

# Advanced Embedded Software Development

## Homework 3

-Ashish Tak

### Question 1

Boot sequence log showing the BBG getting an ethernet address from the network:

```
Starting network: OK
Starting dhcpd...
no interfaces have a carrier
forked to background, child pid 111
[ 3.066464] net eth0: initializing cpsw version 1.12 (0)
Starting connman ... done.
Starting dropbear sshd: [ 3.180513] SMSC LAN8710/LAN8720 4a101000.mdio:00: attached PHY driver [SMSC LAN8710]
OK
[ 3.233835] IPv6: ADDRCONF(NETDEV_UP): eth0: link is not ready
Starting sshd: [ 3.471778] urandom_read: 6 callbacks suppressed
[ 3.471793] random: sshd: uninitialized urandom read (32 bytes read)
OK
Starting DHCP server: FAIL
Starting cron ... done.

Welcome to Buildroot, Ashish. YNWA!
buildroot login: [ 5.289502] cpsw 4a100000.ethernet eth0: Link is Up - 100Mbps/Full - flow control rx/tx
[ 5.298522] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
root
Password:
# ifconfig
eth0      Link encap:Ethernet  HWaddr 38:D2:69:52:FC:B0
          inet addr:10.0.0.65  Bcast:10.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::a3b1:9f3e:c764:e37e/64 Scope:Link
          inet6 addr: 2601:281:8580:4f4:3b6a:c741:a72d:9e/64 Scope:Global
          inet6 addr: 2601:281:8580:4f4::138f/128 Scope:Global
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:51 errors:0 dropped:0 overruns:0 frame:0
          TX packets:69 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:10056 (9.8 KiB)  TX bytes:6855 (6.6 KiB)
          Interrupt:46

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

SCP copy of a file from host to the BBG to the /usr/bin directory:

```
# cd /usr/bin/
# ls
[
[[
ar
autossh
awk
basename
bunzip2
bzip2
chrt
chvt
cksum
clear
cmp
crontab
cut
dbclient
mkfifo
mkpasswd
nl
nohup
nproc
nslookup
od
openvt
passwd
paste
patch
pcregrep
pcretest
perf
printf
readlink
```

```
ashish@Merseyside:~/Documents/Homework2/Cross-compile-dir$ scp crontest.c root@10.0.0.65:/usr/bin
root@10.0.0.65's password:
crontest.c
```

```
ls
[
[[
ar
autossh
awk
basename
bunzip2
bzip2
chrt
chvt
cksum
clear
cmp
crontab
crontest.c
cut
dbclient
microcom
mkfifo
mkpasswd
nl
nohup
nproc
nslookup
od
openvt
passwd
paste
patch
pcregrep
pcretest
perf
printf
readlink
```

## Question 2

Host debugging session using the “manual” configuration command method:

```
ashish@Merseyside:~/Documents/Homework2/Cross-compile-dir$ arm-linux-gdb file_io
GNU gdb (GDB) 8.1.1
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-pc-linux-gnu --target=arm-buildroot-linux-uclicgncueabihf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from file_io...done.
(gdb) target extended-remote 10.0.0.65:10000
Remote debugging using 10.0.0.65:10000
(gdb) remote put file_io /file_io
Successfully sent file "file_io".
(gdb) set remote exec-file file_io
(gdb) break main
Breakpoint 1 at 0x106f4: file file_io.c, line 8.
(gdb) break file_io.c:20
Breakpoint 2 at 0x1078c: file file_io.c, line 20.
```

```
Breakpoint 1 at 0x106f4: file file_io.c, line 8.
(gdb) break file_io.c:20
Breakpoint 2 at 0x1078c: file file_io.c, line 20.
(gdb) r
Starting program: /home/ashish/Documents/Homework2/Cross-compile-dir/file_io
Reading /lib/ld-uClibc.so.0 from remote target...
warning: File transfers from remote targets can be slow. Use "set sysroot" to access files locally instead.
Reading /lib/ld-uClibc.so.0 from remote target...
Reading /lib//libc.so.0 from remote target...

Breakpoint 1, main () at file_io.c:8
8          printf("\nYou'll Never Walk Alone");
(gdb) n
15          fp= fopen("output.txt", "w");
(gdb) n
17          fputc( 'A', fp );
(gdb) c
Continuing.

Breakpoint 2, main () at file_io.c:21
21          fp= fopen("output.txt", "a");
(gdb) n
23          char *str= (char *)malloc(sizeof(char)*50);
(gdb) c
Continuing.
[Inferior 1 (process 824) exited normally]
```

Console printout from the BBG output:

```
# gdbserver --multi :10000
Listening on port 10000
Remote debugging from host 10.0.0.163
Process /file_io created; pid = 824

You'll Never Walk Alone
Enter a string:Tak

Received character: A
Received string: Tak

Child exited with status 0
[ 176.088356] random: crng init done
```

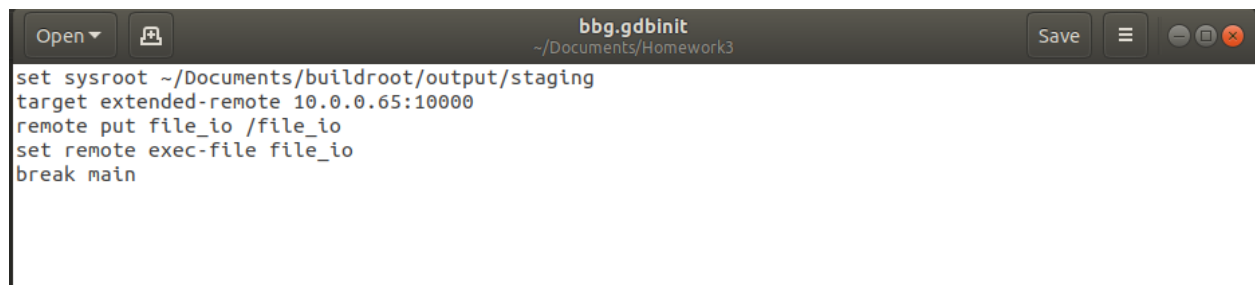
Using a host initialization file (bbg.gdbinit file on github):

```
ashish@Merseyside:~/Documents/Homework2/Cross-compile-dir$ arm-linux-gdb file_io -x ~/Documents/Homew
ork3/bbg.gdbinit
GNU gdb (GDB) 8.1.1
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-pc-linux-gnu --target=arm-buildroot-linux-uclibcgnueabihf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from file_io...done.
Breakpoint 1 at 0x106f4: file file_io.c, line 8.
(gdb) break file ^CQuit
(gdb) break file_io.c:24
Breakpoint 2 at 0x107b4: file file_io.c, line 24.
(gdb) r
Starting program: /home/ashish/Documents/Homework2/Cross-compile-dir/file_io

Breakpoint 1, main () at file_io.c:8
8         printf("\nYou'll Never Walk Alone");
(gdb) n
15        fp= fopen("output.txt", "w");
(gdb) c
Continuing.

Breakpoint 2, main () at file_io.c:25
25        printf("\nEnter a string:");
(gdb) n
26        scanf("%s",str);
(gdb) n
28        fputs(str, fp);
(gdb) n
30        fflush(fp);
(gdb) c
Continuing.
[Inferior 1 (process 906) exited normally]
(gdb) quit
```

### Contents of .gdbinit file:



The image shows a window titled "bbg.gdbinit" with a subtitle "~/Documents/Homework3". The window has a dark theme and includes standard window controls (Open, Save, and window management buttons). The main content area contains the following GDB configuration commands:

```
set sysroot ~/Documents/buildroot/output/staging
target extended-remote 10.0.0.65:10000
remote put file_io /file_io
set remote exec-file file_io
break main
```

### Question 3

Github link: <https://github.com/asta0463/APES/tree/master/HW3>

Module Insertion #1:

```
# insmod timermodule.ko Username="Ashish" period=1000
[ 1944.508226] Timer Module Init
# [ 1945.528203] User name: Ashish
[ 1945.528263] Iteration # 1
[ 1946.567749] User name: Ashish
[ 1946.570514] Iteration # 2
[ 1947.607745] User name: Ashish
[ 1947.610518] Iteration # 3
[ 1948.647752] User name: Ashish
[ 1948.650515] Iteration # 4
[ 1949.687738] User name: Ashish
[ 1949.690504] Iteration # 5
[ 1950.727743] User name: Ashish
[ 1950.730520] Iteration # 6
[ 1951.767772] User name: Ashish
[ 1951.770547] Iteration # 7
[ 1952.807757] User name: Ashish
[ 1952.810524] Iteration # 8
[ 1953.847742] User name: Ashish
[ 1953.850520] Iteration # 9
```

```
# lsmod | grep timermod
timermodule                16384  0
# modinfo timermodule.ko
filename:                   /timermod/timermodule.ko
license:                    GPL
author:                     Ashish Tak
description:                 Basic Timer module
srcversion:                 41B8AA7124F6712643B8354
depends:
name:                       timermodule
vermagic:                   4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:                       Username:charp
parm:                       period:uint
```

```
# rmmod timermodule
[ 1954.890508] Iteration # 10
[ 2099.069437] Timer Module Exit
```

## Module Insertion #2:

```
# insmod timermodule.ko Username="Taks" period=3000
[ 2164.951702] Timer Module Init
# [ 2168.008192] User name: Taks
[ 2168.008252] Iteration # 1
[ 2171.047775] User name: Taks
[ 2171.050551] Iteration # 2
[ 2174.087782] User name: Taks
[ 2174.090551] Iteration # 3
[ 2177.127743] User name: Taks
[ 2177.130514] Iteration # 4
[ 2180.167745] User name: Taks
[ 2180.170510] Iteration # 5
[ 2183.207740] User name: Taks
[ 2183.210512] Iteration # 6
[ 2186.247743] User name: Taks
[ 2186.250518] Iteration # 7
[ 2189.287735] User name: Taks
[ 2189.290502] Iteration # 8
[ 2192.327749] User name: Taks
[ 2192.330520] Iteration # 9
```

```
# lsmod | grep timermod
timermodule                16384  0
# modinfo timermodule.ko
filename:                   /timermod/timermodule.ko
license:                    GPL
author:                     Ashish Tak
description:                 Basic Timer module
srcversion:                 41B8AA7124F6712643B8354
depends:
name:                       timermodule
vermagic:                   4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:                       Username:charp
parm:                       period:uint
```

```
# rmmod timermodule
[ 2195.370566] Iteration # 10
[ 2353.101400] Timer Module Exit
```

## Question 4

- Data structure used: Linked List

- Entries in the seed array:

```
{ "fox", "dog", "cat", "rat", "cat", "tiger", "lion", "lion", "dog", "dog",  
"chicken", "giraffe", "boar", "chicken", "eagle", "rat", "chicken", "boar", "boar", "giraffe",  
"cat", "cat", "crow", "dog", "eagle", "eagle", "boar", "cow", "cow", "cat",  
"crow", "cow", "chicken", "dog", "rat", "tiger", "lion", "lion", "tiger", "cow",  
"pigeon", "rat", "giraffe", "cow", "crow", "cow", "lion", "dog", "crow", "eagle" };
```

- Removal of duplicate occurrences (and parallel sorting):

```
# insmod linkedListModule.ko type="dog" count=5  
[ 493.559191] Initializing the linked list  
[ 493.563346] Final Linked List, after removal of duplicate occurrences:  
[ 493.563358] boar, count: 4  
[ 493.570433] cat, count: 5  
[ 493.573266] chicken, count: 4  
[ 493.575996] cow, count: 6  
[ 493.579166] crow, count: 4  
[ 493.581900] dog, count: 6  
[ 493.584727] eagle, count: 4  
[ 493.587463] fox, count: 1  
[ 493.590432] giraffe, count: 3  
[ 493.593170] lion, count: 5  
[ 493.596264] pigeon, count: 1  
[ 493.599131] rat, count: 4  
[ 493.602138] tiger, count: 3  
[ 493.604874]
```

- Sets of processed data:

- Set 1

- Unique ecosystem:

```
[ 891.875527] boar, count: 4  
[ 891.882605] cat, count: 5  
[ 891.885440] chicken, count: 4  
[ 891.888252] cow, count: 6  
[ 891.891358] crow, count: 4  
[ 891.894095] dog, count: 6  
[ 891.896921] eagle, count: 4  
[ 891.899705] fox, count: 1  
[ 891.902621] giraffe, count: 3  
[ 891.905359] lion, count: 5  
[ 891.908502] pigeon, count: 1  
[ 891.911327] rat, count: 4  
[ 891.914335] tiger, count: 3  
[ 891.917072]
```



- Ecosystem size and amount of memory allocated:

```
[ 891.917073] Total no. of nodes: 13
[ 891.920036]
[ 891.920036] Size in memory: 208 bytes
[ 891.926669]
```

- Set 2

- Criteria 1: No filter (size and elements same as earlier scenario)

```
[ 1434.964905] Without any filter:
[ 1434.976671] boar, count: 4
[ 1434.976680] cat, count: 5
[ 1434.979550] chicken, count: 4
[ 1434.982281] cow, count: 6
[ 1434.985377] crow, count: 4
[ 1434.988160] dog, count: 6
[ 1434.990990] eagle, count: 4
[ 1434.993726] fox, count: 1
[ 1434.996640] giraffe, count: 3
[ 1434.999423] lion, count: 5
[ 1435.002526] pigeon, count: 1
[ 1435.005353] rat, count: 4
[ 1435.008409] tiger, count: 3
[ 1435.011146]
```

- Criteria 2: type="dog"

```
[ 1435.011146] With the type/species filter:
[ 1435.014064] dog, count: 6
[ 1435.021381]
[ 1435.021381]
[ 1435.021381] Total no. of nodes: 1
[ 1435.024120]
[ 1435.024120] Size in memory: 16 bytes
[ 1435.026710]
```

- Criteria 3: count>=5

```
[ 2110.537472] With the count filter:
[ 2110.542790] cat, count: 5
[ 2110.549706] cow, count: 6
[ 2110.552445] dog, count: 6
[ 2110.555180] lion, count: 5
[ 2110.557974]
[ 2110.557974]
[ 2110.557974] Total no. of nodes: 4
[ 2110.560798]
[ 2110.560798] Size in memory: 64 bytes
[ 2110.562343]
```

- Criteria 4: type="dog" and count>=5

```
[ 2110.567343] With both filters:
[ 2110.572659] dog, count: 6
[ 2110.578973]
[ 2110.578973]
[ 2110.578973] Total no. of nodes: 1
# rmmmod linkedListModule
[ 2110.581708]
[ 2110.581708] Size in memory: 16 bytes
```

- Amount of time to insert the module:

```
[ 2110.416313] Initializing the linked list
[ 2110.420717] Final Linked List, after removal of duplicate occurrences:
420717-416313 = 4404 uS
```