OSH Lab1

实验配置环境

本次实验配置的操作环境

- Ubuntu version 17.10.1 x64
- Linux version 3.18.6
- Linux version 4.1.51
- gdb version 7.11.1
- VMWare Fusion version 10.0.1
- QEMU version 2.12.0

linux内核源码的获取及分支管理

在kernel的官网上有三种版本，mainline，stable，longterm

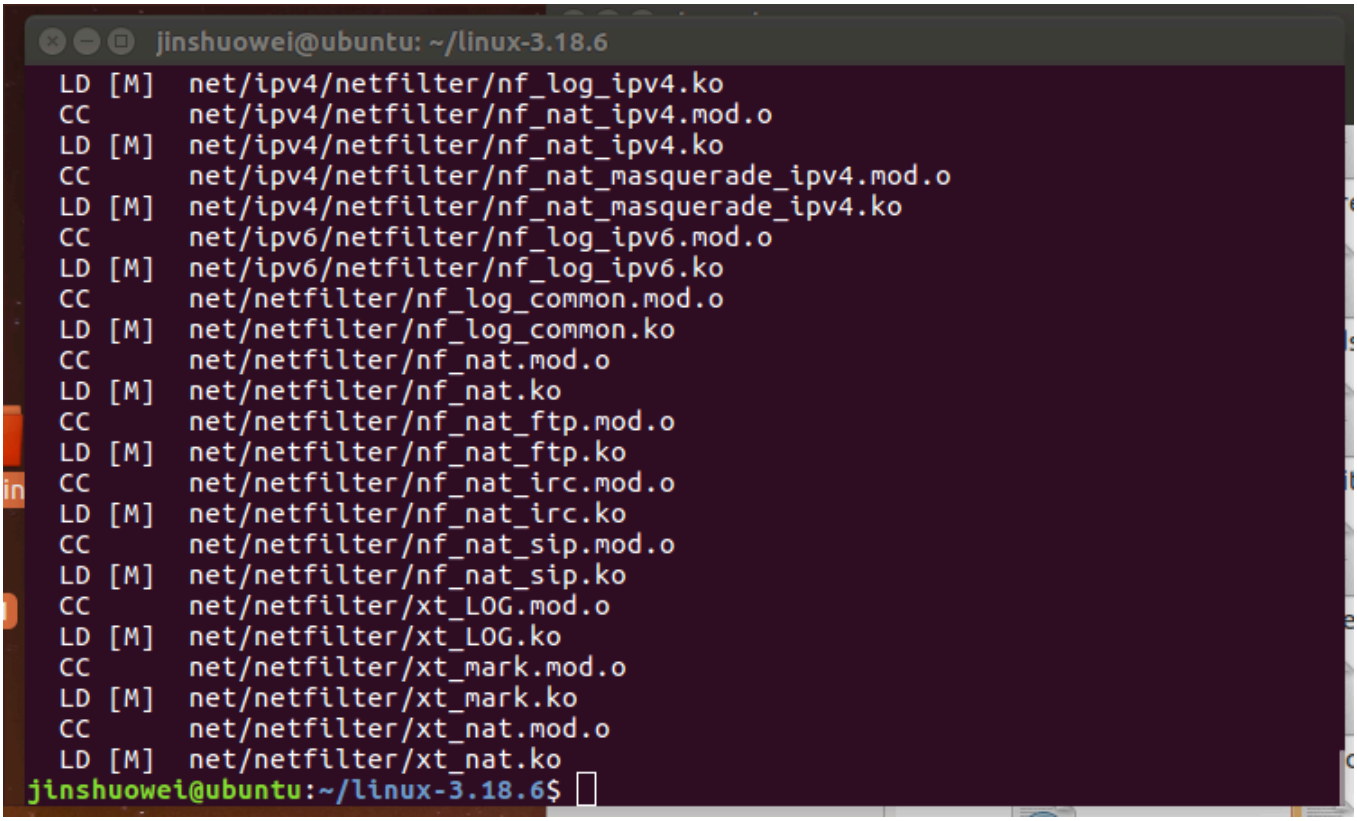
- mainline是主线版本，最新的
- stable是稳定版
- longterm是长期支持版

kernel的官方网站(https://www.kernel.org/)获得，在这里采取了直接在kernel官网下载然后拖入vmware虚拟机中进行解压的方法。
解压完成后输入一下代码

```
xz -d linux-3.18.6.tar.xz
tar -xvf linux-3.18.6.tar
cd linux-3.18.6
make clean
make x86_64_defconfig
#此时发现这边有一个小问题，就是没有打开compile the kernel with debug info 选项
#所以重新再make menuconfig下进行设置
#先输入sudo apt-get install libncurses5-dev libncursesw5-dev

make menuconfig
#再在kernel hacking 下勾上compile the kernel with debug info
#此时再次使用make进行重新编译
make -j 4 #将vmware可使用的cpu

```

注意上一步中其实make内核的时候容易产生较大的问题
因为gcc版本所以会出现bug
此时就需要将gcc版本默认降级就可以成功make了
具体降级的办法如下

```
sudo apt-get install gcc-4.8
sudo update-alternatives --install /usr/bin/gcc gcc /usr/bin/gcc-4.8 100
sudo update-alternatives --config gcc
```



如图是编译好内核后的结果

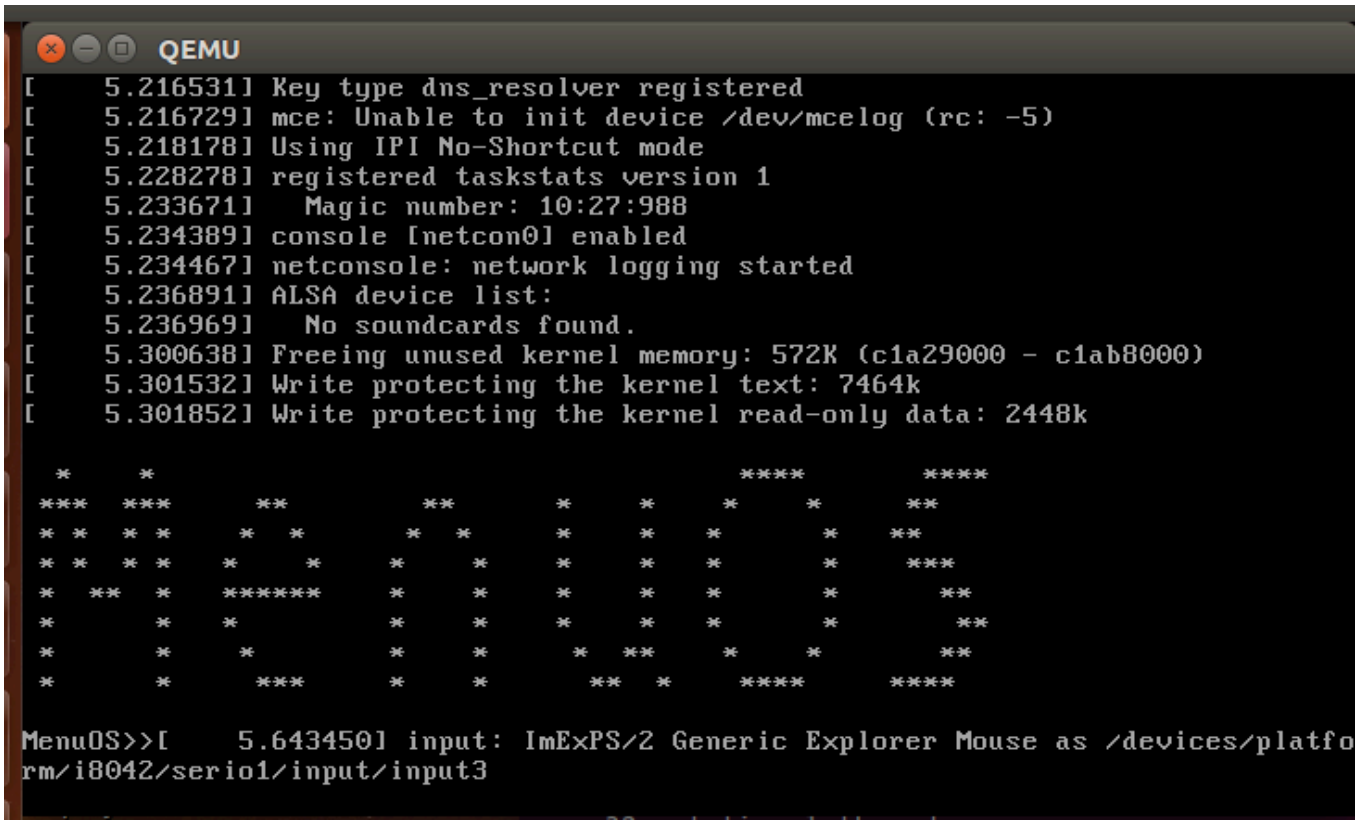
接下来开始制作根文件系统

```
cd ..
mkdir rootfs
git clone https://github.com/mengning/menu.git
cd menu
gcc -o init linktable.c menu.c test.c -m32 -static -lpthread #全部使用静态的方式
cd ../rootfs
cp ../menu/init ./
find . | cpio -o -Hnewc |gzip -9 > ../rootfs.img #把rootfs打包好

```

注意在这里第四步的时候，需要在前面执行一句
sudo apt-get install g++-7-multilib
7:用版本号代替
否则无法运行

启动MenuOS系统

```
cd ..
qemu-system-x86_64 -kernel arch/x86_64/boot/bzImage -initrd rootfs.img -S -s


```

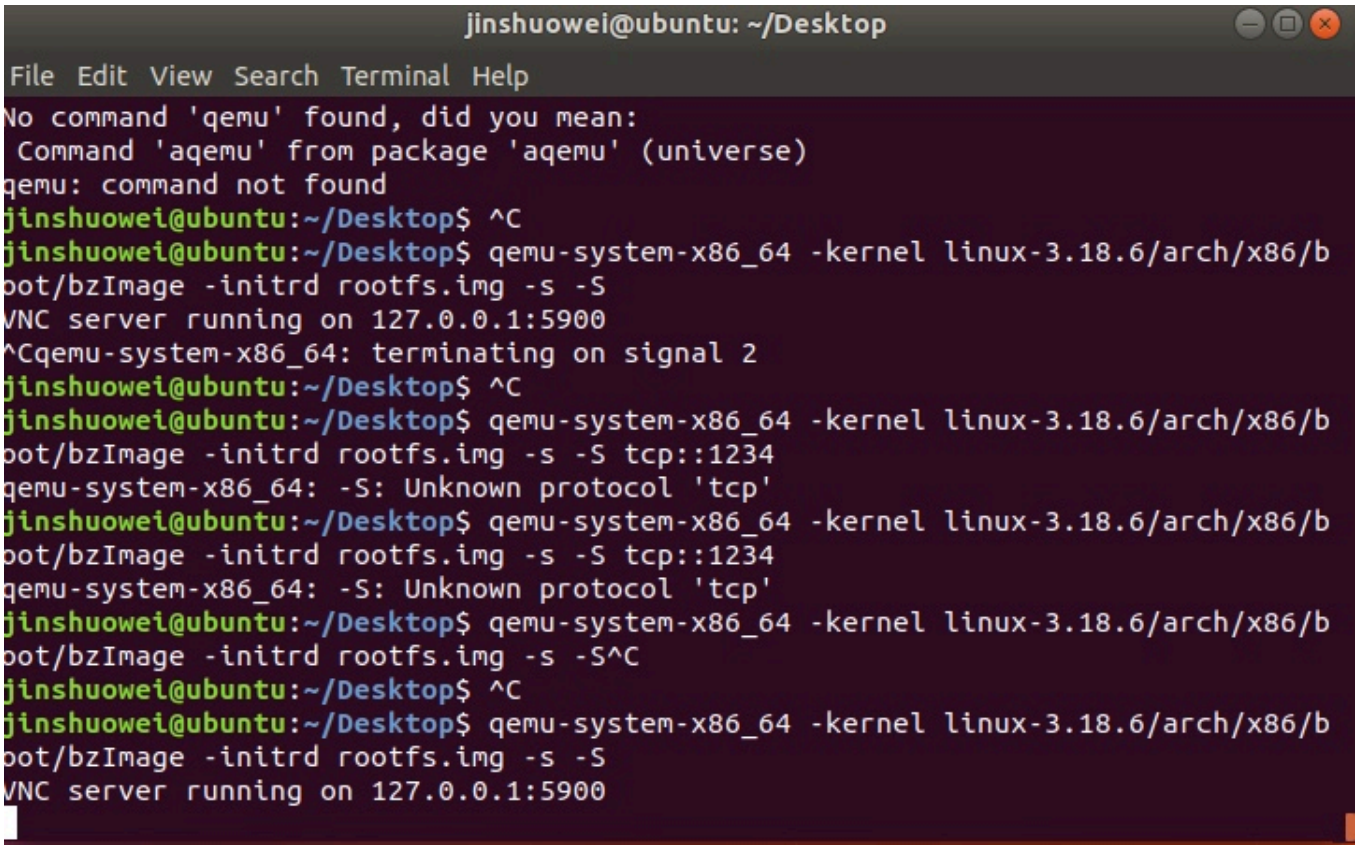


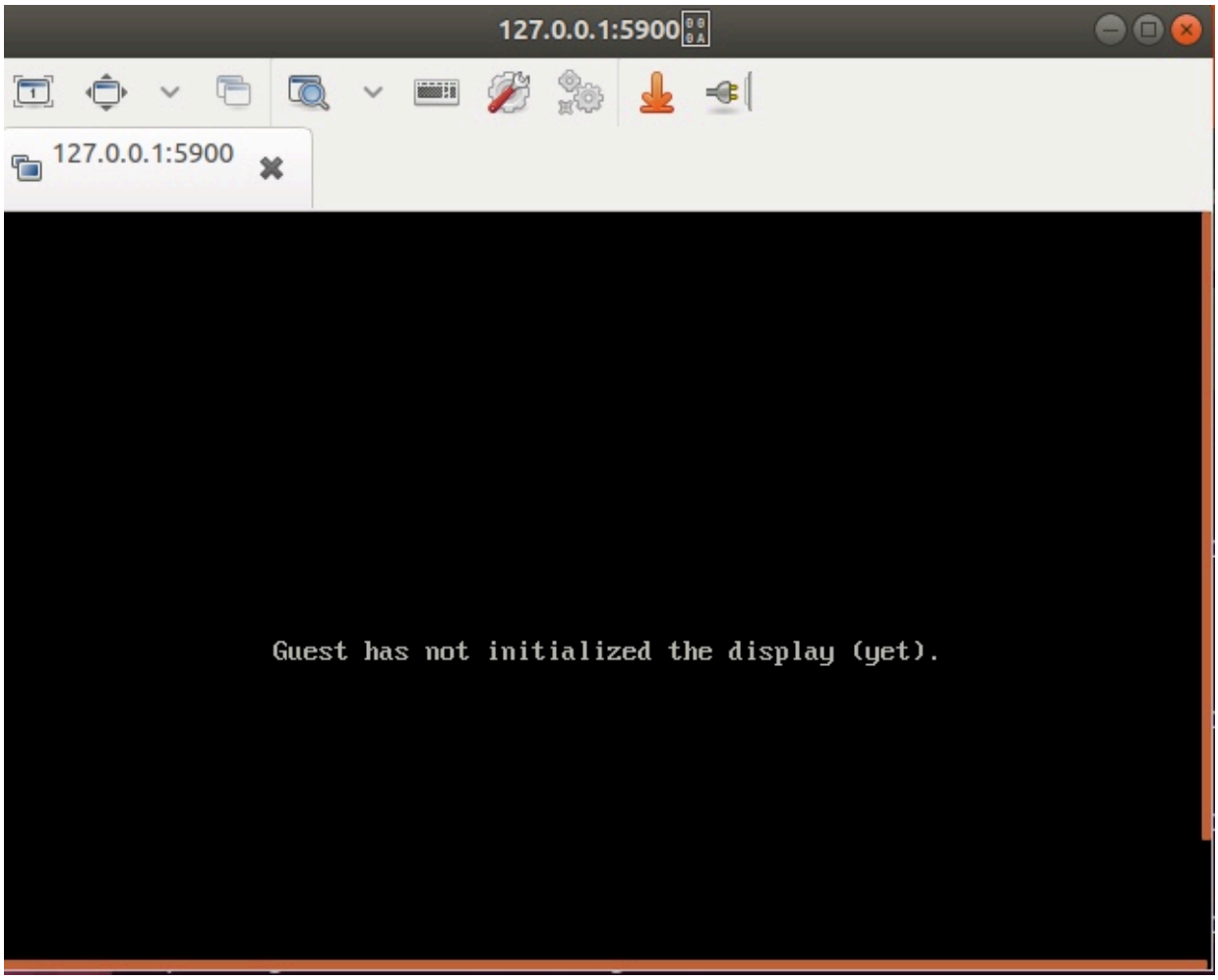
如图是成功启动menuos的界面

使用gdb跟踪调试内核

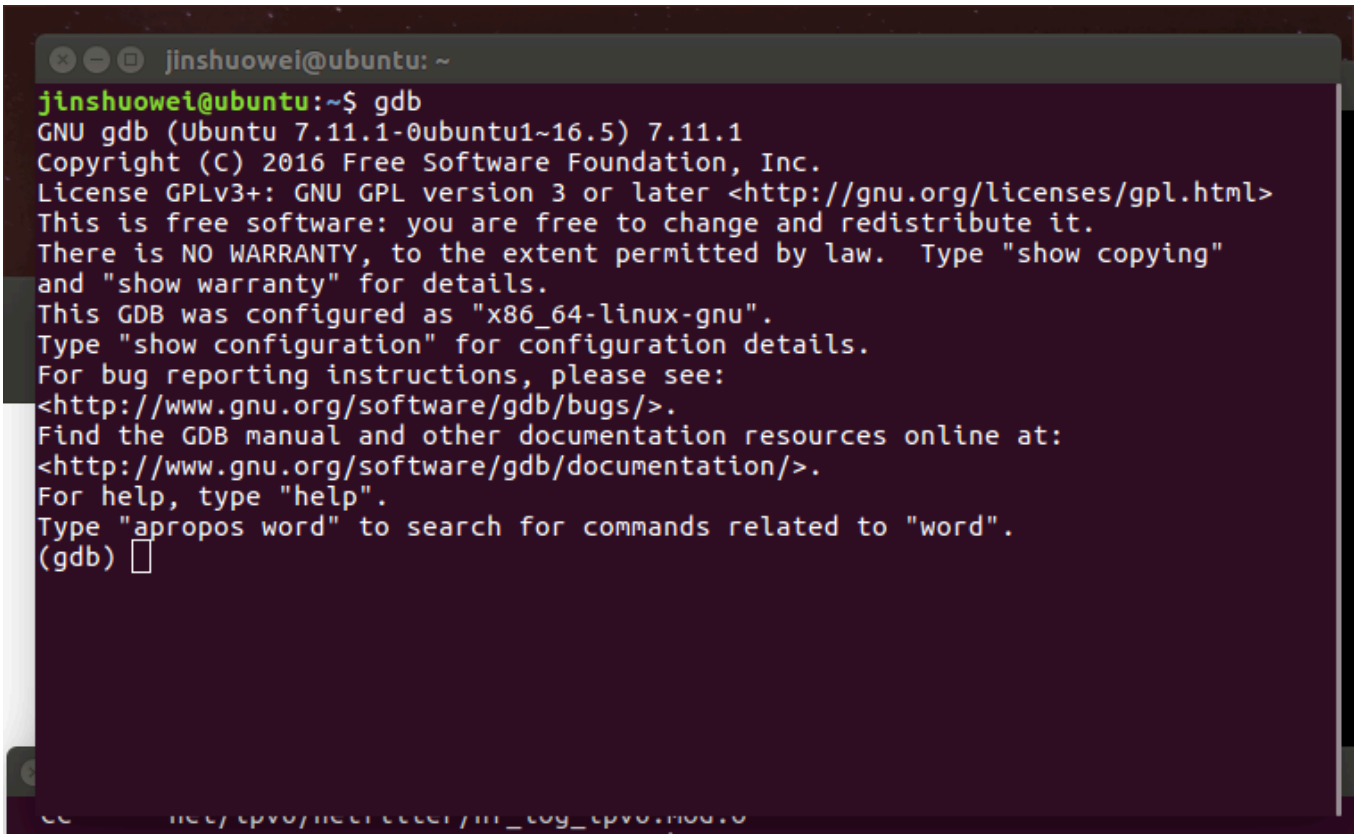
```
cd ..
qemu-system-x86_64 -kernel linux-3.18.6/arch/x86/boot/bzImage -initrd rootfs.img -s -S
```

-S是在程序开始的时候用来冻结CPU的
-s 是使用gdb tcp::1234端口的shorthand
此时输入完命令，发现窗口确实处于被冻结状态
此时使用VNC来连接



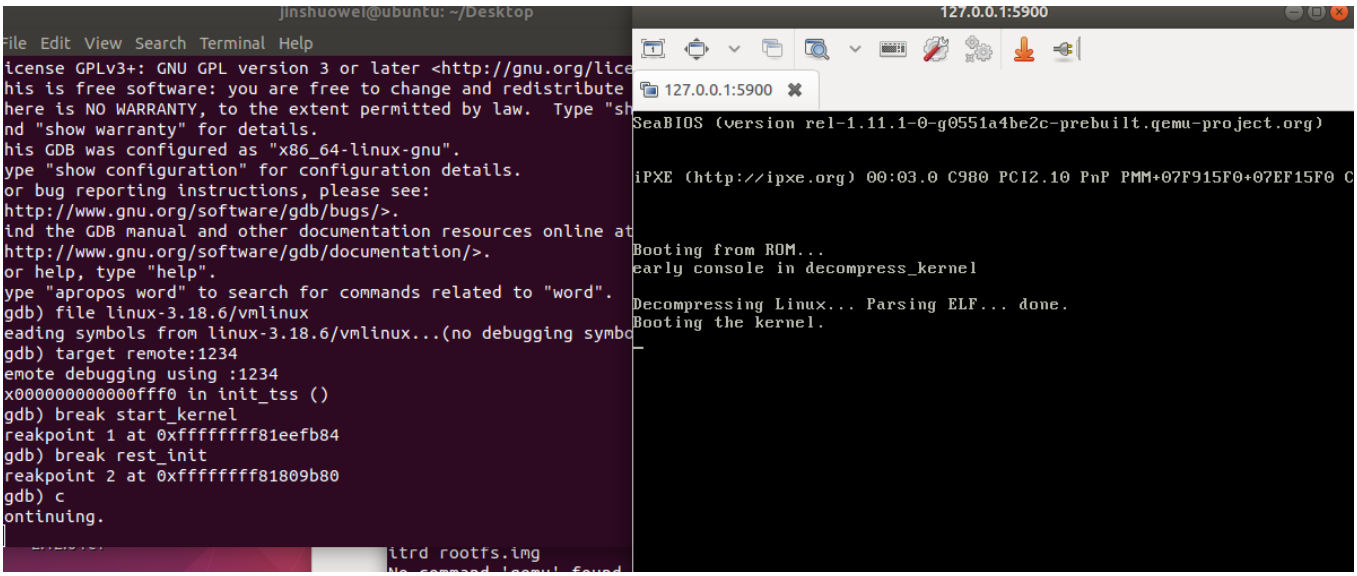


此时再新开一个terminal窗口，用其打开gdb



在**gdb**窗口输入以下命令

```
file linux-3.18.6/vmlinux
target remote:1234
break start_kernel #这样就在内核启动的位置设置了一个断点
c #使得系统开始执行qemu
#用类似的方法可以设置更多的断点
break rest_init
```



在这里发现了qemu程序的一个问题，该程序无法自动启动
所以在这里想要更新一下qemu
于是先到qemu.org上下载了最新版本的qemu
然后直接放在了ubuntu下面进行了解压

然后cd到当那个文件夹下
并输入一下指令

```
./configure
make
make install
```

在./configure时发现少了一些包，又装了一下这些包
接下来清除编译过程中产生的临时文件和过程中产生的文件

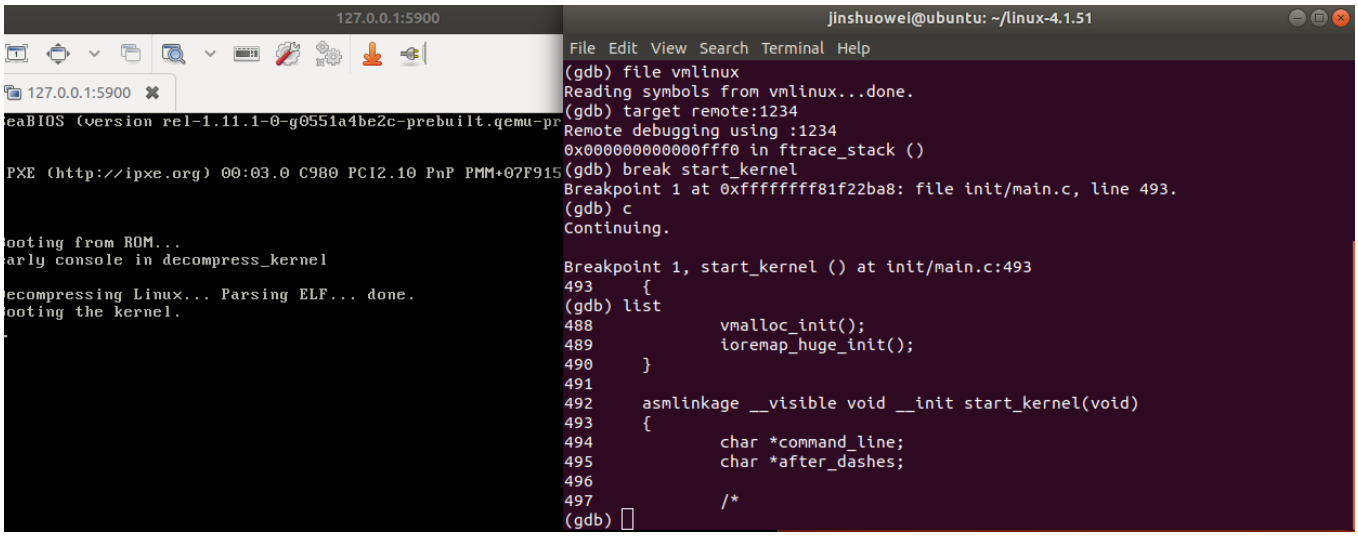
```
make clean
make distclean
```

此时需要用VNC连接远程桌面来访问qemu

此时需要

跟踪内核的启动过程

知道了如何跟踪内核后，需要有目的地跟踪
这时候发现由于linux内核问题，在换到ubuntu17.10.1的时候booting的时候无法启动，这里开始测试内核linux 4.1.51



start_kernel

现在来研究一下start_kernel函数的源代码

```
asmlinkage __visible void __init start_kernel(void)
{
    char *command_line;
    char *after_dashes;

    /*
     * Need to run as early as possible, to initialize the
     * lockdep hash:
```

```
     */
    lockdep_init();
    set_task_stack_end_magic(&init_task);
    smp_setup_processor_id();
    debug_objects_early_init();

    /*
     * Set up the the initial canary ASAP:
     */
    boot_init_stack_canary();

    cgroup_init_early();

    local_irq_disable();
    early_boot_irqs_disabled = true;

/*
 * Interrupts are still disabled. Do necessary setups, then
 * enable them
 */
    boot_cpu_init();
    page_address_init();
    pr_notice("%s", linux_banner);
    setup_arch(&command_line);
    mm_init_cpumask(&init_mm);
    setup_command_line(command_line);
    setup_nr_cpu_ids();
    setup_per_cpu_areas();
    smp_prepare_boot_cpu(); /* arch-specific boot-cpu hooks */

    build_all_zonelists(NULL, NULL);
    page_alloc_init();

    pr_notice("Kernel command line: %s\n", boot_command_line);
    parse_early_param();
    after_dashes = parse_args("Booting kernel",
                  static_command_line, __start___param,
                  __stop___param - __start___param,
                  -1, -1, &unknown_bootoption);
    if (!IS_ERR_OR_NULL(after_dashes))
        parse_args("Setting init args", after_dashes, NULL, 0, -1, -1,
               set_init_arg);

    jump_label_init();

    /*
     * These use large bootmem allocations and must precede
     * kmem_cache_init()
     */
    setup_log_buf(0);
    pidhash_init();
    vfs_caches_init_early();
    sort_main_extable();
    trap_init();
    mm_init();

```

```
65      /*
66       * Set up the scheduler prior starting any interrupts (such as the
67       * timer interrupt). Full topology setup happens at smp_init()
68       * time - but meanwhile we still have a functioning scheduler.
69       */
70      sched_init();
71      /*
72       * Disable preemption - early bootup scheduling is extremely
73       * fragile until we cpu_idle() for the first time.
74       */
75      preempt_disable();
76      if (WARN(!irqs_disabled(),
77               "Interrupts were enabled *very* early, fixing it\n"))
78              local_irq_disable();
79      idr_init_cache();
80      rcu_init();
81
82      /* trace_printk() and trace points may be used after this */
83      trace_init();
84
85      context_tracking_init();
86      radix_tree_init();
87      /* init some links before init_ISA_irqs() */
88      early_irq_init();
89      init_IRQ();
90      tick_init();
91      rcu_init_nohz();
92      init_timers();
93      hrtimers_init();
94      softirq_init();
95      timekeeping_init();
96      time_init();
97      sched_clock_postinit();
98      perf_event_init();
99      profile_init();
100     call_function_init();
101     WARN(!irqs_disabled(), "Interrupts were enabled early\n");
102     early_boot_irqs_disabled = false;
103     local_irq_enable();
104
105     kmem_cache_init_late();
106
107     /*
108      * HACK ALERT! This is early. We're enabling the console before
109      * we've done PCI setups etc, and console_init() must be aware of
110      * this. But we do want output early, in case something goes wrong.
111      */
112     console_init();
113     if (panic_later)
114             panic("Too many boot %s vars at `%s'", panic_later,
115                   panic_param);
116
117     lockdep_info();
118
119     /*
120      * Need to run this when irqs are enabled, because it wants
```

```
121      * to self-test [hard/soft]-irqs on/off lock inversion bugs
122      * too:
123      */
124     locking_selftest();
125 
126 #ifdef CONFIG_BLK_DEV_INITRD
127     if (initrd_start && !initrd_below_start_ok &&
128         page_to_pfn(virt_to_page((void *)initrd_start)) < min_low_pfn) {
129         pr_crit("initrd overwritten (0x%08lx < 0x%08lx) - disabling it.\n",
130             page_to_pfn(virt_to_page((void *)initrd_start)),
131             min_low_pfn);
132         initrd_start = 0;
133     }
134 #endif
135     page_ext_init();
136     debug_objects_mem_init();
137     kmemleak_init();
138     setup_per_cpu_pageset();
139     numa_policy_init();
140     if (late_time_init)
141         late_time_init();
142     sched_clock_init();
143     calibrate_delay();
144     pidmap_init();
145     anon_vma_init();
146     acpi_early_init();
147 #ifdef CONFIG_X86
148     if (efi_enabled(EFI_RUNTIME_SERVICES))
149         efi_enter_virtual_mode();
150 #endif
151 #ifdef CONFIG_X86_ESPFIX64
152     /* Should be run before the first non-init thread is created */
153     init_espfix_bsp();
154 #endif
155     thread_info_cache_init();
156     cred_init();
157     fork_init();
158     proc_caches_init();
159     buffer_init();
160     key_init();
161     security_init();
162     dbg_late_init();
163     vfs_caches_init(totalram_pages);
164     signals_init();
165     /* rootfs populating might need page-writeback */
166     page_writeback_init();
167     proc_root_init();
168     nsfs_init();
169     cpuset_init();
170     cgroup_init();
171     taskstats_init_early();
172     delayacct_init();
173 
174     check_bugs();
175 
176     acpi_subsystem_init();
```

```
177     sfi_init_late();
178
179     if (efi_enabled(EFI_RUNTIME_SERVICES)) {
180         efi_late_init();
181         efi_free_boot_services();
182     }
183
184     ftrace_init();
185
186     /* Do the rest non-__init'ed, we're now alive */
187     rest_init();
188 }
189
190 /* Call all constructor functions linked into the kernel. */
191 static void __init do_ctors(void)
192 {
193 #ifdef CONFIG_CONSTRUCTORS
194     ctor_fn_t *fn = (ctor_fn_t *) __ctors_start;
195
196     for (; fn < (ctor_fn_t *) __ctors_end; fn++)
197         (*fn)();
198 #endif
199 }
200
201 bool initcall_debug;
202 core_param(initcall_debug, initcall_debug, bool, 0644);
203
204 #ifdef CONFIG_KALLSYMS
205 struct blacklist_entry {
206     struct list_head next;
207     char *buf;
208 };
209
210
```

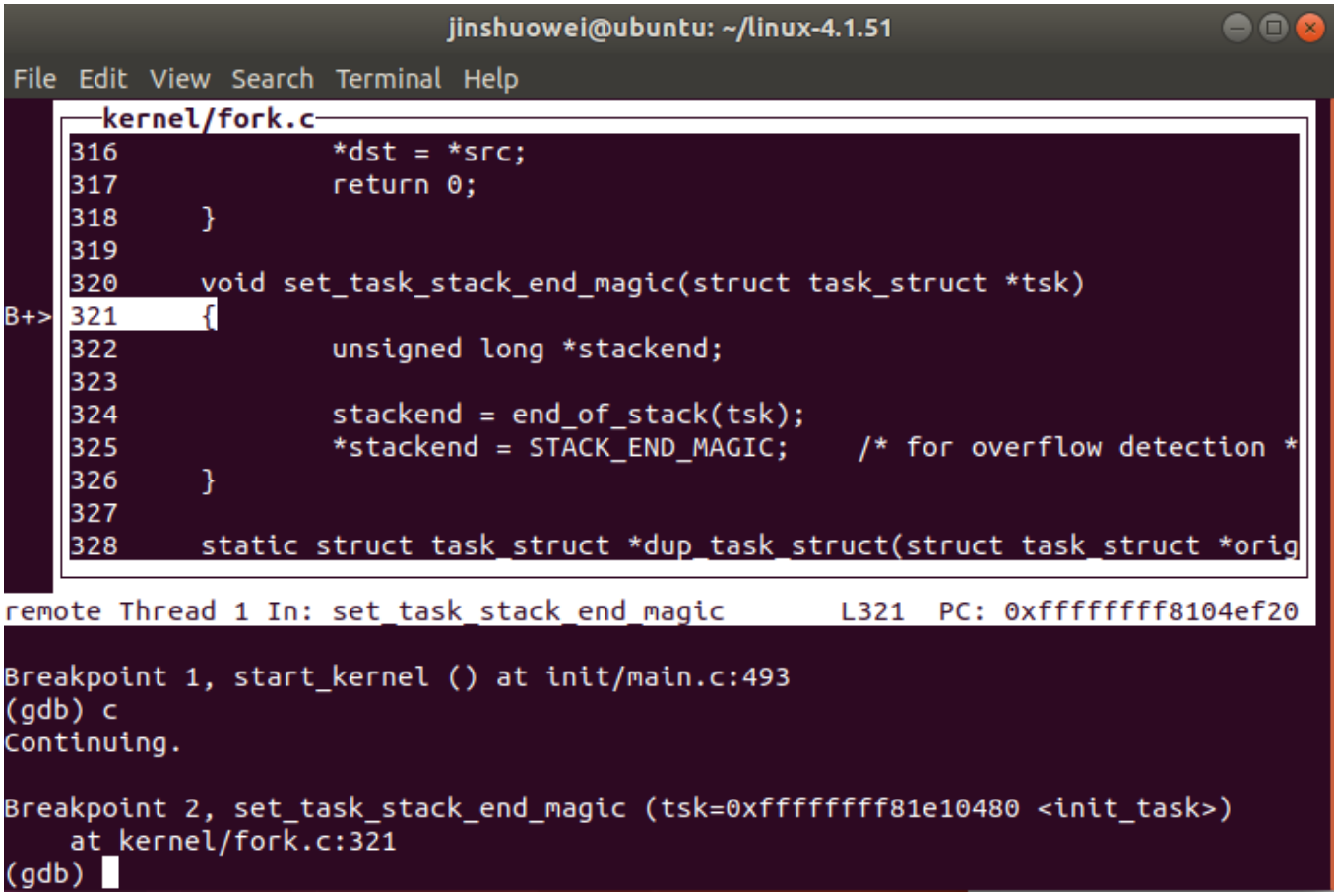
无论研究什么内核模块，都应该先来研究start_kernel，因为所有内核重要的模块都会在这里初始化

- 初始化lock validator（lockdep_init)
- 初始化高端内存的映射表 (page_address_init())
- 设置操作系统的第一个进程init (set_task_stack_end_magic)
- 设置obj_hash, obj_static_pool两个全局变量
- 内核架构相关初始化函数，包含处理器相关参数的初始化、内核启动参数的获取和前期处理、内存子系统的早期初始化 (setup_arch)
- 初始化文件系统的缓冲区，并计算最大可以使用的文件缓存（buffer_init()）
- 对内核陷阱异常进行初始化，初始化一些中断向量，在ARM系统里是空函数，没有任何的初始化（trap_init()）
- 初始化软件中断（softirq_init()）
- 设置内存页分配通知器 (page_alloc_init)

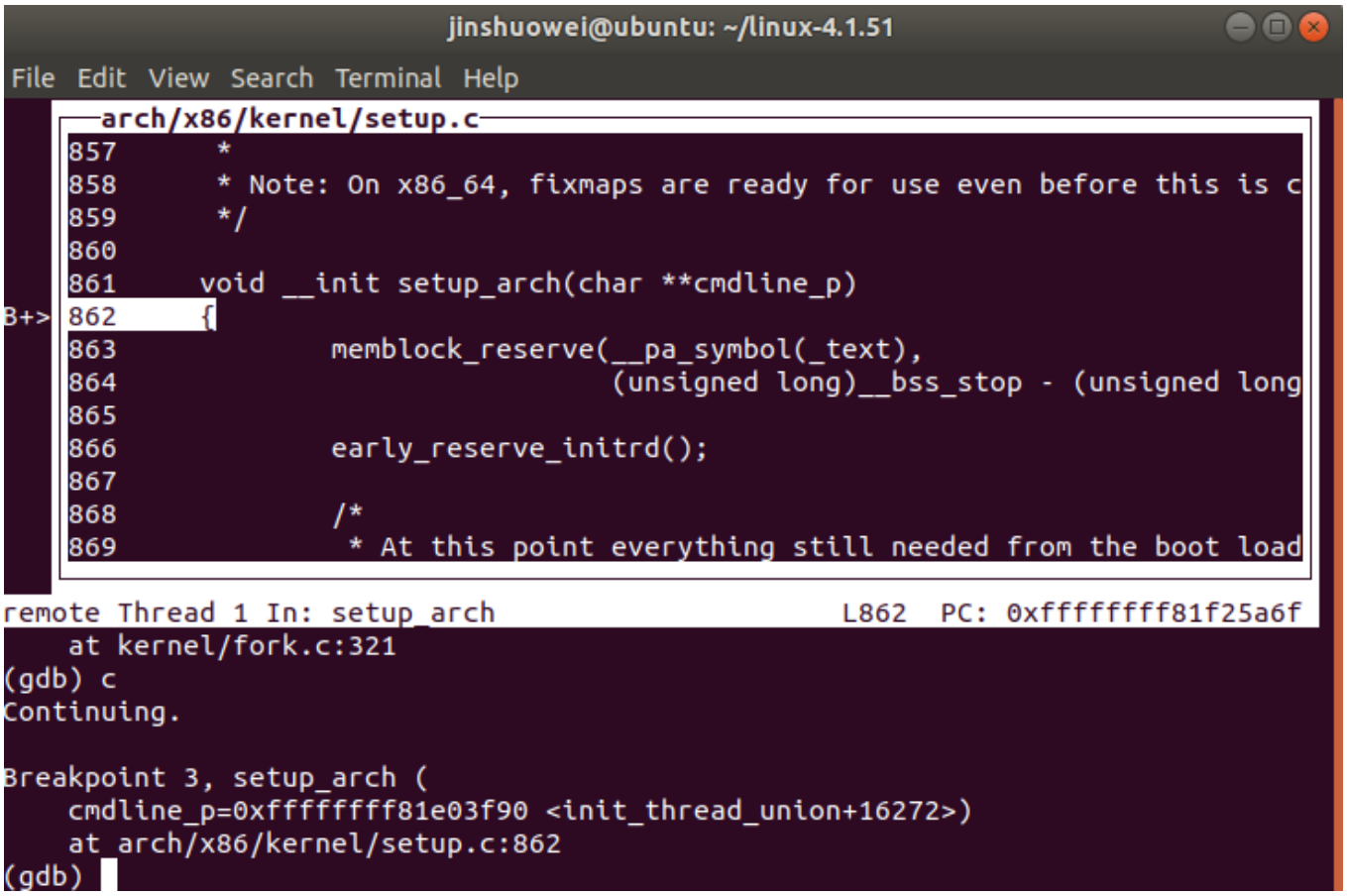
- 中断描述符号表初始化 (trap_init)
- 初始化内存管理器 (mm_init)
- 对进程调度器的数据结构进行初始化 (sched_init)
- 初始化直接读拷贝更新的锁机制 (rcu_init)
- 初始化内核信号队列（ signals_init()）
- 初始化系统时钟，开启一个硬件定时器 (time_init)
- 启用中断操作 (local_irq_enable)
- 检查CPU配置、FPU等是否非法使用不具备的功能，检查CPU BUG，软件规避BUG (check_bugs())
- 控制台初始化 (console_init)
- 完成剩余部分 (rest_init)

现在我们先将断点设置到set_task_stack_end_magic()函数处
因为在start_kernel()中，我们看到调用的第一个函数式lockdep_init(),该函数会初始化内核死锁检测机制的hash table,接下来就是set_task_stack_end_magic()函数。所以先看一下set_task_stack_end_magic()函数

set_task_stack_end_magic()



setup_arch



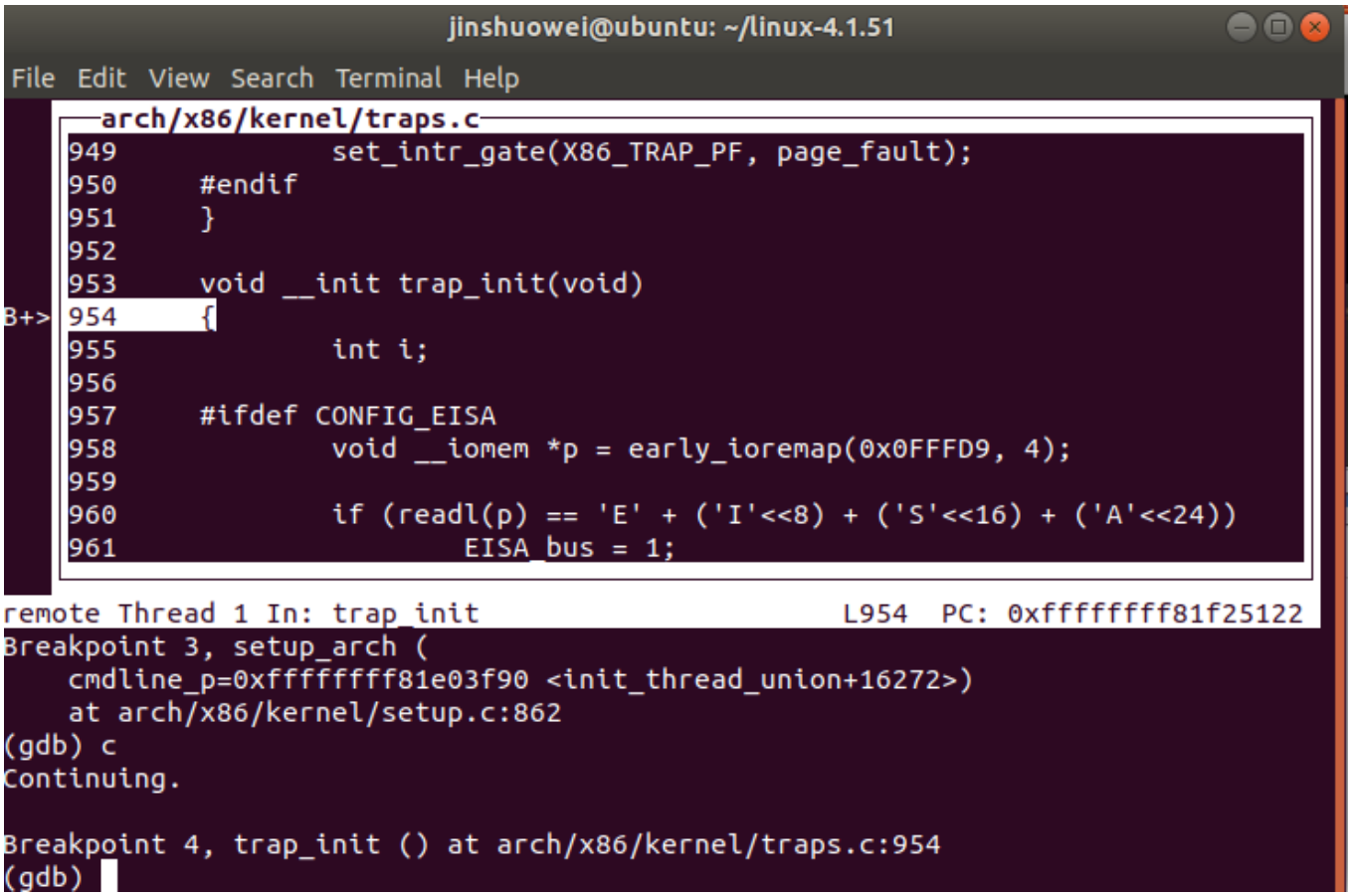
下面找出代码进行分析

```
1  void __init setup_arch(char **cmdline_p)
2  {
3      struct tag *tags = (struct tag *)&init_tags; //定义了一个默认的内核参数列表
4      struct machine_desc *mdesc;      //设备描述的结构体
5      char *from = default_command_line;
6      init_tags.mem.start = PHYS_OFFSET;
7      unwind_init();
8      setup_processor();                    //汇编的CPU初始化部分
9      mdesc = setup_machine(machine_arch_type);
10     machine_desc = mdesc;
11     machine_name = mdesc->name;
12     //下面一部分通过匹配struct machine_desc结构体数据，初始化一些全局变量
13     //通过struct machine_desc 中的soft_reboot设置重启类型
14     if (mdesc->soft_reboot)
15         reboot_setup("s");
16
17     //检查bootloader是否传入参数，如果传入，则给tags赋值，若果没有传入则传递默认的启动参数地址
18     if (__atags_pointer)
19         tags = phys_to_virt(__atags_pointer);
20     else if (mdesc->boot_params) {
21 #ifdef CONFIG_MMU
22         /*
23          * We still are executing with a minimal MMU mapping created
24          * with the presumption that the machine default for this
25          * is located in the first MB of RAM.  Anything else will
26          * fault and silently hang the kernel at this point.
27          */
28         if (mdesc->boot_params < PHYS_OFFSET ||
29             mdesc->boot_params >= PHYS_OFFSET + SZ_1M) {
```

```
30              printk(KERN_WARNING
31                     "Default boot params at physical 0x%08lx out of reach\n",
32                     mdesc->boot_params);
33          } else
34 #endif
35          {
36              tags = phys_to_virt(mdesc->boot_params);
37          }
38      }
39
40 #if defined(CONFIG_DEPRECATED_PARAM_STRUCT)
41      /*
42       * If we have the old style parameters, convert them to
43       * a tag list.
44       */
45      if (tags->hdr.tag != ATAG_CORE)  //内核参数列表第一项为ATAG_CORE
46          convert_to_tag_list(tags);
47      //如果不是，这需要转换成新的内核参数类型，新的内核参数类型用下面的structtag结构表示
48 #endif
49      if (tags->hdr.tag != ATAG_CORE)
50          tags = (struct tag *)&init_tags;
51      //如果没有内核参数，则选用默认的内核参数，在init_tags文件中有定义
52
53      if (mdesc->fixup)
54          mdesc->fixup(mdesc, tags, &from, &meminfo);
55      //用选用的内核参数列表填充meminfo ，fixup函数出现在注册machine_desc中，即MACHINE_START、
    MACHINE_END定义中，这个函数，有些板子有，但在2410中没有定义这个函数。
56
57      if (tags->hdr.tag == ATAG_CORE) {
58          if (meminfo.nr_banks != 0)  //如果内存被初始化过
59              squash_mem_tags(tags);
60          //如果是tag list,那么如果系统已经创建了默认的meminfo.nr_banks，清除tags中关于MEM的参数，以免再
    次被初始化
61
62          save_atags(tags);
63          parse_tags(tags);   //做一些针对各个tags的处理
64      }
65      //解析内核参数列表，然后调用内核参数列表的处理函数对这些参数进行处理。比如，如果列表为命令行，则最终会用
    parse_tag_cmdlin函数进行解析，这个函数用_tagtable编译连接到了内核里
66
67      init_mm.start_code = (unsigned long) _text;
68      init_mm.end_code   = (unsigned long) _etext;
69      init_mm.end_data   = (unsigned long) _edata;
70      init_mm.brk    = (unsigned long) _end;
71      //记录了内核代码的起始，结束虚拟地址
72
73      /* parse_early_param needs a boot_command_line */
74      strlcpy(boot_command_line, from, COMMAND_LINE_SIZE);
75
76      /* populate cmd_line too for later use, preserving boot_command_line */
77      strlcpy(cmd_line, boot_command_line, COMMAND_LINE_SIZE);
78      *cmdline_p = cmd_line;
79      //将boot_command_line复制到cmd_line中
80
81      parse_early_param();                //解释命令行参数
82
```

```
83      arm_memblock_init(&meminfo, mdesc); //将设备实体登记注册到总线空间链表中去
84
85      paging_init(mdesc);
86      request_standard_resources(mdesc);
87
88  #ifdef CONFIG_SMP
89      if (is_smp())
90          smp_init_cpus();    //要配置CONFIG_KEXEC，否则为空函数,2410中没有配置
91  #endif
92      reserve_crashkernel();
93
94      cpu_init(); //初始化一个CPU，并设置一个per-CPU栈
95      tcm_init(); //初始化ARM内部的TCM（紧耦合内存）
96
97  #ifdef CONFIG_MULTI_IRQ_HANDLER
98      handle_arch_irq = mdesc->handle_irq;
99  #endif
100
101 #ifdef CONFIG_VT
102 #if defined(CONFIG_VGA_CONSOLE)
103     conswitchp = &vga_con;
104 #elif defined(CONFIG_DUMMY_CONSOLE)
105     conswitchp = &dummy_con;
106 #endif
107 #endif
108     early_trap_init();      //对中断向量表进行早期的初始化
109     //如果设备描述结构体定义了init_early函数（应该是早期初始化之意），则在这里调用
110     if (mdesc->init_early)
111         mdesc->init_early();
112 }
```

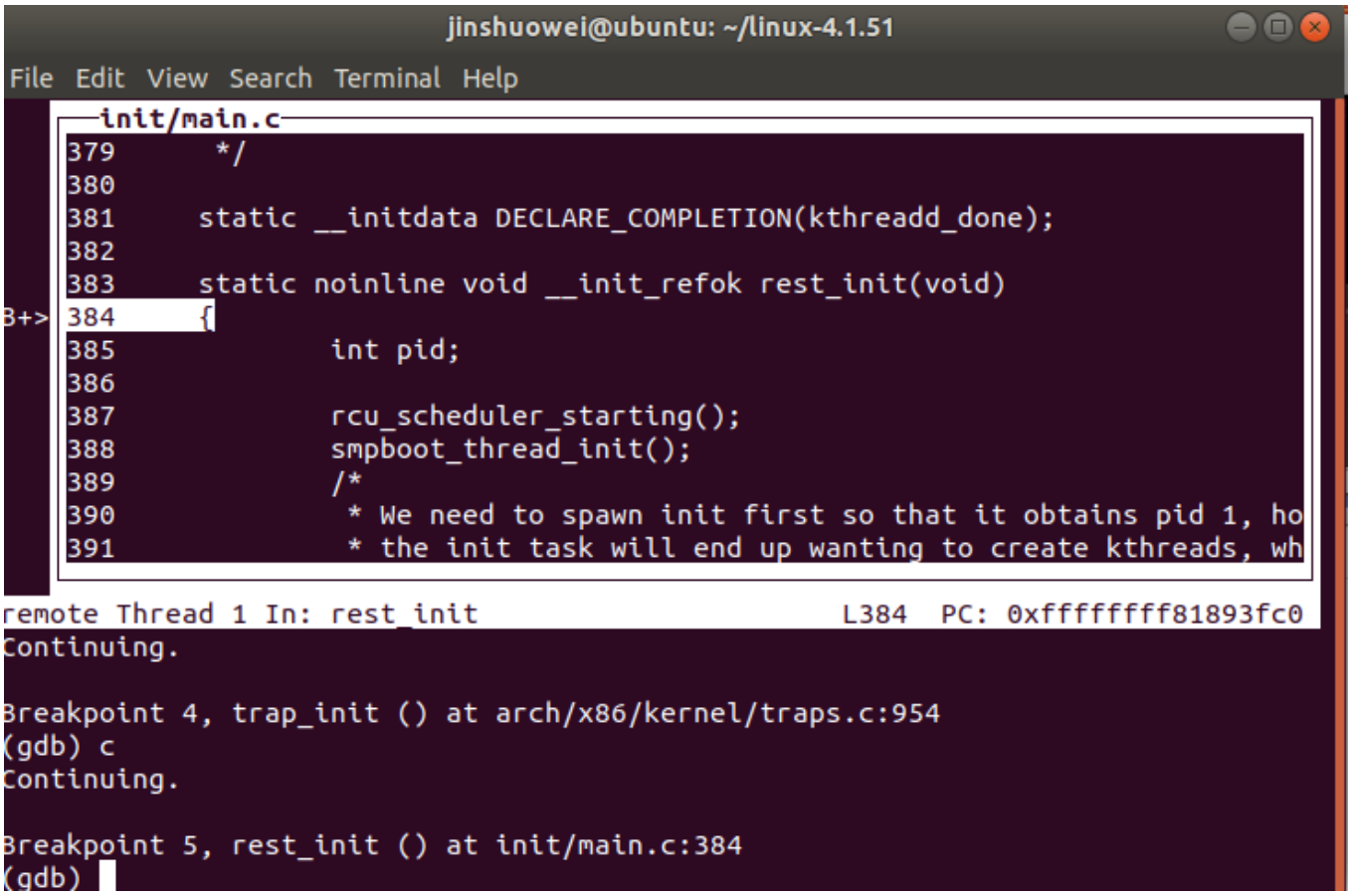
trap_init




```c
void __init trap_init(void)
{
    int i;

#ifdef CONFIG_EISA
    void __iomem *p = early_ioremap(0x0FFFD9, 4);

    if (readl(p) == 'E' + ('I'<<8) + ('S'<<16) + ('A'<<24))
        EISA_bus = 1;
    early_iounmap(p, 4);
#endif

    set_intr_gate(X86_TRAP_DE, divide_error);
    set_intr_gate_ist(X86_TRAP_NMI, &nmi, NMI_STACK);
    /* int4 can be called from all */
    set_system_intr_gate(X86_TRAP_OF, &overflow);
    set_intr_gate(X86_TRAP_BR, bounds);
    set_intr_gate(X86_TRAP_UD, invalid_op);
    set_intr_gate(X86_TRAP_NM, device_not_available);
#ifdef CONFIG_X86_32
    set_task_gate(X86_TRAP_DF, GDT_ENTRY_DOUBLEFAULT_TSS);
#else
    set_intr_gate_ist(X86_TRAP_DF, &double_fault, DOUBLEFAULT_STACK);
#endif
    set_intr_gate(X86_TRAP_OLD_MF, coprocessor_segment_overrun);
    set_intr_gate(X86_TRAP_TS, invalid_TSS);
    set_intr_gate(X86_TRAP_NP, segment_not_present);
    set_intr_gate(X86_TRAP_SS, stack_segment);
    set_intr_gate(X86_TRAP_GP, general_protection);
    set_intr_gate(X86_TRAP_SPURIOUS, spurious_interrupt_bug);
```

```
    set_intr_gate(X86_TRAP_MF, coprocessor_error);
    set_intr_gate(X86_TRAP_AC, alignment_check);
#ifdef CONFIG_X86_MCE
    set_intr_gate_ist(X86_TRAP_MC, &machine_check, MCE_STACK);
#endif
    set_intr_gate(X86_TRAP_XF, simd_coprocessor_error);

    /* Reserve all the builtin and the syscall vector: */
    for (i = 0; i < FIRST_EXTERNAL_VECTOR; i++)
        set_bit(i, used_vectors);

#ifdef CONFIG_IA32_EMULATION
    set_system_intr_gate(IA32_SYSCALL_VECTOR, ia32_syscall);
    set_bit(IA32_SYSCALL_VECTOR, used_vectors);
#endif

#ifdef CONFIG_X86_32
    set_system_trap_gate(SYSCALL_VECTOR, &system_call);
    set_bit(SYSCALL_VECTOR, used_vectors);
#endif

    /*
     * Set the IDT descriptor to a fixed read-only location, so that the
     * "sidt" instruction will not leak the location of the kernel, and
     * to defend the IDT against arbitrary memory write vulnerabilities.
     * It will be reloaded in cpu_init() */
    __set_fixmap(FIX_RO_IDT, __pa_symbol(idt_table), PAGE_KERNEL_RO);
    idt_descr.address = fix_to_virt(FIX_RO_IDT);

    /*
     * Should be a barrier for any external CPU state:
     */
    cpu_init();

    /*
     * X86_TRAP_DB and X86_TRAP_BP have been set
     * in early_trap_init(). However, ITS works only after
     * cpu_init() loads TSS. See comments in early_trap_init().
     */
    set_intr_gate_ist(X86_TRAP_DB, &debug, DEBUG_STACK);
    /* int3 can be called from all */
    set_system_intr_gate_ist(X86_TRAP_BP, &int3, DEBUG_STACK);

    x86_init.irqs.trap_init();

#ifdef CONFIG_X86_64
    memcpy(&debug_idt_table, &idt_table, IDT_ENTRIES * 16);
    set_nmi_gate(X86_TRAP_DB, &debug);
    set_nmi_gate(X86_TRAP_BP, &int3);
#endif
}

```

rest_init()



rest_init()函数分析

(1)rest_init中调用kernel_thread函数启动了2个内核线程，分别是：kernel_init和kthreadd

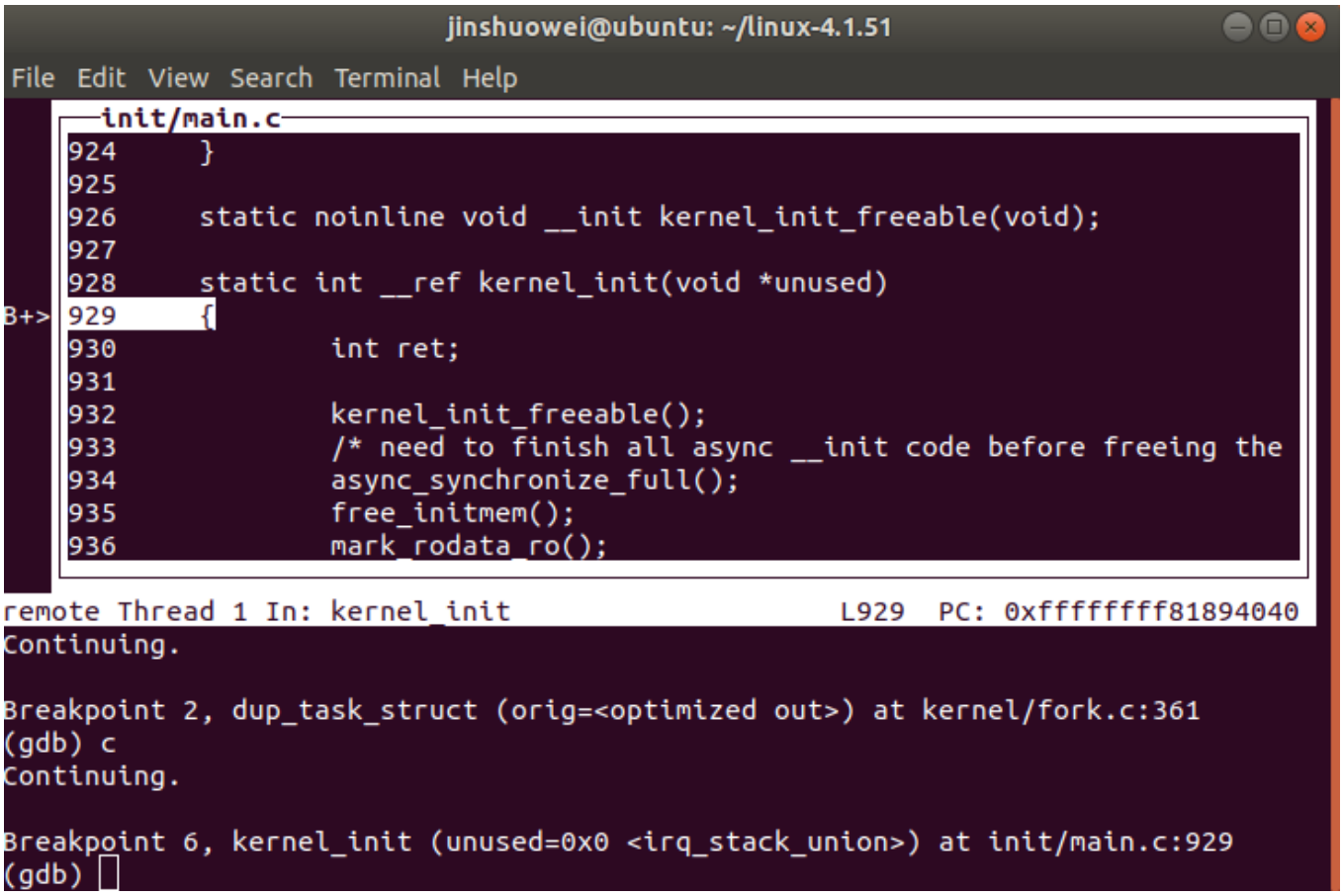
(2)调用schedule函数开启了内核的调度系统，从此linux系统开始转起来了。

(3)rest_init最终调用cpu_idle函数结束了整个内核的启动。也就是说linux内核最终结束了一个函数cpu_idle。这个函数里面肯定是死循环。

(4)简单来说，linux内核最终的状态是：有事干的时候去执行有意义的工作（执行各个进程任务），实在没活干的时候就去死循环（实际上死循环也可以看成是一个任务）。

(5)之前已经启动了内核调度系统，调度系统会负责考评系统中所有的进程，这些进程里面只有有哪个需要被运行，调度系统就会终止cpu_idle死循环进程（空闲进程）转而去执行有意义的干活的进程。这样操作系统就转起来了。

kernel_init()



1. 打开控制台设备

```
    if (sys_open((const char __user *) "/dev/console", O_RDWR, 0) < 0)
        printk(KERN_WARNING "Warning: unable to open an initial console.\n");

    (void) sys_dup(0);
    (void) sys_dup(0);
```

2. 挂载根文件系统

```
    if (sys_access((const char __user *) ramdisk_execute_command, 0) != 0) {
        ramdisk_execute_command = NULL;
        prepare_namespace();
    }
```

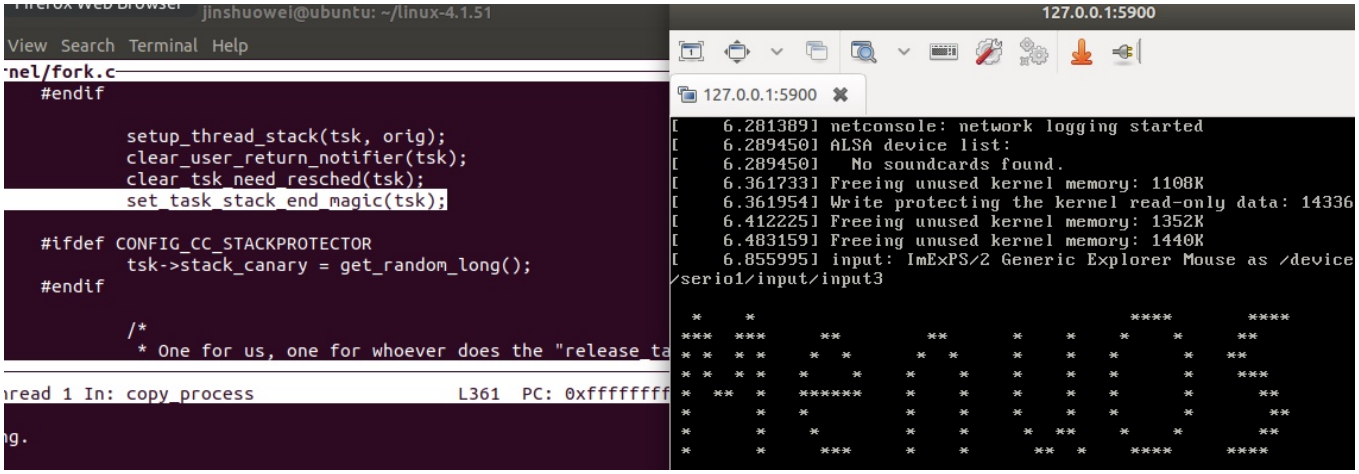
- prepare_namespace这个函数负责挂载根文件系统
- 如果内核挂载根文件系统成功，则会打印出：VFS: Mounted root (xxxx filesystem) on device xxxx.
  如果挂载根文件系统失败，则会打印：No filesystem could mount root, tried: xxxx

3. 启动init进程

```
if (ramdisk_execute_command) {
        run_init_process(ramdisk_execute_command);
        printk(KERN_WARNING "Failed to execute %s\n",
                ramdisk_execute_command);
    }
```

```
6
7       /*
8        * We try each of these until one succeeds.
9        *
10       * The Bourne shell can be used instead of init if we are
11       * trying to recover a really broken machine.
12       */
13      if (execute_command) {
14          run_init_process(execute_command);
15          printk(KERN_WARNING "Failed to execute %s.  Attempting "
16                      "defaults...\n", execute_command);
17      }
18      run_init_process("/sbin/init");
19      run_init_process("/etc/init");
20      run_init_process("/bin/init");
21      run_init_process("/bin/sh");
22
23      panic("No init found.  Try passing init= option to kernel. "
24            "See Linux Documentation/init.txt for guidance.");
```

启动完成



实验总结

本次实验麻烦之处其实在于环境的配置，对于linux启动事件的跟踪只要像助教所说那样对于linux源代码进行比较一些研究之后不难分析。

但是在配置环境的时候却遇到了很多麻烦，一开始在ubuntu 16.04下面配置，并选的linux版本号是3.18后来发现qemu会在这种情况下卡死，这个问题不好解决。后来于是换到ubuntu17.10下进行实验，此时却发现gcc版本过高，编译较老的内核的时候又会出错，于是将gcc降级到4.8。后来发现因为内核的原因，在测试的时候qemu会卡在booting界面无法启动，于是将内核版本号升级到4.15最终终于成功。