RTEMS State of the World

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Overview

• Some mission updates
• Information on 4.11 releases
• Improvements already merged for 4.12
• Introduction of new features
• Desirable changes
Some RTEMS Missions

• NASA Solar Dynamics Observatory (SDO)
  – Seven years in flight
• NASA Magnetospheric Multiscale (MMS)
  – Approaching two years
• ESA Planck
  – Seven years in flight
• NASA Fermi Gamma-ray Space Telescope
  – Eight years so far
• Upcoming missions:
  – APL Solar Probe Plus, GSFC WFIRST, ESA Exomars

https://www.rtems.org/
Why So Long?

- Many code improvements
  - SMP, New TCP/IP Stack, ports, etc., etc.
- Many non-code project process improvements
  - RSB instead of shipping tool binaries
  - Project hosting moved to OSU OSL
  - New “getting started”
  - Tool Changes
    - Revision Control Change: CVS to Git
    - Bug Tracking/Wiki Change: Bugzilla/Mediawiki to Trac
    - Documentation System Change: Texinfo to Sphinx
    - Introduction of waf build system
- Release process and supporting scripts completely broken by tool changes. Rewritten and now in git. Works great!
  - 4.11.1 released one day after 4.11.0 to correct packaging issue

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RTEMS 4.11 Features

• SMP is functional, but considered experimental
  – SPARC up to four cores with LEON3 (GR712RC) and LEON4 (GR740)
  – PowerPC up to 24 cores on NXP QorIQ T4240
  – ARM on Xilinx Zynq, Altera Cyclone V, Realview
  – x86 needs context switch algorithm fix and APIC support

• New architecture ports
  – ephipany, moxie, nios2, or1k, sparc64, v850
  – New ports collectively added 12 new BSPs

• Many other new features
  – JFFS2, dynamic loading, tracing, warning removal, etc.
New BSPs in 4.11

- 59 more BSPs than in 4.10 even after removing some
- This table is ONLY BSPs added to existing ports

<p>| | |</p>
<table>
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</tr>
<tr>
<td>SPARC</td>
<td>NGMP</td>
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</table>
4.11 Cross Development Tools Versions

- Cross development tools
  - GCC – 4.9.3
  - GNU Binary Utilities – 2.26
  - GDB – 7.9
  - Newlib – 2.20 snapshot from 20150423
  - Autoconf – 2.69
  - Automake – 1.12.6
- Qemu – Git snapshot with patches
- DTC – 1.4.1

- NOTE: Some may have patches applied by RSB and some targets may not use these versions

http://www.rtems.org
RTEMS Tools

RTEMS Users

RTEMS Developers

Continuous Integration Testing

CLI

GUI

RTEMS Source Builder (RSB)

RTEMS Tester

RTEMS LD

RTEMS Trace Linker (TLD)

Capture Trace

Coverage Testing and Reporting

Config

Macro Expansion

ELF/DWARF

Symbol Management

RAP

INI

Izma

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RTEMS Tools Status for 4.11

- RTEMS Source Builder to build cross development tools, supporting tools, and target libraries
  - provides source and reproducible results appropriate for configuration control
- RTEMS Tester to enable users to test on the own hardware or simulators
- 4.11 includes initial release or significant update of
  - RTEMS Trace Linker
  - RTEMS Dynamic Loader and RTEMS LD
  - RTEMS Capture Engine
- Possible: More granular coverage test reporting
New Sphinx Documentation

- Sphinx
- Used by Python and recently adopted by Linux kernel
- Simple ASCII markup
- sphinx-doc.org

Wanted:
- Inline programming examples
- BSP Specific Howtos
- Guides to common tasks and problems
- Inclusion of newlib documentation
- Easy to contribute!

http://www.rtems.org
4.12 Overview

• Significant improvements to SMP
  – SMP now considered production quality
• RTEMS libbsd TCP/IP stack status
• General additions
• BSP specific improvements
• Removed obsolete ports and BSPs
• Tool Updates
SMP Application Features

• Clustered scheduling
  – Flexible link-time configuration
  – Fixed-priority scheduler
  – Job-level fixed-priority scheduler (EDF)

• C11/C++11 thread-local storage

• SMP features supported in Classic and POSIX
  – Mutex locking protocol, affinity, scheduler

http://www.rtems.org
Multicore Programming Libraries

• OpenMP 4.5
  – See http://www.openmp.org for specification
  – Included in standard RTEMS GCC via libgomp
  – See https://gcc.gnu.org/onlinedocs/libgomp

• Embedded Multicore Building Blocks
  – See https://embb.io/ for details
  – Code is at https://github.com/siemens/embb
SMP Locking Improvements

• State of the art locking protocols for application mutexes
  – O(m) Independence-Preserving Protocol (OMIP, priority inheritance)
  – Multiprocessor Resource Sharing Protocol (MRSP, priority ceiling)

• Internal locking
  – RTEMS core uses fine-grained locking
  – Lock profiling is supported
  – Lock-free timestamps (see https://devel.rtems.org/ticket/2271)
  – Scalable timeout support (see https://devel.rtems.org/ticket/2554)
  – Capture (e.g. trace) engine is lock-free on SMP
SMP Capable BSPs

- **SPARC**
  - GR740: Quad-Core LEON4
  - GR712RC: Dual-Core LEON3FT
- **PowerPC**
  - NXP QoriQ: various up to 24 processor T4240
- **ARM**
  - Xilinx Zynq: Dual-Core Dual-Core Cortex-A9
  - Altera Cyclone V: Dual-Core Cortex-A9
  - Raspberry Pi2: Quad-Core Cortex-A7
- **x86**
  - x86 needs context switch algorithm fix and APIC support
SMP Libraries Likely Undesirable to Support

• Cilk™ Plus
  – See https://www.cilkplus.org/ for details
  – Supports multicore and vector processing

• OpenACC (Open Accelerators)
  – See http://www.openacc.org/ for details
  – Focus is heterogeneous CPU/GPU systems

• Both are currently supported in GCC but are single vendor solutions. Neither appears to have developed a community or be cross architecture.
libbsd TCP/IP Stack Status

• Currently based on FreeBSD 9.3
• BSPs supported
  – ARM: Realview, Zynq, atsamv, Cyclone V, LPC24xx
  – M68K: genmcf548x
  – PowerPC: some QorIQ
  – x86: pc386 (multiple families of PCI NICs)
• Many features including IPV4, IPV6, packet filtering, USB mass storage, and more

• Update to FreeBSD 12 is near completion.
  – Includes basic support for Wifi

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General Improvements

- Linux compatible interface for i2c/SPI
- Dynamic Driver Manager
- Enhance PCI Bus Library
- Dynamic Library supports more architectures
- Multithreaded GDB remote server!!
RTEMS Debug Server

- GDB debug server which conforms to the latest GDB remote protocol.
- Thread aware support.
  - You can get a list of all stopped tasks and you can switch to a thread and inspect the stack.
- No GDB patches required.
- Simple IDE integration where GDB is supported.

- Fast with support for range stepping.
- Full attach and detach support.
- Supports the 'stop-all' model where all tasks are stopped on connection, break-point, watch-point, crash and ctrl-C. Support for 'non-stop' could be added.
- An unhandled exception such as a machine check or bus error leaves you on the offending instruction.
- Invasive debugging agent, linked to the application. It uses target resources such as the CPU, memory and networking.
RTEMS Debug Server Status

• Available on “master” as cpukit/libdebugger
• Architecture support is currently limited to i386 and ARM Cortex-A9
• Only transport to host supported is TCP/IP

• We welcome support and funding to add more targets and transports
*** LIBBSD DEBUGGER 1 TEST ***

RTEMS Shell on /dev/console. Use 'help' to list commands.
[/] # nexus0: <RTEMS Nexus device>
cgem0: <Cadence CGEM Gigabit Ethernet Interface> on nexus0
miibus0: <MII bus> on cgem0
e1000phy0: <Marvell 88E1512 Gigabit PHY> PHY 0 on miibus0
e1000phy0: none, 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, 1000baseT-FDX, 1000baseT-FDX-master, auto
cgem0: Ethernet address: fa:69:35:9e:04:2f
zy7_slcr0: <Zynq-7000 slcr block> on nexus0
notice: cgem0: link state changed to DOWN
add host 10.10.5.1: gateway cgem0
add net default: gateway 10.10.5.1
rtems-db: remote running
rtems-db: tcp remote: listing on port: 1122
notice: cgem0: link state changed to UP
rtems-db: tcp remote: connect host: 10.10.5.2
rtems-db: remote running
rtems-db: arm debug: (v3.0) ARMv7 [v7, all CP14 registers] breakpoints:5 watchpoints:3
rtems-db: sys: : suspending
rtems-db: sys: thd: 0a010001: signal: 0
rtems-db: sys: thd: 0a010002: signal: 0
rtems-db: events running
rtems-db: tcp remote: disconnect host
rtems-db: events finishing
rtems-db: sys: : resuming
rtems-db: tcp remote: listing on port: 1122

http://www.rtems.org
GDB Session with Debug Server

```
$ /opt/work/rttems/4.12/bin/arm-rttems4.12-gdb-nx ./build/arm-rttems4.12-
xilinx_zynq_zedboard/debugger01.exe
GNU gdb (GDB) 7.12
Copyright (C) 2016 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying" and "show warranty" for details.
This GDB was configured as "--host=x86_64-freebsd10.3 --target=arm-rttems4.12".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"....
Reading symbols from ./build/arm-rttems4.12-gdb-nx..
 `cpu_self=optimized out`, level=optimized out) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
`_Thread_Do_dispatch(cpusel=optimized out, level=optimized out) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
 arm_interrupt_disable() at
`/opt/work/rttems/4.12/xilinx_zynq_zedboard/lib/include/rttems/cpu.h:344`
344 asm volatile {
(gdb) bt
#0 arm_interrupt_disable() at
`/opt/work/rttems/4.12/xilinx_zynq_zedboard/lib/include/rttems/cpu.h:344`
#1 _Thread_Do_dispatch(cpusel=optimized out, level=optimized out) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#2 0x000172da in Thread_Dispatch_direct(cpusel=optimized out) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#3 0x001f3f22 in rttems_task_sleep_after(ticks=ticks@entry=1) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#4 0x001f3fbc in fillBufferPoll(tty=0x4313c0) at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#5 rttems_shell_main_loop at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#6 rttems_shell_loop at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#7 rttems_termios_read tty(tty=entry=0x4313c0, buffer=0x407d66 "") at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#8 rttems_termios_read_l at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#9 rttems_termios_read_tty(tty=entry=0x4313c0, buffer=0x407d66 "") at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#10 rttems_termios_read at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#11 rttems_termios_read at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#12 rttems_termios_read at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
#13 rttems_termios_read at
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#18 rttems_termios_read at
`/opt/work/rttems/4.12/src/c../c../c/s/refill.c:119`
```
BSP Specific Improvements

• Added ARM ATSAMV BSP for Atmel SAM V71/V70/E70/S70 (Cortex-M7)

• I386/PC
  – Many NICs supported via new network stack
  – Some dependencies on legacy HW addressed

• Raspberry Pi and Beagle variants continue to gain peripherals
  – Pi TCP/IP is close. See
    https://lists.rtems.org/pipermail/devel/2016-September/016092.html
## BSPs and Ports Obsoleted in 4.12

- **Ports removed:**
  - AVR, H8/300, M32R
- This table is ONLY BSPs removed from existing ports

<table>
<thead>
<tr>
<th>Processor</th>
<th>Ports</th>
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<tr>
<td>ARM</td>
<td>gba, gp32, nds</td>
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<tr>
<td>M68K</td>
<td>gen68302, idp, mvme136, ods68302, sim68000, simcpu32</td>
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<tr>
<td>MIPS</td>
<td>genmmongoosev</td>
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<tr>
<td>PowerPC</td>
<td>ep1a, mbx821_001, mbx821_002b, mbx821_002, mbx860_001b, mbx860_002, mbx860_005b, mbx860_1b, score603e</td>
</tr>
<tr>
<td>SPARC</td>
<td>sis</td>
</tr>
</tbody>
</table>

Please help us identify BSPs and ports for obsolete hardware that are no longer in use

http://www.rtems.org
4.12 Cross Development Tools Versions

• Cross development tools
  – GCC – 6.x snapshot now, plan to use 7.x release
  – GNU Binary Utilities – 2.27
  – GDB – 7.12
  – Newlib – 2.4.0 snapshot from 20161025
  – Autoconf – 2.69
  – Automake – 1.12.6

• Qemu – Git snapshot with patches

• DTC – 1.4.1

• NOTE: Some may have patches applied by RSB and some targets may not use these versions
A Few Desirable Improvements

- Conversion of RTEMS to waf build system
  - Build time will go from minutes to seconds
- PC BSP support EFI bootloader, non-legacy hardware, and a clean "non-legacy BSP"
- Pi3 working: UART configuration is different
- More SMP capable BSPs: Pi3 and PC
  - x86 needs context switch algorithm fix, APIC, and APCI support
  - Pi3 needs someone to make it work
- Microblaze port

Improvements occur only when the community supports the project

http://www.rtems.org
Thank You!

• All of the improvements that have been made are thanks to the community supporting the project via:
  – Funding core developers
  – Contributing new features and fixes
Contact Information

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