

Celebrating the ARRL Centennial

# **High-Speed Wireless Networking in the UHF and Microwave Bands**

Montgomery Amateur Radio Club  
Rockville, Maryland

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W2LNX@arrl.net and mesh@KB3TCB.com

# Introduction

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- brief history of ham radio wireless networking
- Ubiquiti airMAX wireless networking equipment
- current high-speed wireless digital networks
- building a high-speed wireless digital network
- conclusions

# Personal history of wireless networking

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- TAPR Terminal Node Controller (TNC) 2 – 1985
- the Phil Karn, KA9Q NOS TCP/IP package – 1991
- Dale Heatherington, WA4DSY 56KB radio modem – 1987
- Automatic Packet Reporting System (APRS) – 1992
- Broadband-Hamnet™ (formerly HSMM-Mesh™) – 2010
- Doodle Labs DL435-30 420 MHz miniPCI cards – 2012
- Ubiquiti airMAX wireless networking products – today

# Personal history of wireless networking

my first TNC – 1985 – used PBBS and later APRS

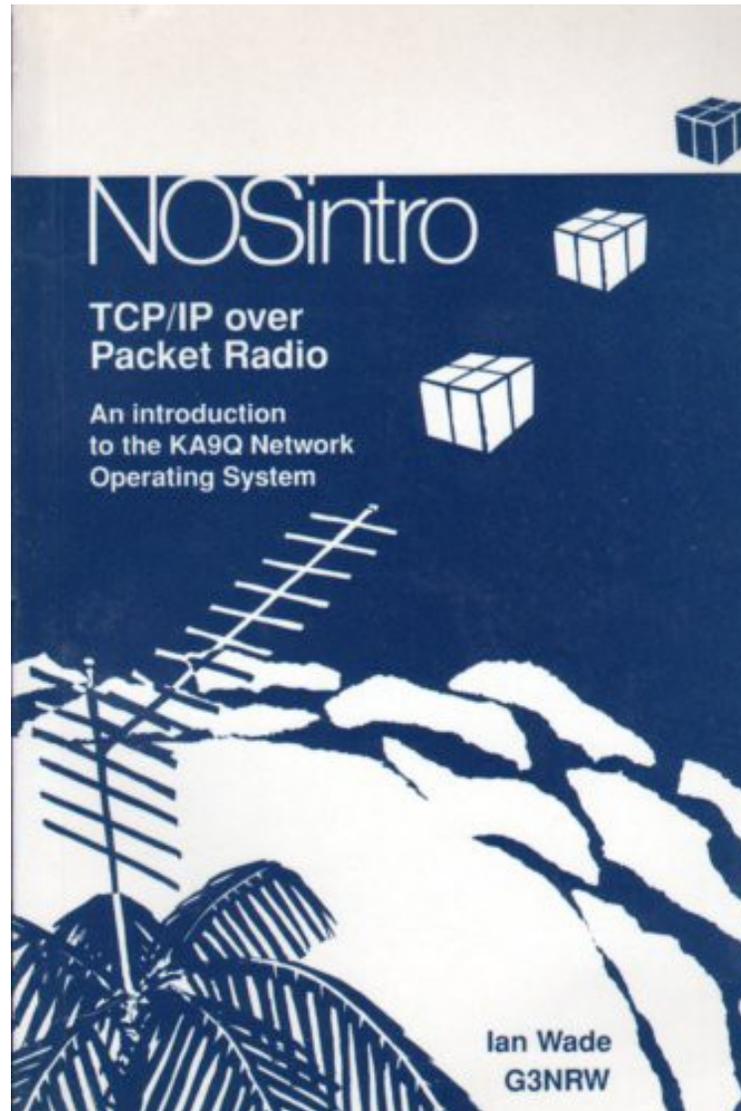


TAPR TNC 2 and FT-208R

# Personal history of wireless networking

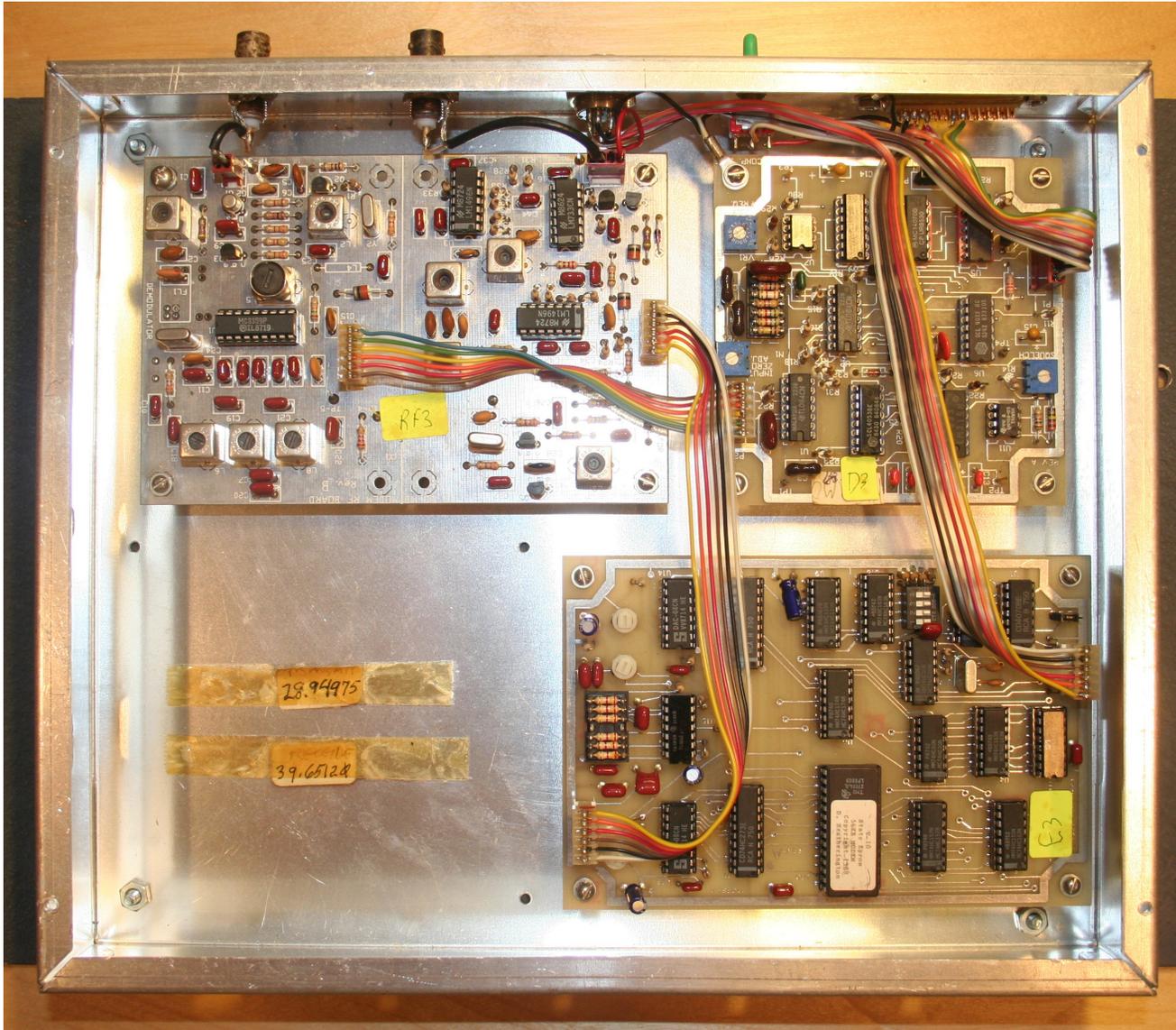
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used KA9Q NOS TCP/IP package on IBM PC – late 1980s



# Personal history of wireless networking

built WA4DSY 56KB modem – experimented in late 1980s



GRAPES WA4DSY 56 KB modem kit

# Personal history of wireless networking

met Bob Bruninga, WB4APR in Washington, DC – about 1995



APRSdos

# Personal history of wireless networking

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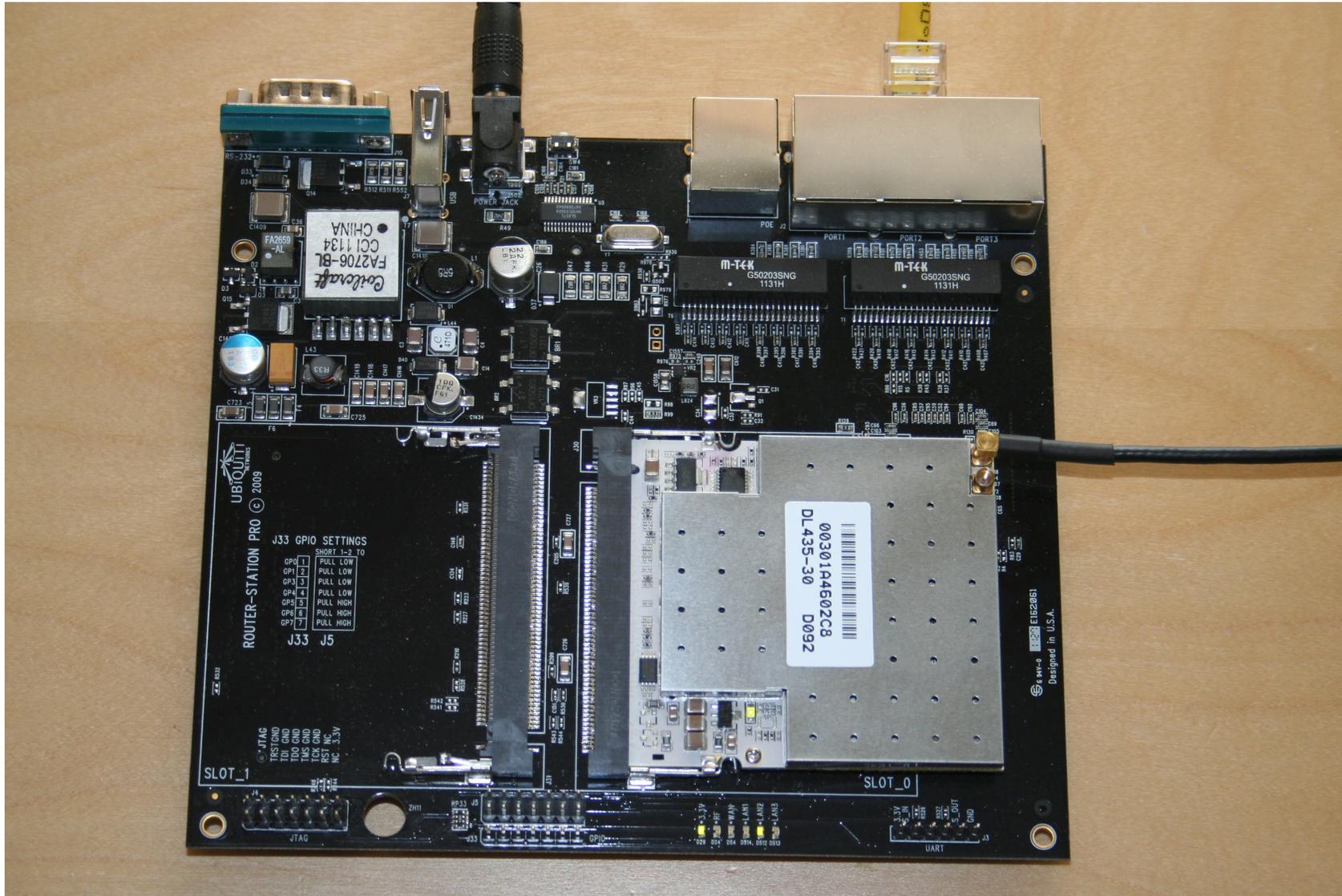
experimented with HSMM-Mesh™ with MARC members – 2012



Linksys WRT54GL wireless router

# Personal history of wireless networking

discovered Doodle Labs 420 MHz miniPCI cards – 2012

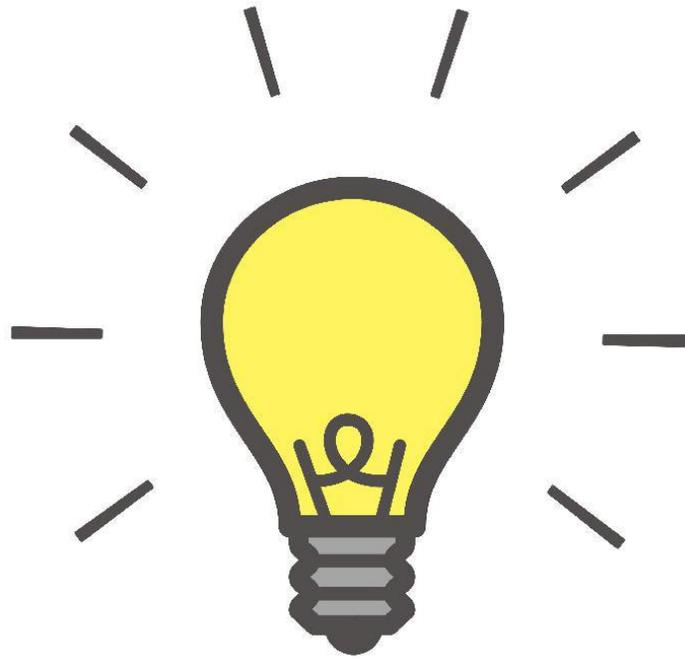


Doodle Labs DL435-30 in Ubiquiti RouterStation Pro

# Personal history of wireless networking

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This suggested a big idea – 2012



Can we build a high-speed ham radio wireless network using commercial off the shelf (COTS) equipment?

# Personal history of wireless networking



K1ZZ and W2LNX at the ARRL Centennial Convention

# History of wireless networking

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A hundred years ago – ARRL was founded as a network of amateur radio operators to relay messages

Today – wireless networking is

- automatic
- digital
- reliable
- microwave frequencies
- sensitive receivers
- low power transmitters
- less expensive
- COTS

We've come a long way!

# Ubiquiti wireless networking products

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Based on IEEE 802.11 protocols – uses OFDM and TDMA

airMAX	Ubiquiti	ISM	amateur
M900 900 MHz	902-928	902-928	902-928
M2 2.4 GHz	2402-2462	2400-2500	2390-2450
M3 3 GHz (1)	3370-3730		3300-3500 (3)
M5 5 GHz	5725-5850	5725-5875 (2)	5650-5925

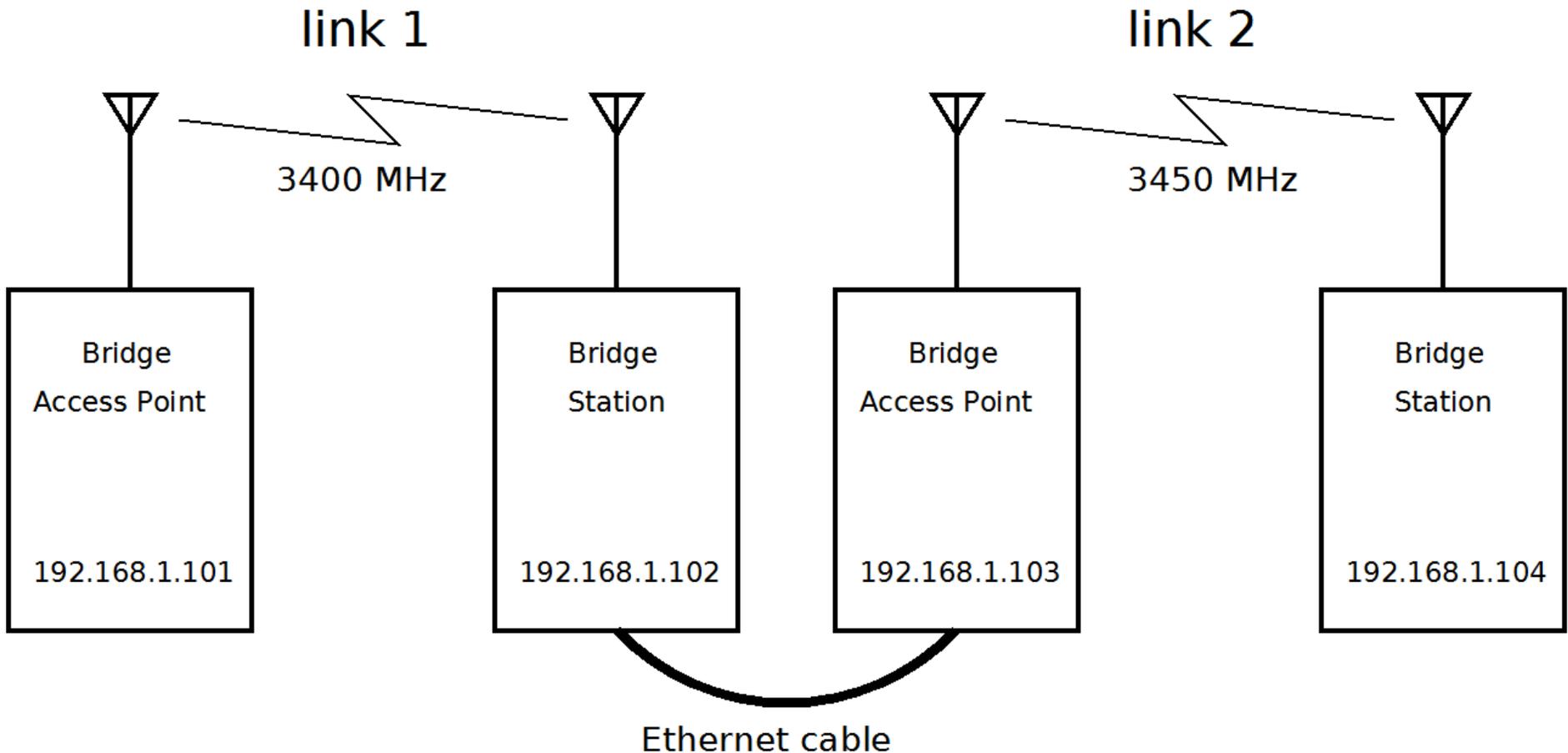
(1) for export from USA – purchased from Streakwave Wireless

(2) U-NII: 5150-5350, 5470-5825 MHz

(3) ARRL band plan

# Ubiquiti demonstration network

two link wireless network



- default Network Mode of airMAX router is **Bridge**
- no latency

# Ubiquiti demonstration network

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wireless network ham radio station



Grandstream GXP1105 IP phone and NanoStation M3

# Ubiquiti demonstration network

## wireless network relay station



two NanoStation M3 routers

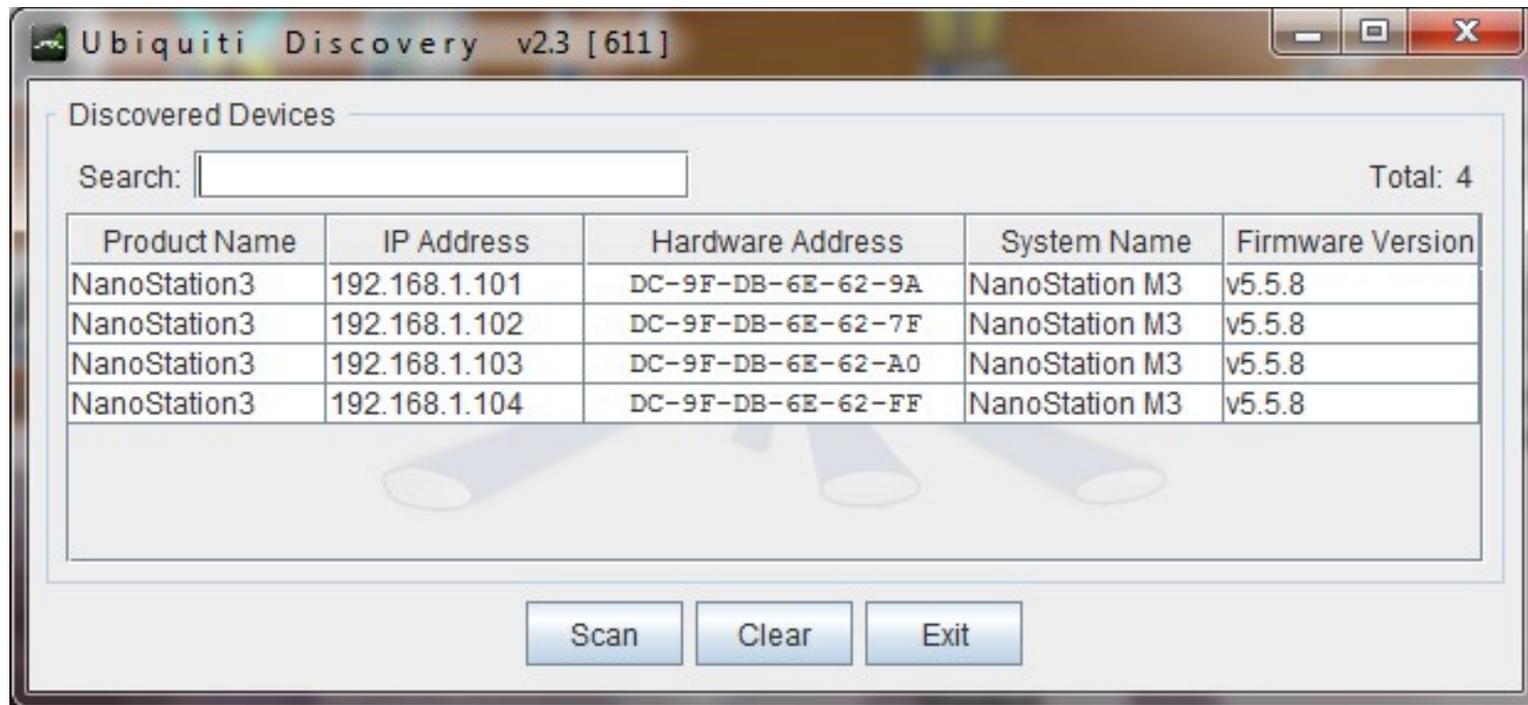


FOSCAM FI8910W IP camera

# Ubiquiti demonstration network

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## Discovering the network



Ubiquiti Discovery program

- works on a different subnet

# Ubiquiti demonstration network

## Access point

**NanoStation M3** airOS™

MAIN WIRELESS NETWORK ADVANCED SERVICES SYSTEM Tools: Logout

**Status**

Device Name:	W2LNX-NS-M3-101	AP MAC:	DC:9F:DB:6E:62:9A
Network Mode:	Bridge	Connections:	1
Wireless Mode:	Access Point	Noise Floor:	-98 dBm
SSID:	ubnt	Transmit CCQ:	98.1 %
Security:	none	airMAX:	Enabled
Version:	v5.5.8	airMAX Quality:	 100 %
Uptime:	00:17:11	airMAX Capacity:	 100 %
Date:	2014-02-05 18:41:04	airSelect:	Disabled
Channel/Frequency:	80 / 3400 MHz		
Channel Width:	5 MHz		
Distance:	0.1 miles (0.2 km)		
TX/RX Chains:	2X2		
WLAN0 MAC	DC:9F:DB:6E:62:9A		
LAN0 MAC	DC:9F:DB:6F:62:9A		
LAN1 MAC	DE:9F:DB:6F:62:9A		
LAN0 / LAN1	100Mbps-Full / 100Mbps-Full		

airOS MAIN screen

# Ubiquiti demonstration network

## Station – client

**NanoStation M3** **airOS**

MAIN WIRELESS NETWORK ADVANCED SERVICES SYSTEM Tools: Logout

**Status**

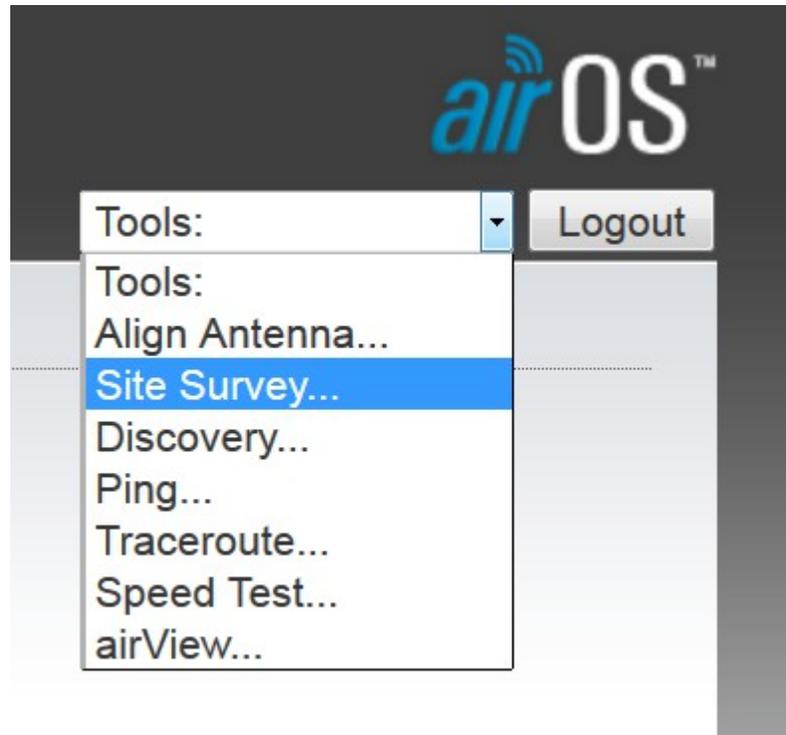
Device Name:	W2LNX-NS-M3-102	AP MAC:	DC:9F:DB:6E:62:9A
Network Mode:	Bridge	Signal Strength:	-50 dBm
Wireless Mode:	Station	Horizontal / Vertical:	-51 / -54 dBm
SSID:	ubnt	Noise Floor:	-100 dBm
Security:	none	Transmit CCQ:	97.8 %
Version:	v5.5.8	TX/RX Rate:	32.5 Mbps / 32.5 Mbps
Uptime:	01:07:04	airMAX:	Enabled
Date:	2014-02-05 19:30:58	airMAX Priority:	None
Channel/Frequency:	80 / 3400 MHz	airMAX Quality:	100 %
Channel Width:	5 MHz	airMAX Capacity:	100 %
Distance:	0.1 miles (0.2 km)		
TX/RX Chains:	2X2		
WLAN0 MAC	DC:9F:DB:6E:62:7F		
LAN0 MAC	DC:9F:DB:6F:62:7F		
LAN1 MAC	DE:9F:DB:6F:62:7F		
LAN0 / LAN1	Unplugged / 100Mbps-Full		

airOS MAIN screen

# Ubiquiti demonstration network

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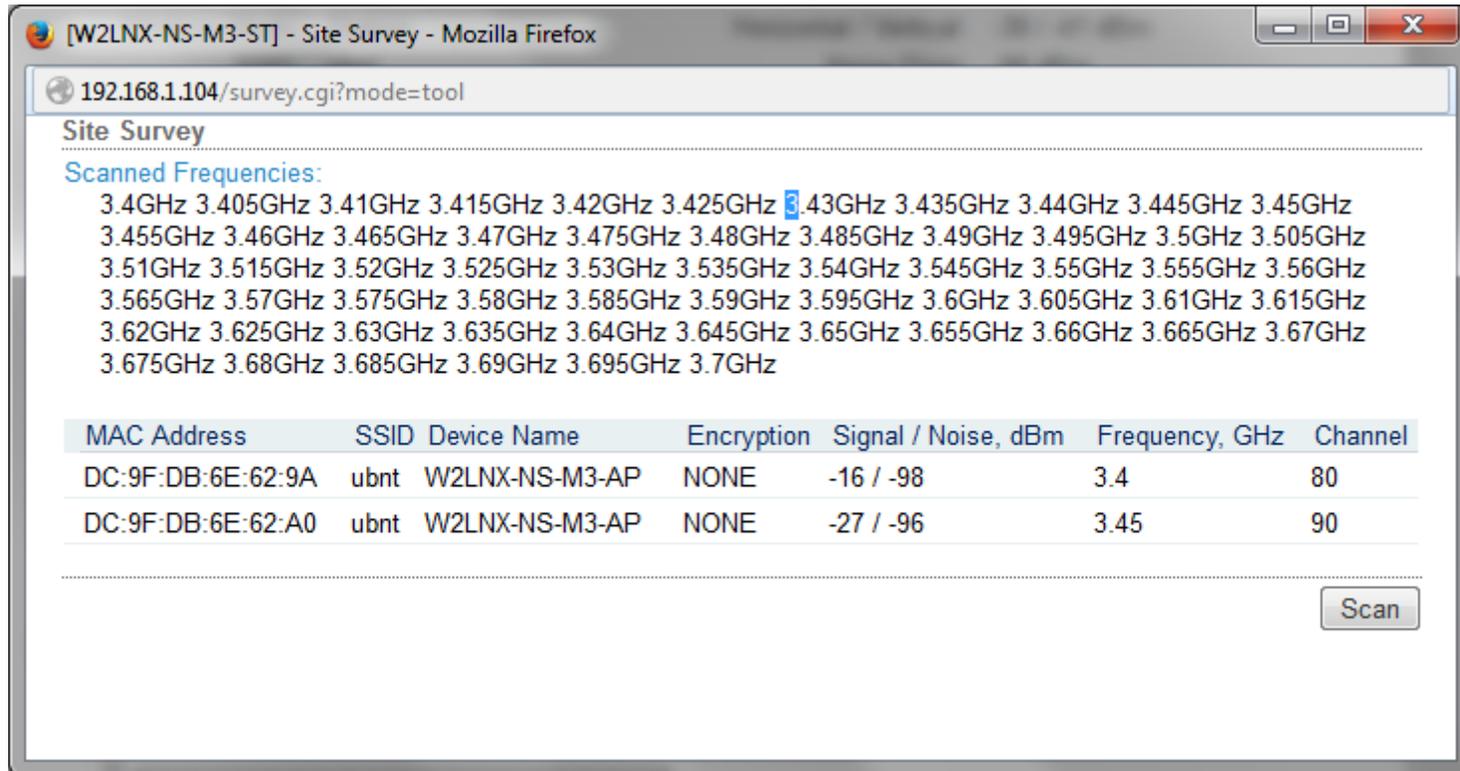
## Discovering the network



airOS Tools

# Ubiquiti demonstration network

## Discovering the network



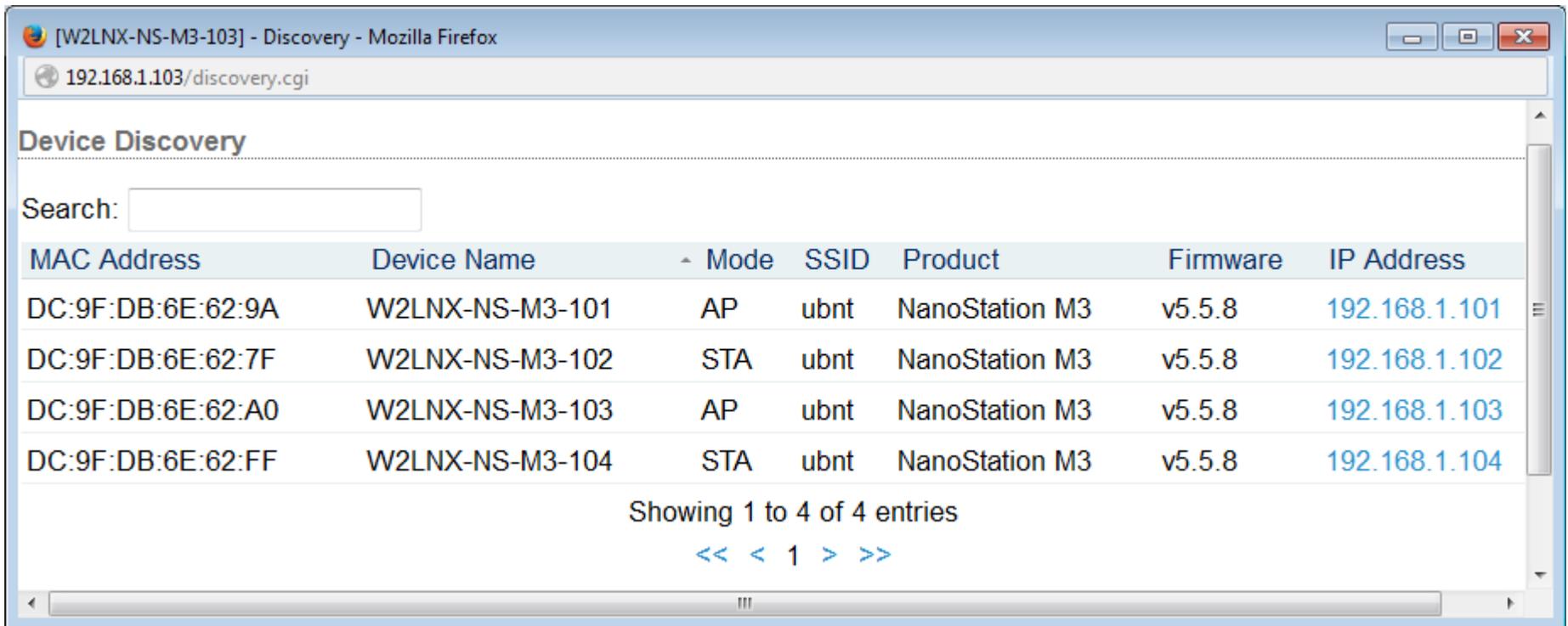
airOS Site Survey tool

discovered:

- access points
- frequencies

# Ubiquiti demonstration network

## Discovering the network



MAC Address	Device Name	Mode	SSID	Product	Firmware	IP Address
DC:9F:DB:6E:62:9A	W2LNX-NS-M3-101	AP	ubnt	NanoStation M3	v5.5.8	192.168.1.101
DC:9F:DB:6E:62:7F	W2LNX-NS-M3-102	STA	ubnt	NanoStation M3	v5.5.8	192.168.1.102
DC:9F:DB:6E:62:A0	W2LNX-NS-M3-103	AP	ubnt	NanoStation M3	v5.5.8	192.168.1.103
DC:9F:DB:6E:62:FF	W2LNX-NS-M3-104	STA	ubnt	NanoStation M3	v5.5.8	192.168.1.104

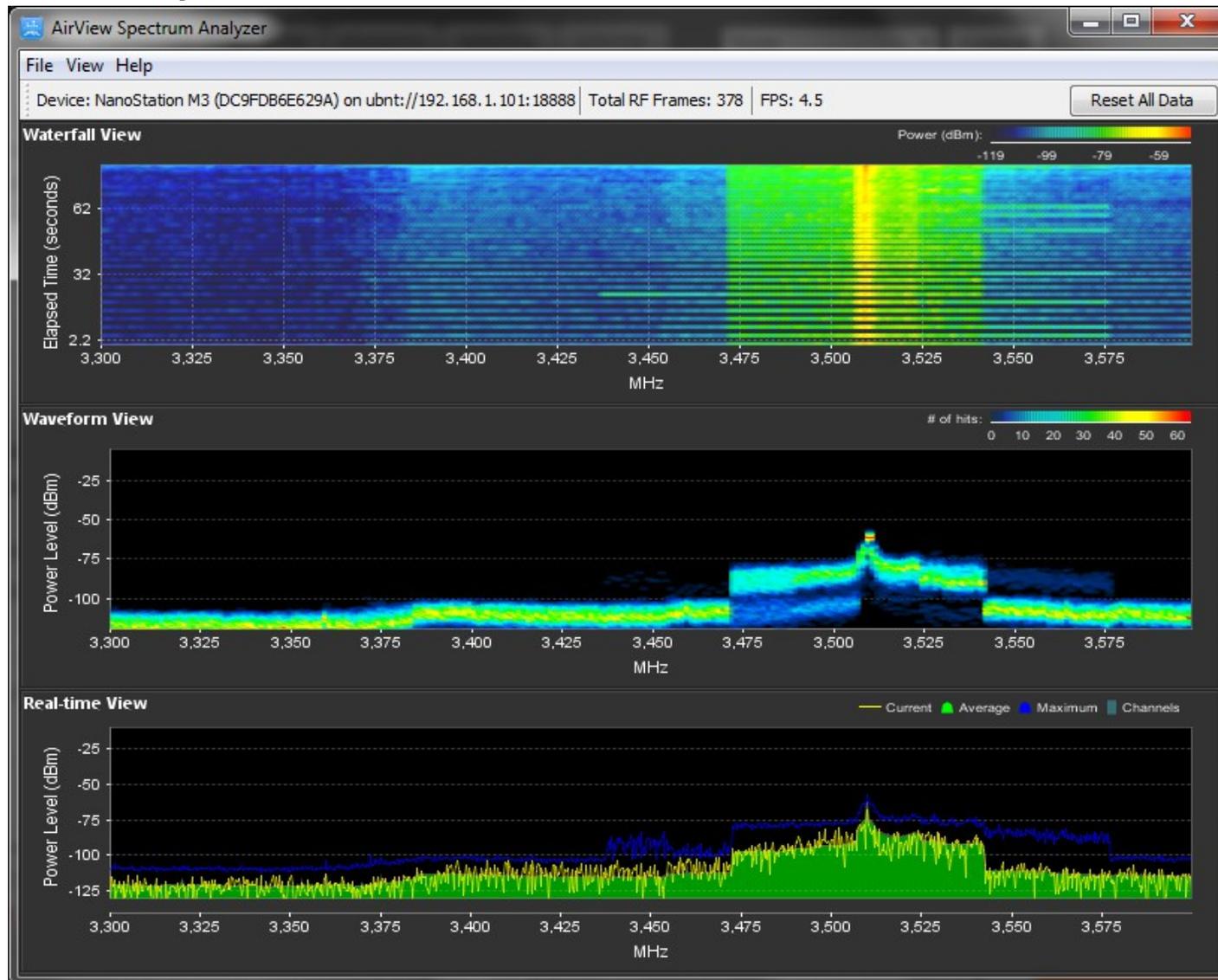
airOS Discovery tool

discovered:

- Device Name – broadcast station identification
- IP Address – broadcast IP address

# Ubiquiti demonstration network

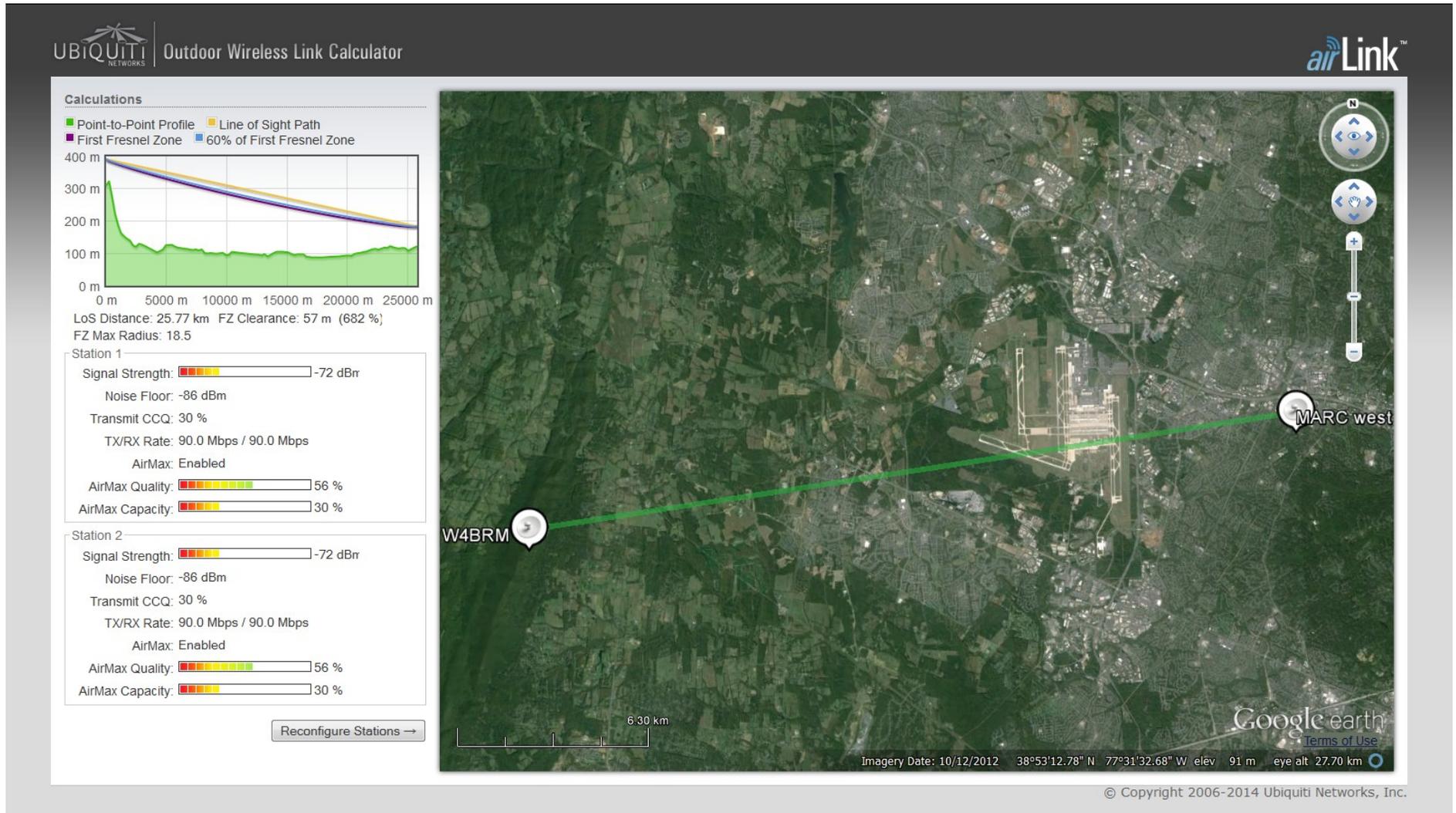
## spectrum analyzer



airOS airView tool

# MARC repeater west site to W4BRM test

16 miles on 5 GHz



airLink simulation

# MARC repeater west site to W4BRM test

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access point at W4BRM



Ubiquiti 5 GHz sector antenna

# MARC repeater west site to W4BRM test

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station at W2LNX



NanoBeam M5 NBE-M5-400

# MARC repeater west site to W4BRM test

access point at W4BRM

**rocket M5<sup>GPS</sup>** **airOS™**

MAIN WIRELESS NETWORK ADVANCED SERVICES SYSTEM Tools: Logout

### Status

Device Name: M5GPS1	AP MAC: 00:27:22:28:68:16
Network Mode: Bridge	Connections: 2
Wireless Mode: Access Point WDS	Noise Floor: -91 dBm
SSID: W4BRM	Transmit CCQ: 93.4 %
Security: none	airMAX: Enabled
Version: v5.5.8	airMAX Quality:  60 %
Uptime: 24 days 23:45:47	airMAX Capacity:  60 %
Date: 2014-08-21 17:55:55	airSelect: Disabled
Channel/Frequency: 161 / 5805 MHz	airSync: Disabled
Channel Width: 20 MHz	GPS Signal Quality:  90 %
Distance: 15.9 miles (25.7 km)	Latitude / Longitude: 38.922386 / -77.663048
TX/RX Chains: 2X2	Altitude: 323 m
WLAN0 MAC 00:27:22:28:68:16	
LAN0 MAC 00:27:22:29:68:16	
LAN1 MAC 02:27:22:29:68:16	
LAN0 / LAN1 100Mbps-Full / Unplugged	

### Monitor

[Throughput](#) | [Stations](#) | [Interfaces](#) | [ARP Table](#) | [Bridge Table](#) | [Routes](#) | [GPS Details](#) | [Log](#)

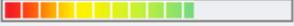
Station MAC	Device Name	Signal / Noise, dBm	Distance	TX/RX, Mbps	CCQ, %	Connection Time	Last IP	Action
<a href="#">24:A4:3C:60:9A:43</a>	NSM5-3	-68 / -91	0.1 miles (0.2 km)	117 / 117	98	19:07:51	<a href="#">192.168.1.23</a>	<a href="#">kick</a>
<a href="#">24:A4:3C:D6:8D:C6</a>	W2LNX-NB-M5-11	-78 / -91	15.9 miles (25.7 km)	39 / 39	93	00:29:21	<a href="#">192.168.1.110</a>	<a href="#">kick</a>

W4BRM access point main

# MARC repeater west site to W4BRM test

station at W2LNX

The screenshot displays the web interface for a NanoBeam M5 device. The top navigation bar includes tabs for MAIN, WIRELESS, NETWORK, ADVANCED, SERVICES, and SYSTEM, along with a Tools dropdown and a Logout button. The main content area is titled 'Status' and provides detailed information about the device and its wireless configuration.

Device Model:	NanoBeamM5 400	AP MAC:	00:27:22:28:68:16
Device Name:	W2LNX-NB-M5-110	Signal Strength:	 -76 dBm
Network Mode:	Bridge	Chain 0 / Chain 1:	-82 / -77 dBm
Wireless Mode:	Station WDS	Noise Floor:	-102 dBm
SSID:	W4BRM	Transmit CCQ:	90.6 %
Security:	none	TX/RX Rate:	26 Mbps / 52 Mbps
Version:	v5.5.9 (XW)	airMAX:	Enabled
Uptime:	00:32:01	airMAX Priority:	None
Date:	2014-04-03 13:32:56	airMAX Quality:	 29 %
Channel/Frequency:	161 / 5805 MHz	airMAX Capacity:	 32 %
Channel Width:	20 MHz		
Distance:	16.3 miles (26.3 km)		
TX/RX Chains:	2X2		
Antenna:	400 - 25 dBi		
WLAN0 MAC	24:A4:3C:D6:8D:C6		
LAN0 MAC	24:A4:3C:D7:8D:C6		
LAN0	100Mbps-Full		

W2LNX station main

# MARC repeater west site to W4BRM test

station at W2LNX

## Monitor

[Throughput](#) | [AP Information](#) | [Interfaces](#) | [ARP Table](#) | [Bridge Table](#) | [Routes](#) | [Log](#)

Access Point	00:27:22:28:68:16	
Device Name: M5GPS1	Negotiated Rate	Last Signal, dBm
Product: R5N-GPS	MCS0	N/A
Firmware: v5.5.8	MCS1	N/A
Connection Time: 00:15:37	MCS2	-76
Signal Strength: -76 dBm	MCS3	-76
Noise Floor: -101 dBm	MCS4	-77
Distance: 17.2 miles (27.7 km)	MCS5	N/A
CCQ: 88%	MCS6	N/A
Last IP: <a href="#">192.168.1.41</a>	MCS7	N/A
TX/RX Rate: 52.0 Mbps / 52.0 Mbps	MCS8	N/A
TX/RX Bit Rate: 7.45 kbps / 7.83 kbps	MCS9	N/A
TX/RX Packets: 3381 / 4934	MCS10	N/A
TX/RX Packet Rate, pps: 0 / 5	MCS11	-76
Bytes Transmitted: 893847 (872.90 kBytes)	MCS12	N/A
Bytes Received: 938566 (916.57 kBytes)	MCS13	N/A
	MCS14	N/A
	MCS15	N/A

W2LNX station access point information

# MARC repeater west site to W4BRM test

station at W2LNX

## Site Survey

### Scanned Frequencies:

5.765GHz 5.785GHz 5.805GHz 5.825GHz

MAC Address	SSID	Device Name	Encryption	Signal / Noise, dBm	Frequency, GHz	Channel
10:0D:7F:D0:51:78	D05178	.\$	WPA	-84 / -101	5.785	157
00:24:6C:05:84:0B			WPA2	-87 / -101	5.805	161
00:24:6C:05:84:08	IGSWLAN		WPA2	-89 / -101	5.805	161
34:BD:C8:04:47:6F	CoxWiFi		NONE	-82 / -101	5.765	153
34:BD:C8:04:47:6D	xfinitywifi		NONE	-82 / -101	5.765	153
00:27:22:28:68:16	W4BRM	M5GPS1	NONE	-76 / -101	5.805	161
34:BD:C8:04:47:6E	CableWiFi		NONE	-82 / -101	5.765	153
00:24:6C:05:84:0A	IGSVISITOR		NONE	-90 / -101	5.805	161
34:BD:C8:04:8A:CF	CoxWiFi		NONE	-84 / -101	5.825	165
34:BD:C8:04:8A:CD	xfinitywifi		NONE	-83 / -101	5.825	165
34:BD:C8:04:8A:CE	CableWiFi		NONE	-84 / -101	5.825	165
10:BD:18:6B:47:4D	xfinitywifi		NONE	-89 / -101	5.825	165

W2LNX station site survey

- 5 GHz band – shared with unlicensed users

# MARC repeater west site to W4BRM test

access point at W4BRM

[M5GPS1] - Speed Test - Mozilla Firefox

w4brm.no-ip.biz:8001/sptest.cgi

### Network Speed Test

Select Destination IP: 192.168.1.110

User: ubnt

Password: ●●●●

Remote WEB Port: 80

Show Advanced Options

Test Results

RX: 4.39 Mbps  
TX: 4.84 Mbps  
Total: 9.23 Mbps

Warning! If traffic shaping is enabled on either device the speed test results will be limited accordingly.

Run Test

network speed test

# High-Speed amateur wireless networks today

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## Mid-Atlantic area:

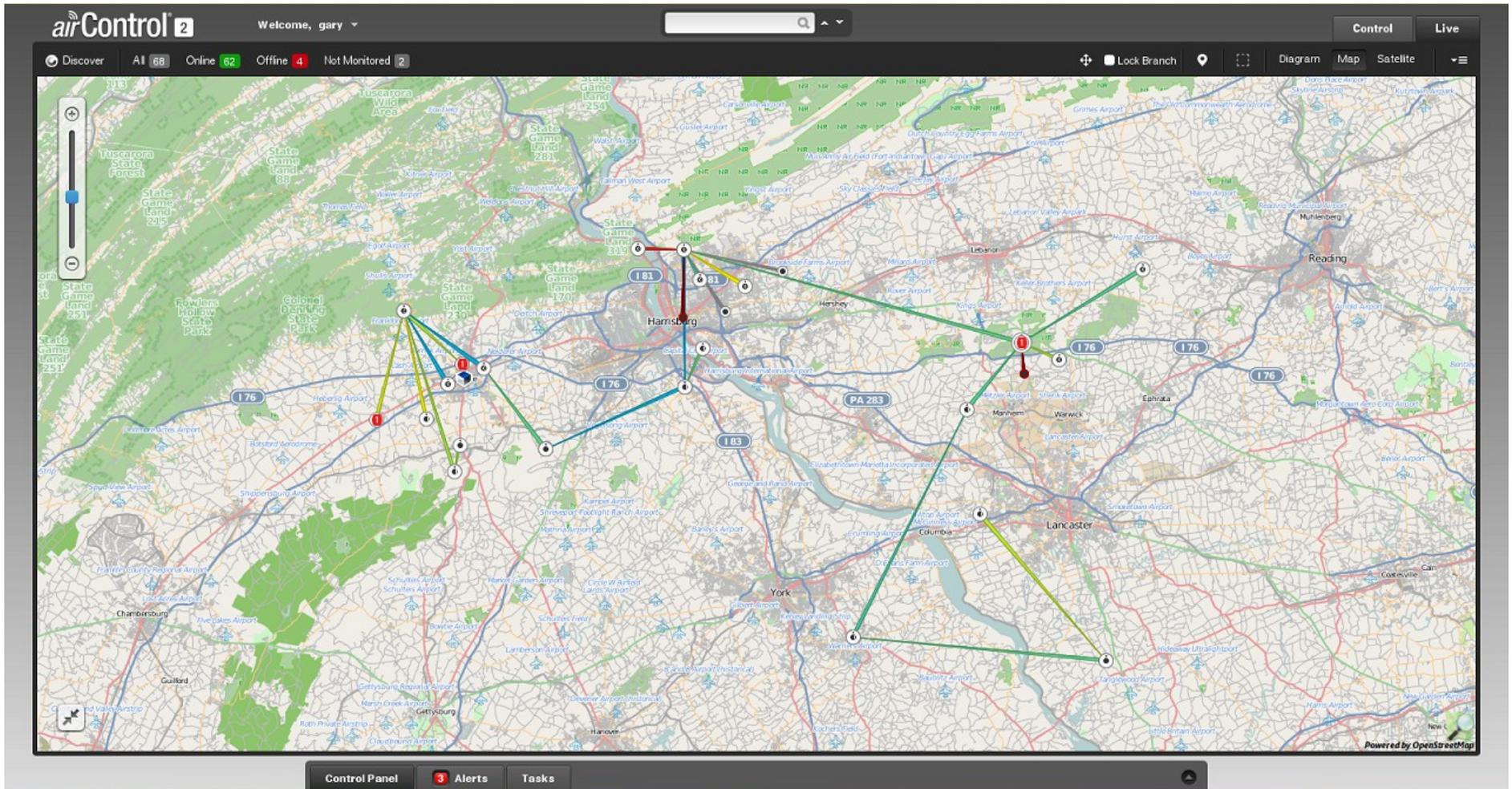
- CPIN – in service
  - extending to Damascus – under construction
- BRATS – in service
- MARC – in planning stages
  - extend to Damascus
- ARCS – in planning stages

## other USA:

- Broadband-Hamnet – Austin, TX area – in service
- HamWAN – Seattle, WA area – in service
- BCWARN – British Columbia area – in service
- and more

# High-Speed amateur wireless networks today

## Central Pennsylvania IP Network (CPIN)

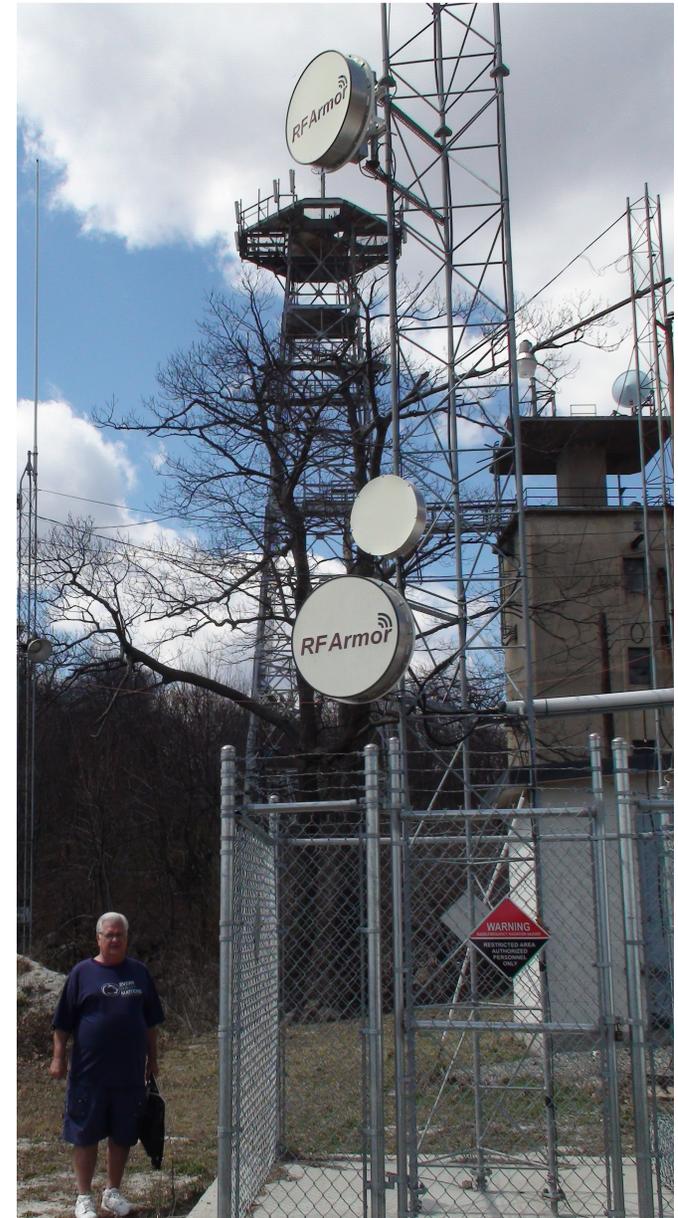


network map

# High-Speed amateur wireless networks today

## Central Pennsylvania IP Network

- Ubiquiti equipment
- primarily on 5 GHz
- 13 High-profile relay sites
- 157 Miles of network backbone
- 20 IP Cameras
- Asterisk IP telephone system
- and more



Gary Blacksmith, WA3CP0

# High-Speed amateur wireless networks today

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## Baltimore Radio Amateur Television Society (BRATS)

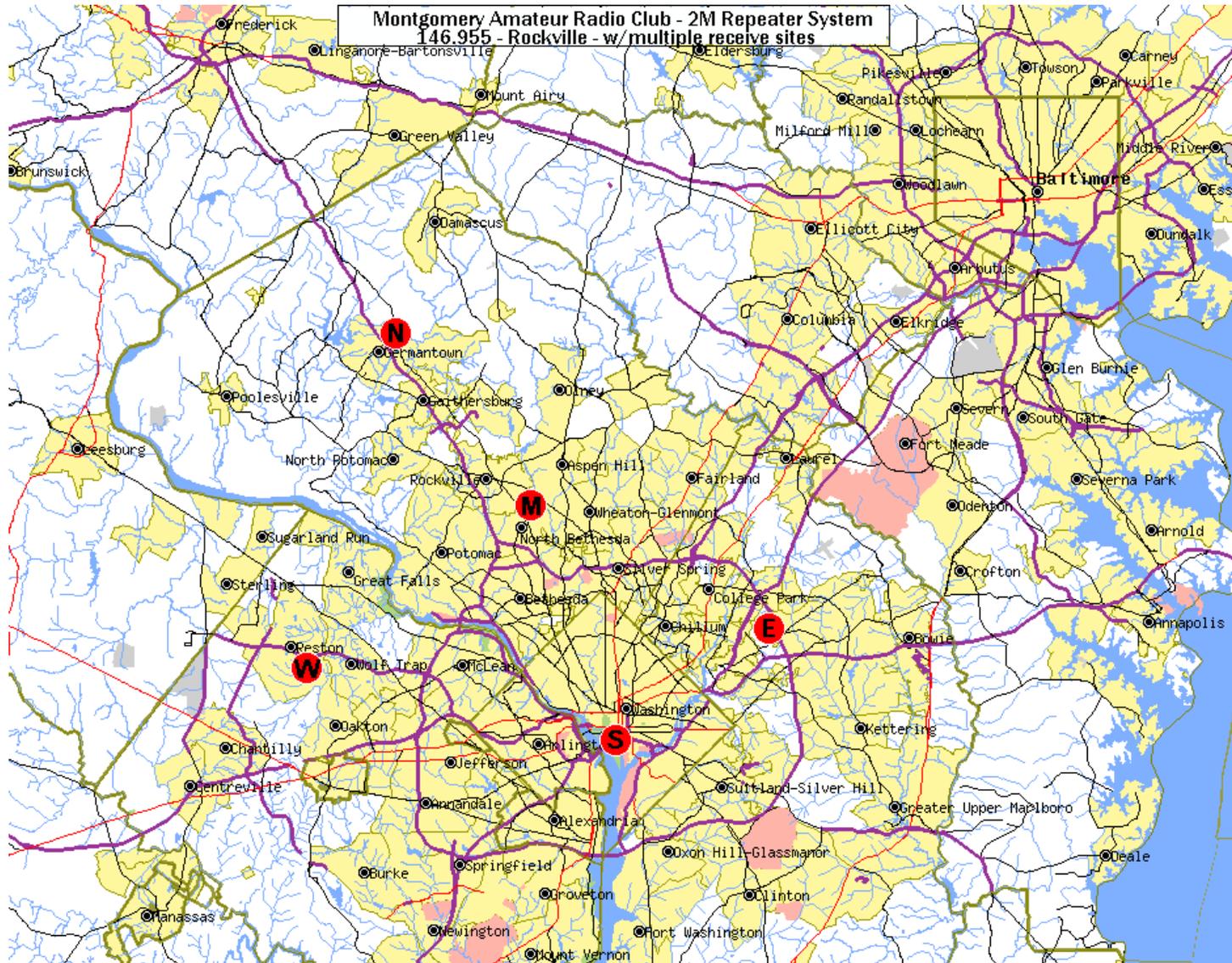
- replaces analog repeater links
- 5 sites across 20 miles
- 5 GHz Ubiquiti equipment



Edmond Rosen, N3GXH holding a 5 GHz RD-5G30 RocketDish

# Building a high-speed backbone network

## Montgomery Amateur Radio Club (MARC), Rockville, MD



repeater system

# Building a high-speed backbone network

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## Ashton Radio Communications Society (ARCS), Ashton, MD

- repeater system:
  - Ashton, MD
  - Damascus, MD
  - Brookeville, MD
  - Ellicott City, MD
  - NW Washington, DC
  - Jessup, MD
  - Frederick, MD
  - near Mt. Weather, VA



3.4 GHz RocketDish RD-3G26



# Building local community area networks

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Connecting the end-user to the high-speed backbone network

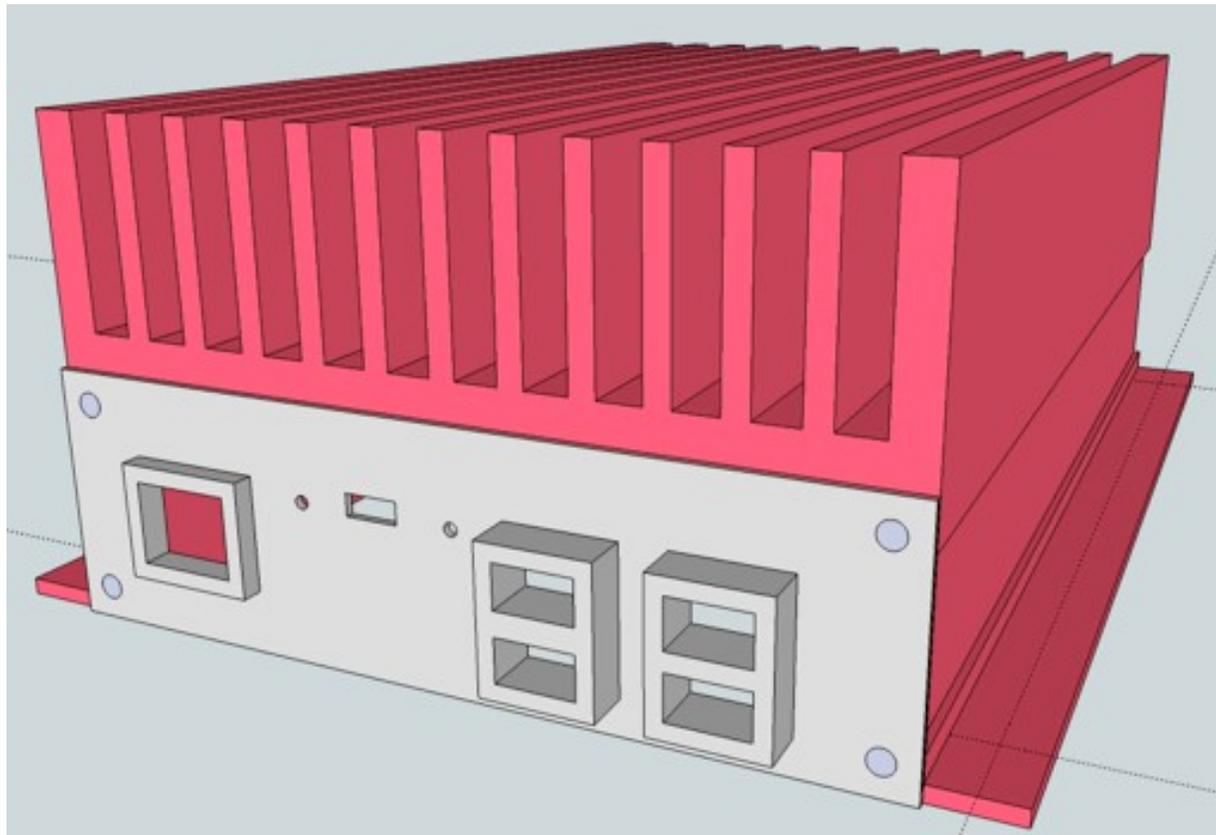
- new radios – products being developed
  - UDRX-440 – NW Digital Radio
  - CS7000 – Connect Systems, Inc.
  - Whitebox radio – Chris Testa, KD2BMH
  - others

# Building local community area networks

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Connecting the end-user to the high-speed backbone network

- NW Digital Radio – Bryan Hoyer, K7UDR and John Hays, K7VE



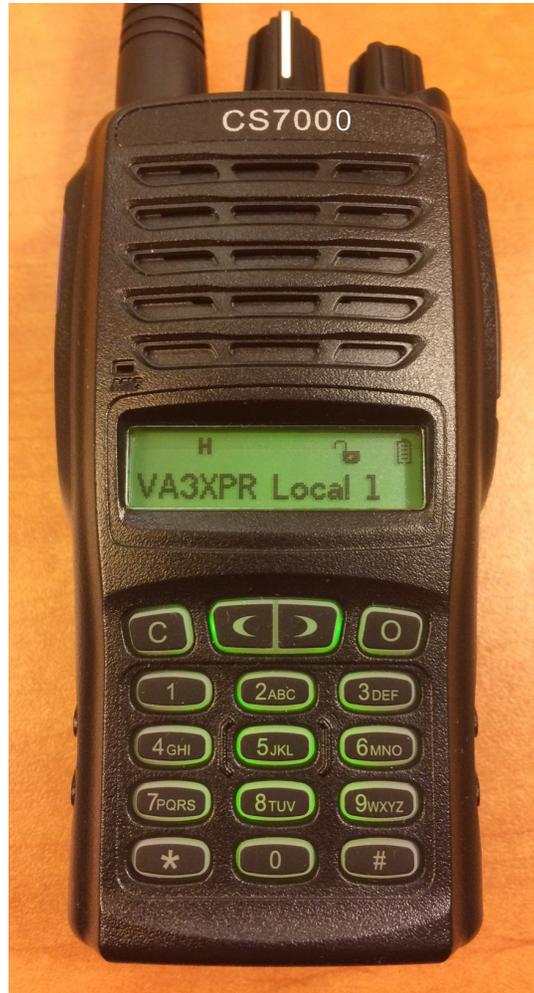
UDRX-440 narrow band data radio with FSK, GMSK modems

# Building local community area networks

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Connecting the end-user to the high-speed backbone network

- Connect Systems, Inc. – Jerry Wanger, KK6LFS



mockup of CS7000 narrow band data radio with GMSK, 4FSK modems

# Building local community area networks

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Connecting the end-user to the high-speed backbone network

- Chris Testa, KD2BMH



Bravo broadband data radio

# Building local community area networks

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## Connecting the end-user to the high-speed backbone network

- existing radios
  - Doodle Labs – 420 MHz broadband
  - VHF/UHF FM radios with 9600 bps data port
    - audio tap before FM modulator and after the FM demodulator
    - can D-STAR hotspots be used as 4800 bps GMSK modems?
      - **wanted:** inexpensive 9600 bps GMSK modem
  - VHF/UHF FM radios
    - 1200 bps AX.25 TNCs
    - *fldigi* robust modes
  - RTL-SDR USB receiver dongle

# Building local community area networks

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Connecting the end-user to the high-speed backbone network

- some amateur radio applications – old is new
  - analog and digital repeater linking
  - remote receiver – ham license not required!
  - APRS – extend the network
  - Winlink – extend the network
  - remote HF station operation
  - VOIP – extend the D-STAR, Echolink, IRLP, Allstar networks
  - CW over IP – CWCom program and AD9X serial adapter
  - serial over IP – Lantronix serial to Ethernet adapter

# Building local community area networks

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Connecting the end-user to the high-speed backbone network

- some Internet applications
  - VOIP – Asterisk
  - Web camera
  - Web and file transfer services
  - email services
  - multicast services
  - Web SDR – remote software defined receivers
    - University of Twente, Enschede, NL

# Building an amateur radio wireless network

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## Issues:

- no single point of failure – distributed servers
- authentication – imperative on shared frequencies
  - is not encryption
  - DCC 2013: Heikki Hannikainen, OH7LZB, presentation *Authenticated Amateur Radio Services on the Internet*
    - use standard Internet protocols and tools
- network topology and frequencies – what works best
- station ID and IP address
  - are broadcast by Ubiquiti equipment
- **idea:** self assign an IP address
  - created from station latitude and longitude

# Conclusions

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This is ham radio at its finest!

- additional emergency communication tools from a distressed area
- high speed networks are being built today
  - network is built one link at a time
- attract next generation of hams
  - platform to build and experiment with networking
- take advantage of COTS equipment
- take advantage of proven Internet protocols
- this is fun!

# Conclusions

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This is...



Together, we can build a national high-speed amateur radio digital communications network.

**Please join us!**

## References and resources

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The conference paper and presentation visuals are at

[http://tapr.org/pub\\_dcc33.html](http://tapr.org/pub_dcc33.html)

More information is at Keith's Website

<http://www.remoteamateur.com>

# Acknowledgments

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- Ron Adams, KB3SYA
- Tony Faiola, K3WX
- Dick Hayman, WN3R
- Ken Jamrogowicz, KE2N
- Phil Karn, KA9Q
- Bill Kisse, W3MSH
- Bruce Perens, K6BP
- Gary Pierce, KN4AQ
- Terry Sharar, W3EDS
- Chris Sylvain, KB3CS

# Questions

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