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Community-Centered Wireless Infrastructure Networks

How cities can control their 5G future and close digital divides with software-defined networks, open technology, and shared spectrum

COMMISSIONED BY THE COMMUNITY WIRELESS COALITION

APRIL 2021

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Acknowledgements

This white paper was made possible through generous sponsorship from Sidewalk Infrastructure Partners. The authors wish to thank the many individuals and organizations who supported the development of the paper by contributing their time, expertise, and perspectives, including:

Jim Baller, Keller and Heckman

Josh Breitbart, Open Society Foundations

Caitlin Chambers and Leigh Whiting, Sidewalk Infrastructure Partners

Danny Fuchs and Erman Eruz, HR&A Advisors

Joanne Hovis, CTC Technology and Energy

Blair Levin, The Brookings Institution

Francella Ochillo, Next Century Cities

Howard Pfeffer, Internet2

Elizabeth Rosenblatt and Kyle McEneaney, Schmidt Futures

Angela Siefer, National Digital Inclusion Alliance

Mari Silbey, US Ignite

Deb Socia, The Enterprise Center

Katie Watson-Jordan, Internet Society

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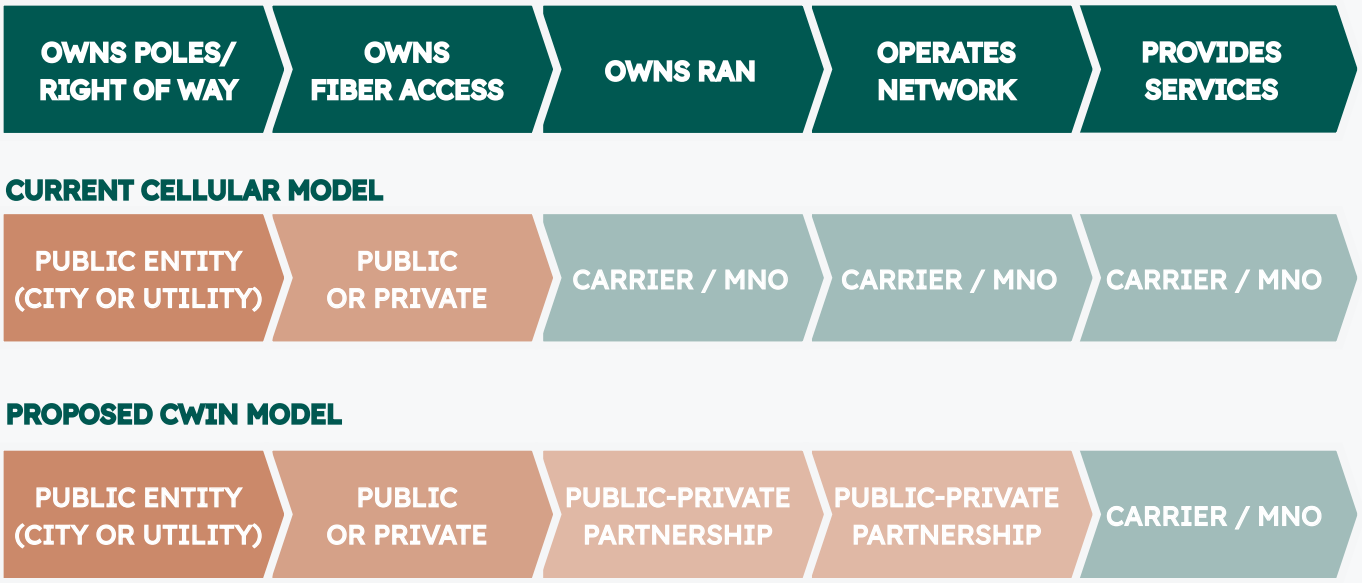
I. Introduction

This white paper explains how communities can ensure access to fifth-generation wireless bandwidth and services ("5G") for all residents through citywide, architecturally coherent, shared wireless networks. The public-private partnership approach outlined below — made possible by recent developments in private wireless networking — enables communities to co-create ubiquitous, resource-efficient, and flexible neutral host networks that facilitate equitable deployment of wireless connectivity. Drawing on lessons from community-led efforts over the past decade, this paper argues that cities can, and should, combine public infrastructure with privately-implemented 5G technology and service to provide broadband solutions that prioritize both municipal objectives and innovation to bridge the digital divide.

This paper proposes the Community-centered Wireless Infrastructure Network ("CWIN") model, in which cities partner with a private neutral host infrastructure provider that will finance and operate radio access networks that prioritize city and community use cases while simultaneously hosting the services of commercial Mobile Network Operators ("MNOs") and internet service providers ("ISPs").

To prioritize municipal use cases, communities can establish a shared infrastructure model that catalyzes a competitive marketplace of broadband service providers. By also providing a clearly defined financial commitment to the public-private partnership — potentially in the form of recently announced federal or state funding for broadband and critical capital projects — communities have the opportunity for significant financial upside from the commercialization of the shared network while limiting downside risk both operationally and financially. Furthermore, such neutral host solutions will ultimately benefit the entire municipal ecosystem, including

CWIN calls for public-private partnership to build and operate a shared citywide radio access network



incumbent broadband providers, who will enjoy shared economics and faster network deployment timelines.

While the first community wireless networks were built nearly 20 years ago, a confluence of factors now provides the opportunity to realize their full potential for ensuring access to affordable broadband service. Commercial-grade wireless networks, once highly proprietary and expensive to build and maintain, have become increasingly accessible through the adoption of software-defined architectures and modular physical components. This allows new entrants and legacy carriers alike to deploy high-performance wireless networks. Critically, software-defined networking allows hardware and components to be shared by many stakeholders simultaneously: MNOs, ISPs, municipalities, and community-based organizations.

These developments have already spawned an evolution in private networking business models in the private sector from industrial Internet-of-Things ("IoT") to plug-and-play multi-carrier neutral host networks. **Cities, which have chronically suffered from a lack of control over their broadband infrastructure, should harness this same radio access revolution to enable local decision-making in pursuit of urban planning and equity goals.** While municipal-led approaches to broadband have a long history, these recent advances and the growing criticality of broadband make it the right time for rethinking the public-private partnership model for wireless networks.

Cities today face an urban digital divide

Connectivity is critical for innovation, growth, and equity in the 21st century; basic access to broadband must now be understood as an essential utility, like electricity. Public education, for instance, cannot be equitably delivered without equitable broadband access. Currently, millions of American students without access to high-speed internet are falling behind their peers as schoolwork becomes increasingly digitized — a trend accelerated by COVID-19. Unaddressed, the digital divide is metastasizing into a public education failure that could permanently set back a generation of students, disproportionately affecting low-income families and communities of color. But the divide doesn't just leave students behind—residents of all ages need affordable, consistent broadband access to engage economically, civically, and socially. Telehealth services, municipal agencies, and local businesses likewise suffer with inadequate connectivity.

The digital divide is too often narrowly framed as only a rural dilemma, when in fact cities large and small suffer from chronic network access problems. Of the 18.4 million American households who have neither in-home nor wireless broadband subscriptions, more than 75% are in urban or metropolitan areas.[1] The problem is even more severe than the statistics imply, due to outdated definitions and flawed methodologies, worsening existing inequities as shown by race and income.[2] [3] For those who do have service, too many face performance limitations such as monthly data caps, limited upstream bandwidth, or wireless coverage gaps that inhibit actual broadband performance and usability.

> **If broadband is the electricity of the 21st century, a huge subset of urban Americans are still home with the lights off, waiting to be connected to a ubiquitous and reliable grid.**

For decades, mayors and local leaders have recognized the importance of ubiquitous broadband access to the future of their cities. A 2020 survey of U.S. mayors showed infrastructure investment as a top priority for economic recovery, with 89% saying that smart technologies are needed to help employees return to work with confidence.[4] These efforts are not new, but limited regulatory authority, constrained balance sheets, and powerful entrenched interests have long stood in the way of implementing comprehensive, citywide strategies.

New applications of high-speed connectivity, such as connected vehicles and IoT-based smart city systems, are increasing pressure on cities to assure that all residents and businesses enjoy a high level of broadband connectivity.

As the stakes rise, an imbalance of risk and reward compounds the challenge: municipalities currently receive blame for broadband failures but have little control over network deployment and do not appropriately share in the financial rewards of success. This contradiction has become more stark as the value and importance of cities' assets to the delivery of broadband rises.

Shared neutral host networks enable a more efficient and equitable 5G rollout

The provision of 5G networks on high frequency spectrum delivers higher bandwidth but over a shorter range. For cities, this means playing host to increasingly dense wireless networks with equipment located much closer to the user, referred to as the network 'edge.' This densification relies on increased use of publicly owned infrastructure, from streetlights to municipal property in rights of way. To secure such infrastructure, the rights to lay fiber, and power interconnection, service providers typically pursue individual permits with a variety of public departments and key stakeholders such as utilities. This process, when extended to the thousands of sites needed to densify 4G and 5G networks, threatens to overwhelm many cities' administrative capabilities, while simultaneously proving tedious, unpredictable, and expensive for the service providers. As multiple carriers build-out across the same local area, the permitting process further strains public resources through the effective duplication of efforts.

> **For cities to thrive in a connected age, they must find new models for citywide broadband deployment that create shared, open, and future-ready infrastructure, and this begins with recognizing the value of the unique assets cities have under their control.**

Rather than exclusively leasing rights of way and municipal assets to incumbent franchise-holders at rates made artificially low by Federal Communications Commission ("FCC") mandate, cities should seize the opportunity made available by their responsibility for public land use to work with technology and implementation partners to **develop shared, neutral host infrastructure.**

By combining disparate pieces of equipment and deployment models into a single resource-efficient infrastructure, the city can ensure broadband is available and affordable in previously underserved areas. This CWIN model will transform the economics for service

providers and create an open platform on which incumbents and new market entrants can competitively deliver connectivity, generating tenancy revenues that can be shared between the private and public partners. Co-located with this infrastructure, the city and its partners can also operate and manage its own wireless network dedicated to municipal uses ranging from connecting underserved residents to accelerating the adoption of connected community technologies such as smart grids and autonomous vehicle corridors.

This digital infrastructure will also empower cities to use real-time data to drive greater sustainability in applications from industrial water consumption to home energy management. Properly structured, such a hybrid and innovative approach to network design and implementation would give cities more control of their connectivity future, reducing the digital divide, enabling new civic services, and generating long-term revenue sources.

In a neutral host wireless infrastructure model, one provider manages municipal assets, enabling operators to share the same physical equipment and a radio access network. This model is distinct from a shared infrastructure model where access to municipal assets is made open to multiple MNOs, where either each MNO, or their respective vendors, manage the deployment of discrete sets of physical equipment onto the municipal asset.

> **Achieving this vision requires recognizing that shared wireless networks are key components of municipal infrastructure and should be treated and funded as such.**

The first electric networks of the early 1900s brought progress and innovation to those who were connected, but universal access required decades of technological advancement, federal financing, and new business models. Broadband today is at such a moment, providing an opportunity for forward-thinking cities to implement models that leverage municipal assets to facilitate equitable access for their residents.

"As a result of innovation in wireless infrastructure, we will see radical new business models emerge for how everything from streetlights and home heating to energy and water consumption is monitored and managed. These innovative models will move away from the slow process control and poor visibility, and often no tracking of consumption, that we currently have."

Mark Skilton, Professor of Practice Information Systems Management, Warwick Business School [18]

II. A seemingly intractable problem

Since the advent of telecommunications, cities have borne much of the brunt of criticism for poor coverage, high rates, and inadequate customer service, despite having little to no control over those commercially provided services. Whether underserved residents petition City Hall, complain to their ISP, or suffer in silence, the final blame for this failure is increasingly cast upon the city. The ISPs are not winners here either: ISPs consistently rank at the bottom of customer satisfaction surveys, ranking 45th out of 46 industries covered by the American Consumer Satisfaction Index.[5]

5G alone is not the solution

Traditional broadband provision is failing to meet Americans' needs in terms of performance, choice, and, in particular, equity. Whether wired or wireless, the system is premised upon service providers building networks to serve the highest-margin customers. The advent of 5G wireless technology is often portrayed as the solution — bringing high-speed, low-latency connections through cellular networks and obviating the need to wire every home and business. However, the 5G deployment being touted by carriers right now will not solve this problem alone. In fact, should the status quo of network deployment continue, 5G will make cities' digital divide problems worse.

> 'I don't know how any of us can think that 5G will be different, that the ISPs will make different decisions than they did with previous technologies."
>
> Angela Siefer, Executive Director, National Digital Inclusion Alliance[19]

At this rate, the rollout of 5G will not cover entire cities or regions for years.

The rollout of 4G offers a historical perspective on the challenges—and long road—ahead. More than a decade after carriers began rolling out LTE networks, data on 4G coverage remains unreliable and overstated. The rollout of 5G will likely take as long or longer than the 4G rollout did—at least a decade by many estimates. Small cells—the densely deployed access points that will be necessary for 5G networks—are among the most visible and often controversial components of this next wireless generation. As further described below, 5G requires at least 60 times the number of access points 4G does. The GSM Association optimistically forecasted that 5G will not reach a 50% share of consumer cellular connections until 2025, and this was two years before the COVID-19 public health crisis changed many deployment plans.[6]

Both cities and carriers lose in a status quo approach

As carriers begin to deploy this necessary multitude of new access points, they are quickly realizing that existing network architectures and business models are not working. Previously, carriers built macro **coverage** networks across a footprint of large towers to ensure subscribers have basic voice and data services in as many places as possible. To realize the promise of the newest generation networks, however, carriers now need to rely on dense **capacity** networks or risk overloading the existing macro network. These capacity networks are composed of many more tightly packed small cells, which must be separated by only a few hundred or thousand feet. Effectively

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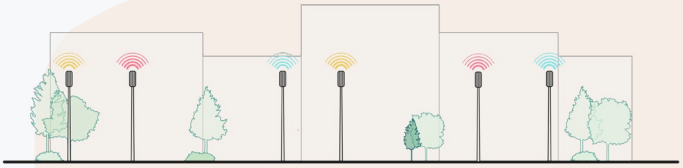
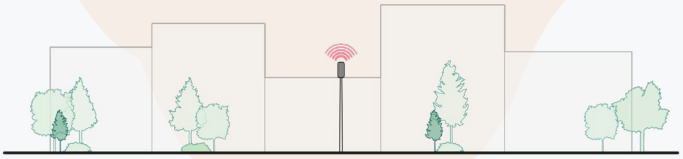


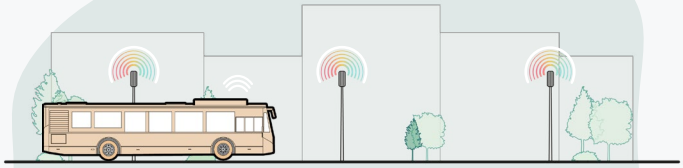
Affluent Neighborhood

Uncoordinated deployment leads to redundant capital expenditure and disparate service levels across neighborhoods.



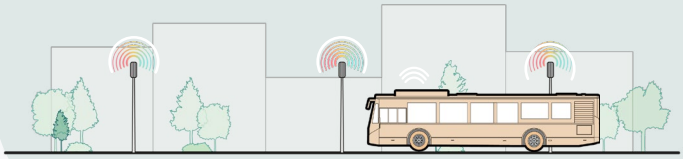
Underserved Neighborhood

SHARED FUTURE



Affluent Neighborhood

Shared infrastructure enables efficient, equitable coverage, while provisioning new networks for city-prioritized use cases such as borderless classrooms.



Underserved Neighborhood

deploying small cell capacity networks is a complex undertaking— requiring the placement of equipment in public rights of way using municipal assets.

Current 5G plans are not, and may never be, funded at the scale needed for a national deployment. To drive revenue per user, carriers' 5G plans prioritize placing expensive equipment in areas with the highest-paying subscribers, exacerbating inequity and widening the digital divide.

5G deployment is leaving cities inundated by an endless flood of permitting requests and disruptive construction, and with increasingly less control over where and how it happens. Currently underserved neighborhoods will remain devoid of coverage, while areas with the highest average revenue per user ("ARPU") are becoming battlegrounds between the carriers. The result is overbuilt, uncoordinated, and unattractive vertical infrastructure encumbered by multiple pole attachments and mismatched equipment from different companies. This cluttered streetscape—a form of visual pollution—is already an urban nuisance, with 58% of cities in a 2018 study citing resident complaints over the aesthetics of small cell deployments.[7] Cities must review dozens of "smart pole" pitches, with procurement inefficiencies adding direct costs, creating unnecessary administrative burden, and lacking a clear connection to residents' needs. The FCC's mandated 60 day "shot clock" forces rapid decision making, preventing meaningful resident engagement and cities' ability to implement a coherent strategy.

> "Cities should take the lead in developing the framework to deploy next generation networks. [...] A city-organized effort would likely be more legitimate, more practical, and could actually be an important catalyst for asymmetric value creation in driving new deployment and addressing the digital divide."
>
> Blair Levin, Nonresident Senior Fellow - Metropolitan Policy Program, Brookings Institution[20]

But it's not just cities—carriers are also poorly served by the status quo approach to the 5G rollout. The fundamental promise of 5G relies on increases in capacity and optimizing the use of scarce radio spectrum. However, carriers are currently approaching this problem like they did in previous generations. Without addressing cost and network efficiency, a focus on densification puts operators in a dreaded cycle of reduced revenues and increased costs. Carriers are investing in or leasing redundant fiber connections and small cells, with the industry expecting a dramatic increase from 13,000 small cells in 2017 to over 800,000 by 2026.[8] As carriers build 5G base stations that cover smaller physical footprints, they risk deploying less and less profitably, disappointing their shareholders and restricting incentives to provide connectivity to underserved populations.

5G is at risk of becoming a market failure that benefits neither consumers nor municipalities nor service providers.

National regulations are failing cities

Creating a better wireless broadband future requires coordination across all levels of government, but to date, national leadership has failed to move the needle. Indeed, legacy regulatory actions by the FCC, including setting maximum pole attachment rates and establishing a 60-day permitting shot clock, have in some cases exacerbated cities' problems.

These nationally set controls limit local government's role in ensuring an equitable buildout, while leading to a mispricing of municipal infrastructure over time. Data usage and dependency will continue to grow exponentially, while the local municipalities responsible for underlying physical infrastructure continue to be compensated at the artificially low fixed rates. In recent years, the FCC has placed faith in broadband expansion largely on incumbents responding to market forces, leaving municipalities and communities without a seat at the table in setting national policy. Yet a 2021 survey found that less than 25% of state and local leaders have confidence in the ability of national ISPs to use federal funds to close the digital divide.[9] In contrast, a recent report showed that removing restrictions on community-owned networks improves broadband availability, illustrating a positive federal role possible under the new administration.[10]

III. New technology lays the groundwork for a better solution

Software-defined networks and open standards

New developments in wireless technology are bringing together principles of modularity, open standards, and local control to create mechanisms for delivering broadband more flexibly,

efficiently, and competitively at the community scale. Modular and shared networking architectures can be customized to each city's topography, assets, and needs. A movement to bring open stack computing standards to radio access networks ("RAN")—known as OpenRAN—enables new technology players to innovate and borrow common solutions from the public computing community. OpenRAN allows network operators—which have historically relied on proprietary technology from a small group of expensive vendors—to more swiftly deploy 5G solutions at lower cost and at equal or better quality, answering the call for faster overall deployment timelines and reduced capital costs. OpenRAN is also increasingly viewed as an alternative to relying on expensive proprietary equipment and untrusted foreign vendors that could compromise national security. The FCC has recently opened a Notice of Inquiry on OpenRAN to better understand the status of open and virtualized network environments today and the steps needed to encourage broader deployment.[11]

> "Today, the RAN is the most restrictive and expensive part of the network because all of its major components have to come from the same vendor. There is no way to mix and match. If we can unlock the RAN and diversify the equipment, we might be able to increase security, reduce our exposure to any single foreign vendor, lower costs, and push the equipment market to where the U.S. is uniquely skilled in software."
>
> Acting FCC Chairwoman Jessica Rosenworcel, OpenRAN Notice of Inquiry, 2021

Such designs taken together combine data analytics with software-defined networks to enable long-term flexibility and reduce the need for future construction.

By implementing an open interface on general purpose platforms, such networks can be "sliceable," with separate logical networks sharing one physical infrastructure. Somewhat analogous to how the virtualization of servers and containerization of applications now allow customers to share processing in cloud services, sliceable networks will allow carriers to share physical antennas and radios to provide separate services and next generation use cases. This approach further improves network efficiencies and economics while reducing necessary build-out.

Shared spectrum

Similarly, the FCC's recent release of new spectrum under innovative licensing models that promote spectrum sharing, particularly Citizens Broadband Radio Service ("CBRS"), lowers barriers for new network providers. Unlike prior allocations of broadband-capable frequencies, CBRS enables access without the need for service providers to buy spectrum or, with its highly local allocation scheme, reducing the capital intensiveness of spectrum ownership. As new spectrum becomes available for wireless networks (with additional allocations expected in the next few years), new parties will enter the market and cities will have the ability to engage with a much wider set of potential partners.

As new entrants seek opportunities to expand, they will be increasingly open to more innovative frameworks that allow cities to benefit from long-term growth in both revenue and public services. The result is an opportunity for city-led, citywide broadband business models.

Cities have the ability to demand that their priorities are met

Achieving this vision requires cities to take a more active role in seeking and structuring partnerships with network providers. **Cities control the most important resource in this equation—permissions, rights of way, and other infrastructure necessary to deploy advanced broadband**

networks. While some cities directly control fiber, conduit, and vertical infrastructure such as streetlights, all municipalities control and manage significant rights of way, which are prerequisites to network deployment. Municipalities can leverage their position to ensure community needs are met by proactively working with carriers, technology providers, and other third-party partners as broadband networks are developed.

Cities should expect—and demand —more from network providers operating within their jurisdictions. Municipal leaders willing to proactively engage with aligned capital and technology partners to deploy the CWIN model outlined below can structure a public-private partnership which will commercialize the city's assets in a way that places municipal and public needs above all. In contrast to the traditional leased network deployment model, this new model can provide material long-term benefits to cities.

IV. CWIN enables an open technology platform for community-first broadband

Recent technological developments have enabled the opportunity for cities to chart a new path forward. By combining existing business models and technologies, we propose a new model—the **Community-centered Wireless Infrastructure Network** ("CWIN")—in which a private entity brings financial capital and technological and operating capabilities, working in partnership with the city to build and operate the network as described below. Whether targeting a fully ubiquitous network from inception or an incremental approach to building coverage over time, such a solution will include the following components:

- **Flexible private networking to meet municipal uses.** Recognizing that cities have distinct network needs across departments and use cases, the solution should include a private networking platform for municipal use. Provided over licensed and unlicensed spectrum alike, this wireless network should be deployed citywide and sliced to prioritize the use cases that matter most to the city and its residents. Network slicing will allow for the optimization, segmentation, and prioritization of dense spectrum, creating private, reliable, low-latency networks appropriate for each municipal use case. Perhaps the most important example is the opportunity for a "**borderless classroom**," providing dedicated connectivity to students, teachers, and staff by covering schools and homes. Another potential use case is a network slice providing secure, municipal-wide network resources for public works officials, which in peak network capacity times or periods of emergency could supersede those of a less time-sensitive municipal administrative task.
- **Shared multi-tenant architecture.** The solution should include a citywide, physically uniform street architecture, designed in partnership with the city and able to accommodate all carriers, smart city technology providers, and other future stakeholders. To avoid overbuilds, infrastructure is expected to be deployed via neutral host structures, using equipment that can accommodate multiple carriers and spectrum bands.

- **Software-defined open infrastructure.** Over time, OpenRAN will enable further shared, cost-efficient infrastructure. Through this technology, carriers can deploy their coverage densely across common infrastructure. Based on commercial off-the-shelf hardware, this will be a single, 5G spectrum-compatible, modular, and software-defined infrastructure.

Wireless broadband complements wired networks

Fiber-to-the-premises ("FTTP") is often framed as the only solution to persistent broadband disparities. While necessary to backhaul wireless networks, fiber does not solve many problems facing cities, nor is it a one-size-fits-all solution for every community.

First, fiber can be prohibitively expensive to bring to every residence and business in a city. An analysis of municipal fiber networks by University of Pennsylvania researchers found that the majority of projects studied will struggle to break even, stressing cities' borrowing capabilities and requiring capital bailouts from general funds and/or state or federal sources.[12] Cities should carefully consider whether they can ensure ubiquitous residential broadband more sustainably by building "fiber-to-the-block" and relying on 5G fixed wireless solutions to deliver the last-mile service to the home or business in certain areas.

Furthermore, fiber networks, while providing the underlying backhaul, do not address the need for a coordinated and equitable rollout of 5G cellular networks. Even with municipal fiber, each carrier will build its own discrete small cell infrastructure in the most economically attractive areas, resulting in the unequal and cluttered rollout previously discussed. Cities will be increasingly inundated with permitting requests from multiple counterparties looking to build access points on their fiber. The promised cellular-based 5G use cases may only be fully realized in business districts and wealthier neighborhoods.

Municipalities have pursued a range of solutions to ensure inclusive fiber access. Such projects have historically taken the form of fiber networks and employed a number of business models ranging from full public ownership, operations and service to private ownership, service and operations with public support, and multiple variations in between. Notable examples of open-access approaches include Chattanooga, Tennessee, whose city-owned utility built and operates a citywide fiber network, and UTOPIA (Utah Telecommunication Open Infrastructure Agency) Fiber, a group of 11 Utah cities operating at the wholesale level using an active Ethernet infrastructure. These projects have found varying levels of success.[13] While an analysis of historic municipal fiber models falls beyond the scope of this paper, it is important to understand why municipalities should also focus on software-defined wireless networks as both a complement—and in some cases an alternative—to these deployments.

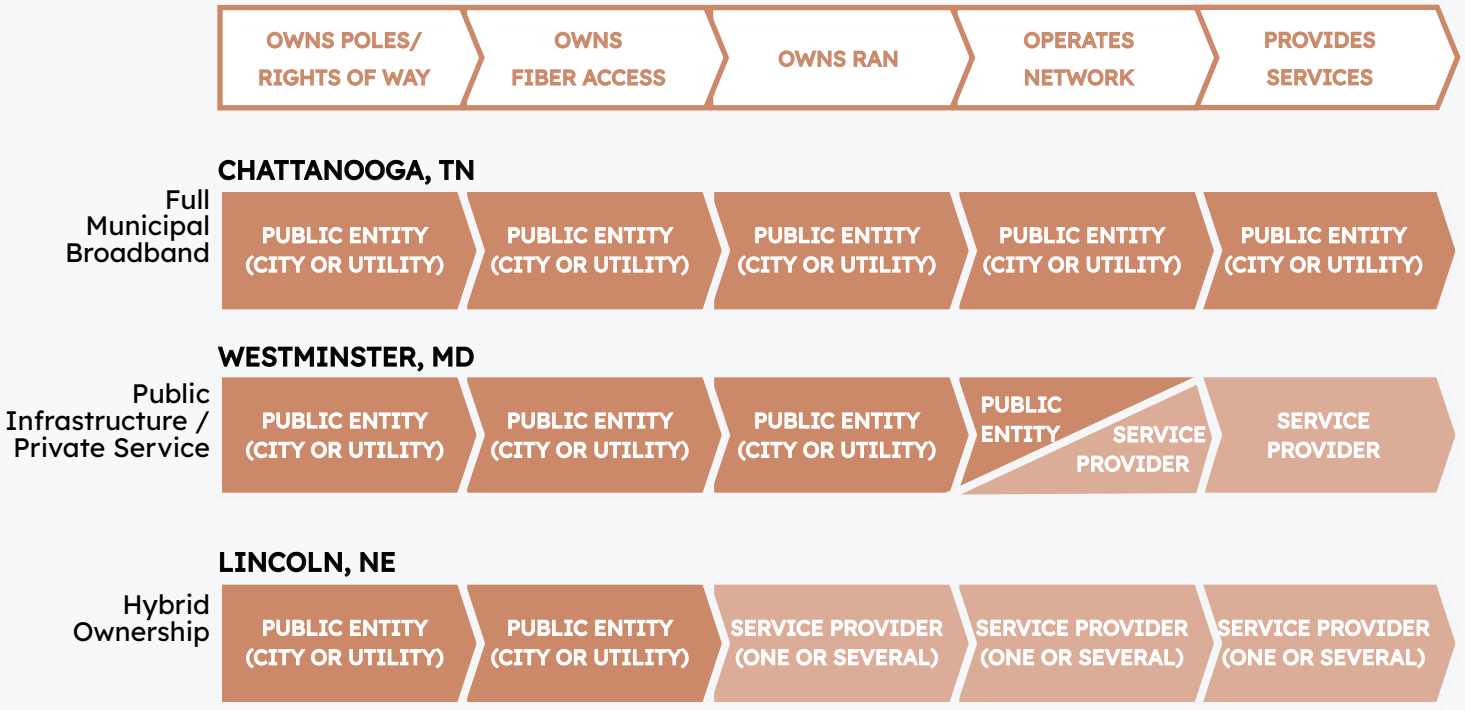
We applaud the efforts of cities to build fiber networks, particularly those that enable an open-access ISP market, and recognize the unparalleled bandwidth and reliability provided by fiber technology. Critically, the distributed small cells of the wireless networks proposed in this paper require a robust fiber backbone. Cities with existing fiber networks— whether publicly or privately owned—will therefore have a head start in pursuing the CWIN model. By owning and controlling a fiber network that connects key hubs and neighborhoods, a given city can enable the construction of wireless clusters that provide last-mile fixed wireless access to customers in harder-to-reach areas and ensure equitable build-out of cellular broadband across communities, regardless of economic status.

In particular, the "Public Infrastructure / Private Service" public-private partnership model recently proposed by the Coalition for Local Internet Choice ("CLIC") closely complements the wireless model proposed in this paper. In the CLIC model, the public sector constructs and owns a fiber network, while private ISPs operate and offer service on this public infrastructure, assuming performance and market risks. The public sector can therefore control where the fiber network is built and how it is managed, providing a backbone over which a municipally-aligned wireless private partner can offer services in line with the CWIN model. This approach must delineate between the assets owned by the city (conduit, middle-mile dark fiber, rights of way, street furniture, poles) and those owned by the private partner on the wireless side (radios, last-mile fiber laterals). An early example is New York City's recent Universal Solicitation for Broadband, providing private partners with access to more than 100,000 City-owned assets with which to deliver services to close the digital divide.

Private partners add particular value to wireless networks

As discussed above, many cities are well-equipped to construct and own dark fiber infrastructure. Wireless networks, on the other hand, are generally far more commercially and technically intensive than fiber, often requiring more frequent maintenance and upgrades. Building shared access points requires capital and the ability to commercialize the radio access network by striking deals with carriers or other service providers. Network design requires both physical engineering considerations and radio frequency ("RF") design. Access to wireless spectrum has required either costly frequency licenses, typically awarded through nationwide auctions, or the use of crowded, unlicensed spectrum such as 2.4GHz and 5GHz Wi-Fi used in consumer

City Business Models for Fiber-based Broadband[21]



devices. Coupled with proprietary, carrier-specific radios and equipment, the design and operation of wireless networks has proven challenging for municipalities to tackle alone.

The first generation of Wi-Fi-based municipal wireless networks was pioneered by cities like San Francisco and Chicago in the early 2000s, only to be abandoned in the face of financial and operational challenges.[14] Advertising-supported networks have had more recent success in delivering free Wi-Fi at scale, including LinkNYC's deployment of nearly 2,000 fiber-connected access points. Many advertising-driven business models, however, have struggled to align parties toward comprehensive, equitable deployment. Community-based organizations, on the other hand, have built networks focused on equity and explicitly designed to address local priorities such as job training and resilience, from the Detroit Community Technology Project to NYC Mesh.[15]

Most recently, the allocation of CBRS spectrum launched a new generation of projects by cities, communities, school districts, and other stakeholders. In Fontana, California, for example, the school district launched a program to provide private wireless access for 36,000 students impacted by the COVID-19 pandemic.[16] Similar efforts are underway in cities from Greensboro, North Carolina to Tucson, Arizona, where funding for implementation and expansion remains a priority.[17]

Whether a smaller pilot led by community stakeholders or a government-led initiative, a scaled citywide wireless network requires not only upfront capital but a sustainable revenue model for ongoing operations and upgrades—needs that a private partner can best provide for. In particular, the market and performance risk associated with co-locating multiple carriers and ISPs on a shared infrastructure and slicing that network for each partner is best aligned with private sector risk profiles, particularly given the fast-evolving, earlier-stage nature of 5G technologies and applications. Such an approach could complement community-based organizations, providing new tools for local businesses and nonprofits alike to deploy their own networks on this shared infrastructure.

Cities should seek a neutral host partner, not a retail provider

The CWIN model depends upon sharing a single radio access network among multiple stakeholders. This makes it unlikely that any one provider of retail communications services would be a successful neutral host provider. Such providers should be able to operate and slice the network for a variety of customers, set up city-specific networks, and take on the majority of risk associated with network commercialization without needing to operate a retail network itself.

There will be—and need to be—new entrants to the wireless market. Relying on carriers alone to build hundreds of thousands of additional small cell sites where only tens of thousands exist now will mean that the 5G build-out will go faster in some parts of some cities while lagging everywhere else. Neutral host networks are fairer, funded by new entrants with new resources, and more likely to be built with long-term infrastructure considerations in mind.

In partnering with private third parties to implement the innovative CWIN solution outlined above, a city should expect a wide range of benefits in exchange for providing access to its infrastructure, including revenue sharing, civic services, and community stewardship.

V. Municipalities should expect to benefit holistically

Financial benefits

Cities have the opportunity to require that a wireless infrastructure partner:

- **Fund the cost of a single, architecturally unified wireless network infrastructure** that covers all of the municipality, with the partner investing all necessary capital up front;
- **Share revenues or profits with the city** from hosting tenants on the network, allowing the public to benefit from returns that are not capped by arbitrary limits on public rights of way lease rates, and which can well exceed the capped returns from leasing assets under the status quo model; and
- **Build, manage, and lease neutral host network infrastructure** that can accommodate any number of commercial partners, from carriers to enterprises to municipal users.

Civic services

The provision of new and enhanced civic services should be central to any arrangement. Specifically the private partner should:

- **Establish dedicated networks** that can be used for municipal, healthcare, educational, or commercial use;
- **Provide cohesive management of city communications right-of-way, fiber, and street furniture assets** for the shared use of multiple private partners, generating revenue for the city, lowering construction and maintenance hassles, and streamlining network permitting and deployment; and
- **Continue to partner with enterprises, carriers, and ISPs** to bring new access solutions to communities by investing in additional build-outs of fiber (including building directly to the premise) and small cells, in coordination with input from a diverse group of community members and stakeholders.

Community stewardship

Recognizing that closing the digital divide and achieving broadband equity requires the engagement of all communities, cities should expect their partner to:

- **Assist the city in establishing a broadband stewardship committee** that represents community needs by reviewing and informing decisions on physical architecture, coverage, and service guidelines, and acceptable use policies for network infrastructure and data;
- **Create and support local partnerships** to ensure that the advanced network infrastructure benefits local organizations and residents, including ensuring affordability of access; and
- **Launch a community employment initiative** that includes job- and skills-training for residents in the operations and management of the network.

PUBLIC-PRIVATE PARTNERSHIP (P3) STRUCTURE

Each party's commitments enable a single, architecturally coherent wireless network infrastructure that covers the entire community from the beginning.

CITY COMMITMENTS

- **City-wide coordination:** nominates "wireless network champion" and group of community leaders to advise the P3
- **Public asset access:** provides access to municipal broadband assets, including fiber, conduit and street furniture and general streamlined permitting and approvals process
- **Alignment with private partner:** selects partner, provides credit enhancement to support some cost recovery, and becomes a direct network customer

CITY BENEFITS

- **Proactive, equity-focused role:** decides where wireless networks are deployed, how they look, and what they cover, led by a goal of universal coverage
- **Dedicated network "slices":** receives dedicated connectivity for municipal, healthcare, or educational uses, including a borderless classroom for all students
- **Reduced administrative burden:** cohesive management of public assets for the shared use of private partners
- **Revenue sharing:** uncapped share of revenues or profits from network tenants, allowing the public to benefit from long-term value of rights of way and partnership

PRIVATE PARTNER COMMITMENTS

- **Upfront capital:** invests all necessary capital up front to fund the cost of equipment and installation
- **Network operations:** bears responsibility for operations and performance of the network
- **Technology:** selects and convenes best-in-class technology partners to contribute to network development and operations
- **Commercialization:** secures tenancy on the network and is the counterparty to commercial offtake agreements

PRIVATE PARTNER BENEFITS

- **Long-term returns:** stable investment underpinned by essential municipal infrastructure
- **Meeting a market and social need:** financing the bridge between wireless service providers and municipalities necessary for the equitable deployment of 5G networks
- **Enabling innovation:** advanced wireless networks are a foundation for future connected communities and technology-driven opportunities

SERVICE PROVIDER COMMITMENTS

- **Use of shared infrastructure:** delivers services via a sliced active neutral host infrastructure owned and operated by the P3
- **Agreement to partner with P3:** executes shared infrastructure master lease that includes make-ready, siting, permitting
- **Payment of lease fees to P3:** pays single ongoing fee to cover the entire cost of site acquisition, network deployment, and operations

SERVICE PROVIDER BENEFITS

- **Lower capital and operating costs:** captures sharing economics by pooling resources of multiple providers
- **Streamlined deployment:** provides rapid access to a city-wide network vs. individual poles with a single agreement and bundled make-ready services
- **Reduced administrative friction:** master agreement with a purpose-built P3 reduces traditional multi-phase procurement processes to single negotiation
- **Strengthen relationship with city:** participates in a streamlined structure that has clear benefits for government, residents, and property owners

VI. A successful public-private partnership requires municipalities to make certain commitments

To achieve these benefits, cities need to understand the expectations of their private partners, including making institutional changes where necessary. While local context and regulations may make certain commitments more challenging, the list below outlines actions that will enable the CWIN's public-private partnership structure described above:

Citywide coordination

- **Appointment of a broadband champion.** A city should select a single point of contact to lead internal and external broadband engagement. To maximize the value of municipal assets, a city needs an empowered individual to steward its strategy, working across departments to convene stakeholders and decision-makers and serve as liaison for the private partner, helping to secure necessary approvals and buy-in for the given project.
- **Commitment to active stewardship.** To ensure the network serves the community's priorities, a city should empower community leaders in the form of a stewardship committee providing oversight regarding network access locations, traffic priorities, and acceptable use policies for network and data.

Public asset access

- **Access to municipal broadband assets.** To speed citywide deployment, a city should make available key rights of way, existing fiber and conduit, streetlights, and other relevant assets through a one-time permitting process.
- **General streamlined permitting and approvals process.** As the volume of requests increases, a streamlined process will be critical to reducing administrative burden on the city and its connectivity partner.

Alignment with private partner

- **Selection of a strong partner to enable municipal connectivity.** Through a competitive process, a city should select a neutral host infrastructure and operations partner with the resources needed to invest at scale. Rather than directly providing service, such a partner must be committed to an open, neutral host infrastructure while avoiding redundancies and inefficiencies.
- **Participation in risk sharing.** To enable the city to share in significant long-term returns, some level of risk sharing is required. In particular, to enable large-scale buildout, a city should consider committing to support a portion of the network costs if revenues fall short early in the project. Cities should simultaneously seek to minimize the size of this

commitment through federal funding and philanthropic grants. Unlike the status quo of leasing at below-market rates, this approach aligns both parties' incentives over the long term and enables greater upside.

- **Agreement to become a tenant of the network.** By transitioning a significant portion of municipal traffic to the new network, including public service delivery and smart city applications, a city can serve as a key anchor tenant, providing early business model support along with some of the financial commitment listed above.

VII. Towards a community-led, open connectivity platform

As advanced broadband networks become critical components of urban infrastructure, cities deserve to be an equal partner in their deployment. This new city-led model enables the use of key municipal resources, particularly urban rights of way, to solve municipal problems, provide services, and generate revenue. **By proactively working with an aligned partner to provide the foundations of the CWIN model's open connectivity platform, cities can enable the capital-efficient rollout of a future-proofed, ubiquitous network.**

Such a system will enable a border-to-border, one-time deployment of a robust citywide network, ready to lease to carriers and other network providers for rapid 5G deployment to provision equal broadband service to all members of the community. Each stakeholder will receive significant benefits:

- Residents and local businesses will enjoy new, affordable connectivity choices, higher performance, and an improved streetscape, coupled with a meaningful role in stewarding equitable deployment and operations to close the digital divide.
- Carriers will be able to deploy new networks more rapidly and efficiently, at equal or better quality to current deployments, avoiding duplicative investments and benefiting from reduced capital expenditures.
- Cities will receive new purpose-built wireless networks to meet their needs and those of their students and residents, share in the long-term financial value of the infrastructure, and benefit from improved educational, economic development, and equity outcomes.

Cities today are held responsible for the equitable availability of internet connectivity, regardless of their involvement in the provision of such services, or the lack thereof. Through the CWIN model's public-private partnership approach the time is finally right for cities to gain control by leveraging their assets to ensure that residents receive the services they deserve, while ensuring fair compensation for the long-term value of the networks they unlock.

Glossary

5G: "Fifth Generation" wireless technology, the next evolution of mobile technology after 4G LTE; brings faster speeds through lower latency and higher throughput, improved efficiency and reliability, as well as increased capacity to sustain an exponential increase in connections.

Backhaul: The segment of a network that communicates between a local point of presence or wireless access point and the global internet; this term often generically refers to both the "middle-mile" and "last-mile" segments of the network, defined below.

Citizens Broadband Radio Service ("CBRS"): A block of spectrum in the 3550 - 3700 MHz frequency range, historically used by the US government. In 2020, the FCC auctioned a portion of the block on a county-by-county basis for commercial use while ensuring a large portion of the spectrum was left for unlicensed, general usage.

Conduit: Underground rigid tubing that holds and protects the individual fiber optic cable strands; conduit is sometimes installed with excess capacity available for the pulling of more fiber.

Dark fiber: Installed but unutilized fiber optic cable that can be leased to third party network operators and/or service providers (in contrast to 'lit' fiber which refers to an actively managed fiber service).

Fiber-to-the-premises ("FTTP"): The delivery of internet access directly to a user or location via fiber optical cable.

Internet-of-Things ("IoT"): The interconnection of everyday objects and devices to the internet, enabling them to send and receive data.

Last-mile: The final leg of a telecommunications network that delivers services to retail end-users.

Middle-mile: The segment of a telecommunications network linking a network operator's core networking equipment to the local network architecture at the last-mile.

Mobile Network Operator ("MNO"): A provider of cellular-based mobile network services; in the US, the largest MNOs are AT&T, T-Mobile, and Verizon.

Neutral host wireless infrastructure: A model in which one provider manages municipal assets, enabling operators to share the same physical equipment and a radio access network. This is distinct from a shared infrastructure model where access to municipal assets is made open to multiple MNOs, where either each MNO, or their respective vendors, manage the deployment of discrete sets of physical equipment onto the municipal asset.

OpenRAN: Industry-wide radio access network standards with common interfaces used to disaggregate hardware and software; OpenRAN interfaces support interoperation between different vendors' equipment so that RAN software can be sourced and integrated from any number of vendors of off-the-shelf, non-specialized hardware.

Radio access network ("RAN"): Radio equipment that broadcasts a signal from a fixed point to provide a wireless connection, along with equipment to coordinate the management of networking resources across radio sites. The RAN transmits a signal to various other wireless endpoints (e.g., other access points or mobile devices) and connects them to the core network.

Rights of Way ("RoW"): The legal right to pass or place equipment along a specific physical route; in this paper, RoW refers to property rights necessary for hosting wired or wireless infrastructure.

Small cell: A 'smaller scale' low-powered access point with a smaller physical footprint than a typical cellular tower site. Small cells come in many different forms - mostly in the shape of a box less than 2ft in height, length, and width.

Radio spectrum: The part of the electromagnetic spectrum with frequencies from 30 Hz to 300 GHz. These electromagnetic waves - radio waves - are widely used in telecommunications and as a fixed resource are increasingly in demand by a diverse and large number of users.

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