

## 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

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

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

- Send your **Prj1+StudentID.tar** file to **TA**.
- **Executable files will cause failure in e-mail.**

# Resources

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- 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](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.)

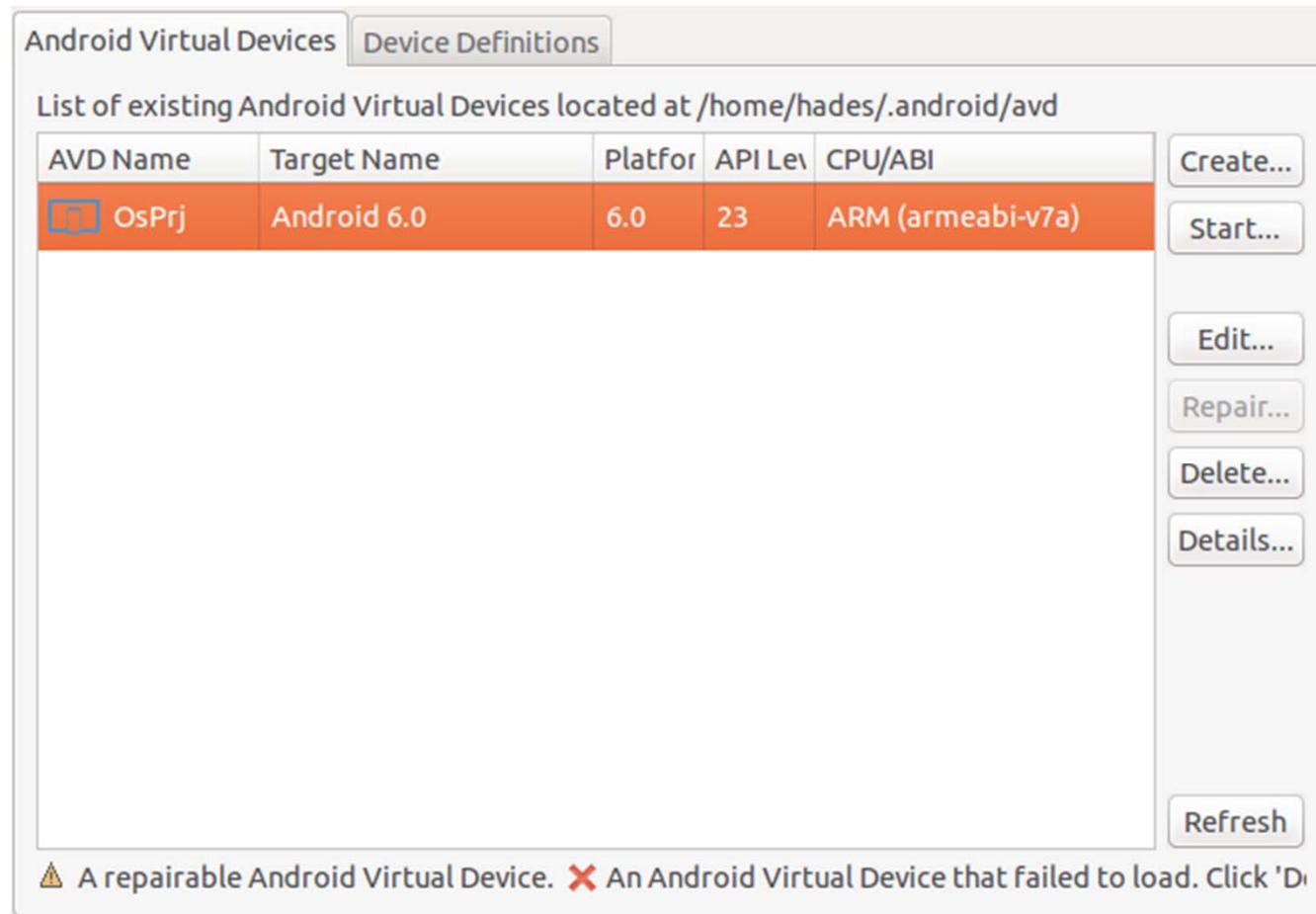
AVD Name:	OsPrj-YourStudentNumber
Device:	Nexus 7 (2012) (7.0", 800 × 1280: tvdpi)
Target:	Android 6.0 - API Level 23
CPU/ABI:	ARM (armeabi-v7a)
Keyboard:	<input checked="" type="checkbox"/> Hardware keyboard present
Skin:	Skin with dynamic hardware controls
Front Camera:	None
Back Camera:	None
Memory 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](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](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.

# Linux Modules

- Kernel modules are pieces of code that can be **loaded and unloaded** into the kernel upon demand.
- With modules, we can implement some system calls without re-compilation.
- Please study the following example to learn how to use modules so you can solve Problem 1.

# Modules Source File

- You need to write .c files as the sources to create a module. The following file's name is hello.c.

```
#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_hellocall 356
|
static int (*oldcall)(void);
static int sys_hellocall(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_hellocall]);
    syscall[__NR_hellocall] = (unsigned long )sys_hellocall;
    printk(KERN_INFO "module load!\n");
    return 0;
}

static void addsyscall_exit(void)
{
    long *syscall = (long*)0xc000d8c4;
    syscall[__NR_hellocall] = (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. 356 here is the syscall number.

```
#define __NR_helloworld 356

static int sys_helloworld(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.

# Problems

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- We have four problems for project 1.
- Problem 1-3 is about implementing a system call with modules.
- Problem 4 is implementing a synchronization algorithm.

# 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 **391**.

# 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 */
```

You can make some revisions on them if you can get the correct result.

# 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 pinfo is null, set the value in `struct pinfo` 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.

# 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

# Tips

- task\_struct is defined in about line 1270 if you download the Android source code from the website we have provided.
- Some illegal operations (e.g, no-assigned struct pointer) will make your Android virtual device crushed. Be careful.
- Implement the system call with modules. You don't have to revise the kernel code.
- You only need to **submit your module's source code** for Problem 1.

# 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 – Caesar Encryption Sever

- Caesar cipher, is one of the simplest and most widely known encryption techniques. During encryption, each letter in the plaintext is replaced by a letter some fixed number of positions down the alphabet. In this problem, we set the number=3.
- For example,
  - Plain: ABCDEFGHIJKLMNOPQRSTUVWXYZ
  - Cipher: DEFGHIJKLMNOPQRSTUVWXYZABC
  - Plain: abcdefghijklmnopqrstuvwxyz
  - Cipher: defghijklmnopqrstuvwxyzabc
- Please develop a Caesar Encryption Server, which receives plaintext from clients and sends the corresponding ciphertext to clients.
- **Only the letters** need to be encrypted, e.g. **How are you?** → **Krz duh brx?**
- The Server can serve at most **2 clients** concurrently, more clients coming have to wait.
- The server-side program must be **concurrent multi-threaded**.
- Client input :**q** to end the service.
- For simplicity, you can execute one server and multiple clients in **one host**.
- Before you start this problem, I highly recommend you to read these two pages:
  - <http://www.yolinux.com/TUTORIALS/LinuxTutorialPosixThreads.html>
  - [http://www.linuxhowtos.org/C\\_C++/socket.htm](http://www.linuxhowtos.org/C_C++/socket.htm)
- All you need about multi-thread and network programming in Linux can be found in the pages above.

# Problem 4 – Server Framework

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <string.h>
4 #include <unistd.h>
5 #include <pthread.h>
6 #include <sys/types.h>
7 #include <sys/socket.h>
8 #include <netinet/in.h>
9 void *serve(void * newsockfd);
10 int main(int argc, char *argv[]){
11     ///////////////////////////////////////////////////////////////////
12     //DO NOT change this part if you are not familiar with Linux Network Programming
13     int sockfd, newsockfd, portno, clilen, n;
14     char buffer[256];
15     struct sockaddr_in serv_addr, cli_addr;
16     sockfd = socket(AF_INET, SOCK_STREAM, 0);
17     if (sockfd < 0){
18         printf("ERROR opening socket\n");
19         exit(1);
20     }
21     bzero((char *) &serv_addr, sizeof(serv_addr));
22     serv_addr.sin_family = AF_INET;
23     //the port number (>2000 generally) of server is randomly assigned
24     portno = 2050;
25     serv_addr.sin_port = htons(portno);
26     //the ip address of server
27     serv_addr.sin_addr.s_addr = INADDR_ANY;
28     if (bind(sockfd, (struct sockaddr *)&serv_addr, sizeof(serv_addr)) < 0){
29         printf("Error on binding\n");
30         exit(1);
31     }
32     listen(sockfd, 5);
33     clilen = sizeof(cli_addr);
34     printf("Server initiating...\n");
35     //DO NOT change this part if you are not familiar with Linux Network Programming
36     ///////////////////////////////////////////////////////////////////
```

# Problem 4 – Server Framework

```
36 //////////////////////////////////////////////////////////////////
37 //Finish your Concurrent Multi-thread (NOT Multi-process) service here
38 //////////////////////////////////////////////////////////////////
39
40 //////////////////////////////////////////////////////////////////
41 return 0;
42 }
43
44 void *serve(void *sockfd){
45     int newsockfd = (int)(*((int*)sockfd));
46 //////////////////////////////////////////////////////////////////
47
48 //Finish your Encryption service here
49 //////////////////////////////////////////////////////////////////
50
51 }
52 //////////////////////////////////////////////////////////////////
53 }
```

# Problem 4 – Client Framework

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <unistd.h>
4 #include <string.h>
5 #include <sys/types.h>
6 #include <sys/socket.h>
7 #include <netinet/in.h>
8 #include <netdb.h>
9 int main(int argc, char *argv[]){
10     //DO NOT change this part if you are not familiar with Linux Network Programming
11     int sockfd, portno, n;
12     struct sockaddr_in serv_addr;
13     struct hostent *server;
14     char buffer[256];
15     //the port number of server
16     portno = 2050;
17     sockfd = socket(AF_INET, SOCK_STREAM, 0);
18     if (sockfd < 0){
19         printf("ERROR opening socket");
20         exit(1);
21     }
22     server = gethostbyname("127.0.0.1");
23     if (server == NULL)
24     {
25         printf("ERROR, no such host");
26         exit(0);
27     }
28     bzero((char *)&serv_addr, sizeof(serv_addr));
29     serv_addr.sin_family = AF_INET;
30     bcopy((char *)server->h_addr, (char *)&serv_addr.sin_addr.s_addr,
31           server->h_length);
32     serv_addr.sin_port = htons(portno);
33
34     if (connect(sockfd, (struct sockaddr *)&serv_addr, sizeof(serv_addr)) < 0){
35         printf("ERROR connecting");
36         exit(1);
37     }
38     printf("Please enter the message:\n");
39     //DO NOT change this part if you are not familiar with Linux Network Programming
40     ///////////////////////////////////////////////////////////////////
41
42     //Finish your client program here
43
44     ///////////////////////////////////////////////////////////////////
45
46
47     return 0;
48 }
```

# Problem 4 – Tips

- Source file: client.c server.c
- During test, you may get this error:
  - Error on binding

```
root@phonenix16-machine: ~/Desktop/server
root@phonenix16-machine:~/Desktop/server# ./server
Error on binding
root@phonenix16-machine:~/Desktop/server#
```

- The reason is the zombie server you just started is occupying the port 2050, find its PID.
  - netstat -tunlp|grep 2050
  - Or ps -ef |grep *server\_program\_name*
- And kill it!
  - kill -9 *pid*

# Problem 4 – A Sample

Start server-side program first, then client-side programs!

The image displays four terminal windows arranged in a 2x2 grid, illustrating the communication between a server and two client programs.

- Top-left window:** Shows the server-side application. It starts by initiating the server, then receives messages from clients. The messages are "Today is a good day" and "What's this". It then closes its thread.
- Top-right window:** Shows the first client-side application. It prompts the user to enter a message ("Please enter the message:"). The user enters "Today is a good day" (highlighted with a red box). The server responds with a long string of characters: "Wrgdb lv d jrrg gdb".
- Bottom-left window:** Shows the second client-side application. It prompts the user to enter a message ("Please enter the message:"). The user enters "What's this" (highlighted with a red box). The server responds with "Zkdw'v wklv". The user then types ":q" (highlighted with a red box) to quit the session.
- Bottom-right window:** Shows another instance of the client-side application. It prompts the user to enter a message ("Please enter the message:"). The user enters "How are you?" (highlighted with a red box). The server responds with "Please wait...". The user then enters another "How are you?" (highlighted with a red box). The server responds with "Krz duh brx?".

# 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 [ -s $HOME/.bashrc ]; then
112     . $HOME/.bashrc
113     if [ -f /etc/bash_completion.d/* ]; then
114         for c in $(ls /etc/bash_completion.d/*); do
115             . $c
116         done
117     fi
118
119     export PATH=$PATH:$ANDROID_NDK/platform-tools
120     export PATH=$PATH:$ANDROID_NDK/tools
121     export PATH=$PATH:$ANDROID_NDK
122
```

# For Help?

## ■ Teaching Assistant

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## ■ Some useful website

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

# For Help?

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## Q&A