KCFN Feasibility Study

produced for

The Urban Neighborhood Initiative

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Abstract

The object of this study is to provide the information necessary for The Urban Neighborhood Initiative, its constituent neighborhoods, and the community at large to make an informed decision about co-operating on a 'free network' in the core of Kansas City.

In Part I of the study, we give an overview of the motivations, methodologies and design patterns behind free networks, their component technologies, and potential applications. In Part II, we explain the architecture and current footprint of the Kansas City Freedom Network. Finally, in Part III of the study, we examine the feasibility of extending the KCFN to the core, propose a plan for doing so, and give estimates of cost.

Our finding is that the corridor in question is fertile with opportunities for network growth. To successfully seed network growth, UNI and UNI partners would do well to support operator training programs aimed at establishing a corps of community technologists.

1 Introduction

1.1 Network Models – Proprietary, Private, & Free

The vast majority of people think of 'The Internet' as a monolith. In actuality, however, The Internet is made up of some 40,000 carrier networks, interoperating via shared protocols, and with the autonomy to run their networks as they see fit. While some of these networks are state-run or designed for research and education, the vast majority are 'proprietary' networks. Proprietary networks have many advantages, including large geographic reach, access to wholesale connectivity markets, and the ability to peer with other networks. With these advantages, however, come some significant limitations. Proprietary networks are owned by telecom companies, and their use comes at a steep cost to the user. Moreover, users have little to no say over how the network is run, meaning that they are perpetually at the mercy of the operator to upgrade or troubleshoot the network.

At the same time, countless private networks extend connectivity into homes and businesses worldwide. While these networks are limited in their reach, they offer their owners the freedom to decide when, where, and how the network functions. Home users establish private networks (generally referred to as Local Area Networks) for a variety of reasons, including added security, the ability to serve multiple devices via a single gateway, and to enable wireless connectivity. In corporate and public sector IT environments, private networks (generally referred to as intranets) are used to support a wide array of business-critical applications.

Until recently, there was a sharp distinction between proprietary networks and their private counterparts. Networks were either large, commercial enterprises or small, private undertakings meant to augment an existing Internet connection. Over the past few years, however, advances in network technology have led to the emergence of a new sort of network. These new networks, refered to as 'free' networks, represent a middleground. They are capable of achieving significant geographic reach and of peering with other networks, yet they also give their owners the freedom to build, upgrade, and utilize connectivity as they see fit. This blend of capabilities and freedoms is achieved by a model in which ownership is distributed amongst many parties under a common license.

Using powerful, low-cost microwave equipment and the free network model, communities throughout the world have been able to save money and spur economic development, while at the same time working to ensure that none are left without lifeline access. Such networks now span major cities and entire regions, participate in large Internet Exchange Points (wholesale markets where carriers exchange traffic), and enable innovative and community-driven applications.

The basic principle behind free networks is the same principle that has catapulted the Internet to its profound success - that when networks join together, the sum is much greater than its parts. In networking theory, this principle is known as *Metcalf's Law*.

The upshot for individuals and community institutions is that owning part of a common network is a much better value proposition than owning all of a private one. In exchange for contributing their resources, participants are allowed to utilize those resources contributed by others. While contributors retain complete and total ownership of their infrastructure, they license its use to other participants in exchange for a reciprocal agreement. This is the purpose of the *Network Commons License* — a legal framework for governing free networks maintained by a global consoritum including The Free Network Foundation.

This framework works particularly well in computer networks, where technical measures can be used to make sure that participants don't utilize more than their fair share of the network's resources. In this way, we can avoid the *tragedy of the commons* and bolster the long-term sustainability of the network.

Yet, technical measures are not enough to guarantee success. In order for the network to thrive, it is essential that it be coupled with a significant educational effort. The free network model requires that participants and prospective participants actually be able to take advantage of the freedom to expand and improve the network. The skills to do so are attainable, but the fact remains that they must be attained. In the end, the only way to achieve a sustainable model is for those who use the network to be its primary stewards.

Many high-profile municipal networks have failed precisely because individuals and businesses were not allowed, were not able, or were not willing to make necessary improvements. To this end, it is critical that the network be built with free and open technologies, that it be as simple as possible to operate and maintain, and that community egagement be made a priority at every turn.

Using open technologies and providing ample educational opportunities fosters a highly distributed ownership model. It is this model that gives free networks their strength — empowering communities to own their own networks, *without* requiring outsized commitments of capital, and *with* a boundless potential for good.

1.2 Free Network Advantages

Free networks are more than just the Internet — they're an opportunity for a new sort of connectivity, rooted in community. While significantly reducing barriers to access is certainly one of their primary benefits, they are also designed to serve as a platform for community media, local applications, and advanced functionalities.

It is important to understand that while free networks can (and should) be connected to the global Internet, they are first and foremost independent networks. Aside from the electricity required to run the network equipment (less than a lightbulb per home), there is no cost for moving data *within* the network. Because free networks function as a commons, participants can communicate with one another directly, without ever having to pay an ISP for service. With this in mind, here are just a few of the potential applications:

- By connecting the network to an Internet Exchange Point or other wholesale connectivity market, it is possible to provide all those who wish to access the Internet with significantly less expensive options for getting online. In this regard, the network essentially functions as an Internet co-op — by pooling their purchasing power, participants are able to get much better prices than they ever could on the retail market.
- By connecting the network to a school or business intranet, students and faculty or employees can be granted secure, authenticated access to an organization's digital resources, including an Internet gateway.
- Educational and cultural institutions can easily make content archives and learning materials available to the community without having to pay for web hosting. This is especially beneficial when the content is multimedia, which requires significant amounts of bandwidth.
- Network participants can make video and voice calls to one another without having to pay for cellular or Internet service.
- Organization of the network by neighborhood and block encourages the establishment and use of bulletin boards and chatrooms that connect

neighbors and strengthen communities.

- Youth can learn valuable skills by building and maintaining the network. These system administration skills are highly sought after by employers. The use of free and open tools means that anyone can understand and improve the network.

1.3 Wireless Communications

In Internet-speak 'Layer 1' refers to the physical medium used to transmit information. A variety of Layer 1 technologies exist, such as hybrid-fiber-coax (Cable), copper (DSL and Ethernet), fiber optics (Active Ethernet), and microwave (WiFi, Cellular). Most free networks use microwaves as their primary medium, though larger freenets also make use of copper and fiber optics. Each of these media has its own set of benefits and drawbacks — the choice of which to use is driven by the interplay of geography and economics. It is our opinion that microwave represents the optimal choice for this project.

In large part this is due to the fact that microwave infrastructure is by far the least expensive to install and maintain. It does not require the trenching or hanging of cables, nor does it require expensive or proprietary equipment. Since it first came to the consumer market twenty years ago, the cost of microwave network capacity has decreased by a factor of more than 1000x. This trend continues today, with a host of significant advances achieving commercial viability.

At the same time, microwave is not without significant drawbacks. In the United States, unlicensed microwave communications is restricted to three specific frequency bands. As more and more WiFi devices come online, these bands are becoming increasingly congested. Left unchecked and unmanaged, this interference has the potential to significantly reduce network performance.

In addition to congestion, it is important to consider the fact that microwaves are significantly weakened when passing through opaque materials such as earth, wood, concrete, and steel. While some penetration of these materials is possible, backbone network links demand a clear path, and repeaters will be required to cover the insides of buildings.

Despite these limitations, microwave technology ultimately represents the best choice of medium due to its long range, small cost, and ease of use. As the network grows and capacity demands increase microwave links can be reinforced with copper, fiber, and advanced wireless technologies such as milimeter-wave and laser.

1.4 Free Network Architecture

The architecture employed by the KCFN was developed by the Free Network Foundation between 2011 and the present, in collaboration with networking groups from around the world, including guifi.net, Freifunk, WLAN Slovenia, and Connecting for Good.

1.4.1 Physical Plant

Before any network devices are powered on, there is a significant amount of engineering and effort that must go in to making sure network hardware is safely installed. Here are a few of the best practices in device installation:

Cabling It is important that all outdoor cable installation be done with UV-rated, shielded ethernet cables. We recommend Ubiquiti ToughCable Carrier Grade, for its low cost and outstanding durability. Indoor installations should always use plenum-rated cable, to ensure that cables do not become a health hazard in case of a fire. We also recommend that all cables be installed out of the public eye, and out of the public reach.

Mounting Devices mounted to the sides of building should be anchored into masonry or studs, and should be mounted using UFL approved brackets. Self-tapping screws ease installation, and provide for a secure brace.

Masts The two primary methods for mast construction are hold-offs and non-penetrating roof mounts. Hold-off mounts should be secured in at least three places, and anchored into masonry. Roof mounts should use UFL approved bases, dense masonry ballast, and a non-conducting mast, such as EMT conduit. The weight of the ballast, in ounces, should exceed the wind-bearing surface area of any antenna elements, in square inches, by a factor of five.

Power Delivery For safety and ease of installation, we recommend that power be delivered to all devices using IEEE 802.3 Power-over-Ethernet.

In this way, no electrical cabling has to be installed, and electrical hazards are significantly curtailed.

Grounding Any installations that exceed their surroundings in height should be grounded. This can be achieved by running a ground wire, or by using grounded RJ-45 ethernet jacks, and cable that has an integral ground wire, such as Ubiquiti ToughCable.

Gear Security Gear such as switches, dedicated routers, servers, and power distribution units should be located indoors or in a weather-rated outdoor enclosure. Indoor installations should be placed in a utility closet or other secure room.

1.4.2 Hardware

Through lab and field testing, we have selected components and developed a suite of four network devices. All of the hardware employed is readily available, off-the-shelf equipment, selected for performance, durability, and software support. We call this suite of devices the 'FreedomStack':

FreedomNode The node is the smallest of the four devices, and is designed to connect a single family or small business to the network. For optimum performance, the node should be located indoors, such that it has a view of the nearest relay. The suggested hardware for a node costs under $50. In case a home or business already has a router, the cost can be reduced to less than $25.

Technical Details: The recommended hardware for a FreedomNode is the Netgear WNDR3800, though any WRT-compatible dual-band router can be used. By using a dual-band device, the node is able to connect to the Freedom Network on the 5.8GHz band, while using the 2.4GHz band to provide access to clients devices such as laptops, tablets, and phones. In this way, the node functions as a wireless modem, and as a wireless router. For modem functionality alone, we recommend the TP-Link 703n.

FreedomRelay The relay is a block-level network anchor. It serves to connect a group of nodes to the neighborhood-wide network. Relays should be placed outdoors, such that they can be seen by as many nodes as possible, and so that they can see a neighboring relay or tower. The suggested hardware for a relay costs under $500.

Technical Details: The recommended hardware for a FreedomRelay is a ALIX 2D2 Motherboard with two Ubiquiti SR71-15 SuperRange radio modules, four 5GHz 8dBi omni antennae, MMXC to SMA feed cables, outdoor enclosure, passive Power-over-Ethernet adapter and associated mouting hardware. The use of a dual-radio setup enables the relay to perform as a full duplex device, avoiding the need for a single radio to split its time between receive and transmit cycles. The relays and nodes in any given neighborhood form a mesh network, meaning that devices can move around or power off, and the rest of the network will adapt and continue to function. The use of duplex devices is critical for the performance of the mesh.

FreedomTower The tower is a neighborhood-level network hub. It acts as a bridge between a neighborhood network and the city-wide network of towers. Towers must be located on roofs or hilltops with line of sight to at least two other towers. The baseline cost for a tower is roughly $1300.

Techincal Details: The recommended hardware for a FreedomTower is two Ubiquiti Rocket M5's equipped with 30 dBi dish antennae, three Rocket M5's equipped with 16 dBi 120-degree sector antennae, and a Ubiquiti ToughSwitch8-Pro.

FreedomLink The link is intended to serve as a city-wide Internet gateway, content server, network controller, or all of the above. Links must be placed in a datacenter environment, with roof access for the radio gear and line of sight to at least two towers. While the suggested hardware for a link costs $3000, link operation requires an ongoing capital expenditure of at least $250/month.

Technical Details: The recommended hardware for a FreedomLink is two Ubiquiti Rocket M5's equipped with 30 dBi dish antennae, four Dell PowerEdge 2950 rackmount servers, and one Cisco Catalyst WS-C2960S-24TS-S 24-port 10/100/1000 switch.

1.4.3 Firmware

Of the devices listed above, the majority are classified as 'embedded devices' — low-power computers responsible for a very specific task. These particular devices are designed to establish wireless links and make decisions about network routing. In order to function, they require an operating system for embedded systems, otherwise known as a 'firmware'.

In addition to their performance and reliability, the selected hardware was chosen because it is capable of running OpenWRT, a significantly stripped down version of the GNU/Linux operating system that powers most web servers. Free networks run on free software, because access to the source code makes it possible to know exactly what is going on inside the machine, and to make any modifications one desires.

OpenWRT comes in many varieties, each with its own set of features. The Kansas City Freedom Network uses a customized version of *quick mesh project* or qmp. qmp is mesh network firmware that leverages recent advances in network routing and management, and is maintained by The guifi.net Foundation. In addition to the basic utility of OpenWRT, it has the following advanced functionalities:

Address Management IP address management is handled automatically, without user or administrator intervention. The default behaviour is to assign each device a block of addresses capable of supporting 255 clients.

Techincal Details: During the device initialization process, a unique address is generated by cryptographically hashing the MAC address of the primary network adapter. The chosen hash function is the CRC-16 cipher.

Routing The routing protocol employed by qmp is BMX6, developed by Axel Neumann of Freifunk Berlin. The protocol is used to dynamically determine the best path for traffic.

Technical Details: BMX6 is an IPv6 native, distance-vector protocol. It is designed to automatically respond not just to changes in the network, but to the actual quality of the links between devices. BMX6 has excellent loop avoidance and route convergence properties, but perhaps its greatest strength is extremely low overhead, especially when compared to other mesh systems.

Instrumentation & Management qmp includes tools for collecting information on usage and device status through a command and control server. It also includes tools for remotely managing device configuration, reducing the need for on-site management.

Technical Details: The snmp and collectd libraries are used for instrumentation, and rUCI is used for remote management.

1.4.4 Software

While the combination of hardware and firmware above enables network devices to effectively communicate, other pieces of software are required to make the network truly useful. While all common software can be used over the network, here are some of the particular free software utilities that we recommend:

Firewalling For connecting the network to other large networks, such as ISPs or intranets, we recommend pfSense. It is strong on security, and has a host of enterprise-grade features

Tunneling TunnelDigger, developed by the Slovenian free network, can be used to create VPN tunnels between devices. In this way, a device can be strictly associated with a particular gateway router, or can be linked directly to any other device.

Media Publishing GNU MediaGoblin is designed to publish photos, videos, and text in a clean, presentable way. It supports community contributions, as well as bulk uploads.

Distributed File Storage Tahoe is a way for neighbors to store files on each others' computers while maintaining complete privacy. This way, if somebody's computer crashes, their important files can be recovered from the storage grid.

Community Mapping TidePools is a mapping application that allows communities to crowd-source map information. The neighborhood knows itself best, and can share information about what is going on, and where.

2 The Kansas City Freedom Network

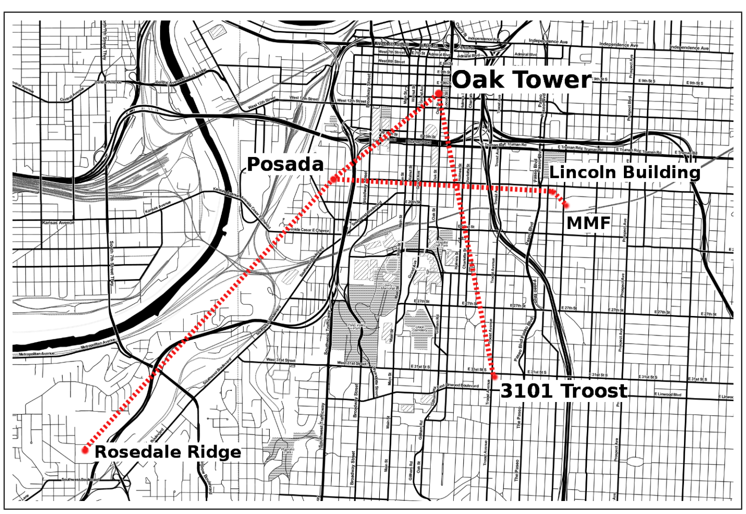
2.1 Governance & Operations

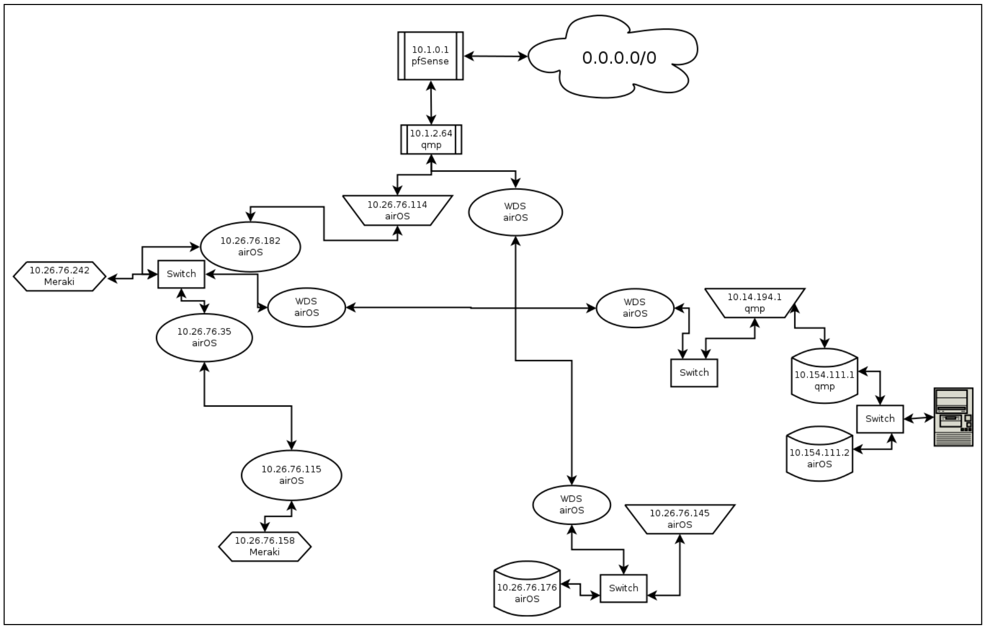
The Kansas City Freedom Network was established in December of 2012, when Connecting for Good and The Free Network Foundation joined forces to bring connectivity to the Rosedale Ridge Housing Project in Kansas City, KS. Since that time, the KCFN has welcomed the Mutual Musicians Foundation and Reconciliation Services to the coalition, and expanded to serve several hundred families and a number of organizations around the metro.

While participants are free to do as they like in accordance with the Network Commons License, cooperation amongst operators is central to keeping the network running smoothly. As such, the KCFN holds a weekly meeting to coordinate its activities, make decisions that have network-wide implications, and plan for the future. Decisions at the network level are made using a consensus process.

2.2 Existing Infrastructure

The Kansas City Freedom Network extends accross Kansas City, Kansas and Kansas City, Missouri. It serves residential and enterprise clients with symmetrical, high-speed connectivity. Figure 1 is a to-scale map of the network as it exists today, while figure 2 is a logical map, showing network devices and their connectivity:





While the figures above paint a decent picture of our current footprint, it is equally important to understand the social and economic infrastructure that supports these devices. The best way to understand the network is to review the installations that are in place today:

Oak Tower Oak Tower, at 11th and Oak, hosts the FreedomLink that currently serves as KCFN's primary Internet gateway. The link is owned by Connecting for Good, which purchases colocation, radio rights, and Internet service from Joe's Datacenter on a monthly basis.

Technical Details: This link consists of a single Dell server running pfSense, connected to two Rocket M5's on the 27th floor via a Netgear 3800 running qmp. One Rocket is equipped with a 30 dBi dish antenna, while the other is equipped with a variable beam-width sector antenna. Both radios shoot through storm windows to connect with the towers at 3101 Troost and Posada del Sol.

Posada del Sol The FreedomTower at Posada del Sol, on the 1700 block of Summit Street in KC, MO serves as an important distribution point in the network. The Mutual Musicians Foundation owns a dish that connects to the Lincoln Building. Connecting for Good owns two dishes, with one connecting to the sector antenna at Oak Tower, and the other connecting to the tower at Rosedale Ridge. Six access points serve residents inside the building. The owner of the building, Westside Housing, provides space to Connecting for Good and the KCFN in exchange for network access.

Technical Details: CFG owns two Rocket M5's with 30 dBi dish antennae. The MMF owns a NanoBridge M365. All three radios are mounted to a 10' non-penetrating mast atop the seven story building. Six Meraki access points — one on each floor — distribute access throughout the building. All three dishes, along with one of the indoor access points, are linked to a five-port ToughSwitch and Uninterruptible Power Supply located in a utility closet on the seventh floor.

Lincoln Building The FreedomTower at the Lincoln Building serves the area surrounding 18^{th} & Vine. Of the two radios at the Lincoln Building, one connects to Posada del Sol, while the other anchors a neighborhood mesh. The tower is owned and operated by the Mutual Musician's Foundation, which receives space from the Black Economic Union.

Technical Details A NanoBridge M365 and Nanostation M5 are mounted to a 10' non-penetrating mast atop the roof of the three story building. They are connected to a TouchSwitch and UPS inside a utility closet on the third floor.

Mutual Musicians Foundation The MMF hosts a FreedomRelay, serving the 1800 block of Highland Ave, portions of 19th Street, and the Foundation itself. In addition to a powerful mesh repeater, there is a dedicated media server, and a WiFi hotspot for the use of musicians, administrators, and neighbors.

Technical Details: A Rocket M5 with 10 dBi dual-omni, and a Bullet M2 with 9 dBi horizontal omni are attached to a 10' hold-off mast anchored into roof cornice of the two story building. These radios are attached to a ToughSwitch in the first floor office via an alloy conduit anchored into exterior brick face. A Dell XPS in the office runs Debian GNU/Linux, and is also attached to the switch.

Rosedale Ridge The FreedomTower at Rosedale Ridge connects to Posada del Sol, and serves residents of the complex via four access points. While the eqipment there is currently owned by Connecting for Good, it is to be given to the complex owner, Yarco, in December of 2013.

Technical Details: A Rocket M5 with 30 dBi dish is mounted on a 10' non-penetrating mast atop the three story building at the north of the complex. Four Meraki access point in the courtyard distribute connectivity through the complex.

3101 Troost The FreedomTower at 3101 Troost is jointly owned by Reconciliation Services and Connecting for Good, and connects directly to the FreedomLink at Oak Tower. In addition to one device dedicated to anchoring a neighborhood mesh, there is a WiFi hot spot that serves the bus stop at 31^{st} & Troost.

Technical Details: A Rocket M5 with 30 dBi dish is mounted on a railing atop the five story building, and connects to Oak. A nearby non-penetrating boom holds the Nanostation M2 Loco that lights up the bus stop. The Rocket M5 and variable beam sector that anchors the neighborhood network is mounted on a railing atop the belfry, one story up.

In addition to these existing sites, two additional towers are slated to be brought online in the near future:

Lincoln Prep Lincoln Prep, because of its commanding vista, appropriate architecture, and historical significance, will be a key site in the KCFN. After months of preparation, construction at the site is slated to begin in February.

Technical Details: Multiple hold-off mounts will be used to mount two NanoBridge M5's, and a Unifi Outdoor radio above the cafeteria. Routing and switching gear will be located in an adjacent mechanical closet.

Mary L. Kelly Center The Upper Room Program is currently seeking funding to improve and extend the KCFN backbone from Oak Tower to 3101 Troost, and from 3101 Troost to the Kelly Center at 51^{st} & South Benton. Access and education for the surrounding communities are paramount concerns.

Technical Details: Unlike most links in KCFN, the proposed backbone would use 24GHz radios, achieving speeds in excess of one gigabit per second.

3 Study Results

3.1 Objectives

In order to assess the feasbility of extending the KCFN inside the UNI footprint, it is essential to define well-established targets for any potential work. The proposal that follows is intended to satisfy the following requirements:

Purpose This proposal is for a project intended to improve the state of connectvity for businesses and residents within the urban core, establish local hubs for connectivity and digital skills education, and demonstrate an organizing model that can be replicated in other communities.

Scope The geographical area under consideration is bounded by 22nd Street on the North, 71 Highway on the East, 52nd Street on the South, and Troost Avenue on the West. In addition to The UNI and UNI Partner organizations, it should involve an array of area residents, businesses, non-profits, and community groups.

Coverage The paramount concern is improving the availability of affordable residential Internet service for those within the designated geographic scope. While it isn't possible to guarantee coverage to 100% of residences with a community network approach, our objective should be to allow any and all blocks within the area to participate. This will not be possible without significant investment and involvement from within the community itself.

Functionality Those that elect to participate in the network, in addition to gaining access to resouces published on the KCFN, should have the ability to purchase low-cost Internet access.

Performance While exact performance figures will depend case-by-case on a number of factors, the KCFN should enable broadband connectivity capable of supporting telephony, web 2.0, and multimedia applications.

Cost The total cost of accessing the Internet via the KCFN, including hardware, should be lower than existing alternatives over the course of one year.

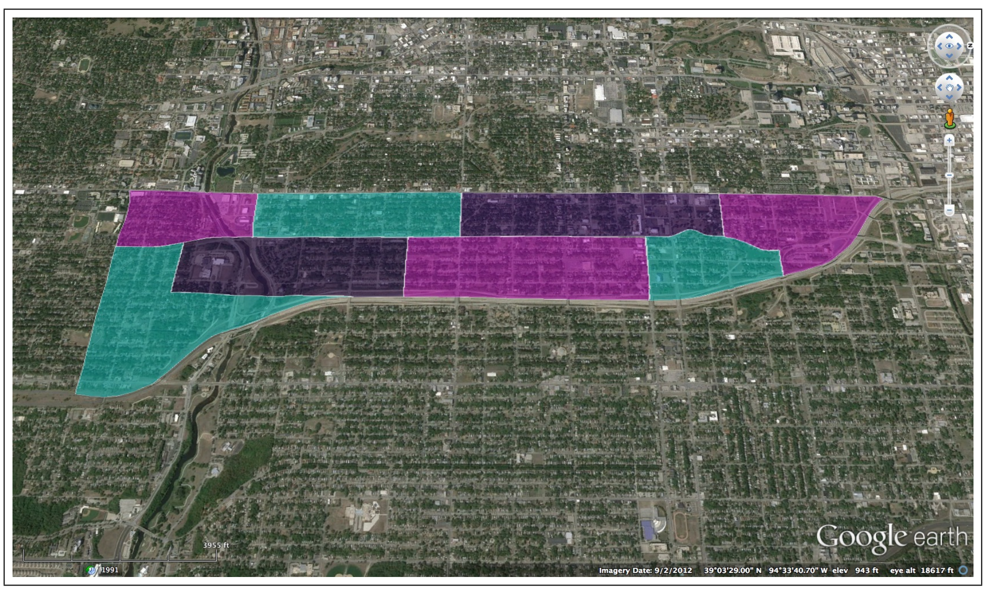
Sustainibility Above all, this effort should aim to foster a digital commons that is sustainable in the long term — focusing first and foremost on education, grassroots support, and the capacity for ongoing, organic growth.

3.2 Survey Information

The primary physical considerations in determining build feasibility and an appropriate course of action are topographic terrain, available structures, and the RF environment. We surveyed the target area in November and December of 2013, and January of 2014, analyzing the lay of the land and assesing spectrum availability.

3.2.1 Overall Terrain

The terrain in question is varied in topology and foliage density, and large enough to make the use of a single, homogeneous network architecture impractical. As such, we have divided the area into eight distinct 'clouds'. These clouds do not conform to existing neighborhood boundaries, but are instead focused on producing an efficient and cost-effective organizational scheme for the network.



The eight clouds, as depicted in the map above, are as follows:

Kelly Cloud The Kelly Cloud presents the most difficult terrain in the study area, with a significant rise in elevation to the west of 71 Highway, large foliage, and few commercial structures. The Kelly Center provides sight lines to the eastern face of Blue Hills, but a higher than usual density of relays will be required to achieve desired levels of coverage, especially in the ravine near 48^{th} & Brooklyn.

Rockhurst Cloud While the Rockhurst cloud has a similar dearth of viable commercial relay sites, the terrain is more forgiving. Decent lines of sight should be achievable at street level, requiring roughly 2 relays per block.

Paseo Cloud The Paseo cloud presents extremely favorable conditions. Paseo Academy's commanding vista offers good coverage of the slight slope that rises north from Cleaver II Boulevard. Slightly thinner than average tree cover will aid in establishing relays.

Bancroft Cloud While the Bancroft cloud does not have many useful multistory buildings, the terrain is relatively forgiving. Despite steep gradients running East to West, longer relay connections should be acheivable running South-North along major thoroughfares.

Eastern Cloud In the Eastern cloud, there are fewer steep gradients, and a decent number of valuable relay sites. Slightly lower than average relay density should be achievable.

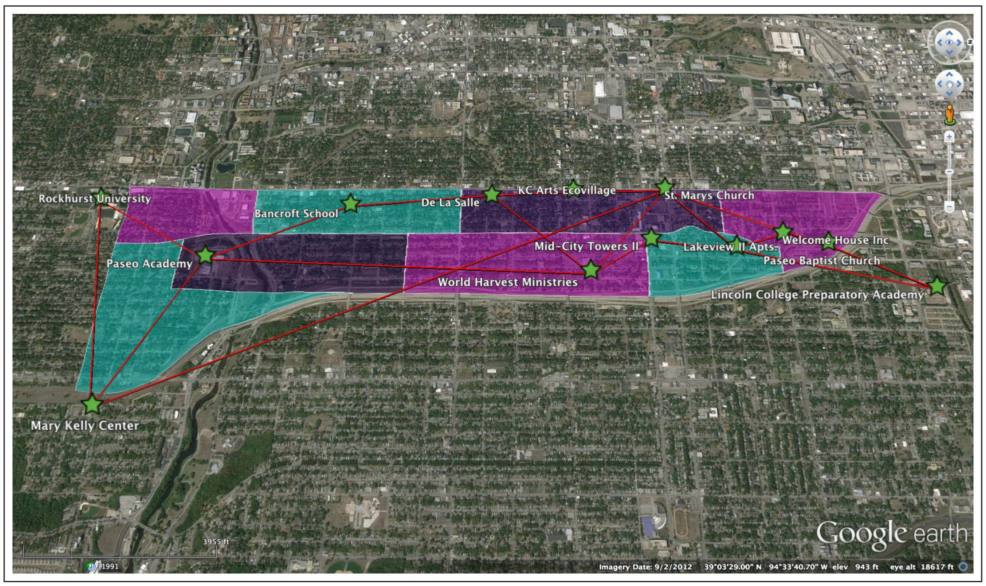
St. Mary's Cloud In St. Mary's cloud, there are a large number of commercial buildings, with ample opportunities for interconnection. Relays will primarily communicate above tree level here, and sepctrum management will be a key factor. A higher density of multi-dwelling units will result in a higher ratio of relays to nodes.

Mt. Hope Cloud The Mt. Hope cloud, like the Rockhurst Cloud, will need approximately two relays per block. This is due to slight but considerable slopes, and a lack of prominent edifices.

Beacon Cloud Presuming the availablity of high-rise structures on West Paseo, the Beacon cloud should be relatively easy to cover. These high-rise structure, situated on a relatively open plain, will reduce the need for block-level relays.

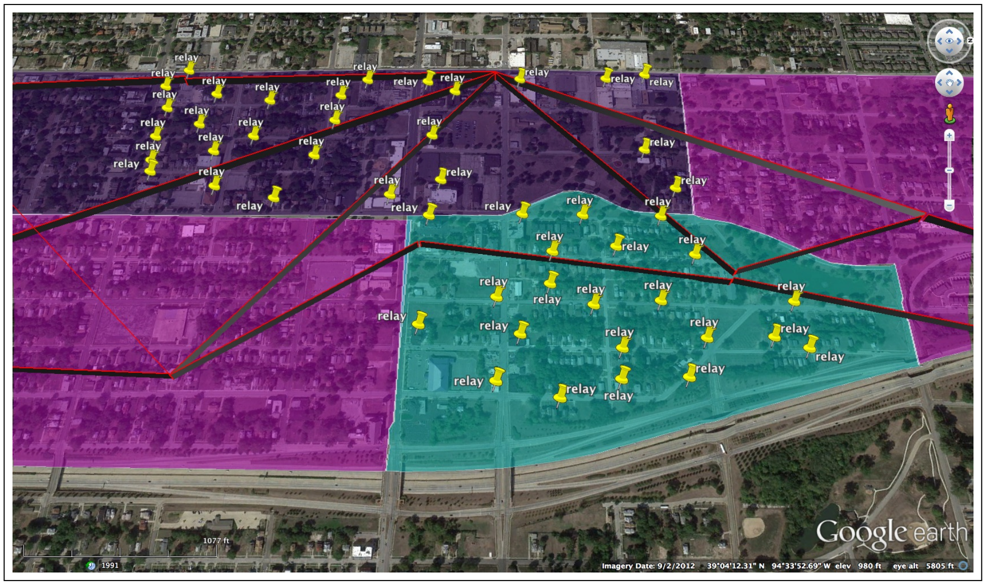
3.2.2 Structures

While terrain is certainly key, it must be coupled with a knowledge of which structures are suitable for the placement of equipment. Numerous factors affect the suitability of a structure, include its location, height, roof architecture, constructure, and usage. The map below illustrates how an ideal tower-to-tower network would be arranged:



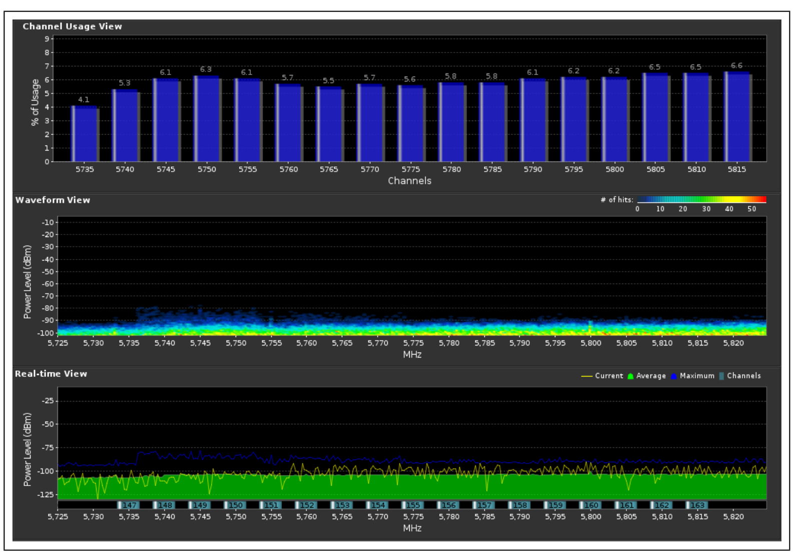
While we have determined these sites as the ideal tower placements, we understand that the facts on the ground in each neighborhood will inform final selection of locations.

In addition to surveying the entire study footprint for tower locations, we conducted detailed studies of the St. Mary's and Mt. Hope clouds. These detailed studies were used to create the projections of cost presented in our findings. The following map depicts a proposed distribution of relays across two of the clouds:



3.2.3 RF Environment

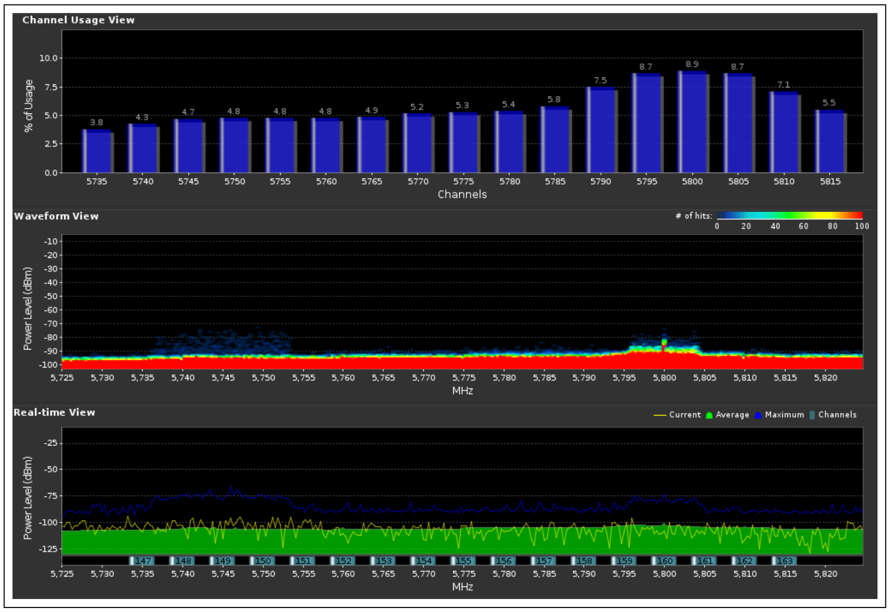
Our finding is that while appropriate channel selection and efficiency will be critical, there is ample spectrum available for use in the target geography. In order to assess spectrum health, we conducted sector surveys from the roof of St. Mary's, at 31st & Troost, and the Kelly Center at 51st & Chestnut. Looking to the north of St. Mary's, there is more than 50MHz of usable spectrum:



To the east of St. Mary's 75MHz is usable, with a noise floor below 90dBi. This is enough spectrum for three or four high throughput point-to-point links:

To the south of St. Mary's there is 65MHz of clean, usable spectrum, which should be more than enough to build the requisite links:

At the southern end of the study area, the situation looks quite similar, though with a slightly higher thermal floor. Looking north from the Kelly Center, there is 70MHz available:



Looking west from the Kelly center, towards Blue Hills and some of the most challenging terrain, virtually the entire 5GHz ISM band is available:

3.3 Social & Political Considerations

Though the laws of physics are unbending, they are certainly less complex than the laws of human interaction. Over the past several months, we have reached out to community leaders to guage interest in the project of building a network for and by the community. Those leaders include Margaret May, Mark Stalsworth, Wanda Taylor, Jonathon Bish, Joanne Bushinger, and decision makers at Kansas City Public Schools, and Kansas City Public Libraries. We have received promising indications of future partnership from all.

There will doubtlessly be further planning and exploration as we move forward, in order to assure that all parties have a sound understanding of the obstacles and opportunties afforded by this endeavour. Community organizing will be the bulk of the work in building a network, and we are confident that these and other partners are more than up to the task.

3.4 Findings

On the basis of our survey results and prior field experience, we have devised a proposed plan of action and associated cost estimates. These projections are intended to serve as a starting point for collaboration, and certainly do not reflect the only viable path towards accomplishing the stated objectives.

3.4.1 Proposed Plan

Phase 0 - Q1,2 2014 Improvements to the network, including the construction of a high-speed backbone, fully fault-tolerant routing, and robust user authentication are slated for completion in the first half of 2014. This should provide lead time for the UNI and UNI partners to organize programming around the network. More than raising capital for Phase I construction projects, we advise focusing on community outreach and education: building teams, and beginning to identify network operators.

Phase I - Q3,4 2014 Once the current round of network improvements is implemented, the first clouds should begin to come online. We have identified the St. Mary's and Bancroft clouds as the ideal locales for pilot work. Phase I would involve a concerted effort to raise public awareness of the network, construction of a FreedomTower for the Bancroft cloud, and the initial rollout of relays and nodes in the indicated areas.

Connecting for Good and Free Network Foundation engineers, rather than directly building and operating the networks, should be regarded mainly in an advisory role: training operators, and supervising the rollout.

Phase II - 2015 In Phase II, all remaining clouds should come online, while established ones proliferate and achieve desired coverage levels. CFG and FNF would continue to play a supporting role, ensuring continuity of operation of core infrastructure, but the onus of neighborhood network operation should be squarely on the community itself.

Phase III - 2016 & Beyond Once the initial rollout of the network is complete, focus should shift entirely to sustaining the effort. Responsibility for core infrastructure should be shared with or transferred to proven community operators. Training future operators and network participants will become the responsibility of network participants, along with Connecting for Good. The Free Network Foundation will serve only as an as-needed resource for solving high-level technical issues. The network, at this point, should be a point of pride for the community, and very much viewed as a cooperative, participatory effort.

3.4.2 Costs

While the community-driven model has its definite strengths, it can also make it difficult to give precise estimates of cost. Below, we provide the hard costs associated with building various network components, and estimates of the total number of such devices that would be required to achieve full coverage in each of the eight network clouds.

FreedomTower:

Item	Q'ty Req'd	Unit Cost	Total Cost
Ubiquiti ToughCable	2000ft	$.22/ft	$220
Ubiquiti ToughConnectors	20	$.53	$10.60
Ubiquiti ToughSwitch-8	1	$188	$188
Ubiquiti Rocket M5	5	$85	$425
Ubiquiti RocketDish 5G30	2	$150	$300
Ubiquiti Sector 5G19-120	3	$140	$420
3-Gang Cluster Mount	1	$131	$131
Alix 2D13 Router	1	$139	$139
Rohn-25GBRM Mount	1	$1458	$1458
Rohn-BRM6PAD Insulator	1	$360.90	$360.90
Rohn-LRCL Arrest	2	$123	$246
#4 Copper Wire	40'	$1.69/ft	$67.60
Rohn-25G Tower Section	2	$117.95	$235.90
Labor	75hr	$75	$ 3750
Total	-	-	$7,952

FreedomRelay:

Item	Q'ty Req'd	Unit Cost	Total Cost
Ubqiuiti ToughCable	500ft	$.22/ft	$55
Alix 2D2 Router	1	$110	$110
Alix 2C4 Enclosure	1	$60	$60
Ubiquiti SR71-15	2	$85.99	$171.98
L-Com HG5808U Antenna	4	$78.95	$315.80
Laird SMA Adapter	4	$7.75	$31
Passive PoE Adapter	1	$3.50	$3.50
Alix BRK1D Mount	1	$2.50	$2.50
Labor	2hr	$50	$100
Total	-	-	$849.78

FreedomNode:

Item	Q'ty Req'd	Unit Cost	Total Cost
Netgear WNDR3800	1	$114.99	$114.99
Labor	1hr	$25	$25
Total	-	-	$139.99

Based on the cost figures above, and the density, terrain, extant structures, foliage, and RF environment encountered in our survey, we project the following costs to achieve full coverage of the entire UNI footprint:

	Towers	Relays	Nodes	Total
Kelly	1	55	400	456
	$7,952	$46,737.90	$55,596	$110,285.90
Rockhurst	1	48	300	349
	$7,952	$40,789.44	$41,997	$90,738.44
Paseo	1	35	250	386
	$7,952	$29,742.30	$34,997.50	$72,691.80
Bancroft	1	55	400	456
	$7,952	$46,737.90	$55,996	$110,685.90
Eastern	1	46	500	547
	$7,952	$39,089.88	$69,995	$117,036.88
St. Mary's	2	65	300	366
	$15,904	$55,235.70	$41,997	$113,136.70
Mt. Hope	2	49	310	360
	$15,904	$41,639.22	$43,396.90	$100,940.12
Beacon	1	30	200	231
	$7,952	$25,493.40	$27,998	$61,443.40
Totals	10	383	2,660	3,053
	$79,520	$325,465.74	$372,373.40	$777,359.14

In looking at these numbers, it is important to keep in mind that for the network to succeed, as much of the capital investment as possible should come from the community itself. Outside support, if utilized, should be limited to funding initial tower builds, to seed organic, internal growth.

Organizational support should focus on outreach and education, with the aim of producing a corps of capable network operators from inside the community. Aside from create jobs, this approach fosters a self-sufficient and sustainable network that does not depend on any single entity.

4 Conclusion

Few would argue with the idea that connectivity creates opportunity. The real challenge lies in figuring out how to fight for access in a way that is both sustainable and effective. We believe that the key to success lies not in technology alone, but in technology and education enabling communities to invest in themselves.

By stewarding the emergence of a network with no single owner or operator, we can help make sure that Kansas City's core doesn't depend on budget policy or grant funding just to get online. The Network Commons License provides a framework for building just such a network.

We urge you to examine the NCL, and ask you to consider the ideas and proposals in this document. We know that they are not exactly conventional, but they have proven themselves effective time and again.

Together, we have the opportunity to demonstrate a powerful new model for digital inclusion and profoundly impact the future of our community, our city, and our society.