We all know ham radio can provide consistent voice communications "when all else fails," but what about an on-the-fly digital network for e-mail, video and internet links? Oh yeah, "we do that..."

HSMM-MESH
Networking in EmComm Applications

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The question of "relevance" is often raised when amateur radio operators express interest in supporting the emergency communications requirements of local governments, the Red Cross, Salvation Army, National Weather Service, and other agencies. There are jokes about Morse Code and the compelling "cool factor" of $5,000 digital portable public safety radios. Even a discussion of cell phones can sometimes put amateur radio into the "south forty" of potential backup solutions, even though this is patently unjustified on many levels. Besides having a corps of trained, equipped, and able operators to perform common communications tasks, we bring a toolkit of flexibly deployable solutions to immediate communications problems and challenges. HSMM-MESH networking is one such solution and tool.

Photo A– Map of the Fair Lawn, New Jersey, fireworks area with the locations of each HSMM-MESH node noted. (Photo A courtesy of KC2RSS. All other photos courtesy of the author.)

What is an HSMM-MESH/ Broadband-Hamnet Network?

HSMM-MESH combines the **H**igh **S**peed **M**ulti **M**edia capabilities of wireless Ethernet with routers that can perform automatic network (**MESH**) configuration. An HSMM-MESH network uses a set of specially-programmed wireless routers that search out "neighboring" routers and then exchange information among themselves about which routers are on the network and what other routers they each can contact and with what level of signal quality. Using this technology, routers can arrive on a site and be joined to a network within a few seconds. This is done using a periodic, but automatic, reconfiguration process to become part of the network. It enables user data and devices to move their data automatically and transparently across a set of routers.

Recently, a new version of the software has emerged which is called "Broadband-Hamnet." This is a replacement for the older, "HSMM-MESH" network software. While it is incompatible, it is inclusive of familiar features and capabilities and all users are encouraged to migrate their networks. In this article, we will use the terms interchangeably to describe how the system can be used rather than to describe specific software. (For more on the history and background of HSMM-MESH for amateur radio, see the sidebar "The HSMM-MESH Story.")

What Can I Do with a Broadband-Hamnet Network?

An HSMM-MESH/Broadband-Hamnet network can be a stand-alone network without an Internet connection or it can be augmented with an Internet connec-

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tion, allowing users without direct access to the Internet to gain such access for themselves or for their devices. In this mode, the mesh extends the reach of the Internet into buildings, over hills and around corners where it would not otherwise be available. In the case where the HSMM-MESH/Broadband-Hamnet network is "standalone", or even if it is equipped with an Internet Gateway, users and devices can access other computers for databases, Internet Relay Chat (IRC) servers, Voice over IP (VoIP), an FLDIGI Server Gateway for HF/VHF/UHF digital modes, video surveillance using IP cameras, and more!

Beating the Doldrums

During the doldrums of the winter of 2013, several of us in northern New Jersey began to discuss HSMM-MESH networking. It turned out that many of us already had functional nodes that we had "played with," but which were now sitting unused in our closets and under our workbenches. Then Mike Hoeft, K2MPH, the Passaic County Radio Officer and a sergeant with the county Sheriff's Department, put out a question to his amateur radio contacts asking about the feasibility of mesh networking. Well, that was all it took to get gear moving back onto benches and out into the field. We started testing at every opportunity.

First, we flashed (loaded) the HSMM-MESH code into a whole bunch of Linksys routers, creating new mesh nodes (see sidebar, "Flashing a Node"). Then we flashed and meshed a couple of nodes at the Fair Lawn Radio Club at one of their weekly gatherings. Then, we found ourselves testing across parks and parking lots to get a feel for what a stock unit could do with stock antennas. Next came terminal-to-terminal communications using a variety of laptops across the mesh, and that was quickly followed by IP cameras provided by Karl, W2KBF. These tests were exciting!

We brought nodes to the Bergen Amateur Radio Association Hamfest and got interest from many hams there who saw the video across the room! More testing and flashing of nodes followed, with many hams from several different groups and clubs participating and collaborating. We started to look at repeater sites as potential node locations and for operational opportunities to apply the HSMM-MESH network nodes. On the horizon for the next few months were the Memorial Day Parade in Fair Lawn, the Fair Lawn Fireworks, and a 1,400 rider bike tour. Wheels started to turn— and fast!

We Love a Parade!

Karl, Garry, KD2DDK, and Steve, WB2BYX, embedded a camera within the Fair Lawn Memorial Day Parade and relayed video to the reviewing stand using HSMM-MESH. It worked pretty well and gave us experience in setting up and configuring the nodes, cameras and computers used to view the video. Coordination of moving units also became a topic of discussion and, in the end, the experience was really worthwhile, both as a technology trial and as a useful video tool at the finish line.

Ka-Boom!

Our next event was the Fair Lawn fireworks for Independence Day, held in a large park with a swimming pond separating the public from the launch area. This event had always been covered by hams using FM voice simplex, but we decided to see what we could do to improve things with the cameras and an Internet gateway. Our plan was to deploy nodes with operators around the park's perimeter accesses, in the

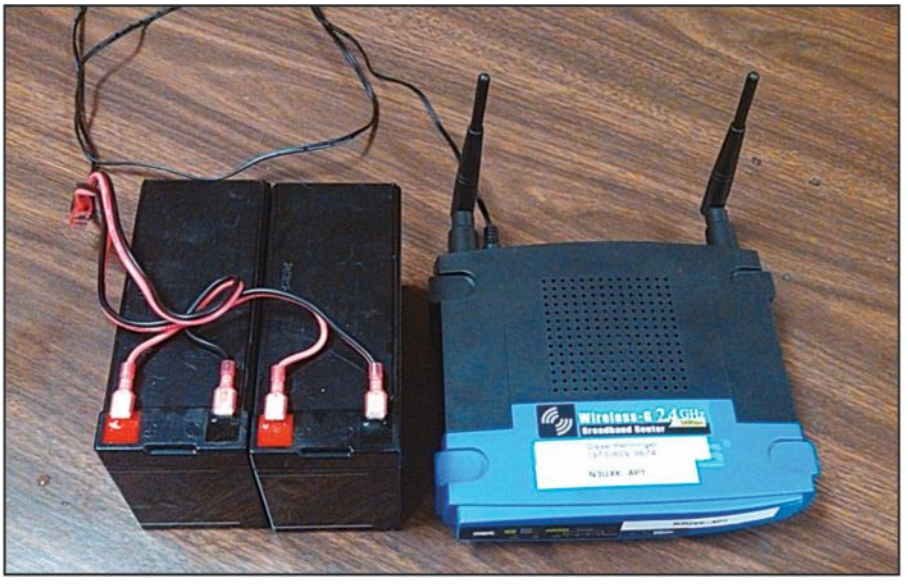


Photo B– A simple portable node consists of nothing more than a Linksys router a 12-volt DC battery.

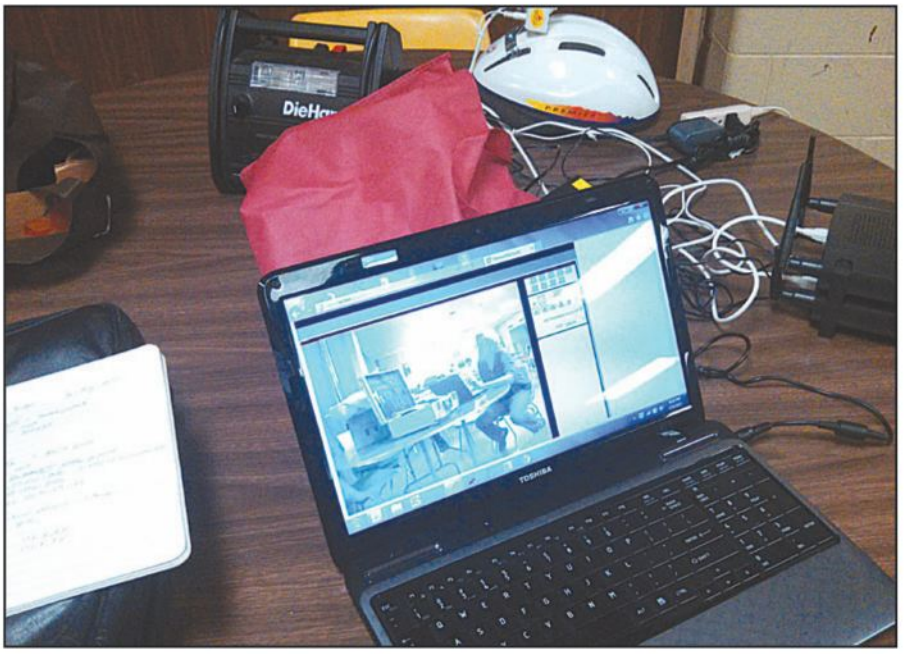


Photo C– W2KBF's video setup includes a helmet camera/transmitter (in back ground) and a receive monitor on a laptop.

public viewing area and in a net control operator location (photo A).

Heavy rain caused a one week postponement of this event, which allowed us to refine and to practice our deployment, first at an indoor tabletop exercise and then in the park itself. Through the inspiration and hard work of Zach, KC2RSS, we added an Internet Relay Chat server. These were valuable experiences for all involved and fixes and adjustments were made. Remember, "practice, practice, practice" or "You fight as you train, so train as you fight." Our preparations over the weeks and days leading up to the fireworks really helped us deliver what we expected and perhaps a bit more.

At the fireworks display, we were able to deploy an autonomous "MESH" network across the park, run entirely from portable DC power (photo B). Karl, W2KBF, had a "helmet" camera which provided a flexible, mobile platform for providing video in spots across the venue (photo C). I incorporated a second camera into a "SuperNode" (photo D) that has lots of integrated functions and was deployed in the public viewing area, focused on the crowd. The capability of autonomous video cameras was of such a quality that we were approached by local law enforcement to work on future plans to interconnect each of our video feeds to enhance coverage. The cameras we used had automatic infrared lighting which proved to be quite effective over a large area. Score one for amateur radio!

We also used texting via the Internet Relay Chat Server that was implemented on a small Raspberry Pi Ubuntu-based computer. The group texting "chat room" was local to the site and did not rely on the Internet to work. It solved the problem of acoustic interference with voice communications (fireworks can be *loud*)! It further kept our laptops off of the wireless cellular networks where the public would be streaming video to their friends. This allowed for unfettered and effective communications of key information (fig. 1). Just to be certain, we had two servers on the mesh network in case one failed to operate. One was co-located with a node at net control while the backup was in the SuperNode. In practice, both systems worked fine so we had a functional backup for the duration of the event. Score another for amateur radio!

Our Internet gateway, also incorporated into the SuperNode, allowed for access to outside resources for

The HSMM-MESH Story

Amateur radio operators themselves are an asset in emergencies because they often are "solutions-oriented" individuals who can cobble together functional systems with available resources "when all else fails." While this is good, amateur radio operators can often do more than simply fill a gap;– we can create and fill opportunity spaces that were unaddressed by the infrastructure of traditional communications services and do it economically and effectively.

One such technology solution is the HSMM-MESH network software designed, written and supported by a creative group of radio amateurs in Austin, Texas. These intrepid souls started with some inexpensive Linksys Routers (WRT-54G family) and then modified a free package of software (Open-WRT) to address the operational, legal and functional requirements of amateur radio to produce the HSMM-MESH software.

Currently, Glenn Currie, KD5MFW; David Rivenburg, AD5OO; Bob Morgan, WB5AOH, and Rick Kirchhof, NG5V, are working on a newer package of software that will support additional hardware platforms which should be available about the time you read this.

For more information on "HSMM-MESH" and the newer "Broadband-Hamnet" software, updates and application ideas, go to Jim Kinter, K5KTF's wonderful website: <http://www.hsmm-mesh.org/>.

"Flashing" a Node

What is involved in getting on the air with an HSMM-MESH node?

Currently, most of the Linksys WRT-54G, WRT-54GS and WRT-GL models will easily and inexpensively support HSMM-MESH operations. You can go to the <www.hsmm-mesh.org> website for guidance on the specific versions of each that are supported, along with a wealth of other information.

The next step is to log in to the Management Console of your router (usually <http://192.168.0.1> with a null name and password of "admin") and go to the Administration tab where you will find a place for the firmware upgrade. If you have the HSMM-MESH software available from the HSMM-MESH web site, you can simply upload it and it will automatically install and reboot. This step is commonly referred to as "flashing the code" into the router. After that, you can follow instructions on the same web site or on various YouTube videos to configure your node with your callsign and other parameters.

Photo D– The author's "super node" in progress. When completed, it included an autonomous video camera, Raspberry Pi Server, and an Internet gateway.

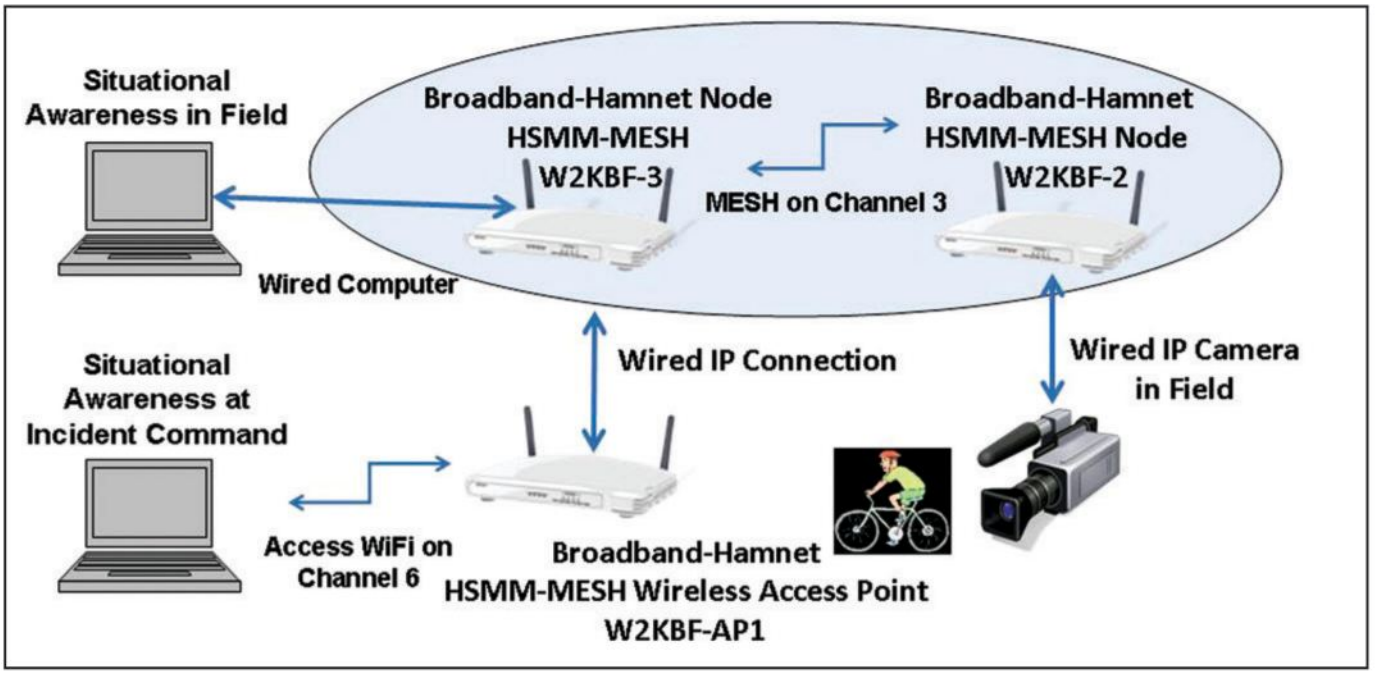


Fig. 1– How our HSMM-MESH/Broadband-Hamnet Network worked: The IP camera acted as a video web server and was accessed by Incident Command through a WiFi access point and the HSMM-MESH network. The camera was plugged into W2KBF-2 using an Ethernet cable. W2KBF-2 is an HSMM-MESH node, providing all of its services to other HSMM-MESH nodes, such as W2KBF-3 and W2TTT-1. MESH nodes permit wireless connections only to other MESH nodes. Computer access is via either a wireless access point, such as W2KBF-AP1, or through direct wiring to an HSMM-MESH node, such as W2KBF-3.

weather-related situational awareness. This came in handy as we were able to make adjustments in our deployment and keep the Fireworks Committee informed of the pending lightning and rain which ended up accelerating the start of the show in order to get the crowd home safely before the storm arrived. Score one more for amateur radio!

Not everything was rosy, of course, but we took note of what needed to be improved and brainstormed on how we might make those improvements. The importance of a post-event review cannot be underestimated, as it gives you a roadmap to improvement.

It was a great team effort that integrated traditional voice communications with a whole bunch of new and effective technology! Garry, KD2DDK; Karl, W2KBF (photo E); Randy, WU2S; Bill, KB2OCJ; Zach, KC2RSS; and I formed a core team, but there were many others who couldn't attend the fireworks, but contributed during the fabrication, configuration and testing of nodes over the days and weeks before the event (photo F). What was particularly noteworthy was that the core team from the Fair Lawn Radio Emergency Service/Fair Lawn Radio Club was effectively augmented and integrated with other operators from Bergen County RACES, Passaic County RACES/ARES, the Bergen Amateur Radio Association, the American Red Cross Amateur Radio Club (ARC Squared), and Boy Scout Troop 139/Venture Crew 7373. These folks all helped make the event a success.

Photo E– Garry, KD2DDK, and Karl, W2KBF, "flashing nodes" to add stations to the HSMM-MESH network.

On-the-Fly Networking

A few weeks later, several radio amateurs attended the Sussex County Hamfest and just happened to bring along their HSMM-MESH nodes. Within minutes, we created a surprisingly interesting network, which bodes well for the future of HSMM-MESH. While it is clear that the 2.4 GHz WiFi "radios" need line of sight, it is equally clear that if they *do*

Photo F– Dave, N3UXK; Gurz, KD2CK; Eagle Scout Arslan Gungil; Bill, KB2OCJ, and Nancy, N2FWI, were among those who worked "in the background" to help set up the network for the Fourth of July fireworks.

have line of sight, then long paths are possible.

We started with two demonstration nodes in the indoor part of the flea market. Only one node had visibility to the outside via a large door, where another node was set up by Dave, N2KTO. Dave had set up a node on a portable antenna stand and was able to maintain quality links to the W2BCC-1 and W2BCC-2 nodes located on a hill several miles away—all done with stock transmit power! Once we are able to have access to higher locations near important operational areas, we should be able to link sites, allowing for remote access to the mesh network. Further, this is an ideal example of how we can apply the HSMM-MESH network to extend the Internet to areas where it would have poor or marginal performance, such as into an evacuation shelter building or an interior office or basement. In this way, amateur radio can cover "the last mile."

Looking Forward

Our next steps to improve network connectivity include an effort to standardize our packaging and power solutions, while also improving our antennas and bi-directional amplifiers. Refining our network node configurations, adding reliable file storage, and voice and video servers will also extend our capabilities and usefulness to public officials and ease our operational challenges.

For the Ramapo Rally Bike Tour, we placed an Internet gateway partway up a hill, away from the crowded start/finish area, which provided reliable access even when crowds with phones formed in the assembly area below. We also placed cameras in the expansive start/finish and parking areas so that we could monitor the flow of cyclists into and out of the area.

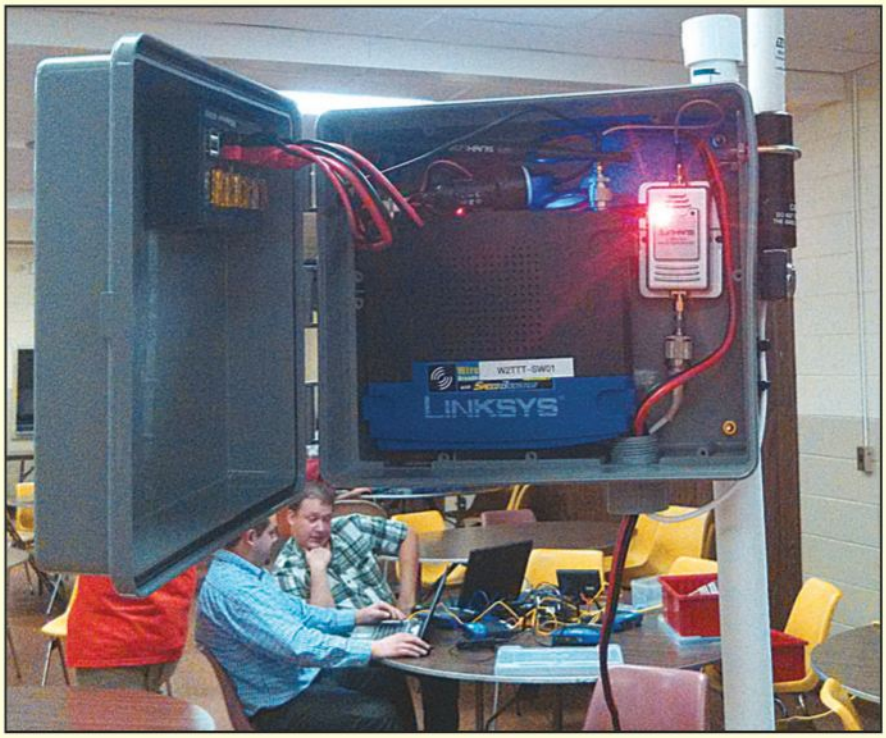
Documentation of our work is evolving rapidly, so we are using the "ComTechGroup" Yahoo group to store and exchange data among those interested this exciting area of amateur radio. You are welcome to join at <groups.yahoo.com/groups/ComTechGroup>, see what we are doing and share your experiences as well!

Part 97 or Part 15?

The FCC has amateur radio regulations in Part 97, while some consumer and other unlicensed devices such as these WiFi routers and access points are regulated under Part 1. WiFi channels 1–6 fall within the 13-centimeter amateur radio band (2300–2310/2390–2450 MHz; see table below), so can be used by hams under either set of rules. If we modify the devices to upgrade our transmitter power or antennas, then we are no longer in compliance with Part 15. As a reminder, as long as these nodes are used as Part 97 devices, we are required to follow the normal amateur radio operating rules including those applying to the control operator, identification and the types of traffic handled.

WiFi Channel	Frequency Range (MHz)
1	2401–2423
2	2404–2428
3	2411–2433
4	2416–2438
5	2421–2443
6	2426–2448

WiFi channels within the 13-centimeter ham band (2300-2310 / 2390-2450 MHz). Note that these channels overlap. Each one has a 22-MHz bandwidth.



Operating under FCC Part 97 rules allows amateurs more flexibility with their nodes. This node, for example, puts out 2 watts, far above the maximum allowed for unlicensed Part 15 use.