4-hour Written Re-Exam in Computer Systems

Department of Computer Science, University of Copenhagen (DIKU)
Date: April 17, 2018

Preamble

This is the text is an excerpt of the exam set for the 4 hour written re-exam in Computer Systems (CompSys), B1+2-2017/18. This document consists of 10 pages excluding this preamble; make sure you have them all. Read the rest of this preamble carefully. Your submission will be graded as a whole, on the 7-point grading scale, with external censorship.

- You can answer in either Danish or English.
- Remember to write your exam number on all pages.
- You do not have to hand-in this preamble.

Expected usage of time and space

The set is divided into sub-parts that each are given a rough guiding estimate of the time needed. However, your exact usage of time can differ depending on prior knowledge and skill.

Furthermore, all questions includes formatted space (lines, figures, tables, etc.) for in-line answers. Please use these as much as possible. The available spaces are intended to be large enough to include a satisfactory answer of the question; thus, full answers of the question does not necessarily use all available space.
If you find yourself in a position where you need more space or have to redo (partly) an answer to a question, continue on the backside of a paper or write on a separate sheet of paper. Ensure that the question number is included and that you in the in-lined answer space refers to it; e.g. write "*The [rest of this] answer is written on backside of/in appended page XX.*"

For the true/false and multiple-choice questions with one right answer give only one clearly marked answer. If more answers are given, it will be interpreted as incorrectly answered. Thus, if you change your answer, make sure that this shows clearly.

Exam Policy

This is an *individual*, open-book exam. You may use the course book, notes and any documents printed or stored on your computer, but you may not search the Internet or communicate with others to answer the exam.

Errors and Ambiguities

In the event of errors or ambiguities in the exam text, you are expected to state your assumptions as to the intended meaning in your answer. Some ambiguities may be intentional.

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1 Machine architecture (80 minutes)

1.1 True/False Questions (8 minutes)

For each statement, answer True or False. (Put one "X" in each.)	True	False
a) Within Boolean arithmetic then `~(A & B) = (~A)^(~B)`.		
b) The largest `unsigned char` has the value 256.		
c) The lowest `signed char` has the value -128.		
d) Assume `x` and `y` are signed natural values (e.g. `long`), then the C expression `(x < y) == ((-x) > (-y))` is always evaluated to true.		
e) In the Linux call model, the return address of a procedure call is located in a special purpose register.		

1.2 Multiple Choice Questions (8 minutes)

In each of the following questions choose one answer.

Multiple Choice Questions, 1.2.1: In a pipelined architecture, resolving correctness of a predicted jump is performed in the:

☐ **a)** Fetch phase (`F`),

☐ **b)** decode phase (`D`),

☐ **c)** execute phase (`X`), or

☐ **d)** memory phase (`M`).

Multiple Choice Questions, 1.2.2: The 6-bit two's complement number `100101` represents the value

☐ **a)** 37,

☐ **b)** 27,

☐ **c)** 17,

☐ **d)** -17,

☐ **e)** -27, or

☐ **f)** -37.

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1.3 Data Cache (16 minutes)

Given a byte-addressed machine with 16-bit addresses. The machine is equipped with a 4-way set associative data cache of 8 kilobytes. Cache have a block size of 16 bytes.

Data Cache, 1.3.1: For each bit in the table below, indicate which bits of the address would be used for

- block offset (denote it with `O`),
- cache tag (denote it with `T`), and
- set index (denote it with `S`).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Data Cache, 1.3.2: Consider the stream of storage references in hexadecimal format:

`0xA010` , `0xF020` , `0xFF20` , `0xFF0C` , `0x0028` , `0xF0A4` , `0xF034` .

Assuming that the cache initially is cold followed by referencing the above stream. Given that the cache uses LRU replacement, what is the effect of a following reference to address: `0x0024`.

Block Offset:	`0x`
Set Index:	`0x`
Cache tag:	`0x`
Cache hit or miss:	
In case of cache miss, which cache tag is evicted:	

Data Cache, 1.3.3: Briefly argument for your answer regarding cache hit/miss and address eviction and show the content of the set before and after the reference.

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1.4 Assembler programming (30 minutes)

Consider the following program written in X86-assembler.

```
1  program:
2    movq  %rdi, %rax
3    movl  $0, %edx
4    jmp L2
5  L3:
6    addq  (%rax), %rdx
7    addq  $8, %rax
8  L2:
9    cmpq  %rsi, %rdx
10   jl  L3
11   subq  %rdi, %rax
12   sarq  $2, %rax
13   ret
```

Assembler programming, 1.4.1: Rewrite the above X86-assembler program to a C program and explain the functionality of the program. The resulting program should not have a goto-style and minor syntactical mistakes are acceptable.

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Assembler programming, 1.4.2: Argument for your choice of statements and expression. Specify which part of the program are not directly translated and argue why.

Assembler programming, 1.4.3: Briefly describe the semantic difference between logical and arithmetical shifts.

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2 Operating Systems (80 minutes)

2.1 True/False Questions (8 minutes)

For each statement, answer True or False. (Put one "X" in each.)	True	False
a) `fopen()` is not a system call.		
b) There is never more physical memory than virtual memory.		
c) System calls are implemented via signals.		
d) Virtual memory requires a disk.		
e) System calls run in user mode.		
f) Condition variables cannot be efficiently implemented solely with mutexes.		

2.2 Multiple Choice Questions (12 minutes)

In each of the following questions, you may put one or more answers.

Multiple Choice Questions, 2.2.1: Which of the following operations are guaranteed to execute atomically?

☐ **a)** `pthread_cond_signal()`

☐ **b)** `pthread_mutex_lock()`

☐ **c)** `x++` (when `x` is `int`)

☐ **d)** `memcpy(&x, &y, sizeof(x))`

☐ **e)** `pthread_cond_wait()`

☐ **f)** `exit(0)`

Multiple Choice Questions, 2.2.2: Consider a demand-paged system with the following time-measured utilisations:

CPU utilisation	50%
Paging disk	0.7%
Other I/O devices	75%

Which of the following would likely improve CPU utilisation?

☐ **a)** Install a faster CPU.

☐ **b)** Install a bigger paging disk.

☐ **c)** Install a faster paging disk.

☐ **d)** Install more main memory.

☐ **e)** Increase the degree of multiprogramming.

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2.3 Long Questions (36 minutes)

Long Questions, 2.3.1: Which of the following programming techniques and data structures are "good" for a demand-paged environment, and which are "bad" (performance-wise)? Explain your answers.

- Stack
- Hash table
- Sequential search of array
- Sequential search of linked list
- Binary search of array
- Vector operations (such as vector addition or computing dot products)

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3 Computer Networks (80 minutes)

3.1 True/False Questions (8 minutes)

For each statement, answer True or False. (Put one "X" in each.)	True	False
a) Implementation of link layer protocols span both hardware (network controllers) and software (operating systems).		
b) Peer-to-peer architectures exhibit better scalability because adding peers results in an increase in cumulative bandwidth available for all communicating parties.		
c) For a TCP connection, the receive window can never become zero.		
d) Convergence time of OSPF protocol is independent of the number of edges in a network.		

3.2 Multiple Choice Questions (15 minutes)

In each of the following questions choose one answer.

Multiple Choice Questions, 3.2.1: Consider a two dimensional even parity scheme for error detection. Using this scheme compute the parity bits of the 8-bit ASCII[1] representation of "REEXAM" where each byte of the word forms a row for the two dimensional parity scheme. The resultant parity bits (row followed by column parity bits) are

☐ **a)** 111100 00000110

☐ **b)** 111101 00000010

☐ **c)** 100101 00001110

☐ **d)** None of the above

Multiple Choice Questions, 3.2.2: The broadcast address of the network 117.18.31.54/18 is

☐ **a)** 117.18.31.255

☐ **b)** 117.18.63.255

☐ **c)** 117.18.127.255

☐ **d)** None of the above

[1] ASCII codes of A-Z lie contiguously between decimal numbers 65-90.

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3.3 Short Questions (24 minutes)

Short Questions, 3.3.1: Why is an ARP query sent within a broadcast frame while the ARP response is sent within a frame having a specific destination address?

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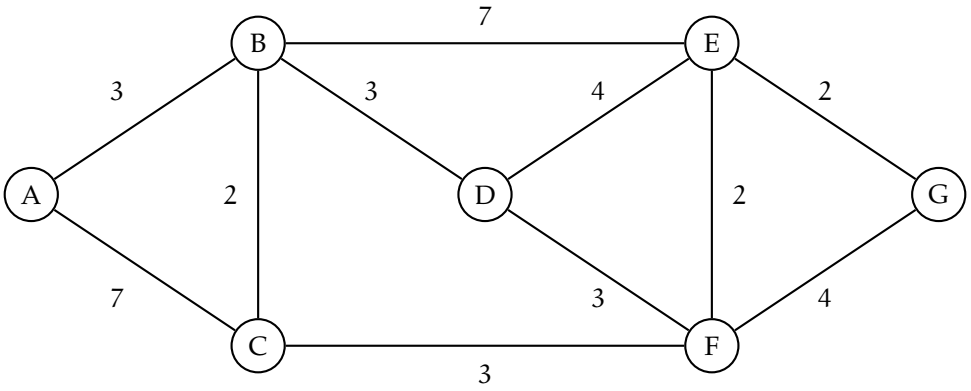
3.4 Network Routing (18 minutes)

Consider the network topology outlined in the graph below



Network Routing, 3.4.1: Apply the link state routing algorithm and compute the forwarding tables on nodes A and D. (Note: Remember to show the steps of the algorithm.)

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Network Routing, 3.4.2: List the problems that are overcome using hierarchical routing.