

Advanced Embedded Software Development

Homework 3

Tanmay Chaturvedi

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1. Github Repository:

<https://github.com/TanmayChaturvedi1/Advanced-Embedded-Software-Development/tree/master/Assignment3> Linux Kernel Modules

Problem 1.

console boot sequence/dmesg log

```
[ 6.112354] Freeing unused kernel memory: 1024K
[ 6.229047] EXT4-fs (mmcblk0p2): re-mounted. Opts: data=ordered
Starting syslogd: OK
Starting klogd: OK
Initializing random number generator... [ 6.495358] random: dd: uninitialized urandom read (512 bytes read)
done.
Starting system message bus: [ 6.591339] random: dbus-uuidgen: uninitialized urandom read (12 bytes read)
[ 6.599232] random: dbus-uuidgen: uninitialized urandom read (8 bytes read)
done.
Starting network: OK
Starting dhcpd...
no interfaces have a carrier
forked to background, child pid 113
[ 7.220386] net eth0: initializing cpsw version 1.12 (0)
Starting connman ... done.
Starting dropbear sshd: [ 7.330102] SMSC LAN8710/LAN8720 4a101000.mdio:00: attached PHY driver [SMSC LAN8710/LAN8720] (nii_bus:phy_addr=4a101000.mdio:00, irq=POLL)
OK
[ 7.377375] IPv6: ADDRCONF(NETDEV_UP): eth0: link is not ready
[ 7.531935] random_read: 4 callbacks suppressed
[ 7.531949] random: connman: uninitialized urandom read (8 bytes read)
[ 7.544919] random: ssh-keygen: uninitialized urandom read (32 bytes read)
Starting sshd: [ 7.642335] random: sshd: uninitialized urandom read (32 bytes read)
OK
Starting cron ... done.

Welcome to Buildroot - Tanmay Chaturvedi
buildroot login: [ 13.609523] cpsw 4a100000.ethernet eth0: Link is Up - 100Mbps/Full - flow control off
[ 13.618350] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[ 75.538909] random: crng init done
root
Password:
# ifconfig
eth0      Link encap:Ethernet  HWaddr 38:D2:69:7D:04:3D
          inet addr:128.138.189.130  Bcast:128.138.189.255  Mask:255.255.255.0
          inet6 addr: fe80::5c44:d359:5008:4280/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:6857 errors:0 dropped:0 overruns:0 frame:0
          TX packets:33 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:574188 (560.7 KiB)  TX bytes:9924 (9.6 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 to BBG Successful:



```

File Edit View Search Terminal Help
tanmay@tanmay-VirtualBox: ~/projects/myProblem4

tanmay@tanmay-VirtualBox:~/projects/myProblem4$ ssh root@128.138.189.97:5000
ssh: Could not resolve hostname 128.138.189.97:5000: Name or service not known
tanmay@tanmay-VirtualBox:~/projects/myProblem4$ ssh root@128.138.189.97
root@128.138.189.97's password:
# gdb-multiarch
# gdb
# sh: gdb: not found
# sh: gdb: not found
# ifconfig
eth0      Link encap:Ethernet  HWaddr 38:D2:69:7D:04:3D
          inet addr:128.138.189.97  Bcast:128.138.189.255  Mask:255.255.255.0
          inet6 addr: fe80::ba3f:cb7:2130:161f/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:269152 errors:0 dropped:0 overruns:0 frame:0
          TX packets:23419 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:22298413 (21.2 MiB)  TX bytes:8286690 (7.8 MiB)
          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)

# exit
Connection to 128.138.189.97 closed.
tanmay@tanmay-VirtualBox:~/projects/myProblem4$ ssh root@128.138.189.97
root@128.138.189.97's password:
# gdbserver --multi 128.138.189.97:5000
Listening on port 5000
Remote debugging from host 10.201.57.97
Process /root/fileio created; pid = 300
My name is Tanmay Chaturvedi@location Donetanmay
$ tanmay
Child exited with status 0
Process /root/fileio created; pid = 301

File Edit View Search Terminal Help
No symbol "remote" in current context.
(gdb) set remote exec-file fileio
(gdb) r
Starting program: /home/tanmay/projects/myProblem4/fileio
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 in
stead.
Reading /lib/ld-uclibc.so.0 from remote target...
Reading /lib//libc.so.0 from remote target...
[Inferior 1 (process 300) exited normally]
(gdb) bt
No stack.
(gdb) t b
No breakpoints or watchpoints.
(gdb) p var
No symbol "var" in current context.
(gdb) p a
No symbol "a" in current context.
(gdb) break 15
Breakpoint 1 at 0x1072c: file fileio.c, line 15.
(gdb) r
Starting program: /home/tanmay/projects/myProblem4/fileio
Reading /lib/ld-uclibc.so.0 from remote target...
Reading /lib/ld-uclibc.so.0 from remote target...
Reading /lib//libc.so.0 from remote target...
Breakpoint 1, main () at fileio.c:15
15      FILE* file_ptr = fopen( FILE_NAME, "w" );
(gdb) p a
$1 = 0
(gdb) s
17      chmod( FILE_NAME, 00400 | 00200);
(gdb) s
19      int a = 15;
(gdb) p a
$2 = 0
(gdb) print a
$3 = 0
(gdb) list locals
Function "locals" not defined.
(gdb) list local
Function "local" not defined.
(gdb) s
25
(gdb) print a
$4 = 15
(gdb)
  
```

3. Gdbinit file:

```

tanmay@tanmay-VirtualBox:~/projects/myProblem4$ cat gdbinit
target extended-remote 128.138.189.97:5000

remote put /home/tanmay/projects/myProblem4/fileio fileio

file fileio

set remote exec-file fileio

break main
r
s
s
s
i b
b 30
s
s
p a
c

tanmay@tanmay-VirtualBox:~/projects/myProblem4$
  
```

4. Gdbinit auto debugging execution:

```

Fri 16:53
tanmay@tanmay-VirtualBox: ~/projects/myProblem4
File Edit View Search Terminal Help
tanmay@tanmay-VirtualBox:~/projects/myProblem4$ nano gdbinit
tanmay@tanmay-VirtualBox:~/projects/myProblem4$ gdb-multiarch -x gdbinit
GNU gdb (Ubuntu 8.1-0ubuntu1) 8.1.0.20180409-git
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 'x86_64-linux-gnu'.
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'.
Breakpoint 1 at 0x18720: file file0.c, line 12.
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 in
stead.
Reading /lib/ld-uclibc.so.0 from remote target...
Reading /lib/libc.so.0 from remote target...
Breakpoint 1, main () at file0.c:12
12      printf("My name is Tanny Chaturvedi");
13
14      FILE* file_ptr = fopen(FILE_NAME, "w");
15      chmod(FILE_NAME, 00400 | 00200);
16      int n = 15;
17
18      Num      Type      Disps      End Address      What
19      -----
20      1      breakpoint      keep y      0x00010720 in main at file0.c:12
21      Breakpoint already hit 1 time
22      Breakpoint 2 at 0x1882c: file file0.c, line 30.
23      20      int open = fputc(INPUT_CHAR, file_ptr); /*Writing 'A' (ASCII) 65*/
24      21      fclose(file_ptr);
25      31 = 15
26
27      Breakpoint 2, main () at file0.c:33
28      33      fputs(str_ptr, file_ptr);
29      (gdb) r
30      The program being debugged has been started already.
31      Start it from the beginning? (y or n) n
32      Program not restarted.
33      (gdb) c
34      A debugging session is active.
35
36      collisions:0 txqueuelen:1000
37      RX bytes:22298413 (21.2 MiB) TX bytes:8280690 (7.8 MiB)
38      Interrupt:46
39
40      lo      Link encap:Local Loopback
41      Inet addr:127.0.0.1 Mask:255.0.0.0
42      Inet6 addr:::1/128 Scope:Host
43      UP LOOPBACK RUNNING MTU:65536 Metric:1
44      RX packets:0 errors:0 dropped:0 overruns:0 frame:0
45      TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
46      collisions:0 txqueuelen:1000
47      RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)
48
49      # exit
50      Connection to 128.138.189.97 closed.
51      tanmay@tanmay-VirtualBox:~/projects/myProblem4$ ssh root@128.138.189.97
52      root@128.138.189.97's password:
53      # gdbserver -multi 128.138.189.97:5000
54      Listening on port 5000
55      Remote debugging from host 10.201.57.97
56      Process /root/file0 created; pid = 300
57      My name is Tanny ChaturvediAllocation DoneTanny
58      65tanmay
59      Child exited with status 0
60      Process /root/file0 created; pid = 301
61      Remote side has terminated connection. GDBserver will reopen the connection.
62      Listening on port 5000
63      Remote debugging from host 10.201.57.97
64      Remote side has terminated connection. GDBserver will reopen the connection.
65      Remote debugging from host 10.201.57.97
66      Remote side has terminated connection. GDBserver will reopen the connection.
67      Remote debugging from host 10.201.57.97
68      Remote side has terminated connection. GDBserver will reopen the connection.
69      Listening on port 5000
70      Remote debugging from host 10.201.57.97
71      Process /root/file0 created; pid = 329
72      tanmay
73      Remote side has terminated connection. GDBserver will reopen the connection.
74      Listening on port 5000
75      Remote debugging from host 10.201.57.97
76      Process /root/file0 created; pid = 330
77      My name is Tanny ChaturvediAllocation DoneRemote side has terminated connection. GDBserver will re
78      open the connection.
79      Listening on port 5000

```

Question 3

1. Timer Load with Param: Input period = 1000msec and input string = "tanny"

```

# insmod tanmay_kernel.ko input_string=Tanny input_period=1000
[ 103.234068] tanmay_kernel: loading out-of-tree module taints kernel.
[ 103.242732] Entered the kernel module
# [ 104.322277] Name is Tanny and count is 0

```

2. Dmesg log

```

[ 1.709904] Registering SUP/SVBP emulation handler
[ 1.715010] SmartReflex Class3 initialized
[ 1.720551] mmcblk0: p1 p2
[ 1.780413] mmc1: new high speed MMC card at address 0001
[ 1.780829] mmcblk1: mmc1:0001 P1XXXX 3.60 GiB
[ 1.796475] mmcblk1boot0: mmc1:0001 P1XXXX partition 1 2.00 MiB
[ 1.803962] random: fast init done
[ 1.808070] mmcblk1boot1: mmc1:0001 P1XXXX partition 2 2.00 MiB
[ 1.815385] mmcblk1pmb: mmc1:0001 P1XXXX partition 3 128 MiB
[ 1.825941] mmcblk1: p1
[ 1.852390] tps65217 0-0024: TPS65217 ID 0xe version 1.2
[ 1.858659] omap_i2c 44e0b000.i2c: bus 0 rev0.11 at 400 kHz
[ 1.868288] omap_i2c 4819c000.i2c: bus 2 rev0.11 at 100 kHz
[ 1.875650] hctosys: unable to open rtc device (rtc0)
[ 1.881084] sr_init: No PMIO hook to init smartreflex
[ 1.886607] sr_init: platform driver register failed for SR
[ 2.040496] EXT4-fs (mmcblk0p2): recovery complete
[ 2.051210] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. Opts: (null)
[ 2.057864] UFS: Mounted root (ext4 filesystem) on device 179:2.
[ 2.072364] devtmpfs: mounted
[ 2.078081] Freeing unused kernel memory: 1024K
[ 2.201550] EXT4-fs (mmcblk0p2): re-mounted. Opts: data=ordered
[ 2.464563] random: dd: uninitialized urandom read (512 bytes read)
[ 2.562417] random: dbus-uuidgen: uninitialized urandom read (12 bytes read)
[ 2.569968] random: dbus-uuidgen: uninitialized urandom read (8 bytes read)
[ 3.176005] net eth0: initializing cpsw version 1.12 (0)
[ 3.284173] SMSC LAN8710/LAN8720 4a101000.mdio:00: attached PHY driver [SMSC LAN8710/LAN8720] (mii_bus:phy_addr=4a101000.mdio:00, irq=POLL)
[ 3.336671] IPv6: ADDRCONF(NETDEV_UP): eth0: link is not ready
[ 3.483765] urandom_read: 4 callbacks suppressed
[ 3.492779] random: s3b-keygen: uninitialized urandom read (32 bytes read)
[ 3.497227] random: connmand: uninitialized urandom read (8 bytes read)
[ 3.603742] random: sshd: uninitialized urandom read (32 bytes read)
[ 9.525000] cpsw 4a100000.ethernet eth0: Link is Up - 100Mbps/Full - flow control off
[ 9.532101] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[ 89.272364] random: crng init done
[ 103.234068] tanmay_kernel: loading out-of-tree module taints kernel.
[ 103.242732] Entered the kernel module
[ 104.322277] Name is Tanny and count is 0
[ 105.361800] Name is Tanny and count is 1
[ 106.401806] Name is Tanny and count is 2
[ 107.441810] Name is Tanny and count is 3
[ 108.481822] Name is Tanny and count is 4
[ 109.521835] Name is Tanny and count is 5
[ 110.561840] Name is Tanny and count is 6
[ 111.601846] Name is Tanny and count is 7
[ 112.641853] Name is Tanny and count is 8
[ 113.681862] Name is Tanny and count is 9
[ 114.721876] Name is Tanny and count is 10
[ 115.761884] Name is Tanny and count is 11
[ 116.801889] Name is Tanny and count is 12
[ 117.841895] Name is Tanny and count is 13
[ 118.227598] Exited the kernel module

```


3. Module info:

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko
filename:           /home/tanmay/projects/Homework3/tanmay_kernel.ko
version:            1.0
description:        A Kernel Module that works on Linux Timer
author:             Tanmay Chaturvedi
license:            GPL
srcversion:         4660ED467C2BE0BAD45EBA2
depends:
name:               tanmay_kernel
vermagic:           4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:               input_period:int
parm:               input_string:charp
```

4. Module exit

```
# rmmod tanmay_kernel.ko [ 116.801889] Name is Tanny and count is 12
[ 117.841895] Name is Tanny and count is 13
[ 118.227598] Exited the kernel module
```

5. Timer Load with Param: Input period = 3000msec and input string = "AESD"

```
# insmod tanmay_kernel.ko input_string=AESD_HW3 input_period=3000
[ 356.382135] Entered the kernel module
# [ 359.443595] Name is AESD_HW3 and count is 0
[ 362.483116] Name is AESD_HW3 and count is 1
[ 365.523124] Name is AESD_HW3 and count is 2
[ 368.563132] Name is AESD_HW3 and count is 3
[ 371.603140] Name is AESD_HW3 and count is 4
[ 374.643154] Name is AESD_HW3 and count is 5
# rmmod tanmay_kernel.ko
[ 376.784480] Exited the kernel module
```

6. DMESG Log

```
[ 356.382135] Entered the kernel module
[ 359.443595] Name is AESD_HW3 and count is 0
[ 362.483116] Name is AESD_HW3 and count is 1
[ 365.523124] Name is AESD_HW3 and count is 2
[ 368.563132] Name is AESD_HW3 and count is 3
[ 371.603140] Name is AESD_HW3 and count is 4
[ 374.643154] Name is AESD_HW3 and count is 5
[ 376.784480] Exited the kernel module
```

7. Module Info:

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko
filename:           /home/tanmay/projects/Homework3/tanmay_kernel.ko
version:            1.0
description:        A Kernel Module that works on Linux Timer
author:             Tanmay Chaturvedi
license:            GPL
srcversion:         4660ED467C2BE0BAD45EBA2
depends:
name:               tanmay_kernel
vermagic:           4.14.40 SMP mod_unload modversions ARMv6 p2v8
parm:               input_period:int
parm:               input_string:charp
```

8. Module exit:

```
# rmmod tanmay_kernel.ko  
[ 376.784480] Exited the kernel module
```

9. Dmesg when no argument given

```
tanmay@tanmay-VirtualBox:~/projects/Homework3$ modinfo tanmay_kernel.ko  
filename:       /home/tanmay/projects/Homework3/tanmay_kernel.ko  
version:        1.0  
description:     A Kernel Module that works on Linux Timer  
author:         Tanmay Chaturvedi  
license:        GPL  
srcversion:     4660ED467C2BE0BAD45EBA2  
depends:           
name:           tanmay_kernel  
vermagic:       4.14.40 SMP mod_unload modversions ARMv6 p2v8  
parm:           input_period:int  
parm:           input_string:charp
```

Question 4.

Section 1. Ecosystem:

Data structure used: Linked List

Entries:

```
{"Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Donkey", "Rabbit", \  
    "Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Anteater", "Rabbit", \  
    "Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Ape", "Rabbit", \  
    "Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Deer", "Rabbit", \  
    "Cat", "Cat", "Dog", "Dog", "Alligator", "Mouse", "Tiger", "Zebra", "Gorilla", "Rabbit", };
```

Output generated after sorting, reporting number of nodes generated and dynamic memory allocated.

```

[ 3903.483149] Sorted Element = Dog
[ 3903.486561] Sorted Element = Dog
[ 3903.489925] Sorted Element = Dog
[ 3903.493295] Sorted Element = Dog
[ 3903.496704] Sorted Element = Dog
[ 3903.500071] Sorted Element = Dog
[ 3903.503485] Sorted Element = Dog
[ 3903.506866] Sorted Element = Dog
[ 3903.510242] Sorted Element = Dog
[ 3903.513657] Sorted Element = Donkey
[ 3903.517301] Sorted Element = Gorilla
[ 3903.521034] Sorted Element = Mouse
[ 3903.524624] Sorted Element = Mouse
[ 3903.528181] Sorted Element = Mouse
[ 3903.531737] Sorted Element = Mouse
[ 3903.535327] Sorted Element = Mouse
[ 3903.538880] Sorted Element = Rabbit
[ 3903.542530] Sorted Element = Rabbit
[ 3903.546214] Sorted Element = Rabbit
[ 3903.549856] Sorted Element = Rabbit
[ 3903.553536] Sorted Element = Rabbit
[ 3903.557186] Sorted Element = Tiger
[ 3903.560744] Sorted Element = Tiger
[ 3903.564333] Sorted Element = Tiger
[ 3903.567885] Sorted Element = Tiger
[ 3903.571431] Sorted Element = Tiger
[ 3903.575020] Sorted Element = Zebra
[ 3903.578576] Sorted Element = Zebra
[ 3903.582122] Sorted Element = Zebra
[ 3903.585714] Sorted Element = Zebra
[ 3903.589267] Sorted Element = Zebra
[ 3903.592851] Animal Name: = Alligator and Respective Count = 5
[ 3903.598902] Animal Name: = Anteater and Respective Count = 1
[ 3903.604852] Animal Name: = Ape and Respective Count = 1
[ 3903.610307] Animal Name: = Cat and Respective Count = 10
[ 3903.615896] Animal Name: = Deer and Respective Count = 1
[ 3903.621443] Animal Name: = Dog and Respective Count = 10
[ 3903.627022] Animal Name: = Donkey and Respective Count = 1
[ 3903.632756] Animal Name: = Gorilla and Respective Count = 1
[ 3903.638620] Animal Name: = Mouse and Respective Count = 5
[ 3903.644298] Animal Name: = Rabbit and Respective Count = 5
[ 3903.650040] Animal Name: = Tiger and Respective Count = 5
[ 3903.655721] Animal Name: = Zebra and Respective Count = 5
[ 3903.661365] Total Nodes = 12
[ 3903.661376] Total amount of memory dynamically allocated for nodes = 192 bytes
[ 3908.673104] Exited the kernel module
#

```

Section 2.:

- a. When command line argument is : **insmod tanmay_kernel1.ko**
 ➔ **Default value, means no input argument for animal name and count**


```

File Edit View Search Terminal Help
[ 158.610197] Sorted Element = Mouse
[ 158.613788] Sorted Element = Mouse
[ 158.617335] Sorted Element = Mouse
[ 158.620926] Sorted Element = Mouse
[ 158.624474] Sorted Element = Mouse
[ 158.628029] Sorted Element = Rabbit
[ 158.631708] Sorted Element = Rabbit
[ 158.635346] Sorted Element = Rabbit
[ 158.638985] Sorted Element = Rabbit
[ 158.642664] Sorted Element = Rabbit
[ 158.646305] Sorted Element = Tiger
[ 158.649853] Sorted Element = Tiger
[ 158.653438] Sorted Element = Tiger
[ 158.656989] Sorted Element = Tiger
[ 158.660541] Sorted Element = Tiger
[ 158.664133] Sorted Element = Zebra
[ 158.667683] Sorted Element = Zebra
[ 158.671268] Sorted Element = Zebra
[ 158.674816] Sorted Element = Zebra
[ 158.678364] Sorted Element = Zebra
[ 158.681980] Animal Name: = Alligator and Respective Count = 5
[ 158.687979] Animal Name: = Anteater and Respective Count = 1
[ 158.693925] Animal Name: = Ape and Respective Count = 1
[ 158.699379] Animal Name: = Cat and Respective Count = 10
[ 158.704964] Animal Name: = Deer and Respective Count = 1
[ 158.710505] Animal Name: = Dog and Respective Count = 10
[ 158.716084] Animal Name: = Donkey and Respective Count = 1
[ 158.721848] Animal Name: = Gorilla and Respective Count = 1
[ 158.727663] Animal Name: = Mouse and Respective Count = 5
[ 158.733342] Animal Name: = Rabbit and Respective Count = 5
[ 158.739065] Animal Name: = Tiger and Respective Count = 5
[ 158.744741] Animal Name: = Zebra and Respective Count = 5
[ 158.750375] Total Nodes = 12
[ 158.750385] Total amount of memory dynamically allocated for nodes = 192 bytes
[ 158.753431] Previous Animal Name: = Alligator and Respective Count = 5
[ 158.767808] Previous Animal Name: = Anteater and Respective Count = 1
[ 158.774567] Previous Animal Name: = Ape and Respective Count = 1
[ 158.780871] Previous Animal Name: = Cat and Respective Count = 10
[ 158.787235] Previous Animal Name: = Deer and Respective Count = 1
[ 158.793627] Previous Animal Name: = Dog and Respective Count = 10
[ 158.799983] Previous Animal Name: = Donkey and Respective Count = 1
[ 158.806558] Previous Animal Name: = Gorilla and Respective Count = 1
[ 158.813232] Previous Animal Name: = Mouse and Respective Count = 5
[ 158.819691] Previous Animal Name: = Rabbit and Respective Count = 5
[ 158.826271] Previous Animal Name: = Tiger and Respective Count = 5
[ 158.832764] Previous Animal Name: = Zebra and Respective Count = 5

```

When module is exited, total memory freed is 192 bytes

```

[ 266.094542] Exited the kernel module
[ 266.098326] Total size freed = 192 bytes

```

- b. When command line argument is : `insmod tanmay_kernel1.ko input_animal_type=Dog`
 → Only name given as argument


```

[ 886.261690] Sorted Element = Dog
[ 886.265061] Sorted Element = Dog
[ 886.268435] Sorted Element = Dog
[ 886.271838] Sorted Element = Dog
[ 886.275207] Sorted Element = Dog
[ 886.278574] Sorted Element = Dog
[ 886.281982] Sorted Element = Donkey
[ 886.285622] Sorted Element = Gorilla
[ 886.289352] Sorted Element = Mouse
[ 886.292941] Sorted Element = Mouse
[ 886.296492] Sorted Element = Mouse
[ 886.300045] Sorted Element = Mouse
[ 886.303632] Sorted Element = Mouse
[ 886.307180] Sorted Element = Rabbit
[ 886.310858] Sorted Element = Rabbit
[ 886.314506] Sorted Element = Rabbit
[ 886.318149] Sorted Element = Rabbit
[ 886.321829] Sorted Element = Rabbit
[ 886.325473] Sorted Element = Tiger
[ 886.329029] Sorted Element = Tiger
[ 886.332617] Sorted Element = Tiger
[ 886.336166] Sorted Element = Tiger
[ 886.339719] Sorted Element = Tiger
[ 886.343308] Sorted Element = Zebra
[ 886.346857] Sorted Element = Zebra
[ 886.350410] Sorted Element = Zebra
[ 886.353998] Sorted Element = Zebra
[ 886.357551] Sorted Element = Zebra
[ 886.361165] Animal Name: = Alligator and Respective Count = 5
[ 886.367162] Animal Name: = Anteater and Respective Count = 1
[ 886.373110] Animal Name: = Ape and Respective Count = 1
[ 886.378566] Animal Name: = Cat and Respective Count = 10
[ 886.384154] Animal Name: = Deer and Respective Count = 1
[ 886.389701] Animal Name: = Dog and Respective Count = 10
[ 886.395279] Animal Name: = Donkey and Respective Count = 1
[ 886.401049] Animal Name: = Gorilla and Respective Count = 1
[ 886.406862] Animal Name: = Mouse and Respective Count = 5
[ 886.412532] Animal Name: = Rabbit and Respective Count = 5
[ 886.418259] Animal Name: = Tiger and Respective Count = 5
[ 886.423933] Animal Name: = Zebra and Respective Count = 5
[ 886.429568] Total Nodes = 12
[ 886.429578] Total amount of memory dynamically allocated for nodes = 192 bytes

```

Only “Dog” and its respective count is stored in the filtered linked list.

```

[ 886.432629] Filtered Node # is 1, Name: = Dog and Respective Count = 10
[ 889.449263] Exited the kernel module
[ 889.453299] Total size freed = 192 bytes
[ 889.457393] Total size freed = 16 bytes

```

When module is freed 192 bytes freed from first linkedlist and 16bytes freed from filtered linked list.

- c. When command line argument is : `insmod tanmay_kernel1.ko count_greater_than=6`
 → Only count given as argument

```

[ 592.469677] Sorted Element = Donkey
[ 592.473355] Sorted Element = Gorilla
[ 592.477088] Sorted Element = Mouse
[ 592.480638] Sorted Element = Mouse
[ 592.484228] Sorted Element = Mouse
[ 592.487782] Sorted Element = Mouse
[ 592.491371] Sorted Element = Mouse
[ 592.494927] Sorted Element = Rabbit
[ 592.498567] Sorted Element = Rabbit
[ 592.502249] Sorted Element = Rabbit
[ 592.505886] Sorted Element = Rabbit
[ 592.509525] Sorted Element = Rabbit
[ 592.513212] Sorted Element = Tiger
[ 592.516767] Sorted Element = Tiger
[ 592.520316] Sorted Element = Tiger
[ 592.523909] Sorted Element = Tiger
[ 592.527469] Sorted Element = Tiger
[ 592.531059] Sorted Element = Zebra
[ 592.534610] Sorted Element = Zebra
[ 592.538155] Sorted Element = Zebra
[ 592.541750] Sorted Element = Zebra
[ 592.545305] Sorted Element = Zebra
[ 592.548883] Animal Name: = Alligator and Respective Count = 5
[ 592.554920] Animal Name: = Anteater and Respective Count = 1
[ 592.560871] Animal Name: = Ape and Respective Count = 1
[ 592.566333] Animal Name: = Cat and Respective Count = 10
[ 592.571918] Animal Name: = Deer and Respective Count = 1
[ 592.577467] Animal Name: = Dog and Respective Count = 10
[ 592.583054] Animal Name: = Donkey and Respective Count = 1
[ 592.588790] Animal Name: = Gorilla and Respective Count = 1
[ 592.594651] Animal Name: = Mouse and Respective Count = 5
[ 592.600289] Animal Name: = Rabbit and Respective Count = 5
[ 592.606063] Animal Name: = Tiger and Respective Count = 5
[ 592.611737] Animal Name: = Zebra and Respective Count = 5
[ 592.617379] Total Nodes = 12
[ 592.617390] Total amount of memory dynamically allocated for nodes = 192 bytes

```

Only elements with count > 6 and are stored in the filtered list.

```

[ 797.026914] Node # is 1, Name: = Cat and Respective Count = 10
[ 797.040579] Node # is 2, Name: = Dog and Respective Count = 10
[ 799.346942] Exited the kernel module
[ 799.350972] Total size freed = 192 bytes
[ 799.355077] Total size freed = 32 bytes

```

When module is freed 192 bytes freed from first linkedlist and 32 bytes freed from filtered linked list.

- d. When command line argument is : `insmod tanmay_kernel1.ko input_animal_type=Tiger count_greater_than=3`
 ➔ Name and count given as argument

```
[ 592.469677] Sorted Element = Donkey
[ 592.473355] Sorted Element = Gorilla
[ 592.477088] Sorted Element = Mouse
[ 592.480638] Sorted Element = Mouse
[ 592.484228] Sorted Element = Mouse
[ 592.487782] Sorted Element = Mouse
[ 592.491371] Sorted Element = Mouse
[ 592.494927] Sorted Element = Rabbit
[ 592.498567] Sorted Element = Rabbit
[ 592.502249] Sorted Element = Rabbit
[ 592.505886] Sorted Element = Rabbit
[ 592.509525] Sorted Element = Rabbit
[ 592.513212] Sorted Element = Tiger
[ 592.516767] Sorted Element = Tiger
[ 592.520316] Sorted Element = Tiger
[ 592.523909] Sorted Element = Tiger
[ 592.527469] Sorted Element = Tiger
[ 592.531059] Sorted Element = Zebra
[ 592.534610] Sorted Element = Zebra
[ 592.538155] Sorted Element = Zebra
[ 592.541750] Sorted Element = Zebra
[ 592.545305] Sorted Element = Zebra
[ 592.548883] Animal Name: = Alligator and Respective Count = 5
[ 592.554920] Animal Name: = Anteater and Respective Count = 1
[ 592.560871] Animal Name: = Ape and Respective Count = 1
[ 592.566333] Animal Name: = Cat and Respective Count = 10
[ 592.571918] Animal Name: = Deer and Respective Count = 1
[ 592.577467] Animal Name: = Dog and Respective Count = 10
[ 592.583054] Animal Name: = Donkey and Respective Count = 1
[ 592.588790] Animal Name: = Gorilla and Respective Count = 1
[ 592.594651] Animal Name: = Mouse and Respective Count = 5
[ 592.600289] Animal Name: = Rabbit and Respective Count = 5
[ 592.606063] Animal Name: = Tiger and Respective Count = 5
[ 592.611737] Animal Name: = Zebra and Respective Count = 5
[ 592.617379] Total Nodes = 12
[ 592.617390] Total amount of memory dynamically allocated for nodes = 192 bytes
```

Elements with name = Tiger OR Count>3 are stored in filtered array.

```
[ 592.620402] Node # is 1, Name: = Alligator and Respective Count = 5
[ 592.634550] Node # is 2, Name: = Cat and Respective Count = 10
[ 592.640644] Node # is 3, Name: = Dog and Respective Count = 10
[ 592.646771] Node # is 4, Name: = Mouse and Respective Count = 5
[ 592.652990] Node # is 5, Name: = Rabbit and Respective Count = 5
[ 592.659256] Filtered Node # is 6, Name: = Tiger and Respective Count = 5
[ 592.666297] Node # is 7, Name: = Zebra and Respective Count = 5
[ 597.057370] Exited the kernel module
[ 597.061413] Total size freed = 192 bytes
[ 597.065511] Total size freed = 112 bytes
```

Total 192 bytes freed in the original linkedlist and 112 bytes in the filtered linked list.

e. Time to load kernel module:

```
[ 112.982355] linkedlist_kernel_module: loading out-of-tree module taints kernel.
[ 112.990983] initialize kernel module
```

= 112.990983-112.982355

= 0.008628 sec

f. Time to exit kernel module

```
[ 266.094542] Exited the kernel module
[ 266.098326] Total size freed = 192 bytes
[ 266.102663] Total size freed = 192 bytes
```

= 166.102663 – 266.094542 = 0.008121 sec