BATMAN and the LinuxKPI: Running Linux drivers on FreeBSD 🦇

Aymeric Wibo

A little bit about myself

- CS student at UCLouvain, in Belgium 🇧🇪
- Part-time at Bnewable (energy storage solutions startup) ⚡
- Interested in computer graphics (and BSD).
- **GSoC 2023 student.**

Dog (Bubbles)

🔭 What is the focus of this talk?

- The LinuxKPI & the state of affairs w.r.t. porting Linux drivers to FreeBSD.
- Will end with a case study on porting BATMAN to FreeBSD (my GSoC project).

🤔 What is the LinuxKPI?

- Kinda just a bunch of C headers which map Linux kernel functions (the KPI) to FreeBSD ones.
- **Internal kernel functions**, not syscalls, that's (part of) the Linuxulator's job.
- Headers rooted in `sys/compat/linuxkpi/common/include`.

Example function: `get_random_u32_below`

In `sys/compat/linuxkpi/common/include/linux/random.h`:

```c
static inline u32
get_random_u32_below(u32 ceil)
{

        return (arc4random_uniform(ceil));
}
```

`get_random_u32_below` is the Linux function, `arc4random_uniform` is FreeBSD's equivalent.

Let's port a simple Linux driver!!

Original Linux code:

```c
#include <linux/module.h>

static int __init demo_init(void) {
        pr_info("Hello from this demo module!\n");
        return 0;
}

module_init(demo_init);

MODULE_LICENSE("GPL");
MODULE_AUTHOR("Aymeric Wibo");
MODULE_DESCRIPTION("Super simple linux driver");
MODULE_VERSION("0.0.0");
```

Let's port a simple Linux driver!

```c
#include <linux/kernel.h>
#include <linux/module.h>

static int __init demo_init(void) {
        pr_info("Hello from this demo module!\n");
        return 0;
}

module_init(demo_init);

MODULE_LICENSE("GPL");
MODULE_AUTHOR("Aymeric Wibo");
MODULE_DESCRIPTION("Super simple linux driver");

#if defined(__linux__)
MODULE_VERSION("0.0.0");
#endif

#if defined(__FreeBSD__)
MODULE_VERSION(demo, 0);
MODULE_DEPEND(demo, linuxkpi, 1, 1, 1);
#endif
```

🛠️ Makefile...

```
.PATH: .

KMOD=   demo
SRCS=   demo.c

SRCS+=          ${LINUXKPI_GENSRCS}
CFLAGS+=        ${LINUXKPI_INCLUDES}

.include <bsd.kmod.mk>
```

🧪 Testing

```
$ kldload ./demo.ko
$ dmesg | tail -n 1
Hello from this demo module!
```

It works!

What can LinuxKPI do for us today?

- More than print hello world!
- Full network drivers (e.g. `iwlwifi(4)`).
- Full graphics drivers (e.g. `graphics/drm-kmod` with `i915` , `radeon` , `amd`).

✨ Adding new stuff

Update to the demo module

```
#include <linux/kernel.h>

static int __init demo_init(void) {
        hypothetical_function("Hello from this demo module!\n");
        return 0;
}
```

😲 Doesn't build!

```
demo.c:4:2: error: call to undeclared function 'hypothetical_function'; ISO C99
 and later do not support implicit function declarations [-Wimplicit-function-d
eclaration]
    4 |         hypothetical_function("Hello from this demo module!\n");
      |         ^
1 error generated.
*** Error code 1
```

🌳 Add stub

In `linux/kernel.h`:

```c
static inline void
hypothetical_function(const char *str)
{

        pr_debug("TODO: %s\n", __func__);
}
```

What does this do on Linux?

```
$ modprobe ./demo.ko
$ dmesg | tail -n 1
!eludom omed siht morf olleH
```

What does this do on FreeBSD?

```
$ kldload ./demo.ko
$ dmesg | tail -n 1
TODO: hypothetical_function
```

Does this matter?

Yes? Implement observed behaviour 👀

```
static inline void
hypothetical_function(const char *str)
{

        ssize_t const len = strlen(str);
        for (ssize_t i = len - 2; i >= 0; i++)
                pr_info("%c", str[i]);
        pr_info("\n");
}
```

⚠️ Can't be isomorphic to GPL code!

What about now?

```
$ kldload ./demo.ko
$ dmesg | tail -n 1
!eludom omed siht morf olleH
```

It works!

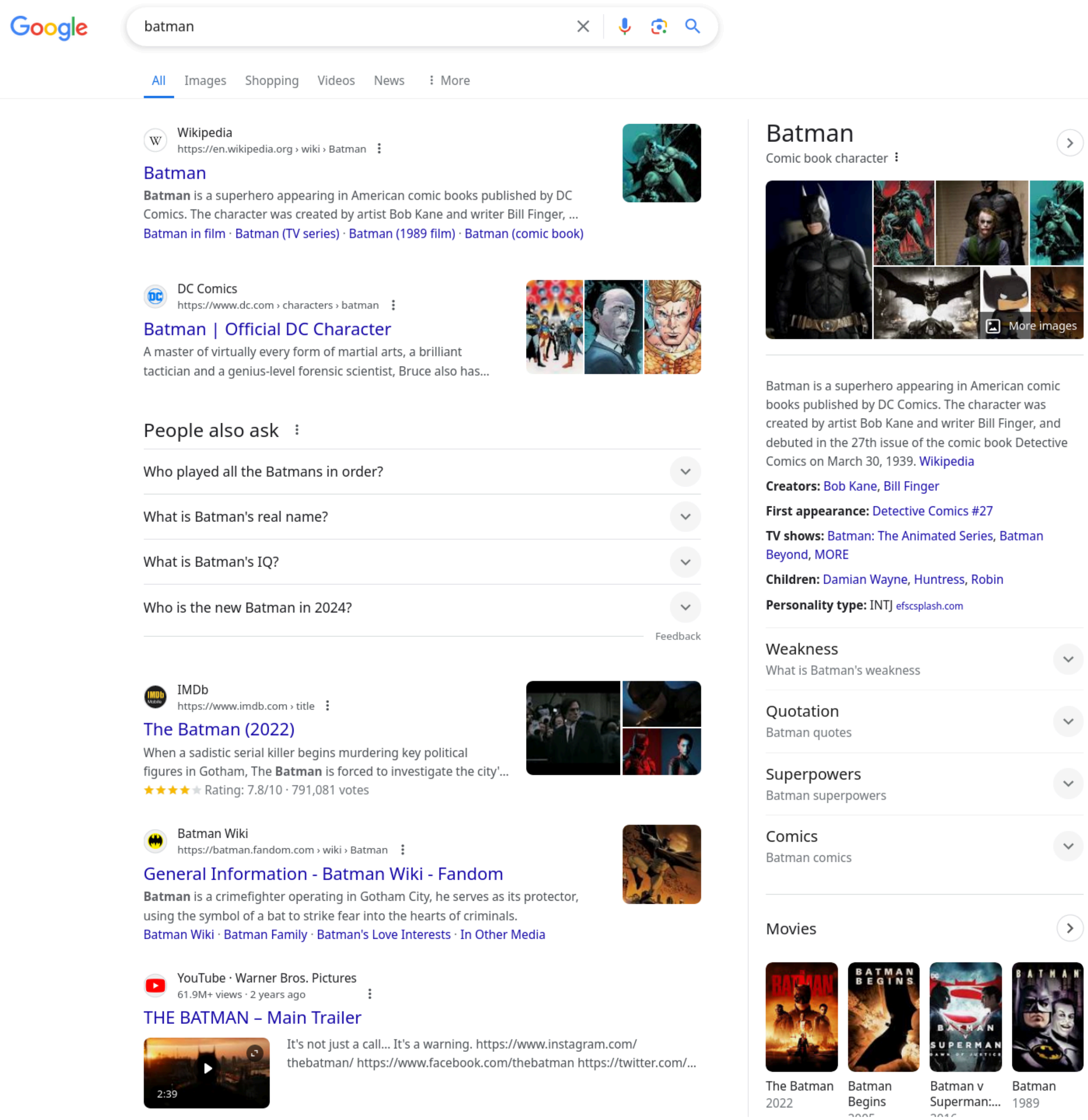
Questions related to LinuxKPI?

🦇 BATMAN: A case study

📚 A little bit of background...

What's a BATMAN?

- Very annoying to Google.
- Better Approach to Mobile Ad-hoc Networking.
- Essentially OSPF/OLSR, but optimized for big wireless meshes (i.e. constantly changing topology/link quality, &c).



Google

batman

All · Images · Shopping · Videos · News · More

Wikipedia
https://en.wikipedia.org › wiki › Batman

Batman

Batman is a superhero appearing in American comic books published by DC Comics. The character was created by artist Bob Kane and writer Bill Finger, ...

Batman in film · Batman (TV series) · Batman (1989 film) · Batman (comic book)

DC Comics
https://www.dc.com › characters › batman

Batman | Official DC Character

A master of virtually every form of martial arts, a brilliant tactician and a genius-level forensic scientist, Bruce also has...

People also ask

Who played all the Batmans in order?

What is Batman's real name?

What is Batman's IQ?

Who is the new Batman in 2024?

Feedback

IMDb
https://www.imdb.com › title

The Batman (2022)

When a sadistic serial killer begins murdering key political figures in Gotham, The **Batman** is forced to investigate the city'...

★★★★☆ Rating: 7.8/10 · 791,081 votes

Batman Wiki
https://batman.fandom.com › wiki › Batman

General Information - Batman Wiki - Fandom

Batman is a crimefighter operating in Gotham City, he serves as its protector, using the symbol of a bat to strike fear into the hearts of criminals.

Batman Wiki · Batman Family · Batman's Love Interests · In Other Media

YouTube · Warner Bros. Pictures
61.9M+ views · 2 years ago

THE BATMAN – Main Trailer

2:39

It's not just a call... It's a warning. https://www.instagram.com/thebatman/ https://www.facebook.com/thebatman https://twitter.com/...

Batman

Comic book character

More images

Batman is a superhero appearing in American comic books published by DC Comics. The character was created by artist Bob Kane and writer Bill Finger, and debuted in the 27th issue of the comic book Detective Comics on March 30, 1939. Wikipedia

Creators: Bob Kane, Bill Finger

First appearance: Detective Comics #27

TV shows: Batman: The Animated Series, Batman Beyond, MORE

Children: Damian Wayne, Huntress, Robin

Personality type: INTJ efscsplash.com

Weakness
What is Batman's weakness

Quotation
Batman quotes

Superpowers
Batman superpowers

Comics
Batman comics

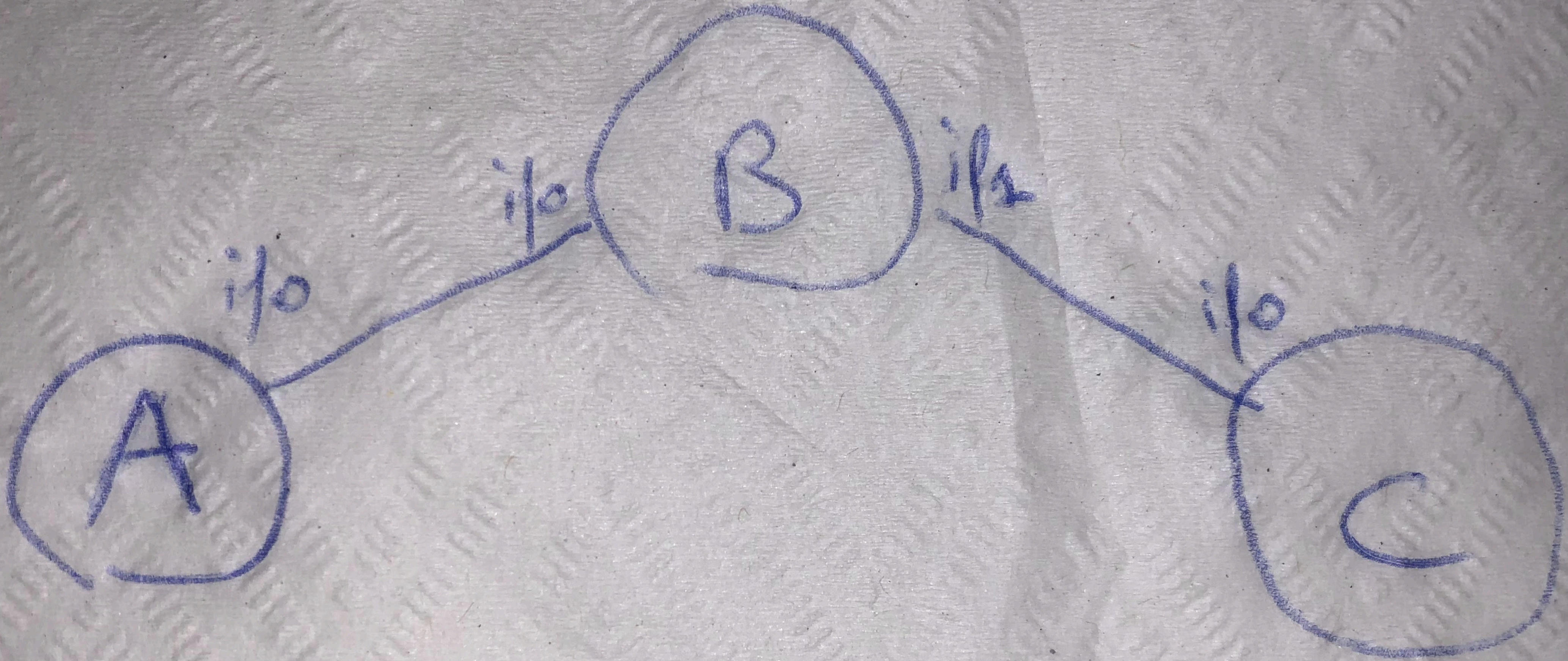
Movies

The Batman
2022

Batman Begins

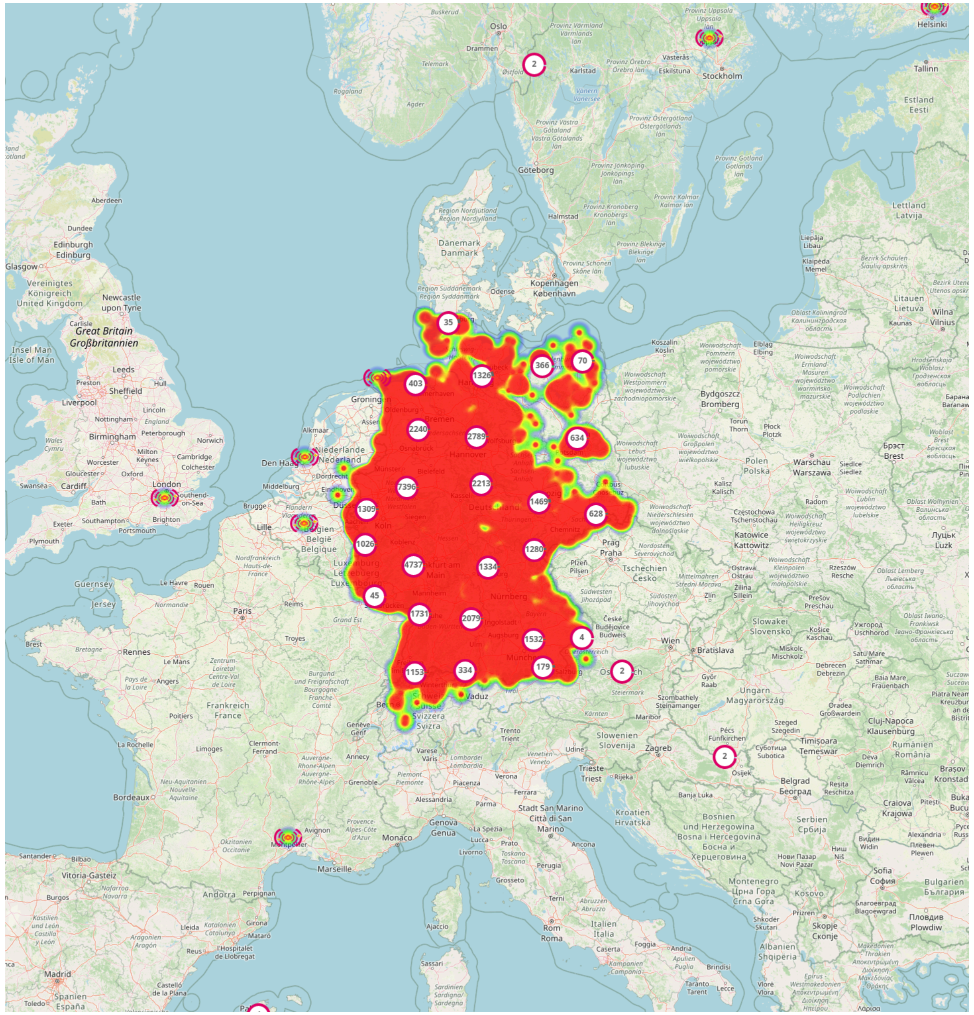
Batman v Superman:...

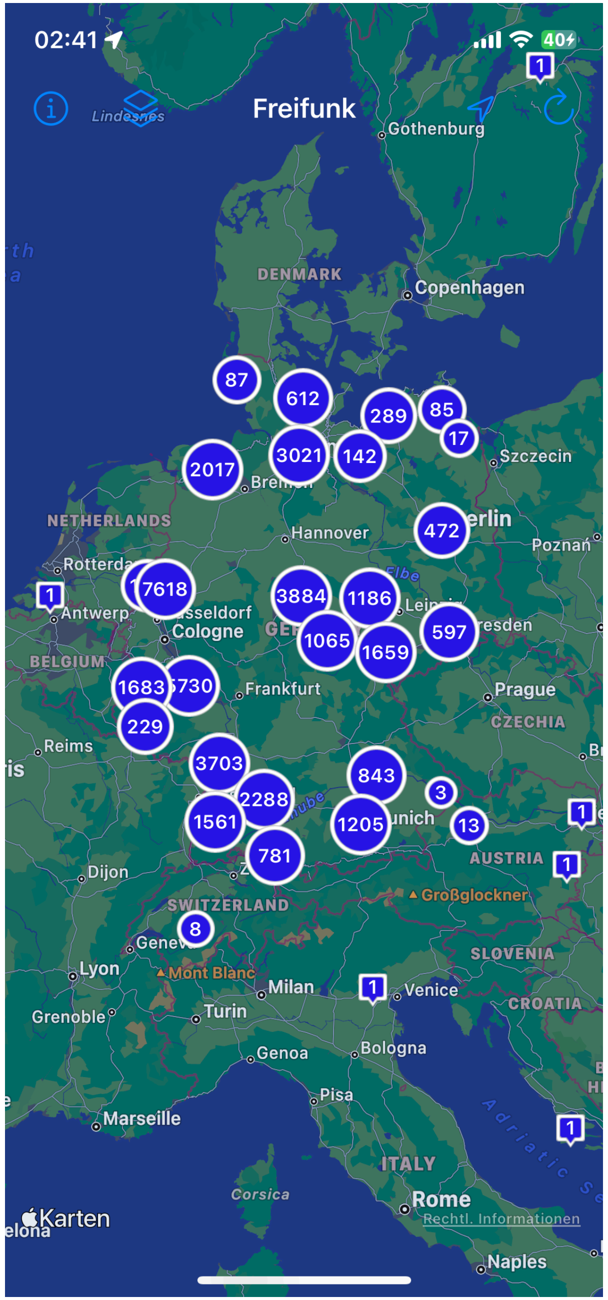
Batman
1989

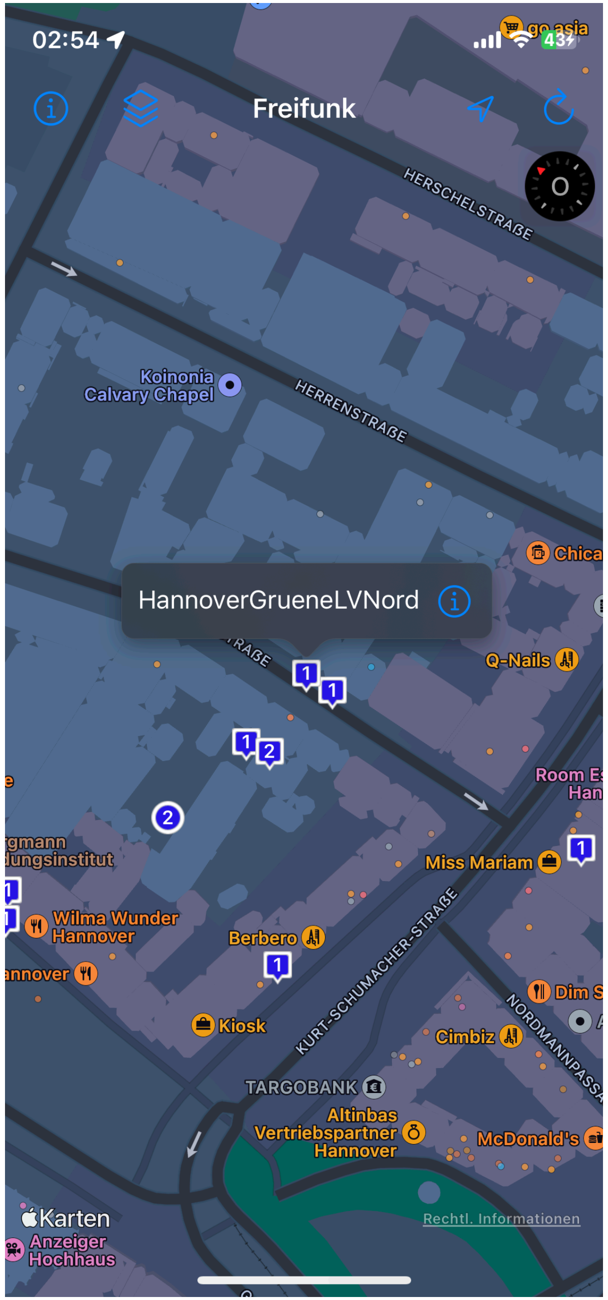

i/0
A
i/0
B
i/1
i/0
C

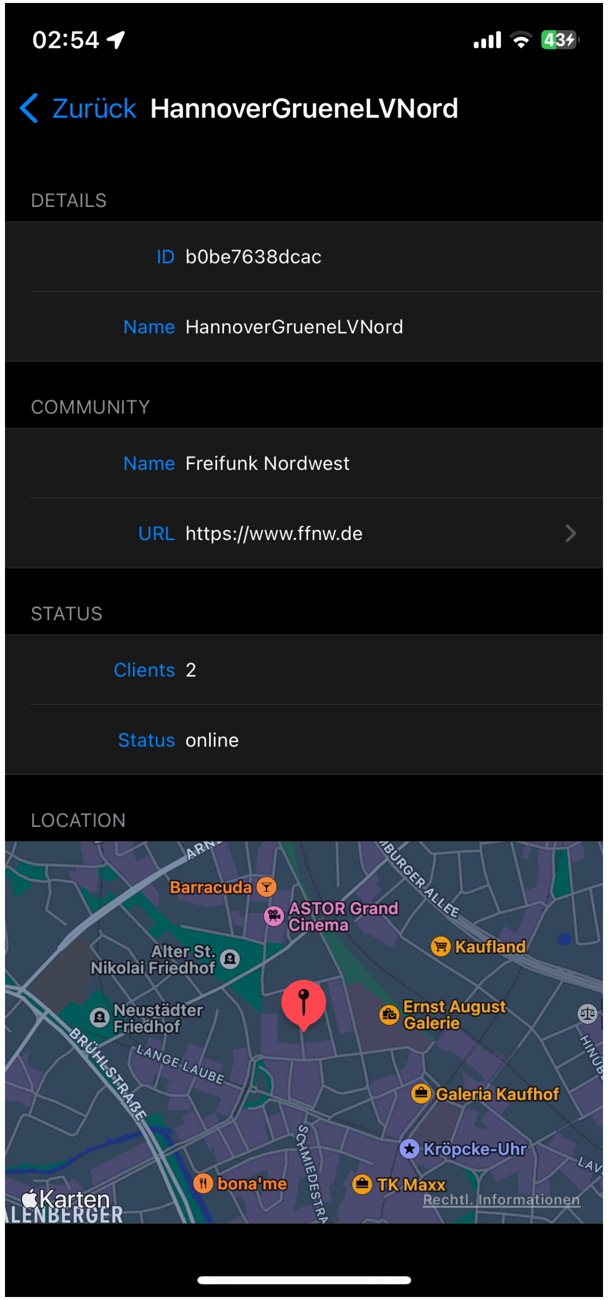
What is it used for?

- Driving force is *Freifunk*.
- Community wireless mesh networks.








02:54

< Zurück HannoverGrueneLVNord

DETAILS

ID b0be7638dcac

Name HannoverGrueneLVNord

COMMUNITY

Name Freifunk Nordwest

URL https://www.ffnw.de

STATUS

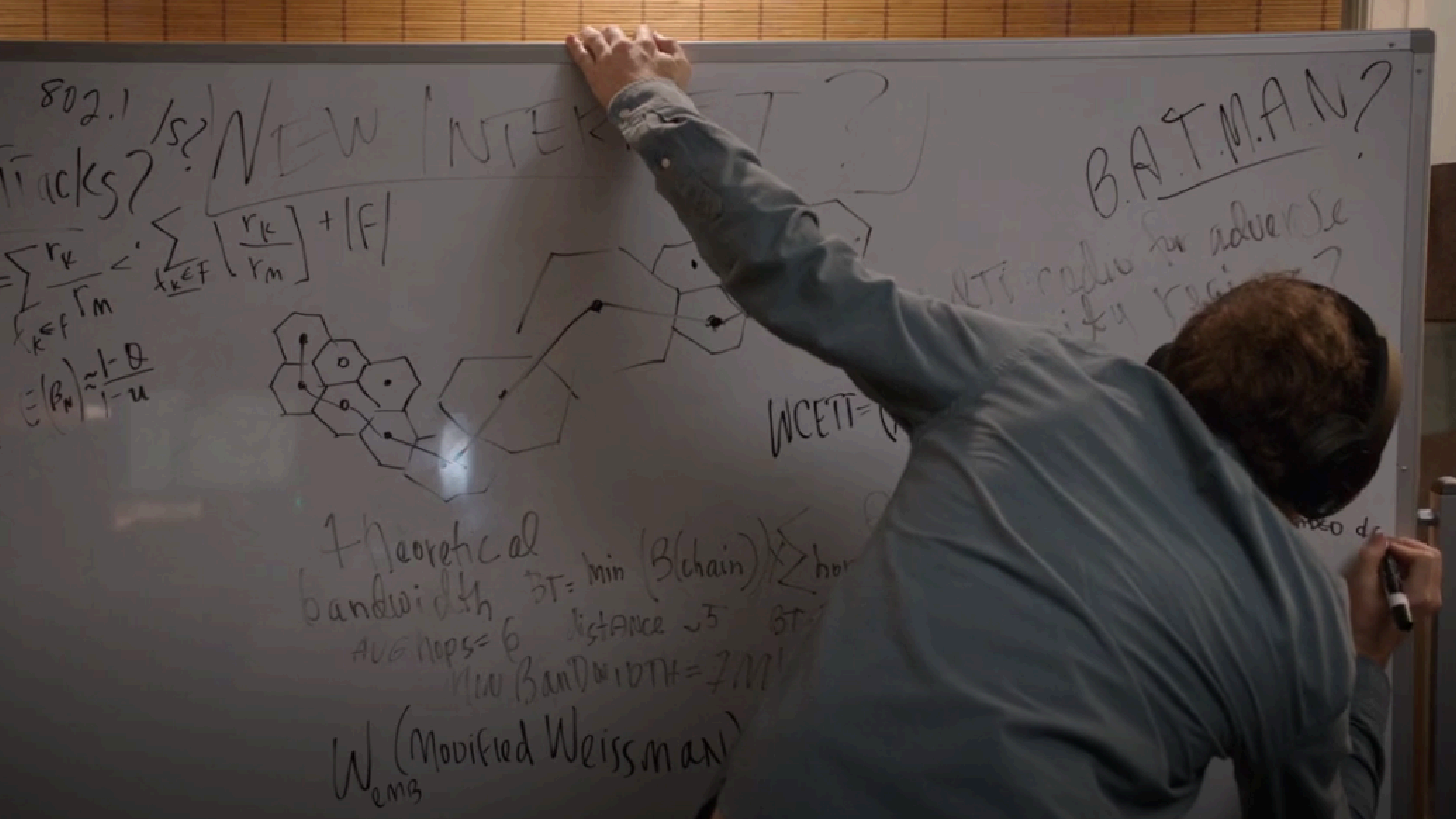
Clients 2

Status online

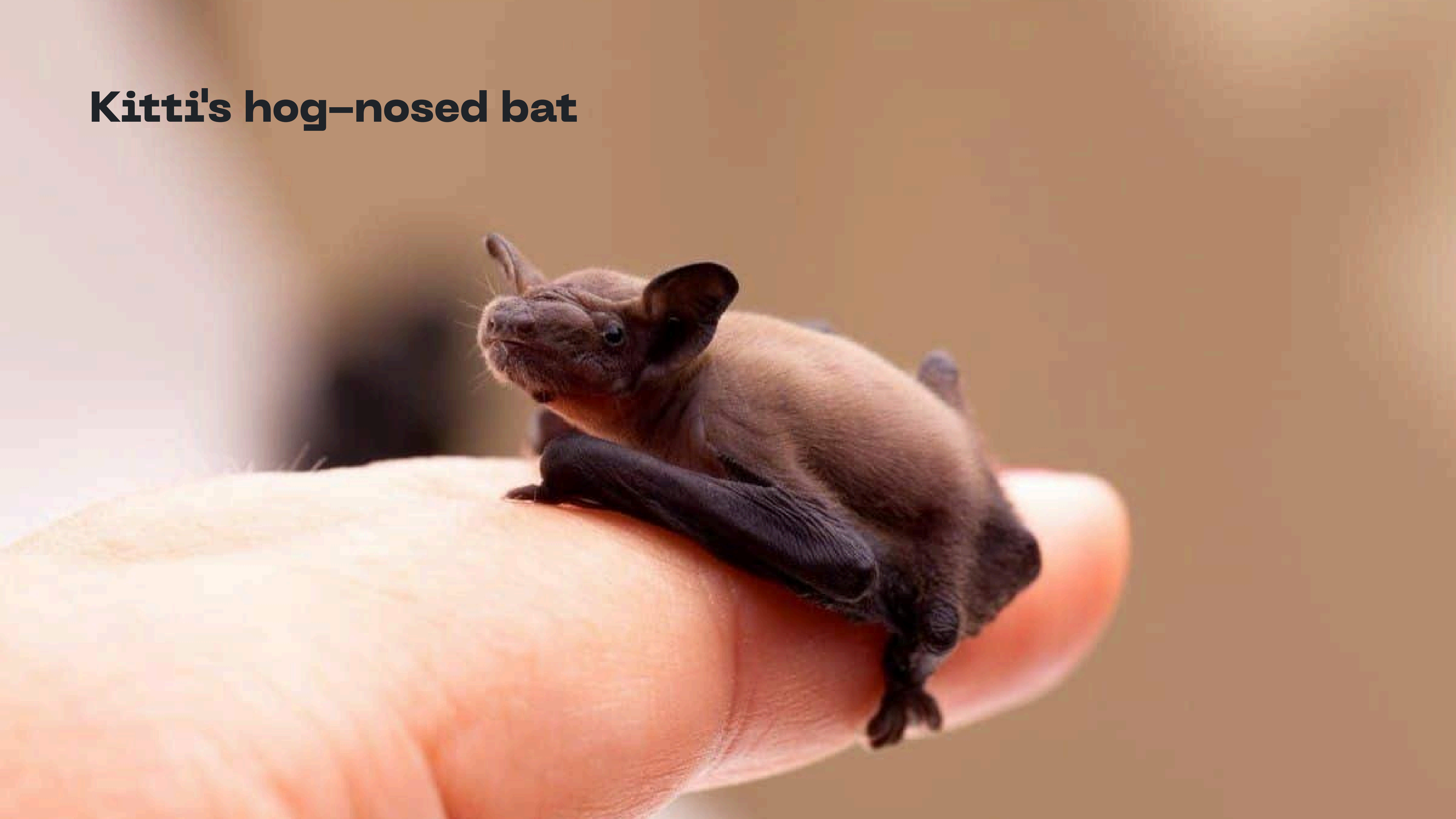
LOCATION

Quick history of BATMAN 📖

- Freifunk were feeling limited by OLSR – topology changes are expensive!
- Initially, userspace `batmand`.
- Then, `batman-adv` kernel module (BATMAN IV & V).
- BMX6/7 → offshoot.


802.1
1s?
Tracks?
NEW INTER
?
B.A.T.M.A.N?
Multi-radio for adverse
ify regi ?
$\sum_{f_k \in F} \frac{r_k}{r_m} < \sum_{f_k \in F} \left[\frac{r_k}{r_m} \right] + |F|$
$E(\beta_N) \approx \frac{1-\theta}{1-u}$
WCETT=(
Theoretical bandwidth
BT = min (B(chain)) × ∑ hor
AVG hops = 6
distance ~5
BT
MIN BANDWIDTH = 7M
W_{emb} (Modified Weissman)
video dc

Kitti's hog-nosed bat



How does BATMAN work? 🦾

- Only cares about local changes in topology.
- Layer 2 routing protocol → everything above gets wrapped.

How does BATMAN work? 🦾

Example Tee Cee Pee packet:

```
Frame 1077: 90 bytes on wire (720 bits), 90 bytes captured (720 bits) on interface bridge1, id 0
Ethernet II, Src: NetApp_af:d2:91 (00:a0:98:af:d2:91), Dst: NetApp_fd:37:f5 (00:a0:98:fd:37:f5)
    Destination: NetApp_fd:37:f5 (00:a0:98:fd:37:f5)
    Source: NetApp_af:d2:91 (00:a0:98:af:d2:91)
    Type: Unknown (0x4305)
B.A.T.M.A.N. Unicast, Dst: NetApp_91:93:b7 (00:a0:98:91:93:b7)
    Packet Type: BATADV_UNICAST (64)
    Version: 15
    Time to Live: 50
    TT Version: 2
    Destination: NetApp_91:93:b7 (00:a0:98:91:93:b7)
Ethernet II, Src: 12:2f:75:58:d2:ad (12:2f:75:58:d2:ad), Dst: ea:3c:ec:a5:b8:f1 (ea:3c:ec:a5:b8:f1)
    Destination: ea:3c:ec:a5:b8:f1 (ea:3c:ec:a5:b8:f1)
    Source: 12:2f:75:58:d2:ad (12:2f:75:58:d2:ad)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 10.0.0.3, Dst: 10.0.0.1
Transmission Control Protocol, Src Port: 420, Dst Port: 58684, Seq: 1, Ack: 7, Len: 0
```

How does BATMAN work? 💪

- Provided by kernel module `batman-adv` on Linux (`batman_adv` on FreeBSD).
- So-called "hard" vs "soft" interfaces (e.g. `vtnet0` vs `batadv0`).
- Sends out "echolocation" packets (ELP) to discover neighbours (new in BATMAN V) (hard).
- Sends out OGM(2) packets to discover best routes (soft).

How to set up a BATMAN network on FreeBSD? 😈

```
$ kldload batman_adv
$ ifconfig vtnet0 mtu 1532 up
$ ifconfig batadv create ra BATMAN_V
batadv0
$ ifconfig vtnet0 master batadv0
$ ifconfig batadv0 inet 10.0.0.1/24
```

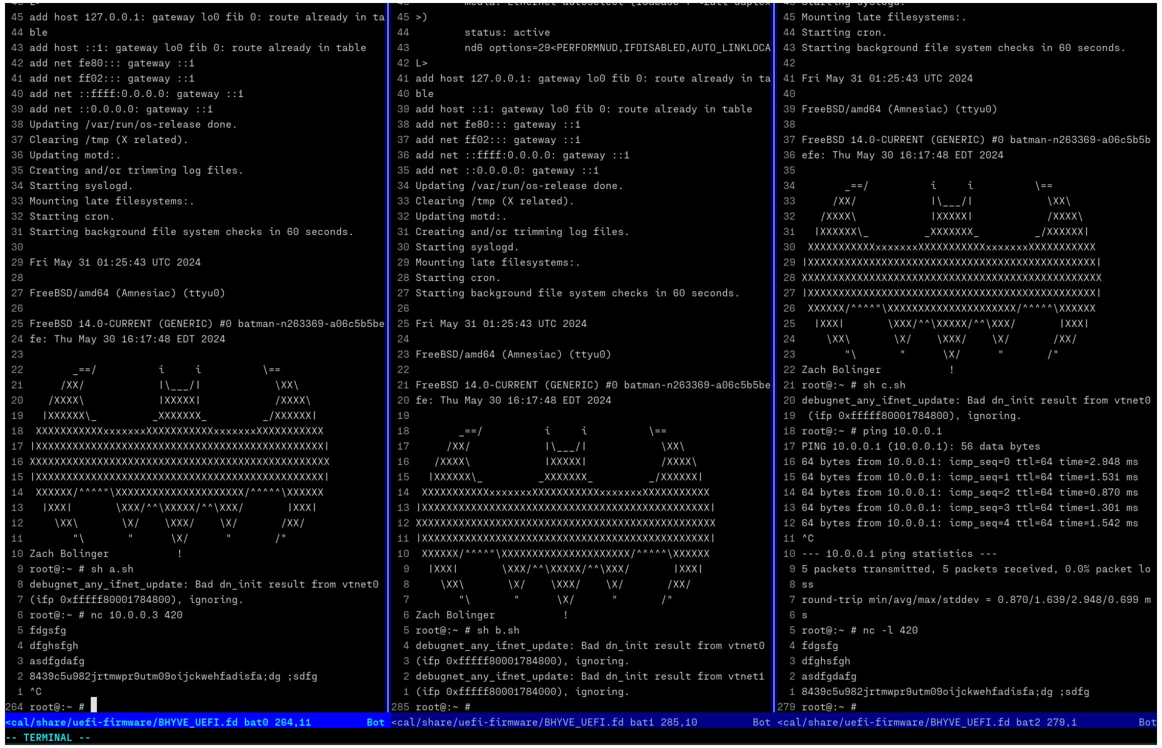
MTU of 1532 to give room to BATMAN header.

How to set up a BATMAN network through the Linuxulator? 🐧

Exactly the same way as on Linux!

```
$ ip link set up mtu 1532 dev eth0
$ ip link add name bat0 type batadv
$ ip link set dev eth0 master bat0
$ ip link set up dev bat0
$ ip addr add 10.0.0.1/24 dev bat0
```

Quick demo of a BATMAN 🚀



```
add host 127.0.0.1: gateway lo0 fib 0: route already in ta
ble
add host ::1: gateway lo0 fib 0: route already in table
add net fe80::: gateway ::1
add net ff02::: gateway ::1
add net ::ffff:0.0.0.0: gateway ::1
add net ::0.0.0.0: gateway ::1
Updating /var/run/os-release done.
Clearing /tmp (X related).
Updating motd:.
Creating and/or trimming log files.
Starting syslogd.
Mounting late filesystems:.
Starting cron.
Starting background file system checks in 60 seconds.

Fri May 31 01:25:43 UTC 2024

FreeBSD/amd64 (Amnesiac) (ttyu0)

FreeBSD 14.0-CURRENT (GENERIC) #0 batman-n263369-a06c5b5be
fe: Thu May 30 16:17:48 EDT 2024

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    \XX\       \X/    \XXX/    \X/       /XX/
       "\       "      \X/      "       /"
Zach Bolinger           !
root@:~ # sh a.sh
debugnet_any_ifnet_update: Bad dn_init result from vtnet0
(ifp 0xfffff80001784800), ignoring.
root@:~ # nc 10.0.0.3 420
fdgsfg
dfghsfgh
asdfgdafg
8439c5u982jrtmwpr9utm09oijckwehfadisfa;dg ;sdfg
^C
root@:~ #
<cal/share/uefi-firmware/BHYVE_UEFI.fd bat0 264,11       Bot
-- TERMINAL --
```

```
>)
        status: active
        nd6 options=29<PERFORMNUD,IFDISABLED,AUTO_LINKLOCA
L>
add host 127.0.0.1: gateway lo0 fib 0: route already in ta
ble
add host ::1: gateway lo0 fib 0: route already in table
add net fe80::: gateway ::1
add net ff02::: gateway ::1
add net ::ffff:0.0.0.0: gateway ::1
add net ::0.0.0.0: gateway ::1
Updating /var/run/os-release done.
Clearing /tmp (X related).
Updating motd:.
Creating and/or trimming log files.
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Fri May 31 01:25:43 UTC 2024

FreeBSD/amd64 (Amnesiac) (ttyu0)

FreeBSD 14.0-CURRENT (GENERIC) #0 batman-n263369-a06c5b5be
fe: Thu May 30 16:17:48 EDT 2024

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|XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
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|XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
 XXXXXX/^^^^"\XXXXXXXXXXXXXXXXXXXXX/^^^^^\XXXXXX
  |XXX|       \XXX/^^\XXXXX/^^\XXX/       |XXX|
    \XX\       \X/    \XXX/    \X/       /XX/
       "\       "      \X/      "       /"
Zach Bolinger           !
root@:~ # sh b.sh
debugnet_any_ifnet_update: Bad dn_init result from vtnet0
(ifp 0xfffff80001784800), ignoring.
debugnet_any_ifnet_update: Bad dn_init result from vtnet1
(ifp 0xfffff80001784000), ignoring.
root@:~ #
<cal/share/uefi-firmware/BHYVE_UEFI.fd bat1 285,10       Bot
```

```
Mounting late filesystems:.
Starting cron.
Starting background file system checks in 60 seconds.

Fri May 31 01:25:43 UTC 2024

FreeBSD/amd64 (Amnesiac) (ttyu0)

FreeBSD 14.0-CURRENT (GENERIC) #0 batman-n263369-a06c5b5b
efe: Thu May 30 16:17:48 EDT 2024

       _==/          i     i          \==
     /XX/            |\___/|            \XX\
   /XXXX\            |XXXXX|            /XXXX\
  |XXXXXX\_         _XXXXXXX_         _/XXXXXX|
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|XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
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  |XXX|       \XXX/^^\XXXXX/^^\XXX/       |XXX|
    \XX\       \X/    \XXX/    \X/       /XX/
       "\       "      \X/      "       /"
Zach Bolinger           !
root@:~ # sh c.sh
debugnet_any_ifnet_update: Bad dn_init result from vtnet0
 (ifp 0xfffff80001784800), ignoring.
root@:~ # ping 10.0.0.1
PING 10.0.0.1 (10.0.0.1): 56 data bytes
64 bytes from 10.0.0.1: icmp_seq=0 ttl=64 time=2.948 ms
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=1.531 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.870 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=1.301 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=1.542 ms
^C
--- 10.0.0.1 ping statistics ---
5 packets transmitted, 5 packets received, 0.0% packet lo
ss
round-trip min/avg/max/stddev = 0.870/1.639/2.948/0.699 m
s
root@:~ # nc -l 420
fdgsfg
dfghsfgh
asdfgdafg
8439c5u982jrtmwpr9utm09oijckwehfadisfa;dg ;sdfg
root@:~ #
<cal/share/uefi-firmware/BHYVE_UEFI.fd bat2 279,1       Bot
```

What are the major things that had to be done to get `batman-adv` ported?

What had to be done to get `batman-adv` ported: `ifconfig`/Netlink

- `batadv` cloner with `ra` parameter (only on Netlink, no `ioctl`).
- No modification of other settings (yet, need Generic Netlink) – only defaults.
- Add concept of setting the "master" interface to FreeBSD and FreeBSD's Netlink.
- Thanks **melifaro@**!

What had to be done to get `batman-adv` ported: Linuxulator

- Just the conversion from `batX` (Linux) to `batadvX` (FreeBSD) → `ifname_bsd_to_linux_ifp`.

What had to be done to get `batman-adv` ported:

Changes to `batman-adv`

- Goal: keep this source code as similar as possible to Linux!
- Not always possible though 😢
- Guard namespace collisions, e.g.:

```
#if defined(__FreeBSD__)
        soft_iface = linux_dev_get_by_index(net, ifindex);
#else
        soft_iface = dev_get_by_index(net, ifindex);
#endif
```

What had to be done to get `batman-adv` ported: Changes to `batman-adv`

- Biggest modification to `batman-adv` needed by far is to add the cloner for the soft interface:

```c
static struct if_clone_addreq_v2 batadv_ifc_addreq = {
        .version = 2, /* For netlink callbacks. */
        .flags = IFC_F_AUTOUNIT,
        .match_f = batadv_softif_ifc_match,
        .create_f = batadv_softif_ifc_create,
        .destroy_f = batadv_softif_ifc_destroy,
        .create_nl_f = batadv_softif_ifc_create_nl,
        .modify_nl_f = batadv_softif_ifc_modify_nl,
        .dump_nl_f = batadv_softif_ifc_dump_nl,
};
```

What had to be done to get `batman-adv` ported:

Changes to `batman-adv`

- On Linux, this is `struct rtnl_link_ops batadv_link_ops`, but would require deep changes to/integration with FreeBSD network code.
- Sometimes supporting something with the LinuxKPI is not a worthwhile tradeoff!

What had to be done to get `batman-adv` ported: LinuxKPI (`struct net_device`)

- Linux's equivalent to `struct ifnet`.
- Made it the same as `struct ifnet`.
- Fields in common aliased, other Linux stuff bolted on at the end.
- Means `struct net_device` can be passed around as `struct ifnet` (and vice-versa).

```c
struct net_device *
linuxkpi_alloc_netdev_ifp(size_t priv_len, u_char type,
    void(*setup_func)(struct net_device *))
{
        struct net_device *ndev;
        if_t ifp;

        ndev = malloc(sizeof(*ndev) + priv_len, M_NETDEV, M_NOWAIT);
        if (ndev == NULL)
                return (ndev);
        ifp = (if_t)ndev;

        linuxkpi_init_dummy_netdev(ndev);
        if_fill_domain(ifp, type, IF_NODOM);
        ndev->has_ifp = true;

        memset(ndev->drv_priv, 0, priv_len);
        setup_func(ndev);

        return (ndev);
}
```

What had to be done to get `batman-adv` ported: LinuxKPI (`struct net_device`)

- `linuxkpi_dev_queue_xmit` (equivalent to `ifp->if_output`).
- `linuxkpi_netif_rx` (equivalent to `ifp->if_input`).
- The `struct net_device` is just cast to `struct ifnet` to get the `ifp` .

What had to be done to get `batman-adv` ported: LinuxKPI (`struct sk_buff`)

- Linux's equivalent to `mbuf`.
- Way more complex and has a ton of random functions (`skb_*`).
- Not currently backed by `mbuf` – data is being copied back and forth (don't sue me 😢).
- Big function is `linuxkpi_skb_from_mbuf`, the other way is easier.

Many more things!

That you'll have the pleasure of discovering though my upcoming reviews :)

🔮 The future?

- `batman_adv` in ports!
- Wi-Fi support!! (Only `sys/net/if_ethersubr.c` interfaces at the moment).
- Backing `sk_buff`'s with `mbuf`'s.
- Upstreaming LinuxKPI changes.
- `batctl`?
- Demo mesh.

🚨 Call to action 🚨

- This was actually not too bad, even though I was intimidated by the LinuxKPI at first.
- If you have a Linux driver you want to port, it could be worth trying!
- Important for FreeBSD's continued relevancy in certain domains.

That's all folks 🐰

Questions?

Reach out to me 📫

- Have a beer! 🍻
- FreeBSD email: **obiwac@freebsd.org**
- Website: **https://obiw.ac**
- GitHub: **https://github.com/obiwac**
- Discord: **@obiwac**