HAMNET – Status Update

Over the last 15 years, HAMNET (Highspeed Amateur Radio Multimedia NETwork) has developed from an experiment into a stable infrastructure, particularly in German-speaking countries.

It generally connects unmanned amateur radio stations via microwave links using the IPv4 and BGP protocols and provides a platform for networking amateur radio applications.

This presentation will show how HAMNET has evolved and how it could evolve (challenges in deployment, expansion in Europe, densification of the backbone, higher speeds, access technologies for non-line-of-sight propagation).

Agenda

- Quick personal facts
- HAMNET – Mission Statement
- HAMNET in a nutshell
- How has HAMNET evolved? Pitfalls and Mitigation!
- How may HAMNET evolve further?

Quick personal facts

- Jann Traschewski, DG8NGN <dg8ngn@darc.de>
- VHF Manager of the German Amateur Radio Club (DARC e.V.)
- Member of the German IP Coordination Team for HAMNET
- Profession: Systems engineer at Rohde & Schwarz in Munich
- Family: Three boys, all under 10 years old, and a lovely wife!
- Location: JN59lj, Nuremberg

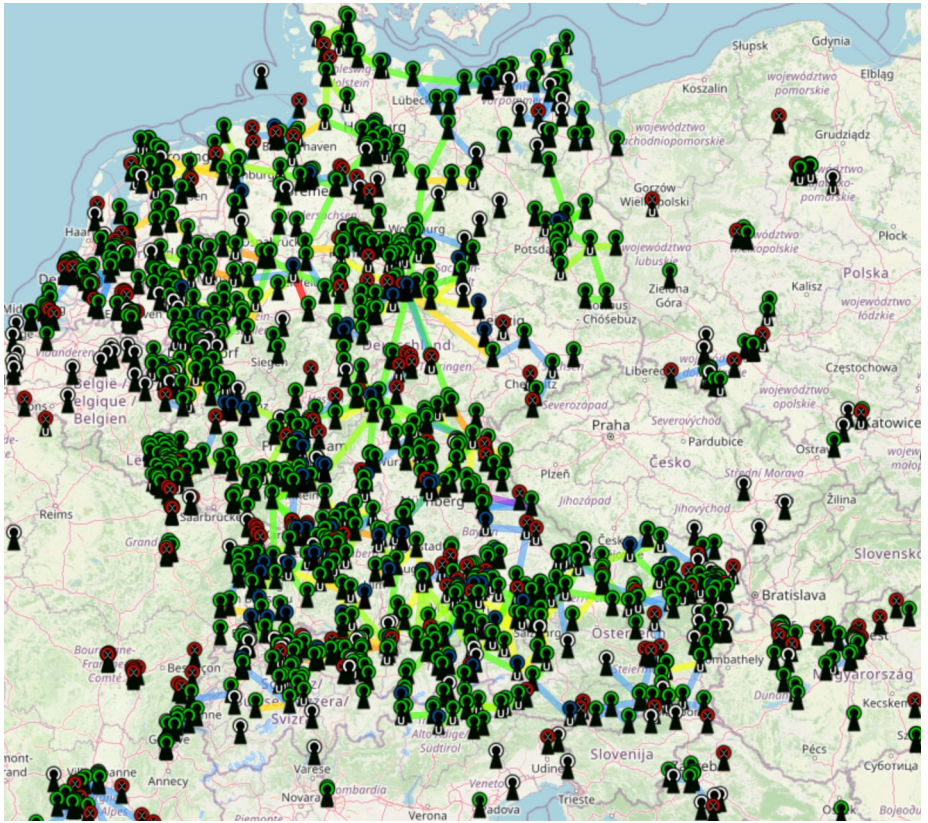
HAMNET – Mission Statement

The mission of HAMNET is to build and maintain an European (or even larger) TCP/IP-based Radio-only Network for the Amateur Radio Community providing IP end-to-end connectivity.

HAMNET in a nutshell

- Network for licensed Amateur Radio Operators
- RF Backbone on the 6-cm amateur radio band (with exceptions)
- RF User Access on 13-cm and 6-cm (typically line of sight necessary)
- As of today: 90% used for Amateur Radio „Infrastructure“ (not end-users) to interconnect e.g. repeaters or use it as transit to access Internet Services
- VPN access from the Internet for Amateur Radio Operators (e.g. to maintain repeaters or to use HAMNET services)
- Using IPv4 addresses from the globally unique IP space 44.128.0.0/10 (ARDC)
- Using 16-bit and 32-bit private autonomous system numbers (RFC 1930 & RFC 6996) for BGP routing
- Using the Domains „hamnet.radio“, „hamnet.cloud“ and „hamnet.network“
- High Potential for further Projects on the Application Layer

HAMNET in a nutshell



http://hamnetdb.net ← Click on Map

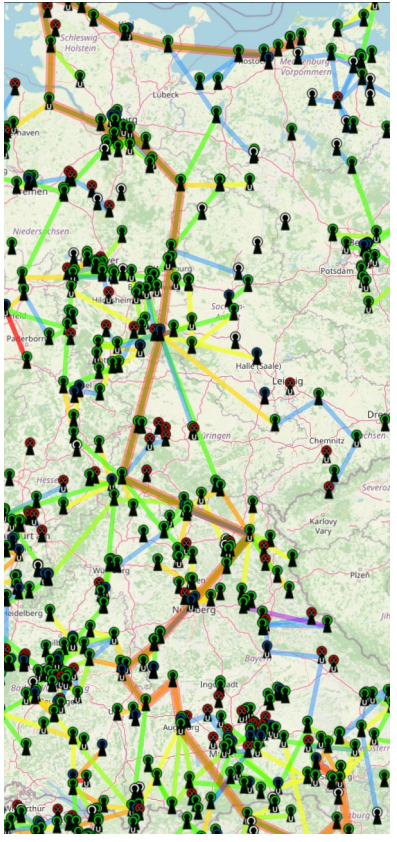
User Access

Interlinks

HAMNET in a nutshell

```
[dg8ngn@router.db0mbg] > tool traceroute router.do0rdg.hamnet.radio use-dns=yes
 # ADDRESS                              LOSS SENT    LAST     AVG    BEST   WORST STD-DEV STATUS
 1 bb-db0mbg.oe2xzr.hamnet.radio          0%    4  22.7ms    19.5    11.5    31.5     8.3
 2 bb-oe2xzr.oe2xgr.hamnet.radio          0%    4  10.4ms    13.6     6.1    24.1     6.6
 3 bb-oe2xgr.oe2xhr.hamnet.radio          0%    4  17.8ms    18.6    10.1    24.2     5.4
 4 bb-oe2xhr.oe2xwr.hamnet.radio          0%    4  41.9ms    37.6    22.4    55.1    12.3
 5 bb-oe2xwr.oe7xxr.hamnet.radio          0%    4  28.6ms    32.2    20.4    59.4    16.1
 6 bb-oe7xxr.db0fox.hamnet.radio          0%    4  55.1ms    38.5    24.3    55.1    11.7
 7 bb-db0fox.db0zka.hamnet.radio          0%    4  70.4ms    43.9    26.7    70.4    17.3
 8 bb-db0zka.db0don.hamnet.radio          0%    4  41.1ms    40.8    27.2    48.2     8.3
 9 bb-db0don.db0dlg.hamnet.radio          0%    4  41.8ms    61.7    41.8      88    16.7
10 bb-db0dlg.db0saa.hamnet.radio          0%    4  44.6ms      87    44.6   145.3      37
11 bb-db0saa.db0fha.hamnet.radio          0%    4  37.1ms   164.7    37.1   348.9   115.2
12 bb-db0fha.db0faa.hamnet.radio          0%    4  55.1ms    82.3    55.1   125.3    26.7
13 bb-db0faa.db0hbg.hamnet.radio          0%    4  36.6ms    97.2    36.6   169.8    48.7
14 bb-db0hbg.db0zb.hamnet.radio           0%    4  55.7ms    98.4    55.7   167.9    42.8
15 bb-db0zb.db0taw.hamnet.radio           0%    4  89.7ms    92.1    71.2   117.4    16.5
16 bb-db0taw.db0hex.hamnet.radio          0%    4    66ms    99.7      66   131.5    26.7
17 bb-db0hex.db0dan.hamnet.radio          0%    4  86.2ms   109.6    86.2   159.8    29.4
18 bb-db0dan.db0hhh.hamnet.radio          0%    4  67.2ms   120.9    67.2   185.3    46.5
19 bb-db0hhh.db0chh.hamnet.radio          0%    4 100.7ms   109.7   100.7   123.8       9
20 bb-db0chh.db0xh.hamnet.radio           0%    4 128.4ms   134.3    91.4   220.6    51.8
21 bb-db0xh.db0wot.hamnet.radio           0%    4   101ms     128    89.4   175.5    34.6
22 bb-db0wot.db0hei.hamnet.radio          0%    4 158.4ms   222.6   158.4   347.6    88.4
23 bb-db0hei.db0xn.hamnet.radio           0%    3 229.5ms   168.3   136.6   229.5    43.3
24 bb-db0xn.dm0sl.hamnet.radio            0%    3  99.7ms   153.4    99.7   191.2      39
25 bb-dm0sl.dm0kil.hamnet.radio           0%    3 140.2ms   151.4   140.2   171.8    14.5
26 bb-dm0kil.db0vc.hamnet.radio           0%    3 123.5ms   357.4   123.5   797.4   311.3
27 bb-db0vc.db0hro.hamnet.radio           0%    3    76ms   170.7      76   284.2      86
28 router.do0rdg.hamnet.radio             0%    3  85.5ms   165.1    85.5   268.4    76.5
```

TRACEROUTE



HAMNET – Evolvement

Personal Case in 2009: Local repeater IP connection got weak due to crowded 2,4 GHz Wifi Spectrum → Upgrade?

Can’t we use the 5 GHz Amateur Spectrum with more Power?
Can’t we use our globally unique IP space 44/8 rather then RFC1918 IPs?

Yes, we can! National Regulator approved application for a 5 GHz channel with 10 MHz bandwidth and 15W ERP power (nowadays up to 1kW ERP).
We switched to Net44 IP space and promoted to do the same, so our small regional RF networks can grow together without IP conflicts.

We started to build RF links and VPN links to interconnect different regions.

HAMNET – Evolvement

Bridging vs. Routing:
Some regions started to build large layer-2 segments over many radio links.
Links can be weak or fail → hard to debug! No transparency to end-users!

Lesson learned:
- Use a /29 for each RF hop → Traceroute will show the problem

Other best praxis:
- Use a single IP prefix for the whole site → Keeps routing tables small
- Split your IP prefix internal to e.g. address local trustful devices vs. RF users
  → Single firewall rule to allow access to the Internet for local devices

HAMNET – Evolvement

Routing Protocols:
IP resources have been allocated by regions. Regions played with OSPF, BGP Confederation, OLSR, …

How to interconnect regions? What happens if a region gets multiple connections to another region? In general: What to do if the topology changes? How many admins need to interact?

Lesson learned: We need to find a routing protocol considering each single site as a **full independent** site in the network.

HAMNET – Evolvement

Routing: Why not trying eBGP for each site?
32-bit private ASN range (RFC 6996) = 4.200.000.000 to 4.294.967.294

Pros:
- Every single site is fully independent → No problems with topology change
- Only site operators of directly connected sites need to interact

Cons:
- This decision is hardly to roll back in practice
- The routing protocol only knows „0“ or „1“ → link quality is not taken into account in routing decision → active BGP-links must be stable!
- Does it scale? ASN Path can be longer than what we see on the Internet

We don’t see any issues in daily operation.

HAMNET – Evolvement

What is a HAMNET site?

A HAMNET site is part of the RF backbone and
- usually runs one or multiple RF links on the network
- may offer some local services (e.g. webcam, voip-server, ...)
- may offer RF user access

What is a HAMNET user?

A HAMNET user can connect to the HAMNET using
- radio gear on a HAMNET site with RF user access (DHCP protocol using static and/or dynamic leases)
- a HAMNET VPN service on the Internet

HAMNET – Evolvement

Adjacent Channel Interference at the HAMNET site DB0HEX

HAMNET – Evolvement

Adjacent Channel Interference can be mitigated by:

- Frequency Separation (limited spectrum)
- Power Level Reduction (if highest modulation coding scheme reached)
- Using higher gain antennas
  - sometimes less power needed for full MCS at receiver
  - sometimes less power received at interfered nearby dish
- Physical Separation
  - different mounting position
  - use RF shields to avoid RF feeds “seeing” each other

HAMNET – Evolvement

Lessens learned in case of adjacent channel interference:

- The impact on large parts of the HAMNET can be high, since the site claims to be able to transport data, but packets will die on transit → packet loss
- Problems can not been seen by pure signal level monitoring
- Problems may only occur on large packets (MTU 1500) – BGP link is up!

Please take care on deploying a HAMNET site:

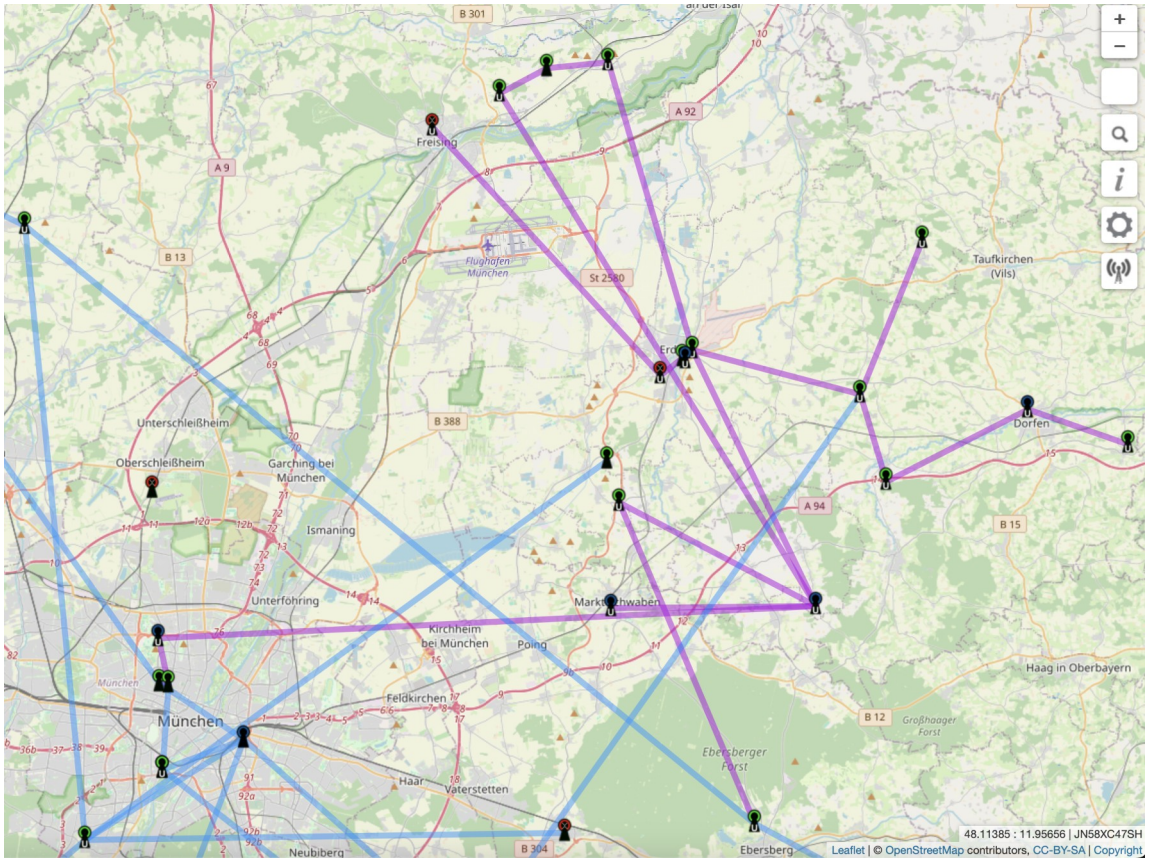
- Invest enough time to measure the power levels received between your (or other) radios on site and take actions
- Sometimes it is not possible to add another link on an existing site

HAMNET – Evolvement

Why are some lines “purple” on the Map?

Some radio connections do not operate under amateur radio conditions, but are part of the HAMNET. The color has been added to distinguish them.

Wireless LAN links can solve adjacent channel interference issues and 60 GHz links can offer high speed connections.



HAMNET – Evolvement

HAMNET Net Neutrality Issues

Created by firewall misconfigurations on BGP routers

- Usually not by intention (missing experience)
- Standard configurations being adapted rather than built from scratch
- Hard to track
  - NAT all connections on transit
  - Firewall if not established or related (asynchronous routing will be blocked)

Created by uncoordinated VPN tunnels with BGP routing between distant HAMNET sites

- Traffic will be soaked into VPN tunnel instead of using radio links

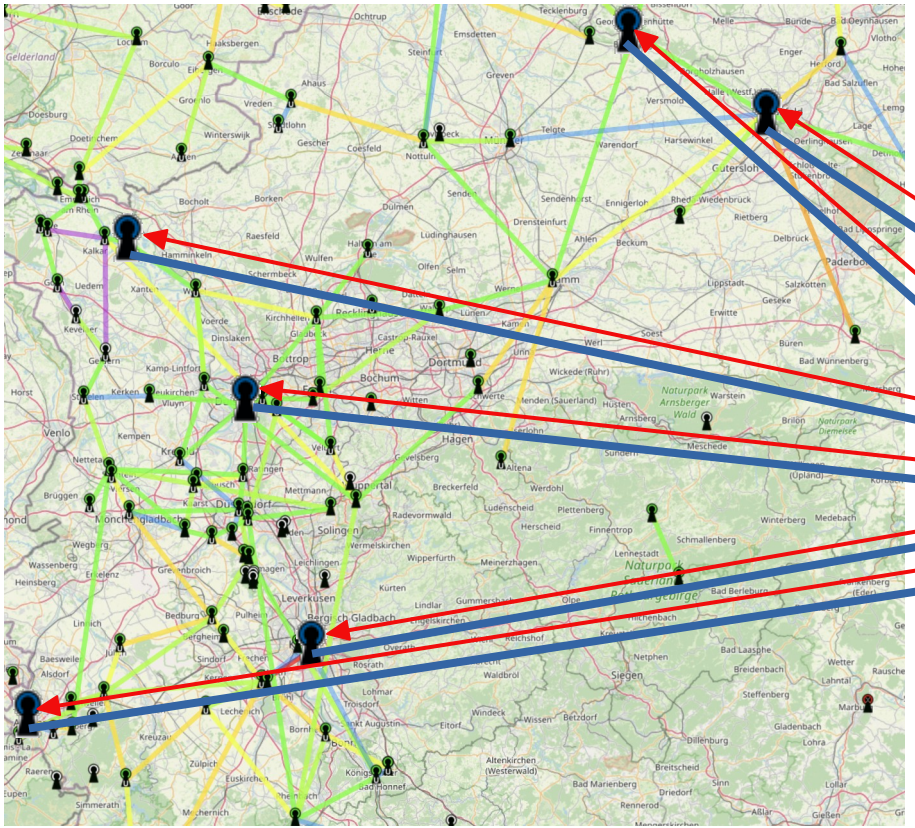
HAMNET – Evolvement

HAMNET Backbone Capacity issues

- Self-hosted HAMNET VPN services for end users popped up within the HAMNET
- Communication from/to VPN users led to bottlenecks on the HAMNET backbone (e.g. video streaming), although other “dual homed” HAMNET sites with native internet connectivity were within the RF path.

Is there an easy way to free up RF backbone capacity by making use of these “dual homed” HAMNET sites? → The “HamCloud” idea has been born!

HAMNET – Evolvement



HAMNET (Radio Layer)

VPN tunnel + BGP routing
Import all from HAMNET

VPN tunnel + BGP routing **with filter**
Export 44.148.128.0/17 to HAMNET

HamCloud-Services

VPN-Users
http://vpn.hamnet.network

HamCloud (44.148.128.0/17)

HAMNET – Evolvement

HamCloud will:

- Import all routes from HAMNET
- Export only routes within 44.148.128.0/17 (HamCloud allocation)

HAMNET internal RF routing will not be influenced (no shortcuts via HamCloud).

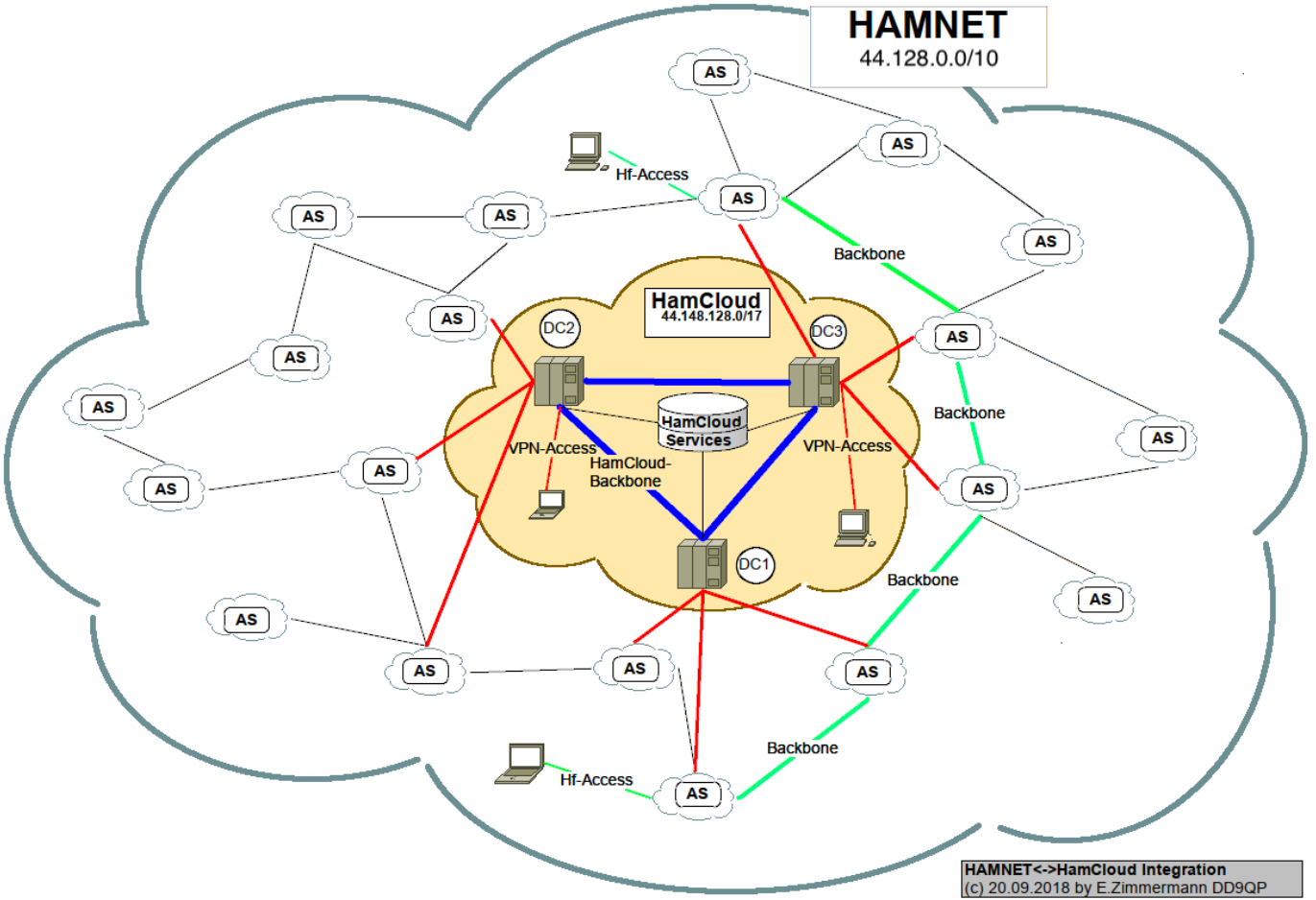
Traffic from/to HamCloud will be routed on the shortest path possible (Hop-Count) to/from HAMNET.

HamCloud VPN Users will live inside the HamCloud allocation and therefore benefit from the best connectivity to/from the HAMNET.

HAMNET – Evolvement

HamCloud “inside”:

3 Datacenters using OSPF to interconnect



HAMNET – Evolvement

Some key factors to get amateurs on board:

- Keep it simple, stupid (make it easy for everyone)
- Make things transparent (provide a clear policy)
- Power to the User (give users options to select the communication path)

Domains will help:

- “hamnet.cloud” = used for Hosts on the HamCloud (VPN Tunnels used)
- “hamnet.radio” = used for Hosts on the HAMNET (Radio Network)
- “hamnet.network” = used for Hosts on the Internet

HAMNET – Evolvement

Current HamCloud Services:
https://de.hamnet.network/hamcloud (e.g. APRS-Servers, Echolink Proxy Servers, DX-Cluster Access, Packet Radio Node IGATE, DMR-Servers, ...)

Since the connection from HAMNET to HamCloud is available through many VPN-tunnels, it doesn’t matter if the currently used VPN-tunnel fails. The new route may just have some RF hops more in between.

→ The HAMNET Backbone will provide redundancy!

HAMNET – Evolvement

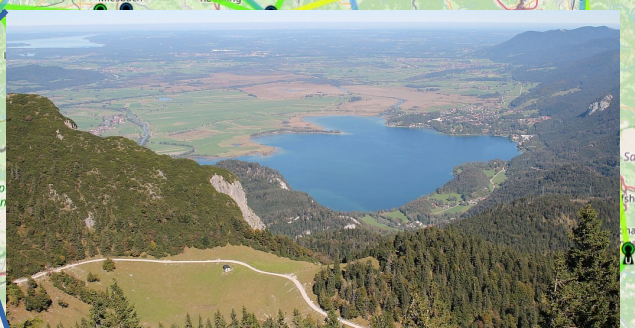
What else is possible on the HAMNET Backbone?

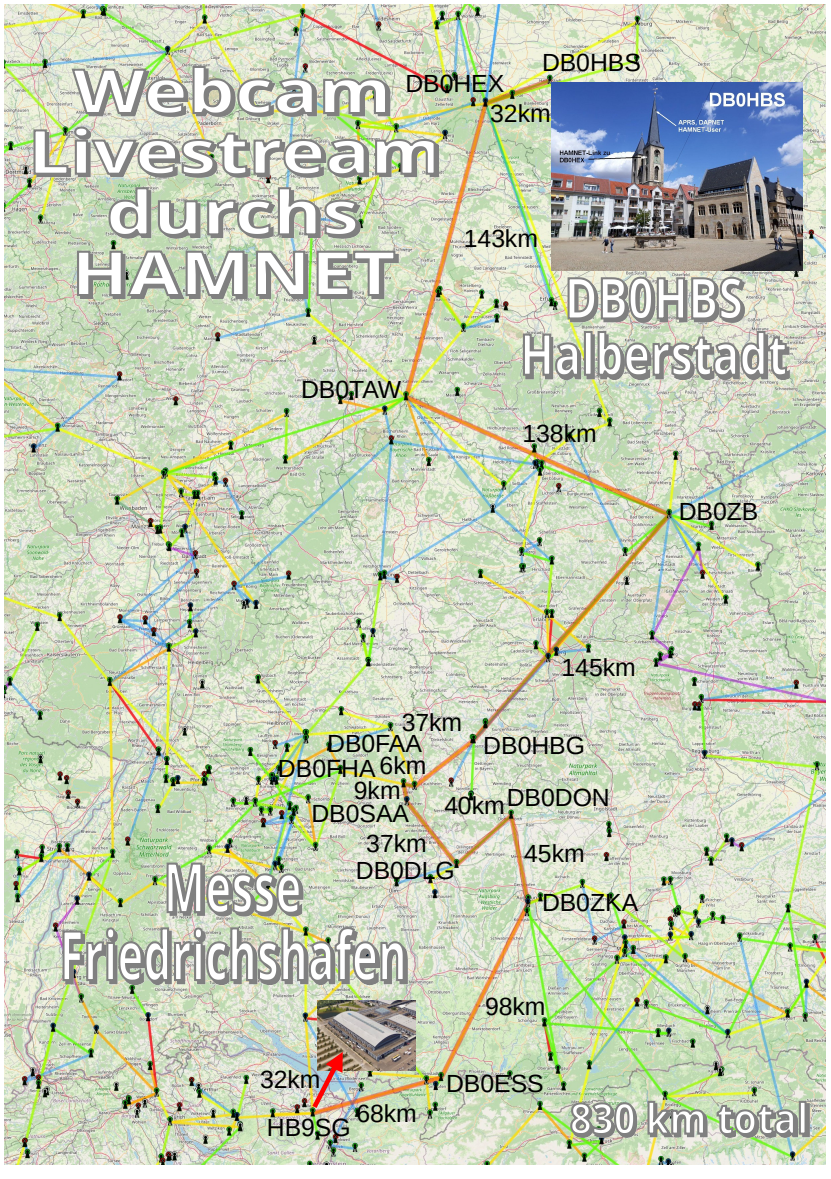
It is an IP-Network. You can transport almost everything from A to B and vice versa. Be creative!

Examples:

- HAM RADIO Fair in Friedrichshafen:
  - We show a 2,5 MBit/s videostream from DB0HBS (almost 1000km radio links in between)
  - We provide access to a WebSDR from the Alps through HAMNET
- Some regions interconnect all of their FM repeaters
- Some regions run EmComm services on it (HAMNET Sites are hardened)
- There is VoIP telephony inside the HAMNET
- …

OpenWebRX Livestream durchs HAMNET
DB0HZS Herzogstand -> Messe Friedrichshafen




Webcam
Livestream
durchs
HAMNET
DB0HEX
DB0HBS
32km
DB0HBS
143km
DB0HBS
Halberstadt
DB0TAW
138km
DB0ZB
145km
37km
DB0FAA
DB0HBG
DB0FHA
6km
9km
40km
DB0DON
DB0SAA
37km
45km
DB0DLG
Messe
Friedrichshafen
DB0ZKA
98km
32km
DB0ESS
68km
HB9SG
830 km total

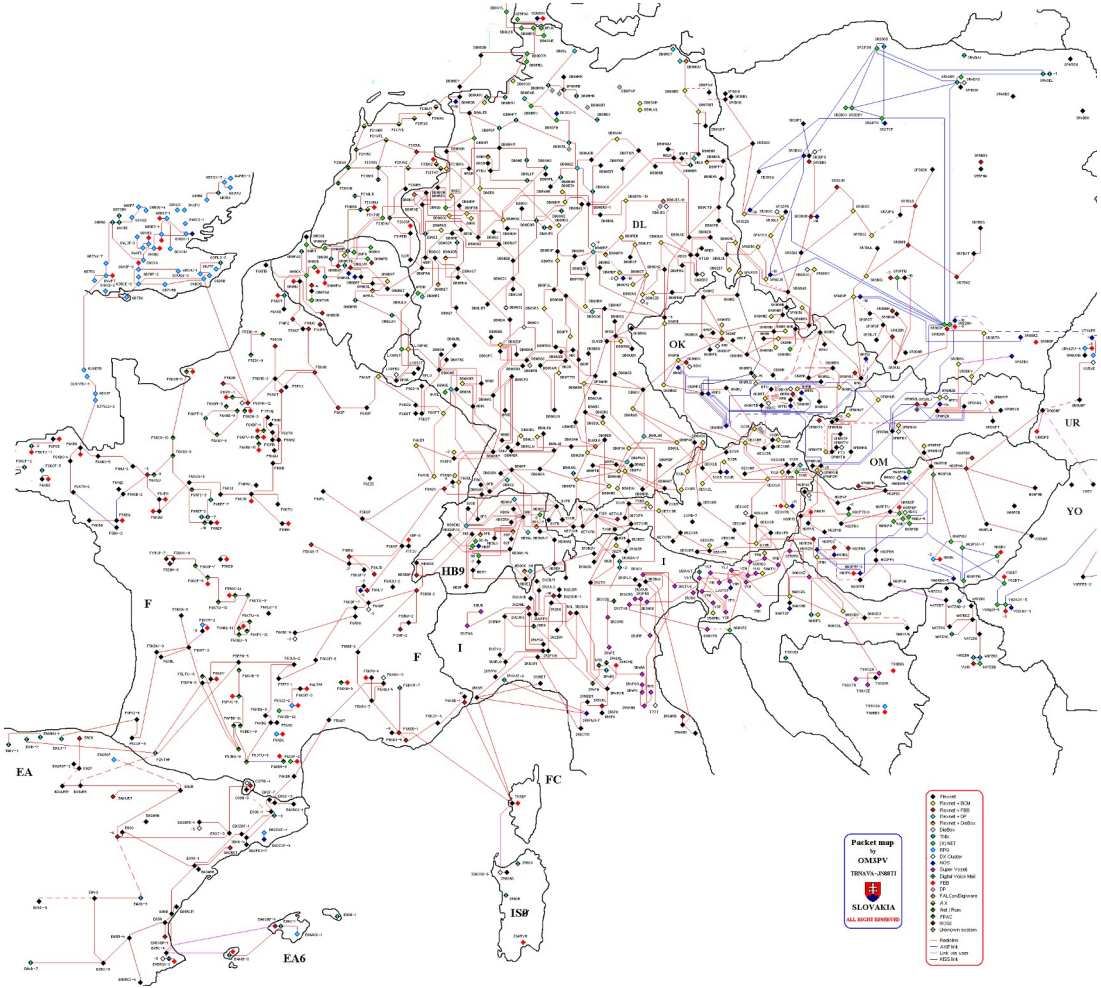
HAMNET – Future Evolvement?

Packet Radio Map as of the late 90s by OM3PV

Interlinks:
- 23-cm: 19k2 FSK
- 70-cm: 9k6 FSK

User Access:
- 70-cm: 9k6 FSK / 1k2 AFSK
- 2-m: 1k2 AFSK

Can HAMNET grow that large, too?



HAMNET – Future Evolvement?

What do we need for further expansion?

- Most important:
  Access to sites, which can interconnect other sites by line of sight!

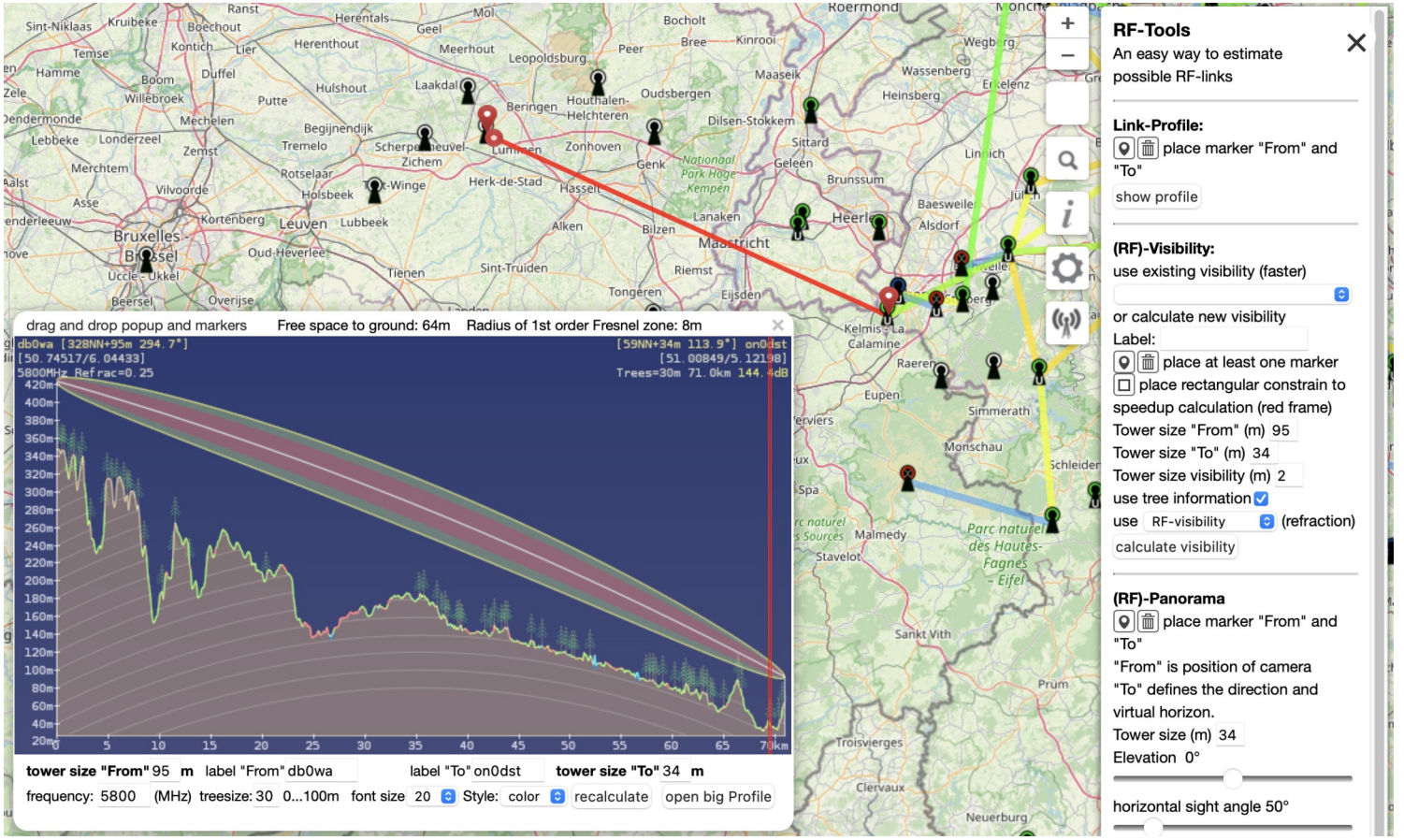
- Propagation Tools:
  HamnetDB RF-Tools → https://hamnetdb.net/map.cgi
  https://www.radiofresnel.com

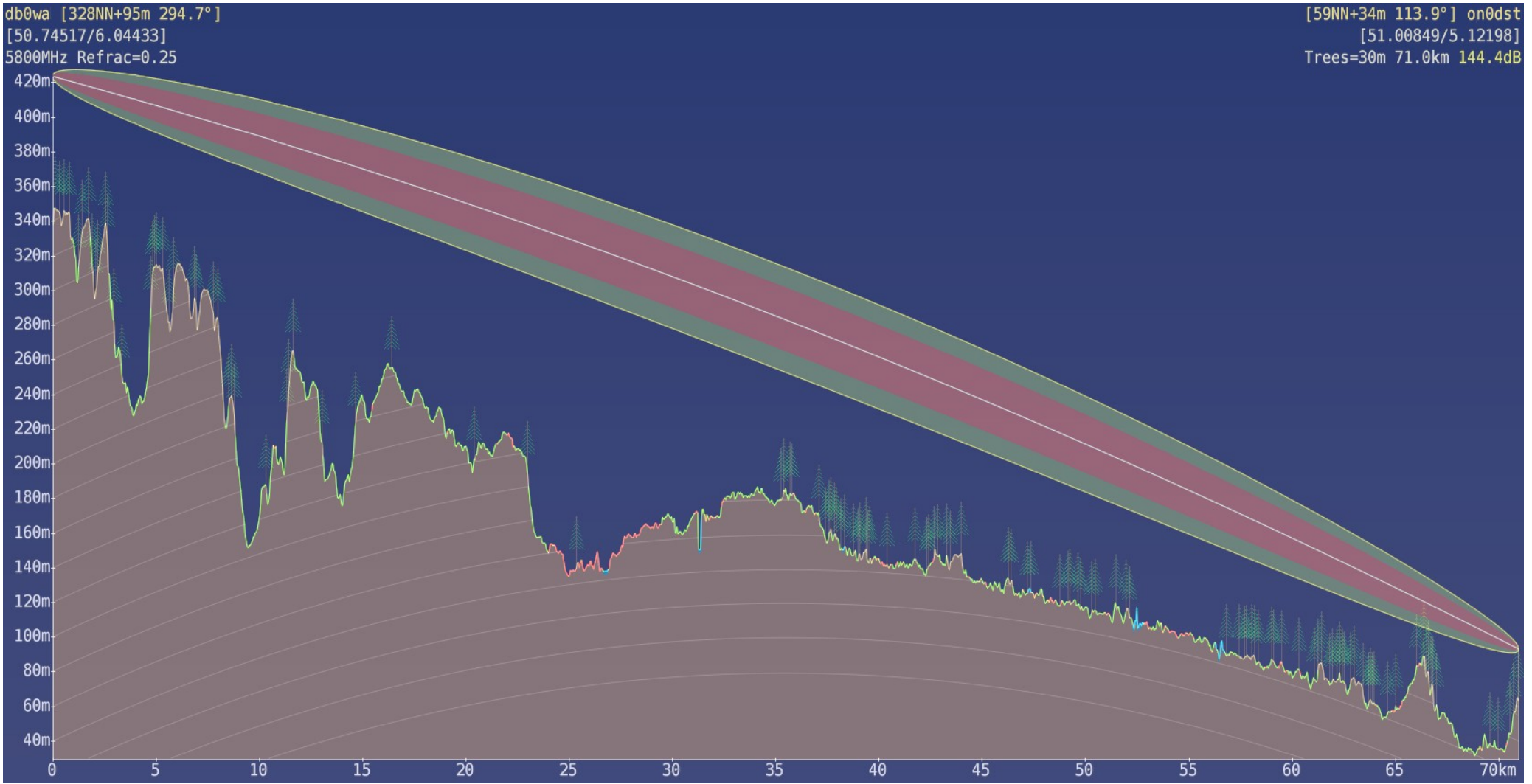
- IP-Resources / AS-Numbers / HAMNET-Uplink (Radio- or VPN-Connection)

HAMNET – Future Evolvement?

HamnetDB
RF-Tools

All you need is
“line-of-sight”




db0wa [328NN+95m 294.7°]
[50.74517/6.04433]
5800MHz Refrac=0.25
[59NN+34m 113.9°] on0dst
[51.00849/5.12198]
Trees=30m 71.0km 144.4dB
420m
400m
380m
360m
340m
320m
300m
280m
260m
240m
220m
200m
180m
160m
140m
120m
100m
80m
60m
40m
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70km

HAMNET – Future Evolvement?

IP-Resources / AS-Numbers / HAMNET-Uplink (Radio- or VPN-Connection)

- Contact me! <dg8ngn@darc.de> or “dg8ngn” on most platforms

- IP-/AS-Allocation Scheme for Quickstart available:
  https://hamnetdb.net/?q=xy
- HAMNET-Uplink via VPN:
  Connection to DB0GW or DB0FHN

HAMNET – Future Evolvement?

Applications?

- My personal backlog:
  - SIP-Server on HamCloud providing 2 SIP lines
    - 1st SIP-Line will force Clients to use Peer-to-Peer Mode (Radio only)
    - 2nd SIP-Line will force Clients to transfer audio via Server (VPN Tunnel)
      → End-Users will have the choice to select desired SIP line

- Further Ideas:
  - <hidden to avoid personal overload>
  - Your ideas?

HAMNET – Future Evolvement?

HAMNET RF Access for endusers:
Most users don’t have a HAMNET site nearby (if so, they often suffer from a missing “line-of-sight” issue)

Use lower radio bands:

- 23cm: Standard WiFi gear with 5 MHz RF bandwidth and transverters?
- 70cm / soon 23cm: https://hackaday.io/project/164092-npr-new-packet-radio
- 70-cm: GSM/GPRS (Osmocom Implementation) → EDGE?

Use satellites:

- Access via QO-100?
  - http://f4hdk.free.fr/NPR_VSAT/
  - https://destevez.net/2022/11/using-gse-and-dvb-s2-for-ip-traffic/

HAMNET – Future Evolvement?

Improving the HAMNET Backbone:

10 GHz

- Plenty of spectrum (500 MHz) available (we run 2 links on 10 GHz)
- Expensive gear available (2k€++, one end!)
- Transverters for Standard Wifi Gear to make it affordable?
- Spectrum: “Use it or loose it”?

Other stuff to explore:

- THz Laser-Links? Laser = Speed; Fallback = existing 5 GHz infrastructure
- Playing with LTE B40 (TDD) on 13cm: Looking for Ericsson B40T gear...
- Playing with 5G SA n40 (TDD): https://docs.srsran.com/projects/project/en/latest/tutorials/source/cotsUE/source/index.html
- Playing with OpenWifi on 70cm/23cm: https://github.com/open-sdr/openwifi