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ERECTOR SET: Building Muni Wi-Fi Networks

I'll start off in the daily **eight@two** blog posts here with some core [802.11](#) and [802.16](#) citywide infrastructure build out to provide an idea of just how these citywide 802 networks need to be designed and planned out.

In this episode I'll dive into the different components and the software that is needed to mesh across the metro areas. Over the next few days I'll then talk about the services and applications that ride over these networks as well. At some point we'll get into how these muni builds should be approached from a funding and commitment to usage basis as well. Maybe Rome will be built in a few days...

802 muni networks are built with two initial key factors in mind - coverage and capacity. The coverage factor is at the end user edge, connecting end users via 802.11b-g Wi-Fi to the muni mesh end point routers. Capacity begins at the high speed broadband IP injection points. From the IP injection points, 802.11a and 802.16 wireless "backhaul" extends this high capacity broadband IP in a muni mesh network to the end user connectivity points out at the edge. Because high capacity broadband IP injection is paramount, the design should be planned outward from the broadband injection points onward out into the mesh toward the end user access points at the edge. When you get to the end user edge, it is there where you work on the density of points, positioning, and strength of signal for best coverage.

It is also important to consider how many separate connections it takes to get to the backhaul routers and then onward over the backhaul to the gateway routers at the broadband injection points. Each point to point "hop" causes a latency in the signal and a reduction in bandwidth. Therefore having multiple injection points is very important, you can have the same high bandwidth, just more "paths" to get to it with the least number of router hops.

There are "point to point" meshed grid connections and point to multipoint "starburst" design techniques to consider when connecting to the backhaul points and the IP injection. A muni mesh design therefore is very dependent on the overall router geographic density, path design, the capabilities of the software to route over these paths in real time, and in maximizing the number of paths with the least hops to get to the gateway IP injection points. Intelligent predictive routing software that operates in real time is the key.

The best 802 muni design will be limited if the software controlling the signals and their multiple paths through the muni mesh is not capable of real time predictive routing. The OS must real time control direction and path changes based on the broadband signal capacity available, end user numbers, user distribution, and the geographic user density. A true intelligent mesh network has this OS software embedded into each mesh radio access router.

The problem in failed muni designs is that typically the 802 wireless hardware used was running on recycled indoor wireline routing technology and weak software routing systems. It's not good 802 Muni Wi-Fi design to build a wireless mesh network intended to support hundreds of thousands of end users with a dated variation of wireline "spanning tree" design. That typically won't work, it gets bogged way down in bandwidth drop and high latency with the rising numbers of connected end users.

True muni mesh access and backhaul routers are built in a weatherproof and high wind resistant enclosure and operate in the carrier class for quality of service (QoS), they are not what you are used to seeing in a home like a Linksys, Netgear, or D-Link. Home based wireless does not have any roaming access point to point mesh capability. Typically muni access routers are based on 802.11 b-g technology for coverage, and 802.11a and/or 802.16 for IP capacity injection and backhaul routing. The injected IP bandwidth is symmetrical uplink and downlink, which is not the case with DSL and cable modems, those have very slow uplink asymmetry. That is a big problem when connecting VPN, VLAN, WAN, and when using VoIP phones.

In particular, I'll talk about [Tropos](#) gear here and their software as a reference. The Tropos routers are each a fully intelligent mesh system in of themselves - they have the mesh "brain" operating system software embedded in each. They have excellent Wi-Fi broadcast and receive sensitivity, they can be deployed in low node density for any given level of performance and coverage. Fewer Tropos routers are required to achieve carrier-class quality of service (QoS) performance.

The Tropos OS software enables their outdoor stationery access routers, mobile routers, and indoor routers. Tropos 5320 MetroMesh routers are ruggedized and weatherized and can be mounted on external structures such as buildings or lamp-posts. The 5320 is dual radio, there is a second 802.11a - 5 GHz spectrum radio that is configured to act as the capacity layer for backhaul to the other routers. This is a big step up from having capacity delivered out to a point and then sending it out to multiple end unit routers at the edge. Dual radio design eliminates "hops", which cause signal latency and bandwidth drop off. Latency sensitive applications such as voice over internet protocol (VoIP) telephone service is better served with the 5320 dual radio routers. Coverage **AND** capacity.

Next, Tropos 4210 mobile routers are for vehicular and marine applications. The mobile router meshes with the fixed routers in the muni network, and they are equipped with the same high-power radios. These establish tactical response network points, and provide Wi-Fi access in high-speed mobile environments such as police & fire, EMS, utility trucks, commuter trains, buses, and offshore boats. Each Tropos 4210 router rebroadcasts around it the same 802.11 b-g IP connectivity for other Wi-Fi users nearby - it's a mobile hot spot on the go.

The Tropos 3210 indoor router extends the metro-scale Wi-Fi coverage area indoors. It provides the same high performance, scalability, mobility and multi-use network capability as the outdoor models. It is designed to replace or enhance blocked internal areas and hard-to-wire indoor environments. [Ruckus Networks](#) also

has some really excellent consumer level units with patented antenna and broadcast software to accomplish the same receive and rebroadcast function indoors.

Once the [Tropos MetroMesh OS](#) software is up and running, the Muni Wi-Fi system is set for performance testing and fine tuning. This is typically done with purpose-built mobile drive-test gear. Tropos has one that determines in the real world environment the block-by-block metro-scale coverage and throughput capacity. Tropos "Drive" software can be configured to emulate the characteristics of any Wi-Fi user device, say a Dell laptop with Linksys card. Testers drive throughout the area, and utilizing integrated GPS technology, accurately plot both the coverage and throughput capacity onto maps, providing a view of real-world 802.11 b-g Wi-Fi performance.

Tropos has additional software that analyzes the results of the mobile drive around testing and further tweaks the network capacity in real time. It enables network operators to perform a plethora of important functions, including over the air configuration and updates of the edge routers, with whole network performance monitoring and statistical capture. It enables precise coverage and capacity tuning without the hassle and cost of sending out truck rolls to adjust points internally.

Finally, another software system is used as an advanced network analyzer and optimizer. It gives visibility into network-wide performance statistics, in real-time. Not just overall mesh performance, but to each mesh point down to the end user's performance as well. It retrieves data from the OS that is embedded in each access router and identifies opportunities for performance coverage and capacity optimization.

Those are the basics of the muni mesh system design, gear, and software. At the capacity level there are also devices and systems that use the 802.16 "Wi-Max" for backhaul and broadband injection.

[Wi-Max back haul](#)

In the last episode, we configured the Muni Wi-Fi mesh network concentrating on the 802.11 products side. We also worked on the robust metro mesh OS software and the analysis software was discussed as the key to getting a Muni Wi-Fi network properly established for both geographic coverage and user capacity. Software is paramount, it's what makes the network "work" and provides the real time intelligent analysis, adjustable capacity and coverage, and the real time dynamic routing of traffic along the highest throughput path to the broadband internet injection points.

To get back and forth to those broadband injection IP points, a network can be "switched" or transferred over to 802.16 Wi-Max routers in aggregated sections~groups. These 802.16 back haul routers operate at greater capacity capability while maintaining low latency and bandwidth loss. Wi-Max at the backbone, and Wi-Fi at the edge mesh is a hybrid design that provides the best 802 application at the right portion~section of the network. Capacity at the core back haul, coverage at the Wi-Fi 802.11 b-g edge.

Some key players in this 802.16 range are [Redline Communications](#), [Alvarion](#), and [Motorola Canopy](#). To connect to aggregated groups of 802.11 b-g routers, there are level 2 mesh configurations: 802.16 point-to-point (P2P) back haul; and 802.16 point to multi point (P2MP).

In a P2P configuration a wireless connection string is made to and through each point. Each 802.16 router is positioned side by side with, and connected directly to, an 802.11 router that then feeds it's group of meshed sibling 802.11 routers. Each of these 802.11 - 802.16 pairs then proceed P2P to the next 802.16 - 802.11 router pairing and on again to lead to the gateway broadband injection point. If they are chained along a fiber ring or a fiber line, they can "T" connect into this fiber gateway broadband injection source at any of the individual positions, or in multiple positions (better).

Another variant of this approach is to wireless connect an outer circular area of 802.16 routers to 3-6 802.16 backhaul units that are placed together firing outward forming sectors. This is typical in a sonnet fiber ring. In a starburst pattern these central sectorized units can broadcast toward outer "sectors" in the P2MP configuration. The inner points are then also connected to high speed broadband injection access. It's a hub and spoke approach to use the outer ring and then transmit capacity bi-directional to the central hub. 802.16 gear has wireless connectivity trouble with obstructions and foliage, so typically these routers need to be mounted up on buildings or on taller street lights over any line of sight (LOS) problems. The better units have 144Mbps over-the-air bit rate with up to 90Mbps net Ethernet throughput ([Redline Communications AN-80i](#)). That enables high capacity for VoIP, video, and heavy data traffic back haul (CAPACITY!).

We're now all back haul connected, and we have our 802.11 b-g muni mesh set up. It's now time to move into and talk access software, access gear, and services that can be broadcast over this Muni Wi-Max and Muni Wi-Fi hybrid network.

[Accessing the metro mesh](#)

So, we now have a new killer metro mesh 802.11 b-g Muni Wi-Fi network built out and we're also 802.11 and 802.16 backhaul connected to fiber optic gateways with high speed/high capacity IP access. It's time to talk access software and how that works connecting and enabling end users.

When you have a wide area Muni Wi-Fi system you have possibly hundreds of thousands of users trying to access and roam across thousands of 802.11 b-g access router points. That alone is daunting. But consider that you're also going to have many different types of access requests, and several different types of access data requirements - core data, voice, and video streams. Add into this that some of these access requests will need to be pooled together in user groups. Groups will be required for utilities, EMS, hospitals, police, fire, schools, hotels, corporations, separate municipalities, communities, and individual consumers. Not your basic household Wi-Fi access network! Access management software, control, and security is where the rubber meets the road...

One prime company for this type of software task is [Aptilo Networks](#). Aptilo offers comprehensive wireless service management platforms designed for service providers, enterprises, and municipalities needing rapidly deployable, scalable multi service access solutions that can easily manage data and voice services over metro wireless, Wi-Fi ~ Wi-Max networks.

Some muni network operators choose to develop this type access software system themselves, EarthLink does. The problem with that is the enormous amount of detail demanding specialization and the need for extremely robust data crunching and storage capabilities. With database size and data storage requirements

that can be extremely demanding, you're in need of a software system that is scalable and able to work with top database software like MS SQL and Oracle. This isn't an Excel spreadsheet task...

Aptilo's metro wireless service management solution enables highly secure authentication, authorization, encryption. It's Quality of Service (QoS) support enforces service flow parameters for different users, devices and services, thereby enabling prioritizing of police and other public safety responder traffic within a single system. The Aptilo system is also already fully integrated with the leading metro mesh vendors such as Tropos, BelAir and Firetide.

[The Aptilo Service Management Platform](#) is the core component of the Aptilo Metro Wireless Service Management System. [The Aptilo Service Portal](#) is the main tool for automatic processing and display of data, and is used together with the [Aptilo Access Controller](#) which securely communicates with the service platforms and oversees access and QoS control for Aptilo's solutions. Together these Aptilo software packages allow secure username & password connectivity, enable QoS for high priority and time sensitive data like police, fire, EMS, VoIP, and video. And it allows each separate grouping of individuals or entities to be managed and historically stored for analysis, billing, and data retrieval.

Get connected. Mobile client devices do not require anything other than a standard web browser or supported client software to connect to the network. The Aptilo Access Controller automatically redirects the user to the web based service captive portal, a splash screen showing the connection options and user account creation along with providing the necessary information to login and connect.

The authentication process enables client terminals to be authenticated without the installation of any special software other than a standard web browser with Secure Sockets Layer (SSL) support. The Aptilo solution supports the following types of authentication:

- 1) RADIUS Server located in the Aptilo Service Management Platform
- 2) Remote RADIUS server interaction via RADIUS proxy
- 3) Roaming support through RADIUS proxy
- 4) Online Credit Card payments
- 5) Mobile Phone account charging
- 6) SMS-OTP (One-Time-Passwords)
- 7) Vouchers, Scratch Cards, and E-Vouchers
- 8) 802.1x (MD-5, EAP-TLS, EAP-SIM, etc.)
- 9) Automatic MAC/Cookie-address logon
- 10) Software based clients for automatic end-user access from various vendors and service providers (e.g. WISPr compatible clients, iPass, Boingo and Vodafone)
- 11) PMS (Property Management System) interaction for hotel room billing

So there is our user layer access brain. Of course what has to happen now is an interaction with an Internet Service Provider (ISP), which is par for the course wired or 802 wireless. That actually can be self or 3rd party provided, depending on who you are getting the core broadband connectivity from for the 802 network.

Uses on the Muni Network Part 1

We have access! We have a speedy 802.11 ~ 802.16 roaming network. We ready to let her rip!

What's a key function on this muni system that will save business costs, cause revenue and savings to increase for both suppliers and consumers, and vastly lower down time benefiting both as well? Wi-Fi enabled, Automated Meter Reading (AMR)!

There are devices now available to upgrade electric, gas, and water meters to automatically read the usage at the end user site, and automatically send this data onward to the utility for constant real time monitoring of service, demand, and usage. This is a tremendous advantage over the century old method, a manual mechanical device that has to be physically accessed by a human, usually in 30 day increments, or even guesstimated and read every 60-90 days. Stone age technology...

There are some pseudo "at distance" reading devices, however all this really does is semi automate the process. You can place a radio device on the meter, and then drive around with a radio receiver and "read" that instant collection of usage. But you still have no real time user demand information, nor do you have the huge cost reductions in automated usage reading with these labor intensive operations and transportation costs.

In addition, you're not real time viewing the utility demand and system load balancing, which especially in electric can save greatly on distribution and the daily spot injection of additional electric capacity. With a minute by minute detailed database history this 802.11 AMR creates, daily quantity energy planning can be calculated out far more accurately. And end users can view a report on their own usage or on a potential property they may purchase, and thus make better informed decisions.

So how does this 802.11 AMR system work? It starts at the usage meter, mainly as a coverage device. The data does not "tax" the capacity of the system, it is small in quantity and usually done in 15 minute increments at most. One company that supplies these devices is [SmartSynch](#).

SmartSynch's motto is "embrace the power of information" and that is what I am talking about here. Their "SmartMeter System" is an end-to-end solution that manages the access and delivery of metering information, providing utilities with critical usage and rate data as well as real-time metering alarms. SmartSynch's AMI *Intelligence* solutions engage utilities and users in real-time with the information each needs to effect changes by making economically and environmentally intelligent energy choices.

Each SmartMeter can be configured to transmit interval data as often as every 15 minutes. Utilities can then present timely and accurate metering data to customers and offer dynamic rate incentives for decreased

usage at peak times. The SmartMeter System also supports critical-peak pricing functionality, enabling utilities to designate certain peak usage periods as energy prices warrant.

Smartsynch was awarded a **GoingGreen** top 100 award for their technology saving on utility costs and making end users far more efficient saving energy and money. SmartSynch's data enables utilities to increase their power and operational efficiency while affording their customers the ability to manage daily energy usage and significantly reduce their electricity bills and the impact on the environment. *Green is good!*

When an energy outage occurs, an 802.11 "alarm" is sent to the host system, where it is recorded and routed to end users, outage management systems, and meter technicians as they are received. The SmartMeter will transmit a "last gasp" notification when detecting an AC power outage at the metering point and will notify when the AC power is restored. The benefit is localizing the problem in real time without having to hunt it down. And getting power restored quicker and at lower cost.

The muni Wi-Fi during these outages will stay on due to battery backup. When the truck rolls to the repair area it will mesh into the Wi-Fi network with its mobile access point and rebroadcast the network into the surrounding area. With this IP connectivity back to home base, data, voice, and video can be interchanged facilitating the operation smoothly and integrating all departments seamlessly. Even the end user can be notified of the progress in real time.

The same goes for gas utilities and water. In [Corpus Christi's installation](#) they calculated a \$30,000,000 savings in costs with a similar AMR system over the next 20 years. And they used this network to then add on police, fire, EMS, city inspectors, businesses, and consumers for additional return on investment.

[Calling all cars! Police, Fire, EMS, Inspectors, and more...](#)

Just like we enabled the utility trucks, we now similarly take advantage of the muni 802 and enable police, fire, EMS, inspectors, and the mobile public workforce. The network is already justifying the build cost with excellent Return On Investment (ROI) on the utility side. That's due to automatic meter read (AMR); far more efficient utility demand & load monitoring; superior load balancing; lower cost and faster outage response and repair; and higher overall system and worker productivity across the board. The same will hold true for these new added public and private users and their various types of 802 access needs.

The FCC has dedicated public safety its own 802 band to help ensure these folks are not competing with the general public user traffic and are operating on a secured separate band. That band is in the 4.9 GHz range and vendors like Tropos Networks have access router models that are specific for it, and are built out with 802.11 routers in the same chassis.

On this 4.9 Hz access band, users are going to want to access data files, pictures, streaming video clips, and real time surveillance video cameras. The [Tropos 9532 router](#) has a 4.9 GHz & 2.4 GHz dual band capability. Typically, these separate 2.4 GHz bands are set up as pure 802.11g for higher bandwidth and better coverage. They can get away with that g only detail because the end users are known commodities and the equipment can be specified for 11g. This allows for better signal throughput capability, especially for video and VoIP radio & telephony.

Like in the previous utilities application, there are specific mobile 4.9 GHz access routers that increase connectivity coverage and act to rebroadcast the signal around the mobile vehicle for improved wireless connectivity by lower power devices that are operating in the area. The [Tropos 9422 router](#) is such a critter. It allows the mobile operator to take the entire base station's intranet along, enables access to video surveillance, and to set up at the scene their own data, voice, and video and send it to base.

The above holds true for fire, & EMS. Hospitals can extend to the edge with video, voice and data which increases reaction time and improves edge capability. The muni workforce also benefits. Besides meter read, they also can increase response time and improve productivity for inspectors and investigators.

[The Roamin' Empire - All Hail Receiver!](#)

...and his **802** noblemen the "transmitters" too. Here's what to do on the new Roamin' Muni Wi-Fi network.

Get connected... Whatever **802.11** device you have, go to the wireless connection window and search for networks. Several will probably appear, just as they do on a home or indoor business **802.11** b-g search. The network name will appear, say for example "[Shark^{fi}~](#) Key West". Click on it and it will connect to the best access router near you and then mesh back wirelessly to the gateway IP broadband access.

That [Aptilio access management software](#) then kicks in. As an unidentified end user it's ready to greet you. You may have a device and software that prompts first for your username and password. If your account is already set up and you're paid up, enter here (Squidly, password) and automatically trigger the Aptilo software to register you in and you're good to go. **Happy, happy, joy, joy...**

If you need a [Shark^{fi}~](#) account, you can get one in this example when you open a web browser. The first page will open to a [Shark^{fi}~](#) "splash page" that shows where you are Muni Wi-Fi connected and your options for getting through and onto the Muni Wi-Fi mesh.

Here at the splash page will be choices for the type of access account you want, say a day, a week, a month, or a longer term account. You'll also be able to select bandwidth, choosing if you want a standard "T-1" class [Shark^{fi}~](#) account at 1.5 Mbps up/down symmetric, or a business class Tiger "[Shark^{fi}~](#)" account at 3 Mbps down and 1.5 Mbps up? **Get the drift so to speak!**

Then the splash page will present your payment options and go through a form fill session to get you all set up. Then "**Kerplunk!**", you're swimming in Muni Wi-Fi! Say hi to SpongeBob if you surf past him.

What to do? Take advantage of the mobility. Pick up a mobile **802.11** b-g device you can leverage your untethered capabilities with. Here are some links that list many tested and compatible devices you may choose: [Wi-Fi Alliance certified](#) .

Of course you also can get Voice over Internet Protocol (VoIP) telephone service from various vendors like Vonage, Covad, Skype, etc.. Here is a site that you can check out various providers: [VoIP](#)

It's also possible to use your computer, tab PC, or PDA as a converged data and voice machine by installing the VoIP softphone on it. It then will integrate with email programs like MS Outlook. One such provider is [IP Blue](#).

Another option obviously is to Muni Wi-Fi your music like what's available using the [iPod Touch](#) and the [Logitech Squeezebox](#) with [SlimServer](#) software. That enables your music to be accessed and played anywhere on the wireless mesh network.

Access and services options for the Muni Wi-Fi network

Let's start out with some different meter reading. [Digital Payment Technologies](#) has meters and a system to allow 802.11 Wi-Fi access to parking meters that makes life an lot easier for municipalities, operators, universities, and customers. They have a patented on-street electronic parking meter design and a full featured web based remote management software system that can be addressed and managed via proactive email alarming for repair and maintenance. The meters can also be remote updated for rate and configuration information, allowing different rates to be programmed in for various time of day, days, and/or for events. These also allow various payment methods like credit cards, vouchers, monthly billing cards, access passes etc.. Imagine not having to run out to the car to dump in more change. Just access the meter over the **802** network and add in more time. Ran out of dough? Have you bud do it for you, from London, Tokyo, Sydney, etc.!

[Virtual Private Network](#) (VPN) is a communications network tunneled through another network, and dedicated for a specific purpose. One application is secure communications through the public internet, which in our case here is our Muni Wi-Fi. Distributing VPN to homes, telecommuters, and small offices may put access to sensitive information to end users so security is typically applied to these connections via encryption. The VPN is connection allows you to securely take all of your data, audio, and video with you as you roam throughout the Muni Wi-Fi area. It also allows you to securely access other sources on the fly, opening up a whole new world of productivity while being able to be mobile and interact with other persons and entities - anywhere. At the café talking about a project and forgot a few notes and pictures back at the office? No problem, tunnel in and access the office LAN. Get a VoIP call from a friend while out shopping that needs to know how you connected that home theater system? VPN into your home files and photos back home and forward them on. At the store and get worried about whether you left the gate open and the dog might get out? VPN to your home web cam network securely and check.

Muni Wi-Fi opens up a whole new world of converged communications. Hosted [Microsoft Exchange Server](#) email [with Outlook software](#) (requires [Shockwave](#)) on the user end is far superior to using a painfully limited web based service like Gmail, Yahoo, and Hotmail. The Outlook software is far more robust, has many more useful features, integrates seamlessly with the entire [Microsoft Office 2007 suite](#) (Outlook, Excel, PowerPoint, Word, OneNote, Explorer 7), and also with powerful third party software like [Cisco Unified Communications](#) and [Adobe Acrobat Pro 8](#). Businesses and individuals are now fully enabled and mobile, with an entire suite of software and VoIP phone capabilities that were only available to huge enterprise business just recently, and then that was limited to chained to a wall wired LAN connections. Free at last!

Another mobile feature that is useful is [Google Maps](#). Instantly, on the run, receive satellite views of locations, directions, businesses in the area you need, etc. etc.. They now even have "[street view](#)" which gives you a 360

degree view of points from the street at thousands of spot in major cities, soon to be expanded further. Click the little guy and have fun, drag him to another street for a view from there. And with GPS, you can track where you are or a colleague from the office or home.

That just a few applications and uses for the Muni Wi-Fi network. As the blog entries are added we'll certainly add more. *Until next time, [Happy Trails...](#)*