The HAMNET
Mikrotik's role in the world of Amateur Radio

Jann Traschewski, DG8NGN
German Amateur Radio Club (DARC e.V.)
dg8ngn@darc.de
Introduction – Jann, DG8NGN

Member of the German Amateur IP-Coordination Team
- Region South: Jann Traschewski, DG8NGN
- Region North-West: Egbert Zimmermann, DD9QP
- Region North-East: Thomas Osterried, DL9SAU

VHF/UHF/Microwave Manager DARC e.V.

Profession:
System Engineer for Spectrum Monitoring Systems (Rohde & Schwarz Munich)
Facts about Amateur Radio

- **Exams**
  - Germany: Multiple-Choice Test
    - Class A (full license)
    - Class E (entry level license: less power, less frequency bands)
- **License allows Amateur Radio Operation on Amateur Radio Frequencies**
- **Amateur Radio Operators have their own worldwide unique Callsign**
  - e.g. Jann Traschewski = DG8NGN
- **Amateur Radio Operators are everywhere around us (esp. in technical business)**
  - ~2 million amateur radio operators worldwide (~70.000 in Germany)
  - growing numbers in the last few years
Facts about Amateur Radio

- Amateur Radio has its own national laws (rights & duties)
  - Amateur radio homebrew: Due to the technical knowledge proven by the exams, amateurs are allowed to build and operate their homemade radios
  - No commercial usage: Amateurs may not use their radio frequencies to provide commercial services
  - No obsurced messages: Amateurs may not obscure the content of their transmissions
  - Identification: Amateurs need to identify with their callsign regularly
Amateur Radio Operation

- Space Communication
- Moonbounce

International Space Station
Callsign: DP0ISS

8.6m diameter Dish!!

Moonbounce station from Joe, K5SO
(http://www.k5so.com)
Amateur Radio Operation

- Weak Signal Propagation Reporter

- very low power (e.g. 20dBm)
- very low bandwidth
- very high range

WSPRnet propagation map 14 MHz (http://wsprnet.org)
Amateur Radio Operation

• Repeater Operation
  standalone vs. interconnected repeaters
  Amateur Radio Interlinks vs. Internet based Links

Olympic Tower
Munich

Telecommunication Tower
Nuremberg

Diego Delso [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons
Digital Radio Networks

• Packet Radio Network
  - own protocol (AX.25)
  - own hardware (modems/radios)
  - „Peak“ Packet Radio ~ 1997
    • 2000 nodes (system designed for max. 600)
    • Interconnection speed typical 1,2 or 9,6 kbit/s
    • Large areas of Europe covered by Packet Radio
  - TCP/IP encapsulation in AX.25
    • Phil Karns, KA9Q, IP-stack implementation from 1985 envolved into the Linux kernel
    • Amateurs gathered the full IP address block 44.0.0.0/8 for worldwide usage in 1980
The „HAMNET“

- **Highspeed Amateurradio Multimedia Network**
- From „TCP/IP over AX.25“ to „AX.25 over TCP/IP“
  - TCP/IP networks carry each kind of data
- Network is based on commercial wireless devices mainly used in the 6-cm amateur band (5650 MHz – 5850 MHz), Useraccess on 13-cm, 9-cm and 6-cm band
- Network covers mostly the Germany speaking region in Europe and grewed already over the language border
The network
Standard Deployment Example #1

2.3 GHz User Access Antenna
~20 $

up to 32dBm

2.3 GHz user access trx
Mikrotik Metal 2SHPn
~99 $

5 GHz mid range link antenna (MIMO) + build-in trx
Mikrotik QRT-5
~169 $

23dBi

LAN+PoE

Router with 4x PoE out
Mikrotik RB750UP
~59 $

LAN+PoE

5 GHz trx (MIMO)
Mikrotik BaseBox5
~89 $

LAN+PoE

5 GHz long range link antenna (MIMO)
Mikrotik mANT30 PA
~129 $

30dBi
Standard Deployment Example #2

Switch with 4x PoE out
Mikrotik RB260GSP
~56 $

5 GHz user access antenna (MIMO) + Transceiver Mikrotik mANTBox 15s
~139 $ each

North-West
15dBi
up to 31dBm

LAN+PoE

North-East

LAN+PoE

South
LAN+PoE

LAN to Router

Switch with 4x PoE out
Mikrotik RB260GSP
~56 $
Network Management – Principles & IP Allocations

- Keeping the experimental nature of amateur radio
  - Regional network management
  - Active regions will get enough resources (IP-addresses, AS-numbers)
  - Active regions will „speak“ eBGP to neighbors

- IP numbers for German regions will be provided by the German IP coordination team (cf. RIPE)
Network Management – ASN allocations (16 bit)

- The HAMNET is using the private AS space as noted in RFC 1930 (AS64512 to AS65535)

RFC 1930  Guidelines for creation of an AS  March 1996

10. Reserved AS Numbers

The Internet Assigned Numbers Authority (IANA) has reserved the following block of AS numbers for private use (not to be advertised on the global Internet):

64512 through 65535
Network Management – ASN allocations (16 bit)

- The allocation to different countries is not yet coordinated in a global way, thus we try to synchronize our wikis with recent changes:
  - DL: http://www.de.ampr.org/dokumentation/as-nummern

<table>
<thead>
<tr>
<th>Country</th>
<th>ASN Block</th>
<th>Local documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>OE</td>
<td>64512-64599</td>
<td>Wiki</td>
</tr>
<tr>
<td>I</td>
<td>64600-64619</td>
<td>Wiki</td>
</tr>
<tr>
<td>DL</td>
<td>64620-64683</td>
<td>List or WHOIS-Search</td>
</tr>
<tr>
<td>LX</td>
<td>64684-64685</td>
<td>Wiki</td>
</tr>
<tr>
<td>CR</td>
<td>64686-64690</td>
<td>Wiki</td>
</tr>
<tr>
<td>PA</td>
<td>64691-64694</td>
<td>Wiki</td>
</tr>
<tr>
<td>S5</td>
<td>64695-64704</td>
<td>Wiki</td>
</tr>
<tr>
<td>HA</td>
<td>64705-64707</td>
<td>Wiki</td>
</tr>
<tr>
<td>EA</td>
<td>64708-64719</td>
<td>Wiki</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HB</td>
<td>64720-64739</td>
<td>Wiki</td>
</tr>
<tr>
<td>HB0</td>
<td>64740-64741</td>
<td>Wiki</td>
</tr>
<tr>
<td>F</td>
<td>64742-64777</td>
<td>Wiki</td>
</tr>
<tr>
<td>ON</td>
<td>64778-64788</td>
<td>Wiki</td>
</tr>
<tr>
<td>TA</td>
<td>64789-64799</td>
<td>Wiki</td>
</tr>
<tr>
<td>SP</td>
<td>64800-64839</td>
<td>Wiki</td>
</tr>
<tr>
<td>YO</td>
<td>64840-64849</td>
<td>Wiki</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>65510-65534</td>
<td>Wiki</td>
</tr>
</tbody>
</table>
Network Management – ASN allocations (32 bit)

- RFC 6996 reflects the new 32-bit private AS number block 4200000000 to 4294967294

- Amateur usage:
  - 42 <3-digit country code ITU-T X.121> <5-digits free usage per country>

5. IANA Considerations

IANA has reserved, for Private Use, a contiguous block of 1023 Autonomous System numbers from the "16-bit Autonomous System Numbers" registry, namely 64512 - 65534 inclusive.

IANA has also reserved, for Private Use, a contiguous block of 94,967,295 Autonomous System numbers from the "32-bit Autonomous System Numbers" registry, namely 4200000000 - 4294967294 inclusive.

These reservations have been documented in the IANA "Autonomous System (AS) Numbers" registry [IANA.AS].
Routing within a region

- Each region is free to use its favorite routing protocol (e.g. OLSR, B.A.T.M.A.N., OSPF, internal BGP)
- Internal BGP is often used
  - Full Mesh: Each node needs to talk to each other node (more traffic, does not scale → $n(n-1)/2$ BGP links necessary)
  - Route Reflector: Each node needs to talk to the route reflector (Single point of failure)
  - BGP Confederation (preferred): ASN block 65510 to 65534 is used as internal AS numbers
Deployment - Sites

- Get in touch with anybody on this site: http://hamnetdb.net/?m=util&func=maintainer

Maintainers with write-access in this database:

<table>
<thead>
<tr>
<th>Callsign</th>
<th>Full Name</th>
<th>Comment</th>
<th>Edited</th>
</tr>
</thead>
<tbody>
<tr>
<td>db1hdn</td>
<td>Dennis</td>
<td>Admin DB0ROW, DB0RTN</td>
<td>364d dh6bb</td>
</tr>
<tr>
<td>db5jl</td>
<td>Detlev</td>
<td>C21</td>
<td>536d dg8ngn</td>
</tr>
<tr>
<td>db7mj</td>
<td>Peter</td>
<td>Sysop DB0ESS</td>
<td>477d dl8mbt</td>
</tr>
<tr>
<td>db7yi</td>
<td>Michael</td>
<td>Sysop DB0PM</td>
<td>595d dg8ngn</td>
</tr>
<tr>
<td>db8zp</td>
<td>Peter</td>
<td>Sysop DB0TAN</td>
<td>403d dg8ngn</td>
</tr>
<tr>
<td>dc1dmr</td>
<td>Matti</td>
<td></td>
<td>92d dh3wr</td>
</tr>
<tr>
<td>dc1nf</td>
<td>Dieter</td>
<td>Sysop DB0ADS</td>
<td>303d dg8ngn</td>
</tr>
<tr>
<td>dc1paa</td>
<td>Michael</td>
<td>Sysop DB0ALU</td>
<td>557d dg8ngn</td>
</tr>
<tr>
<td>dc1rd</td>
<td>Rainer</td>
<td>Sysop DB0SL</td>
<td>423d dg8ngn</td>
</tr>
<tr>
<td>dc2ve</td>
<td>Frank</td>
<td>Verwaltung AS64650</td>
<td>538d dg8ngn</td>
</tr>
<tr>
<td>dc4ab</td>
<td>Andreas</td>
<td>Sysop DB0DUX</td>
<td>293d dk2cna</td>
</tr>
</tbody>
</table>

- They can create an account for you to edit the database
- Or ask me (dg8ngn@darc.de) to get you an account
Deployment - Sites

- Login to http://hamnetdb.net
- Click on „Sites“
- Press „New Site“
- Fill the following data into the form:
  - Call sign
  - Descriptive Name
  - Latitude, Longitude and meters above ground
  - Comma separated list of maintainers
Deployment - Sites

- Click onto your site and scroll down the list
- Have a look for nearby sites and check the link profile by clicking "Profile"

Check for line of sight (5 GHz) and get in touch with the operator
Deployment – Link Budget

• You might want to calculate your link budget to estimate the data rate you could achieve

• Check your data sheet of your TRX (e.g. Mikrotik QRT 5)

  → Gain is 23 +/- 1dBi

  → TX level at MCS7 (Modulation and Coding Scheme: 64-QAM with Coding rate 5/6) will be 24dBm

  → RX at MCS7 needs -78dBm of receiving power level

• Check additional losses of antenna gain by looking into chart „gain vs. frequency“ (if provided by manufacturer)
Deployment – Link Budget

- There are many link budget calculation tools on the web
- Pick one and put the worst case values in (e.g. http://en.jirous.com/calculation-wifi):

Fresnel zone

Fresnel zone is an area where most of the power between antennas is transmitted, it is cigar shaped. If there is a barrier in this area, the transmission attenuation increases. Calculated radius is in the middle of the link and at the end it decreases.
Deployment – Link Budget

- Estimated receiving level is -71dBm, so we have 7dB left for inaccuracy (e.g. unknown frequency/gain behavior)

- Keep in mind that changing bandwidth from 20 MHz down to 10 MHz will give you 3dB more gain (respectively 6dB by narrowing down to 5 MHz) but the throughput will suffer from the same factor (divided by 2 respectively 4)

- Running 2 spatial streams (horizontal and vertical polarization) at the same time will give us 130 Mbit/s:

<table>
<thead>
<tr>
<th>MCS index</th>
<th>Spatial streams</th>
<th>Modulation type</th>
<th>Coding rate</th>
<th>Data rate (Mbit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 MHz channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 MHz channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>800 ns GI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>800 ns GI</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>64-QAM</td>
<td>5/6</td>
<td>65.00</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>64-QAM</td>
<td>5/6</td>
<td>130.00</td>
</tr>
</tbody>
</table>

Deployment – Spectrum Regulatory

- Before deploying a radio link for an automatic radio station you need to check the rules which apply for your country
- Germany
  - Automatic radio stations need a special license (they get a special call sign e.g. „db0xyz“) from the regulation authority „BNetzA“ (200,- € per call sign)
  - Different rules will apply per band or even frequency ranges (e.g. 10 MHz bandwidth maximum in Germany) by law
  - Each desired frequency usage needs to be applied at the regulation authority
  - Frequencies will be granted/denied after ~4-5 month
Deployment - Identification

- Radio amateurs need to identify in regular intervals
  - ESSID (e.g. HAMNET-DB0ABC-DB0XYZ)

- But is a transmission coming from DB0ABC or DB0XYZ?
  → Only valid with fixed convention (e.g. AP-Mode = first call sign and Station-Mode = second call sign)
  → How to handle Point-to-Multipoint Links?
Deployment - Identification

- Using locally administered MAC-addresses
  - Encoding of call sign into the free bits in a MAC-address

```
<table>
<thead>
<tr>
<th>Byte 6</th>
<th>Byte 5</th>
<th>Byte 4</th>
<th>Byte 3</th>
<th>Byte 2</th>
<th>Byte 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRRRRXX</td>
<td>RRRRRNN</td>
<td>RRRRRSS</td>
<td>RRRRRSS</td>
<td>RRRRRSS</td>
<td>RRRRRSS</td>
</tr>
</tbody>
</table>
```

8 Bit 1 8 Bit 1 8 Bit 1 8 Bit 1 8 Bit 1 8 Bit 1

R = Bits for coding the call sign
S = Bits for the station identifier (SSID)
N = reserved for future applications
X = Standardbits according to IEEE 802
  - Bit 1: 0 = unicast / 1 = multicast
  - Bit 2: 0 = globally unique / 1 = locally administered

Details and Tools/Scripts available (in German) on:
http://db0fhn.efi.fh-nuernberg.de/doku.php?id=projects:wlan:proposal
Deployment - Identification

- Neighbor Discovery Protocols
  - There are plenty of neighbor discovery protocols in the wild (CDP, LLDP, MNDP, ...)
  - Just set the „Identity“ to your call sign and you're fine

Neighbor List of HAMNET Station „DB0DOS“
(Mikrotik and Ubiquiti Devices)
Deployment – AS/IP-Subnet-Allocation

- Regions need to get an AS- and IP-Allocation
  - The German IP Coordination is taking care

http://www.de.ampr.org/dokumentation/as-nummern/as-list-de
Deployment – AS-Allocation

- Information is reflected in the HAMNETDB

http://hamnetdb.net/?m=as
Deployment – IP-Subnet-Allocation

- Information is reflected in the HAMNETDB

<table>
<thead>
<tr>
<th>Subnet-IP</th>
<th>Type</th>
<th>Own AS</th>
<th>Parent</th>
<th>Radio parameters / Comment</th>
<th>Edited</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.130.53.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64631</td>
<td></td>
<td>393d dg8ngn</td>
</tr>
<tr>
<td>44.130.56.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64625</td>
<td></td>
<td>393d dg8ngn</td>
</tr>
<tr>
<td>44.130.59.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64530</td>
<td></td>
<td>393d dg8ngn</td>
</tr>
<tr>
<td>44.130.60.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64626</td>
<td></td>
<td>393d dg8ngn</td>
</tr>
<tr>
<td>44.130.61.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64626</td>
<td></td>
<td>393d dg8ngn</td>
</tr>
<tr>
<td>44.130.99.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64626</td>
<td></td>
<td>186d dg8ngn</td>
</tr>
<tr>
<td>44.130.146.0/24</td>
<td>AS-Packet-Radio</td>
<td>-</td>
<td>AS64627</td>
<td>Distrikt-L Packet-Radic Netz</td>
<td>162d dd9qp</td>
</tr>
<tr>
<td>44.224.10.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64625</td>
<td></td>
<td>665d dg8ngn</td>
</tr>
<tr>
<td>44.224.12.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64626</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.224.14.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64627</td>
<td>Distrikt-L Backbone Netz</td>
<td>579d dg8ngn</td>
</tr>
<tr>
<td>44.224.16.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64628</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.224.18.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64629</td>
<td>Berlin Backbone Netz</td>
<td>585d dl7uaz</td>
</tr>
<tr>
<td>44.224.20.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64630</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.224.22.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64631</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.225.20.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64625</td>
<td></td>
<td>689d dl8mtb</td>
</tr>
<tr>
<td>44.225.24.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64626</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.225.28.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64627</td>
<td>Distrikt-L User/Services Netz</td>
<td>579d dd9qp</td>
</tr>
<tr>
<td>44.225.32.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64628</td>
<td></td>
<td>594d dg8ngn</td>
</tr>
<tr>
<td>44.225.36.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64629</td>
<td>Berlin User-Service Netz</td>
<td>456d dl9au</td>
</tr>
<tr>
<td>44.225.40.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64630</td>
<td></td>
<td>688d dl8mtb</td>
</tr>
<tr>
<td>44.225.44.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64631</td>
<td></td>
<td>688d dl8mtb</td>
</tr>
</tbody>
</table>

http://hamnetdb.net/?m=subnet
Deployment – „IP-Subnetting“

- Each region gets a /23 for the backbone (transfernetworks) and a /24 for user-/services (sitenetworks)
- Best practice:
  - Each site has a single router
  - Each site gets a /27 network from the maintainer (leave the next /27 free in case a network needs to be increased)
  - The sitenetwork will be announced by the router to the network
  - The sitenetwork can be splitted „internally“ at the site into several networks (e.g. /28 for users and /28 for services) → easy firewalling
  - Each site uses a /29 transfer network to interconnect to another site
Deployment – Network Documentation

• The HAMNETDB provides network management capabilities

• Data structure (AS, Hosts, Subnets, Sites):
  - Hosts belong to sites (user defined)
  - Hosts belong to subnets (by nature)
  - Subnets belong to AS (user defined)

→ The HAMNETDB is able to visualize data
Deployment – Network Documentation Example

### Site db0zm (München-Freimann Studentenstadt)
- **Coordinates:** 48.184086,11.611249 - 48°11.05' N 11°36.67' E - 48°11.02' N 11°36.40' E
- **Elevation:** 65 m above ground
- **Maintainer:** dl8rds, dg8ngn, dl8mbt, dd5ki
- Am Standort ist auch
  - 2m FM Relais DB0ZM 145.750
  - 70cm FM-Relais DB0NJ 438.775
  - 70cm DMR-Relais DB0NJ 439.4375
- **Site configuration:** [https://www.dropbox.com/s/0sd219kow4lb23f/DB0ZM.gif](https://www.dropbox.com/s/0sd219kow4lb23f/DB0ZM.gif)

**Last edited 2013-12-07 by dl8mbt**

<table>
<thead>
<tr>
<th>Site db0zm (München-Freimann Studentenstadt)</th>
<th>Backbone-Network</th>
<th>Site db0zm (München-Freimann Studentenstadt)</th>
<th>Backbone-Network</th>
<th>Site db0zm (München-Freimann Studentenstadt)</th>
<th>Backbone-Network</th>
<th>Site db0zm (München-Freimann Studentenstadt)</th>
<th>Backbone-Network</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="image1">Image 1</a></td>
<td><a href="image2">Image 2</a></td>
<td><a href="image3">Image 3</a></td>
<td><a href="image4">Image 4</a></td>
<td><a href="image5">Image 5</a></td>
<td><a href="image6">Image 6</a></td>
<td><a href="image7">Image 7</a></td>
<td><a href="image8">Image 8</a></td>
</tr>
<tr>
<td>db0zm (München-Freimann Studentenstadt)</td>
<td>44.224.10.49</td>
<td>db0zm (München-Freimann Studentenstadt)</td>
<td>44.224.10.40/29</td>
<td>db0zm (München-Freimann Studentenstadt)</td>
<td>44.224.10.72/29</td>
<td>db0zm (München-Freimann Studentenstadt)</td>
<td>44.224.10.73</td>
</tr>
<tr>
<td>Station WDS (NStreme)</td>
<td>000c423a644c</td>
<td>Station WDS (NStreme)</td>
<td>000c4260a61f</td>
<td>Station WDS (NStreme)</td>
<td>000c436fb3f2</td>
<td>Station WDS (NStreme)</td>
<td>000c436fb3f2</td>
</tr>
<tr>
<td>db0zm (München-Freimann Studentenstadt)</td>
<td>BackBone-Network</td>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>bb-db0tvmb.db0zm</td>
<td>44.224.10.49</td>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>000c423ba644c</td>
<td>BackBone-Network</td>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>bb-db0tvmb.db0tvm</td>
<td>44.224.10.54</td>
<td>db0tvm (München Olympiaturm)</td>
<td>44.224.10.54</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>000b6b234bca</td>
<td>BackBone-Network</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>bb-db0wai.db0wai</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>000c4260f56a</td>
<td>BackBone-Network</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>bb-db0wai.db0wai</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>000c4260f56a</td>
<td>BackBone-Network</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0wai (München Thalkirchen)</td>
<td>44.224.10.41</td>
<td>db0ebe (Ebersberg Aussichtsturm)</td>
<td>44.224.10.78</td>
</tr>
<tr>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
<td>8.6km - 207.5° - Show in Linktool</td>
</tr>
</tbody>
</table>

**Notes:**
- Backbone-Network: 44.224.10.49 - 44.224.10.48/29
- Network Frequency: 5685MHz, 10Mhz, horizontal
- Network Frequency: 5825MHz, 10Mhz, horizontal
- Network Frequency: 5795MHz, 10Mhz, vertical
- 2m FM Relais DB0ZM 145.750
- 70cm FM-Relais DB0NJ 438.775
- 70cm DMR-Relais DB0NJ 439.4375
- Site configuration: [https://www.dropbox.com/s/0sd219kow4lb23f/DB0ZM.gif](https://www.dropbox.com/s/0sd219kow4lb23f/DB0ZM.gif)
## Deployment – Network Documentation Example

<table>
<thead>
<tr>
<th>Host-IP</th>
<th>M</th>
<th>Hostname</th>
<th>Type</th>
<th>Site</th>
<th>Radio parameters / Comment</th>
<th>Edited</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.224.10.46</td>
<td></td>
<td>bb-db0wai.db0zm</td>
<td>Routing-Radio</td>
<td>db0zm</td>
<td>Station WDS (NStreme)</td>
<td>584d dg8ngn</td>
</tr>
<tr>
<td>44.224.10.49</td>
<td></td>
<td>bb-db0tvm.db0zm</td>
<td>Routing-Radio</td>
<td>db0zm</td>
<td>Station WDS (NStreme)</td>
<td>584d dg8ngn</td>
</tr>
<tr>
<td>44.224.10.73</td>
<td></td>
<td>bb-db0ebe.db0zm</td>
<td>Routing-Radio</td>
<td>db0zm</td>
<td>Station WDS (NStreme)</td>
<td>378d dg8ngn</td>
</tr>
<tr>
<td>44.224.10.74</td>
<td></td>
<td>lnk-db0ebe.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td></td>
<td>584d dg8ngn</td>
</tr>
<tr>
<td>44.225.20.193</td>
<td></td>
<td>router.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Routerboard RB433AH (WAI, TVM)</td>
<td>584d dg8ngn</td>
</tr>
<tr>
<td>44.225.20.194</td>
<td></td>
<td>allstarlink.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>2m FM-Relais DB0ZM</td>
<td>667d dg8ngn</td>
</tr>
<tr>
<td>44.225.20.195</td>
<td></td>
<td>eoeip.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Routerboard RB411AH (EBE)</td>
<td>667d dg8ngn</td>
</tr>
<tr>
<td>44.225.20.196</td>
<td></td>
<td>hamnetdb.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Raspberry PI mit Debian - ProxyPa..</td>
<td>506d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.197</td>
<td></td>
<td>webcam-nord.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Kamerarechner WL500GP OpenWRT - h..</td>
<td>589d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.198</td>
<td></td>
<td>webcam-sued.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Kamerarechner WL500GP OpenWRT - h..</td>
<td>589d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.199</td>
<td></td>
<td>dmr.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>db0nj 439.4375 MHz, Motorola DR30..</td>
<td>269d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.200</td>
<td></td>
<td>proxmox.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Server for Virtual Machines</td>
<td>7m dg8ngn</td>
</tr>
<tr>
<td>44.225.20.201</td>
<td></td>
<td>ipmi.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Remote Console</td>
<td>7m dg8ngn</td>
</tr>
<tr>
<td>44.225.20.202</td>
<td></td>
<td>winxp.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Windows VM</td>
<td>6m dg8ngn</td>
</tr>
<tr>
<td>44.225.20.203</td>
<td></td>
<td>dhcp-44-225-20-203.db0zm</td>
<td>DHCP-Range</td>
<td>db0zm</td>
<td>assigned dynamically</td>
<td>0s system</td>
</tr>
<tr>
<td>44.225.20.204</td>
<td></td>
<td>dhcp-44-225-20-204.db0zm</td>
<td>DHCP-Range</td>
<td>db0zm</td>
<td>assigned dynamically</td>
<td>0s system</td>
</tr>
<tr>
<td>44.225.20.205</td>
<td></td>
<td>wetter.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Wetterstation Davis Vantage Vue -..</td>
<td>102d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.206</td>
<td></td>
<td>netio.db0zm</td>
<td>Service</td>
<td>db0zm</td>
<td>Schaltsteckdose - 1: DMR-Relais D..</td>
<td>269d dl8mbt</td>
</tr>
</tbody>
</table>

18 entries.
## Deployment – Network Documentation Example

### Surrounding subnets

<table>
<thead>
<tr>
<th>Subnet-IP</th>
<th>Type</th>
<th>Own AS</th>
<th>Parent</th>
<th>Radio parameters / Comment</th>
<th>Edited</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.224.10.0/23</td>
<td>AS-Backbone</td>
<td>-</td>
<td>AS64625</td>
<td></td>
<td>665d dg8ngn</td>
</tr>
<tr>
<td>44.224.10.40/29</td>
<td>Backbone-Network</td>
<td>-</td>
<td>AS64625</td>
<td>db0zm, db0wai - 5825MHz, 10MHz, horizontal</td>
<td>691d dl8mbt</td>
</tr>
<tr>
<td>44.224.10.48/29</td>
<td>Backbone-Network</td>
<td>-</td>
<td>AS64625</td>
<td>db0tvm, db0zm - 5685MHz, 10MHz, horizontal</td>
<td>691d dl8mbt</td>
</tr>
<tr>
<td>44.224.10.72/29</td>
<td>Backbone-Network</td>
<td>-</td>
<td>AS64625</td>
<td>db0zm, db0ebe - 5795MHz, 10MHz, vertikal</td>
<td>691d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.0/22</td>
<td>AS-User/Services</td>
<td>-</td>
<td>AS64625</td>
<td></td>
<td>689d dl8mbt</td>
</tr>
<tr>
<td>44.225.20.192/28</td>
<td>Site-Network</td>
<td>AS65530</td>
<td>AS64625</td>
<td>db0zm</td>
<td>264d dg8ngn</td>
</tr>
</tbody>
</table>

6 entries.

### Surrounding AS

<table>
<thead>
<tr>
<th>AS</th>
<th>Name</th>
<th>Maintainer</th>
<th>Comment</th>
<th>Edited</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS64625</td>
<td>DISTRIKT-C-625-AS</td>
<td>dl3mbg, dg8ngn</td>
<td>Oberbayern</td>
<td>567d dl8mbt</td>
</tr>
</tbody>
</table>

1 entry.

### Other sites near db0zm:

<table>
<thead>
<tr>
<th>Site</th>
<th>Name</th>
<th>Distance</th>
<th>Direction</th>
<th>Above ground</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>db0tvm</td>
<td>München Olympiaturm</td>
<td>4.4 km</td>
<td>256.2°</td>
<td>200 m</td>
<td>Profile</td>
</tr>
<tr>
<td>dl0muc</td>
<td>Clubstation Chaos Computer C.</td>
<td>5.0 km</td>
<td>228.0°</td>
<td>30 m</td>
<td>Profile</td>
</tr>
</tbody>
</table>
Deployment – Network Documentation Example
Deployment – Network Documentation Example
Deployment - Typical User Setup

44.0.0.0/8
HAMNET / AMPRNet

Keep 44.0.0.0/8 for radio amateurs only!
Motivation –
Intranet for Radio Amateurs

• Trusted “Intranet” for radio amateurs
  - Packets from net44 are supposed to come from an amateur radio operator
  - Providing gateways from the Intranet to Radio is OK without further authentication of the individual amateur (e.g. access to shared Remote Transceivers, ...)

• End-to-End communication
  - NAT is evil...
  - No need to struggle around with portforwarding
  - No Firewall issues (cf. central DPI firewalls at universities... )
Motivation – Building a RF backbone

- Backbone for services (cf. Packet Radio Network – BBS, Convers, …)

Transport of:
- DATV, VoIP (DMR, D-Star, Echolink, Asterisk), APRS, Packet Radio
  - whatever you can transport on TCP/IP...

- Build an independent network for emergency communication (where the funding could come from…)

- Connecting public non-commercial webcams to the Internet
Motivation – Learning & Experimentation

• Building your own Internet
  – Technology you usually don't get in touch with (Routing protocols, Server-to-Server VPNs, DNS-Hosting, …)
  – Large testbed to improve things

• Building your own backhaul
  – GHz wave propagation
  – System Integration of backhaul technology
Application Examples - FM Repeater Group (SVXLink)

- Hansa-Link Network
Application Examples - FM Repeater Group (Allstarlink)

- Link (Süd) Tirol
Anwendung - Live-Streaming

Hier wird in einem Flashplayer Live-Stream von Amateurstations angezeigt. Benutzer können hier ebenfalls ihren eigenen Kanal bekommen. Bitte mit nrw-atv@online.de Kontakt aufnehmen.

DB0KWE Livestream
ATV-Livebild das im Moment in Weisweiler ausgestrahlt wird

DB0KO Livestream
ATV-Livebild das im Moment in Köln ausgestrahlt wird

DL9KAR Livestream
Bei Bedarf kann Bernd hier einen Videostream senden

DH3WR Livestream
Bei Bedarf kann Ralf hier einen Videostream senden

DF5KT Livestream
Bei Bedarf kann Norbert hier einen Videostream senden

DL2KBH Livestream
Bei Bedarf kann Dieter hier einen Videostream senden

test Livestream
ATV-Livebild das im Moment in xxx ausgestrahlt wird
Application Examples - Searchengines
Application Examples - WebSDR

http://websdr.org
Application Examples - Webcams

Kronplatz - Bruneck / Pustertal - Blick nach Norden über das Tauferer Tal
27.12.13 21:40 -2.8°C (f/3.5 25s iso1600)

http://www.foto-webcam.eu
Challenges – More bands

- 9cm – 3.4 GHz is available for amateur radio
  - more expensive compared to 6cm/13cm
- 3cm – 10 GHz: No Equipment from Mikrotik
- 24 GHz: Transverters
  - high price
- or even higher? 47 GHz, 76 GHz, ...
- Homebrew Up-/Downconverter?
  - Full duplex with Mikrotik
    NStreme Dual possible
    - One card in TX mode
    - One card in RX mode

24 GHz Transverter seen at MUM, Ljubljana, 2016
Challenges – Spurious emissions

- 5 MHz bandwidth
  - +/- 20 MHz → own signal seen again (lower level)
  - +/- 40 MHz → own signal seen again (less lower level)

- 10 MHz bandwidth
  - +/- 40 MHz → own signal seen again (lower level)
Spurious emissions suppressed

- Metal 5SPHn + Filters

Recommendation:
„Wireless - What you see is not always what you get“ by Ron Touw (LinITX, United Kingdom)
Challenges – EMC (electromagnetic compatibility)

- Don't interfere with other nearby radio users
- Don't interfere with your own amateur radio applications in other radio bands (e.g. 2-m-band)
- Unshielded wireless boards in plastic cases?!?
- Do shielding products work?
- Use Cat7 cables only!
- Ferrite rings might help…
Challenges – User Access Technology

- Connectivity more important than speed
- Reduced bandwidth = less noise → longer range
- Lower band = better for non-line-of-sight requirements
- **Wishlist**
  - 70cm band 432 MHz: 2 MHz, 1 MHz, 500 kHz, **200 kHz**, 100 kHz
  - 23cm band 1296 MHz: 10 MHz, 5 MHz, 2 MHz, **1 MHz**, 500 kHz, 200 kHz (10 MHz / 5 MHz available from Doodlelabs)
- We run D-Star DD 128kbit/s User Access on 23cm
- SDR experiments (HackRF, USRP, …)
- Internet of Things?
Challenges – Routing Protocols

• Most routing protocols doesn't take changing conditions on a radio link into account
  – Packet loss (any kind of reason, e.g. Interference)
  – Changing troughput due to adaptive modulation and coding (AMC)
  – TX-ccq and RX-ccq (Client connection quality)
  → Flapping routes, unreliable connections...

• There are some protocols to test (B.A.T.M.A.N., OLSR, Mikrotik MME, Babel)
  – Protocols can be tested within a region, however sometimes communication between two stations might be better routed using a path through an external autonomous system...

• Requirement: KISS (Keep it simple, stupid)
Possible Cooperations?

• Distributors
  – German Radio Club DARC e.V. invests in the digital backbone
  – See “challenges” to solve...

• Mikrotik
  – The HAMNET is a large testbed for e.g. a new layer 3 routing protocol taking radio qualities into account

• Wireless Internet Service Providers
  – Recently we took over an old WISP network and all the obligations to deconstruct the network
Urgent topics from amateur radio perspective

- Popular Amateur Radio User Access frequencies are under threat (e.g. 2392 MHz or 2397 MHz) due to the „FCC / ETSI firmware lockdown“
  Special solution for authorized group of people (e.g. amateurs, military, government purpose, ...) needed

- New 802.11ac chipsets do not support 5 MHz and 10 MHz bandwidth
  Demand needs to be addressed to the chipset manufacturers
Impressions

Gefrorenen Wand, OE7XGR, 3255m

Observatorium Sonnblick, OE2XSR, 3106m

Gefrorenen Wand, OE7XGR, 3255m