

Project 1: Android Process Tree

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Objectives

- Install and use Android Virtual Devices.
- Install NDK, cross compile the program and run it on AVD.
- Effectively use Linux system calls for process control and management.
- Familiarize task_struct
- Concurrent execution of processes.

Enviroment

■ Implementation

- AVD(Android Virtual Devices)
 - ▶ SDK version r24.4.1

■ Development

- Linux (64-bits)
 - ▶ Ubuntu (recommended)
 - ▶ Debian
 - ▶ Fedora
- VMware

What to Submit

- A “tar” file of your DIRECTORY, containing:
 - “Android.mk”
 - Any “.cc”, “.c”, and “.h” files
 - Any “readme” or “.pdf” files asked for in the project
 - A text file containing the runs of your programs for each of the project parts “testscript”
 - ▶ Do not submit ALL runs you have done, just the output required to demonstrate a successful (or unsuccessful) run
 - ▶ If you cannot get your program to work, submit a run of whatever you can get to work as you can get partial credit
- **DO NOT SUBMIT** your object or executable files, remove them before you pack your directory

How to Submit

- Pack your entire Project directory (Only including JNI dircetory)

```
tar -cvf Prj1+StudentID.tar project1
```

- Send your **Prj1+StudentID.tar** file to
cs356.sjtu@gmail.com

- Executable files will cause failure in e-mail.

For Help?

■ Teaching Assistant

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Resources

- Programming in C/UNIX System Calls and Subroutines using C
 - <http://www.cs.cf.ac.uk/Dave/C/CE.html>
- Posix Thread Programming
 - <https://computing.llnl.gov/tutorials/pthreads/>
- Android SDK Install
 - <http://developer.android.com/sdk/installing/index.html?pkg=tools>
- Android.mk
 - http://developer.android.com/ndk/guides/android_mk.html

Install JDK

- JDK is Java SE Development Kit which is necessary for android project.
- You can download the latest version for your system in:
 - <http://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html>
- Don't forget to modify your **Environment Variables**.
 - For Windows, just run the .exe file. Every thing will be done automatically.
 - For Linux, add these to `~/.bashrc`

```
export JAVA_HOME=/usr/lib/jdk1.8.0_73
export JRE_HOME=/usr/lib/jdk1.8.0_73/jre
export CLASSPATH=.:${CLASSPATH}:$JAVA_HOME/lib:$JRE_HOME/lib
export PATH=$PATH:$JAVA_HOME/bin:$JRE_HOME/bin
```

1

Install SDK

■ For Windows

- <http://www.cs.sjtu.edu.cn/~fwu/teaching/res/android-sdk-windows.7z>

■ For Linux

- <http://www.cs.sjtu.edu.cn/~fwu/teaching/res/android-sdk-linux.tar.gz>

■ Extract them into a proper location.

Set Up AVD

■ For Windows

- Double click “AVD Manager.exe”

■ For Linux

- Execute `./tools/android avd` in SDK folder.

■ The recommended configuration of AVD is in next page.

Set Up AVD (cont.)

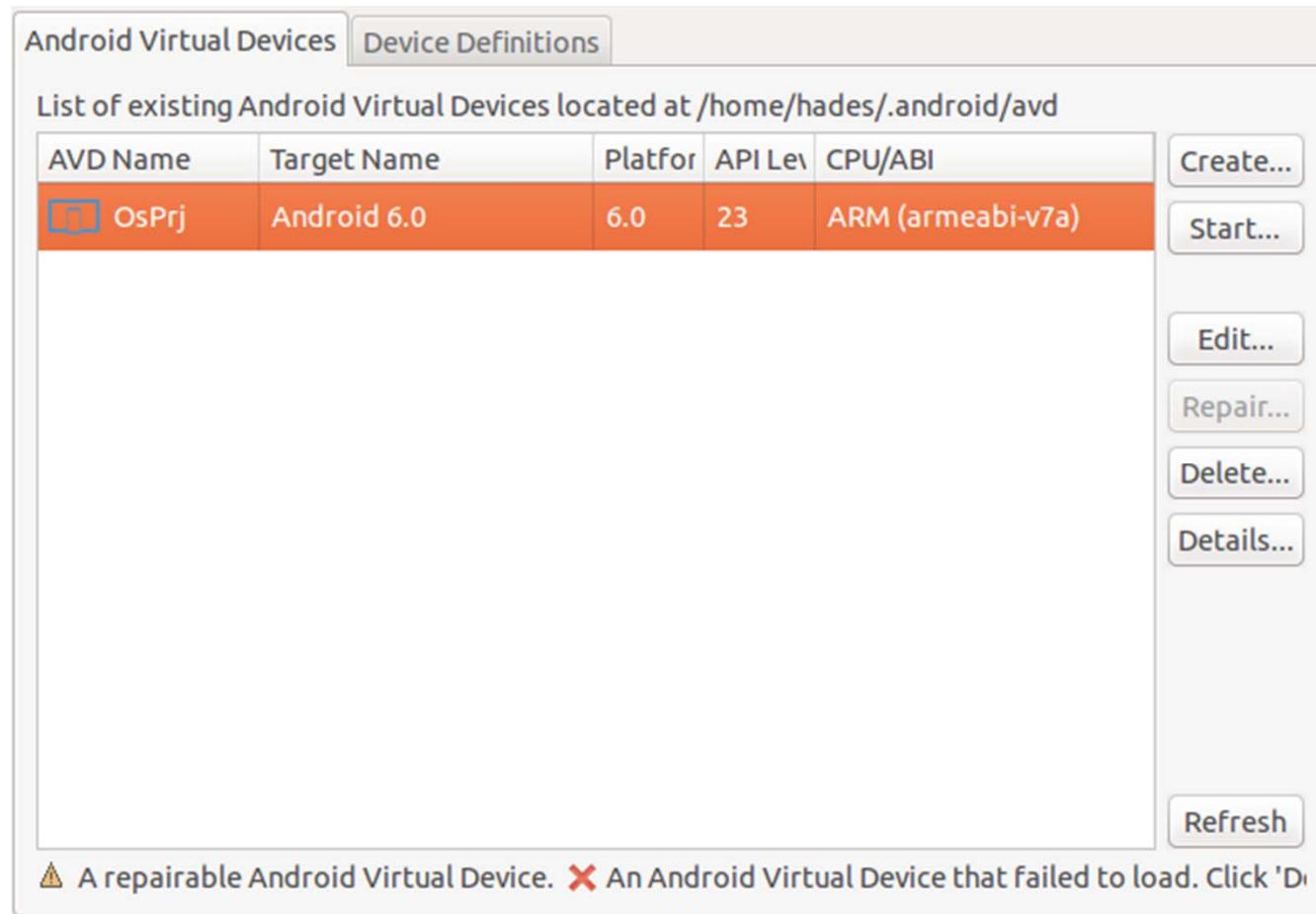
AVD Name:	OsPrj-YourStudentNumber
Device:	Nexus 7 (2012) (7.0", 800 × 1280: tvdpi)
Target:	Android 6.0 - API Level 23
CPU/ABI:	ARM (armeabi-v7a)
Keyboard:	<input checked="" type="checkbox"/> Hardware keyboard present
Skin:	Skin with dynamic hardware controls
Front Camera:	None
Back Camera:	None
Memory Options:	RAM: 768 VM Heap: 32
Internal Storage:	1 GiB
SD Card:	<input checked="" type="radio"/> Size: 1 GiB <input type="radio"/> File: Browse...
Emulation Options:	<input type="checkbox"/> Snapshot <input type="checkbox"/> Use Host GPU

■ You can modify these parameter by yourself except “AVD Name” and “Target”.

■ There will be a **warning** when RAM is bigger than 768 in Windows.

Set Up AVD (cont.)

- Click Start to start your avd



Set Up AVD (cont.)

- If your Linux is 64-bits, you may get error report when you creating avd:
 - Failed to create the SD card.
 - Failed to create sdcard in the AVD fold
- This is because your 64-bits system doesn't have 32-bits lib. Then you should install the necessary lib:
 - `sudo apt-get install libc6:i386 libgcc1:i386 gcc-4.6-base:i386 libstdc++5:i386 libstdc++6:i386`

Set Up AVD (cont.)

■ More Error

```
Starting emulator for AVD 'OsPrj'  
/home/wangbo/Kit/android-sdk-linux/tools/emulator: error  
while loading shared libraries: libstdc++.so.6: cannot open  
shared object file: No such file or directory
```

- `sudo apt-get install lib32stdc++6`

■ If there is any error when you installing the lib, change your software source and update it.

Set Up NDK

- Because our computer is x86 architecture while most Android devices are ARM architecture, executable files compiled on our computer cannot be executed on the AVD.
- We should cross compile the C files using toolchains in NDK.

Set Up NDK (cont.)

■ For Windows

- http://www.cs.sjtu.edu.cn/~fwu/teaching/res/android-ndk-r11-windows-x86_64.zip

■ For Linux

- http://www.cs.sjtu.edu.cn/~fwu/teaching/res/android-ndk-r11-linux-x86_64.zip

■ Extract them into a proper location.

Set Up NDK (cont.)

- Extract the NDK files to a proper location.
 - `~/android` or `/usr/lib/android/` for Linux
 - `X:\android-ndk-windows` for Windows
- Add location path to your **Environment Variables**
- Type `ndk-build -v` to check whether the installation is completed.

Build Project by NDK

- Make project directory.

```
mkdir hello
```

```
mkdir hello/jni
```

- Put your source code files in JNI folder.

Build Project by NDK (cont.)

■ Writing a “Hello World” program

- For `hello.h`

```
#ifndef HELLOHEADER_H_
#define HELLOHEADER_H_
#include <stdio.h>
#endif /*HELLOHEADER_H_*/
```

Build Project by NDK (cont.)

■ Writing a “Hello World” program

- For `hello.c`

```
#include "hello.h"
int main(int argc, char *argv[]){
    printf("Hello World!\n");
    return 0;
}
```

Build Project by NDK (cont.)

■ Writing a “Hello World” program

- For `Android.mk` which is make file for any project.

`LOCAL_PATH := $(call my-dir)`

```
include $(CLEAR_VARS)
LOCAL_SRC_FILES := hello.c
LOCAL_MODULE := helloARM
LOCAL_CFLAGS += -pie -fPIE
LOCAL_LDFLAGS += -pie -fPIE
LOCAL_FORCE_STATIC_EXECUTABLE := true
```

your source code

output file name

These two line mustn't be
change.

`include $(BUILD_EXECUTABLE)`

Build Project by NDK (cont.)

- The `LOCAL_CFLAGS += -pie -fPIE` and `LOCAL_LDFLAGS += -pie -fPIE` make the program compiled based on PIE. Without these two lines, the program can not be executed in Android.
- Type `ndk-build` in jni folder
- The executable file is in `hello/libs/armeabi`

Running on AVD

- To install and run the program you compiled, you can use the multi-purpose Android Debug Bridge (ADB) utility.
- Location of ADB
 - #your sdk location#/platform-tools/
 - You can add this directory to **Environment Variables** so that you can directly type **adb** in other directory.

Some ADB command

- To check the AVD status:
 - `adb devices`
- To move a file to the emulator:
 - `adb push #source path ~/hello/hello.o# #target path on device /data/misc#`
- To use shell on Android:
 - `adb shell`
 - Then you can use shell command like linux.
- To pull a file out of the emulator:
 - `adb pull #source path in device# #target path#`
- More commands about adb:
 - `adb help`

Running on AVD (cont.)

- After uploading your program file to your AVD, you should type the following command in shell to make it executable:
 - `chmod +x #file name#`
 - `chmod 777 #file name#`
- Then, you can run your program on AVD.

Problem 1

- In Linux, we can use `ps` to check the current process.
- Furthermore, we can use `pstree` to see the process tree intuitively.
- In Android, we can use `ps`, but cannot use `pstree`

Problem 1

■ Write a new system call in Linux.

- The system call you write should take two arguments and return the process tree information in a depth-first-search (DFS) order.
- Each system call must be assigned a number. Your system call should be assigned number **356**.

Problem 1 (cont.)

■ The prototype for your system call will be:

- int ptree(struct prinfo *buf, int *nr);

■ You should define struct prinfo as:

```
struct prinfo {  
    pid_t parent_pid;          /* process id of parent */  
    pid_t pid;                 /* process id */  
    pid_t first_child_pid;     /* pid of youngest child */  
    pid_t next_sibling_pid;    /* pid of older sibling */  
    long state;                /* current state of process */  
    long uid;                  /* user id of process owner */  
    char comm[64];              /* name of program executed */  
};
```

Problem 1 (cont.)

- The argument `buf` points to a buffer for the process data, and `nr` points to the size of this buffer (number of entries). The system call copies as many entries of the process tree data to the buffer as possible, and stores the number of entries actually copied in `nr`.
- If pointer correlated with the variable in `struct prinfo` is null, set the value in `struct prinfo` to 0.
- For example, the `first_child_pid` should be set to 0 if the process does not have a child.

Problem 1 (cont.)

- Linux maintains a list of all processes in a doubly linked list. Each entry in this list is a `task_struct` structure, which is defined in `include/linux/sched.h`. When traversing the process tree data structures, it is necessary to prevent the data structures from changing in order to ensure consistency.
- For this purpose the kernel relies on a special lock, the `tasklist_lock`. You should grab this lock before you begin the traversal, and only release the lock when the traversal is completed. While holding the lock, your code may not perform any operations that may result in a sleep, such as memory allocation, copying of data into and out from the kernel etc. Use the following code to grab and then release the lock:

```
read_lock(&tasklist_lock);  
...  
...  
read_unlock(&tasklist_lock);
```

Problem 1 (cont.)

- In order to learn about system calls, you may find it helpful to search the linux kernel for other system calls and see how they are defined. You can use the [Linux Cross-Reference](#)(LXR) to investigate different system calls already defined. The files [kernel/sched/core.c](#) and[kernel/timer.c](#) should provide good reference points for defining your system call.
- You should not try to create your own linked list method for the data structures inside the kernel, but use the existing infrastructure. See [include/linux/list.h](#) and look for other places in the kernel where lists are used for examples on how to use them (there are many such places). Also, the course materials contain information about linked lists in the kernel.

Problem 1 (cont.)

- Add system call dynamically.
- Use module.
- But the original android kernel does not support module.
- Compile a New One.
- Kernel is supported on website.
 - <http://www.cs.sjtu.edu.cn/~fwu/teaching/res/android-kernel.tar.gz>
 - Extract the kernel folder into the user folder.
- Linux Only

Start AVD

■ We will start AVD with a new kernel.

- emulator –avd YourAvdName –kernel KernelLocation –show-kernel
- YourAvdName could be OsPrj
- KernelLocation could be ~/kernel/goldfish/arch/arm/boot/zImage
- -show-kernel makes kernel information shown in your shell.

Modules Source File

```
#include<linux/module.h>
#include<linux/kernel.h>
#include<linux/init.h>
#include<linux/sched.h>
#include<linux/unistd.h>
MODULE_LICENSE("Dual BSD/GPL");
#define __NR_hallocall 356
|
static int (*oldcall)(void);
static int sys_hallocall(int n, char* str)
{
    printk("this is my system second call!\n the uid = %ld\n str: %s\n",n,str);
    return n;
}
static int addsyscall_init(void)
{
    long *syscall = (long*)0xc000d8c4;
    oldcall = (int(*)(void))(syscall[__NR_hallocall]);
    syscall[__NR_hallocall] = (unsigned long )sys_hallocall;
    printk(KERN_INFO "module load!\n");
    return 0;
}

static void addsyscall_exit(void)
{
    long *syscall = (long*)0xc000d8c4;
    syscall[__NR_hallocall] = (unsigned long )oldcall;
    printk(KERN_INFO "module exit!\n");
}

module_init(addsyscall_init);
module_exit(addsyscall_exit);
```

Modules Source File - Definition

```
#include<linux/module.h>
#include<linux/kernel.h>
#include<linux/init.h>
#include<linux/sched.h>
#include<linux/unistd.h>
MODULE_LICENSE("Dual BSD/GPL");
```

- Properties of module. No need to change them

```
module_init(addsyscall_init);
module_exit(addsyscall_exit);
```

Modules Source File - Functions

```
static int (*oldcall)(void);
static int addsyscall_init(void)
{
    long *syscall = (long*)0xc000d8c4;
    oldcall = (int(*)(void))(syscall[__NR_hallocall]);
    syscall[__NR_hallocall] = (unsigned long )sys_hallocall;
    printk(KERN_INFO "module load!\n");
    return 0;
}
```

```
module_init(addsyscall_init);
module_exit(addsyscall_exit);
```

```
static void addsyscall_exit(void)
{
    long *syscall = (long*)0xc000d8c4;
    syscall[__NR_hallocall] = (unsigned long )oldcall;
    printk(KERN_INFO "module exit!\n");
}
```

Modules Source File – System Call

- You should change this part to accomplish project.

```
#define __NR_hellowcall 356

static int sys_hellowcall(int n, char* str)
{
    printk("this is my system second call!\n the uid = %ld\n str: %s\n",n,str);
    return n;
}
```

- Sample of using system call

```
#include <stdio.h>
int main(){
    printf("This is a test:\n\n");
    int i=syscall(356,123,"test string");
    printf("Answer is %d!\n",i);
    printf("Test End!:\n\n");
    return 0;
}
```

Modules Make File

```
obj-m := hello.o
KID := ~/kernel/goldfish
CROSS_COMPILE=arm-linux-androideabi-
CC=$(CROSS_COMPILE)gcc
LD=$(CROSS_COMPILE)ld

all:
    make -C $(KID) ARCH=arm CROSS_COMPILE=$(CROSS_COMPILE) M=$(shell pwd) modules

clean:
    rm -rf *.ko *.o *.mod.c *.order *.symvers
```

- Save source file and make file in one folder.
- **KID** is the location of your kernel.
- Add Environment Variable
 - #your ndk location#/toolchains/arm-linux-androideabi-4.9/prebuilt/linux-x86_64/bin
- Type make in shell in the folder.
- Then you will get a file *.ko, this is your module.

Use Module

- Upload your .ko file to avd
- Install mod
 - insmod *.ko
- Remove mod
 - rmmod *.ko
- List mod
 - lsmod
- Delete your .ko file **before** you want to update it.
- Remove the mod installed **before** you delete .ko file.

Some problem

■ Apt-get 404 not found.

- pls try again, the network is not stable.

■ AVD is toooooooo slow.

- pls be patient.

■ android avd can not work.

- Use “ctrl+alt+t” instead of “ctrl+alt+F1”

■ Adb usage

Problem 2

■ Test your new system call

- Write a simple C program which calls **ptree**
- Print the entire process tree (in DFS order) using tabs to indent children with respect to their parents.
- The output format of every process is:

```
printf(/* correct number of \t */);  
printf("%s,%d,%ld,%d,%d,%d,%d\n", p.comm, p.pid, p.state,  
      p.parent_pid, p.first_child_pid, p.next_sibling_pid, p.uid);
```

Problem 2 – Sample Output

■ Example

```
...
init,1,1,0,31,2,0
...
servicemanager,44,1,1,0,45,1000
vold,45,1,1,0,47,0
netd,47,1,1,0,48,0
debuggerd,48,1,1,0,49,0
rild,49,1,1,0,50,1001
surfaceflinger,50,1,1,0,51,1000
zygote,51,1,1,369,52,0
    system_server,369,1,51,0,421,1000
...
ndroid.launcher,529,1,51,0,550,10008
...
...
kthreadd,2,1,0,3,0,0
...
ksoftirqd/0,3,1,2,0,4,0
kworker/0:0,4,1,2,0,5,0
...
khelper,6,1,2,0,7,0
...
```

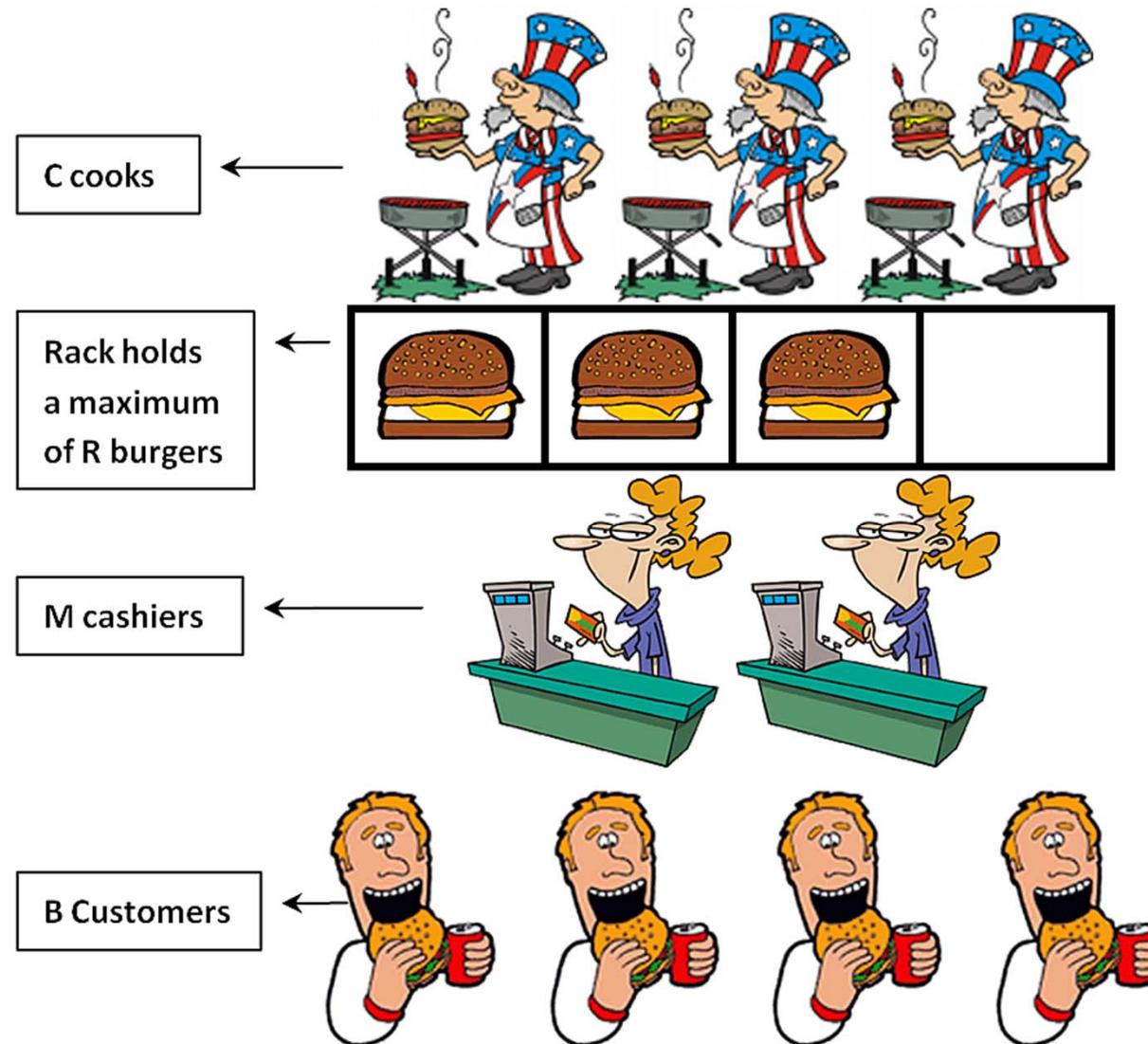
Problem 3

- Generate a new process and output “StudentIDParent” with PID, then generates its children process output “StudentIDChild” with PID.
- Use `execl` to execute `ptree` in the child process, show the relationship between above two process.

Problem 4 – Burger Buddies Problem

- Cooks, Cashiers, and Customers are each modeled as a thread.
- Cashiers sleep until a customer is present.
- A Customer approaching a cashier can start the order process.
- A Customer cannot order until the cashier is ready.
- Once the order is placed, a cashier has to get a burger from the rack.
- If a burger is not available, a cashier must wait until one is made.
- The cook will always make burgers and place them on the rack.
- The cook will wait if the rack is full.
- There are NO synchronization constraints for a cashier presenting food to the customer.

Problem 4 – Burger Buddies Problem



Problem 4 – General Requirement

- Source file: BurgerBuddies.c
- Executable file: BBC
- Run: BBC #Cooks #Cashiers #Customers
#RackSize

Problem 4 – Sample Output

```
> ./BBC 2 4 41 10
Cooks [2], Cashiers [4], Customers [41]
Begin run.
Cook [1] make a burger.
Cook [1] make a burger.
Cook [2] make a burger.
Customer [10] come.
Casher [3] accepts an order.
Casher [3] take a burger to customor.
Customer [19] come.
Casher [2] accepts an order.
Casher [2] take a burger to customor.
Customer [7] come.
Casher [3] accepts an order.
Casher [3] take a burger to customor.
Customer [17] come.
Casher [2] accepts an order.
Cook [1] make a burger.
Casher [2] take a burger to customor.
.....
```

Environment Variables

- JDK
- Android location (only for Linux)
- NDK location
- ADB location
- For linux, add them to:
 - `~/.bashrc` or `/etc/profile`
 - Then `source ~/.bashrc` or `/etc/profile`

Environment Variables (cont.)

```
111 if [ -e .profile ]; then
112     if [ -f /usr/share/bash-completion/bash_completion ]; then
113         . /usr/share/bash-completion/bash_completion
114     elif [ -f /etc/bash_completion ]; then
115         . /etc/bash_completion
116     fi
117 fi
118
119 export PATH=~/Kit/android-sdk-linux/platform-tools:$PATH
120 export PATH=~/Kit/android-sdk-linux/tools:$PATH
121 export PATH=~/Kit/android-ndk-linux:$PATH
122
```

For Help?

■ Teaching Assistant

- Bo Wang

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 - ▶ WeChat: hadesghost727

- Jiapeng Xie

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■ Some useful website

- <http://www.csdn.net/>
- <http://stackoverflow.com/>
- <http://developer.android.com/>

For Help?

Q&A