Building OpenWrt with the Yocto Project

Yocto Summit 2021

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3MDEB

Agenda

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- Who we are?
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whoami

Tomasz Żyjewski
Embedded Systems Engineer

- @tomzy_0
- tomasz.zyjewski@3mdeb.com

- 2 years in 3mdeb
- Integration of update systems and OS creation for embedded devices
- interested in:
  - Yocto Project
  - OS updates
  - boot-time optimization

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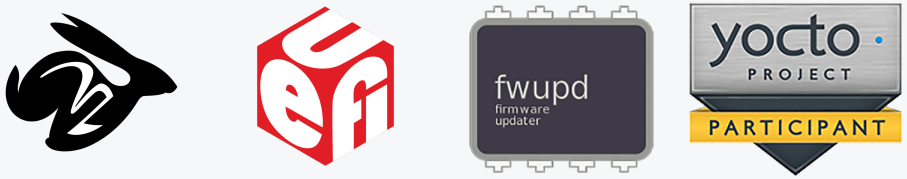
Who we are?



- coreboot licensed service providers since 2016
- coreboot project leadership participants
- UEFI Adopters since 2018
- Official consultants for Linux Foundation fwupd/LVFS project
- Yocto Participants and Embedded Linux experts
- Open Source Firmware enthusiasts and evangelists

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OpenWrt description

- Highly extensible GNU/Linux distribution for embedded devices
  - primarly used to route network traffic
- Fully writable filesystem with optional package management
- Project started in 2004, first release in 2006
  - fun fact: releases were historically named after cocktails, such as White Russian, Kamikaze
  - naming scheme droped after remerge of the LEDE subgroup and OpenWrt
- Support over 1700 different hardware
  - for newer releases (18.06 or later) it is recommended that device has at least 16 MB of flash memory and 64 MB of RAM (128 MB of RAM is preffered)

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OpenWrt description

- Why use OpenWrt?
  - extensibility - over 3000+ standarized applications, can replicate setup on any supported device
  - security - secury by default, keeping software components up-to-date
  - performance and stability - each module receive a lot of testing and bug fixing
  - strong community support - OpenWrt forum and mailing lists
  - research - lots of network performance research are executed on OpenWrt systems, every successful expiriements are available in OpenWrt first
  - open source - no additional cost needed, OpenWrt is provided without any monetary cost

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OpenWrt description

- Releases
  - current stable release: OpenWrt 19.07 (latest version 19.07.7 released on 18 Feb 2021)
  - next stable release: OpenWrt 21.02 (21.02-rc1 released on April, 26th 2021)
- No stable release cycle
  - breaks between releases last from a month to 20 months
- Stable version numbers are mode from the year and the month when a new stable branch was created
- Table of Hardware contains the release version that supports the device
  - every **release** is available on the OpenWrt webpage

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OpenWrt description

- Packages
  - OpenWrt provides several thousand packages
  - there is a package table which always show packages available in the latest update of the stable release
- Packages can be installed in two ways
  - via web interface and LuCI
  - via command-line interface and `opkg` packages manager
- Packages source code is also available
  - source code of some of the OpenWrt packages like LuCI or procd
  - community repository of ported packages
  - base OpenWrt repository, contains patches for basic packages
- Lots of patched packages, every repository has branches for supported releases

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OpenWrt description

- OpenWrt build system, known as `OpenWrt Buildroot`
  - based on modified Buildroot system
  - set of Makefiles and patches that automates the process of building
- Uses kconfig for the configuration of all options
- Provides an integrated cross-compiler toolchain
- Handles standard OpenWrt image build workflow: downloading, patching, configuration, compilation and packaging
- Provides a number of common fixes for known badly behaving packages

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Advantages of using the Yocto Project

- Better management of the components that make up the system
  - division into layers
- Most hardware vendors provide direct support for Yocto
  - support for a new machine is easier to achieve by adding the appropriate bsp layer to the build
- Yocto Project allows to prepare more complex systems
  - extending the functionality of the system by adding layers

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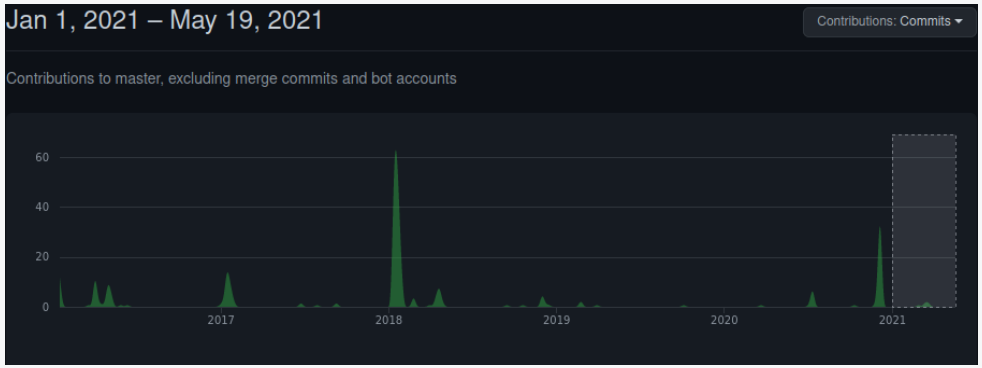
meta-openwrt overview

- Repository - https://github.com/kraj/meta-openwrt
- Maintainer - Khem Raj
- 3 branches - `master`, `dunfell`, `hardknott`
  - `master` branch should be compatible with `gatesgarth` and `hardknott`

```
LAYERSERIES_COMPAT_openwrt-layer = "gatesgarth hardknott"
```

- 19 contributors, last contributions



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meta-openwrt overview

- README.md review
  - kind of outdated, not needed dependencies on `meta-nodejs` and `meta-nodejs-contrib`
  - to build an image `openwrt-distro-defaults` needs to be add to the **`INHERIT`** variable
  - consideration about **`TCLIBC`** - it is not pointed if using `musl` is a must
  - OE release limitations - it should work with **`Sumo`** version and later
- Available images
  - openwrt-image-minimal - has openwrt networking and cli but no UI
  - openwrt-image-base - has openwrt networking, cli, and UI (LuCI)
  - openwrt-image-full - has minimal and base images functionality plus some network related packages, including `relayd` or `tcpdump`

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meta-openwrt overview

- Recipes

```
$ ls meta-openwrt/recipes-*/
meta-openwrt/recipes-core/:
firewall3  fstools  images  iwinfo  jsonpath  libubox  make-ext4fs  netifd
odhcp6c  odhcpd  packagegroups  procd rpcd  ubox  ubus  uci  uclient
ustream-ssl  xtables-addons

meta-openwrt/recipes-extended/:
images  libnl-tiny  libroxml  luci  packagegroups  ugps  usbmode  usign

meta-openwrt/recipes-kernel/:
linux

meta-openwrt/recipes-networking/:
ipset  relayd  uhttpd  umbim  umdnsd  uqmi

meta-openwrt/recipes-support/:
lua  lua-socket

meta-openwrt/recipes-tweaks/:
base-files  busybox  dnsmasq  hostapd  iptables  modutils-initscripts  packagegroups  udev
```


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meta-openwrt overview

- Lots of core recipes use source code from OpenWrt projects repositories
  - each recipe has its own revision from which it retrieves the code, it should be remembered when the OpenWrt version is updated
- Installing OpenWrt specific configurations
  - some recipes like `netifd` use also OpenWrt Github repository to install needed scripts or configuration files
- Recipes from recipes-tweaks are fetched from default OE source, but tweaked for OpenWrt by installing additional files and scripts
  - looks like some of them still needs a lot of patches e.g. `hostapd`

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meta-openwrt overview

- List of provided **bbclasses**

```
$ tree meta-openwrt/classes/
meta-openwrt/classes/
├── openwrt-base-files.bbclass
├── openwrt.bbclass
├── openwrt-distro-defaults.bbclass
├── openwrt-kmods.bbclass
├── openwrt-lua.bbclass
├── openwrt-services.bbclass
└── openwrt-virtual-runtimes.bbclass
```

- Inherited **openwrt-distro-defaults** sets `procd` as init manager, sets up the `DISTRO_FEATURES` and inherits another bbclasses
- **openwrt-base-files** adds OpenWrt github repository to couple of recipes (`dnsmasq`, `hostapd`, `netifd`, `uci`) and than it is used to install OpenWrt specific init scripts or configuration files
    - on `master` branch it use **dd3464023f18** git revision which is near v19.07.5

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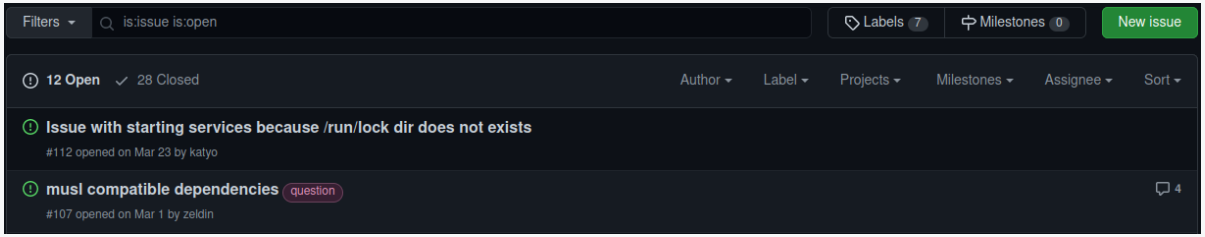
meta-openwrt overview

- Issues review
  - there are 12 open issues
  - some of them are open since 2017, some of them are couple months old
  - the maintainer is responsive and open to any PR improving the state of the layer



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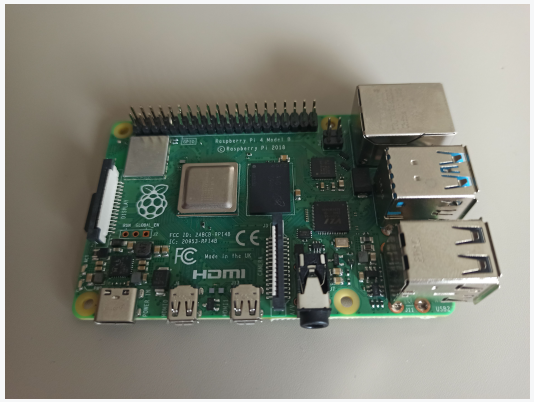
HW - short description

- Raspberry Pi 4 ver. B
  - SoC: Broadcom BCM2711
  - RAM: 4GB
  - WLAN: Cypress CYW43456
  - Ethernet: 1 Gbit port



- Powerful platform, nice for learning
  - OpenWrt releases officially support previous versions of RPi

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Description of tests

- Goals to achieve with this proof of concept
  - log to the device via serial console
  - read system logs
  - connect with Ethernet cable, get IP address
  - log to the device via SSH
  - check data on LuCI
  - change configuration via LuCI, e.g. root password
- Basic features that allows to continue development on the system
  - many topics on the Internet propose to start working with the OpenWrt system by logging in via SSH or changing the configuration in LuCI
  - the ability to read logs allows to analyze and solve problems

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Description of tests

- The reason for the presentation and testing of meta-openwrt
  - I am more familiar with Yocto than Buildroot and would prefer to set up my systems for embedded devices using the first one
  - preparing an OpenWrt image with Yocto will allow to get to know most of the elements inside target system
- Helping each other
  - many users may come across the `meta-openwrt` layer in OpenEmbedded Layer Index
  - raising interest in the meta layer

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Boot OpenWrt community version

- For RPi 4 there is no stable version of OpenWrt released
- Can use **snapshot** version
  - community driven version, new image every few days
  - discussion in the OpenWrt topic
  - for this presentation image rpi-4_snapshot_3.1.57-32_r16707_extra was used
- Booting OpenWrt image allow to make comparison

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Boot OpenWrt community version

- Boot log

```
[    0.000000] Booting Linux on physical CPU 0x0000000000 [0x410fd083]
[    0.000000] Linux version 5.4.117 (builder@buildhost) \
(gcc version 8.4.0 (OpenWrt GCC 8.4.0 r16707-e57e460dc7)) #0 SMP Mon May 10 12:41:06 2021
[    0.000000] Machine model: Raspberry Pi 4 Model B Rev 1.2
(...)
BusyBox v1.33.0 () built-in shell (ash)

   .---.    .-             ..-.     .-.          /
  /     )`-'.-.   .-..  .-.   )   (    ).--.---/---
 /     /    /  ).(.-'_)/   ) /     \  /       /
(     /    /`-' (__.''/   ( (   .   )/       /
 `-.'    /             `-`-' `-'

  rpi-dca632b6ec RaspberryPi4ModelBRev1.2 bl:Apr162020 vl805:000137ad
  3.1.57-32 r16707 unknown SNAPSHOT
  root:mmcblk0p2:05141719-02 boot:mmcblk0p1 cmdL:PARTUUID=05141719-02
  t:2021-05-10 12:43:23  l:0.14,0.12,0.05 @up00:02:26
   rootfs:944.9MB/25.1% boot:383.8MB/6.7% mem:3.7GB/59.6MB
  LAN: 192.168.1.1/24(br-lan), dhcp: 192.168.1.100-249, dhcp.leases: 0
MonMay1012:42:592021 to send to ff02::1%lan@br-lan (Address not available)
MonMay1012:43:152021 to send to ff02::1%lan@br-lan (Address not available)
MonMay1012:43:202021 plugin: exec_read_one: error = Cannot find device "eth1"
update-unavailable
=== WARNING! =====================================
no root password: Use the "passwd" command
=== WARNING! =====================================
root@rpi-dca632b6ec /39#
```


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Boot OpenWrt community version

- Examinate system logs
  - use logread from busybox

```
# logread -f -l 5
Mon May 10 12:42:21 2021 daemon.info urandom_seed[17614]: Seed saved (/etc/urandom.seed)
Mon May 10 12:42:22 2021 daemon.info dnsmasq[16440]: read /etc/hosts - 4 addresses
Mon May 10 12:42:22 2021 daemon.info dnsmasq[16440]: read /tmp/hosts/odhcpd - 1 addresses
Mon May 10 12:42:22 2021 daemon.info dnsmasq[16440]: read /tmp/hosts/dhcp.cfg01411c - 2 addresses
Mon May 10 12:42:22 2021 daemon.info dnsmasq-dhcp[16440]: read /etc/ethers - 0 addresses
```

- Connect to the local PC via Ethernet cable
  - get IP address right away

```
$ ifconfig eno1
eno1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.105  netmask 255.255.255.0  broadcast 192.168.1.255
        inet6 fd1d:bf:8d15:0:85ac:98c6:8e4c:89bd  prefixlen 64  scopeid 0x0<global>
        inet6 fd1d:bf:8d15:0:6e9c:c0fe:e686:8c28  prefixlen 64  scopeid 0x0<global>
```


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Boot OpenWrt community version

- Connect to the RPi4 gateway via SSH

```
BusyBox v1.33.0 () built-in shell (ash)

 |      |.                  .|  |  |  |.     |_   .
 |  -   ||  _  |  -__|     ||  |  |  ||   _||   _
   _____||   __|_____|__|__||________||__|  |____|
         |__|

  rpi-dca632b6ec RaspberryPi4ModelBRev1.2 bl:Apr162020 vl805:000137ad
  3.1.57-32 r16707 ssh SNAPSHOT 192.168.1.105 59768 22 /dev/pts/0
  root:mmcblk0p2:05141719-02 boot:mmcblk0p1 cmdL:PARTUUID=05141719-02
  t:2021-05-10 12:43:04  l:0.20,0.12,0.04 @up00:02:06
   rootfs:944.9MB/25.1% boot:383.8MB/6.7% mem:3.7GB/59.9MB
  LAN: 192.168.1.1/24(br-lan), dhcp: 192.168.1.100-249, dhcp.leases: 1
1620693690 34:17:eb:d7:a5:9f 192.168.1.105 tomzy-OptiPlex-7010 01:34:17:eb:d7:a5:9f
1620693742 00:00:00:00:00:00 0.0.0.0 tomzy-OptiPlex-7010 fdad:74b2:130f::a0f/128
MonMay1012:42:452021 plugin: exec_read_one: error = Cannot find device "eth1"
update-unavailable
=== WARNING! =====================================
no root password: Use the "passwd" command
=== WARNING! =====================================
root@rpi-dca632b6ec /38#
```


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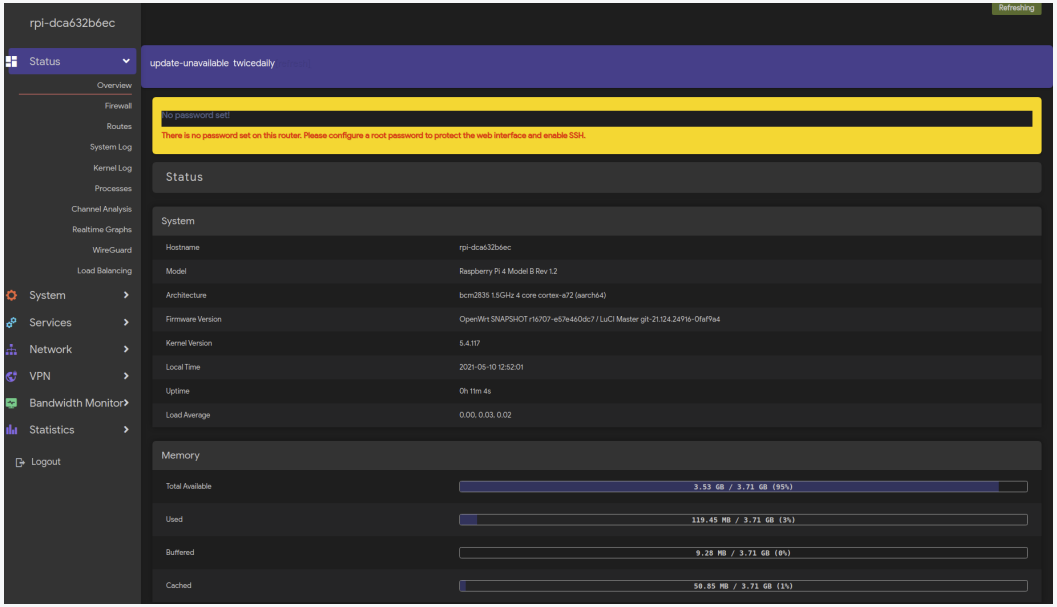
Boot OpenWrt community version

- Open LuCi in web browser



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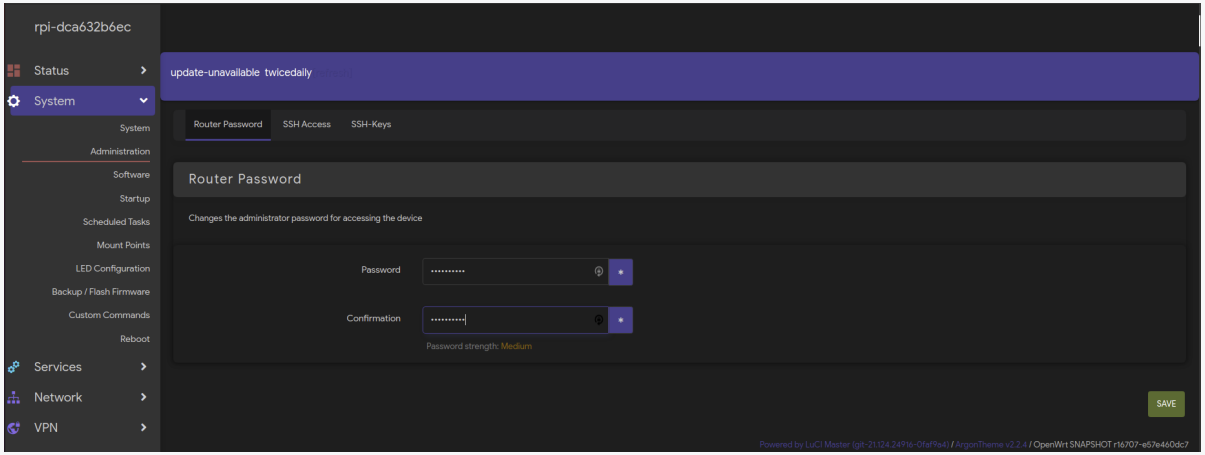
Boot OpenWrt community version

- Change root password via LuCI



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Build OpenWrt with meta-openwrt

- Needed layers to build meta-openwrt based image for Raspberry Pi 4
  - `meta-openwrt`
  - `poky`
  - `meta-raspberrypi`
  - `meta-openembedded`: `meta-oe`, `meta-python` and `meta-networking`
- Used refspecs

```
poky:
  url: https://git.yoctoproject.org/git/poky
  refspec: 6a751048e50c00261d99c2d8d69534f7a8da38a9

meta-openembedded:
  url: https://git.openembedded.org/meta-openembedded
  refspec: f3f7a5f1a4713f145107bb043e0d14cb3a51c62f

meta-openwrt:
  url: https://github.com/kraj/meta-openwrt.git
  refspec: 6e8159a07ce8991cb6b04e3cb15f82b9eadad1e5

meta-raspberrypi:
  url: git://git.yoctoproject.org/meta-raspberrypi
  refspec: 3ae135e590e375c8da26b003bda41c18fb977ae1
```


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Build OpenWrt with meta-openwrt

- According to the documentation
  - `TCLIBC` should point to `musl`
  - `openwrt-distro-defaults` should be add to the `INHERIT` variable
- Additionaly the `ENABLE_UART` variable can be set to `1`
  - enable UART on RPi
  - used in `meta-raspberrypi`
- Tweaks needs to be added to `local.conf`
  - `kas` layer management tool could be used to manage that
  - layer management tools described at Yocto Summit 2020

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Boot meta-openwrt image

- Boot log

```
[    0.000000] Booting Linux on physical CPU 0x0000000000 [0x410fd083]
[    0.000000] Linux version 5.10.17-v8 (oe-user@oe-host) \
(aarch64-ys-linux-musl-gcc (GCC) 10.2.0, GNU ld (GNU Binutils) 2.35.1) \
 #1 SMP PREEMPT Mon Mar 1 09:44:55 UTC 2021
[    0.000000] Machine model: Raspberry Pi 4 Model B Rev 1.2
(...)
Please press Enter to activate this console.
[    6.340173] kmodloader: loading kernel modules from /etc/modules.d/*
[    6.385165] NET: Registered protocol family 10
[    6.391193] Segment Routing with IPv6
[    6.408153] bridge: filtering via arp/ip/ip6tables is no longer available by default. \
Update your scripts to load br_netfilter if you need this.
[    6.514195] xt_time: kernel timezone is -0000
[    6.557067] kmodloader: done loading kernel modules from /etc/modules.d/*

Distro for Yocto Summit 2021 0.0.1 \n \l

root@(none):/#
```


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Boot meta-openwrt image

- Examinate system logs
  - use logread from busybox

```
# logread -f -l 5
Failed to find log object: Not found
Failed to find log object: Not found
Failed to find log object: Not found
```

- Connect to the local PC via Ethernet cable
  - get IP address right away

```
$ ifconfig eno1
eno1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet6 fe80::f0d:a471:f7ae:6289  prefixlen 64  scopeid 0x20<link>
        ether 34:17:eb:d7:a5:9f  txqueuelen 1000  (Ethernet)
(...)
$ ping 192.168.1.1
ping: connect: Network is unreachable
```


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Boot meta-openwrt image

- Checking SSH connection is not possible
    - networking not starting on the RPi `/lib/netifd/mac80211.sh` is missing
    - IP address is not given by the gateway
    - DHCP server may not work correctly on the meta-openwrt based image
- Without IP address accessing LuCI is also impossible
- Running `network` script needed `lock` directory under `/run/lock`
    - adding it allows to read system logs

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Boot meta-openwrt image

- System logs analyze
- `dnsmasq` issue

```
Fri Mar  9 12:35:19 2018 daemon.crit dnsmasq[1160]: Ubus not available: \
set HAVE_UBUS in src/config.h
Fri Mar  9 12:35:19 2018 daemon.crit dnsmasq[1160]: FAILED to start up
```

- `uhttpd` problems

```
Fri Mar  9 12:34:59 2018 daemon.notice procd: /etc/rc.d/S50uhttpd: \
Skipping invalid Lua prefix "/cgi-bin/luci=/usr/lib/lua/luci/sgi/uhttpd.lua"
```

- Missing some packages
  - `collectd`
  - `dropbear`

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Summary

- OpenWrt vs meta-openwrt image comparison

Functionality	OpenWrt community image	meta-openwrt image
accessing via console	working	working
read system logs	working	not working
receiving an IP address	working	not working
accessing via SSH	working	not working
accessing LuCI	working	not working
setting root password via LuCI	working	not working

- Lots of things do not work out of the box
  - this is a good initial set of functionality to check
  - solving the existing problems will allow for further development
- We will try to make improvements to meta-openwrt gradually
  - does not look usable for now

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Contact us

We are open to cooperate and discuss

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Feel free to contact us if you believe we can help you in any way. We are always open to cooperate and discuss.

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Q&A

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