COMP28112 Model Answers

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May 20, 2015

These are my own answers to the COMP281 papers. Use them at your own risk; they are probably all wrong.

2011 Paper

Describe one key difference between client-server and peer-to-peer applications. 2011.1.a (2 marks)

P2p does not have a central point of coordination; all nodes are the same in terms of functionality (though they may have different roles). A client server architecture is dissimilar to this in the fact that the machines that make up the network have different capabilities and responsibilities that cannot be changed.

Explain briefly what failures are known as Byzantine failures and what the Byzantine generals problem refers to. 2011.1.b (2 marks)

Byzantine failures are ones where processes send failed messages since they are malicious or faulty.

The Byzantine Generals problem refers to a situation where two generals are situated on the sides of a valley and want to attack a city in the valley. To win the battle, they must attack at the same time, but they cannot coordinate their attack with any guarantee of timing it properly since they can only send messages through the city where the messengers may be killed or the contents of the message changed.

Describe briefly the two-phase commit protocol. 2011.1.c (2 marks)

Explain briefly why somebody would choose to use Cloud Computing. 2011.1.d (2 marks)

Why is it practically impossible to achieve strict consistency in a distributed system? 2011.1.e (2 marks)

It is practically impossible to achieve strict consistency in a distributed system since latency is not zero, so you can never know exactly what is going on in a remote system at any one time. Messages can get lost or mutated too, which further complicates the sending and updating of state between systems.

Suppose the C function below is to be made available to remote processes using RPC. What particular implementation problem does this highlight? Why is the normal solution only partly satisfactory? 2011.1.f (2 marks)

```
void doIt (int *p, int *q) { (*p)++ ; (*q)-- ; return ; }
```

You would have to serialise and deserialise the values of p and q to have this function run over RPC, because it uses pointers as opposed to actual values. You would also have to update the value of the pointers either as they are updated during the RPC functions execution or after the function has finished executing.

Distinguish carefully between a name server and a directory server. 2011.1.g
(2 marks)

A name server takes the name of a resource and resolves it into the address of the resource (e.g. a URL). A directory server takes attributes about an object (e.g. the amount of RAM of a server or the age and course studied of a student) and returns information about objects that have the same attributes (think LDAP)

What is meant by the term causally ordered multicast? 2011.1.h
(2 marks)

Ummmmm? Maybe take a look here: `http://www.cse.buffalo.edu/~stevko/courses/cse486/spring13/lectures/12-multicast2.pdf`

Looks like every process has a vector clock and when a message is received, the process waits until it can preserve the causal ordering before accepting the message. This means it waits until messages that had been previously sent to it (according to the vector clock) arrive before accepting the new message. Until then, the message is buffered.

What properties are provided by a secure channel? 2011.1.i
(2 marks)

A secure channel is one that third parties cannot eavesdrop on. They might be able to see the data passing through, but it will be encrypted somehow so they wont be able to make sense of it.

The Andrew File System (AFS) uses callback promises. Explain what this means. 2011.1.j
(2 marks)

Dunno? Google turns up not much...

Im guessing that it is a mechanism where if you send a remote server a message, it promises to reply back to you and will cause a callback to execute in your code when it does.

Explain briefly why some applications are not parallelisable. Describe Amdahls law and explain what it can be used for. 2011.2.a (3 marks)

Some applications are not parallelisable because they have operations that are interdependent. For example, if we were building a machine to compute how long it takes for the collatz conjecture to reach 1 given an input number, we could not parallelise it since each stage of the conjuncture depends on the last. Amdahls law dictates how much we can speed up the execution of a program given how much of the program is parallelisable. The law is:

$$\frac{1}{\text{serial portion} + (\frac{1}{\text{num threads}} \times \text{parallel portion})}$$

Explain briefly what the four properties commonly denoted by the acronym ACID are when referring to transactions. 2011.2.b (3 marks)

ACID stands for:

Atomic - All or nothing principle; either the transaction is committed and its changes are applied, or no state is changed as a result of the transaction.

Consistent - Each transaction moves the system from one valid and consistent state to another.

Isolated - Each transaction executes independently from all other transactions (even if they may be happening concurrently). The effect of transactions in progress is hidden from all other transactions.

Durable - Once a transaction is committed, it stays committed even in the event of failure such as power loss etc

A service is replicated onto 3 computers. 2011.2.c (6 marks)

- The first computer, A, has a mean time between failures of 2 days.
- The second computer, B, has a mean time between failures of 3.5 days.
- The third computer, C, has a mean time between failures of 12 days.

When a failure occurs, it takes on average 12 hours to fix.

What is the availability of the replicated service? 2011.2.c.i (2 marks)

We need to find the chance that all the computers will fail at the same time. It is easy to find the up-times for each individual computer:

A - 75%

B - 85.7%

C - 95.83%

The chance that these will all fail at the same time is: $(1 - 0.75) * (1 - 0.875) * (1 - 0.9853) = 0.00046 = 0.046\%$
Therefore, the uptime is going to be $100 - 0.046 = 99.954\%$

What would the availability of the replicated service be if only computers A and B were used? 2011.2.c.ii (2 marks)

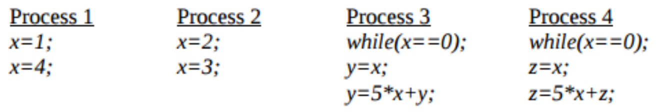
If only A and B were used, it would be:

$1 - ((1 - 0.75) * (1 - 0.875)) = 0.96875 = 96.88\%$

Describe how in the general case of n computers, each with a mean time between failures f_i and an average time to fix a failure t_i you would choose the two computers that provide the highest availability. 2011.2.c.iii (2 marks)

Rank the computers in ascending order of t_x/f_x, and take the top n elements.

The following four processes access a shared variable x. Each process accesses a different replica of the store used to hold this variable. Before any process starts executing, the value of x is 0 in all the replicas. 2011.2.d (8 marks)



Process 1	Process 2	Process 3	Process 4
x=1;	*x=2;*	*while(x==0);*	*while(x==0);*
x=4;	*x=3;*	*y=x;*	*z=x;*
		*y=5*x+y;*	*z=5*x+z;*

When all four processes have completed executing the statements given, are 7 and 14 possible values of y and z respectively, if the replication uses the sequential consistency model? Justify your answer. 2011.2.d.i (4 marks)

With a sequential consistency model, it is not possible for the final values to be $y = 7$ and $z = 14$, since for y to equal 7, x must change state while process 3 is running, and this is not possible in a sequential consistency model since only one process can execute at once.

The possible values of x when process three actually starts are $x = 4$ and $x = 3$, none of which let $y = 7$.

When all four processes have completed executing the statements given, are 7 and 14 possible values of y and z respectively, if the replication uses the causal consistency model? Justify your answer. 2011.2.d.ii (4 marks)

Using a causal consistency model, we still can't get $y = 7, z = 14$, since we need $y = 5 \times (x = 1) + (y = 2)$ and $z = 5 \times (x = 2) + (z = 4)$, but this can never happen, since for $z = 4$, we need to have done $x = 1$, but we need to have done $y = 2$ before that, which means that we would have already done $x = 2$.

Describe in detail the Bully algorithm for the election of a leader in a distributed system. 2011.3.a.i (8 marks)

The Bully Algorithm works like this:

- An initiating client will send a message to all other clients with a higher identifier than itself.
- Any client receiving an election message will then start its own election, sending messages to clients with higher identifiers than itself.
- Only when a process gets no replies (within a timeout) is it considered elected. It then sends a message to all other processes announcing its election.

In this manner, any process that receives a message should always send a message back to the sender

Carefully explain all the assumptions made in the Bully algorithm. 2011.3.a.ii (4 marks)

- The timeouts are reasonable
- All processes know about all other processes (and their loads)
- Messages are delivered quickly
- Messages are delivered reliably

Describe one application for which the Bully algorithm might be applied, indicating why a leader is needed. 2011.3.b (2 marks)

In a peer-to-peer protocol (such as bit torrent), the Bully algorithm can be used to elevate a node to coordinator status if the client that was coordinating the network went offline or started to get a too high load.

In a system containing 6 computers, identified by the integers 1-6, the leader is chosen by the Bully algorithm to be the live one with the highest identifier. Assume for this part that all messages are delivered promptly, and that the computers and the network are entirely reliable. 2011.3.c (6 marks)

How many messages in total are sent so that the computer with identifier 1 after it is rebooted can learn the identity of the leader by triggering an election? Take care to explain your working! 2011.3.c.i (6 marks)

Since identifier 1 is the lowest node, it will exhibit worst case behaviour for the bully algorithm, $O(n^2)$.

This is because 1 will send five messages out (to each other process) to start the election. Client 2 will then send out four messages (to the ones bigger than it) etc, until there are $5 + 4 + 3 + 2 + 1 + 0 = 15$ messages sent. Since every client receiving an election message replies to the sender, then 15 replies will be sent (in addition to the 15 initial message). Then, the winner of the election (6) will send a message out to say that it is elected, which is another 5 messages, bringing the total to 35.

Repeat (i) with the computer rebooted and needing to discover the leader being that with identifier 5 instead. 2011.3.c.ii (2 marks)

If 6 wasn't online anymore, then the number of messages sent would be $(5+4+3+2+1)+(4+3+2+1)+4 = 29$,

2012 Paper

What is a Java servlet? 2012.1.a
(2 marks)

A Java Servlet is a Java program with the capabilities of a server. It could host web pages, provide an API endpoint or other services and is most commonly used to serve content via the `HTTP` protocol.

What is the main assumption on which Cristians clock synchronisation algorithm is based? 2012.1.b
(2 marks)

The time for a message to go from machine A to machine B is (roughly) the same as the time it would take for a message to go from machine B to machine A. This is most often accurate for routes with small round trip times.

Explain the difference between a name server and a directory server. 2012.1.c
(2 marks)

A name server takes a name, matches it to an object and returns attributes about the object. A directory server takes attributes, matches them to an object and returns more attributes about the object.

Explain briefly what is meant by the term middleware. 2012.1.d
(2 marks)

Middleware is software that sits between a client application and the operating system. It provides services to the client application that the operating system does not, such as RPC stubs.

It can also provide an abstraction from the OS to mask the heterogeneity of platforms used in distributed systems (some apps will run on Windows, others on Linux, some on x64, some on ARM architectures etc).

Why is it practically impossible to achieve strict consistency in a distributed system? 2012.1.e
(2 marks)

Strict consistency is when any read to a shared data item returns the most recent write operation on that data item. This means there must be an absolute time ordering of all accesses. Unfortunately, since (as we know from the eight fallacies of Distributed Computing), the latency of any network is not zero and messages are not reliable. This means that any message we send to update other machines about a change of state may not be sent. Since there is no way of getting an absolute global clock or getting any global state, then we cannot achieve real time memory consistency across all nodes, and therefore cannot achieve strict consistency in the system.

Traditional RPC mechanisms cannot handle pointers. What is the problem? 2012.1.f
(2 marks)

In order to handle pointers with RPC, you must serialise the datastructure into a message so that it can be constructed from the same message at the other machine. When the reply is received back at the sender, it can be deserialised again and the values in the datastructure that were changed on the remote machine can be updated in local memory. Traditional RPC mechanisms didn't have this facility.

What is meant by parameter unmarshalling? 2012.1.g
(2 marks)

Extracting the parameters from an RPC message (can be binary data, ascii etc) that was sent from another machine into memory of the local machine.

What is the key difference between caching and replication 2012.1.h
(2 marks)

Replication is keeping two fully fledged entities up to date with each other in order to provide redundancy or distribute the load of a service over more machines.

Caching is merely a small piece of hardware or a small program that remembers the results of expensive computations after they've been done once and returns the result without doing any computation if the same request comes again. Rarely is there any business logic in a cache.

Explain briefly why somebody would like to use Cloud Computing. 2012.1.i (2 marks)

- You don't have to buy and own hardware, you can just rent time from other people's hardware to do computing.
- Clouds are large and therefore provide capacity for horizontal scaling.
- Clouds make it easier to have the computing resources to apply techniques such as load balancing, replication and parallelization. This can make it easier to cope with variable demand.

In the context of lab exercise 2, what would you do to launch a denial of service attack against the server? 2012.1.j (2 marks)

I would find the most computationally expensive operation on the server (maybe list free slots, since it access the database a lot) and set up a tight loop to continuously send requests for this operation to the server. To increase the impact of my attack, I would try and execute it on a machine with a high network bandwidth and low latency, as well as possibly using multiple threads or machines to launch the attack.

Explain briefly what is wrong with the assumption latency is zero in the context of distributed computing. Why is it considered a common fallacy? 2012.2.a (3 marks)

The latency between two computers can never be zero, for a number of reasons. From a purely physical standpoint, information cannot travel faster than the medium through which it is being carried, and even the fastest medium available to us, light has a speed limit. Most of the time, latency is significantly greater than the speed of light divided by the distance travelled, which is because most of the time, the data passes through a network as packets, and is forwarded on from node to node each time. Since multiple computers are used to facilitate this, each one having some small amount of lag, the time between the start point and the destination increases further. At any point along its route, the data could get stuck in a buffer, have to take a detour etc.

Many (new) programmers haven't created applications intended to use distributed systems before, and thus don't realise that waiting for a remote resource, RPC call etc can (will) take orders of magnitude more time than a load from memory might.

Explain briefly what the four properties commonly denoted by the acronym ACID are when referring to transactions. 2012.2.b (3 marks)

Atomicity - Each operation/transaction must either succeed or fail; there is no in-between. If the operation fails, then the state of the system must be exactly as it was before the start of the operation.

Consistency - Each operation or transaction must bring the state of the system from one valid state to another.

Isolation - Operations or transactions happening in parallel must execute as though they were running in a serial manner.

Durability - Once a transaction is committed or an operation is completed, the system will not roll back to a previous state in the event of failure or power loss etc.

Outline the Byzantine Generals problem, and illustrate how one of three being a traitor makes a solution impossible, whereas with one of four it is achievable. 2012.2.c (6 marks)

There are three Byzantine generals on the battlefield. One is the commander and the other two are his deputies. Each of the 'good' generals knows that the others could be corrupt, but not which one (or any of them). In order to make sure they never do the wrong thing, they agree that a commander must receive the same message from both other commanders before he does anything.

However, if one commander is corrupt, they can change every message they receive and make it so that the other two commanders will never do anything since the other two commanders will always receive conflicting messages.

However, if there is one corrupt commander within four (or more) commanders, then they can never cause a deadlock like that, because they will always be a minority among the other non-corrupt commanders.

The following four processes access a shared variable x. Each process accesses a different replica of the store used to hold this variable. Before any process starts executing, the value of x is 0 in all the replicas. 2012.2.d (8 marks)

```
Process 1      Process 2      Process 3      Process 4
x=1;           x=2;           y=0;           z=2;
                              if(x==1)       if(x==2)
                                y=y+1;         z=z+2;
                              if(x==2)       if(x==1)
                                y=y+2;         z=z+1;
```

When all four processes have completed executing the statements given, are 3 and 5 possible values of y and z respectively, if the replication uses the sequential consistency model? Justify your answer. 2012.2.d.i (4 marks)

No, because for $y = 3$ and $z = 5$, the values of x must change during the execution of process 3 and process 4. This cannot occur in a sequential consistency model, since each process must run one after another, and process 3 and 4 don't change the value of x.

When all four processes have completed executing the statements given, are 3 and 5 possible values of y and z respectively, if the replication uses the causal consistency model? Justify your answer. 2012.2.d.ii (4 marks)

No, since for $y = 3$ and $z = 5$ require all of the if statements to evaluate to true and execute all of the additions, since $0 + 1 + 2 = 3$ and $2 + 2 + 1 = 5$. Since process 3 requires x to be 1 first and process 4 requires it to be 2 first, we can only ever get three of the four if statements to execute. This means we can get either $y = 3$ or $z = 5$ (or none of them), but not both.

Explain briefly what is the role of a client stub and a server stub in RPC 2012.3.a (3 marks)

A stub is middleware that sits between an application and the OS. Its role is to facilitate an RPC call, but its exact 'job description' varies based on whether its a client or server stub:

Client:

1. First, the stub will marshal the parameters to the remote method into a text or binary format.
2. The client stub then sends the request to the server (where the server stub will handle it) and waits for a reply.
3. Once it receives a reply the client stub unmarshals the data from the servers reply back into memory and returns back to the client application.

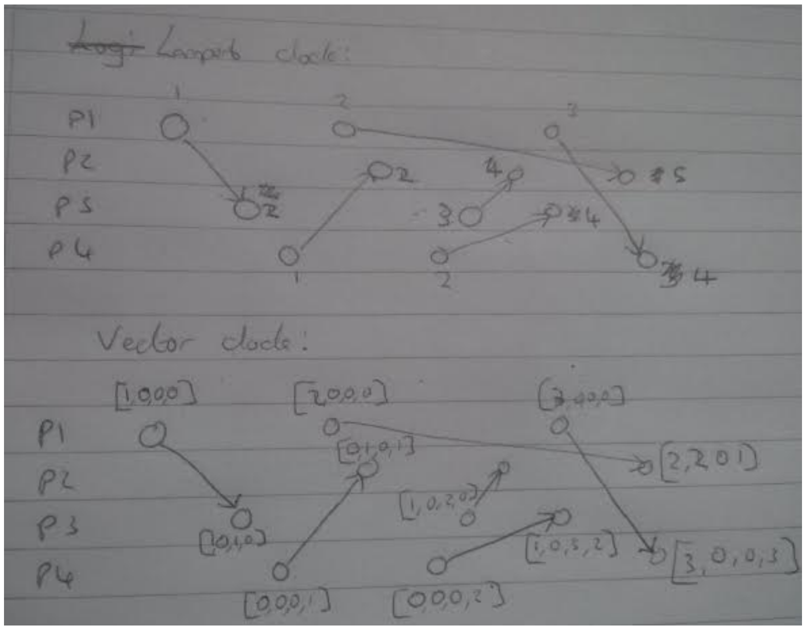
Server:

1. When the server receives a message from a client sub, it unmarshals the parameters and puts them in memory.
2. Then it calls the desired procedure on the server application
3. When the procedure has finished, it marshals the data back into a message and sends it back to the client.

Describe in detail how the two-phase commit protocol can implement distributed transactions 2012.3.b (5 marks)

- There is a server that acts as a coordinator.
- When a client wants to commit a transaction, it sends a message to the server asking to commit.
- The server then sends a message to all clients asking if they are in a state where they can commit.
- Each client sends a reply (either yes or no) as to whether they can commit.
- If all of the clients are in a position to commit, then the server will send out a `global_commit` message and all clients will commit, otherwise, it will send out a `global_abort` message and all clients will abort the transaction.

Consider the figure below, which shows 4 processes and a number of communication events taking place over a period of time. Calculate the value of Lamport clocks and vector clocks for each of the 12 events. You can assume that all logical clocks start initially with zeros. 2012.3.c (6 marks)



In a system containing 7 computers, identified by the integers 1-7, the coordinator is chosen by the Bully algorithm to be the live one with the highest identifier. Assume for this part that all messages are delivered promptly, and that the computers and the network are entirely reliable. At a certain point in time the coordinator (computer 7) and the computer with the second-highest identifier (computer 6) crash. How many messages in total are sent if the computer with identifier 1 is the computer discovering the crash and triggering an election? You need to count all three types of messages that the algorithm sends. You can assume that computers with identifiers 6 and 7 remain crashed during the election. 2012.2.d (6 marks)

First, 1 will send a message to all computers higher than it $(2, 3, 4, 5, 6, 7)$ totalling six messages. Each live process receiving a message from 1 will then send messages to processes higher than it:

Computer	**Election messages sent**
1	$2, 3, 4, 5, 6, 7$
2	$3, 4, 5, 6, 7$
3	$4, 5, 6, 7$
4	$5, 6, 7$
5	$6, 7$
6	Crashed!
7	Crashed!

This totals $6 + 5 + 4 + 3 + 2 = 20$ messages sent.

Each process then receives a reply from the live ones above it:

Computer	**Replies received**
1	$2, 3, 4, 5$
2	$3, 4, 5$
3	$4, 5$
4	5
5	
6	
7	

This totals $4 + 3 + 2 + 1 = 10$ messages.

The winner of the election (5) then sends a message to all other processes to announce its win (five more messages), so a total of $20 + 10 + 5 = 35$ messages are sent.