AQA Computer Science A-Level

4.9.4 The Transmission Control Protocol / Internet Protocol (TCP/IP)

Intermediate Notes

Specification:

4.9.4.1 TCP/IP:

Describe the role of the four layers of the TCP/IP stack (application, transport, network, link)

Describe the role of sockets in the TCP/IP stack

Be familiar with the role of MAC (Media Access Control) addresses

Explain what the well-known ports and client ports are used for and the differences between them.

4.9.4.2 Standard application layer protocols:

Be familiar with the following protocols:

- FTP (File Transfer Protocol)
- HTTP (Hypertext Transfer Protocol)
- HTTPS (Hypertext Transfer Protocol Secure)
- POP3 (Post Office Protocol (v3))
- SMTP (Simple Mail Transfer Protocol)
- SSH (Secure Shell)

Be familiar with FTP client software and an FTP server, with regard to transferring files using anonymous and non-anonymous access

Be familiar with how SSH is used for remote management

Know how an SSH client is used to make a TCP connection to a remote port for the purpose of sending commands to this port using application level protocols such as GET for HTTP, SMTP commands for sending email and POP3 for retrieving email

Be familiar with using SSH to log in securely to a remote computer and execute commands

Explain the role of an email server in retrieving and sending email

Explain the role of a web server in serving up web pages in text form

Understand the role of a web browser in retrieving web pages and web page resources and rendering these accordingly

4.9.4.3 IP address structure:

Know that an IP address is split into a network identifier part and a host identifier part

4.9.4.4 Subnet masking:

Know that networks can be divided into subnets and know how a subnet mask is used to identify the network identifier part of the IP address

4.9.4.5 IP standards:

Know that there are currently two standards of IP address, v4 and v6

Know why v6 was introduced

4.9.4.6 Public and private IP addresses:

Distinguish between routable and non-routable IP addresses

4.9.4.7 Dynamic Host Configuration Protocol (DHCP):

Understand the purpose and function of the DHCP system

4.9.4.8 Network Address Translation (NAT):

Explain the basic concept of NAT and why it is used

4.9.4.9 Port forwarding:

Explain the basic concept of port forwarding and why it is used

4.9.4.10 Client server model:

Be familiar with the client server model

Be familiar with the Websocket protocol and know why it is used and where it is used

Be familiar with the principles of Web CRUD Applications and REST:

- CRUD is an acronym for create, retrieve, update, delete
- REST enables CRUD to be mapped to database functions (SQL)

Compare JSON (Javascript object notation) with XML

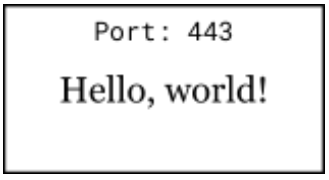
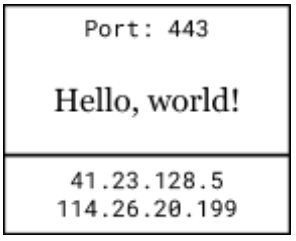
4.9.4.11 Thin- versus thick-client computing

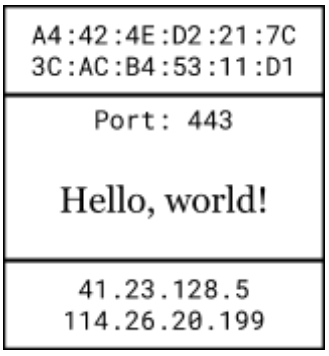
Compare and contrast thin-client computing with thick-client computing

TCP / IP

TCP / IP stands for transmission control protocol / internet protocol. The protocol is used in all parts of the Internet to enable different devices to communicate.

The protocol is formed from four distinct layers that form what's called the TCP / IP stack. These layers are application, transport, network, link and each is responsible for a seperate part of communication over the Internet.

Layer	Role
Application	Selects and uses the correct protocol to transmit data. The layer works with application software like a web browser. Let's suppose we're sending the following message over the Internet: *Hello, world!*
Transport	Establishes an end to end connection between the sender and the receiver and then splits the transmission into packets.  Contained in each packet is the port number to be used which identifies the protocol in use. In this case, port 443 is HTTPS.
Network	Provides the correct IP addresses for each packet's source and destination. These allow routers to send the packet towards their recipient. 

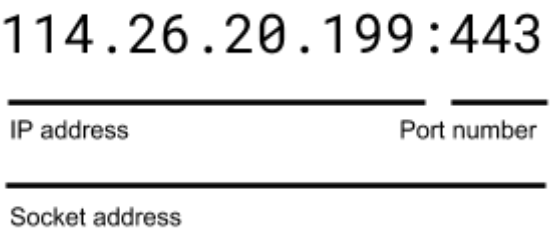
Link	Controls physical connections between pieces of hardware in a network. Adds MAC addresses to packets which it receives from the network layer.  MAC (which stands for media access control) addresses are assigned to every device that can connect to a network by their manufacturer and are unique to that device.

At the receiving end

Once a packet has been received by its intended recipient, it is stripped of its extra information by reversing the TCP / IP stack. The transport layer uses the packet's port number to determine the correct application to send the packet to.

Socket addresses

When an IP address is combined with a port number, a socket address is formed. These are formed from an IP address, followed by a colon, followed by the port number in use.



Because they incorporate a port number, socket addresses identify which of the applications on the recipient device a packet should be sent to.

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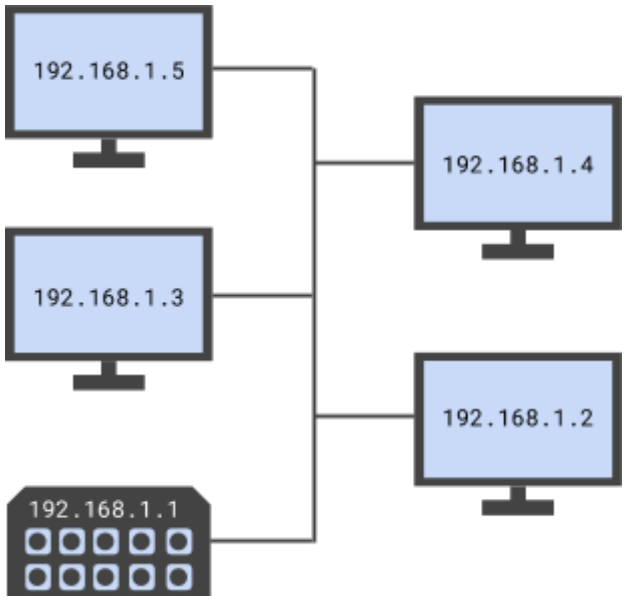
Well-known ports

The table below lists some well-known ports, their port number and their purpose.

Protocol	Port(s)	Purpose
FTP (File transfer protocol)	20 & 21	Used for sending files between devices. Clients can access FTP servers anonymously or non-anonymously by logging in with a username and password.
SSH (Secure shell)	22	Used for remote management of computers, allowing computers to be accessed and controlled remotely. SSH encrypts information during transmission.
HTTP (Hypertext transfer protocol)	80	Web servers hold web pages in text form, which they can deliver to clients using HTTP.
HTTPS (Hypertext transfer protocol secure)	443	HTTPS performs the same function as HTTP, but encrypts information during transmission.
POP3 (Post office protocol 3)	110 & 995	Used for retrieving emails from an email server.
SMTP (Simple mail transfer protocol)	25, 587 & 465	Used for sending emails.

The structure of IP addresses

An IP address is split into two parts: a network identifier and a host identifier. Each of the computers in a network shares the same network identifier but has its own host identifier.



Networks can be divided into smaller networks, called subnets. Each subnet has a different network identifier.

The network identifier part of an IP address can be determined with a subnet mask.

Let's say that a device has an IP address of 192.168.3.24 and a subnet mask of 255.255.255.0.

In order to work out which subnet the device belongs to, we have to apply the subnet mask as follows.

`192.168.3.24`
IP Address of device

`11000000.10101000.00000011.00011000`
IP Address of device (binary)

Convert IP address and subnet mask to binary

`255.255.255.0`
Subnet mask

`11111111.11111111.11111111.00000000`
Subnet mask (binary)

`11000000.10101000.00000011.00000000`
IP address AND subnet mask

Perform the AND operation on the subnet mask and the IP address

`192.168.3.0`
Network identifier (IP address AND subnet mask, in decimal)

As it happens, 255.255.255.0 is a fairly common subnet mask that is easy to use in examples. However, the same procedure can be applied to any subnet mask.

IP address standards

There are two types of IP address in common use: versions four and six (IPv4 and IPv6).

IPv4

IPv4 addresses consist of four parts that are separated by dots. Each of the four parts of an IPv4 address is assigned one byte (eight bits) allowing for numbers from 0 to 255 to be represented.

192.168.34.7

This allows for over 4 billion unique IPv4 addresses. That may sound like a lot, but IPv4 addresses are in short supply. The number of devices on the Internet that require a routable IP address is increasing so rapidly that a new version of IP address had to be created. This was IPv6.

IPv6

IPv6 addresses are formed of eight blocks separated by colons. Each block contains four hexadecimal characters (a-f and 0-9).

2071:0eb8:85a3:8a2f:0000:0000:0370:7264

IPv6 addresses use 128 bits which, compared to IPv4's use of 32, allows for far more unique addresses.

Public and private IP addresses

An IP address is said to be either routable or non-routable (public or private). If every device that is connected to a network had its own public IP address, there wouldn't be enough IP addresses to go around.

Instead, each home or business that requires internet access has a small number of public IP addresses. Most homes have just one public IP address while some businesses will have multiple addresses.

Public IP addresses are globally unique whereas millions of devices can have the same private IP address, provided they are not on the same network. Global authorities are responsible for assigning public IP addresses which ensures that the same address is never issued twice.

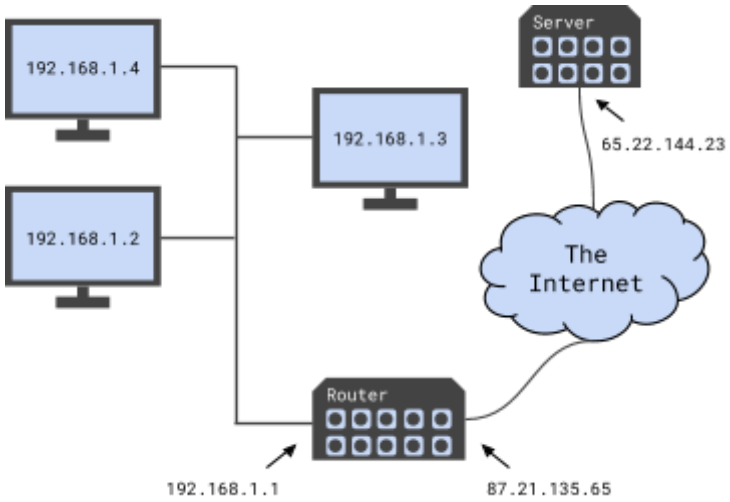
Dynamic host configuration protocol (DHCP)

The number of available private IP addresses within a private network is limited. Assigning each device on a network its own private IP address would not be sensible, as that device may leave and never join again, resulting in a wasted IP address.

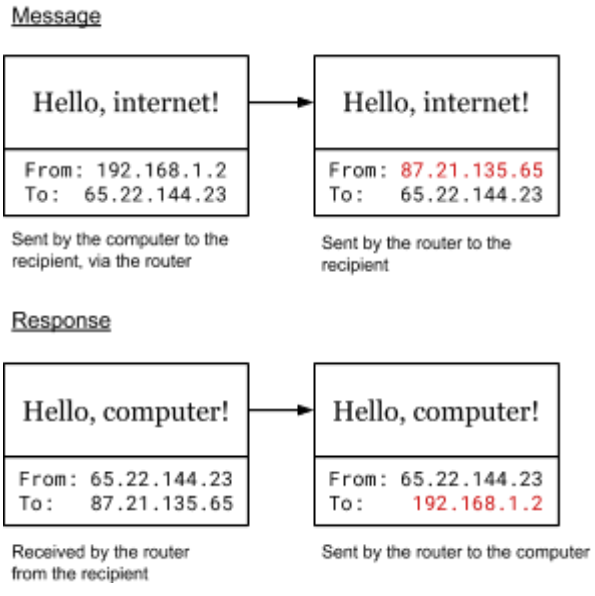
Instead, DHCP is used to assign IP addresses to devices as they join a network. DHCP uses a pool of available IP addresses to allocate IP addresses to new devices for the duration of their session. Once a device leaves the network, the IP address that the device was using is returned to the pool for allocation to a new device.

Network address translation (NAT)

The diagram shows a network consisting of three computers, each of which is allocated a private IP address. The network's router has two IP addresses, one private address on the private network's side and a public address on the Internet's side. There is a server connected to the Internet with a public IP address.



If a device on the network sent a packet to the server, the server couldn't respond to the computer directly because the computer's IP address is private - not globally unique.



NAT gets around this problem. When a device on the private network (let's use 192.168.1.2) needs to communicate with a device on the Internet (let's use the server), it sends packets through the router, which makes a record of the packet before replacing the private IP address of the computer with its own routable IP address.

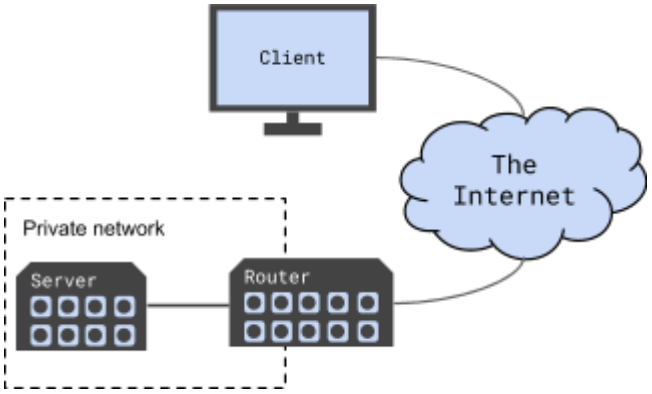
When a response is received, it is sent to the router's public IP address, which then forwards the response to the correct private IP address by using the record it made when sending the packet.

Port forwarding

Port forwarding is used when a client needs to communicate with a server that is connected to a private network.

The client sends packets to the public IP address of the router belonging to the server's private network.

The packets sent by the client contain the port number of the application running on the server that the client wishes to access.



The private network's router then forwards the packets to the server using NAT.

The client server model

In a network that uses the client server model, clients send request messages to servers, which reply to the clients with response messages. These messages may contain requested information, a confirmation that a requested action has been completed, or a message explaining why the requested action hasn't been completed.

APIs

An API (application programming interface) is a name given to a set of protocols relating to how different applications communicate with each other. They define how interaction between the applications should be carried out, allowing applications to make use of other applications.

The websocket protocol

The websocket protocol is an example of an API. The protocol can be used to provide a constant stream of information between two devices, usually a client's web browser and a server.

The connection created by the websocket protocol allows data to be transmitted in both directions at the same time and allows for fast transmission of data, making it useful for online games, instant messaging and video streaming.

Web CRUD Applications and REST

CRUD

CRUD is an acronym for **c**reate, **r**etrieve, **u**pdate, **d**elete; four commands that can be used to query online databases. Each of the four CRUD commands has a SQL equivalent.

CRUD	SQL
Create	INSERT
Retrieve	SELECT
Update	UPDATE
Delete	DELETE

Synoptic Link

Server query language (SQL) is used to query databases.

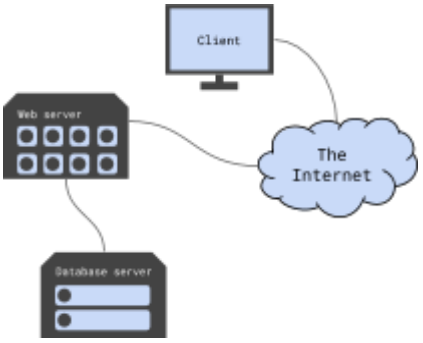
SQL is covered in detail under **fundamentals of databases**.

REST

An acronym for **re**presentational **s**tate **t**ransfer, REST is a design methodology for online database applications that are queried with a web browser.

REST uses the four HTTP request methods POST, GET, PUT and DELETE to query databases.

HTTP	SQL
POST	INSERT
GET	SELECT
PUT	UPDATE
DELETE	DELETE



When a client needs to connect to a database, it follows these steps:

1. Client-server request made by the client to the web browser
2. Web browser responds with the requested web page (which is delivered as a text file)
3. This text file contains JavaScript which loads an API. The API uses REST to enable the database server to be queried by the client with the use of HTTP request methods.
4. The client sends HTTP requests to the database server.
5. The database server responds to the client's requests using either JSON or XML.
6. The client's browser processes the JSON or XML and displays the response to the user.

XML and JSON

Database servers deliver responses to queries using either XML or JSON. XML stands for **e**xtensible **m**arkup **l**anguage and does the same job as **J**ava**S**cript **o**bject **n**otation (JSON).

XML	JSON

`<Department>`
`  <Subject>`
`  <Name>Physics</Name>`
`  <Board>Edexcel</Board>`
`  </Subject>`
`  <Subject>`
`  <Name>Maths</Name>`
`  <Board>AQA</Board>`
`  </Subject>`
`</Department>`
	`{`
	`  "Department": {`
	`  "Subject": [`
	`  {`
	`  "Name": "Physics",`
	`  "Board": "Edexcel"`
	`  },`
	`  {`
	`  "Name": "Maths",`
	`  "Board": "AQA"`
	`  }`
	`  ]`
	`  }`
	`}`

The table above shows the same information represented as both XML and JSON. As the table shows, JSON is more compact, easier to read, easier to create and faster for computers to process than XML. However, XML is sometimes seen to be more flexible than JSON.

Thin- and thick-client computing

Networks can be configured as either thin-client or thick-client networks.

Thin-client networks

In thin-client networks, the majority of the network's processing power belongs to servers which provide services and resources including storage and processing.

It's easy to add new clients to thin-client networks and the clients themselves are inexpensive machines. Thin-client networks also allow for greater centralised control of the network as software updates and security can be managed from the server.

However, thin-client networks require a powerful server which is expensive and requires expertise to set up and maintain.

Thick-client networks

In a thick-client network, the clients are powerful enough to provide their own processing power and storage. This independence eliminates the requirement for a server, although it is possible for thick-client networks can make use of a server.

Thick-client networks require more powerful clients than their thin-client counterparts, making the network expensive to set up. However, the cost and expertise required in setting up and maintaining an expensive server is done away with.

Thick-client networks are harder to maintain because there is no facility to issue updates and manage security from a central server.