Fast Reboots with kload

- Russell Cattelan
  Kernel Engineer
  - cattelan@digitalelves.com
  - http://git.digitalelves.com/?p=FreeBSD_kload.git
How does this help?

- Avoid resetting system
  - BIOS/ POST takes along time
    - Varies from system to system
- New kernel is loaded into memory before reboot
- Modeled on Linux's kexec / kdump
Building on userboot.so

- userboot.so developed for the BHyVe project
  - FreeBSD Hyper Visor.
- Separates the guts of /boot/loader into a library that is usable userspace utilities
  - Forth interpreter
  - elf loader
- Reads and sets up elf images in memory.
  - Primary kernel image
  - Kernel modules i.e. if_re.ko
- Temporary main memory image
- Populates kernel parameter page (kenv)
/sbin/kload

- Loads / configures / adjusts
  - Reads kernel / modules – sets up memory image
  - Builds smap by querying existing kernel via sysctl
    - Map of system memory
- Command Line options
  - -k flag add / override kenv parameters
  - -e execute **NOW** skip shutdown routines
  - -r sends kill signal to all processes – normal reboot
  - -h alternate / loads a kernel not installed in /<arg>/boot
- Initiates kload syscall once everything is ready to go
The running kernel is the loader

- userboot.so / kload does the image loading / setup but it's not in the right spot in memory.
  - First step is to allocate temporary pages in the lower 1 Gig of memory. (This is sometimes a performance issue)
  - Build a very simple scatter gather list of identity mapped pages -- physical address + KERNBASE
  - Setup simple GDT / pagetable
  - Allocate code / stack / control pages
  - Handle AP / interrupt shutdown
Simple page list structure

- `page_list`: series of page address last address in each page being a ptr to next page list
System clean up / shutdown.

- Mostly the same as normal shutdown.
  - Hooks into shutdown chain right before last event when kernel is loaded
  - Last shutdown event is to reset cpu / power down

```c
#define SHUTDOWN_PRI_FIRST EVENTHANDLER_PRI_FIRST
#define SHUTDOWN_PRI_DEFAULT EVENTHANDLER_PRI_ANY
#define SHUTDOWN_PRI_LAST EVENTHANDLER_PRI_LAST
#define SHUTDOWN_PRI_KLOAD EVENTHANDLER_PRI_LAST - 100

/* hook into the shutdown/reboot path so we end up here before cpu reset */
EVENTHANDLER_REGISTER(shutdown_final, kload_shutdown_final, NULL, SHUTDOWN_PRI_KLOAD);
```
• Send Inter Processor Interrupt IPI to cpu 1 – X Application Processors (APs) telling them to **suspend**
  - Mask lapic on each cpu especially timer interrupts
    This code needs to be reconciled with suspend / resume
    - Not ported to i386 yet
• De-install all ioapic interrupts (system wide interrupts routed to a particular lapic)
• Mask lapic (Local Advanced Programmable Interrupt Controller) on cpu 0 Board Support Processor (BSP) disable cpu interrupts
• At this point system is ready to replace kernel
Replace old kernel image

- relocate_kernel
  - Relocates itself and running stack so as to not clobber itself (long jump)
  - Turn off processor interrupts again :-)
  - Install simple GDT with a writeable code segment (CS) and writeable data segment (DS)
  - Install identity mapped page table – entire address space maps to first 1 Gig of memory
  - Walk list of pages copy over the existing kernel pages starting at KERNBASE
  - Push kernel start address on to stack long jump to it
/* first install the new page table */
movq 32(%rcx), %rax /* page table */
movq 40(%rcx), %r9 /* address of control_page with new PT */
movq %rax, %cr3
movq $(X86_CR4_PSE | X86_CR4_PAE), %rax
movq %rax, %cr4

/* then move the stack to the end of control page */
lea 4096(%r9), %rsp
/*
 * now move to the code page
 * should have been passed code_page based
 * on new page table
 */
movq %rdx, %r8
addq $(identity_mapped - relocate_kernel), %r8
/* offset of code segment in new gdt */
pushq$0x08
pushq%r8
/* jump to this spot in the new page */
lretq
identity_mapped:
 /* Do the copies */
.
.
.
pushq16(%r9) /* physfree */
movq 8(%r9), %rax /* modulep */
salq $32, %rax
pushq%rax
pushq$0x8
pushq48(%r9) /* entry # kernel entry pt */
/* jump to kernel entry pt */
lretq
Let's try it out
Known Issues

- Drivers need to correctly shutdown the hardware
  - Realtek driver needs a reset added to re_shuffle
- kmem_alloc_attr sometimes takes a long time to return memory. Even to the point were it would probably be faster to do a normal boot
  - Memory is pre-allocated for now
- Debugging is very hard in asm code – needs to be done with bochs
- Does not have a kload --unload option – memory cannot be released.
More gritty details

- Intel x86 emulator Bochs !!!!
  - This project would have happened without this tool as there is now way to debug things without hardware level instruction debugging / stepping

- GDT page table mirrors what /boot/loader sets up
  - These differ for amd64 and i386
  - PAE kernel not supported?

- Could do tricks with page tables to reduce the number of times the images needs to be copied
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- Could do tricks with page tables to reduce the number of times the images need to be copied
• Global Descriptor Table
  - Old way of loading multiple programs by segmenting memory. Not used by paging systems but still need to setup a minimal GDT.
  - Interrupt Descriptor Table.
  - Create empty IDT table just to make sure, but interrupts should be disabled.
  - Task State Segment – not used during kload should already set to ring0 (full privileges)

Create identity mapped page table
Identity mapped pagetable

- Page size set to 2 meg / page tables are built using 2 meg pages
- Amd64 / PAE used level 3 page tables
  - 512 64 bit / 8byte address per 4k page for a total of 1Gig of memory per page
- i386 uses level 2
  - 1024 32 bit / 4 byte address per 4k page
- Used the same code as the loader to set up page tables as to keep things as simple as possible
• Map all of the address space to the first 1GB

```c
for (i = 0; i < 512; i++) {
    /* Each slot of the level 4 pages points to the same level 3 page */
    PT4[i] = (pt_entry_t)(vtophys(PT3));
    PT4[i] |= PG_V | PG_RW | PG_U;

    /* Each slot of the level 3 pages points to the same level 2 page */
    PT3[i] = (pt_entry_t)(vtophys(PT2));
    PT3[i] |= PG_V | PG_RW | PG_U;

    /* The level 2 page slots are mapped with 2MB pages for 1GB. */
    PT2[i] = i * (2 * 1024 * 1024);
    PT2[i] |= PG_V | PG_RW | PG_PS | PG_U;
}
```
void setup_freebsd_gdt(uint64_t *gdtr)
{
    gdtr[GUEST_NULL_SEL] = 0x0000000000000000;
    gdtr[GUEST_CODE_SEL] = 0x0020980000000000;
    gdtr[GUEST_DATA_SEL] = 0x0000920000000000;
}

From osdevwiki.org each must follow this format
http://wiki.osdev.org/GDT
- Very hard to just decode
References

- http://wiki.freebsd.org/BHyVe
- http://wiki.osdev.org
- http://bhyve.org