Cross Compiling

Real Time Operating Systems and Middleware

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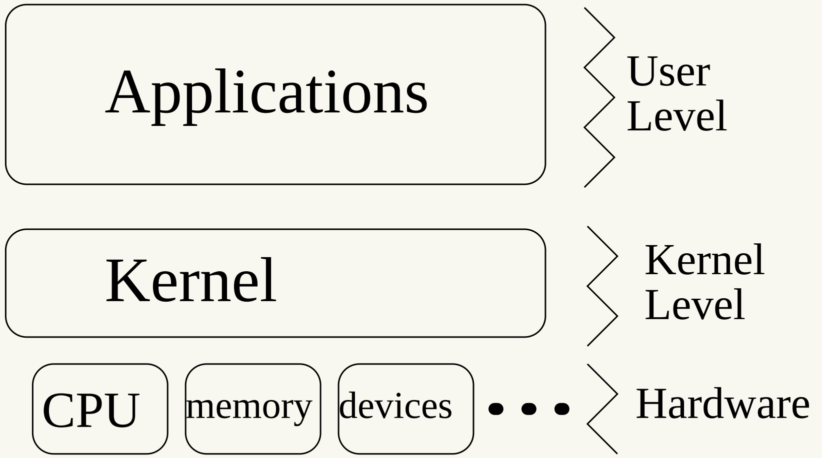
The Kernel

- Kernel $\rightarrow$ OS component interacting with hardware
  - Runs in privileged mode (Kernel Space $\rightarrow$ KS)
  - User Level $\Leftrightarrow$ Kernel Level switch through special CPU instructions (INT, TRAP, ...)
  - User Level invokes *system calls* or IPCs
- Kernel Responsibilities
  - Process management
  - Memory management
  - Device management
  - System Calls



System Libraries

- Applications generally don't invoke system calls directly
- They generally use *system libraries* (like glibc), which
  - Provide a more advanced user interface (example: `fopen()` vs `open()`)
  - Hide the US $\Leftrightarrow$ KS switches
  - Provide some kind of stable ABI (application binary interface)

Static vs Shared Libraries - 1

- Libraries can be *static* or *dynamic*
  - `<libname>.a` vs `<libname>.so`
- Static libraries (`.a`)
  - Collections of object files (`.o`)
  - Application linked to a static library $\Rightarrow$ the needed objects are included into the executable
  - Only needed to compile the application

Static vs Shared Libraries - 2

- Dynamic libraries (`.so`, shared objects)
  - Are not included in the executable
  - Application linked to a dynamic library $\Rightarrow$ only the library symbols names are written in the executable
  - Actual linking is performed at loading time
  - `.so` files are needed to execute the application
- Linking static libraries produces larger executables...
- ...But these executables are “self contained”

Embedded Development

- Embedded systems are generally based on low power CPUs . . .
- . . .And have not much ram or big disks
- $\Rightarrow$ not suitable for hosting development tools
  - Development is often performed by using 2 different machines: *host* and *guest*
  - Guest: the embedded machine; Host: the machine used to compile
  - Host and Guest often have different CPUs and architectures
  - $\Rightarrow$ *cross-compiling* is needed

Cross-Compilers

- Cross Compiler: runs on the Host, but produces binaries for the Target
- Separate the *Host* environment from the *Target* environment
- Embedded systems: sometimes, scarce resources
  - No disks / small (solid state) disks
  - Reduced computational power
  - ...
- In some cases, cross-compilation is the only way to build programs!

Cross-Compiling Environments

- Cross-Compiling environment
  - Cross-compiler (and some related utilities)
  - libraries (at least system libraries)
    - static or dynamic
- C compiler and C library: strictly interconnected
- $\Rightarrow$ building (and using) a proper cross-compiling environment is not easy

Cross-Compilers Internals - gcc

- gcc: Gnu Compiler Collection
  - Compiler: high-level (C, C++, etc...) code → assembly code (`.s` files, machine dependant)
  - Assembler `as`: assembly → machine language (`.o` files, binary)
  - Linker `ld`: multiple `.o` files + libraries → executable (ELF, COFF, PE, . . .) file
  - `ar`, `nm`, `objdump`, . . .
- `gcc -S`: run only the compiler; `gcc -c`: run compiler and assembler, . . .

Cross-Compilers - Dependencies

- Assembler, linker, and similar programs are part of the *binutils* package
  - gcc depends on binutils
- `ld` needs standard libraries to generate executables
  - gcc depends on a standard C library
- But this library must be compiled using gcc...
  - Circular dependency?
  - Building a Cross-Compiler can be tricky...

Cross-Configuring GNU Packages

- gcc, binutils, etc... $\rightarrow$ GNU tools
- `configure` script generated by automake / autoconf (`--host=`, `--target=`, ...)
- Configuration Name (configuration triplet): *cpu-manufacturer-operating_system*
- Systems which support different kernels and OSs: *cpu-manufacturer-kernel-operating_system*
- Examples: `mips-dec-ultrix`, `i586-pc-linux-gnu`, `arm-unknown-elf`, ...

Configuration Names

- `cpu`: type of processor used on the system (tipically ‘i386’, or ‘sparc’, or specific variants like ‘mipsel’)
- `manufacturer`: freeform string indicating the manufacturer of the system (often ‘unknown’, ‘pc’, ...)
- `operating_ system`: name of the OS (system libraries matter)
  - Some embedded systems do not run any OS...
  - $\Rightarrow$ use the object file format, such as ‘elf’ or ‘coff’

Kernel vs OS

- Sometimes, no $1 \leftrightarrow 1$ correspondance between OS and kernel
  - This mainly happens on linux-based systems
- The configuration name can specify both kernel and OS
  - Example: ‘i586-pc-linux-gnulibc1’ vs ‘i586-pc-linux-gnu’
  - The kernel (‘linux’) is separated from the OS
  - The OS depends on the used system libraries (‘gnu’ $\rightarrow$ `glibc`, ...)

Building a gcc Cross-Compiler - Step 1: binutils

- First of all, build binutils

```
./configure --target=arm-unknown-linux-gnu
--host=i686-host_pc-linux-gnu --prefix=...
--disable-nls
```

  - Generally, `--host=` is not needed (config.guess can guess it)

Building a gcc Cross-Compiler - Step 2: system headers

- Then, install some header files needed to build gcc
- Some headers provided by the Linux kernel (API for syscalls)
- Other headers provided by the standard C library (API for standard C functions)
    - *Sanitized* kernel headers
    - glibc headers

Building a gcc Cross-Compiler - Step 3: gcc

- Rember? Circular dependency with standard C library...
  - How to break it?
- gcc must be built 2 times
  - First, to build glibc (no threads, no shared libraries, etc...)
  - Then, a full version after building glibc
- The “first gcc build” (stage1) can compile libraries, but not applications

Building a gcc Cross-Compiler - Step 4: glibc

- After building gcc the first time, glibc is built
- Then, a fully working gcc (using the glibc we just compiled) can be finally built
  - Support for threads, the shared libraries we just built, etc
- For non-x86 architectures, some patches are sometimes needed

Helpful Scripts

- As seen, correctly building a cross-compiler can be difficult, long, and boring...
- ... But there are scripts doing the dirty work for us!
  - crosstool `http://kegel.com/crosstool`
- A slightly different (but more detailed) description can be found on the eglibc web site: `www.eglibc.org`

An Example: ARM Crosscompiler

- Download it from `www.dit.unitn.it/~abeni/Cross/cross.tgz`
- Untar it in `/tmp` and properly set the path:

```
cd /tmp
tar xvzf cross.tgz #use the right path instead of cross.tgz
PATH=$PATH:/tmp/Cross/gcc-4.1.0-glibc-2.3.2/arm-unknown-linux-gnu/bin
```

- Ready to compile: try `arm-unknown-linux-gnu-gcc -v`
- It is an ARM crosscompiler built with crosstool
  - gcc 4.1.0
  - glibc 2.3.2

The Crosscompiler

- The crosscompiler is installed in

  `/tmp/Cross/gcc-4.1.0-glibc-2.3.2/arm-unknown-linux-gnu`

- In particular, the `.../bin` directory contains gcc and the binutils
  - All the commands begin with `arm-unknown-linux-gnu-`
  - Compile a dynamic executable with `arm-unknown-linux-gcc hello.c`
  - Static executable: `arm-unknown-linux-gcc -static hello.c`

Testing the Crosscompiler

- Working ARM cross-compiler
  - Runs on Intel-based PCs
  - Generates ARM executables
- So, we now have an ARM executable... How to run it?
- Can I test the generated executable without using an ARM board?
  - ARM Emulator: Qemu!
  - `qemu-arm a.out`

QEMU

- QEMU: generic (open source) emulator
  - Can also do virtualization
  - Generic: it supports different CPU models ARM
  - Can emulate CPU only or a whole system
- QEMU as a CPU emulator: executes Linux programs compiled for a different CPU. Example: ARM $\rightarrow$ `quemu-arm`
- To execute a static ARM program, `qemu-arm <program_name>`
- What about dynamic executables?

QEMU and Dynamic Executables

- To run a dynamic executable, the system libraries must be dynamically linked to it
- This happens at load time
- QEMU can load dynamic libraries, but you have to provide a path to them
  - `-L` option
- `qemu-arm -L <path to libraries> <program name>`

```
qemu-arm -L \
/tmp/Cross/gcc-4.1.0-glibc-2.3.2/arm-unknown-linux-gnu/arm-unknown-linux-gnu \
/tmp/a.out
```