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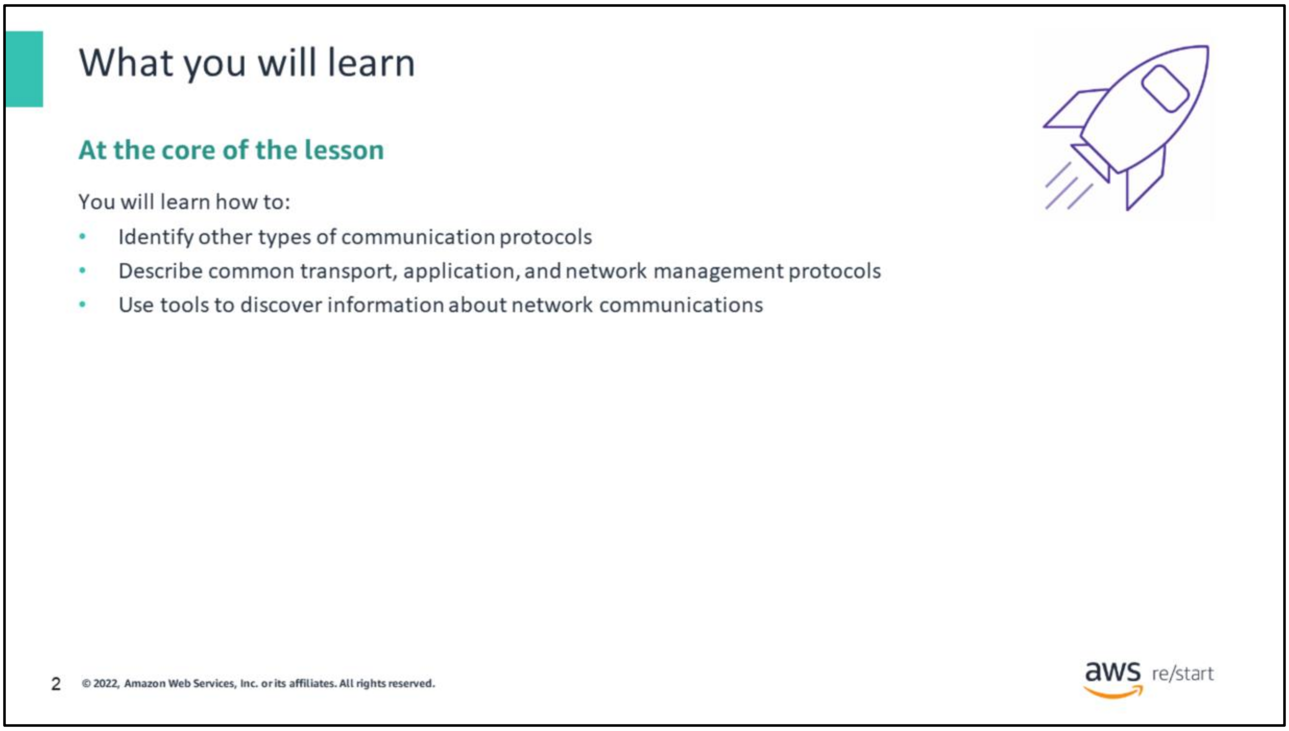
Additional Networking Protocols

Networking Fundamentals

Welcome to Additional Networking Protocols.



What you will learn

At the core of the lesson

You will learn how to:

- Identify other types of communication protocols
- Describe common transport, application, and network management protocols
- Use tools to discover information about network communications

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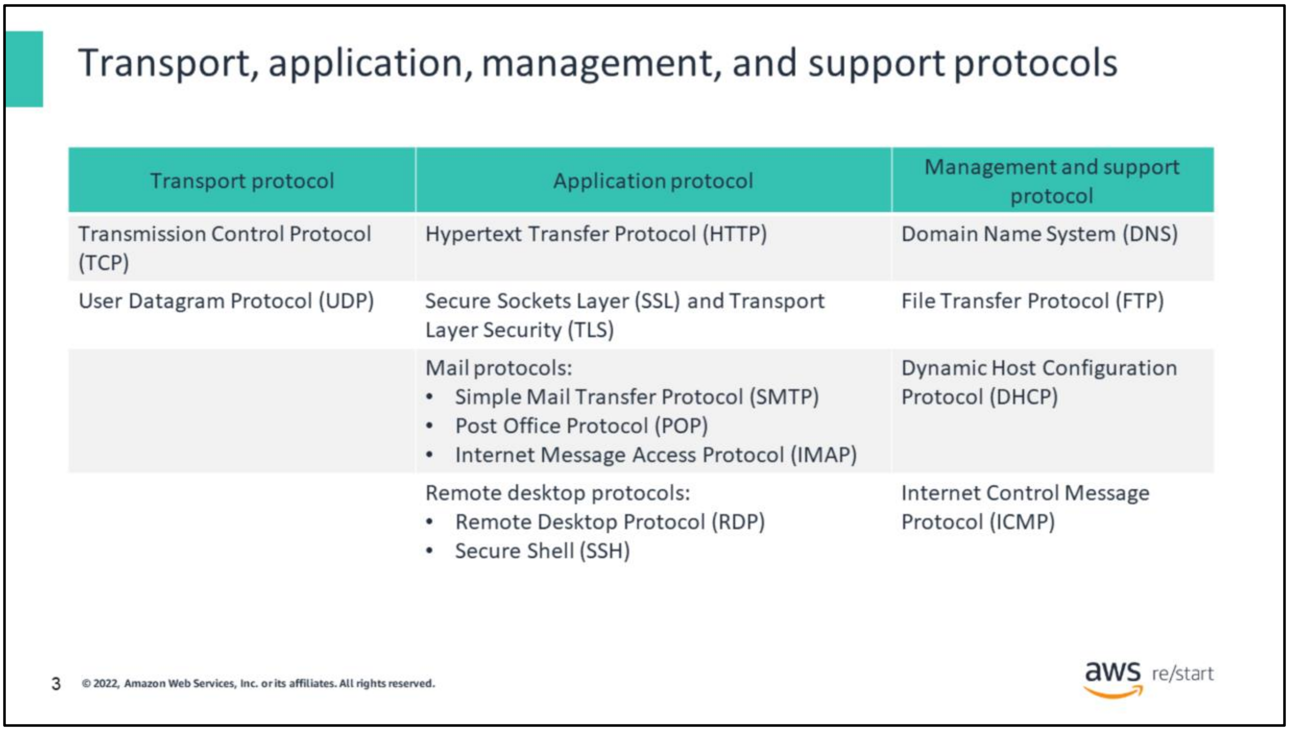


Transport, application, management, and support protocols

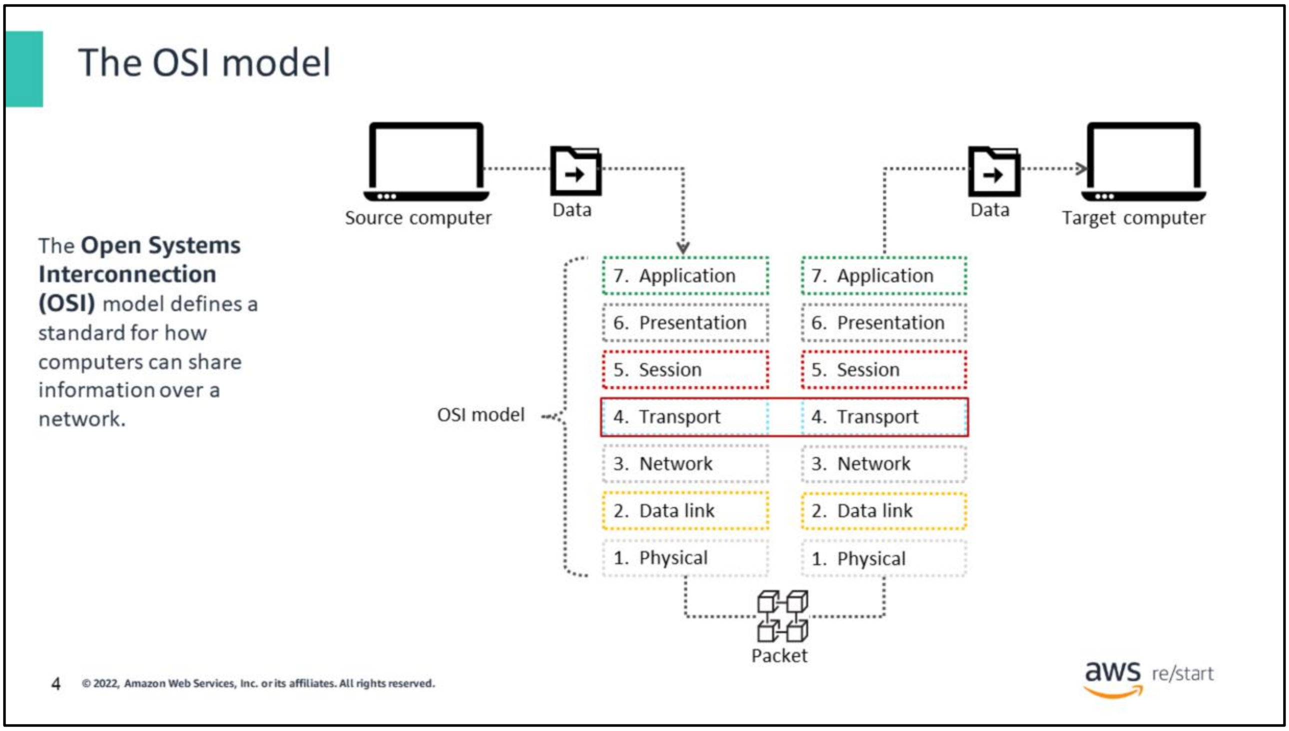
Transport protocol	Application protocol	Management and support protocol
Transmission Control Protocol (TCP)	Hypertext Transfer Protocol (HTTP)	Domain Name System (DNS)
User Datagram Protocol (UDP)	Secure Sockets Layer (SSL) and Transport Layer Security (TLS)	File Transfer Protocol (FTP)
	Mail protocols: • Simple Mail Transfer Protocol (SMTP) • Post Office Protocol (POP) • Internet Message Access Protocol (IMAP)	Dynamic Host Configuration Protocol (DHCP)
	Remote desktop protocols: • Remote Desktop Protocol (RDP) • Secure Shell (SSH)	Internet Control Message Protocol (ICMP)

A communication protocol is a system of rules. These rules permit two or more entities of a communications system to transmit information through any variation of a physical quantity. The different types of communication protocols include transport, application, management, and support protocols.

Transport protocols run over the best-effort IP layer to provide a mechanism for applications to communicate with each other. The two general types of transport protocols are a connectionless protocol (User Datagram Protocol) and a connection-oriented protocol (Transmission Control Protocol).

Application protocols govern various processes, from downloading a webpage to sending an email. Examples include HTTP, SSL, TLS, mail protocols (SMTP, POP, and IMAP), and remote desktop protocols (RDP and SSH).

Management protocols are used to configure and maintain network equipment. Support protocols facilitate and improve network communications.



The OSI model

The **Open Systems Interconnection (OSI)** model defines a standard for how computers can share information over a network.

You might recall the mention of Open Systems Interconnection (OSI) in your previous learning. The OSI model defines a standard for how computers can share information over a network regardless of the hardware or software that they use. The model divides the processing of data that is sent over a network into seven layers.

The diagram illustrates how data flows in an OSI-compliant network from a source computer to a target computer.

In the OSI model, the protocol layer above the internet layer is the transport layer. The two most important protocols in the transport layer are TCP and UDP. TCP provides reliable data delivery service with end-to-end error detection and correction, and UDP provides low-overhead, connectionless datagram delivery service. Both protocols deliver data between the application layer and the internet layer.

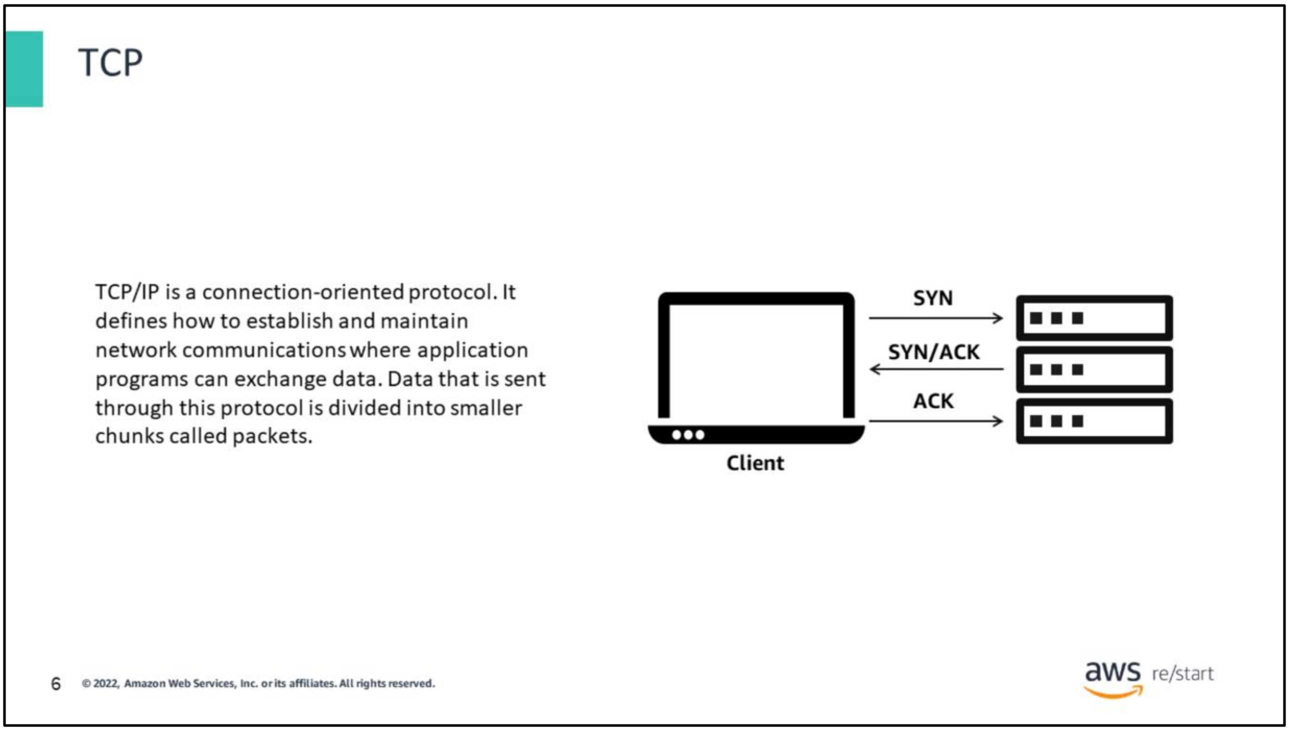
Why is this information important for issues and troubleshooting?

Because TCP and UDP use ports for communication, most layer 4 transport problems revolve around ports being blocked. When troubleshooting layer 4 communications issues, first make sure that no access lists or firewalls are blocking TCP/UPD ports.

Remember that the transport layer controls the reliability of any given link through flow control, segmentation and desegmentation, and error control. Some protocols can keep track of the segments and retransmit the ones that fail. The transport layer acknowledges successful data transmission and sends the next data if no errors have occurred. The transport layer creates packets from the data that it receives from the upper layers.

Transport protocols

In this section, you will learn more about transport protocols.



TCP

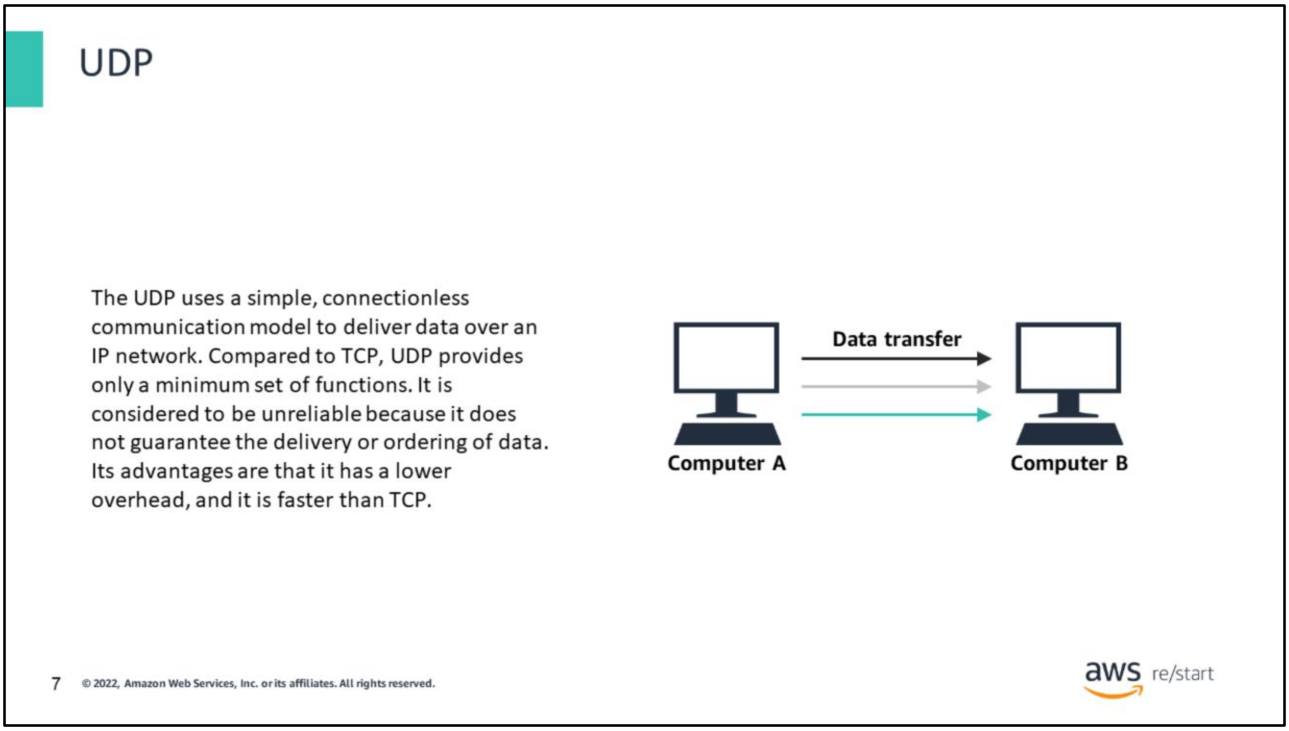
TCP/IP is a connection-oriented protocol. It defines how to establish and maintain network communications where application programs can exchange data. Data that is sent through this protocol is divided into smaller chunks called packets.

Recall that you first learned about TCP/IP earlier in this module. When TCP combines with Internet Protocol (IP), they form the TCP/IP protocol suite, a set of protocols that the internet runs on.

TCP/IP is a connection-oriented protocol. It defines how to establish and maintain network communications where application programs can exchange data. Data that is sent through this protocol is divided into smaller chunks called packets.

The goal of TCP/IP was to support an interconnection of networks, which was referred to as an internetwork, or internet. The internet comprises the groups of networks that communicate over this protocol.

In terms of the OSI model, TCP is a transport-layer protocol. It provides reliable virtual-circuit connection between applications; that is, a connection is established before data transmission begins. Data is sent without errors or duplication and is received in the same order as it is sent. No boundaries are imposed on the data; TCP treats the data as a stream of bytes.



UDP

The UDP uses a simple, connectionless communication model to deliver data over an IP network. Compared to TCP, UDP provides only a minimum set of functions. It is considered to be unreliable because it does not guarantee the delivery or ordering of data. Its advantages are that it has a lower overhead, and it is faster than TCP.

Data transfer
Computer A
Computer B
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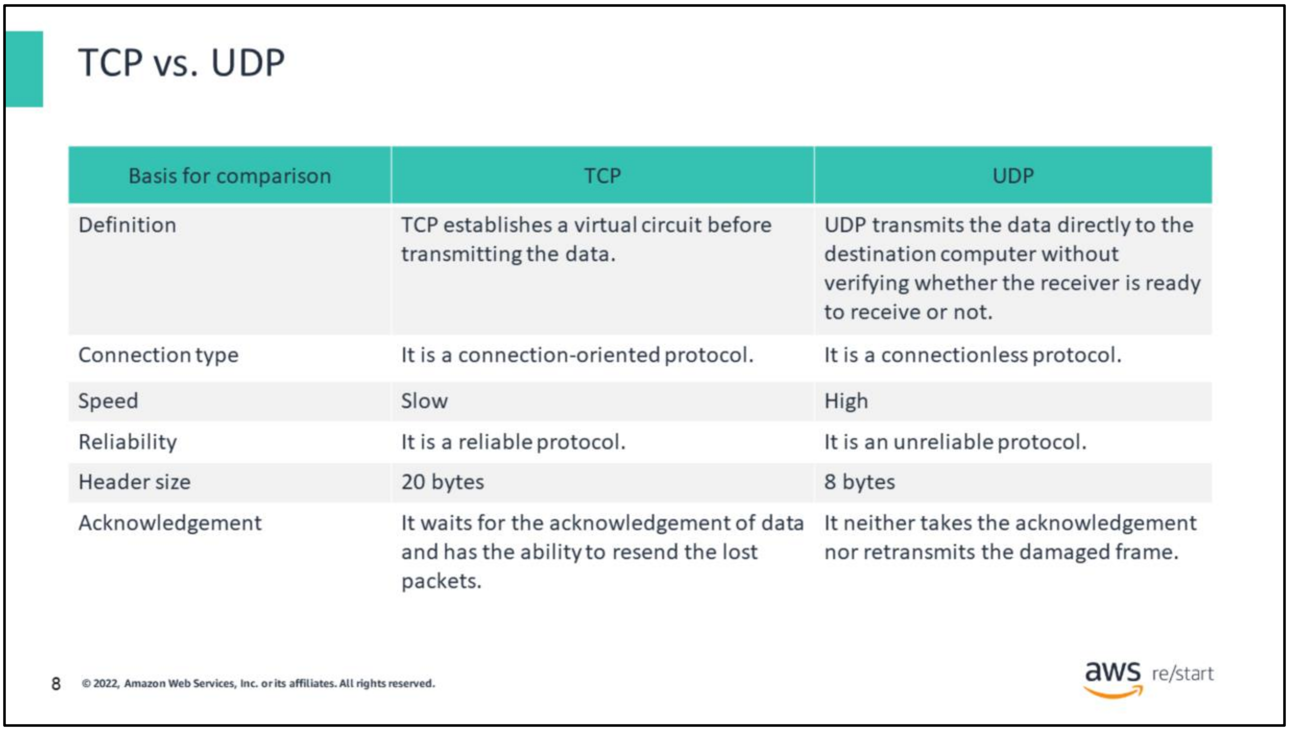
The UDP uses a simple, connectionless communication model to deliver data over an IP network. Compared to TCP, UDP provides only a minimum set of functions. It is considered to be unreliable because it does not guarantee the delivery or ordering of data. Its advantages are that it has a lower overhead, and it is faster than TCP.

Applications that value speed over guaranteed delivery use UDP. Examples include video chat and video streaming. A missed packet might cause a short pause in the video, but the video will still be mostly understandable. However, if the users must wait for all packets to be confirmed and ordered correctly, the delays can severely affect the quality of their experience.

In terms of the OSI model, UDP is also a transport-layer protocol and is an alternative to TCP. It provides an unreliable datagram connection between applications. Data is transmitted link by link; there is no end-to-end connection. The service provides no guarantees. Data can be lost or duplicated, and datagrams can arrive out of order.

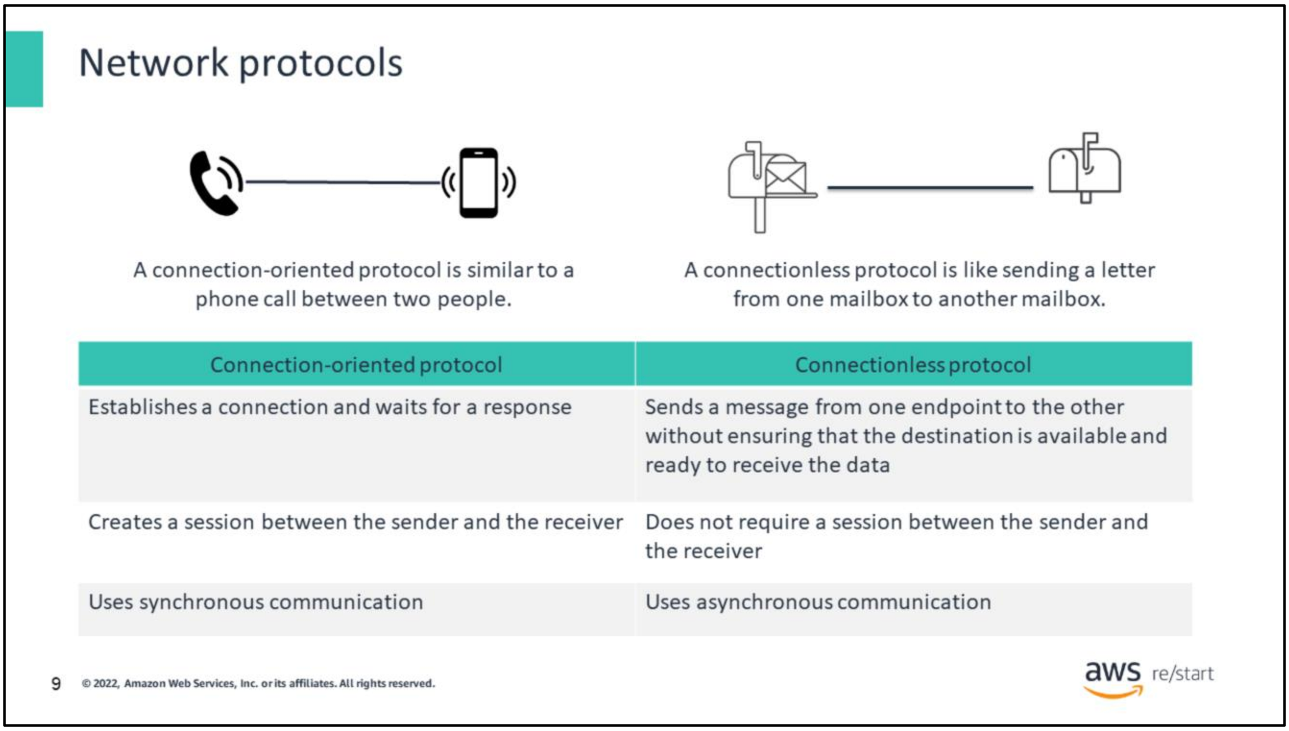


TCP vs. UDP

Basis for comparison	TCP	UDP
Definition	TCP establishes a virtual circuit before transmitting the data.	UDP transmits the data directly to the destination computer without verifying whether the receiver is ready to receive or not.
Connection type	It is a connection-oriented protocol.	It is a connectionless protocol.
Speed	Slow	High
Reliability	It is a reliable protocol.	It is an unreliable protocol.
Header size	20 bytes	8 bytes
Acknowledgement	It waits for the acknowledgement of data and has the ability to resend the lost packets.	It neither takes the acknowledgement nor retransmits the damaged frame.

In comparison, TCP is a connection-oriented protocol, which requires that hosts establish a logical connection with each other before communication can occur. This connection is sometimes called a *virtual circuit*, although the actual data flow uses a packet-switching network.

UDP is a connectionless protocol that treats each datagram as independent from all others. Each datagram must contain all the information that is required for its delivery.



Network protocols

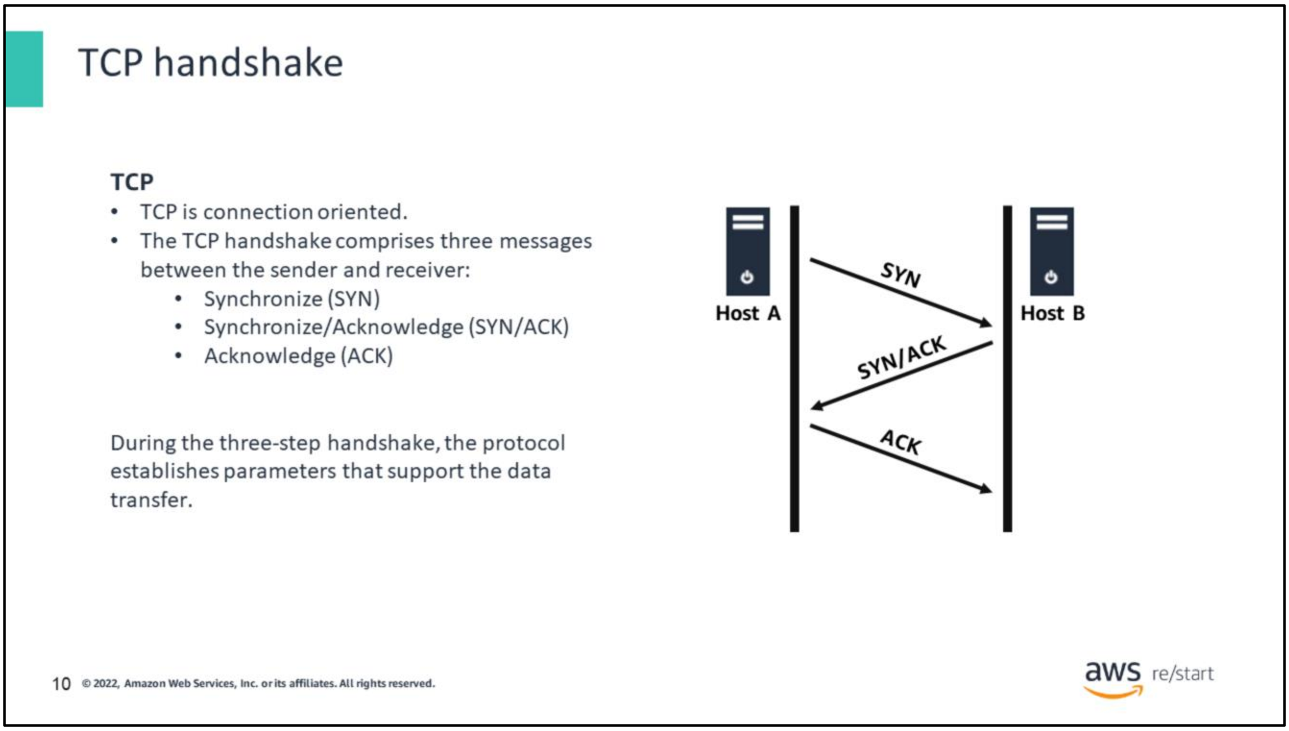
A connection-oriented protocol is similar to a phone call between two people.

A connectionless protocol is like sending a letter from one mailbox to another mailbox.

Connection-oriented protocol	Connectionless protocol
Establishes a connection and waits for a response	Sends a message from one endpoint to the other without ensuring that the destination is available and ready to receive the data
Creates a session between the sender and the receiver	Does not require a session between the sender and the receiver
Uses synchronous communication	Uses asynchronous communication

A network protocol defines the rules for formatting and transmitting data between devices on a network. It typically operates at layer 3 (network) or layer 4 (transport) of the OSI model.

Network protocols fall into two general categories: connection-oriented protocols or connectionless protocols.



TCP handshake

TCP

- TCP is connection oriented.
- The TCP handshake comprises three messages between the sender and receiver:
  - Synchronize (SYN)
  - Synchronize/Acknowledge (SYN/ACK)
  - Acknowledge (ACK)

During the three-step handshake, the protocol establishes parameters that support the data transfer.

TCP is great for transferring important files because connection is guaranteed even though it has a larger overhead (time). It is connection oriented.

TCP has something that is called the TCP handshake. This handshake comprises three messages:

- Synchronize (SYN)
- Synchronize/Acknowledge (SYN/ACK)
- Acknowledge (ACK)

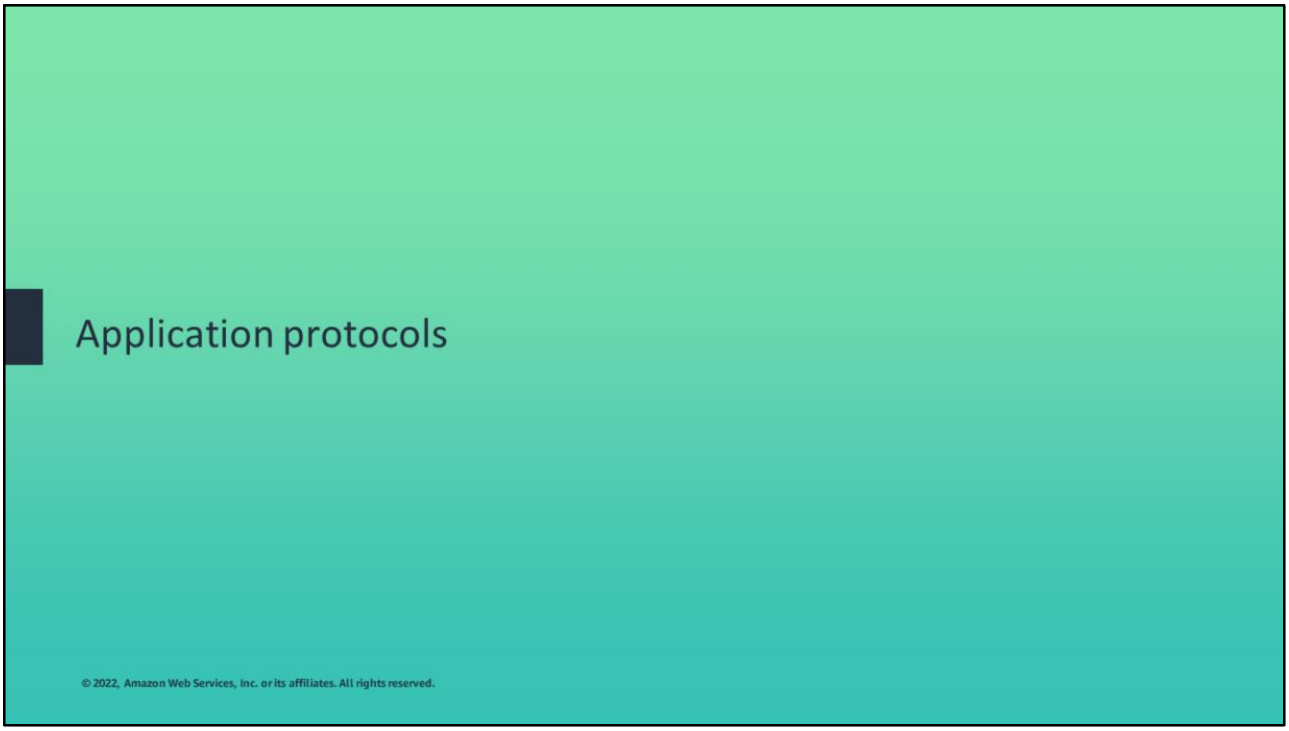
During this handshake, the protocol establishes parameters that support the data transfer between two hosts. For example:

- Host A sends a SYN packet to Host B.
- Host B sends the SYN with an ACK attached to acknowledge that they received it with the message back to Host A.
- Host A sends the last message with ACK to Host B informing them that they received the SYN/ACK message.

Another process gracefully closes the communication between the sender and receiver (similar to saying goodbye to someone) with three messages:

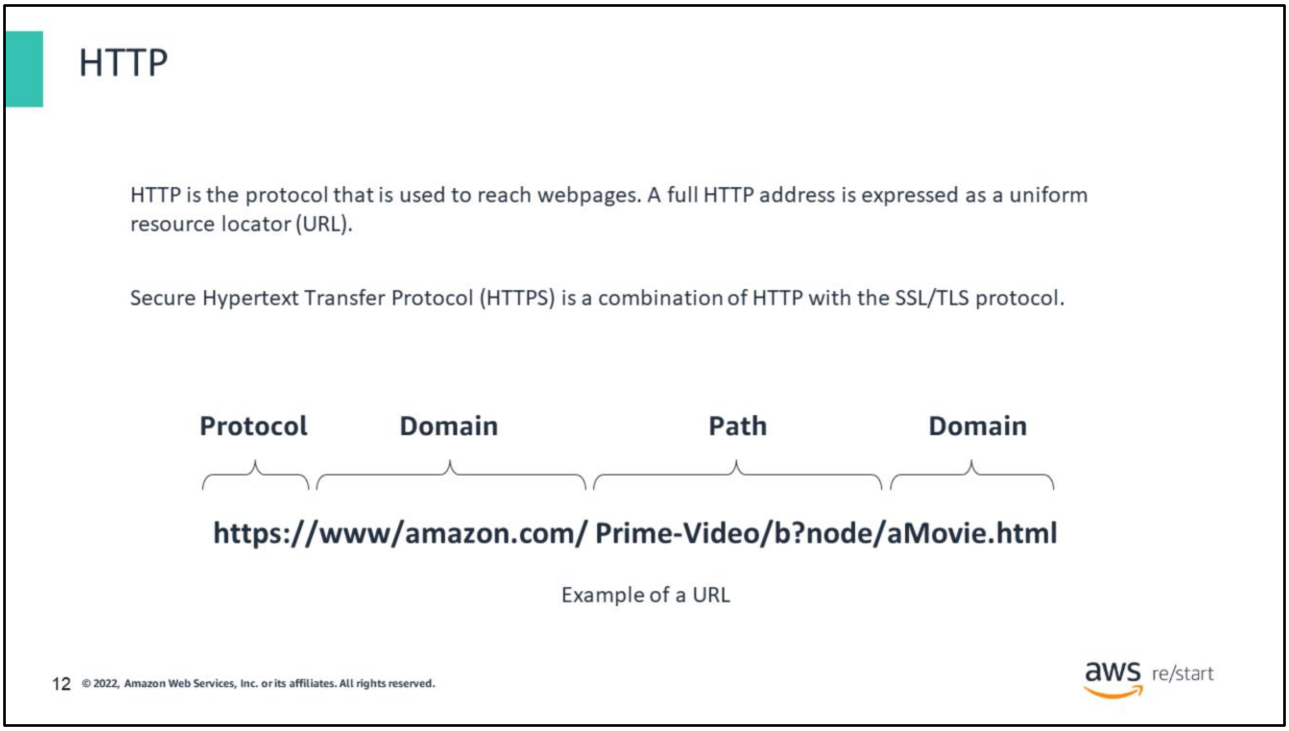
- Finish (FIN)
- Finish/Acknowledge (FIN/ACK)
- Acknowledge (ACK)

There are also flags called reset (RST) flags when a connection closes abruptly and causes an error.



Application protocols

In this section, you will review the types of application protocols.



HTTP

HTTP is the protocol that is used to reach webpages. A full HTTP address is expressed as a uniform resource locator (URL).

Secure Hypertext Transfer Protocol (HTTPS) is a combination of HTTP with the SSL/TLS protocol.

Protocol

Domain

Path

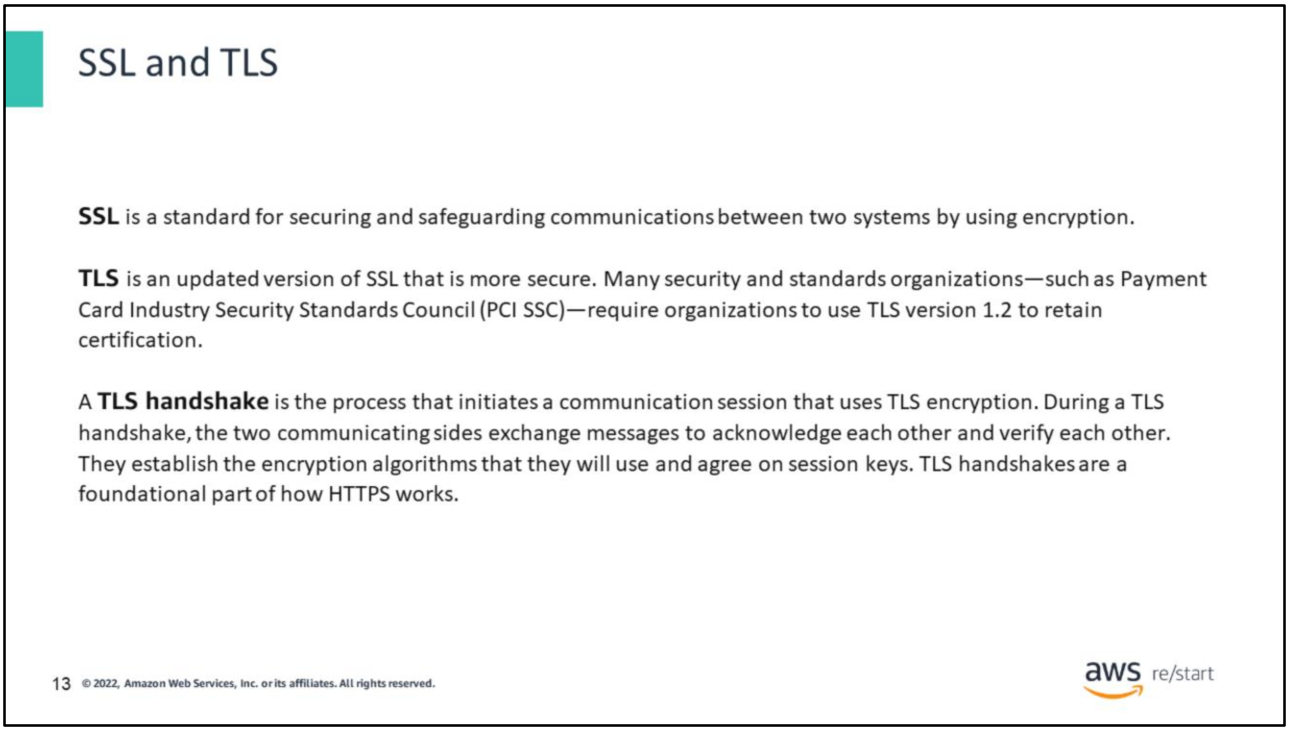
Domain

https://www/amazon.com/ Prime-Video/b?node/aMovie.html

Example of a URL

HTTP is the protocol that is used to reach webpages. A full HTTP address is expressed as a uniform resource locator (URL).

Secure Hypertext Transfer Protocol (HTTPS) is a combination of HTTP with the SSL/TLS protocol.



SSL and TLS

SSL is a standard for securing and safeguarding communications between two systems by using encryption.

TLS is an updated version of SSL that is more secure. Many security and standards organizations—such as Payment Card Industry Security Standards Council (PCI SSC)—require organizations to use TLS version 1.2 to retain certification.

A **TLS handshake** is the process that initiates a communication session that uses TLS encryption. During a TLS handshake, the two communicating sides exchange messages to acknowledge each other and verify each other. They establish the encryption algorithms that they will use and agree on session keys. TLS handshakes are a foundational part of how HTTPS works.

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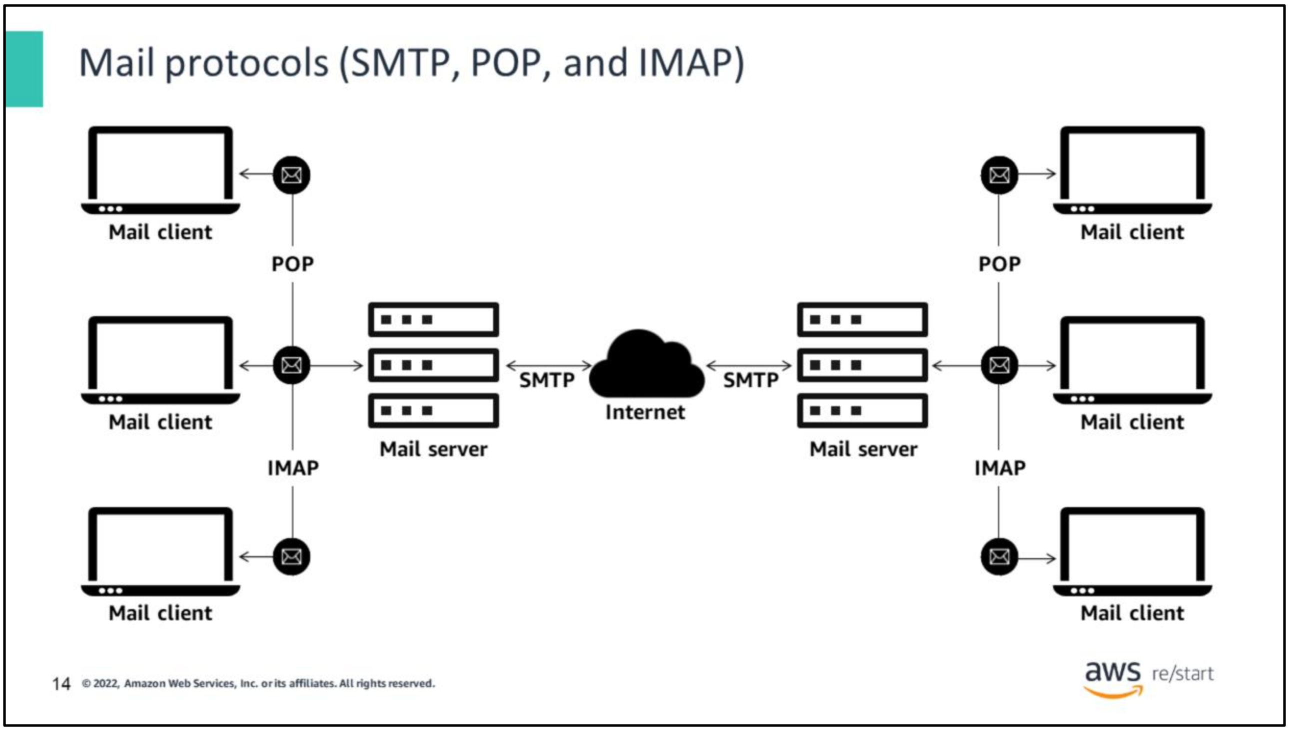
SSL/TLS creates a secure channel between a user’s computer and other devices as they exchange information over the internet. They using three main concepts—encryption, authentication, and integrity—to accomplish this result. Encryption hides data that is being transferred from any third parties. Without SSL/TLS, data gets sent as plain text, and malicious actors can eavesdrop or alter this data. SSL/TLS offers point-to-point protection to ensure that the data is secure during transport.

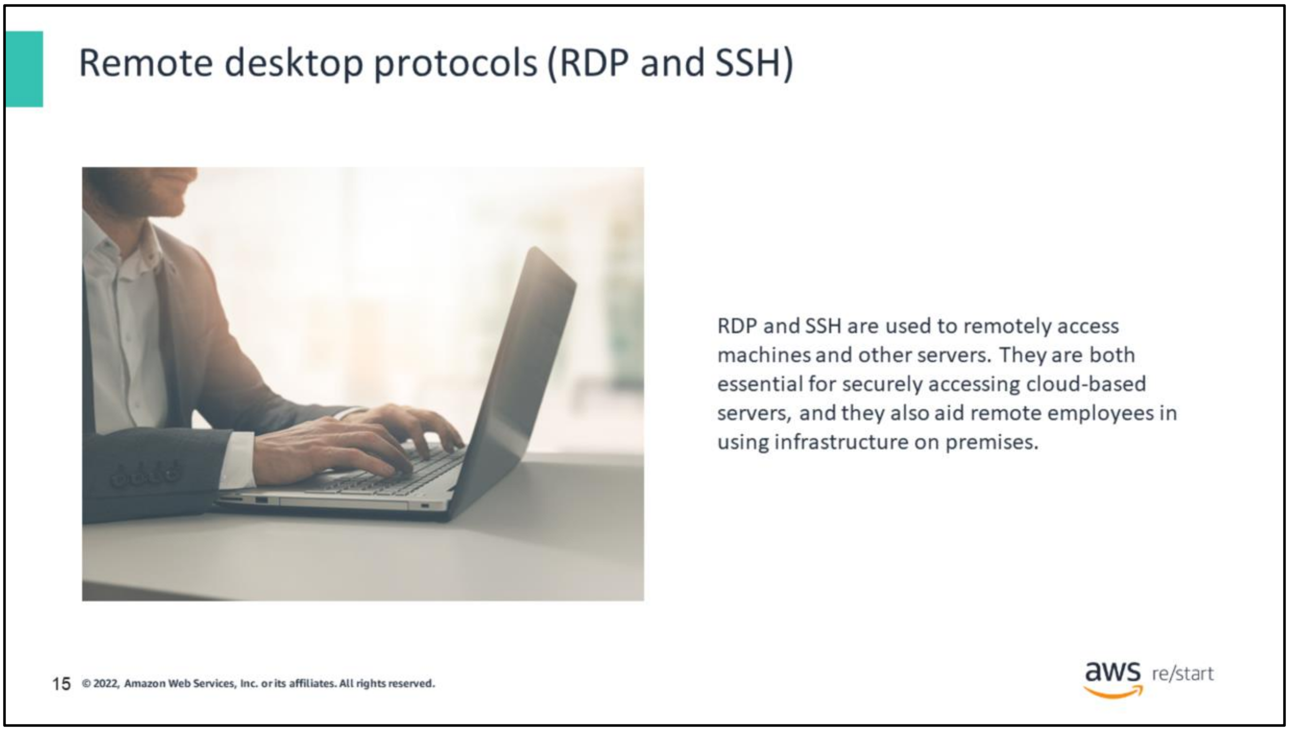
To provision, manage, and deploy public and private SSL/TLS certificates for use with AWS services and internal connected resources, you need AWS Certificate Manager (ACM).



Mail protocols (SMTP, POP, and IMAP)

SMTP is used to transfer email messages between mail servers.

Email clients use POP and IMAP to retrieve email messages from the mail server.



Remote desktop protocols (RDP and SSH)

RDP and SSH are used to remotely access machines and other servers. They are both essential for securely accessing cloud-based servers, and they also aid remote employees in using infrastructure on premises.

RDP is a protocol that is used to access the desktop of a remote Microsoft Windows computer. Use port 3389 with clients that are available on different operating systems.

SSH is a protocol that opens a secure command line interface (CLI) on a remote Linux or Unix computer. The standard TCP port for SSH is 22. SSH is generally used to access Unix-like operating systems, but it can also be used on Microsoft Windows. Windows 10 uses OpenSSH as its default SSH client and SSH server.

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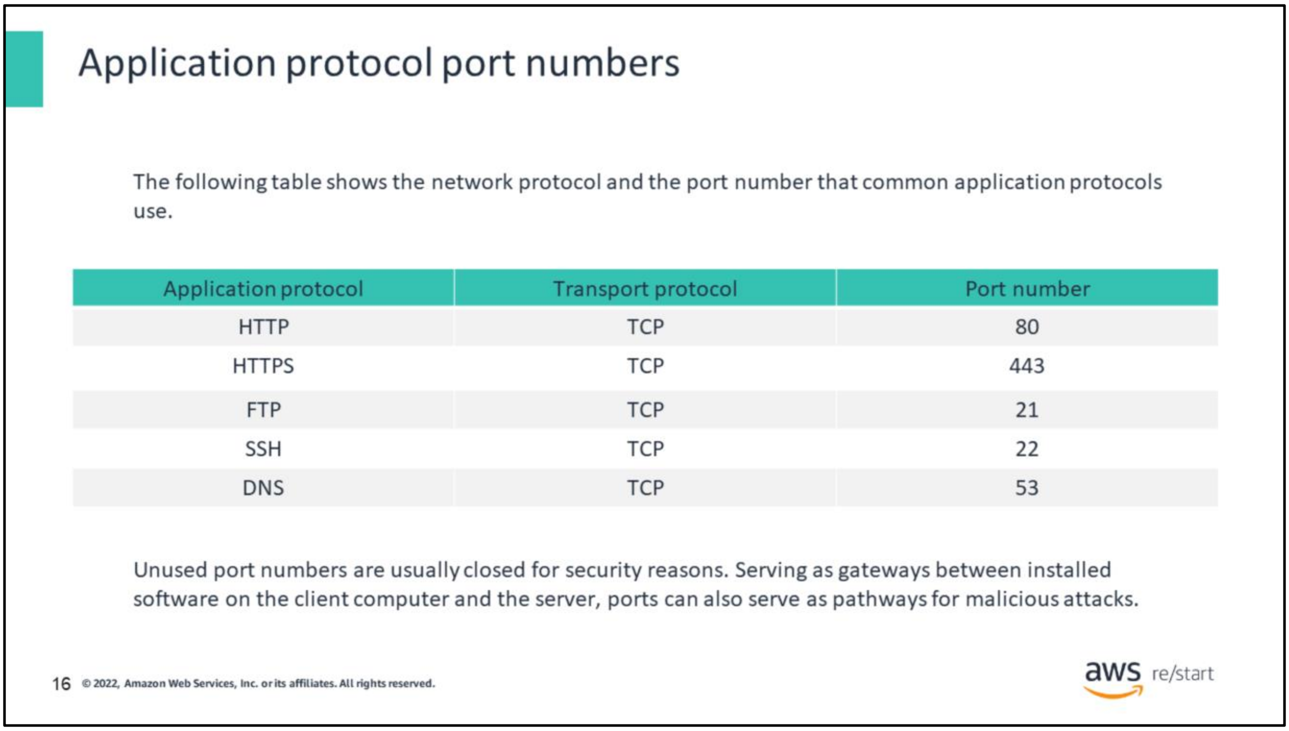

Application protocol port numbers

The following table shows the network protocol and the port number that common application protocols use.

Application protocol	Transport protocol	Port number
HTTP	TCP	80
HTTPS	TCP	443
FTP	TCP	21
SSH	TCP	22
DNS	TCP	53

Unused port numbers are usually closed for security reasons. Serving as gateways between installed software on the client computer and the server, ports can also serve as pathways for malicious attacks.

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Application protocols, such as HTTP and FTP, have assigned port numbers. The next section will discuss FTP and DNS in more detail.

These numbers are data endpoints. The ports provide devices with a way to understand what to do with the data that they receive. For example, a computer might download a file over FTP. The computer connects to the server and downloads the data over port 21. The computer knows how to handle that data because of the port that it used. Thus, the computer is able to complete the download.

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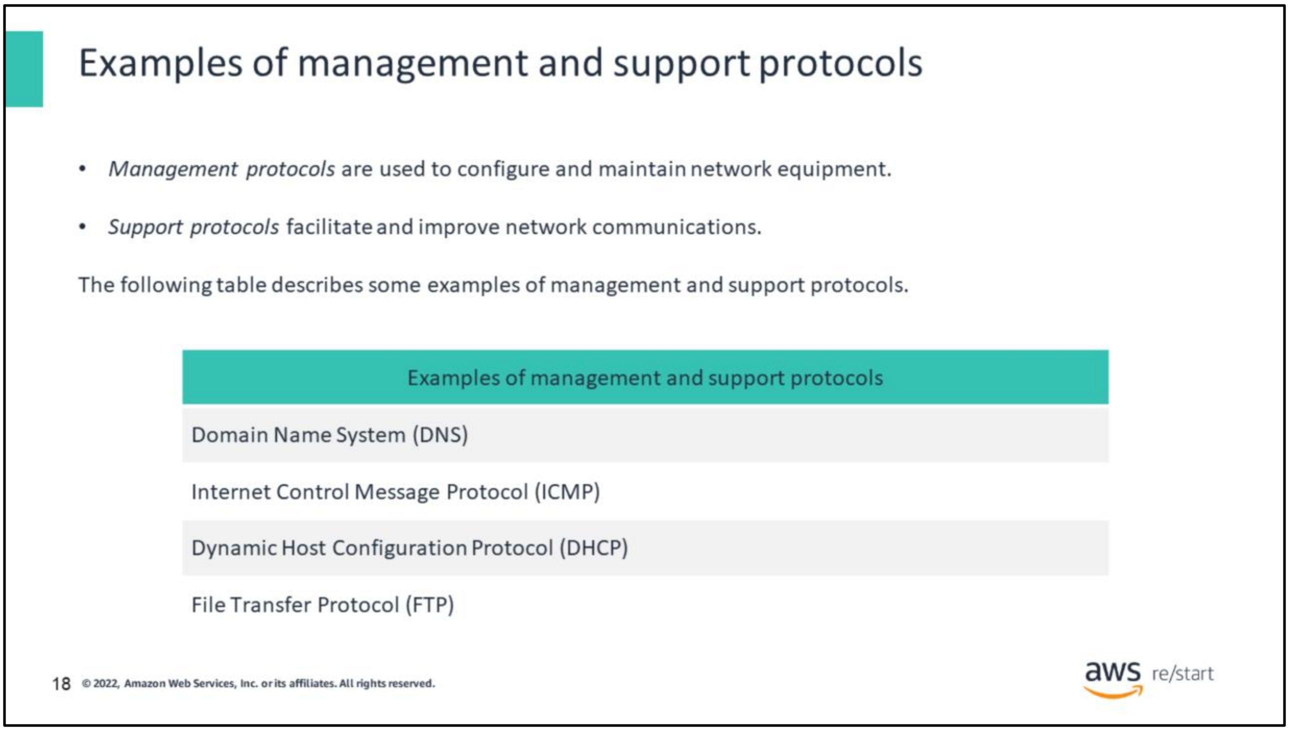
Most of the application protocols fall under the application layer (layer 7) of the OSI model. A few examples of application layer protocols are HTTP, FTP, POP, SMTP, and DNS.

Management and support protocols

In this section, you will review the types of management and support protocols.



Examples of management and support protocols

- *Management protocols* are used to configure and maintain network equipment.
- *Support protocols* facilitate and improve network communications.

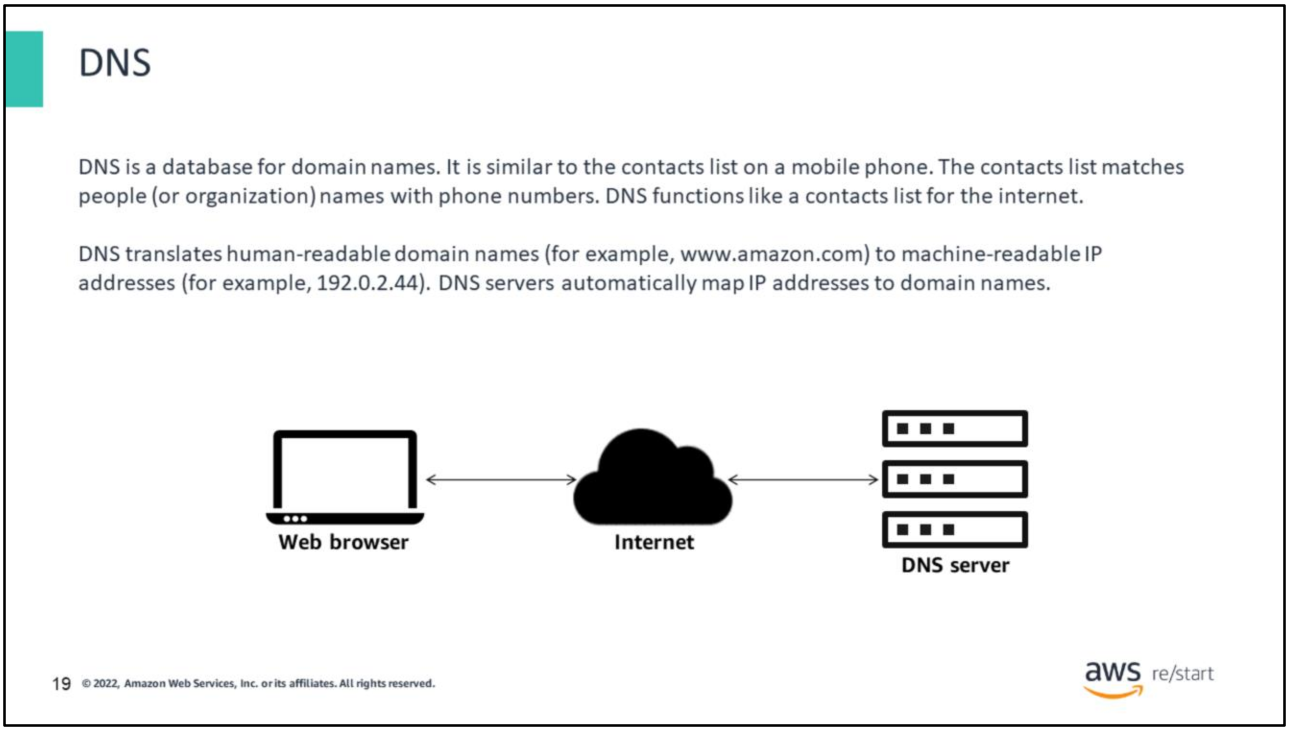
The following table describes some examples of management and support protocols.

Examples of management and support protocols
Domain Name System (DNS)
Internet Control Message Protocol (ICMP)
Dynamic Host Configuration Protocol (DHCP)
File Transfer Protocol (FTP)

Management protocols are used to configure and maintain network equipment. Support protocols enable and improve network communications.

Here are the examples of management and support protocols:

- DNS
- ICMP
- DHCP
- FTP



DNS

DNS is a database for domain names. It is similar to the contacts list on a mobile phone. The contacts list matches people (or organization) names with phone numbers. DNS functions like a contacts list for the internet.

DNS translates human-readable domain names (for example, www.amazon.com) to machine-readable IP addresses (for example, 192.0.2.44). DNS servers automatically map IP addresses to domain names.

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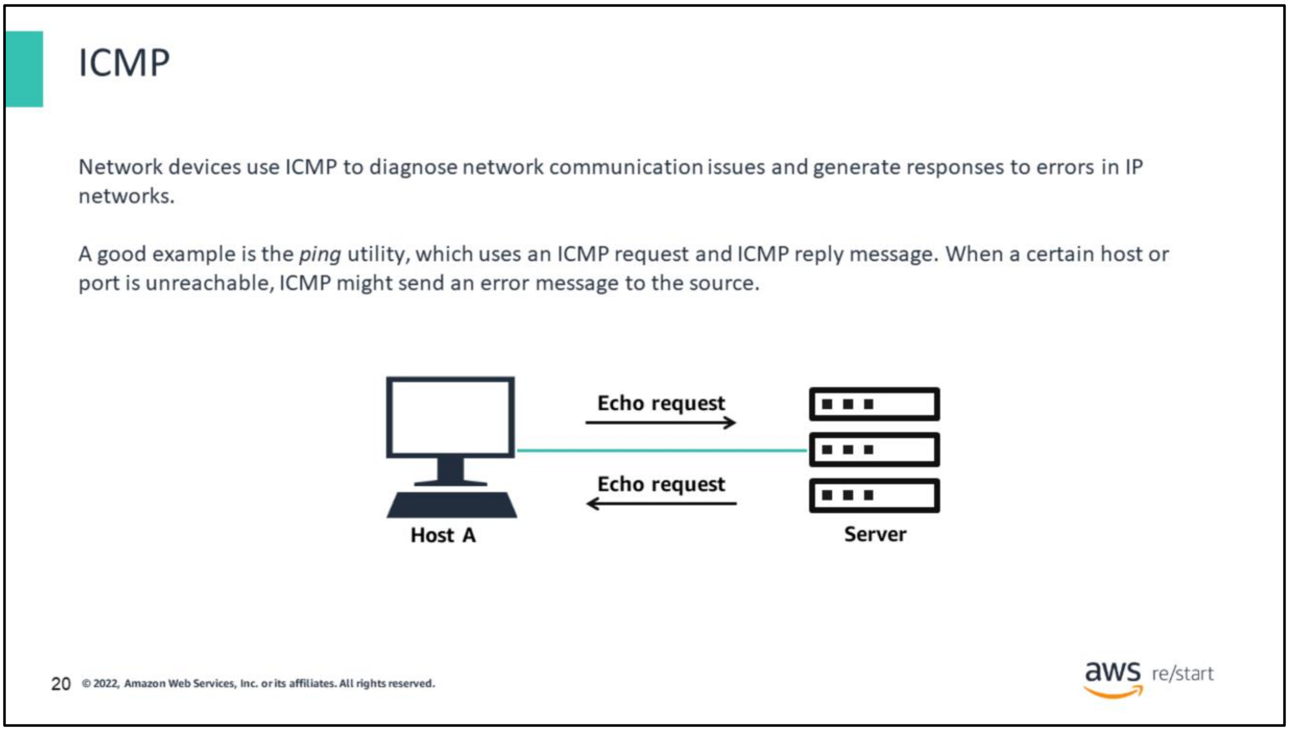

ICMP

Network devices use ICMP to diagnose network communication issues and generate responses to errors in IP networks.

A good example is the *ping* utility, which uses an ICMP request and ICMP reply message. When a certain host or port is unreachable, ICMP might send an error message to the source.

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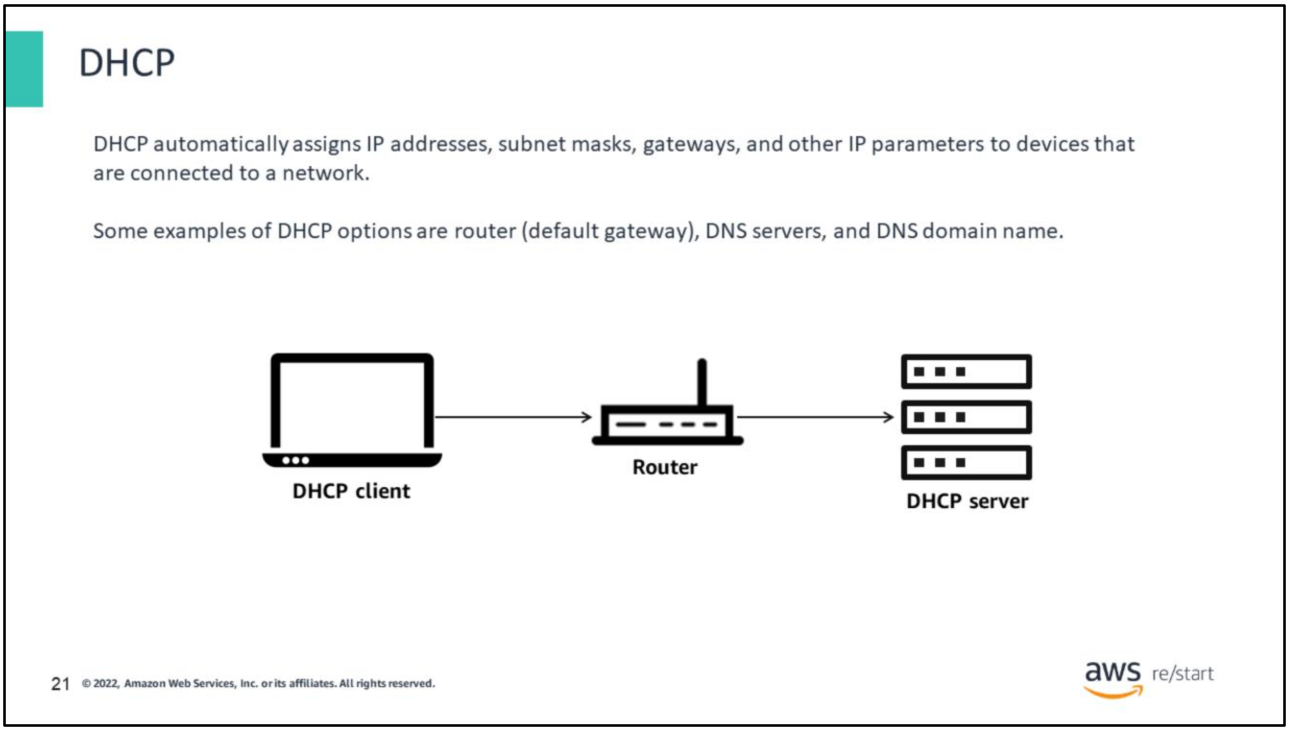

DHCP

DHCP automatically assigns IP addresses, subnet masks, gateways, and other IP parameters to devices that are connected to a network.

Some examples of DHCP options are router (default gateway), DNS servers, and DNS domain name.

DHCP client

Router

DHCP server

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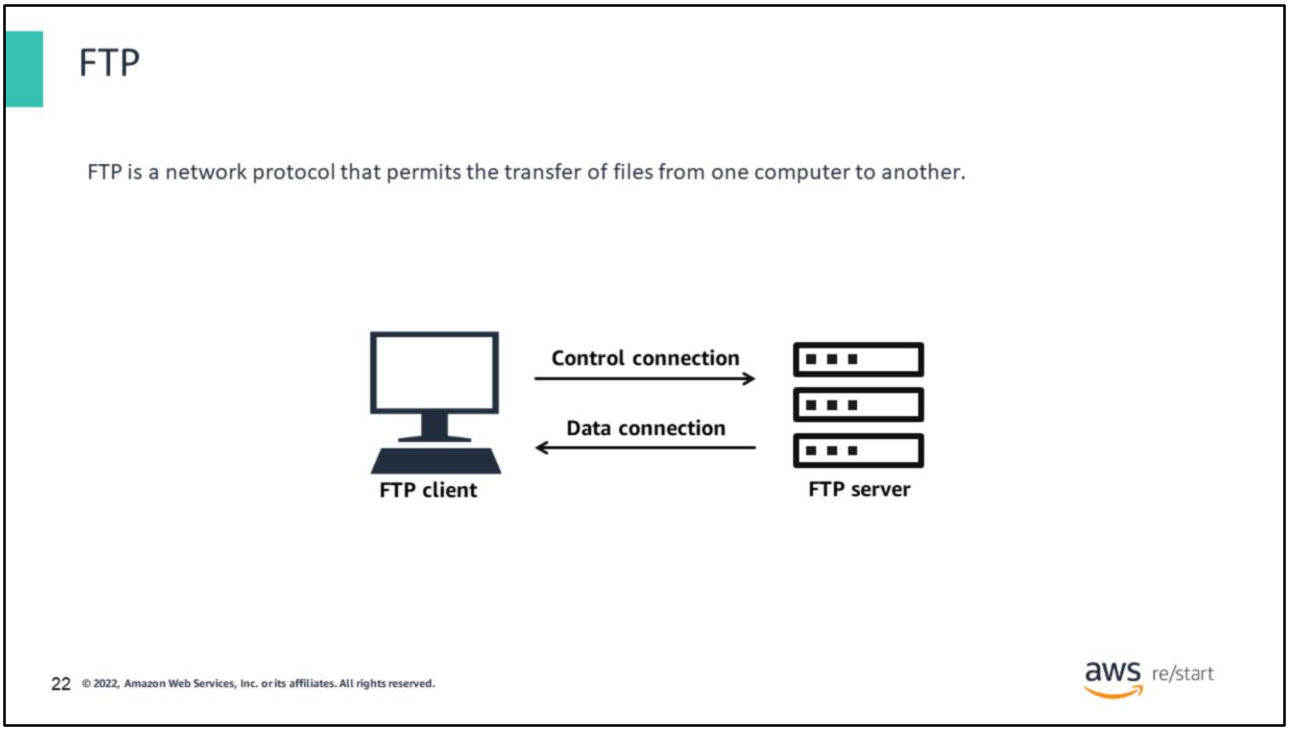
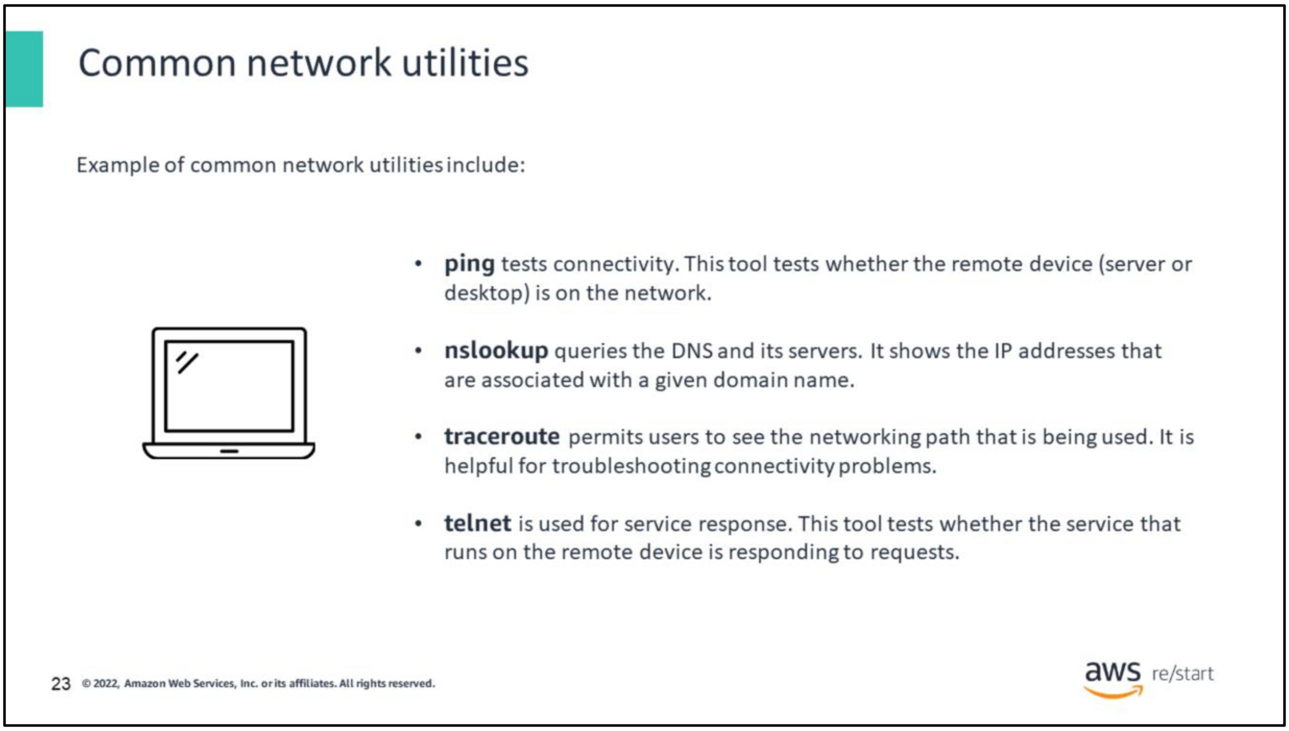


FTP

FTP is a network protocol that permits the transfer of files from one computer to another.

FTP is a network protocol that authorizes the transfer of files from one computer to another. FTP performs two basic functions: PUT and GET. If you have downloaded something such as an image or a file, then you probably used an FTP server.



Common network utilities

Example of common network utilities include:

- **ping** tests connectivity. This tool tests whether the remote device (server or desktop) is on the network.
- **nslookup** queries the DNS and its servers. It shows the IP addresses that are associated with a given domain name.
- **traceroute** permits users to see the networking path that is being used. It is helpful for troubleshooting connectivity problems.
- **telnet** is used for service response. This tool tests whether the service that runs on the remote device is responding to requests.

When you work with networks, it is important to check network performance, bandwidth usage, and network configurations. The following list contains a few common network utilities that you can use to quickly troubleshoot network issues. These tools can help ensure uninterrupted service and prevent long delays.

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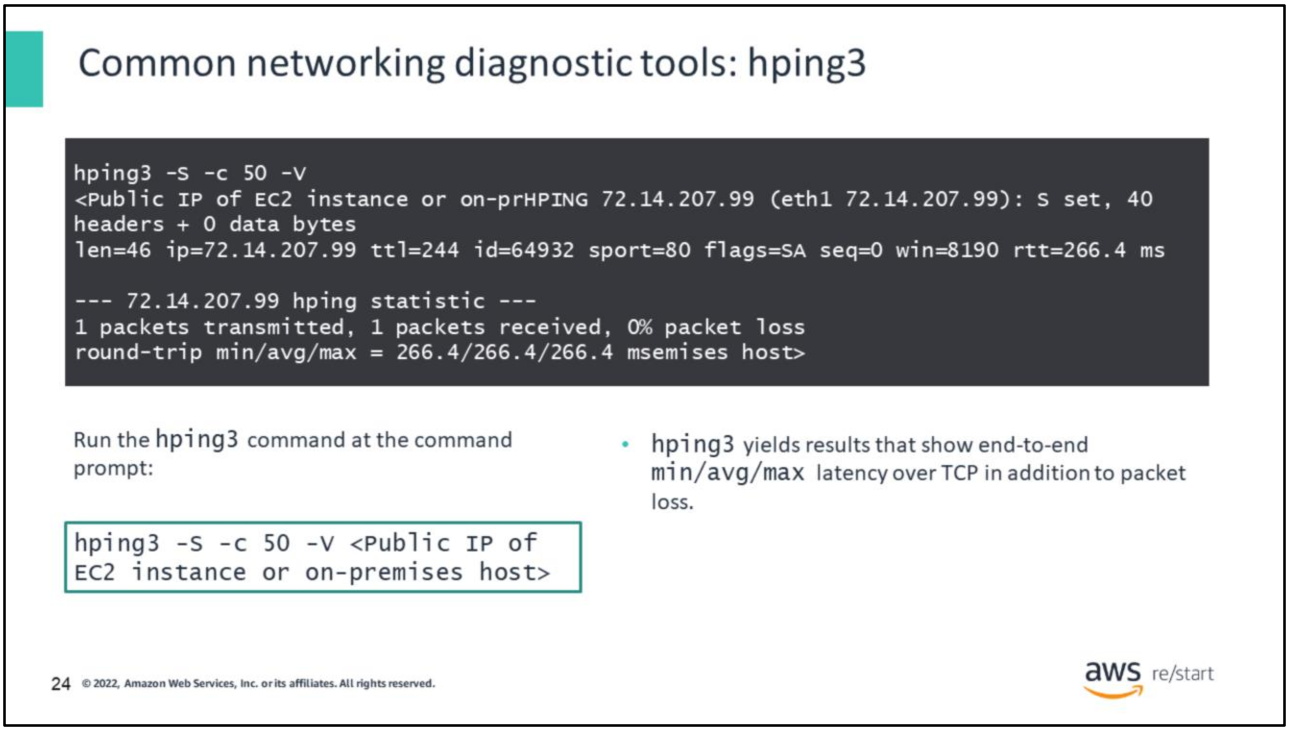


Common networking diagnostic tools: hping3

```
hping3 -S -c 50 -V
<Public IP of EC2 instance or on-prHPING 72.14.207.99 (eth1 72.14.207.99): S set, 40
headers + 0 data bytes
len=46 ip=72.14.207.99 ttl=244 id=64932 sport=80 flags=SA seq=0 win=8190 rtt=266.4 ms

--- 72.14.207.99 hping statistic ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max = 266.4/266.4/266.4 msemises host>
```

Run the `hping3` command at the command prompt:

```
hping3 -S -c 50 -V <Public IP of
EC2 instance or on-premises host>
```

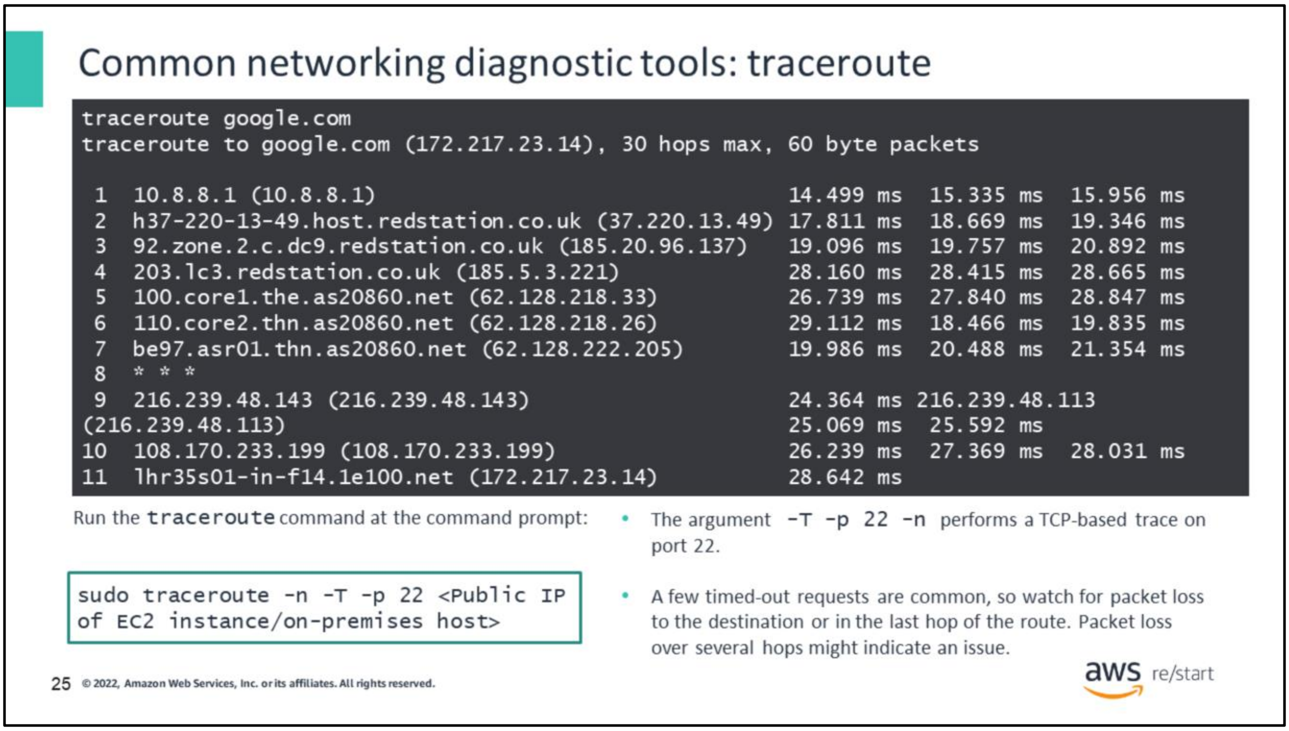
- `hping3` yields results that show end-to-end `min/avg/max` latency over TCP in addition to packet loss.

You might need to troubleshoot network performance issues such as packet loss or latency issues in your running instance of your VPC. When doing so, it is best to use a networking diagnostic utility that will help you identify the trouble spots in the network. The next few slides contain commands that you will type into your Linux command prompt.

Before you begin, be sure that you have enabled **enhanced networking** on your instance.

hping3 is a command line-oriented TCP/IP packet assembler and analyzer that measures end-to-end packet loss and latency over a TCP connection.

This command will scan port 80 on Google. As you can see from the output, the returned packet from Google has SYN and ACK flags set, which indicates an open port.



Common networking diagnostic tools: traceroute

```
traceroute google.com
traceroute to google.com (172.217.23.14), 30 hops max, 60 byte packets

 1  10.8.8.1 (10.8.8.1)                                 14.499 ms  15.335 ms  15.956 ms
 2  h37-220-13-49.host.redstation.co.uk (37.220.13.49) 17.811 ms  18.669 ms  19.346 ms
 3  92.zone.2.c.dc9.redstation.co.uk (185.20.96.137)    19.096 ms  19.757 ms  20.892 ms
 4  203.1c3.redstation.co.uk (185.5.3.221)              28.160 ms  28.415 ms  28.665 ms
 5  100.core1.the.as20860.net (62.128.218.33)           26.739 ms  27.840 ms  28.847 ms
 6  110.core2.thn.as20860.net (62.128.218.26)           29.112 ms  18.466 ms  19.835 ms
 7  be97.asr01.thn.as20860.net (62.128.222.205)         19.986 ms  20.488 ms  21.354 ms
 8  * * *
 9  216.239.48.143 (216.239.48.143)                     24.364 ms 216.239.48.113
(216.239.48.113)                                        25.069 ms  25.592 ms
10  108.170.233.199 (108.170.233.199)                   26.239 ms  27.369 ms  28.031 ms
11  lhr35s01-in-f14.1e100.net (172.217.23.14)           28.642 ms
```

Run the `traceroute` command at the command prompt:

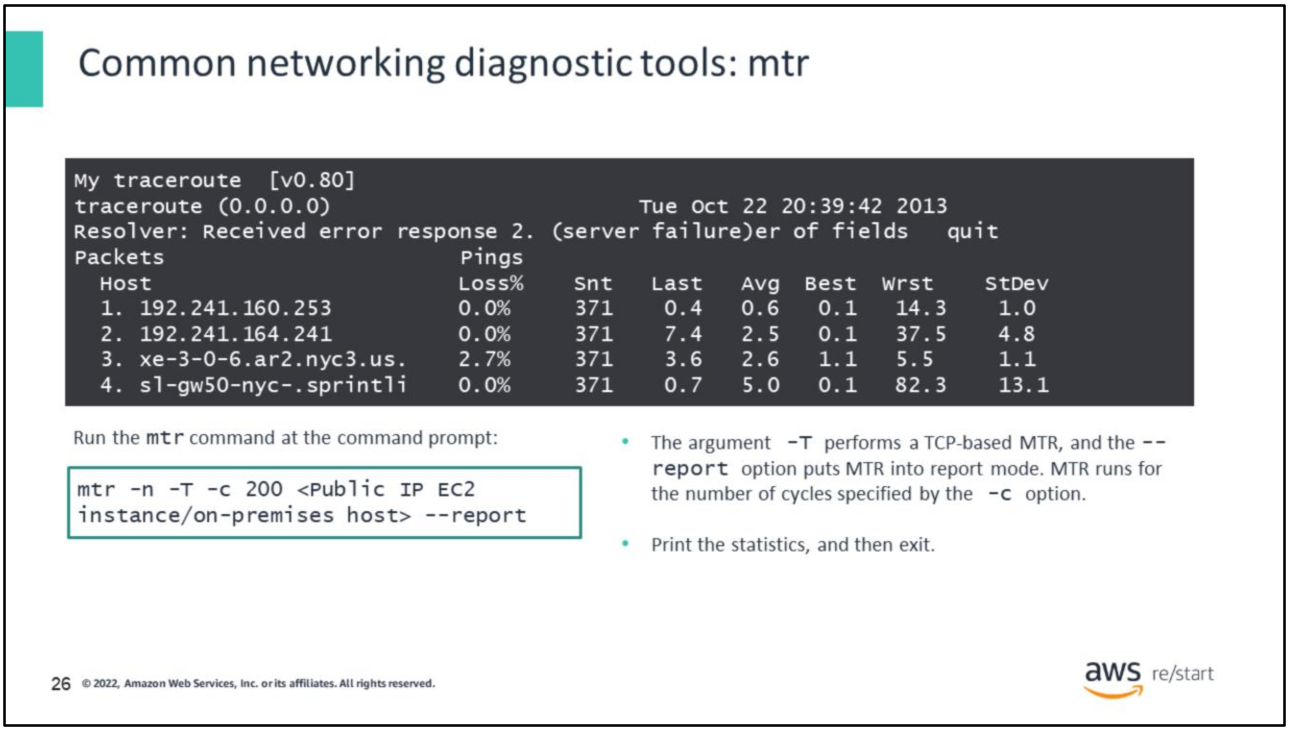
```
sudo traceroute -n -T -p 22 <Public IP
of EC2 instance/on-premises host>
```

- The argument `-T -p 22 -n` performs a TCP-based trace on port 22.
- A few timed-out requests are common, so watch for packet loss to the destination or in the last hop of the route. Packet loss over several hops might indicate an issue.

The Linux traceroute utility identifies the path that is taken from a client node to the destination node. The utility records the time in milliseconds for each router to respond to the request. To troubleshoot network connectivity by using traceroute, run the command from the client to the server and from the server back to the client.

The output shows a number of results:

- The first line shows the hostname and the IP address that is to be reached. It also displays the maximum number of hops to the host that traceroute will attempt and the size of the byte packets to be sent.
- Then, each line lists a hop to get to the destination. The hostname is given followed by the IP address of the hostname. Next is the roundtrip time that it takes for a packet to get to the host and back to the initiating computer.



Common networking diagnostic tools: mtr

```
My traceroute  [v0.80]
traceroute (0.0.0.0)                         Tue Oct 22 20:39:42 2013
Resolver: Received error response 2. (server failure)er of fields   quit
Packets                       Pings
  Host                        Loss%     Snt    Last   Avg  Best  Wrst    StDev
  1. 192.241.160.253          0.0%      371     0.4   0.6   0.1   14.3    1.0
  2. 192.241.164.241          0.0%      371     7.4   2.5   0.1   37.5    4.8
  3. xe-3-0-6.ar2.nyc3.us.    2.7%      371     3.6   2.6   1.1   5.5     1.1
  4. sl-gw50-nyc-.sprintli    0.0%      371     0.7   5.0   0.1   82.3    13.1
```

Run the `mtr` command at the command prompt:

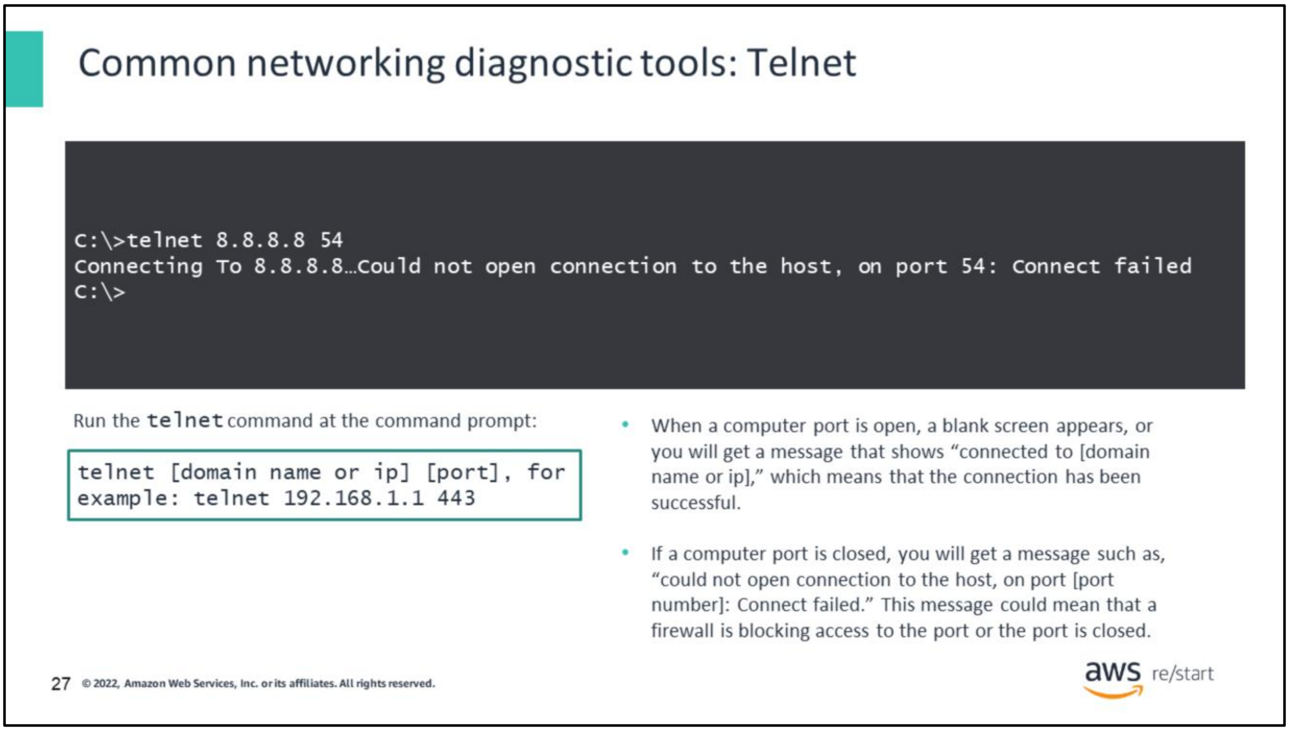
```
mtr -n -T -c 200 <Public IP EC2
instance/on-premises host> --report
```

- The argument `-T` performs a TCP-based MTR, and the `--report` option puts MTR into report mode. MTR runs for the number of cycles specified by the `-c` option.
- Print the statistics, and then exit.

Linux mtr is a command that you type into the command prompt that provides continual, updated output, which you can use to analyze network performance.

You run the command and review the results to identify any packet loss. If you notice sustained packet loss, it might indicate a problem.

Though the output might look similar to the traceroute results, the advantage over traceroute is that the output is constantly updated. With these continual updates, you can track the trends and averages, and you can also see how the network performance varies over time.



Common networking diagnostic tools: Telnet

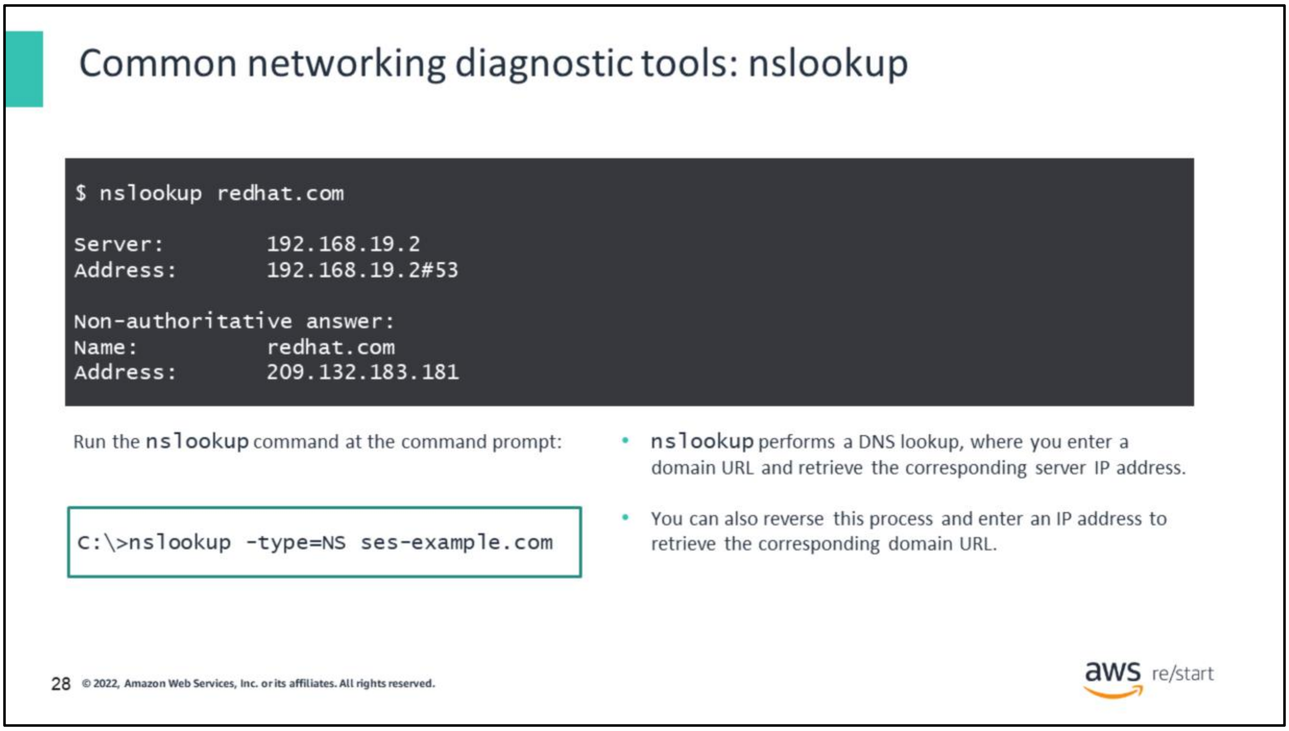
```
C:\>telnet 8.8.8.8 54
Connecting To 8.8.8.8…Could not open connection to the host, on port 54: Connect failed
C:\>
```

Run the `telnet` command at the command prompt:

```
telnet [domain name or ip] [port], for
example: telnet 192.168.1.1 443
```

- When a computer port is open, a blank screen appears, or you will get a message that shows “connected to [domain name or ip],” which means that the connection has been successful.
- If a computer port is closed, you will get a message such as, “could not open connection to the host, on port [port number]: Connect failed.” This message could mean that a firewall is blocking access to the port or the port is closed.

You can use telnet to test individual ports and see whether they are open or not.



Common networking diagnostic tools: nslookup

```
$ nslookup redhat.com

Server:         192.168.19.2
Address:        192.168.19.2#53

Non-authoritative answer:
Name:           redhat.com
Address:        209.132.183.181
```

Run the `nslookup` command at the command prompt:

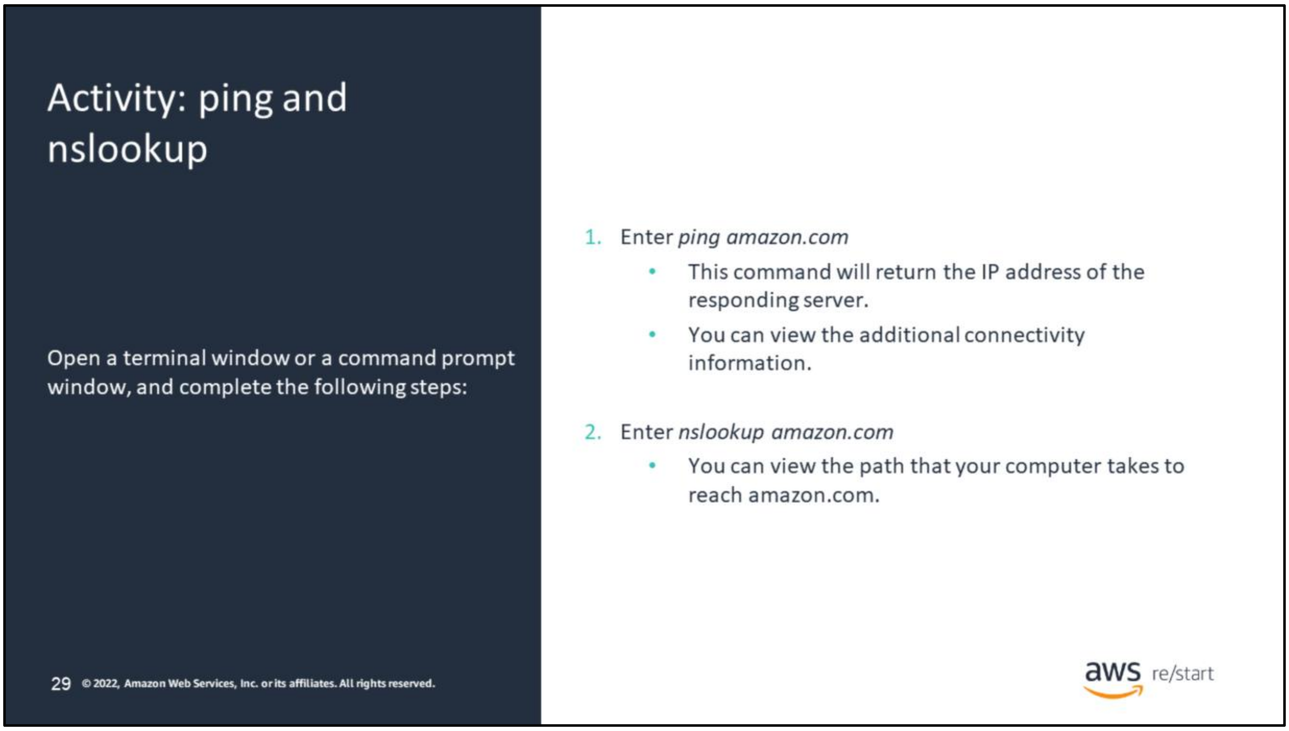
```
C:\>nslookup -type=NS ses-example.com
```

- `nslookup` performs a DNS lookup, where you enter a domain URL and retrieve the corresponding server IP address.
- You can also reverse this process and enter an IP address to retrieve the corresponding domain URL.

nslookup is a network administration command-line tool for querying the DNS to obtain the mapping between domain name and IP address, or other DNS records.

Conclusion

With hping3, traceroute, mtr, telnet, and nslookup, you can diagnose in real time which servers’ domain or addresses are causing issues on your network. This information can be useful when troubleshooting an internal network when you are experiencing network problems.



Activity: ping and nslookup

Open a terminal window or a command prompt window, and complete the following steps:

1. Enter *ping amazon.com*
   - This command will return the IP address of the responding server.
   - You can view the additional connectivity information.
2. Enter *nslookup amazon.com*
   - You can view the path that your computer takes to reach amazon.com.

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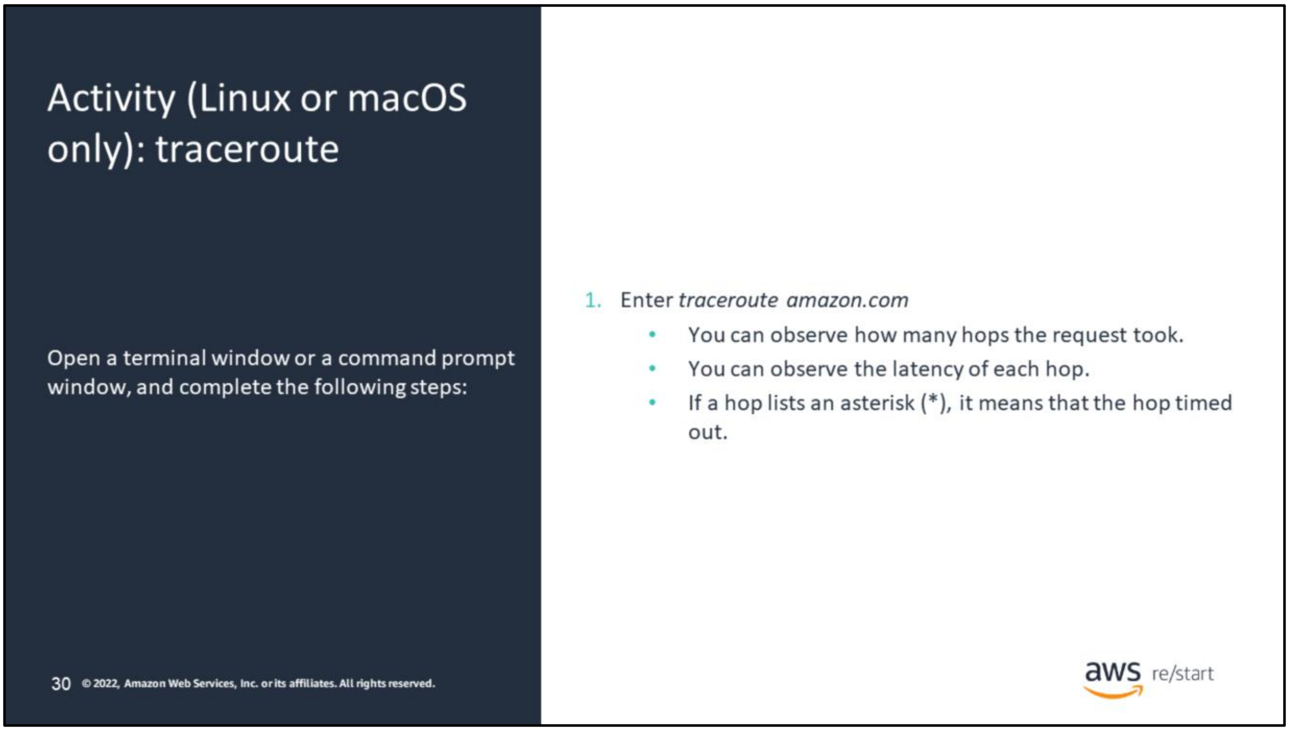

Activity (Linux or macOS only): traceroute

Open a terminal window or a command prompt window, and complete the following steps:

1. Enter *traceroute amazon.com*
   - You can observe how many hops the request took.
   - You can observe the latency of each hop.
   - If a hop lists an asterisk (*), it means that the hop timed out.

Open a terminal window or a command prompt window, and complete the following steps:

1. Enter *traceroute amazon.com*
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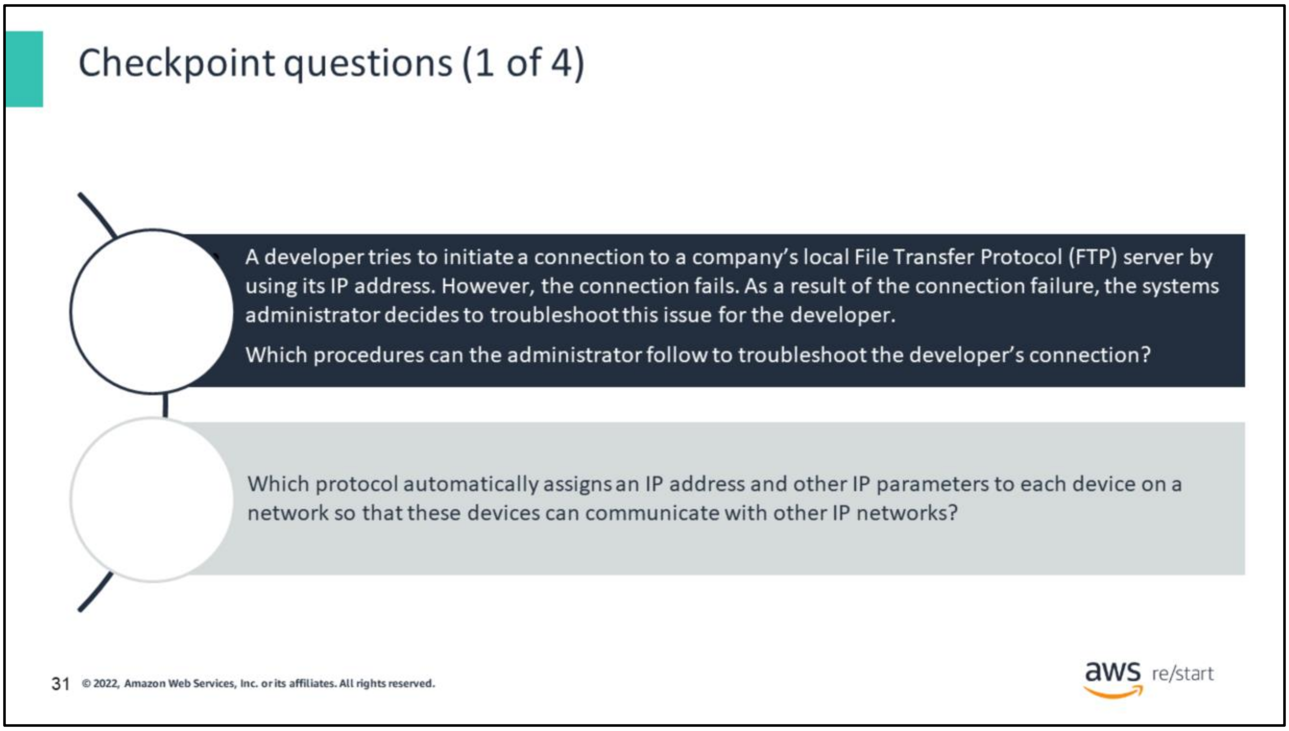


Checkpoint questions (1 of 4)

A developer tries to initiate a connection to a company's local File Transfer Protocol (FTP) server by using its IP address. However, the connection fails. As a result of the connection failure, the systems administrator decides to troubleshoot this issue for the developer.

Which procedures can the administrator follow to troubleshoot the developer's connection?

Which protocol automatically assigns an IP address and other IP parameters to each device on a network so that these devices can communicate with other IP networks?

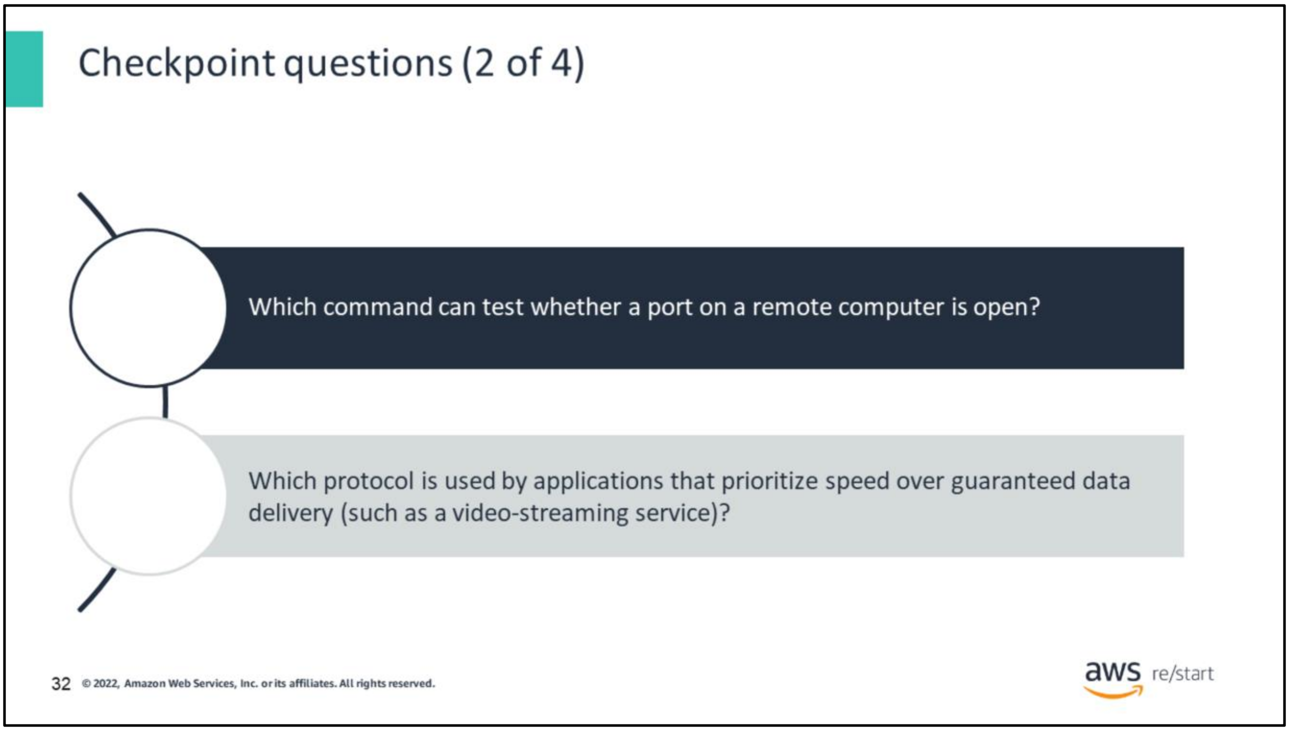
Q1: A developer tries to initiate a connection to a company's local File Transfer Protocol (FTP) server by using its IP address. However, the connection fails. As a result of the connection failure, the systems administrator decides to troubleshoot this issue for the developer.

Which procedures can the administrator follow to troubleshoot the developer's connection?

- Test server connectivity with the ping command.
- Check the firewall traffic rules to verify that port 21 is open.

Q2: Which protocol automatically assigns an IP address and other IP parameters to each device on a network so that these devices can communicate with other IP networks?

- Dynamic Host Configuration Protocol (DHCP)



Checkpoint questions (2 of 4)

Which command can test whether a port on a remote computer is open?

Which protocol is used by applications that prioritize speed over guaranteed data delivery (such as a video-streaming service)?

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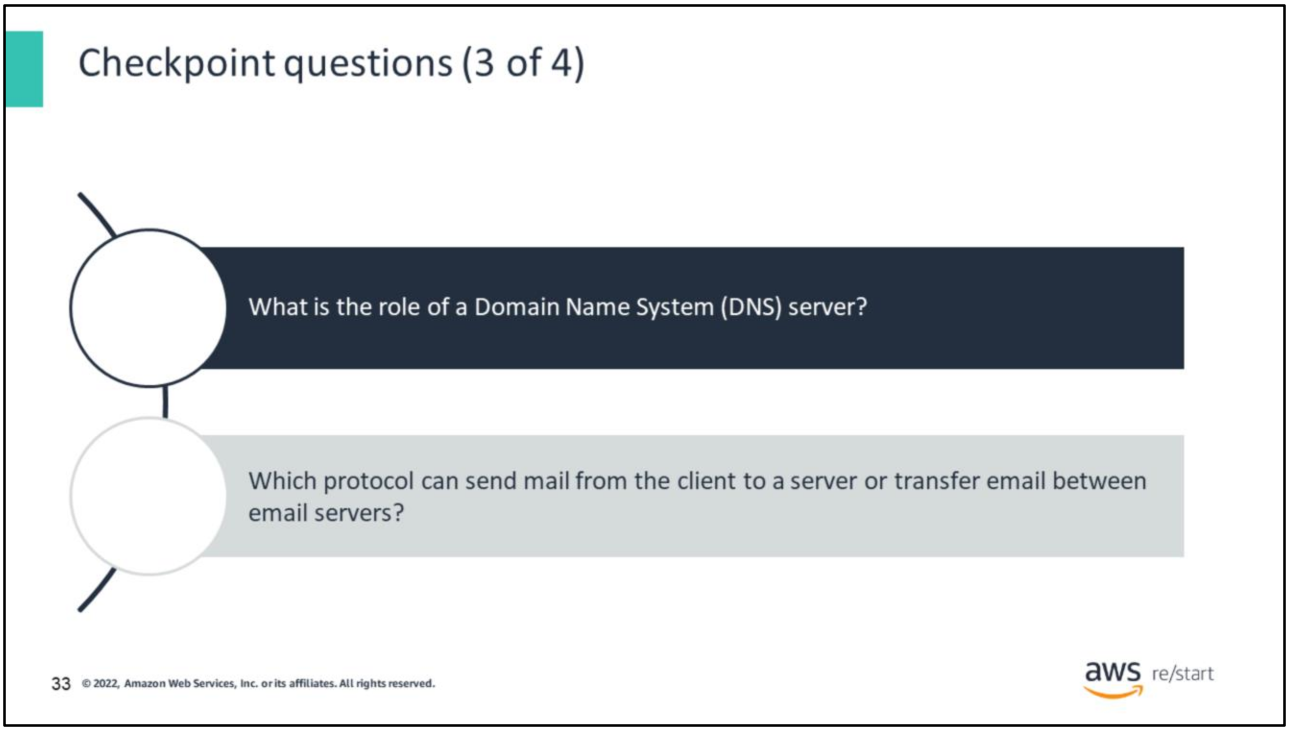
Q1: Which command can test whether a port on a remote computer is open?

- samp>telnet</samp>

Q2: Which protocol is used by applications that prioritize speed over guaranteed data delivery (such as a video-streaming service)?

- User Datagram Protocol (UDP)



Checkpoint questions (3 of 4)

What is the role of a Domain Name System (DNS) server?

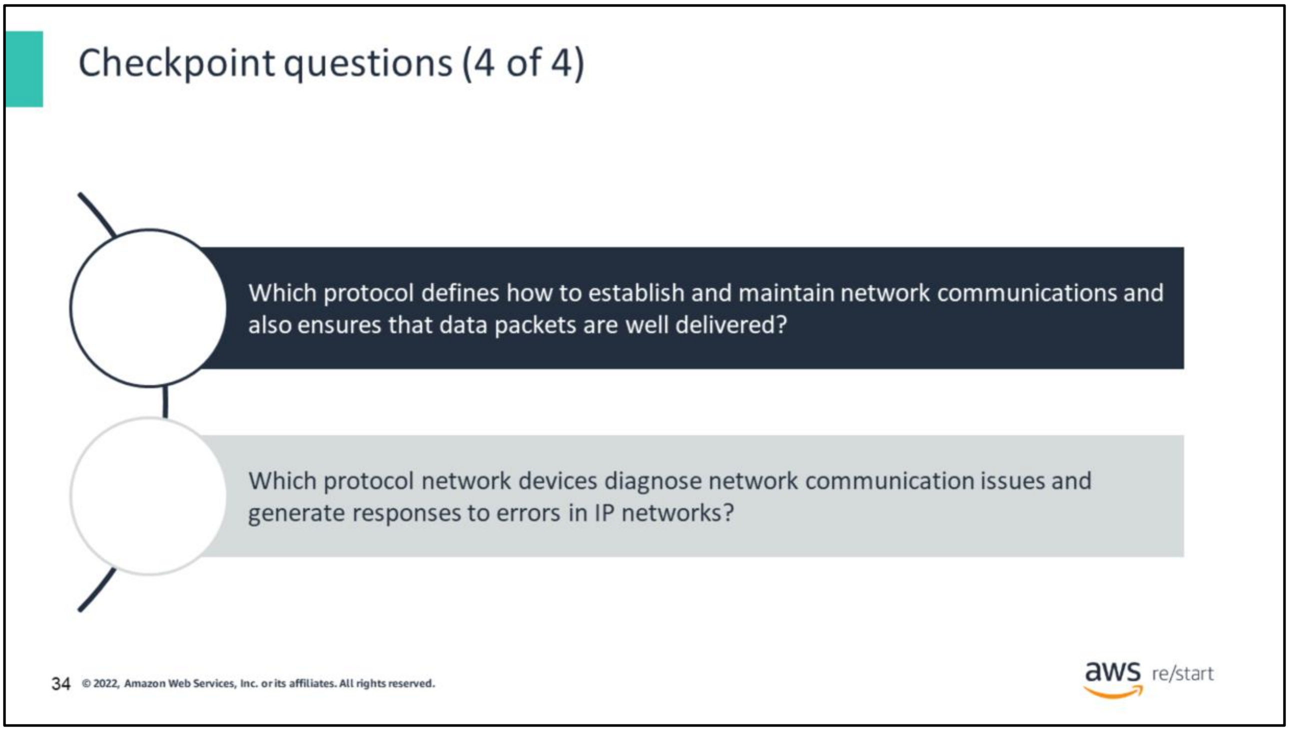
Which protocol can send mail from the client to a server or transfer email between email servers?

Q1: What is the role of a Domain Name System (DNS) server?

- It converts human-readable domain names (such as example.com) into IP addresses.

Q2: Which protocol can send mail from the client to a server or transfer email between email servers?

- Simple Mail Transfer Protocol (SMTP)



Checkpoint questions (4 of 4)

Which protocol defines how to establish and maintain network communications and also ensures that data packets are well delivered?

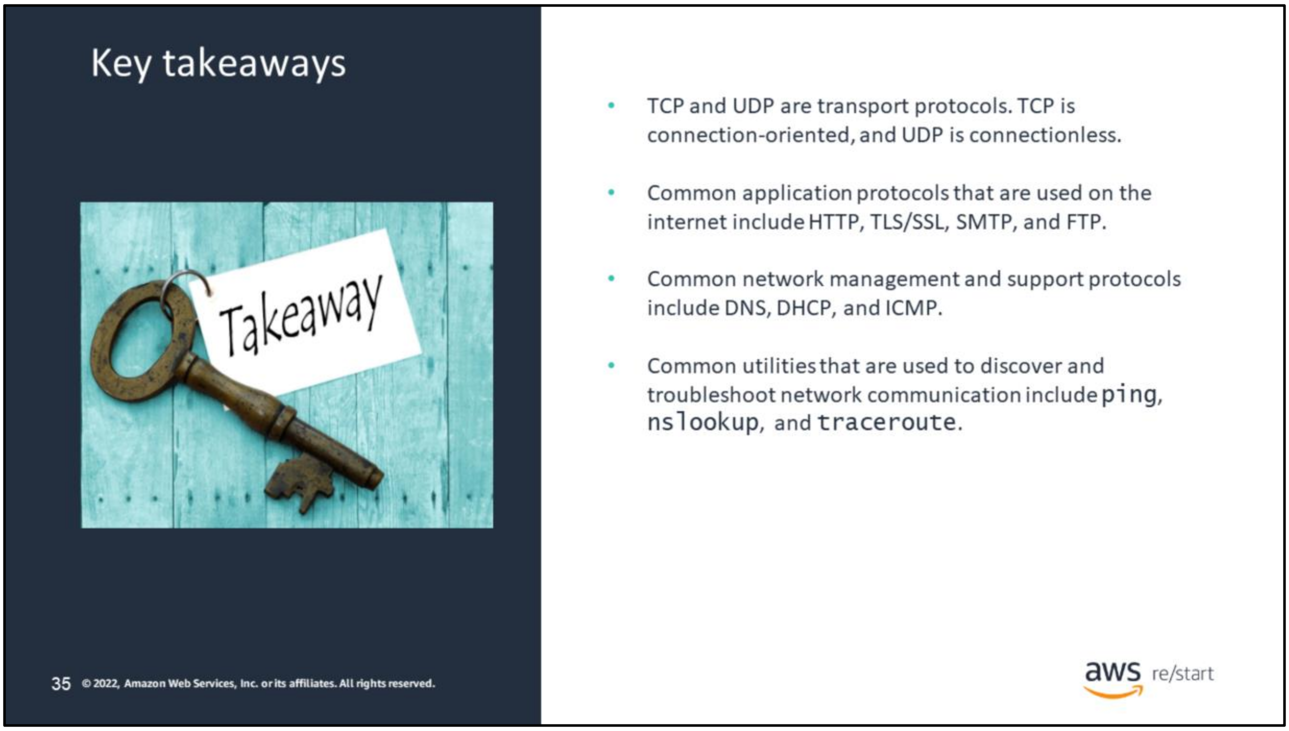
Which protocol network devices diagnose network communication issues and generate responses to errors in IP networks?

Q1: Which protocol defines how to establish and maintain network communications and also ensures that data packets are well delivered?

- Transmission Control Protocol/Internet Protocol (TCP/IP)

Q2: Which protocol network devices diagnose network communication issues and generate responses to errors in IP networks?

- Internet Control Message Protocol (ICMP)



Key takeaways

- TCP and UDP are transport protocols. TCP is connection-oriented, and UDP is connectionless.
- Common application protocols that are used on the internet include HTTP, TLS/SSL, SMTP, and FTP.
- Common network management and support protocols include DNS, DHCP, and ICMP.
- Common utilities that are used to discover and troubleshoot network communication include `ping`, `nslookup`, and `traceroute`.

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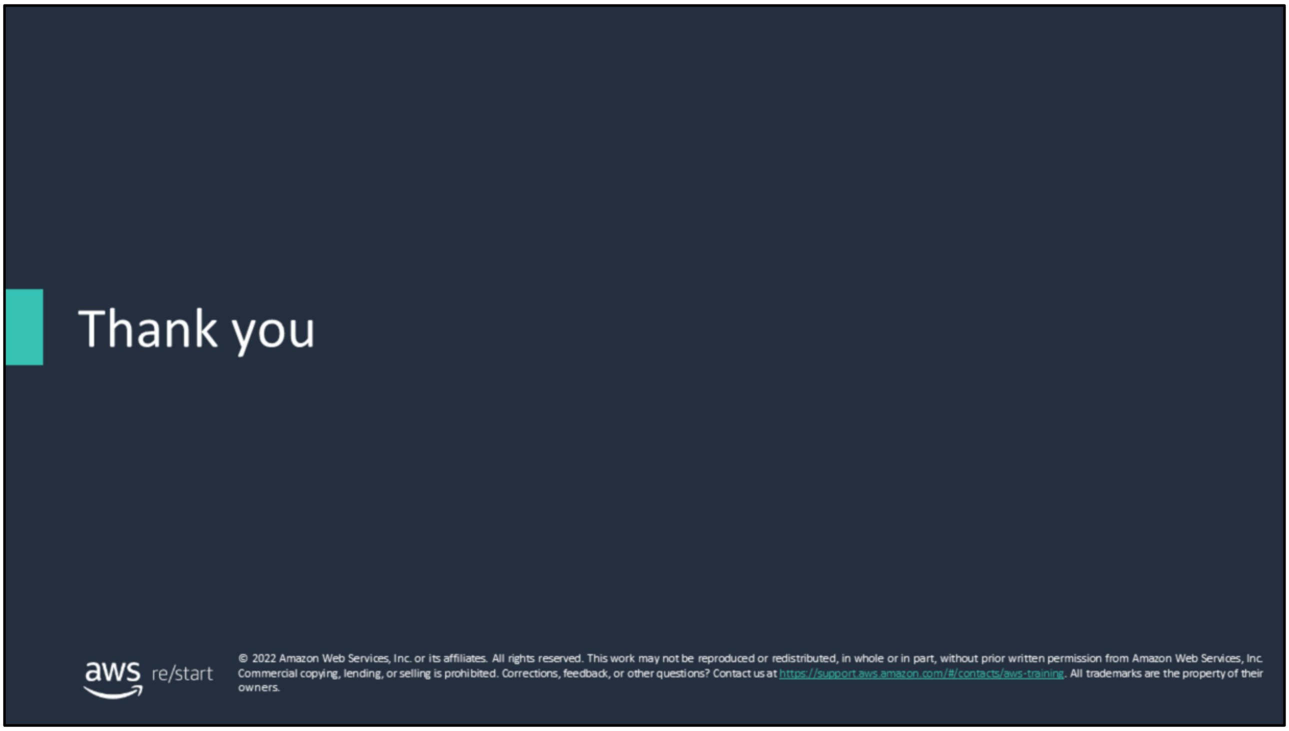

Thank you

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Thank you for completing this module.