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INFO0940
OPERATING SYSTEMS

Project #3

Academic year 2019-2020

Your third project

Hacking the Linux kernel

1. You will implement a kernel-space Key-Value store;
2. The main objective of this assignment is a practice for adding system calls in the Linux kernel;
3. We provide different material to help you (test program, script, ...);
4. It will be a bit more difficult than before. Sorry :(

What's Key-Value Store (KVS) ?

- KVS is a type of data storage applications such as relational database management systems;
- KVS is specialized for storing pairs of Key and Value;
- Example implementations
  - Memcached
  - Redis

How does a KVS work?

Primary **3** operations: *Insert*, *Search*, and *Delete*

- *Insert*: register a Key-Value pair;
- *Search*: find a Value from a Key;
- *Delete*: remove an entry that has a specified Key.

How does a KVS work?

Let's make a KVS storage that has pairs of web-browsers and vendors. First, let's insert the records using the *insert* operation:

- *Insert("Internet Explorer", "Microsoft")*
- *Insert("Edge", "Microsoft")*
- *Insert("Firefox", "Mozilla")*
- *Insert("Chrome", "Google")*

How does a KVS work?

After the insert operations, we will have the pairs of Key and Value in the storage:

How does a KVS work?

Now, we want to know which company provides "Internet Explorer" (a great browser).

We can know it by using the *search* operation:

Search("Internet Explorer")

The *search* operation will find "Microsoft" in the storage.

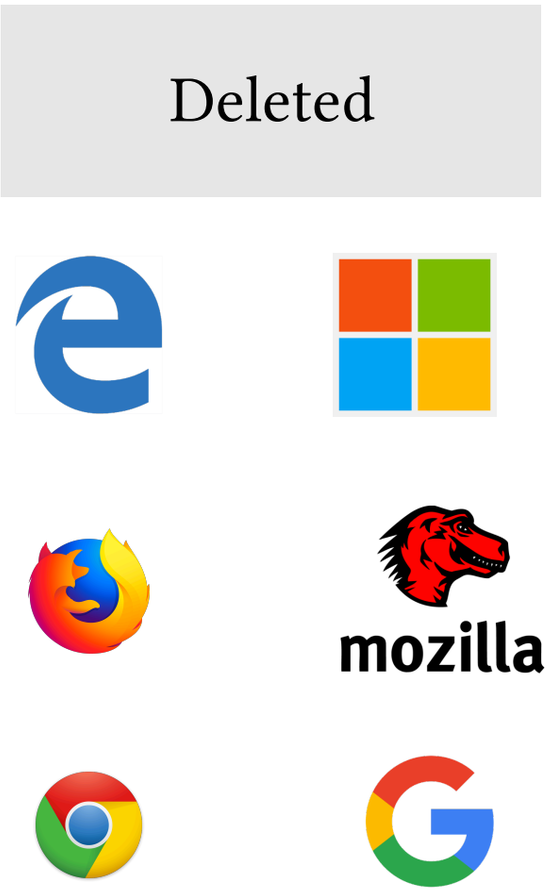
How does a KVS work?

Oh, by the way, Microsoft has stopped to develop Internet Explorer.

If we do not need such old information, we can remove it using the *delete* operation:

Delete("Internet Explorer")

The *delete* operation removes the entry on the storage



KVS within Kernel

- We will implement the KVS functionality inside the Linux kernel;

- Precisely, we will implement 3 system calls for the *insert*, *search*, and *delete* operations;

- The kernel-space KVS will store the pairs of Key and Value inside the kernel address space.

The 3 system calls

Precisely, we will implement 3 system calls for the *insert*, *search*, and *delete* operations;

Kernel C Code

```
long kvs_insert(const char *key, size_t keylen,
                const char *val, size_t vallen);

long kvs_search(const char *key, size_t keylen,
                char *val, size_t max_vallen);

long kvs_delete(const char *key, size_t keylen);
```

THE *INSERT* SYSCALL

```
long kvs_insert(const char *key, size_t keylen,
                const char *val, size_t vallen);
```

- `const char *key`: a pointer to the key string;
- `size_t keylen`: the length of the key;
- `const char *val`: a pointer to the value string;
- `size_t vallen`: the length of the value string;

THE *SEARCH* SYSCALL

```
long kvs_search(const char *key, size_t keylen,
                char *val, size_t max_vallen);
```

- `const char *key`: a pointer to the key string;
- `size_t keylen`: the length of the key;
- `const char *val`: a pointer to a buffer where the return value will be stored by the kernel;
- `size_t max_vallen`: the length of the "*val*" buffer;

THE *DELETE* SYSCALL

```
long kvs_delete(const char *key, size_t keylen);
```

- `const char *key`: a pointer to the key string;
- `size_t keylen`: the length of the key;

EXAMPLE

```
kvs_insert("Internet Explorer", 17, "Microsoft", 9);
kvs_insert("Edge", 4, "Microsoft", 9);
```

```
char buf[16];
kvs_search("Edge", 4, buf, sizeof(buf));
```

Supposedly, the kernel KVS stores "Microsoft" in `buf`.

```
kvs_delete("Internet Explorer”, 17);
```

KVS within Kernel

Demonstration

Hints

For this project, you need to do **some research** but here are some hints to help you:

- You need to add 3 syscalls... think that we **only** consider **x86_32bits** architecture;
- You can investigate within the Linux source code and analyse existing system calls such as `read`, `write`, `fork`, ...
- Don't forget to check user inputs (see lab 5);
- Use `printk` to debug and `goto` for errors handling (see lab 5);
- Check if your kernel was upgraded (`uname -a`).

Submission

- Submit **all patches** that have diffs from Linux-4.15 (the first commit);

- Patches should be made by `git format-patch` (refer to the slides/tutorial page to know how to use it);

- The patch files should be saved in a directory named `patch`, and it should be compressed into an archive called `patch.tar.gz`

Testing environment (1)

- We offer the test setup that actually runs on the submission platform (but it is limited concerning tests).

- **Benefits:**
  - You can test whether your patches are applicable or not;
  - You will be able to have better understanding about expected behaviour.

- Privately, I guess this would be a good starting point!

Testing environment (2)

- How to use it?
  - First download the archive at the following link: http://www.montefiore.ulg.ac.be/~yasukata/lecture/asset/INFO0940_2020/project3/info0940_project3_test.tar.gz
- Then put this archive on your reference VM (for testing):
  - **Don't use this in other places!!!**
- After enter the following command to extract:
  - `tar xvf info0940_project3_test.tar.gz`
- Finally, you will observe 4 entities:
  - `companion  script0.sh  script1.sh  test.c`

Testing environment (3)

The content of this archive:

- `companion`: Linux-4.15 source;
- `script0.sh`:
  - Applies patch and compile the kernel;
  - Initially, patch adaptation part is commented out in order not to delete your modifications.
- `script1.sh`: run tests;
- `test.c`: the test C program that calls your syscalls;

USING TESTING ENVIRONMENT (1)

- Prepare your `patch.tar.gz` (to be submitted), and put it in "`info0940_project3_test`" folder;
- Remove comment out in `script0.sh`:
  - Pay attention to the consequences of this;
  - Your patch will be applied to files in companion*;
  - The commented out part deletes patch files first for cleaning up
- If you do not remove the comment out, `script0.sh` just compiles and installs the kernel

*__Important__: If you have **several** patches, make sure that they are in the right order (e.g., `001_patch1, 002_patch2`, ...). Use the `mv` command to rename patch(es).

USING TESTING ENVIRONMENT (2)

```
#
# Please remove this comment out after your prepare your patch.tar.gz
#
##/bin/rm -rf patch &> /dev/null
##if [ ! -e patch.tar.gz ]; then
##   mark 20 "Could not find expected tar.gz file, please upload the file named patch.tar.gz"
##   exit 1
##fi
#
#tar zxvf patch.tar.gz &> /dev/null
#if [ $? -ne 0 ] ; then
#    mark 20 "System Error 2, Please report to TAs"
#    exit 2
#fi
#
#if [ ! -e patch ]; then
#    mark 20 "Could not find the directory named patch"
#    exit 3
#fi

cd companion &> /dev/null
if [ $? -ne 0 ] ; then
    mark 20 "System Error 3, Please report to TAs"
    exit 4
fi

#
# Please remove this comment out after your prepare your patch.tar.gz
#
#git config --global user.name "student" &> /dev/null
#git config --local user.email "someone@student.uliege.be" &> /dev/null
#echo -n "Applying patches ..."
#git am ../patch/* &> patch.log
#if [ $? -ne 0 ] ; then
#    git reset --hard HEAD &> /dev/null
#    /bin/rm .config
#    git am ../patch/* &> patch.log
#    if [ $? -ne 0 ] ; then
#        mark 20 "Failed, please check the log"
#        cat patch.log
#        exit 5
#    fi
#else
#    echo "OK"
#fi
```

```
#
# Please remove this comment out after your prepare your patch.tar.gz
#
/bin/rm -rf patch &> /dev/null
if [ ! -e patch.tar.gz ]; then
    mark 20 "Could not find expected tar.gz file, please upload the file named patch.tar.gz"
    exit 1
fi

tar zxvf patch.tar.gz &> /dev/null
if [ $? -ne 0 ] ; then
    mark 20 "System Error 2, Please report to TAs"
    exit 2
fi

if [ ! -e patch ]; then
    mark 20 "Could not find the directory named patch"
    exit 3
fi

cd companion &> /dev/null
if [ $? -ne 0 ] ; then
    mark 20 "System Error 3, Please report to TAs"
    exit 4
fi

#
# Please remove this comment out after your prepare your patch.tar.gz
#
#git config --global user.name "student" &> /dev/null
#git config --local user.email "someone@student.uliege.be" &> /dev/null
echo -n "Applying patches ..."
git am ../patch/* &> patch.log
if [ $? -ne 0 ] ; then
    git reset --hard HEAD &> /dev/null
    /bin/rm .config
    git am ../patch/* &> patch.log
    if [ $? -ne 0 ] ; then
        mark 20 "Failed, please check the log"
        cat patch.log
        exit 5
    fi
else
    echo "OK"
fi
```

Using testing environment (3)

- Afterwards, run ./`script0.sh`;
- Supposedly, the script automatically compiles and installs new kernel in companion;
- After ./`script0.sh` completes, reboot the reference VM;
- After reboot, run /`script1.sh`;
- This script executes the actual test program.

Using testing environment (summary)

- First, run ./`script0.sh`
  - This will compile and install the kernel
- Second, please enter "`sudo reboot`"
  - This will reboot
- Third, please run ./`script1.sh`
  - This will run the test

- After you have your submission file `patch.tar.gz`, put it in `info0940_project3_test`, and remove comment outs in `script0.sh`, and repeat from the first step.

Using testing environment

- TAs encourage you to confirm your patch works correctly in our reference VM and the offered environment.
- **Don't use the submission platform for debug:**
  - Panic kernels occupy test runners of submission platform for a long time;
  - If you submit a lot of patches that crash the kernel, you and your friends may need to wait for really long time until starting the test...
- **We limited the number of submissions**

KVS within Kernel: Requirements

Others:

- Group of **two** that you will **keep** the whole semester
- Submit a tar file on the submission platform
- More information on the statements (available this evening).

You should be good programmers: We want clean code (good style), without error and warning. Within kernel programming you can use goto.

Don't forget: We detect **plagiarism** so don't try…

Plagiarism = **0 for the course!**

KVS within Kernel: Requirements

Deadline: 15th April 2020

Happy Coding!