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Cross Building Packages

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Classic Cross Building

Software supported cross building:

- TARGET=mips/TARGET_ARCH=mips64
- trhodes’ bsd.crossbuild.mk
- ./configure --host=mips64-freebsd

And when the above doesn’t work:

- distcc, NFS, and lots of embedded hardware or full system emulators

*See https://wiki.freebsd.org/CrossBuildingPorts for details.

Advantages
Software Supported

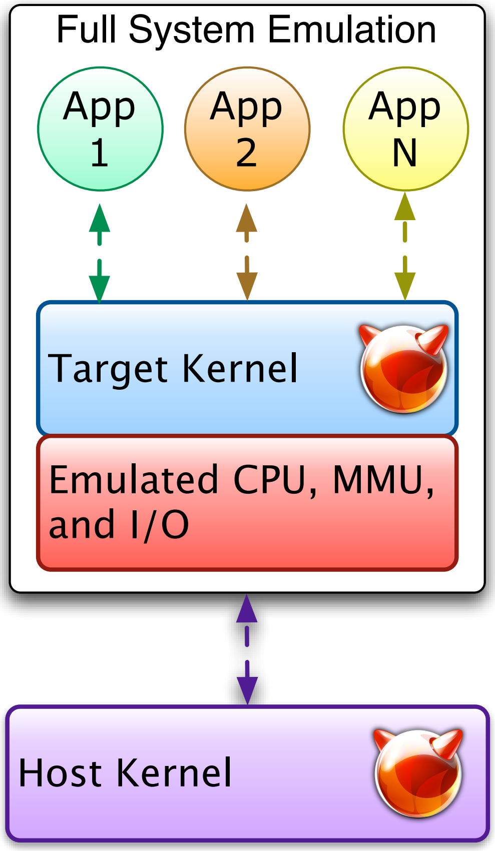
- Very fast results
- Works on lots of different host hardware
- Nice (when it is supported and it works).

Disadvantages Software Supported

- Sources usually need to support cross building, dependencies for two architectures, etc.
- Build may differ from native target compile.
- No unit testing and regression testing during development and post build w/out moving binary to the target.
- No debugging w/out moving binary to the target.

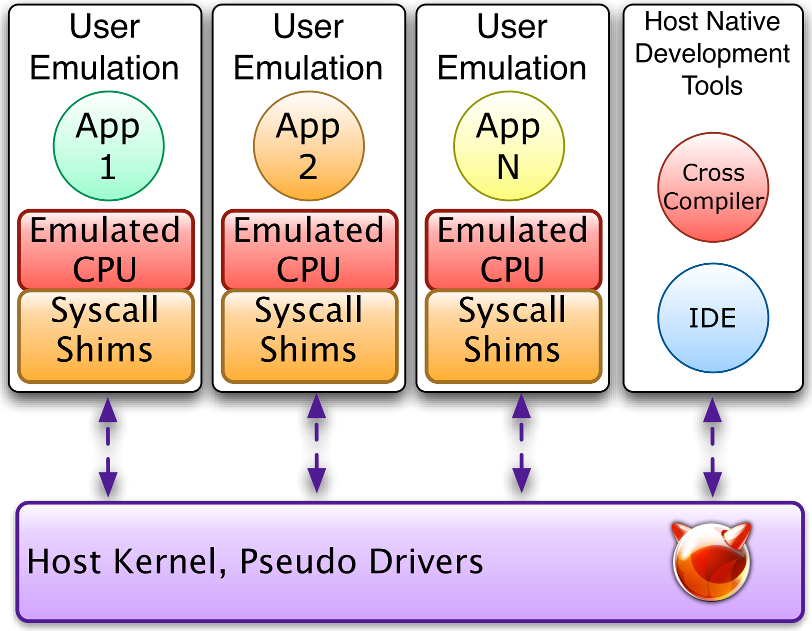
System Mode Emulation

- System mode requires emulation of devices and hardware such as the MMU in addition to the CPU.
- Full target kernel is emulated as well.
- Because it has a lot of overhead may not be too practical for cross building/ development.



User Mode Emulation

- Only CPU is emulated. MMU, I/O, etc. are not.
- System calls are translated to host calls or emulated.
- Can use native host tools for cross development. Cross debugging and testing.

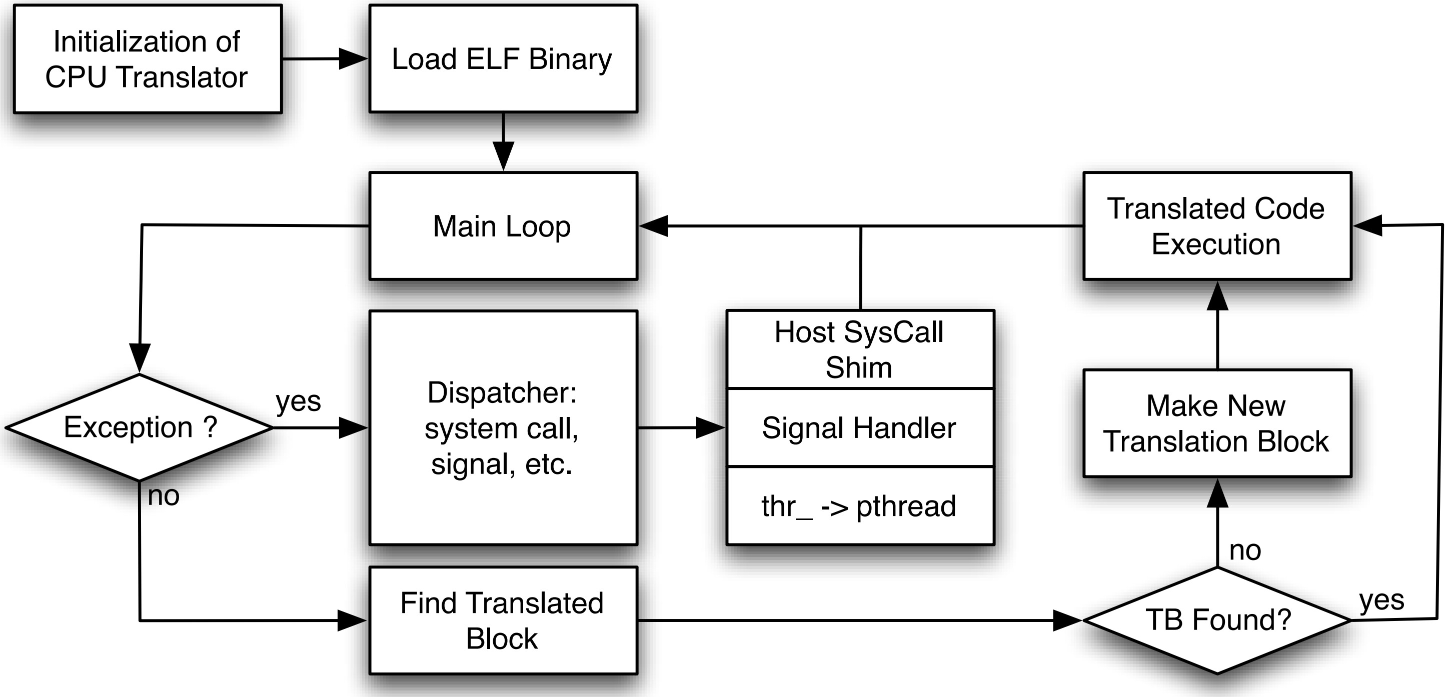


Using Emulation as a Cross Building Tool

- Full System Emulation (“System Mode”)
  - Has been used with distcc, NFS, etc. to offset the performance issues.
- User Only Emulation (“User Mode”)
  - Used by some linux embedded developers.
  - Some preliminary investigation by NetBSD developers.*

* “build.sh: Cross-building NetBSD”, L. Mewburn and M. Green

Qemu User Mode



- No MMU emulation: Simply uses host mmap()‘s with offsets.
- Target kernel threads map one-to-one to host pthread threads.
- Target signals are (in some cases) multiplexed with the host signals.
- Handles endianness and 32-bit target to 64-bit host translation issues

Advantages

- No, or few, changes are needed ports to support cross building. Autoconfig scripts that do things like compile and run bits of test code work.
- Regression/unit tests can be run during cross development or post build checks.
- Can be used to reduce the development cycle time for embedded systems.

Disadvantages

- The emulator may have bugs and missing support which may influence the build results.
- Some system calls are problematic like sysctl(), ioctl(), signals, fork(), threads, _umtx_op(), etc.
- Support for things like new system calls need to also be added to the emulator. May get out of sync with kernel.
- While it is much faster than full system mode emulation there is still a lot of overhead.
- Some kernel support may need to be added to the host.

Initial State of Qemu User Mode on FreeBSD

- Qemu version1.2.0
- Qemu bsd-user (User Mode for *BSD):
  - It would emulate a simple 'Hello World!' app for statically compiled ARM binary.
  - No signals, threads, user mutex, support for other arch's, etc.
  - Explicit support for maybe 10 system calls.

Current Status of Qemu BSD User

- Qemu 1.4.1
- Static and dynamic target binaries supported.
- System calls **not** supported: ktimer_*, cpuset_*, rctl_*, sctp_*, kld*, quota*, jail*, cap_*, jail*, _mac*, sendfile, ptrace, & utrace.
- MIPS64 and ARM has the needed machine dependent code and will run static/dynamic binaries. PPC has some of the machine dependent code and will run some very simple statically linked apps.
- Not all ioctl()'s, sysctl()'s, and sockopts are supported.

* see http://wiki.freebsd.org/QemuUserModeToDo for details.

Cross Building FreeBSD Packages Using Qemu BSD User

- Cross build a ${ARCH} ‘root’ distribution for target. Install in ${DESTDIR}.
- Add devfs: ‘mount -t devfs devfs ${DESTDIR}/dev’
- Build statically linked version of qemu-${ARCH}. Install in ${DESTDIR}/usr/local/bin.
- chroot into ${DESTDIR}.
- ‘cd /usr/ports/${favorite_port} && make package’

*see https://wiki.freebsd.org/QemuUserModeHowTo for the details.

Results

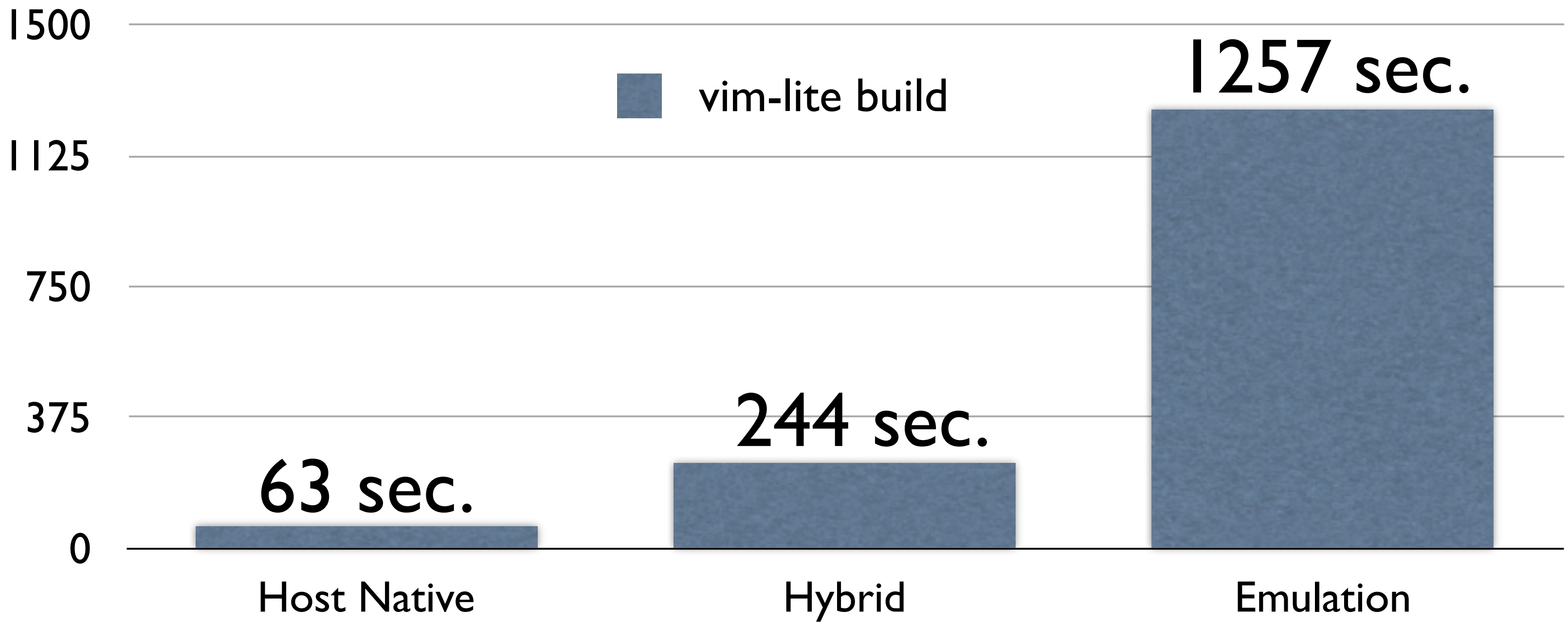
Cross Building MIPS64 Packages

- Added simple script that simply tries to build all packages. If it fails then it goes on to next port.
- Over 9000 packages have been successfully cross built using an old, dual core AMD64 athlon for the emulator host.
- Perl 5.14 regression test results running under user mode emulation: "Failed 2 tests out of 1970, 99.90% okay." (The same two tests fail on target as well.)

*See package repo at http://www.cl.cam.ac.uk/research/security/ctsrd/mips64-packages/

Hybrid Cross Building Environment

Using native cross compiler in user mode emulation build environment:



5.15x Improvement over pure emulation

Kernel Support for Hybrid Environment

Miscellaneous Binary Image Activator:

- ‘imgact_binmisc’ kernel module and ‘binmiscctl’ command-line configuration tool.
- Invokes configured interpreter if given header magic (and optional mask) at file offset matches.
- Makes it possible to use lots of host native binaries in the cross build environment to increase performance.

* See http://people.freebsd.org/~sson/imgact_binmisc/ for source code and patches.

Future Work

- Fix some 32-bit targets on 64-bit hosts issues. Largely with sysctl().
- Add PPC support.
- Review (and most likely rewrite) _umtx_op() syscall shim.
- Qemu code upstream.
- Build system integration.

Q & A

Links:

- https://wiki.freebsd.org/CrossBuildingPorts
- https://wiki.freebsd.org/QemuUserModeToDo
- https://wiki.freebsd.org/QemuUserModeHowTo
- http://www.cl.cam.ac.uk/research/security/ctsrd/mips64-packages/
- http://people.freebsd.org/~sson/imgact_binmisc/

‘binmiscctl’ Examples

- llvm bitcode JIT compiler/interpreter (‘lli’):

```
# binmiscctl add llvmbc --interpreter “/usr/bin/lli  --fake-arg0=” --magic “BC\xc0\xde” --size 4 --offset 0 --concat-old-arg0 --set-enabled
```

- Qemu user mode emulator (‘/usr/bin/qemu-mips64’)

```
# binmiscctl add mips64elf --interpreter “/usr/bin/qemu-mips64” --magic “\x7f\x45\x4c\x46\x02\x02\x01\x00[...]” --mask “\xff\xff\xff\xff\xff\xff\xff\x00[...]” --size 20
```

‘binmiscctl’ Examples

- Disable|enable|delete image activator:

```
# binmiscctl disable|enable|delete llvmbc
```

- Lookup and list image activator:

```
# binmiscctl lookup llvmbc
```

- List all image activators:

```
# binmiscctl list-all
```