ECE 598 – Advanced Operating Systems
Lecture 2

Vince Weaver

http://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

25 January 2018

Announcements

- Homework 1 will be posted
- How is the Raspberry Pi situation?
- Need Pi, SD-card (an extra is nice if you already have Linux on one), USB-micro power for cable. Also some way to write a file to SD-card (SD card reader in laptop is fine).

Compiling your Operating System

- Have you ever built your own kernel?
- Have you ever built your own C-library?
- Have you ever built your entire userspace? web-browser?

The Linux Kernel

- What language is the kernel written in?
- C and assembly (with some helper shell/perl scripts)
- Why C?
  - Low-level, close to hardware (portable assembler)
  - Fast
  - Historical
  - Downsides: buggy, security bugs
- Why not C++ (or Java or Rust or Go)
  - Historical reasons, cost to change

- ◦ Overhead/speed (is 10-15% slower OK?)
- ◦ Higher level languages harder to predict (operator overload, exception handling, garbage collection, etc)

Linux kernel releases

- Currently 4.14
- Linus Torvalds releases kernel
- Spends next two weeks in “merge window” merging all the well-tested patches that have accumulated. Then releases -rc1
- Series of -rc as things are tested
- After -rc7 or -rc8 releases final version. Repeat
- Distributions or volunteers will often maintain older ’stable’ versions that aren’t quite as cutting edge

Linux kernel size

- Git checkout on my machine is 4.5G (before building)
- After building, 9.2G
- 73k files, 31 architectures
- For comparison, September 1991, Linux 0.01
  512kB disk, 100 files, 1 architecture

Building Linux Kernel by Hand

- Check out with git or download tarball:

  `git clone git://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git`

  `http://www.kernel.org/pub/linux/kernel/v4.x/`

- Configure. (complicated and verbose)
  `make config` or `make menuconfig`
  Also can copy existing `.config` and run `make oldconfig`

- Compile.

`make`

What does `make -j 8` do differently?

- Make the modules.

  `make modules`

- `sudo make modules_install`

- `sudo make install` or manually copy bzImage to boot, update boot loader

- Cleanup, `make clean` and `make mrproper`

Building Linux Automated

- If in a distro there are other commands to building a package.
- For example on Debian `make-kpkg --initrd --rootcmd fakeroot kernel_image`
- Then `dpkg -i` to install; easier to track

Overhead (i.e. why not to do it natively on a Pi)

- Size – clean git source tree (x86) 1.8GB, compiled with kernel, 2.5GB, compiled kernel with debug features (x86), 12GB!!!
  Tarball version with compiled kernel (ARM) 1.5GB

- Time to compile – minutes (on fast multicore x86 machine) to hours (18 hours or so on Pi-B+)

Developing Linux

- Fun!
- Despite news reports, odds of getting flamed by Linus (or even have him realize you exist) are very low.
- Can be tedious, can take months to get a change committed
- Much of low-hanging fruit already gone
- Code is not really all that well commented
- Might be stuck bisecting for days

Linux on the Pi

- Mainline kernel, bcm2835/bcm2836 tree
  Missing some features
- Raspberry-pi foundation bcm2708/bcm2709 tree
  More complete, not upstream
- Why everything not upstream? Common problem, especially on ARM. Getting upstream is hard, high standards. Takes patience and time, small one-off ARM boards do not have the resources for the process.

Compiling – how does it work?

Traditionally this is how it works, can vary.

- **compiler** takes C-code (.c), makes assembly language (.s)
- **assembler** takes assembly (.c), makes object file (.obj) machine language
- **linker** takes object file, resolves addresses, arranges output based on *linker script*, creates executable
- Who wrote the first compiler? Assembler? Machine language?

Tools

- compiler: we use gcc, others exist (intel, microsoft, llvm/clang)
- assembler: GNU Assembler as (others: tasm, nasm, masm, etc.)
- linker: ld

Converting C to assembly

- You can use `gcc -S` to have it dump out the assembly it makes
- The whole process is fairly complex, you can take whole classes on it.

Converting Assembly to Machine Language

Thankfully the assembler does this for you.

ARM32 ADD instruction – `0xe0803080` == `add r3, r0, r0, lsl #1`

`ADD{S}<c> <Rd>,<Rn>,<Rm>{,<shift>}`

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
cond				**0**	**0**	**0**	**0**	**1**	**0** **Opcode**	**0**	**S**	**Rn**			

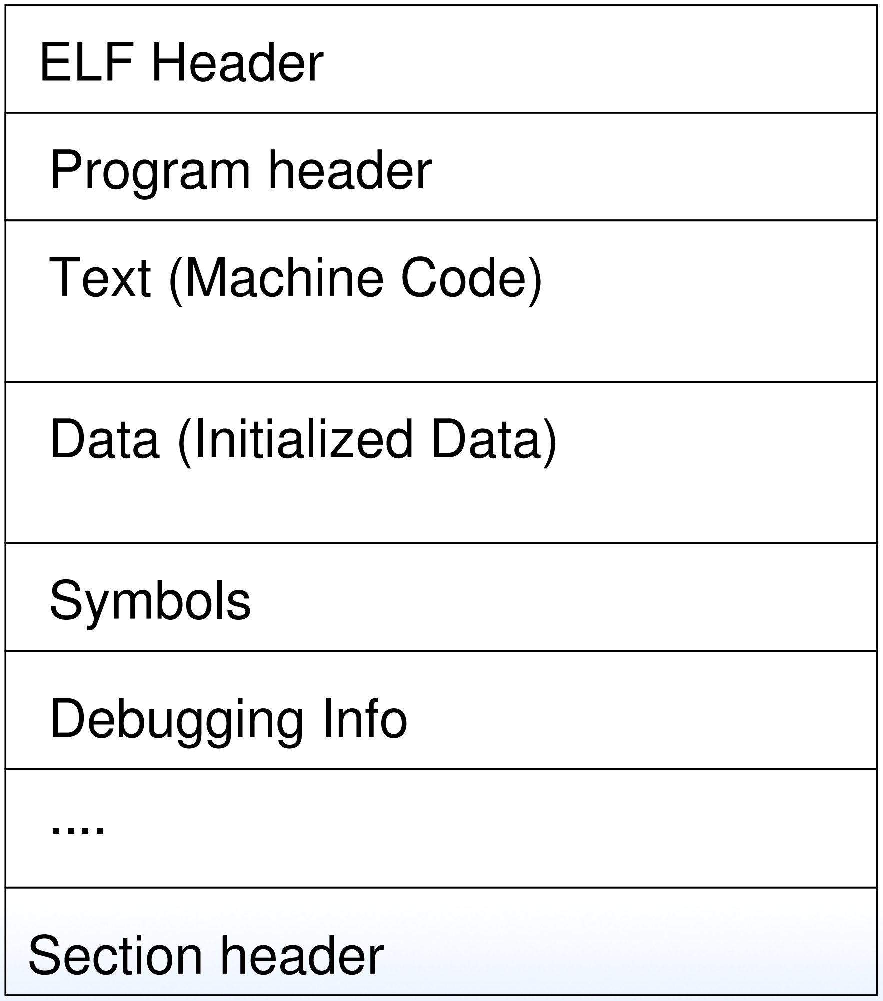
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rd				**Shift imm5**					**Shift typ**		**Sh Reg**	**Rm**			

Executable Format

- ELF (Executable and Linkable Format, Extensible Linking Format)
  Default for Linux and some other similar OSes
  header, then header table describing chunks and where they go

- Other executable formats: a.out, COFF, binary blob

ELF Layout


ELF Header
Program header
Text (Machine Code)
Data (Initialized Data)
Symbols
Debugging Info
....
Section header

ELF Description

- ELF Header includes a “magic number” saying it’s 0x7f,ELF, architecture type, OS type, etc. Also location of program header and section header and entry point.
- Program Header, used for execution:
  has info telling the OS what parts to load, how, and where (address, permission, size, alignment)
- Program Data follows, describes data actually loaded into memory: machine code, initialized data

- Other data: things like symbol names, debugging info (DWARF), etc.
  DWARF backronym = "Debugging with Attributed Record Formats"

- Section Header, used when linking:
  has info on the additional segments in code that aren't loaded into memory, such as debugging, symbols, etc.

Cross-compiling

- Building for a different architecture
- Why? ARM machines often slow
- Why not? Source tree has to be handle this. Makefile. etc. Usually easier to compile natively
- Linux kernel tends to cross compile OK.