community, or it could invest in all hardware costs up to the end-user's front door.

Hardware for wireless mesh networks is significantly less expensive than that for fiber. Network costs will vary as much as how those costs are allocated, given differences in geography, demographics, and other community needs. However, a rough estimate of equipment costs for the most powerful routers ranges from $1000-$2000 per location, for medium-distance routers from $400-$700 per location, and the cost per residence for routers is about $200 (which includes the router as well as additional mounting hardware).

Model Rollout Strategy for Mesh Wireless

Below we outline a model process for engaging community members and guiding network build-out, particularly for the wireless build-out process. Given the modularity and adaptability of the design, however, these process points should be read as a flexible guide with underlying principles that help ensure community engagement. Mesh build-out may include the attachment of gateway routers placed on lampposts and utility poles – ideally at least one per city block – in conjunction with the installation of omnidirectional wireless routers at CAIs. All routers in the mesh should conform to interoperability specifications and allow residents and businesses to use their own hardware to link to mesh gateways, making connectivity cost-effective and ultimately ubiquitous within the community. The successful build-out of a mesh network is best achieved through a step-by-step participatory process involving:

1. Community Outreach;
2. Participatory Network Planning;
3. Set-up of Initial Nodes;
4. Data-gathering, Surveying and Mapping;
5. Assessment of Data; and
6. Cyclical Repetition of the above steps as needed to increase mesh coverage and penetration throughout the community.

In the first stage of build-out, **community outreach** requires:

- Meeting with community groups and other stakeholders to ascertain needs and possible benefits of connectivity (which can be achieved through the administration of interviews, surveys, and meetings); and
- Identifying key sites for initial build-out (i.e. community anchor institutions, local businesses, or possibly the residences of community leaders).

In addition, the collaborative team should distribute information about the process and benefits of setting up a community mesh network in key sites as discussed at community meetings. Finally, the team should identify specific stakeholders from the community (i.e. neighborhood block captains) who can take leadership roles in hosting initial mesh nodes and speaking to other community members about the benefits of connectivity.

In the **participatory network planning** stage, the team should:

- Hold public meetings to facilitate design of networks (including placement of mesh nodes) according to local needs, assets, and challenges;
- Establish working groups – both for stakeholders with capacity to contribute to technical aspects of planning, build-out, maintenance, and expansion; and also for stakeholders with the capacity to contribute to social and civic aspects of planning, build-out, maintenance, and expansion;
- Direct the creation and distribution of databases to store and communicate information about the installation, hosting, and maintenance of network nodes, as well as to allocate responsibility for node ownership and maintenance among municipal agencies, universities, CAIs, and community members.

Next, the team should begin directing the **set-up of initial nodes** (Phase 2 in Figure 3, following the build-out of fiber to municipal and university buildings and CAIs in Phase 1). These installations are useful opportunities for skill-sharing among stakeholders and community members, and can be administered as work parties, service days, or other public events. Suggested locations for initial node installations include: universities; CAIs and municipal buildings (particularly where those locations include fiber connections); and homes, offices, and businesses of core community and university stakeholders who have volunteered to take leadership roles. In addition to site installations, ongoing trainings for working groups can help to ensure that community members are knowledgeable about, and integrated into, the process. Media production training can also be included at this stage to both document the current build-out process and provide a teaching mechanism for future deployments. Materials produced by the media production itself can also serve as a learning tool for those involved to analyze the process in greater depth.

Figure 3 illustrates in bird's eye view three phases of broadband deployment. The process begins at the community hubs – university and municipal buildings and CAIs – and moves farther into the community with both fiber and wireless expansion. Wireless mesh completes the phased build-out and helps saturate the community with connectivity. The diagram below highlights this phased approach from the street level and illustrates the interaction of components at various types of community buildings.

At this stage in deployment, users can begin to contribute to the development of best practices for mesh deployment. Open-source projects have user-focused documentation and online user forums for troubleshooting and development, features that are less likely to be available and less responsive for proprietary network designs.

Data-gathering is an important follow-up phase after a series of node installs. The stakeholder-driven

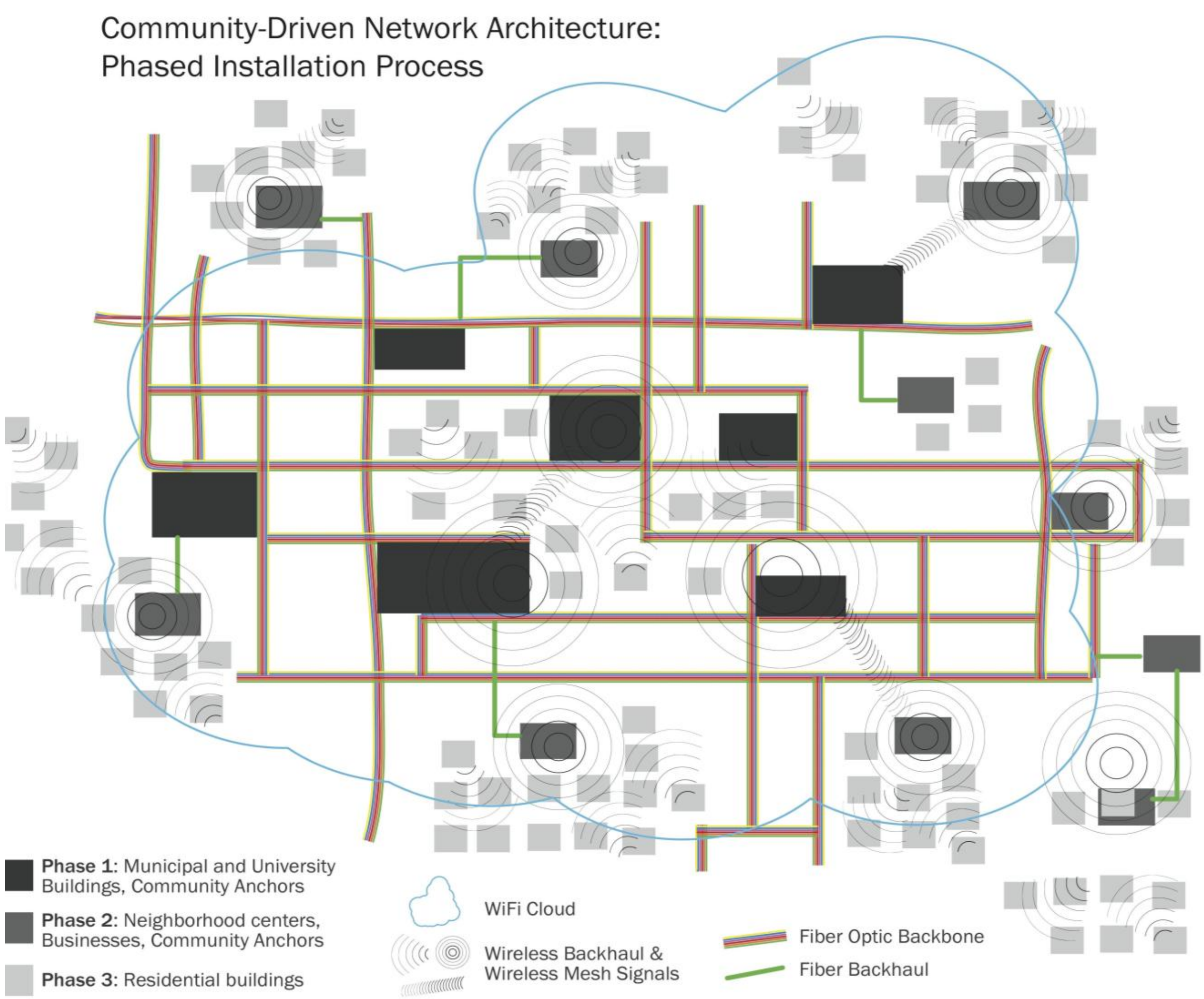

Figure 3: Community-Driven Network Architecture: Phased Installation Process

team can develop a rich record by mapping node sites, running anonymous statistical tests on the routers, estimating propagation areas for those nodes, and holding participatory network round-tables to discuss placement of future nodes. Media produced in previous stages and throughout can further augment data-gathering with qualitative information, and enhance the community-development process. At this stage, the team should also begin canvassing neighborhoods for future installations, presenting neighborhood residents with news and information as well as gathering information from residents interested in hosting future nodes. Data can also be used to better tailor the network for local needs and better functionality. Once data is gathered, the entire process should be repeated in order to expand penetration throughout the community. Phase 3 of deployment in Figure 4 portrays expansion of the mesh network beyond the initial nodes at CAIs into residential neighborhoods, where a concentration of smaller devices can facilitate connectivity.

Throughout the deployment process, ambient wireless interference on Wi-Fi spectrum should also be studied and considered by users, possibly through a spectrum analysis. Interference can be caused by a concentration of consumer electronic devices including Wi-Fi routers already widely used in many residences and businesses. Studying interference among these devices allows community stakeholders to adapt spacing of wireless routers and determine, for example, areas where fiber build-out could be

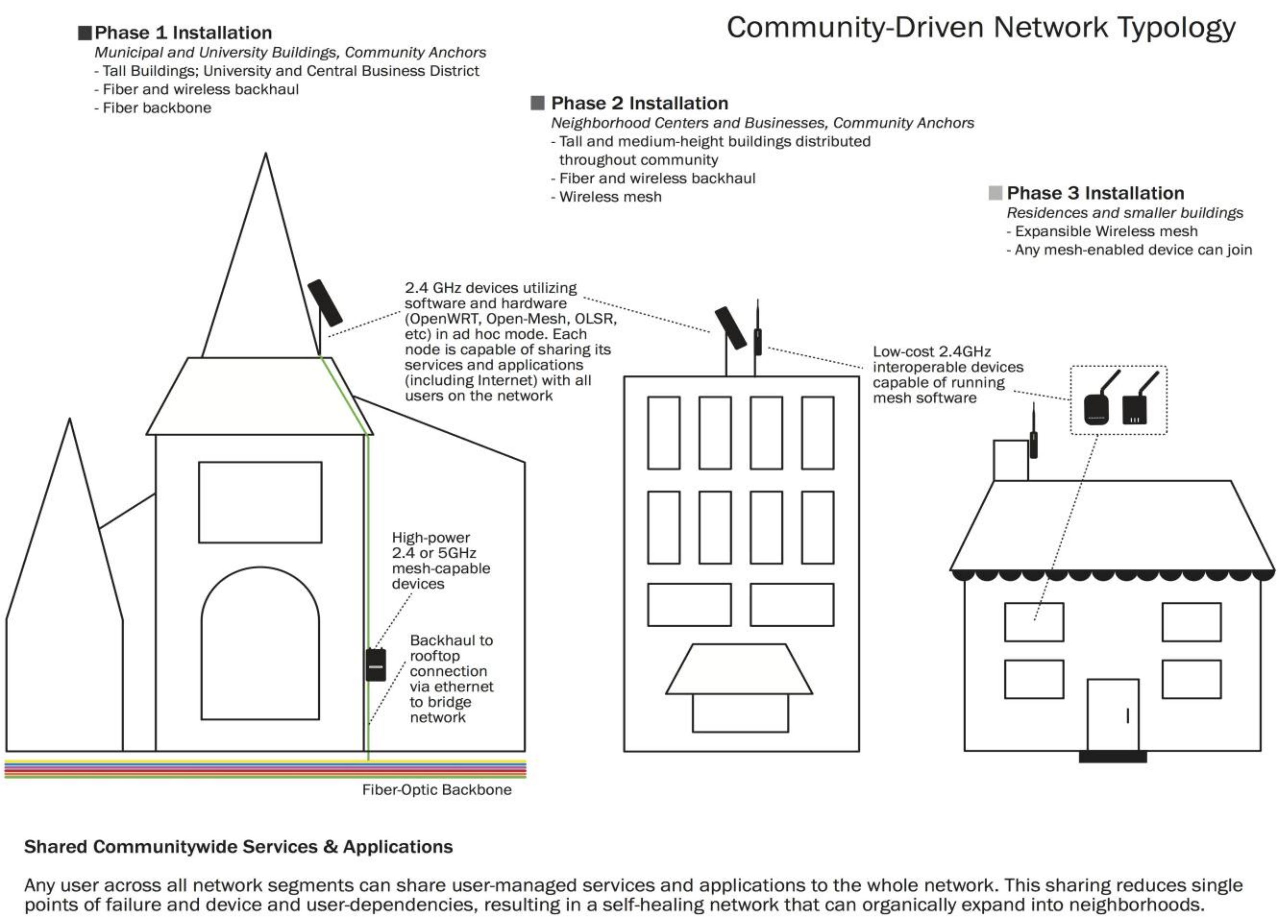

Figure 4: Community-Driven Network Typology

increased. Throughput and other network performance data can itself be shared and gathered over the mesh network.

There is also potential for neighborhoods to gather environmental and other information using the mesh to record data from sensors attached to the network, or from users sharing data via social media or crowdsourcing platforms. This "smart city" capability can improve a community's ability to plan for healthier and more transit-oriented communities.

Potential Challenges and Obstacles

Universities must be flexible in their approaches, maximizing local resources and investment, whether that is from local governments or private community groups and businesses. For example, various state and local regulations may create barriers to some aspects of the model proposed in this paper. Currently eighteen states have enacted some form of barrier to the establishment of municipally-owned networks, with additional restrictions on municipal networks pending in several states.[26] These barriers may take the form of outright bans, as is the case in Arizona, Missouri, Nebraska and Texas; or it may be that state laws serve as an effective de facto ban of municipal networks, where the state enacts significant barriers to municipal broadband deployment instead of barring them outright.[27] Universities wishing to integrate municipal networks into community build-out should make sure they understand any regulatory hurdles that may be in place in their state. Additionally, states and community anchor institutions will need to assess restrictions placed on broadband networks themselves, such as contractual clauses limiting the use of R&E networks to education and research purposes[28], or restrictions on networks subsidized by E-Rate funding, which include Children's Internet Protection Act ("CIPA") compliance and federal statutory requirements that limit the use of E-Rate funded networks for educational purposes.[29]

Careful planning of community deployment can mitigate some of these concerns, ensuring that available network resources are utilized in compliance with any network restrictions. However, communities may also wish to take the opportunity presented by community mobilization around this process to engage with local governments to ensure that state and local regulations reflect the needs of the community and facilitate widespread, efficient broadband build-out to anchor institutions, businesses, and residents.

Conclusion

Universities are well situated to spur the deployment of next generation networks in their communities. The paper proposes a model for universities to extend their infrastructure and expertise beyond the walls of their institutions and work collaboratively with municipal governments, local businesses, residents, and community institutions to spur ultra-high speed network services and applications. The key objectives of the approach include:

- Construction of a high-capacity, reliable fiber optic backbone network interconnecting university and municipal buildings with community anchor institutions (CAIs);
- Expansion of fiber connectivity through local government investment and public-private partnerships to enable high-capacity fiber connections as available infrastructure for low sunk-cost investments by competitive service providers in order to spur local economic development;
- Utilization of open-source mesh wireless technologies to create participant-driven neighborhood networks, provide low-cost Internet access to area residences and businesses, and to leverage fiber infrastructure deeper into communities;
- Support for community Intranet applications, including community data-gathering and storage services.

Through using both fiber and wireless mesh infrastructure the network model seeks not only to provide high-speed Internet access for community anchor institutions, small businesses, and residents but also facilitate the development of a community intranet for community data-gathering to better understand challenges relating to mobility, health, safety, urban management, and education. The paper recommends universities pursue a community-driven planning and network deployment approach that will encourage community members to become engaged stakeholders and create opportunities to leverage community-wide investment and resources.

References

[1] *Global Download Report* [Pando Networks, August 2011]: pg 3, quoted in Frederic Lardinois, "Report: U.S. Broadband Speeds Remain Slow, 26th in the World," SiliconFilter, September 20, 2011, http://siliconfilter.com/report-u-s-broadband-still-slow-ranks-26th-in-the-world [accessed April 11, 2012].

[2] Ibid.

[3] *See The State of the Internet*, Vol. 4, No. 3, [Akami Technolgoies, January 2012], http://www.akamai.com/stateoftheinternet/ [accessed April 10, 2012]. Only San Jose, CA ranked in the top ten in terms of average connection speeds.

[4] "Our Mission," Gig.U: The University Community Next Generation Innovation Project, http://www.gig-u.org/aboutus/our-mission [accessed April 10, 2012].

[5] "FAQs" Gig.U: The University Community Next Generation Innovation Project, http://www.gig-u.org/faqs [accessed April 10, 2012].

[6] Ibid.

[7] Richard Florida et al., *The University and the Creative Economy*, [Creative Class Group, 2006], http://creativeclass.com/rfcgdb/articles/University_andthe_Creative_Economy.pdf [accessed April 11, 2012]; Richard Florida and Maryann P. Feldman, "The Geographic Sources of Innovation: Technical Infrastructure and Project Innovation in the United States," *Annals of the Association of American Geographers*, 84, no. 2 (June 1994), pp. 210-229. *See also:* Joseph E. Stiglitz, "Knowledge as a Global Public Good," in *Global Public Goods: International Cooperation in the 21st Century*, edited by Inge Kaul, Isabelle Grunberg, Marc A. Stern [New York: Oxford University Press, 1999], pp. 308-325.

[8] Robert D. Atkinson, *Innovation in Cities and Innovation by Cities*, [The Information & Innovation Foundation, February 2012] http://www.itif.org/files/2012-innovation-in-cities-by-cities.pdf [accessed April 11, 2012].

[9] "About Us," Gig.U: The University Community Next Generation Innovation Project, http://www.gig-u.org/aboutus [accessed April 10, 2012].

[10] Julie Wagner and Mark Muro, "How Colleges Can Foster Development Zones," *The Atlantic Cities*, February 14, 2012 http://www.theatlanticcities.com/jobs-and-economy/2012/02/how-colleges-can-foster-development-zones/1209/ [accessed April 11, 2012].

[11] United States Department of Commerce in consultation with the National Economic Council, *The Competitiveness and Innovative Capacity of the United States*, January 2012, p. 5-2, http://www.commerce.gov/sites/default/files/documents/2012/january/competes_010511_0.pdf, [accessed April 11, 2012].

[12] Masha Zager, "Santa Monica City Net: How to Grow a Network," *Broadband Communities*, 32, no. 4 (May/June 2011), pp. 44-47. http://www.bbpmag.com/2011mags/mayjune11/BBC_MayJun11_SantaMonica.pdf [accessed April 11, 2012].

[13] Craig Settles, "Why Chattanooga's Broadband Represents Broadband's Future," GigaOM, May 29, 2011, http://gigaom.com/broadband/take-the-chattanooga-choo-choo-to-the-internets-future/ [accessed April 11, 2012]; Marguerite Reardon, "LaFayette, La. Finally Gets its Fiber Network," CNET, February 6, 2009, http://news.cnet.com/8301-11386_3-10158583-76.html [accessed April 11, 2012].

[14] David Talbot, "City With Superfast Internet Invites Innovators to Play," *Technology Review*, February 28, 2012, http://www.technologyreview.com/communications/39801/?p1=MstRcnt [accessed April 11, 2012].

[15] Karl Bode, "AT&T: The U-Verse Build is Over," DSLReports.com, February 9, 2012, http://www.dslreports.com/shownews/ATT-The-UVerse-Build-is-Over-118297 [accessed April 11, 2012].

[16] Bob Brown, "Internet2 Racing Ahead with 110G Ethernet Network," Network World, Alpha Doggs Blog entry posted Nov. 12, 2010, http://www.networkworld.com/community/blog/internet2-racing-ahead-100g-ethernet-network [accessed April 11, 2012]; "National LamdaRail Provides 100 Gigabit Connection for NOAA at Super Computing 2011," Business Wire, Nov. 15, 2011, http://www.businesswire.com/news/home/20111115005488/en/National-LambdaRail-100-Gigabit-Connection-NOAA-Supercomputing [accessed April 11, 2012].

[17] "UC2B's Multipurpose Fiber Rings Explained," Urbana Champaign Big Broadband, Aug. 17, 2010, http://uc2b.net/wp-content/uploads/2010/09/UC2B_Fiber_Rings.pdf [accessed April 11, 2012].

[18] Melissa Bell, "Community WiFi: It's a digital day for the neighborhood," *Washington* Post, March 30, 2012, http://www.washingtonpost.com/lifestyle/style/community-wifi-its-a-digital-day-for-the-neighborhood/2012/03/29/gIQAMIYZlS_story.html [accessed April 11, 2012].

[19] Darma Dailey et al., *Broadband Adoption in Low-Income Communities*, [Social Science Research Council, March 2010] http://www.ssrc.org/publications/view/1EB76F62-C720-DF11-9D32-001CC477EC70/ [accessed April 11, 2012].

[20] Laura Forlano et al., *From the Digital Divide to Digital Excellence*, [New America Foundation, February 2011], http://oti.newamerica.net/publications/policy/from_the_digital_divide_to_digital_excellence [accessed April 11, 2012]: pg 17; Sascha Meinrath and Victor Pickard, *The Rise of the Intranet Era: Media, Research and Policy in an Age of Communications*

Revolution, [New America Foundation, February, 2009], http://www.newamerica.net/publications/policy/rise_intranet_era [accessed April 10, 2011].

[21] "A Smarter Region One Neighborhood at a Time: University Circle Innovation Zone," Case Western University, http://www.case.edu/its/publication/documents/BetaBlockPublic030210.pdf [accessed April 11, 2012].

[22] *See* Joshua Breitbart and Ben Chodoroff, "A Community Wireless Mesh Prototype in Detroit, MI," New America Foundation, August 11, 2010, http://www.newamerica.net/publications/special/a_community_wireless_mesh_prototype_in_detroit_mi_34925 [accessed April 11, 2012].

[23] Laura Forlano et al., *From the Digital Divide to Digital Excellence*, [New America Foundation, February 2011], http://oti.newamerica.net/publications/policy/from_the_digital_divide_to_digital_excellence [accessed April 11, 2012], pp 21-23.

[24]Philadelphia's "Green City, Clean Waters" program is an example of how this model of local planning plays out. Driven by the Philadelphia Water District, it relies on project management at the city level in conjunction with deliberate, comprehensive assessments of the community's watershed problems, while recognizing that "there is a direct connection between all neighborhoods in Philedelphia, whether adjacent to or miles from the City's rivers and creeks, and their watersheds." Philadelphia Water Department, *Green City, Clean Waters*, June 2012, http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf [accessed April 11, 2012], pp 6-8.

[25] "Santa Monica Information Systems," City of Santa Monica, http://www.smgov.net/departments/isd/smcitynet.aspx [accessed April 11, 2012].

[26] Strict bans exist in Arizona, Missouri, Nebraska, and Texas; de facto bans exist in New York, Pennsylvania, and Virginia; and various barriers are also employed in Alabama, Colorado, Florida, Louisiana, Michigan, Minnesota, South Carolina, Tennessee, Utah, Washington, and Wisconsin. See Christopher Mitchell, "Barriers to Municipal Networks," *Broadband Communities*, 32, no. 4 (May/June 2011), pp. 58-59. http://www.bbpmag.com/2011mags/mayjune11/BBC_MayJun11_BarriersToNetworks.pdf [accessed April 11, 2012].

[27] Christopher Mitchell, *Breaking the Broadband Monopoly*, [Institute for Local Self-Reliance, May 2010]: pg 28, http://www.muninetworks.org/reports/breaking-broadband-monopoly [accessed April 10, 2012].

[28] E.g., "R&E Network AUP," NYSERNet, October 24, 2007, http://www.nysernet.org/policies/re_net_aup.pdf [accessed April 11, 2012].

[29] 47 U.S.C. § 254 (H)(1)(b) available at http://www.law.cornell.edu/uscode/html/uscode47/usc_sec_47_00000254----000-.html

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