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Project 1 on Operating Systems class

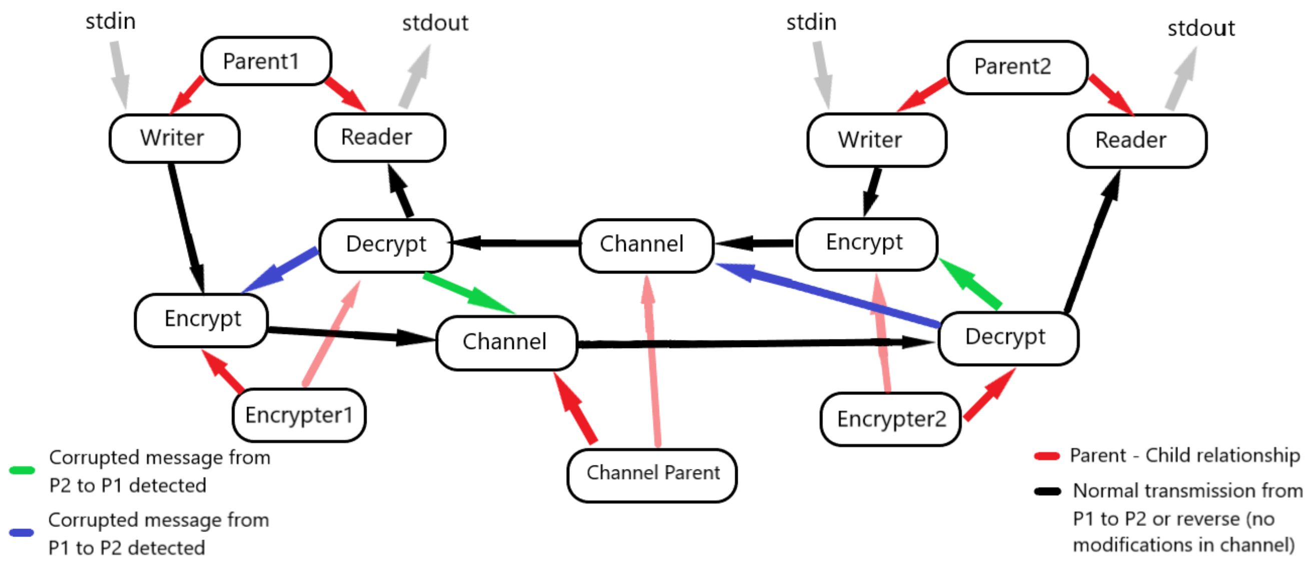
Documentation & Additional comments

Project structure

- `utils.c` & `utils.h` : Implementation & definition for useful functions, as well as some `#define` commands that may be modified (shared memory size, permissions, termination message)
- `parent1.c` & `parent2.c` : Parent processes of P1 and P2 respectively.
- `writer.c` : Used by P1 and P2, to get a new message from the command line and send it.
- `reader.c` : Also used by P1 and P2. It is the final "destination" of a message, where it is displayed in the command line.
- `encrypter1.c` and `encrypter2.c` : Parent processes for ENC1 and ENC2 respectively.
- `encrypt.c` : Used in ENC1 and ENC2. The main task of it is to get a message, concatenate it with the respective hash code and forward it to the channel.
- `decrypt.c` : Also used in ENC1 and ENC2. Mainly used to validate a message using the hash code and forward it to its final destination (either P1 or P2).
- `channel_parent.c` : Parent process of CHAN.
- `channel.c` : The "real" channel, where noise may by added to a message.

Logic & Design

The general idea is to create 2 identical & independent paths: one to send a message from P1 to P2, and another to do the opposite.



There are 5 parent processes to be executed:

- `parent1` and `parent2`, which call `writer` & `reader`
- `encrypter1` and `encypter2` which call `encrypt` & `decrypt`
- `channel_parent`, which calls `channel` 2 times (with different arguments)

After the parent processes create their children using `execvp`, they let them do the real job and wait for them to finish.
Each of the edges in the above diagram is created using a shared memory segment and 2 semaphores, to sychronize the producer and the consumer properly. Each process acts both as a consumer and as a producer (with the exception of `writer`, who "consumes" from `stdin` and `reader` whose "products" are directed to `stdout`). When all the processes have just started, the producers have priority. The first destination of a message is the `writer`, who waits to receive it from stdout. Consequently, `encrypt` waits for `writer` to give it permission to read from the shared memory segment. `channel` waits for `encrypt`, `decrypt` waits for `channel`, and `reader` waits for decrypt. Thanks to the first semaphore, "waiting" does not mean "looping until the producer writes something" but being blocked until the respective semaphore is unlocked. When this happens, the consumer reads from the shared memory. Thanks to the second semaphore, the producer cannot re-write until reading has finished.
The whole procedure is identical, no matter if P1 sent something to P2 or reverse. The only thing that changes is the shared memory and semaphores. The parent processes provide both the reading and writing shared memory and semaphore keys to their children (as arguments). They are created with `#define` commands in the parent's source code and can be easily modified, but with a lot of attention.

Corrupting a message & handling it

The channel parent must receive an argument, an integer which should be between 0 and 100. If greater than 100, it's like giving 100 and if smaller than 0, it's like giving 0. This is the % possibilty of a message being modified while "passing through" a channel child. The channel parent just passes it to the child as an argument. The child, after receiving a message (unless it is a "special" message), makes a simple `rand()` call:

```
if ( (rand() % 100) < chance )
{
    // modify the message
}
```

`chance` is of course the argument mentioned above.
If `channel` modifies the message, `decrypt` will know, by checking if the hash code (which is never modified) is the right for this message. Let's assume a message from **P1 to P2** was modified. In that case, instead of sending it to `reader`, `decrypt` writes a **special** message (`#define`'d in `utils.h`) to the shared memory where its **brother** (`encrypt`) usually **writes** to send a message from **P2 to P1** (see the blue arrows in the diagram). The special message passes through the channel and is received this time by P1's `decrypt`. When `decrypt` receives that special message, it sends it to its **brother** `encrypt`, by writing it to the shared memory where `encrypt` **reads** from to send a message from **P1 to P2**. When `encrypt` receives that message, it "retransmits" the last message that was sent (practically, the message is already in the shared memory, so `encrypt` just uses the semaphores to let `channel` read it again). Of course, the message may be modified again. `decrypt` and `encrypt` print some messages to let us know when a modification and a retransmission have taken place.
The exact same procedure takes place when a message from P2 to P1 is modified by the channel (see the green arrows in the diagram).

Terminating

Another special message is TERM, which indicates the termination of all the processes. Each process is designed to terminate after the handling of that message. But since the two paths are independent, if P1 sends an exit message to P2, only half the running processes will stop immediately. To stop the rest of the processes, the parent processes are used. When a child process terminates, the parent will know (because `wait(NULL)`is called after the children are created) and will send a `SIGQUIT` to the other child. To ensure that each child is terminated properly (without memory leaks or active semaphores and attached shared memory pointers) a `SIGQUIT` handler is used. The only exception here is the `reader` child of P1 and P2 which will terminate as soon as it realizes that the semaphore used for reading a message no longer exists (to avoid random messages at the end of the execution).

Compiling & Executing

Running `make` will create all the needed executables. gcc normally displays a warning ("assignment discards ‘const’ qualifier") 2 times while compiling `channel_parent.c`. It is disabled in the Makefile, but can easily be enabled back.
`parent1` and `parent2` should be executed first, in different terminals. Then `channel_parent`, `encrypter1` and `encrypter2` need to be executed. `encrypter1` and `encrypter2` should **always** be executed last, because they don't initiallize the semaphores they use themselves. `channel_parent`, `encrypter1` and `encrypter2` could be executed in one terminal (in backround) but it would be more preferable to use different terminals since `encrypt` and `decrypt` print retransmission messages.
`channel_parent` needs to be executed along with the possibility argument, otherwise it will stop.
After all the above have been executed, just type anything in `parent1` or `parent2` terminal and it will show up in the other's. Note that a message may be modified more than 1 time in a row.
To terminate, type "TERM" (or whatever exit message you may have defined in `utils.h`), either in `parent1` or `parent2` terminal, and everything will stop.
To delete the executables, run `make clean`.

Performance & other details

Messages usually appear immediately in the destination terminal, even if a retransmission has taken place (unless you chose a very big possibility for modification in channel). You can check for output messages in `encrypter1` and `encrypter2` terminals to find out.
All processes have been extensively checked for memory leaks using valgrind. Occasionally, in `channel` or `decrypt`, it is reported that there is one more memory allocation than the free's, and there are some "still reachable" bytes in the heap. No other leaks have been reported.
Semaphores and shared memory segments are properly deleted, and any attached pointers are dettached without problem.
The default shared memory size is 100 bytes but can be changed in `utils.h`. While reading input, `writer` will check if the length of the message along with the MD5 digest length exeed this limit, and will reject the input message in such case.

Development

Developed and tested in WSL Ubuntu 20.04, using Visual Studio Code. Succesfully tested in DIT Lab Ubuntu 16.04 as well.