Define bandwidth.

1

Define throughput.

2

On a graph diagram of a distributed system, what is represented by the nodes on the graph?

3

Name some properties of edges that connect the nodes in a graph of a distributed system.

4

Why is it that even though connections between nodes can be implemented in different ways (such as wifi or Ethernet), they can be treated as the same?

5

Name the eight axioms of distributed systems.

6

Why is transparency desirable in a distributed system?

7

What is transparency of location? How can we achieve it?

8

Throughput measures the actual rate at which messages are communicated.

2

Bandwidth measures the maximum amount of data that can be communicated within a certain amount of time.

1

The type of connection (wired/wifi/mobile data etc).
The bandwidth.
The latency.

4

The physical nodes of the network (individual systems). Each can host multiple processes and resources.

3

- *Latency is greater than zero.*
- *Bandwidth is less than infinite.*
- *Transport cost is greater than zero.*
- *There is more than administrator.*
- *The network topology can and will change.*
- *The network is not homogeneous (the nodes and edges differ).*
- *The network is not secure.*
- *The network is not reliable.*

6

The implementation details of each connection is abstracted away by many layers of protocols.

5

An attempt to hide the need to know of where a specific resource is physically located.
Use DNS servers to map host names to IP addresses.

8

It allows us to design systems as though the distributed axioms were false.

7

What is transparency of migration? How can we achieve it?

9

What is transparency of relocation? How is it achieved?

10

What is transparency of replication. How is it achieved?

11

What is transparency of access? How is it achieved?

12

What is transparency of concurrency?

13

What is deadlock?

14

What is livelock?

15

What is transparency of failure? How is it achieved?

16

When a host moves location in the network, we shouldn't need to the details of the move.
The DNS architecture implements this, though if a resource keeps moving, then the route through the network and therefore the latency of the connection to the host is hard to predict.

9

Transparency of relocation is when parts of the system move while they are being accessed. This is hard to mitigate, and is often a problem with mobile phone communications.

10

When there is more than one physical resource that does the same job, which one do we use? It is hard to achieve.

11

Transparency of access is the ability to not care about how a node is implemented. This is often achieved using protocols and API's and middleware.

12

Different users shouldn't need to know that others are using the same resource and may be competing for its time. Atomic operations and enforcing consistency are ways to achieve this, but this can force users to wait on each other (deadlock, livelock etc).

13

When two different processes are unable to progress since each is waiting for information from the other.

14

When two processes change with respect to one another so that neither can make progress.

15

Users should not know that a specific node has failed or has recently had downtime. Hard to ensure, since sometimes slow connections are indistinguishable from failed nodes.

16

Define systems software.

17

Describe the start of the mainframe era.

18

What advances were made during the mainframe era?

19

What is the danger of multiprogramming?

20

What three things can help multiprogramming be effective?

21

How does the scheduler make decisions about programs?

22

In the beginning of the PC era, what was a typical PC like?

23

What happens to the price of PC's during the PC era?

24

- *Hardware was vastly more expensive than people.*
- *Only single user programs.*
- *Programs had to be written every time they were to be run.*

18

The underlying level of software which allows applications to perform their tasks efficiently. Examples include device drivers and the operating system.

17

One program could potentially have access to data in other programs, which could present security/compatibility concerns. Memory protection is used so that programs can only read and write stuff they own.

20

- *The ability to store programs was developed.*
- *Batch processing, where jobs would be written to a queue to be executed. Lost the ability to debug.*
- *Use interrupt handlers and buffers to allow the CPU and IO to work in parallel.*
- *Multiprogramming so that one program has the CPU and another has the IO to enable full resource utilisation.*

19

Give them priority levels.

22

- *Fairness policies that impose limits on how much resources jobs should use*
- *Schedulers that aim to minimise the time it takes to complete jobs, by reducing their response and turnaround time.*
- *Preemptive scheduling will temporarily stop jobs if they are hogging resources.*

21

Price falls due to commoditization and competition.

24

Everything was cut back with just a single user in mind; no timesharing, multiprogramming or protection in the OS, few resources such as memory and CPU power etc.

23

How does the usage of PC's change during the PC era?

25

What does WIMP stand for and when was it introduced?

26

What drove an increase in security focus during the PC era?

27

What are the four standard layers of the network protocol stack?

28

When did middleware start to become widely used?

29

In the device era, CPU cycles, storage space and power is all limited. How is this overcome?

30

Since there are millions of requests sent to data centres in the device era, how is the demand handled?

31

What is the aim of the operating system with regard to resource management?

32

Windows, Icons, Menus, Pointer

The WIMP system became common during the PC era.

26

They become used for more simple tasks such as word processing, rather than number crunching and enterprise processing.

25

Name	**Example**
Application Layer	`HTTP`, `POP`, `SSL`
Transport Layer	`TCP`, `UDP`
Internet Layer	`IP`, `ICMP`, `IGMP`
Link Layer	`ARP`, `Ethernet`, `DSL`, `ISDN`

28

The fact that sharing data over networks was becoming increasingly common, which exposed security risks. Authentication and authorisation methods were therefore developed.

27

Make use of connectivity to servers to offload computation somewhere else. This is called the cloud.

30

At the beginning of the web era. API's are used to provide a generic interface between the OS and programming languages so that system calls are no longer needed. The OS must support middleware rather than implementing functions itself.

29

To make the most efficient use of the available resources as possible.

32

Elastically scalable architectures made up of commodity hardware are developed along with middleware such as hadoop and map reduce in order to allow for massively parallel computation.

31

How is memory access controlled by the operating system? 33	*Why is it important that a process only have access to isolated areas of memory?* 34
Each process executes in a sequential manner, what is a disadvantage of this? 35	*What is a* **scheduling policy** *with regard to operating systems?* 36
Describe forking. 37	*Describe threading.* 38
When there are many independent, self-sufficient, autonomous, heterogeneous machines working together with spatial separation, what is required to facilitate effective working? 39	*A significantly long interconnect (i.e. a [redacted]) is not [redacted].* 40

So that processes cannot interfere with each others memory, because of a bug or malicious intent.

34

- *The OS assigns a* **unique identity** *to each process.*
- *Each process is then assigned an* **address space**
- *The OS ensures each process P has a single address space A that is exclusive to that process.*

33

A method of granting each process a time during which it is executed, enabling multiple processes to execute in a concurrent fashion, even though there may be only one physical set of resources.

36

If there was some task that took ages to do, say an API request over a slow network connection, then it might be sensible to execute other tasks (maybe preparing data for another API request) while the current task is executing (i.e. make the tasks concurrent). Due to the sequential nature of processes, this is not done.

35

When a new thread is created in a process:

- *A new child process is created*
- *The address space is shared between the child and the parent.*
- *The parent and child processes are less isolated, and can therefore interact together easier, however, this can be dangerous and a source of bugs.*
- *Since the no memory is copied, threading is less expensive than forking.*

38

When a process forks (through an OS system call) the following happens:

- *A child process is created*
- *It is given a copy of the parent process's address space, though each address space is distinct.*
- *This causes two copies of the process to be active concurrently.*

37

A significantly long interconnect (i.e. a full blown network) is not cost-neutral.

40

Message exchange over a network, best facilitated with a middleware API to abstract away some complexity.

39

Describe an SISD architecture.

41

Describe an SIMD architecture.

42

Describe a MISD architecture.

43

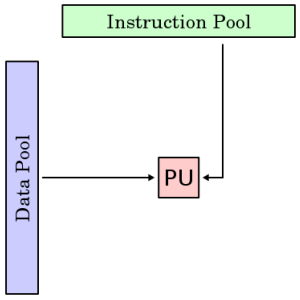
Describe a MIMD architecture.

44

Describe the advantages of a MIMD architecture.

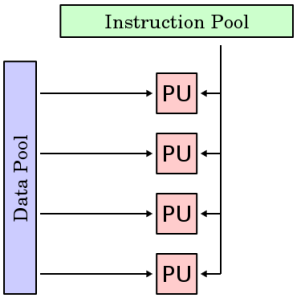
45

What architecture is this:



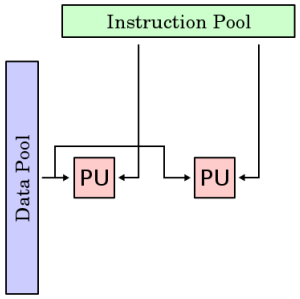
46

What architecture is this:



47

What architecture is this:



48

A single instruction/program, multiple dataset architecture. This could be used to describe a computer with a GPU that is applying **the same** *transformation to many pixels at once. Access to data is* **not** *cost neutral since the data is being shared amongst different instances of a program/instruction.*

42

A single instruction/program, single dataset architecture. An example of this is an older, single core PC, where there is only data space (the main memory) and there is cost neutral access to it.

41

A multiple instruction/program, multiple dataset architecture. Here, a form of interconnect will bind together several self sufficient autonomous components. The interconnect isn't cost neutral, but the gain in functionality is great. This architecture is widely used in applications such as clouds, clusters, and even multi-core PC's.

44

A multiple program/instruction, single dataset architecture. Though not as useful as other architectures, a sample MISD use case is in safety critical systems where two independent processors could compute the same function on the same data and check their results against each other.

43

SISD

46

A MIMD architecture allows you to scale out instead of up. An architecture that lets you scale out is one where you can add more hardware (such as servers/hard drives) as opposed to upgrading existing hardware which is scaling up (i.e. increasing the RAM in a server).

45

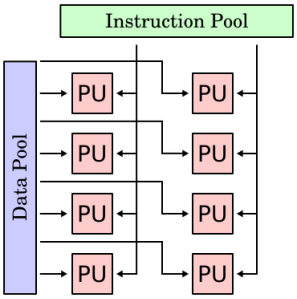
MISD

48

SIMD

47

What architecture is this:



49

MIMD architectures (aka [redacted] *architectures) often communicate over a* [redacted] *such as* [redacted] *that exists* [redacted] *to the architecture itself.*

50

What does vBNS stand for?

51

What does OC stand for? What does OC-n mean?

52

What is the network protocol stack?

53

What are the five layers of the protocol stack?

54

Describe the job of the application layer.

55

Describe the job of the transport layer.

56

MIMD

49

MIMD architectures (aka shared-nothing architectures) often communicate over a network such as the Internet that exists separately to the architecture itself.

50

Very high performance Backbone Network Service.

51

OC stands for Optical Carrier.

$$OC\text{-}n = n \times 54.84 Mbit/s$$

52

Layers of protocols that talk to each other to facilitate network connectivity.

53

$$\begin{aligned} Application &\leftrightarrow Transport \\ &\leftrightarrow Internet \\ &\leftrightarrow Link \\ &\leftrightarrow Physical \end{aligned}$$

54

To take care of specific application needs such as sending emails or HTTP requests.

55

To make sure that there is a logical channel for messages to flow through. E.g. TCP

56

Describe the job of the Internet layer.

57

What is the job of the link layer?

58

What is the job of the physical layer?

59

What is the hourglass model?

60

What is a packet switched network?

61

What is the job of a router in a packet switched network?

62

What are some differences between TCP and UDP?

63

What is packet encapsulation?

64

Making sure that there is a physical channel to pass data through. E.g. MAC

58

To make sure packets sent over the network reach their intended destination. E.g. IP

57

Very varied application layers at the top of the network stack (emails, streaming video etc), as simple protocols as possible in the middle of the stack, and very varied physical devices at the bottom (bluetooth, wifi, optical fibre etc).

60

To physically pass messages between networked components. Deals with all the physics etc. E.g. Wifi

59

To examine the header data in each packet and send the packet on to another router in the network that is closer to the packet's destination, while accounting for how saturated datapaths are in order to find an efficient route.

62

- *A network of networks formed by interconnecting routers.*
- *The message is divided into packets before transmission.*
- *The packets are reconstituted into the original message at reception.*
- *Packets may take varied routes while in transit, and be grouped with unrelated packages from other messages.*

61

Each layer of the networking stack wraps messages in a packet that contains information about the packet. By the time the packet has descended to the physical layer, then it may have many layers of headers and metadata.

64

- *TCP is connection oriented, UDP isn't.*
- *TCP is reliable and ensures that messages arrive at their destination, intact and in the right order. If the messages do not arrive, then it will be known. UDP only provides a corruption guarantee.*
- *UDP is more lightweight than TCP and is better for quick communication where the occasional loss or out of order packet isn't a problem.*

63

Why does packet encapsulation enable flexibility?

65

What does IPC stand for?

66

A successful communication between processes must consist of one process being [redacted] *coinciding with another process being* [redacted]*. This is non trivial with* [redacted]*.*

67

Describe Direct Message Exchange as a Distributed Architecture.

68

What is asymmetric DME?

69

What is a symmetric DME?

70

What is a MME architecture?

71

If a message in a MME architecture goes to more than one destination it is described as being a [redacted]*, if messages only go to one destination, then the system is described as being* [redacted]*.*

72

Inter-Process Communication

66

It doesn't matter about what information the packet is carrying, at each layer of the network stack, the callee layer has multiple choices of what protocol to use for the next level on the stack, and simply chooses the most convenient/suitable one.

65

In order to communicate, the sending process must be in a position to send and the receiving process must be in a position to receive messages. Upon receiving a message, a process may interpret it and then respond.

68

A successful communication between processes must consist of one process being ready to send coinciding with another process being ready to receive. This is non trivial with independent timelines.

67

Direct Message Exchange where no special roles are assigned to processes, also known as a peer-to-peer architecture. Event synchronisation is less simple with a symmetric DME than with an asymmetric one.

70

Direct Message Exchange where processes are assigned special roles such as a client or server in order to simplify the process. All the server has to do is wait for messages and all the client has to do is send messages.

69

If a message in a MME architecture goes to more than one destination it is described as being a public subscribe system, if messages only go to one destination, then the system is described as being point to point.

72

A Mediated Message Exchange architecture is one where inter process communication goes through a central middleware component (often referred to as message orientated middleware). Allows for event synchronisation to be decoupled in time since the middleware is always avalible.

71

What is RPC?

73

Why is middleware such as MME, RPC and RMI beneficial?

74

What is a protocol?

75

The operating system provides an [redacted] *for IPC.*

76

Name two important OS services relied on by an API for IPC in the OS.

77

Sockets are [redacted] *the network stack provided by the operating system to abstract away the details of* [redacted]*. In this manner, communicating processes* [redacted] *to each others sockets in an* [redacted] *style manner.*

78

What the lifecycle of a client side socket?

79

How is a server side socket **set up***?*

80

They raise the level of abstraction at which we can build and engineer distributed systems.

74

A remote procedure call is similar to a message, though the data is passed as parameters to a method. It is often facilitated by middleware such as `CORBA`*. When OOP principles are involved, RPC is called* **Remote Method Invocation (RMI)**.

73

The operating system provides an API (application programming interface) for IPC.

76

A set of rules for inter process communication that stipulates the precise sequence of events that must be enacted by the communicating processes for them to successfully communicate.

75

Sockets are an additional layer on the network stack provided by the operating system to abstract away the details of low level IPC. In this manner, communicating processes read and write to each others sockets in an I/O style manner.

78

- *Keeping network buffers.*
- *Providing synchronisation mechanisms.*

77

1. *The socket is created for a given transport protocol (E.g. UDP) and Internet protocol (E.g. IPv4)*
2. *Set the options for the socket, such as whether it is reusable.*
3. *Bind the socket to the address and port to listen on.*
4. *Start listening for connections, set the maximum number of connections to leave in a queue if there is a significant load.*

80

1. *The socket is created for a given transport protocol (E.g. TCP) and Internet protocol (E.g. IPv6)*
2. *A connection is then opened with the desired IP/port combination.*
3. *The client then sends a request through the socket and waits for a response (through the same socket).*
4. *The server then replies with a response, which may come in chunks.*
5. *Once the response has been received, the socket is closed and discarded.*

79

How are connections handled in a server side socket?

81

When is the benefit most useful from massively parallelising a task?

82

When a task is divided into parts for execution on many machines, what challenges are presented in doing this?

83

Operations that seem [redacted] *may actually* [redacted] *further down the software stack. This can cause problems if seemingly atomic operations are running concurrently, since they could* [redacted] *further down the stack and interfere with each other.*

84

What is a synchronisation primitive?

85

What is a barrier?

86

When can an expression be split into multiple parts?

87

We can split the following expression into `x + y` *and* `a + b` *to be parallelized. What is the blocking point?*

```
c = (a+b) * (x+y)
```

88

When the data can be partitioned and multiple computers can work on the data independently then the performance benefits are most significant.

82

1. *The socket waits to accept a connection.*
2. *When a connection is accepted, a new socket is created with the IP address and port of the connecting client in it.*
3. *The server process then handles the new connection as appropriate, e.g. by spawning a thread and passing the socket to that thread.*
4. *The server process can then continue in its loop (back to stage 1).*

Note that spawned sockets and their handlers need to be closed properly after the client has disconnected.

81

Operations that seem atomic may actually compile down into several different steps further down the software stack. This can cause problems if seemingly atomic operations are running concurrently, since they could interleave further down the stack and interfere with each other.

84

- *What if we have more workers than tasks, or more tasks than workers?*
- *How do we know if all the workers have finished?*
- *How do we aggregate the results of the workers?*

83

A synchronisation primitive that forces multiple processes to wait at the barrier until they have all reached the barrier. For this to be efficient, all the processes must reach the barrier more or less at the same time.

86

A language construct that provides access to a shared variable with a OS/hardware guaranteed atomicity. Used to enforce execution sequences.

85

The assignment to `c`.

88

When independent branches of the expression do not have any shared state, they can be executed in any order or parallelized.

87

When designing tasks for parallelized computation, the goal is to identify and eliminate as many [redacted] *as possible and eliminate them, so that the* [redacted] *can be carried out on different machines as* [redacted] *as possible.*

89

How does map reduce make it easier to make tasks independent?

90

Why are functional programs easy to parallelize?

91

The `map` *function takes* [redacted] *and* [redacted] *and returns* [redacted]

92

Why is `map` *parallelizable?*

93

`Reduce` *takes a* [redacted] *and* [redacted]*, and returns* [redacted]

94

How can `reduce` *be parallelized?*

95

How is the map and the reduce stage synchronised with each other in Hadoop and other map-reduce engines?

96

By limiting the expressiveness of the computation of the tasks so they can be more easily parallelized.

90

When designing tasks for parallelized computation, the goal is to identify and eliminate as many synchronisation points as possible and eliminate them, so that the independent tasks can be carried out on different machines as efficiently as possible.

89

The `map` *function takes a collection* `[i_1, ..., i_n]` *and a function* `f` *and returns the collection* `[f(i_1), ..., f(i_n)]`

92

Since pure functions are side effect free, meaning that two functions used in the same expression are guaranteed not to share state and so can be parallelized safely.

91

`Reduce` *takes a binary associative function* `f(x,y)` *and a collection* `[i_1, ..., i_n]`*, and returns f(i_n,f(...,f(i_0, i_1))...)*

94

Since the function applying to the collection can be applied to each item in the collection independently, and is side effect free.

93

With a barrier.

96

Have different parts of the list run in different tasks and then apply the function to the result of tasks to combine them together again at the end.

95

What useful features do map-reduce engines such as Hadoop implement?

97

Just look over this one. Make sure you understand how the map-reduce architecture works.

98

If you have a network built of identical worker nodes, each working on a partition of some dataset, then the computation is [redacted]*, and could be refered to as a form of* [redacted] *strategy. However, if you have a network built of heterogenous workers that are operating on data that are not partitions of a single dataset, then you have* [redacted] *computation, which is a case of* [redacted]*.*

99

A distributed system working within one company is referred to as an [redacted] *(EAI) system.*

100

A distributed system spanning multiple companies is referred to as an [redacted] *(B2B) system.*

101

What is an RIA?

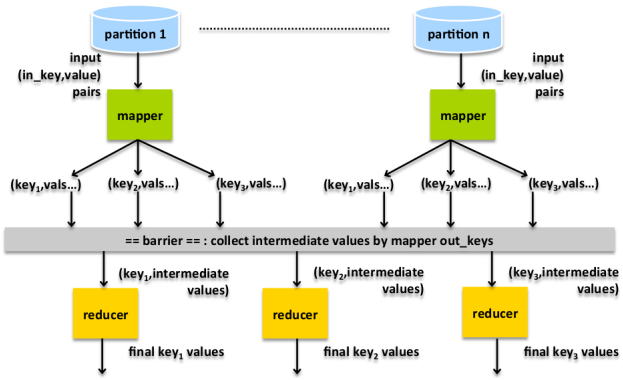
102

What is a web mashup?

103

The `WS-*` *view is a family of standards that all start with* '`WS-`'*. It is an example of a* [redacted] *(SOA), and interactions are defined by a* [redacted] *protocol called* [redacted]*.* `WS-*` *interactions sit on top of other protocols such as* `HTTP` *or* `SMTP`*.*

104



98

- *Load balancing*
- *Fault tolerance*
- *Splitting, spawning and merging of tasks*

97

A distributed system working within one company is referred to as an enterprise application integration (EAI) system.

100

If you have a network built of identical worker nodes, each working on a partition of some dataset, then the computation is not inherently distributed, and could be refered to as a form of divide-and- conoquer strategy. However, if you have a network built of heterogenous workers that are operating on data that are not partitions of a single dataset, then you have an inherently distributed computation, which is a case of unite-and-conquer.

99

A Rich Internet Application (e.g. Gmail)

102

A distributed system spanning multiple companies is referred to as an buisiness to buisiness integration (B2B) system.

101

The `WS-*` *view is a family of standards that all start with* `WS-`*'. It is an example of a Service Oriented Architecture (SOA), and interactions are defined by a higher up protocol called SOAP.* `WS-*` *interactions sit on top of other protocols such as* `HTTP` *or* `SMTP`*.*

104

A lightweight web application that combines processing and data resources from different sources into a single application.

103

What does REST stand for?

105

How does REST operate?

106

In a RESTful service, interactions between components are [redacted], and the service is seen as a [redacted] ([redacted]).

107

What (according to the lecture slides) features do SOAP API's offer to justify them being more heavyweight?

108

This is the real difference between REST and SOAP API's.

109

In the Web of Data view, the web is [redacted].

110

Why is the data exposed by API's often hard to use with processing algorithms?

111

The Web of Data (WoD) is a [redacted], similar to a relational database, but with no predefined [redacted]. The [redacted] between [redacted] define relationships in the data.

112

The sender places a payload into a request such as `HTTP Post`*, which is then sent to a reciever. The reciever will then respond via the same method with the response (if any).*

106

REpresentational State Transfer.

105

- *Security, authemtication and authorization*
- *Robust addressing and reliable messaging*
- *Transactional semantics (fault tolerance features)*

The above are very useful in EAI and B2B contexts.

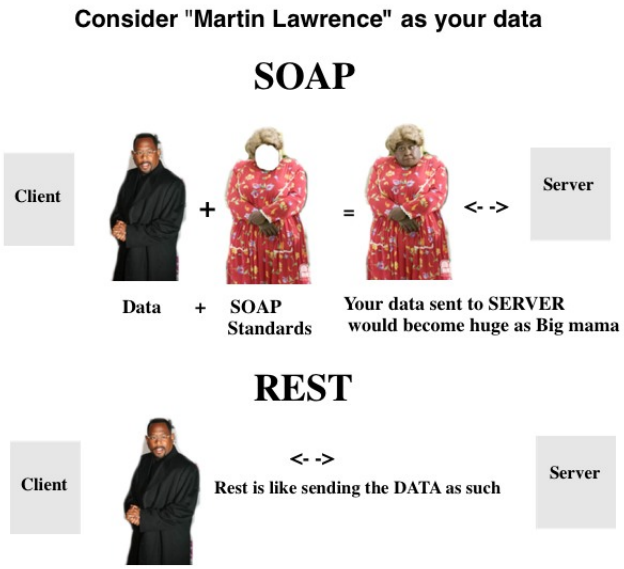
108

In a RESTful service, interactions between components are operations on resources, and the service is seen as a Resource Oriented Architecture (ROA).

107

In the Web of Data view, the web is a massive distributed database.

110



109

The Web of Data (WoD) is a graph, similar to a relational database, but with no predefined schema. The edges between nodes define relationships in the data.

112

Even though the data might be able to be parsed (i.e. if it's in JSON), the semantics of the data are still unclear since different API's follow different specifications and therefore it is hard to extract useful, unambigous data.

111

What does RDF stand for? What is it?

113

In the WoD, we have [redacted] *data where resources are URI-assigned nodes, linked by* [redacted].

114

What does OWL mean?

115

What is the function of the `HEAD` *HTTP verb?*

116

What is the function of the `GET` *HTTP verb?*

117

What is the function of the `POST` *HTTP verb?*

118

What is the function of the `OPTIONS` *HTTP verb?*

119

What does the 'store and forward' model mean?

120

In the WoD, we have linked data where resources are URI-assigned nodes, linked by explicitly declared relationships.

114

Resource Description Language. There are various implementations of RDF, such as XML, turtle format, N-triples format etc.

113

Provides metadata about a resource. Just like a `GET` *request, except the body of the request is not returned. Used to let clients know if cached data has changed.*

116

Web Ontology Language

115

Submits data to the server. The state of the server may change as a result of a `POST` *request.*

118

Gets a resource from the server.

117

When a message needs to be transmitted along a network, but not all the nodes along the path may be active at the same time. Consequently, the message is stored by each node until it has been confirmed to have been received by the next node.

120

Returns the list of commands supported by the server.

119

What is the SMTP protocol?

121

Describe 'reduction to absurdity'.

122

With a Lamport clock, how is the clock of A affected if B sends A a message?

123

Describe the purpose of a mutex.

124

What is a critical section?

125

Describe the two-phase commit.

126

Describe the bully algorithm.

127

Describe Cristian's algorithm?

128

Manchester University: a place where you get a score of 29/30 and yet still 78.7This is a type of argument where an idea is shown to be false by showing that an absurd result can be obtained by the acceptance of the idea.

122

The Simple Mail Transfer Protocol is a method for sending email. It is a stateful, connection based protocol, so a connection to the server must be opened before the message can be transferred, and then closed again after.

121

A mutex ensures that two processes do not enter into a critical section of their execution at the same time and therefore prevents race conditions and enables the safe sharing of resources.

124

```
if LCy < (LCx + 1):
    LCy = LCx + 1
```

123

1. *A coordinator node wishes all of the nodes to perform an action.*
2. *It sends a request to all of the other nodes.*
3. *The other nodes attempt to perform the action, and reply with* `commit` *or* `abort` *depending on whether they to performed the action.*

4a. *If any one of the nodes replied* `abort`*, then the coordinator node will reply* `global_abort` *and all the nodes will roll back their state to that of the start of the transaction.*

4b. *If all the nodes replied* `commit`*, then the coordinator node will send* `global_commit` *and the nodes will retain their current state.*

126

A critical section is a sequence of actions that should execute in an atomic matter. That is to say that if the critical section does not succeed, then the state of the system should be exactly the same as when the critical section started.

125

In order to synchronise the clocks of two systems, one system S will send it's time to another system C. After receiving the request from S, C will then reply with it's own clock time. When S receives this, then it will set its clock to be the time that C sent added to the round trip time (discernible from C's reply) divided by two.

128

1. *A node wants to be a coordinator, so it sends a message to all the other nodes with it's number.*
2. *All the other nodes will only reply if they have a higher number. If they do, they will start another election.*
3. *The process continues until a node receives no replies, and is therefore the coordinator, at which point, it will inform all the other nodes of this.*

127

Describe the Berkly algorithm.

1 *A master node is chosen.*
2 *The master polls the other nodes for the time.*
3 *The master observes the round trip time for each state, and estimates the time of each client.*
4 *The master then averages out the clock times and sends each node a message containing the difference that it is from the average.*