Buildroot: what's new?

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embedded Linux and kernel engineering

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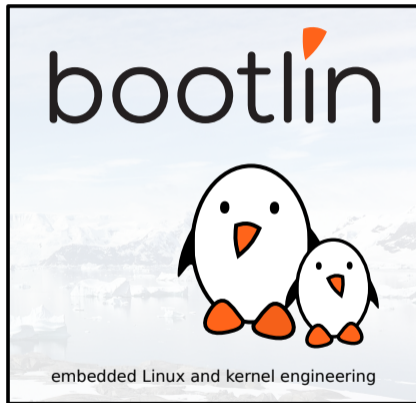
- ▶ CTO/Embedded Linux engineer at Bootlin
  - ▶ Embedded Linux **expertise**
  - ▶ **Development**, consulting and training
  - ▶ Bootloader, Linux kernel, Yocto Project, Buildroot
  - ▶ Strong open-source focus
  - ▶ Freely available training materials
- ▶ Co-maintainer of **Buildroot**
- ▶ Living in **Toulouse**, France

Buildroot at a glance

- ▶ Is an **embedded Linux build system**, builds from source:
  - ▶ cross-compilation toolchain
  - ▶ root filesystem with many libraries/applications, cross-built
  - ▶ kernel and bootloader images
- ▶ **Fast**, simple root filesystem in minutes
- ▶ **Easy** to use and understand: kconfig and make
- ▶ **Small** root filesystem, default 2 MB
- ▶ More than **2500 packages** available
- ▶ Generates filesystem images, not a distribution
- ▶ Vendor neutral
- ▶ Active community, stable releases every 3 months
- ▶ Started in 2001, oldest still maintained build system
- ▶ http://buildroot.org

Agenda

- ▶ See what's new in Buildroot since the last two years
- ▶ Covering Buildroot 2017.11 to Buildroot 2019.11-pre
  - ▶ Community activity
  - ▶ Release schedule
  - ▶ Architecture support
  - ▶ Toolchain support
  - ▶ Package infrastructure improvements
  - ▶ Download infrastructure improvements
  - ▶ Interesting package updates and additions
  - ▶ Reproducible builds
  - ▶ Top-level parallel build
  - ▶ Tooling improvements

Number of commits per release
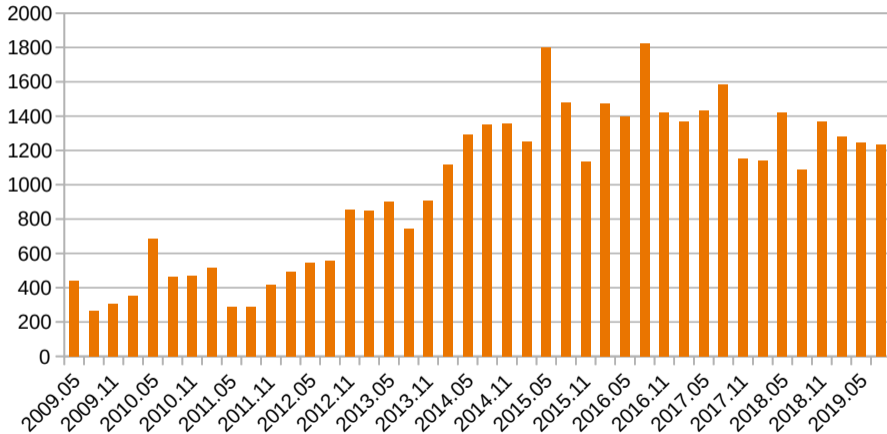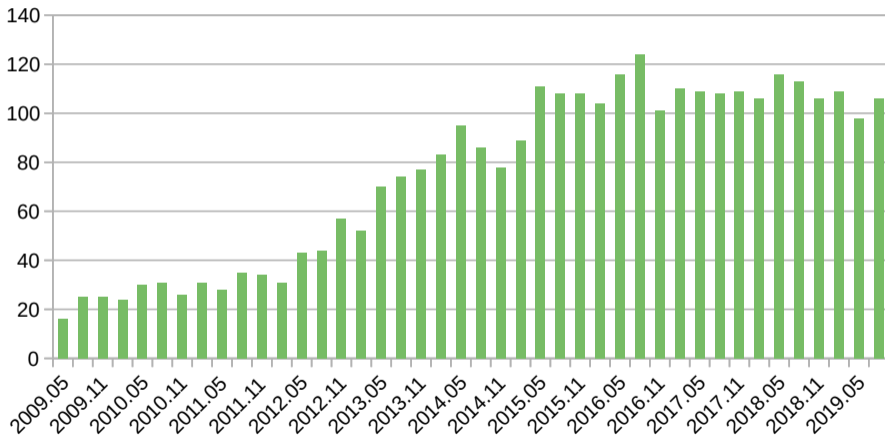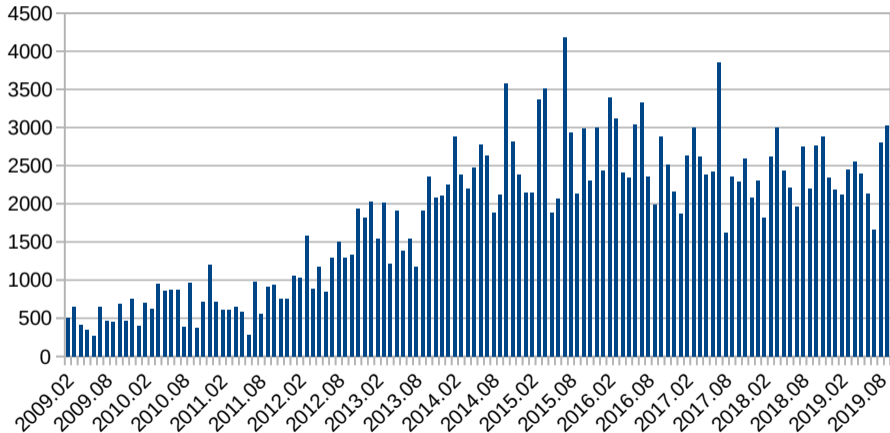
Number of contributors per release

E-mails on the mailing list

Release schedule

- ▶ What we already had
  - ▶ **Four releases** per year: YYYY.02, YYYY.05, YYYY.08, YYYY.11
  - ▶ **3-month cycles**: 2 months development 1 month stabilization
- ▶ What we've added
  - ▶ **LTS**: Long Term Support release
  - ▶ Each **YYYY.02 release is supported during one year**
  - ▶ Security updates, bug fixes
  - ▶ YYYY.02.x maintenance branch, and regular ($\approx$ monthly) point releases
  - ▶ 2017.02: to 2017.02.11, 860 commits
  - ▶ 2018.02: to 2018.02.12, 1075 commits
  - ▶ 2019.02: to 2019.02.6: 734 commits (so far)

Architecture support

- Support for new CPU architectures
  - **RISC-V**, 32-bit and 64-bit
  - **NDS32**
- Support for **new variants** of existing architectures: ARM Cortex cores, x86 cores, MIPS cores, ARC cores, C-SKY cores
- Removal of *Blackfin* architecture
- Overall, **support for**: ARC, ARM, AArch64, C-SKY, m68k, Microblaze, MIPS, NDS32, NIOS2, OpenRISC, PowerPC, RISC-V, SuperH, SPARC, x86, Xtensa

Internal toolchain: Buildroot builds your toolchain from source

- ▶ No significant change, just regular updates
- ▶ **gcc** 8.x and 9.x added, gcc 4.9, 6.x removed
- ▶ **binutils** updated, 2.32
- ▶ **uClibc-ng** updated, 1.0.32
- ▶ **musl** updated, 1.1.24
- ▶ **glibc** updated, 2.30
- ▶ Useful testing done by Romain Naour using the *toolchains-builder* project

External toolchain: Buildroot uses an existing pre-built toolchain

- ▶ ARM toolchains added
- ▶ AArch64 big-endian toolchains from ARM and Linaro added
- ▶ Andes NDS32 toolchain added
- ▶ Updates to numerous existing toolchains
- ▶ Declaring external toolchains from `BR2_EXTERNAL` trees

New package infrastructures: Go and Meson

- ▶ Package infrastructures **factorize the common logic** to configure, build and install packages that use a standardized build system
- ▶ **Two new** package infrastructures:
  - ▶ `golang-package` for Go-based packages
  - ▶ `meson-package` for Meson-based packages
- ▶ **Already** had support for: Autotools, CMake, Kconfig, Luarocks, Perl, Python, Erlang, Waf and kernel modules

Go package example: `docker-cli`

package/docker-cli/docker-cli.mk

```
################################################################################
#
# docker-cli
#
################################################################################

DOCKER_CLI_VERSION = 18.09.9
DOCKER_CLI_SITE = $(call github,docker,cli,v$(DOCKER_CLI_VERSION))
DOCKER_CLI_WORKSPACE = gopath

DOCKER_CLI_LICENSE = Apache-2.0
DOCKER_CLI_LICENSE_FILES = LICENSE

DOCKER_CLI_DEPENDENCIES = host-pkgconf

DOCKER_CLI_TAGS = autogen
DOCKER_CLI_BUILD_TARGETS = cmd/docker

DOCKER_CLI_LDFLAGS = \
        -X github.com/docker/cli/cli.GitCommit=$(DOCKER_CLI_VERSION) \
        -X github.com/docker/cli/cli.Version=$(DOCKER_CLI_VERSION)

DOCKER_CLI_INSTALL_BINS = $(notdir $(DOCKER_CLI_BUILD_TARGETS))

$(eval $(golang-package))
```

Meson package example: `libmpdclient`

package/libmpdclient/libmpdclient.mk

```
################################################################################
#
# libmpdclient
#
################################################################################

LIBMPDCLIENT_VERSION_MAJOR = 2
LIBMPDCLIENT_VERSION = $(LIBMPDCLIENT_VERSION_MAJOR).16
LIBMPDCLIENT_SOURCE = libmpdclient-$(LIBMPDCLIENT_VERSION).tar.xz
LIBMPDCLIENT_SITE = http://www.musicpd.org/download/libmpdclient/$(LIBMPDCLIENT_VERSION_MAJOR)
LIBMPDCLIENT_INSTALL_STAGING = YES
LIBMPDCLIENT_LICENSE = BSD-3-Clause
LIBMPDCLIENT_LICENSE_FILES = COPYING

$(eval $(meson-package))
```

Download infrastructure improvements

- Main improvement: **Git caching**, for Git-fetched packages
  - Before: complete clone of the Git repository, checkout the requested version, create a tarball with the source code, throw away the Git repository
  - Drawback: another full clone next time the package version is changed
  - Now: keep a clone of the git repository in `$DL_DIR/<package>/git/`, much faster download when a Git-fetched package is updated
- Tarballs are now stored in per-package sub-directories in `$DL_DIR`
- Major rewrite of the internals of the download infrastructure, `package/pkg-download.mk`, `support/download/`

```
$DL_DIR
+ uboot
  + git
    + api
    + arch
    + board
    + .git
    + Kbuild
    + Kconfig
    + Makefile
    + MAINTAINERS
    [...]
  + u-boot-2018.11.tar.bz2
  + u-boot-2019.04.tar.bz2
  + uboot-228801a215909365a....tar.gz
  + uboot-37425027b617af670....tar.gz
+ zeromq
  + zeromq-4.2.5.tar.gz
  + zeromq-4.3.1.tar.gz
  + zeromq-4.3.2.tar.gz
```

Package updates and additions

- Between 2017.11 and 2019.08
    - 378 packages have been added
    - 56 packages have been removed, 30 of which are X.org proto packages, Qt4
- Addition of: Rust (compiler, cargo), LLVM/Clang (not as a compiler), Mender, OpenJDK, OpenRC init system, OP-TEE OS, zillions of Perl/Python modules
- Update of all major software stacks: Qt 5.12, X.org 1.20, GStreamer 1.16.1, Wayland 1.17, Weston 6.0, Kodi 17.6.

```
$ git log --format=oneline 2017.11..2019.08 package/ \
  | grep -i bump | wc -l
2858
```

Hardening options

- ▶ Addition of support for building the entire code base with a number of security hardening mechanisms
- ▶ Improvement of Stack Protection options: `BR2_SSP_REGULAR`, `BR2_SSP_STRONG`, `BR2_SSP_ALL`
- ▶ Addition of *RELRO* protection options: `BR2_RELRO_NONE`, `BR2_RELRO_PARTIAL`, `BR2_RELRO_FULL`
- ▶ Addition of buffer-overflow detection (*FORTIFY SOURCE*) options: `BR2_FORTIFY_SOURCE_NONE`, `BR2_FORTIFY_SOURCE_1`, `BR2_FORTIFY_SOURCE_2`
- ▶ Mostly contributed by Rockwell Collins

New target: `make show-info`

- New top-level target:
  `make show-info`
- Outputs a JSON blurb that provides lost of metadata about the packages enabled in the current configuration
- JSON makes it easily usable in scripts and tools
- Allows to analyze the contents of a system, validate the choice of packages, get their download URL, and more.
- Other analysis tool already present:
  - `legal-info`
  - `graph-build`, `graph-size`

```
{
  "busybox": {
    "type": "target",
    "virtual": false,
    "version": "1.31.0",
    "licenses": "GPL-2.0",
    "dl_dir": "busybox",
    "install_target": true,
    "install_staging": false,
    "install_images": false,
    "downloads": [
      {
        "source": "busybox-1.31.0.tar.bz2",
        "uris": [
          "http+http://www.busybox.net/downloads",
          "http|urlencode+http://sources.buildroot.net/busybox",
          "http|urlencode+http://sources.buildroot.net"
        ]
      }
    ],
    "dependencies": [
      "host-skeleton",
      "host-tar",
      "skeleton",
      "toolchain"
    ],
    "reverse_dependencies": []
  },
```

Reproducible builds

- ▶ Goal: given a Buildroot configuration/version, two builds will give two exactly identical results
- ▶ Google Summer of Code in summer 2019, with Atharva Lele working on *Reproducible Builds*
- ▶ Mentored by Arnout Vandecappelle and Yann E. Morin
- ▶ Automated testing on `autobuild.buildroot.org`
  - ▶ Some builds are done twice, with `BR2_REPRODUCIBLE=y`, and then tested for equality
  - ▶ If not equal, comparison done with `diffoscope` to facilitate the analysis
  - ▶ Differences between builds: build time and location
  - ▶ Ultimately between environments
- ▶ Fixes in tar, gzip and cpio handling to avoid timestamp issues
- ▶ More work is needed: improving the diffoscope reporting (in progress), fix the reproducibility issues

Reproducible build result

```
--- /home/naourr/work/instance-1/output-1/images/rootfs.tar
+++ /home/naourr/work/instance-1/output-2/images/rootfs.tar
./usr/lib/asterisk/modules/app_agent_pool.so
/home/naourr/work/instance-1/output-1/host/bin/m68k-linux-readelf --wide --decompress --hex-dump=.rodata {}
 @@ -112,15 +112,15 @@
    0x0000a2f2 20746f20 6a6f696e 20746865 20627269   to join the bri
    0x0000a302 6467652e 0a004552 524f5200 4167656e  dge...ERROR.Agen
    0x0000a312 74202725 73273a20 4661696c 65642074  t '%s': Failed t
    0x0000a322 6f20616c 65727420 74686520 6167656e  o alert the agen
    0x0000a332 742e0a00 4e4f545f 434f4e4e 45435445  t...NOT_CONNECTE
    0x0000a342 44002f68 6f6d652f 6e616f75 72722f77  D./home/naourr/w
    0x0000a352 6f726b2f 696e7374 616e6365 2d312f6f  ork/instance-1/o
 -  0x0000a362 75747075 742d312f 6275696c 642f6173  utput-1/build/as
 +  0x0000a362 75747075 742d322f 6275696c 642f6173  utput-2/build/as
    0x0000a372 74657269 736b2d31 362e362e 312f696e  terisk-16.6.1/in
    0x0000a382 636c7564 652f6173 74657269 736b2f73  clude/asterisk/s
    0x0000a392 7472696e 67732e68 00416374 696f6e49  trings.h.ActionI
    0x0000a3a2 44004163 74696f6e 49443a20 25730d0a  D.ActionID: %s..
    0x0000a3b2 00737461 72740041 67656e74 73207769  .start.Agents wi
    0x0000a3c2 6c6c2066 6f6c6c6f 77004167 656e743a  ll follow.Agent:
    0x0000a3d2 2025730d 0a004e61 6d653a20 25730d0a   %s...Name: %s..
```
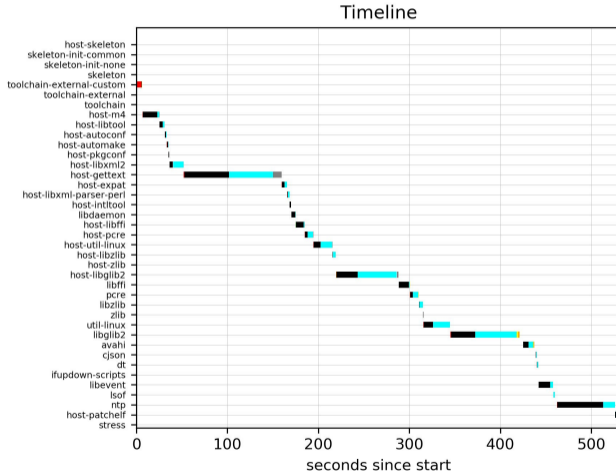
Top-level parallel build

- **Goal**: build several packages in parallel
- Some **preparation** work has been merged
  - Rework the root filesystem image generation logic so that images can be generated in parallel
  - Rework dependencies for download and extract tools to be properly expressed per-package
- Main remaining topic: **per-package directories**
  - Each package has its own `HOST_DIR` (including the compiler sysroot) and `TARGET_DIR`
  - Guarantees that the dependencies seen by the package are always consistent
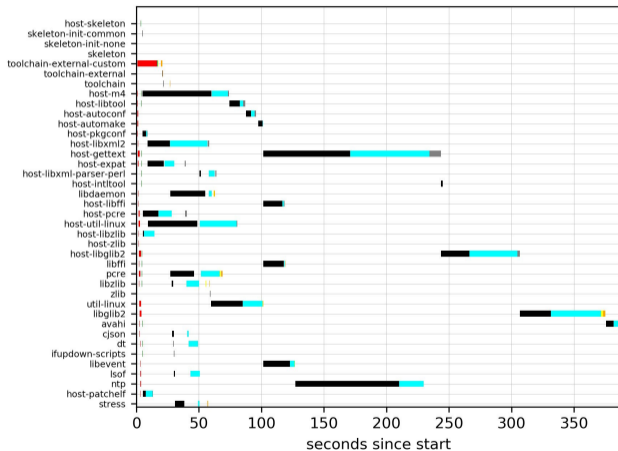 - Last patch series sent in December 2018
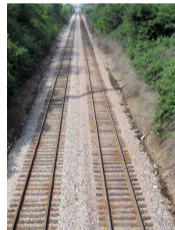
Timeline

With top-level parallel build

Timeline

Runtime tests

- A *runtime test* infrastructure was introduced in 2017.02
- Each test case:
    - Builds a well-defined configuration
    - Boots it under Qemu
    - Runs some tests to verify that a given feature is working
- Complementary to *autobuilder* testing, which tests the build of random configurations
- `./support/testing/run-tests -h`
- Since 2017.11, many new test cases added
    - ATF, Python modules, Perl modules, Lua modules, OpenJDK, X.org/Mesa3D, Docker/Docker-Compose, hardening flags

- Internship of Victor Huesca at Bootlin in summer 2019, mentored by Thomas Petazzoni
- Topic: improve the Buildroot maintenance tooling
  - Use of `release-monitoring.org` for tracking upstream releases
  - Improved Buildroot developer notifications
  - Improved autobuilder search capabilities

Tooling: use of `release-monitoring.org`

- `release-monitoring.org` is a service from the Fedora community that tracks upstream releases of open-source projects
- Currently tracks 27000+ projects
- Buildroot has 2500+ packages, difficult to make sure they are all kept up-to-date
- Buildroot `pkg-stats` script produces a table of statistics about Buildroot packages, especially current version vs. upstream version
- Improvements:
    - Lots of *mappings* between Buildroot packages and `release-monitoring.org` packages added
    - Fixes to Buildroot packages for the package version to match better
    - JSON output in addition to HTML output (useful for tooling, next slide)
    - Speed improvement

release-monitoring.org

Project: busybox

busybox

[🏳 Flag] [Edit]

Latest version
1.31.0

Homepage:
http://www.busybox.net

Backend:
custom

Version scheme:
RPM

Version check url:
http://www.busybox.net/downloads/

Mappings

Distribution	Package name	
Fedora	busybox	[Edit]
Alpine	busybox	[Edit]
NixOS	busybox	[Edit]
Arch Linux	busybox	[Edit]
Arch Linux	mkinitcpio-busybox	[Edit]
Cygwin	busybox	[Edit]
Buildroot	busybox	[Edit]

Status

Status	Updated	Description
OK	2019-10-18 08:55:56 (UTC)	No new version found

Versions

Version	Retrieved on (UTC)
1.31.0	2019-06-10 11:03
1.30.1	2019-02-14 15:02
1.30.0	2019-01-07 12:11
1.29.3	Date information unavailable
1.29.2	Date information unavailable
1.29.1	Date information unavailable
1.29.0	Date information unavailable
1.28.4	Date information unavailable
1.28.3	Date information unavailable
1.28.2	Date information unavailable
1.28.1	Date information unavailable
1.28.0	Date information unavailable
1.27.2	Date information unavailable
1.27.1	Date information unavailable
1.27.0	Date information unavailable
1.26.2	Date information unavailable
1.26.1	Date information unavailable
1.26.0	Date information unavailable

package/bcusdk/bcusdk.mk	2	**autotools** target	Yes	Yes	Yes	0.0.5	**0.0.5** found by distro
package/bdwgc/bdwgc.mk	0	**autotools** target + host	Yes	Yes	Yes	8.0.4	**8.0.4** found by distro
package/beecrypt/beecrypt.mk	3	**autotools** target	Yes	Yes	Yes	4.2.1	**4.2.1** found by distro
package/bellagio/bellagio.mk	5	**autotools** target	Yes	Yes	Yes	0.9.3	**0.9.3** found by distro
package/benejson/benejson.mk	1	**generic** target	Yes	Yes	Yes	0.9.7	**0.9.7** found by distro
package/berkeleydb/berkeleydb.mk	2	**autotools** target + host	Yes	Yes	Yes	5.3.28	**Not found**
package/bind/bind.mk	1	**autotools** target	Yes	Yes	Yes	9.11.10	**9.15.5** found by distro
package/binutils/binutils.mk	30	**autotools** target + host	Yes	Yes	Yes	2.31.1	**2.33.1** found by distro
package/biosdevname/biosdevname.mk	0	**autotools** target	Yes	Yes	Yes	0.7.3	**0.7.3** found by distro
package/bird/bird.mk	0	**autotools** target	Yes	Yes	Yes	2.0.7	**2.0.7** found by distro
package/bison/bison.mk	0	**autotools** host	Yes	Yes	Yes	3.4.1	**3.4.2** found by distro
package/bitcoin/bitcoin.mk	0	**autotools** target	Yes	Yes	Yes	0.16.3	**0.19.0rc1** found by distro
package/bitstream-vera/bitstream-vera.mk	0	**generic** target	Yes	Yes	Yes	1.10	**1.10** found by distro
package/bitstream/bitstream.mk	0	**generic** target	Yes	Yes	Yes	1.4	**1.5** found by distro

Tooling: improved developer notifications

▶ Buildroot has a `DEVELOPERS` file, associating developers with packages, defconfigs, architectures, tests they maintain

▶ Already used to send notifications of build failures reported by the Buildroot autobuilders

▶ Notification e-mail has been improved with:
  ▶ On a weekly basis, notification about packages that are not up-to-date, according to `release-monitoring.org`
  ▶ Failures in the build of defconfigs in Gitlab CI
  ▶ Failures in the execution of runtime tests in Gitlab CI

Tooling: improved developer notifications

```
Packages having a newer version
===============================

              name | found by |          link to release-monitoring.org           | version    | upstream   | orph?
-------------------+----------+---------------------------------------------------+------------+------------+-------
            acpica |  DISTRO  | https://release-monitoring.org/project/00018 | 20190703   | 20190816   |
           acsccid |  DISTRO  | https://release-monitoring.org/project/15661 | 1.1.4      | 1.1.7      |
adwaita-icon-theme |  DISTRO  | https://release-monitoring.org/project/13117 | 3.22.0     | 3.34.0     |
           aespipe |  DISTRO  | https://release-monitoring.org/project/21320 | 2.4e       | 2.4f       | ORPH
           alljoyn |  DISTRO  | https://release-monitoring.org/project/21665 | 16.04.00a  | 16.10.02   |
       alljoyn-tcl |  DISTRO  | https://release-monitoring.org/project/21666 | 16.04.00a  | 16.10.02   |
     android-tools |   GUESS  | https://release-monitoring.org/project/13989 | 4.2.2+git... | 10.0.0_r5 |
          armadillo |  DISTRO  | https://release-monitoring.org/project/07006 | 7.900.1    | 9.800.1    |
            assimp |  DISTRO  | https://release-monitoring.org/project/06988 | 4.1.0      | 5.0.0      |
          asterisk |  DISTRO  | https://release-monitoring.org/project/09838 | 16.5.1     | 16.6.0     |
         at-spi2-atk |  DISTRO  | https://release-monitoring.org/project/07840 | 2.26.2     | 2.34.1     |
       at-spi2-core |  DISTRO  | https://release-monitoring.org/project/07841 | 2.28.0     | 2.34.0     |
               atk |  DISTRO  | https://release-monitoring.org/project/00130 | 2.33.3     | 2.35.1     | ORPH
             atkmm |  DISTRO  | https://release-monitoring.org/project/07962 | 2.24.2     | 2.29.1     |
```

Tooling: improved developer notifications

```
Detail of defconfig failures
----------------------------

                       defconfig | ----------------------- link to the job ----------------------- | orph?
--------------------------------+-----------------------------------------------------------------+------
                 beaglebone_qt5 | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105145 |
      engicam_imx6qdl_icore_qt5 | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105157 |
                  imx6-sabreauto | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105190 |
         minnowboard_max-graphical | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105208 |
               qemu_riscv32_virt | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105337 |
              raspberrypi3_qt5we | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105367 |


Detail of runtime-test failures
-------------------------------

                    runtime-test | ----------------------- link to the job ----------------------- | orph?
-------------------------+-----------------------------------------------------------------+------
                    TestGlxinfo | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105533 | ORPH
        ...ystemSystemdRoIfupdown | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105519 | ORPH
        ...ystemSystemdRoNetworkd | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105521 | ORPH
        ...ystemSystemdRwIfupdown | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105523 | ORPH
        ...ystemSystemdRwNetworkd | https://gitlab.com/buildroot.org/buildroot/-/jobs/318105525 | ORPH
```

Tooling: improved autobuilder search capabilities

- ▶ `autobuild.buildroot.org` collects results from random builds executed by our autobuilders
- ▶ Testing random configurations 24/7, allows to detect numerous dependency problems, version compatibility issues, toolchain problems, and more.
- ▶ Running this testing effort for many years
- ▶ Improvement:
  - ▶ Can now search through build results by config symbol
  - ▶ Ex: *what are the successful builds that had `BR2_PACKAGE_BUSYBOX=y` on ARM, with uClibc ?*
  - ▶ Very useful tool when analyzing build issues, and trying to understand in which situations it happens / since when

Tooling: improved autobuilder search capabilities

Buildroot tests - Search page

Submitter:
Submitter

Subarch:
Sub-Architecture

From:
mm / dd / yyyy

Static?
○ Y ○ N

Failure reason:
Reason

Symbols:
BR2_PACKAGE_BUSYBOX=y

Arch:
arm

C library:
uclibc

To:
mm / dd / yyyy

Status?
● OK ○ NOK ○ TIMEOUT

Search!

Other smaller improvements

- Addition of a `make <pkg>-diff-config` target for *kconfig* based packages: Linux, U-Boot, Busybox, etc.
  - Shows the difference between the current package configuration and the one that is stored in the Buildroot configuration
- Support for generating rootfs images in F2FS and BTRFS formats
- Support for *gettext-tiny* as an alternative to full blown *GNU Gettext*
  - Smaller footprint, smaller build time, for cases where native language support is not needed

Conclusion

- ▶ Very active project
- ▶ LTS release, 1 year maintenance for security/bug fixes
- ▶ New CPU architectures
- ▶ Package infrastructures for new build systems
- ▶ Git caching
- ▶ Packages kept up-to-date, many new packages
- ▶ Reproducible builds effort in progress
- ▶ Maintenance tooling improvements

Getting started with Buildroot tutorial at this ELCE as part of the *Embedded Development Essentials* track, on Wednesday at 2:25 PM.

Questions? Suggestions? Comments?

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`https://bootlin.com/pub/conferences/2019/elce/petazzoni-buildroot-whats-new`