University of BRISTOL

# *Computer System B*

**Dr. Alma Oracevic**
**alma.oracevic@bristol.ac.uk**

bristol.ac.uk

University of BRISTOL

# What did we learn?

- What is security?
- CIA
- Authentication
- Authorization
- Accountability (logs)

bristol.ac.uk

# Computer Security Objectives

## Confidentiality

- Data confidentiality
  - Assures that private or confidential information is not made available or disclosed to unauthorized individuals
- Privacy
  - Assures that individuals control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed

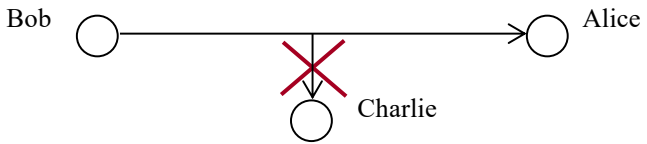
## Integrity

- Data integrity
  - Assures that information and programs are changed only in a specified and authorized manner
- System integrity
  - Assures that a system performs its intended function in an unimpaired manner, free from deliberate or inadvertent unauthorized manipulation of the system

## Availability

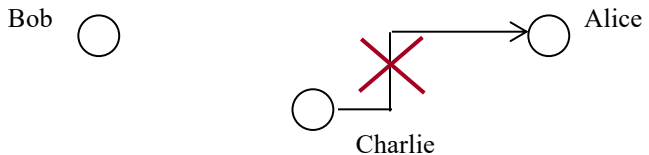
- Assures that systems work promptly and service is not denied to authorized users

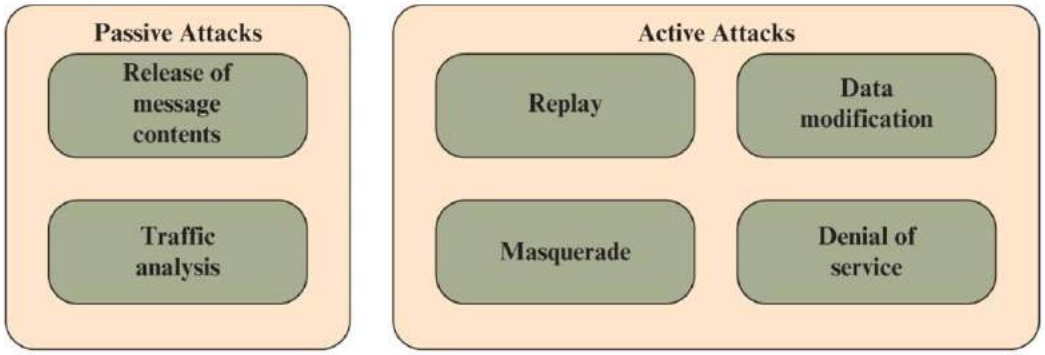
## 1. Confidentiality



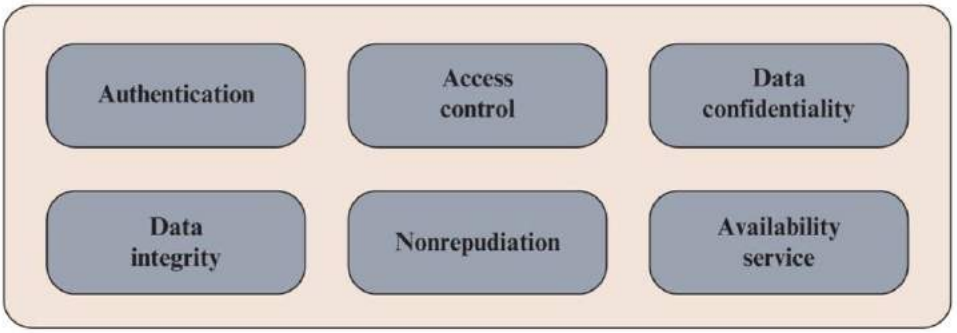

## 2. Message integrity


## 3. Message authentication

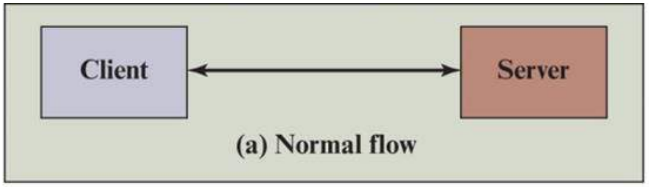




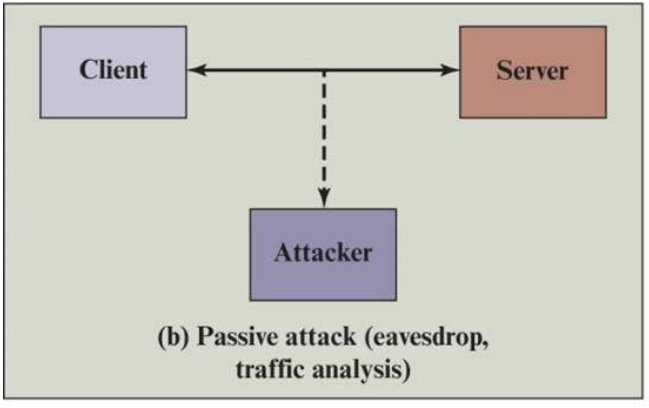

(a) Attacks



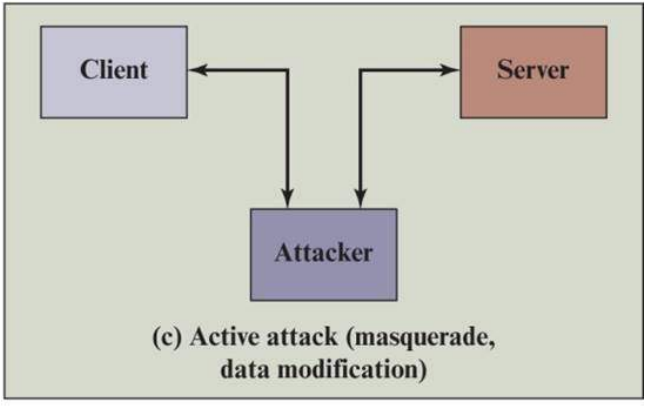

(b) Services



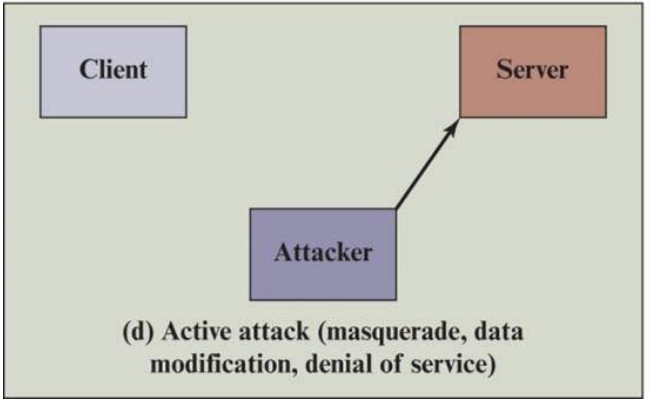

(a) Normal flow



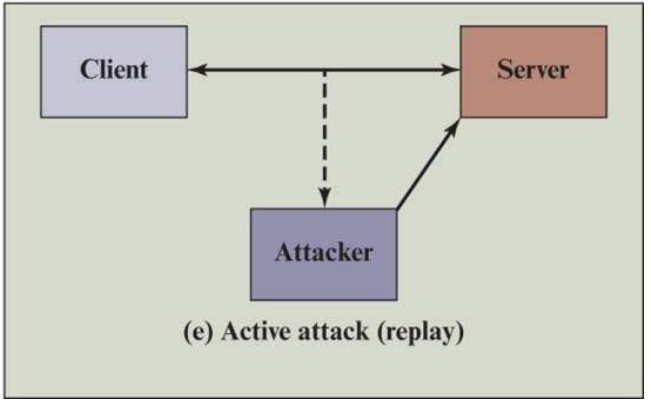

(b) Passive attack (eavesdrop, traffic analysis)



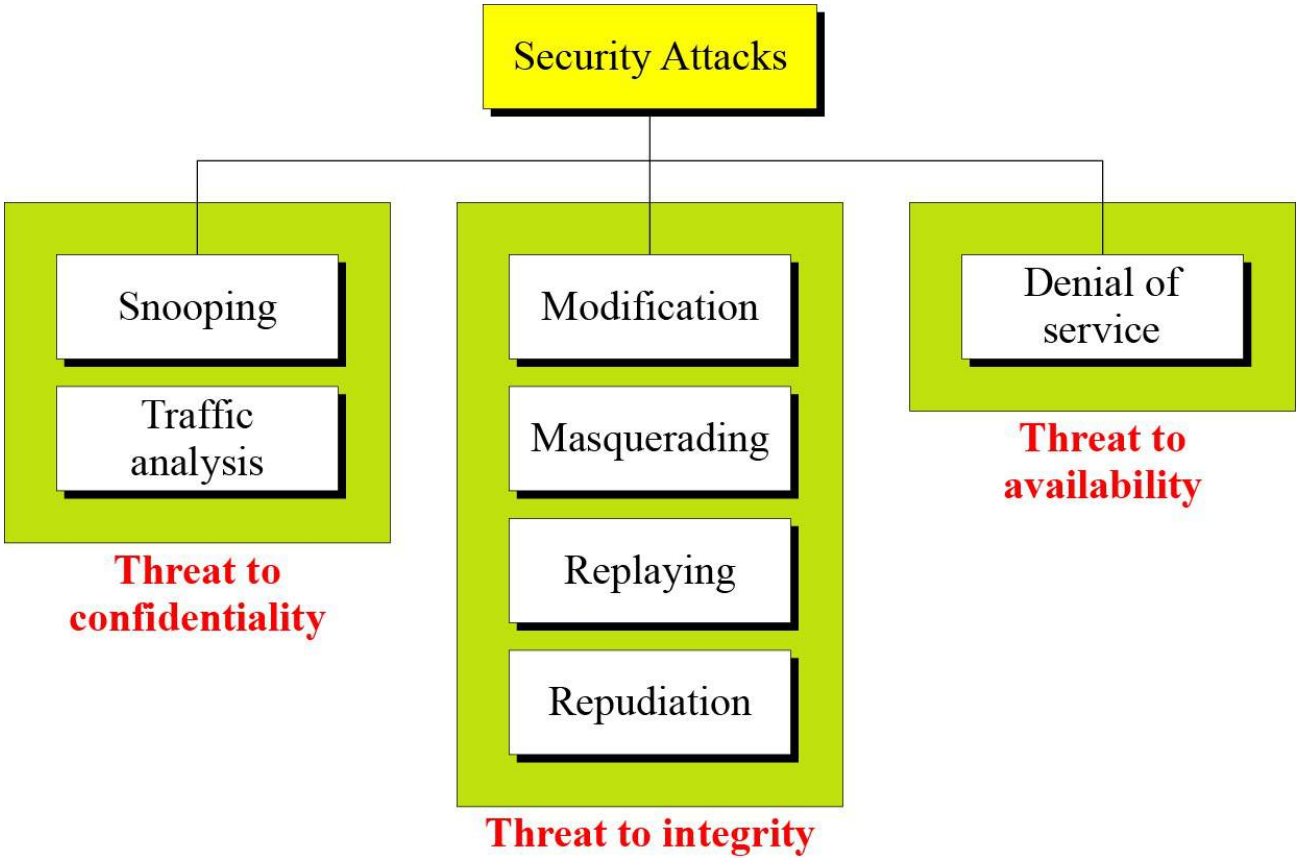

(c) Active attack (masquerade, data modification)

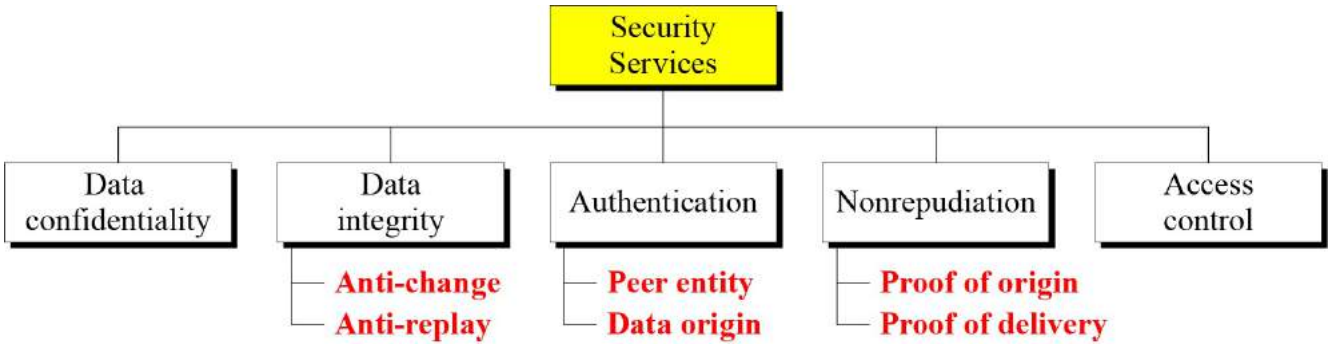



(d) Active attack (masquerade, data modification, denial of service)




(e) Active attack (replay)


Security Attacks
Snooping
Traffic analysis
Threat to confidentiality
Modification
Masquerading
Replaying
Repudiation
Threat to integrity
Denial of service
Threat to availability


Security Services
Data confidentiality
Data integrity
Anti-change
Anti-replay
Authentication
Peer entity
Data origin
Nonrepudiation
Proof of origin
Proof of delivery
Access control

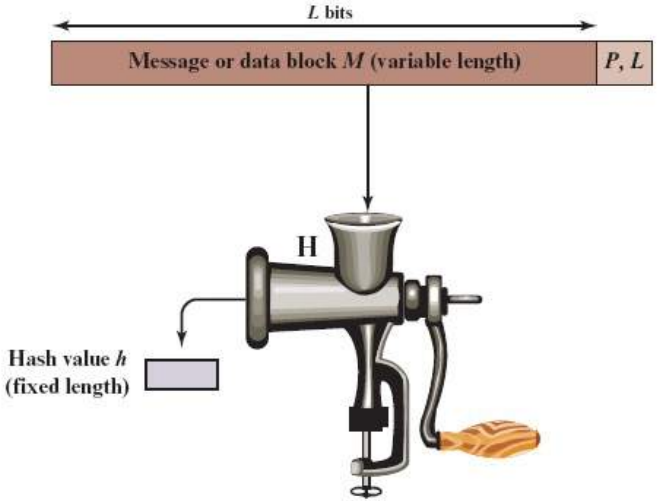
# Security Mechanisms (1 of 2)

- **Cryptographic algorithms:** We can distinguish between reversible cryptographic mechanisms and irreversible cryptographic mechanisms. A reversible cryptographic mechanism is simply an encryption algorithm that allows data to be encrypted and subsequently decrypted. Irreversible cryptographic mechanisms include hash algorithms and message authentication codes, which are used in digital signature and message authentication applications.
- **Data integrity:** This category covers a variety of mechanisms used to assure the integrity of a data unit or stream of data units.
- **Digital signature:** Data appended to, or a cryptographic transformation of, a data unit that allows a recipient of the data unit to prove the source and integrity of the data unit and protect against forgery.

# Security Mechanisms (2 of 2)

- **Authentication exchange:** A mechanism intended to ensure the identity of an entity by means of information exchange.
- **Traffic padding:** The insertion of bits into gaps in a data stream to frustrate traffic analysis attempts.
- **Routing control:** Enables selection of particular physically or logically secure routes for certain data and allows routing changes, especially when a breach of security is suspected.
- **Notarization:** The use of a trusted third party to assure certain properties of a data exchange
- **Access control:** A variety of mechanisms that enforce access rights to resources.

# Hash function




*P*, *L* = padding plus length field

# Message Authentication Code (MAC)

- Also known as a *keyed hash function*
- Typically used between two parties that share a secret key to authenticate information exchanged between those parties
- Takes as input a secret key and a data block and produces a hash value (MAC) which is associated with the protected message
  - –If the integrity of the message needs to be checked, the MAC function can be applied to the message and the result compared with the associated MAC value
  - –An attacker who alters the message will be unable to alter the associated MAC value without knowledge of the secret key

University of BRISTOL

# Today!

- Introduction to Cryptography!
- Introduction to Network Security


bristol.ac.uk

University of BRISTOL

# Classical Encryption Techniques

bristol.ac.uk

# Basic Terminology

- Plaintext
  - The original message
- Ciphertext
  - The coded message
- Enciphering or encryption
  - Process of converting from plaintext to ciphertext
- Deciphering or decryption
  - Restoring the plaintext from the ciphertext
- Cryptography
  - Study of encryption
- Cryptographic system or cipher
  - Schemes used for encryption
- Cryptanalysis
  - Techniques used for deciphering a message without any knowledge of the enciphering details
- Cryptology
  - Areas of cryptography and cryptanalysis together

# Cryptanalysis and Brute-Force Attack

## Cryptanalysis

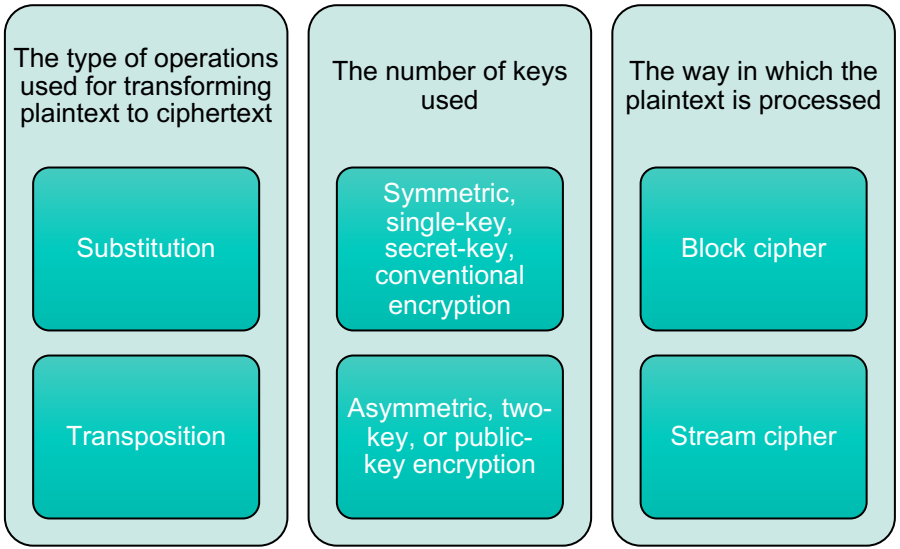
- Attack relies on the nature of the algorithm plus some knowledge of the general characteristics of the plaintext
- Attack exploits the characteristics of the algorithm to attempt to deduce a specific plaintext or to deduce the key being used

## Brute-force attack

- Attacker tries every possible key on a piece of ciphertext until an intelligible translation into plaintext is obtained
- On average, half of all possible keys must be tried to achieve success

# Cryptographic Systems

- Characterized along three independent dimensions:



# Brute-Force Attack

Involves trying every possible key until an intelligible translation of the ciphertext into plaintext is obtained

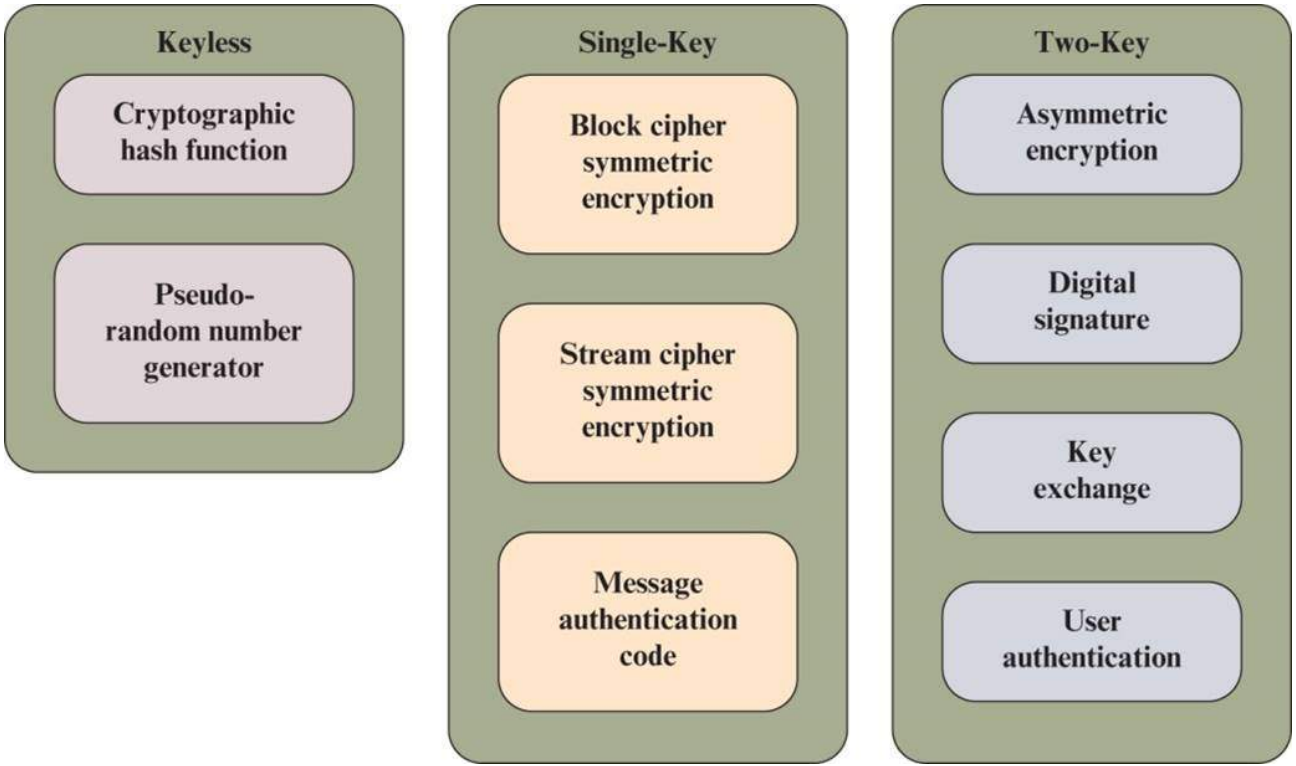
On average, half of all possible keys must be tried to achieve success

To supplement the brute-force approach, some degree of knowledge about the expected plaintext is needed, and some means of automatically distinguishing plaintext from garble is also needed

# Cryptographic Systems

- The type of operations used for transforming plaintext to ciphertext
  - –Substitution
  - –Transposition
- The number of keys used
  - –Symmetric, single-key, secret-key, conventional encryption
  - –Asymmetric, two-key, or public-key encryption
- The way in which the plaintext is processed
  - –Block cipher
  - –Stream cipher

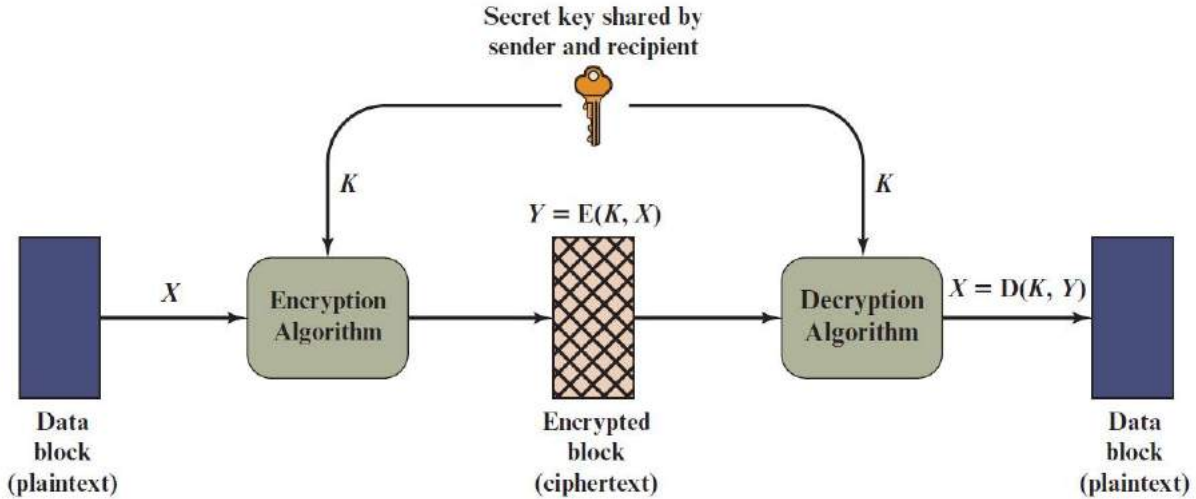
# Cryptographic Algorithms based on number of keys



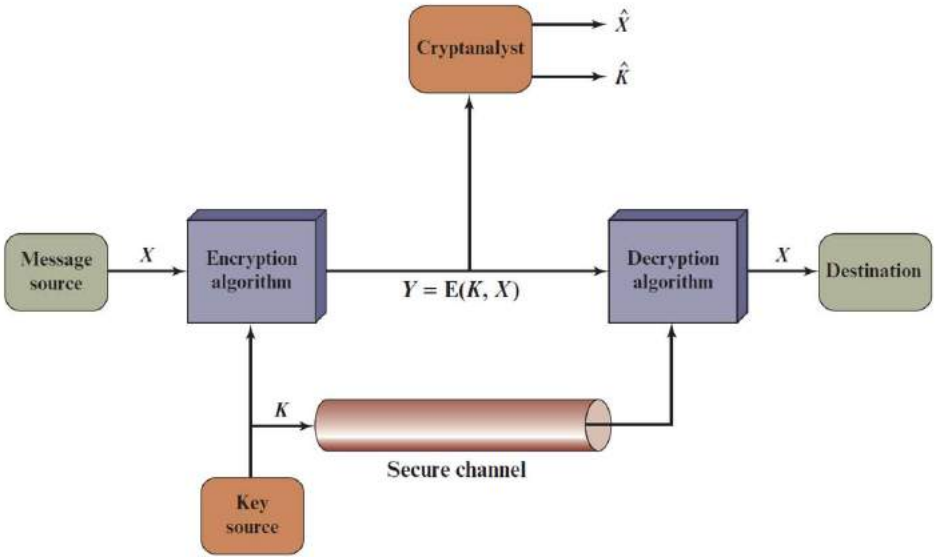
# Symmetric Encryption

- Also referred to as conventional encryption or single-key encryption
- Was the only type of encryption in use prior to the development of public-key encryption in the 1970s
- Remains by far the most widely used of the two types of encryption

# Simplified Model of Symmetric Encryption

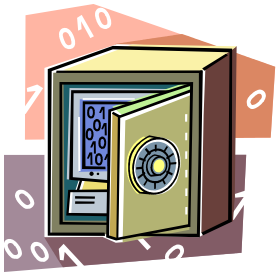


# Model of Symmetric Cryptosystem



# Encryption Scheme Security

- Unconditionally secure
  - No matter how much time an opponent has, it is impossible for him or her to decrypt the ciphertext simply because the required information is not there
- Computationally secure
  - The cost of breaking the cipher exceeds the value of the encrypted information
  - The time required to break the cipher exceeds the useful lifetime of the information



# Substitution Technique

- Is one in which the letters of plaintext are replaced by other letters or by numbers or symbols
- If the plaintext is viewed as a sequence of bits, then substitution involves replacing plaintext bit patterns with ciphertext bit patterns

# Caesar Cipher

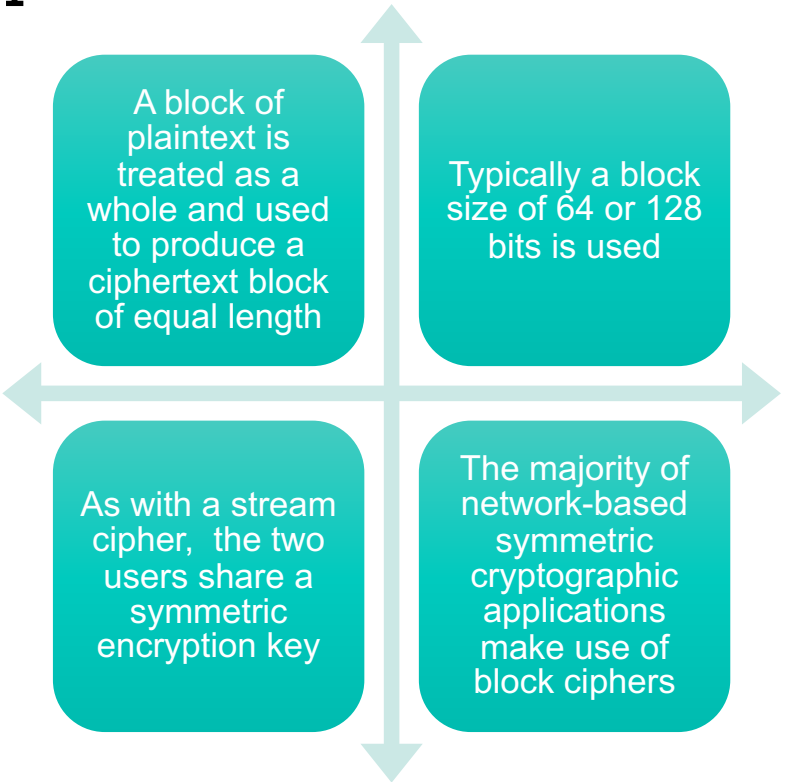


- Simplest and earliest known use of a substitution cipher
- Used by Julius Caesar
- Involves replacing each letter of the alphabet with the letter standing three places further down the alphabet
- Alphabet is wrapped around so that the letter following Z is A

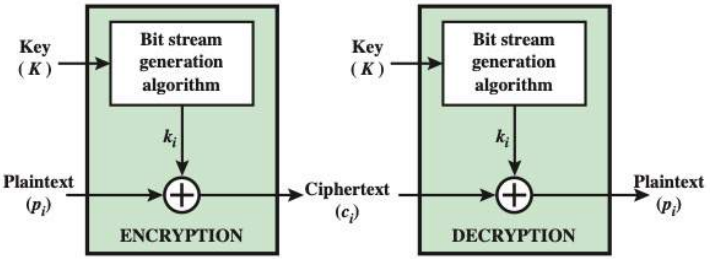
plain: meet me after the toga party

cipher: PHHW PH DIWHU WKH WRJD SDUWB

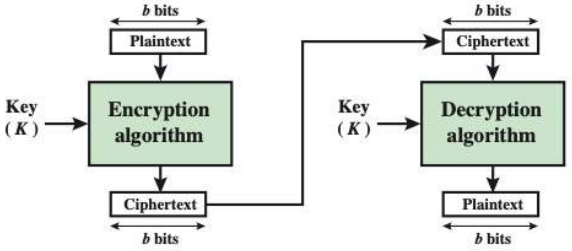
# Block Cipher



# Block Cipher




(a) Stream Cipher Using Algorithmic Bit Stream Generator

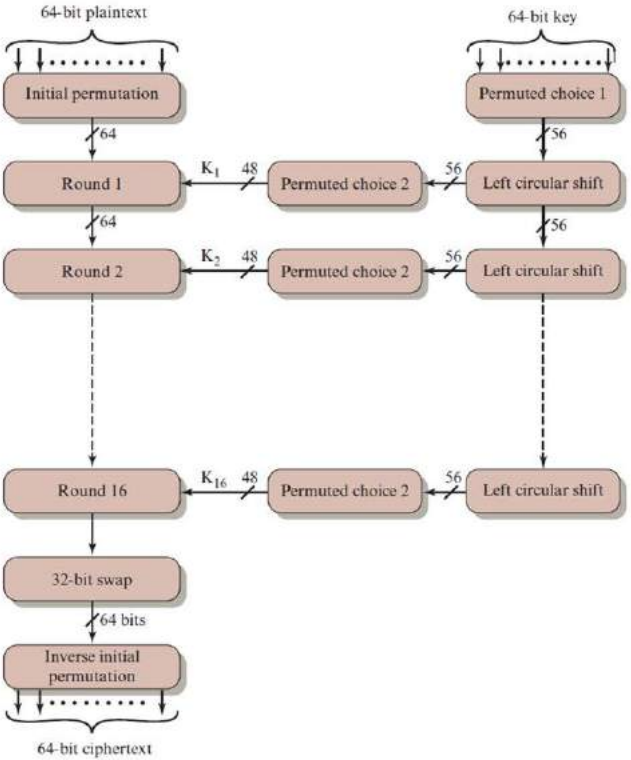



(b) Block Cipher

# Data Encryption Standard (DES)

- Issued in 1977 by the National Bureau of Standards (now NIST) as Federal Information Processing Standard 46
- Was the most widely used encryption scheme until the introduction of the Advanced Encryption Standard (AES) in 2001
- Algorithm itself is referred to as the Data Encryption Algorithm (DEA)
  - Data are encrypted in 64-bit blocks using a 56-bit key
  - The algorithm transforms 64-bit input in a series of steps into a 64-bit output
  - The same steps, with the same key, are used to reverse the encryption

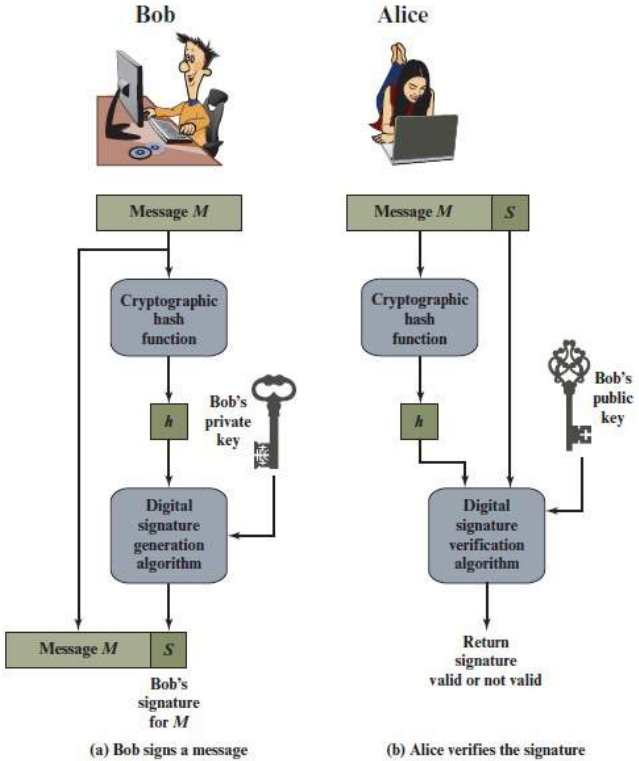
# General Depiction of DES Encryption Algorithm



# Asymmetric Algorithms

- Encryption algorithms that use a single key are referred to as *asymmetric encryption algorithms*
- Digital signature algorithm
  - A digital signature is a value computed with a cryptographic algorithm and associated with a data object in such a way that any recipient of the data can use the signature to verify the data's origin and integrity
- Key exchange
  - The process of securely distributing a symmetric key to two or more parties
- User authentication
  - The process of authenticating that a user attempting to access an application or service is genuine and, similarly, that the application or service is genuine

# Digital Signature



# Digital Signature Properties

- It must verify the author and the date and time of the signature
- It must authenticate the contents at the time of the signature
- It must be verifiable by third parties to resolve disputes

University of BRISTOL

# Introduction to Network security


bristol.ac.uk

# Security?

- widespread use of data processing equipment:
  *computer security*
- widespread use of computer networks and distributed computing systems:
  *network security*

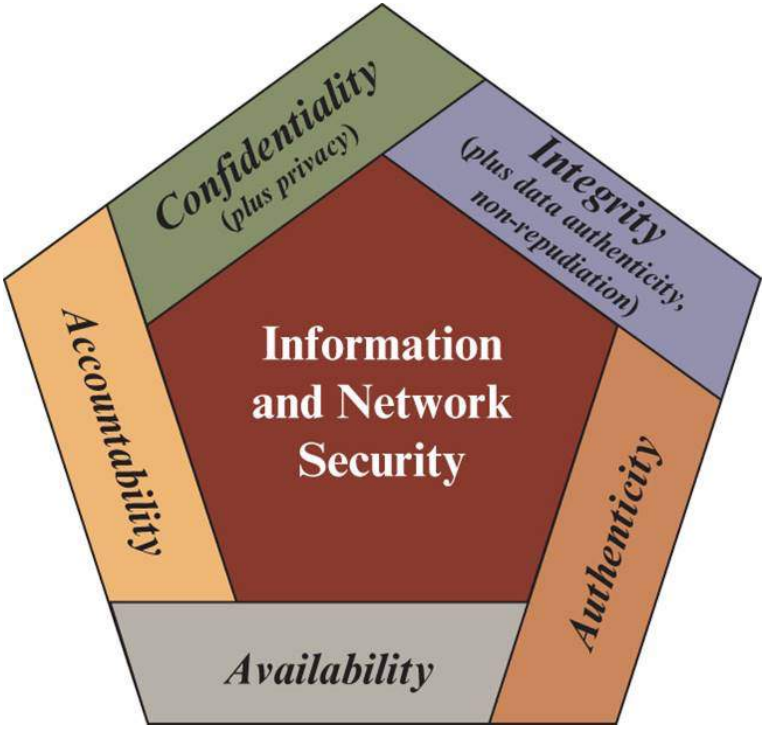
# Cybersecurity

**Information Security**

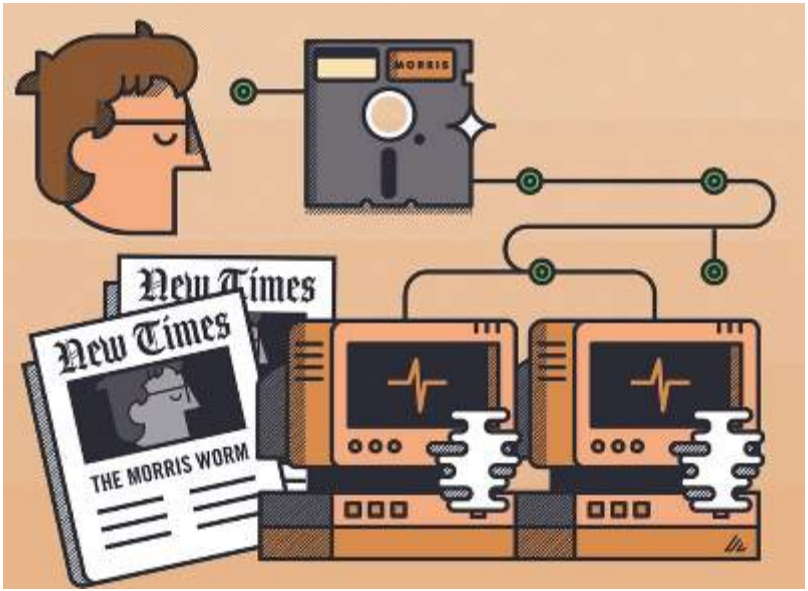
- This term refers to preservation of confidentiality, integrity, and availability of information. In addition, other properties, such as authenticity, accountability, nonrepudiation, and reliability can also be involved

**Network Security**

- This term refers to protection of networks and their service from unauthorized modification, destruction, or disclosure, and provision of assurance that the network performs its critical functions correctly and there are no harmful side effects


Confidentiality
(plus privacy)
Integrity
(plus data authenticity, non-repudiation)
Information and Network Security
Accountability
Authenticity
Availability

# The day that changed everything



# The Brain

*Welcome to the Dungeon*

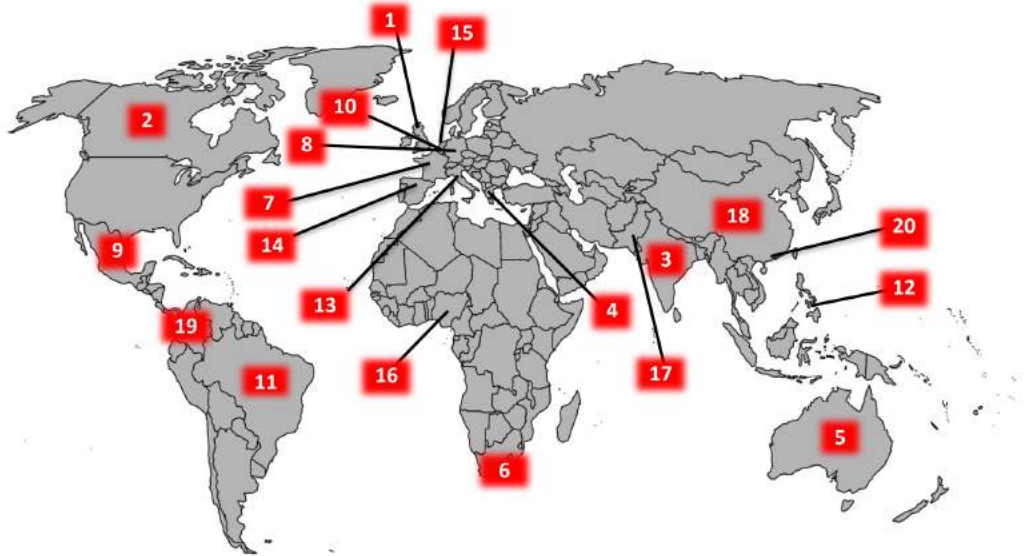
*© 1986 Basit & Amjads (pvt). BRAIN COMPUTER SERVICES 730 NIZAM BLOCK ALLAMA IQBAL TOWN LAHORE-PAKISTAN PHONE: 430791,443248,280530.*

*Beware of this virus.... Contact us for vaccination....*

# But why do we need security?

## 2020 - TOP 20 INTERNATIONAL VICTIM COUNTRIES

*Excluding the United States*[8]




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. United Kingdom | 216,633 | 6. South Africa | 1,754 | 11. Brazil | 951 | 16. Nigeria | 443 |
| 2. Canada | 5,399 | 7. France | 1,640 | 12. Philippines | 898 | 17. Pakistan | 443 |
| 3. India | 2,930 | 8. Germany | 1,578 | 13. Italy | 728 | 18. China | 442 |
| 4. Greece | 2,314 | 9. Mexico | 1,164 | 14. Spain | 618 | 19. Colombia | 418 |
| 5. Australia | 1,807 | 10. Belgium | 1,023 | 15. Netherlands | 450 | 20. Hong Kong | 407 |

Source: 2020 Internet Crime Report

## 2020 CRIME TYPES

### By Victim Count

| Crime Type | Victims | Crime Type | Victims |
|---|---|---|---|
| Phishing/Vishing/Smishing/Pharming | 241,342 | Other | 10,372 |
| Non-Payment/Non-Delivery | 108,869 | Investment | 8,788 |
| Extortion | 76,741 | Lottery/Sweepstakes/Inheritance | 8,501 |
| Personal Data Breach | 45,330 | IPR/Copyright and Counterfeit | 4,213 |
| Identity Theft | 43,330 | Crimes Against Children | 3,202 |
| Spoofing | 28,218 | Corporate Data Breach | 2,794 |
| Misrepresentation | 24,276 | Ransomware | 2,474 |
| Confidence Fraud/Romance | 23,751 | Denial of Service/TDoS | 2,018 |
| Harassment/Threats of Violence | 20,604 | Malware/Scareware/Virus | 1,423 |
| BEC/EAC | 19,369 | Health Care Related | 1,383 |
| Credit Card Fraud | 17,614 | Civil Matter | 968 |
| Employment | 16,879 | Re-shipping | 883 |
| Tech Support | 15,421 | Charity | 659 |
| Real Estate/Rental | 13,638 | Gambling | 391 |
| Advanced Fee | 13,020 | Terrorism | 65 |
| Government Impersonation | 12,827 | Hacktivist | 52 |
| Overpayment | 10,988 | | |

| Descriptors* | | |
|---|---|---|
| Social Media | 35,439 | *These descriptors relate to the medium or tool used to facilitate the crime and are used by the IC3 for tracking purposes only. They are available as descriptors only after another crime type has been selected. Please see Appendix B for more information regarding IC3 data. |
| Virtual Currency | 35,229 | |



Source: 2020 Internet Crime Report

# What is network security?

bristol.ac.uk

# Model for Network Security

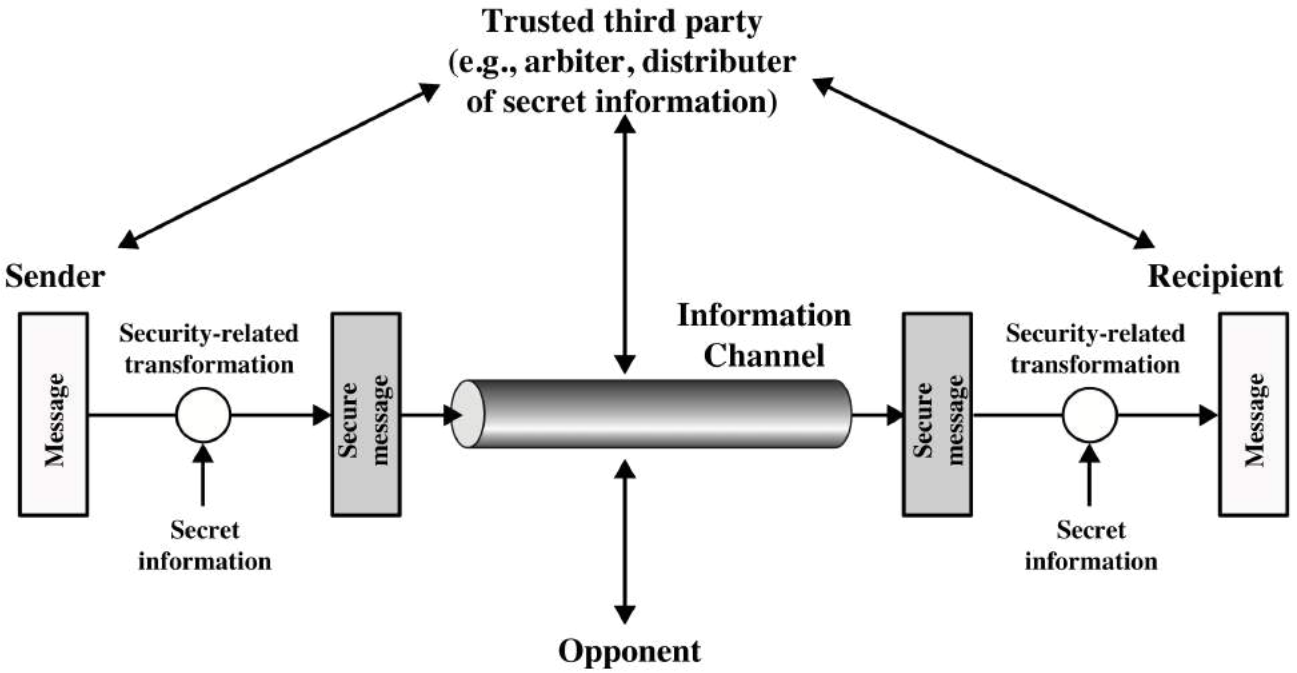
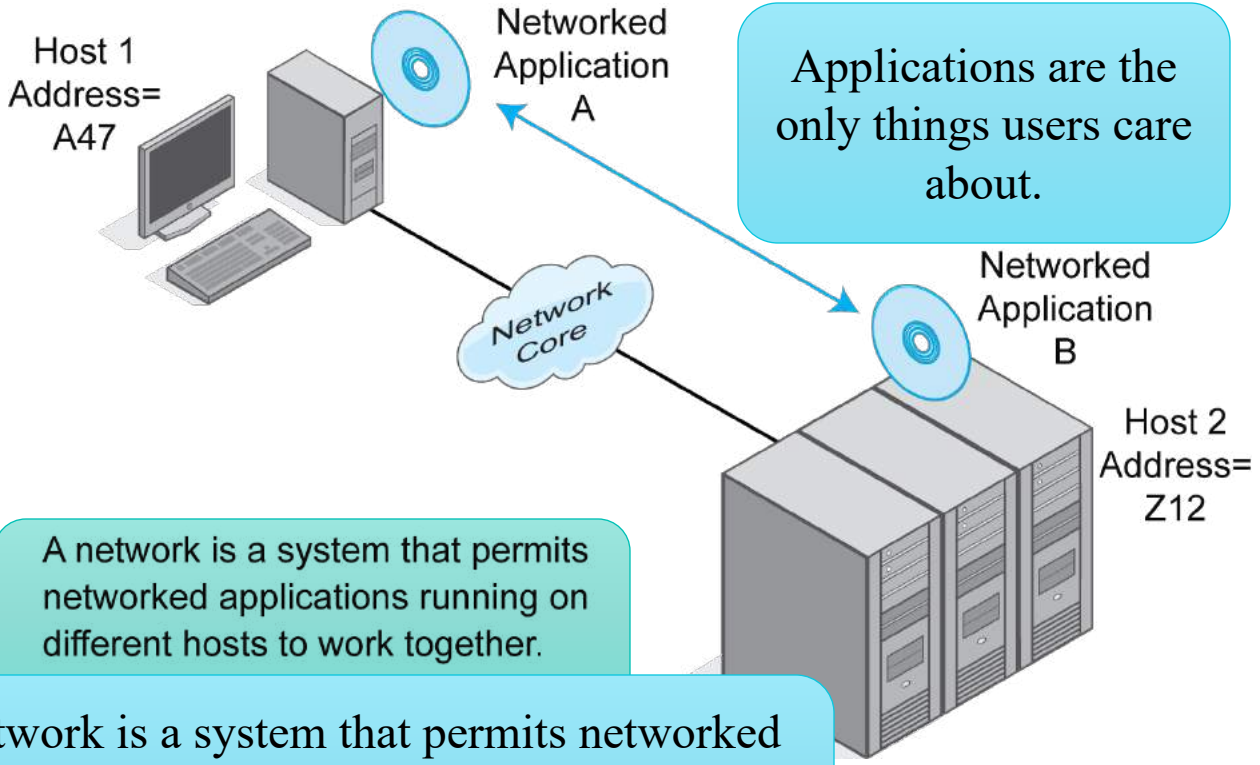




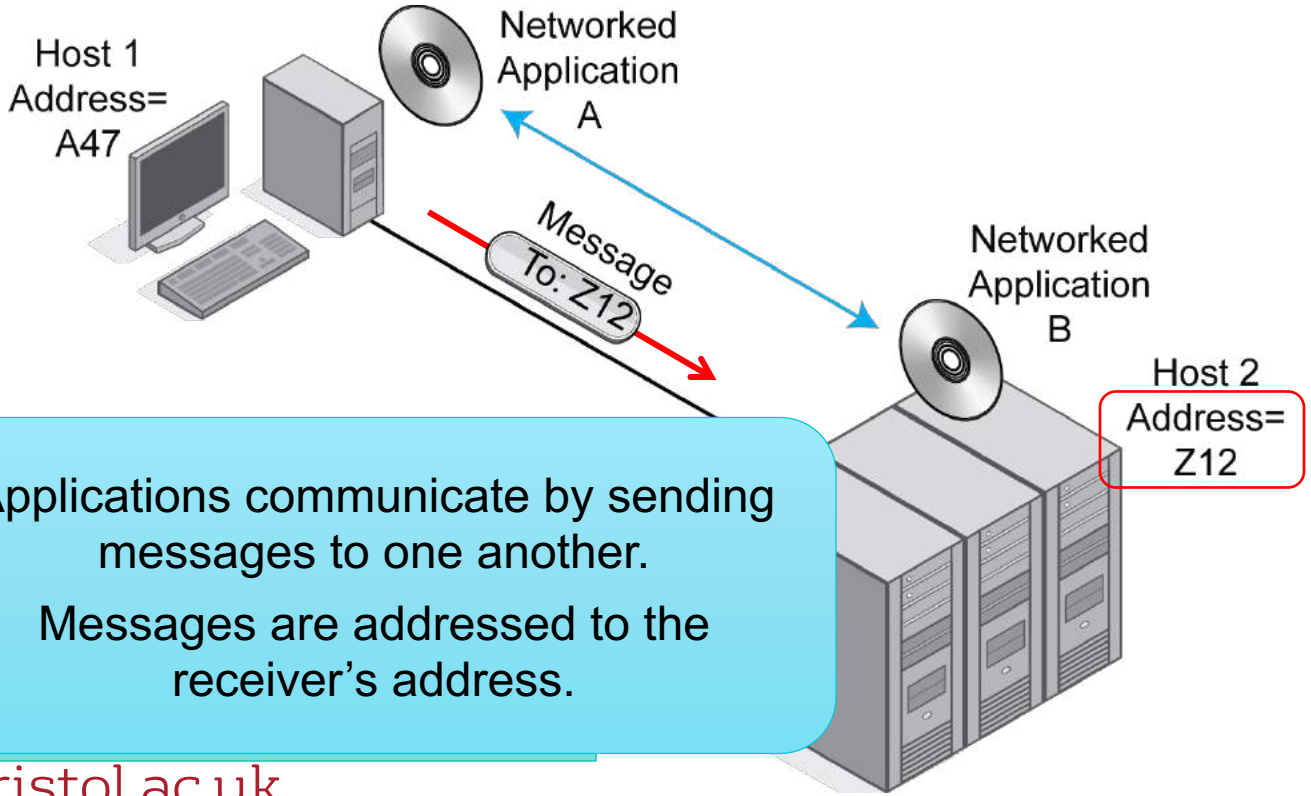

Figure 1.2 Model for Network Security

# Basic Network Terminology




A network is a system that permits networked applications running on different hosts to work together.

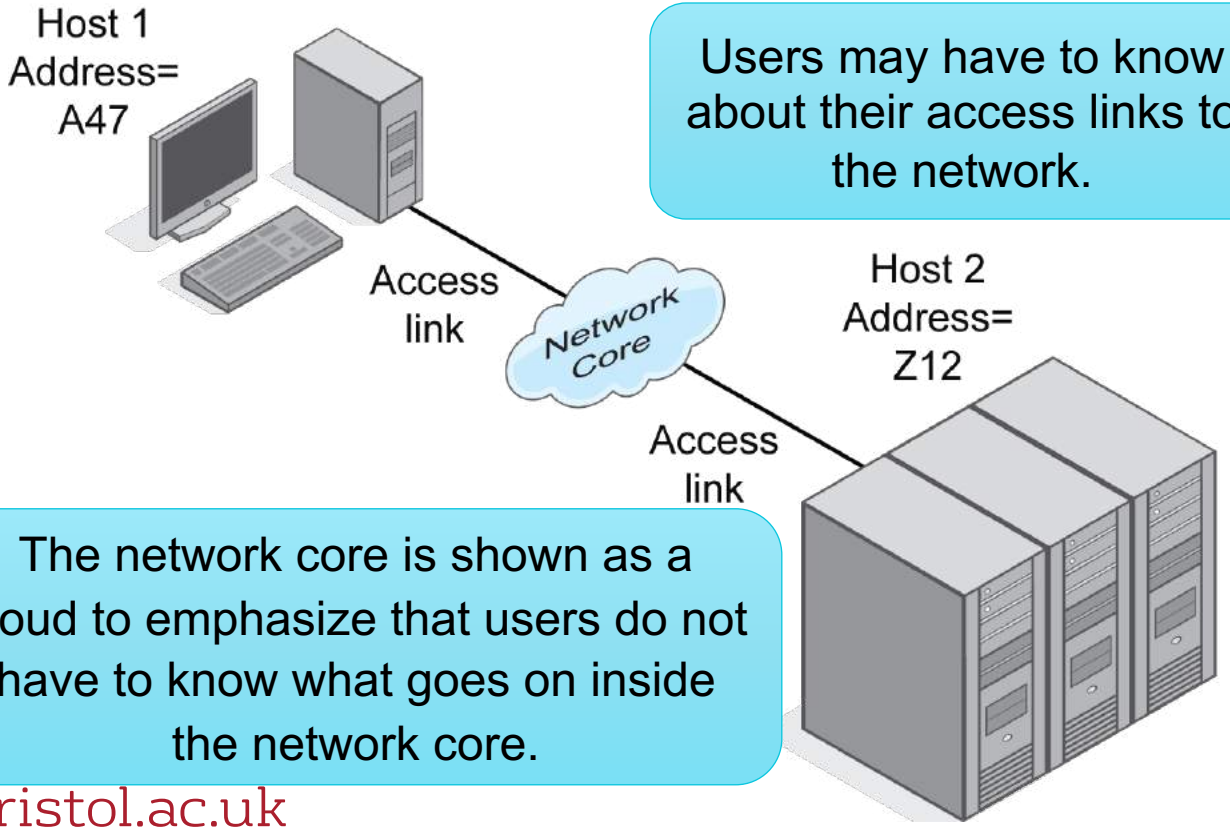
# Basic Network Terminology




Applications communicate by sending messages to one another.

Messages are addressed to the receiver's address.

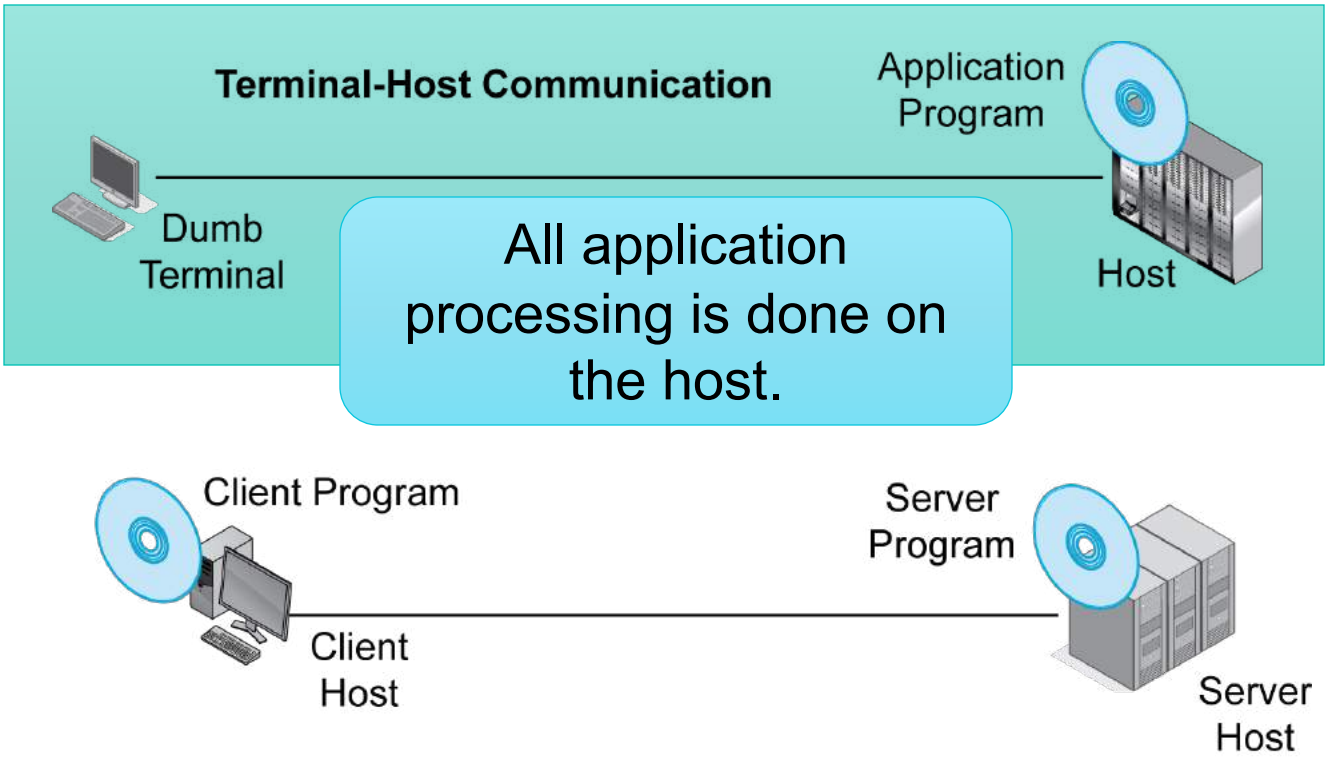
# Basic Network Terminology



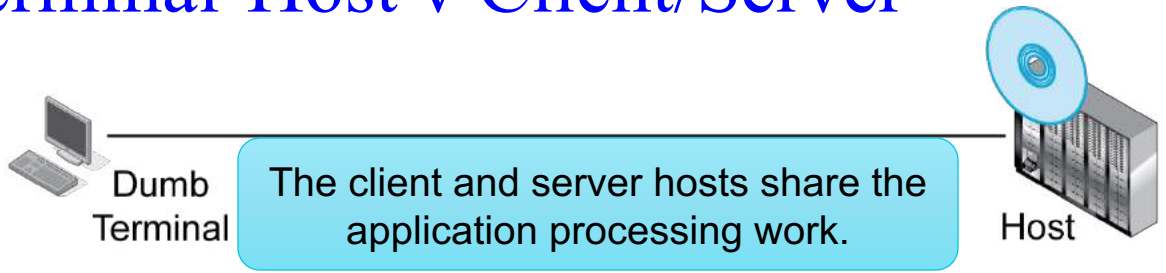

Users may have to know about their access links to the network.

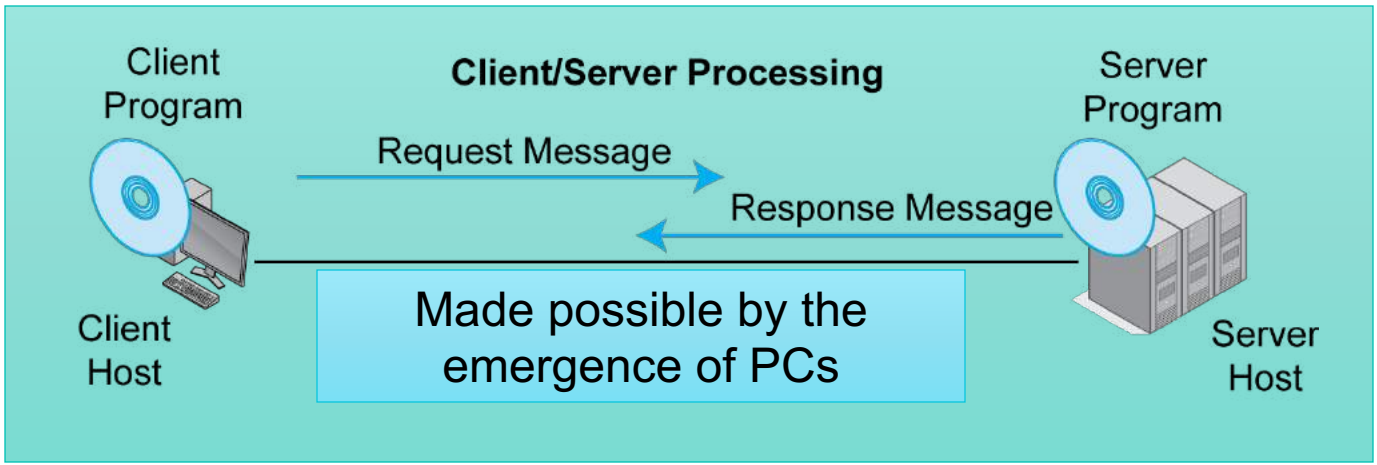
The network core is shown as a cloud to emphasize that users do not have to know what goes on inside the network core.

# Terminal-Host v Client/Server



# Terminal-Host v Client/Server



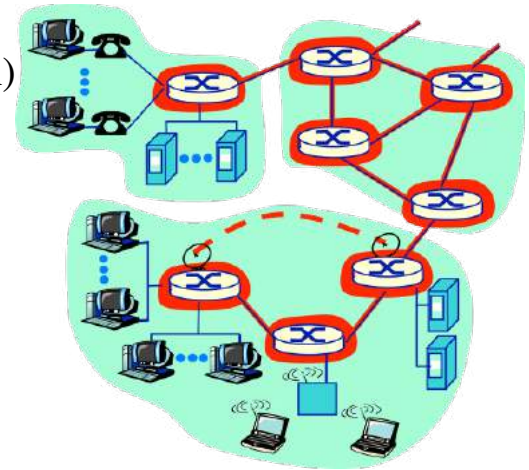



# Network Structure

## The network core

- A mesh of interconnected routers
- **The fundamental question:** How is data routed through the network?
  - **Circuit switching:** dedicated circuit (path) per call used by all data (e.g., telephone)
  - **Packet switching:** data sent in discrete "chunks"

    (packets); each has a path chosen for it

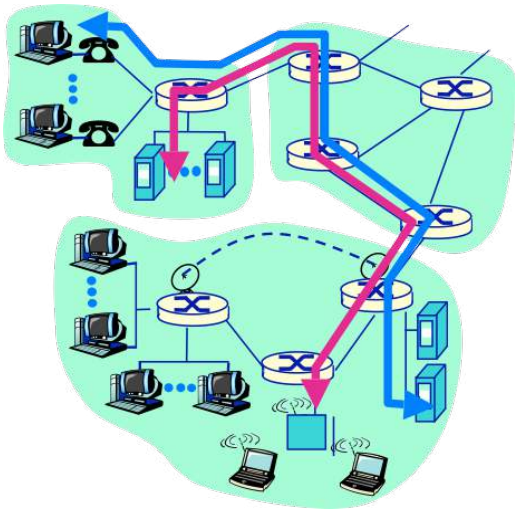


# The Network Core

## Circuit Switching

- Resources reserved end-to-end for the connection (“call”)
  - Resources: Link bandwidth, switch capacity
  - Reservation: Dedicated fraction of available bandwidth, buffers, etc.

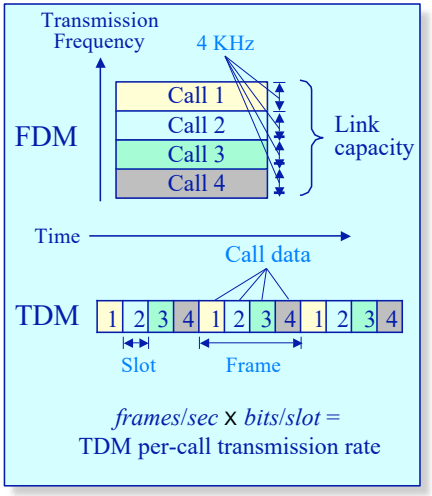
- Circuit-like (guaranteed) performance
  - Call setup required
  - Call rejection (“busy signal”) possible



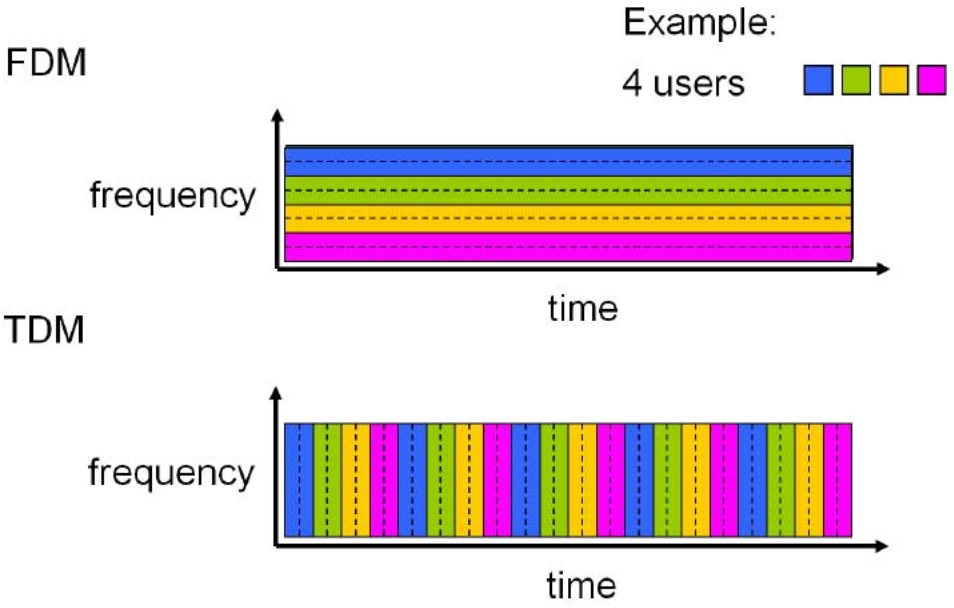
# Circuit Switching

## Allocating fractions of bandwidth — Multiplexing

- Network bandwidth divided into transmission "slots"
  - Slots allocated to calls
  - Slots are unused ("idle") if not used by owning call
  - No sharing of slots!
- How to divide link bandwidth into slots?
  - Frequency division multiplexing (FDM)
  - Time division multiplexing (TDM)



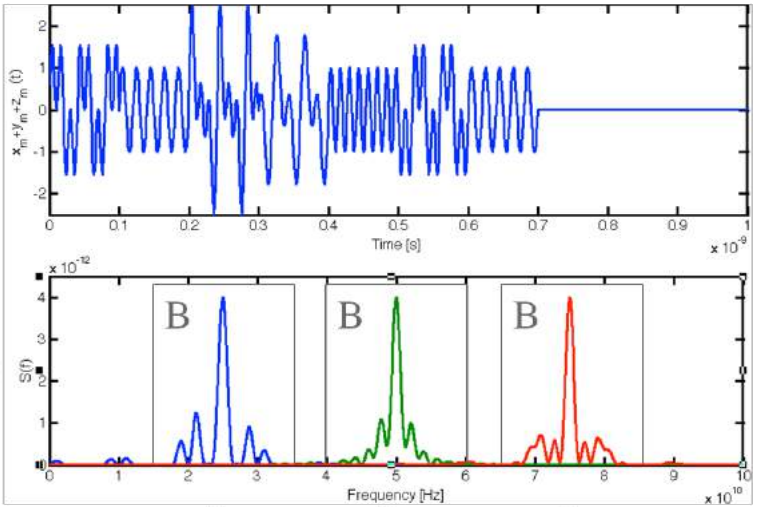
# Multiplexing



# TDM/FDM

$x(t)+y(t)+z(t)$

$S_X(f)+S_Y(f)+S_Z(f)$



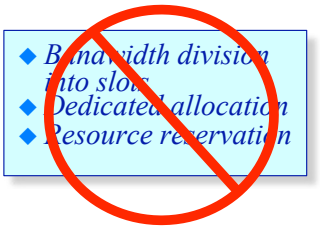

$f_{c1}$ $f_{c2}$ $f_{c3}$

# The Network Core

## Packet Switching

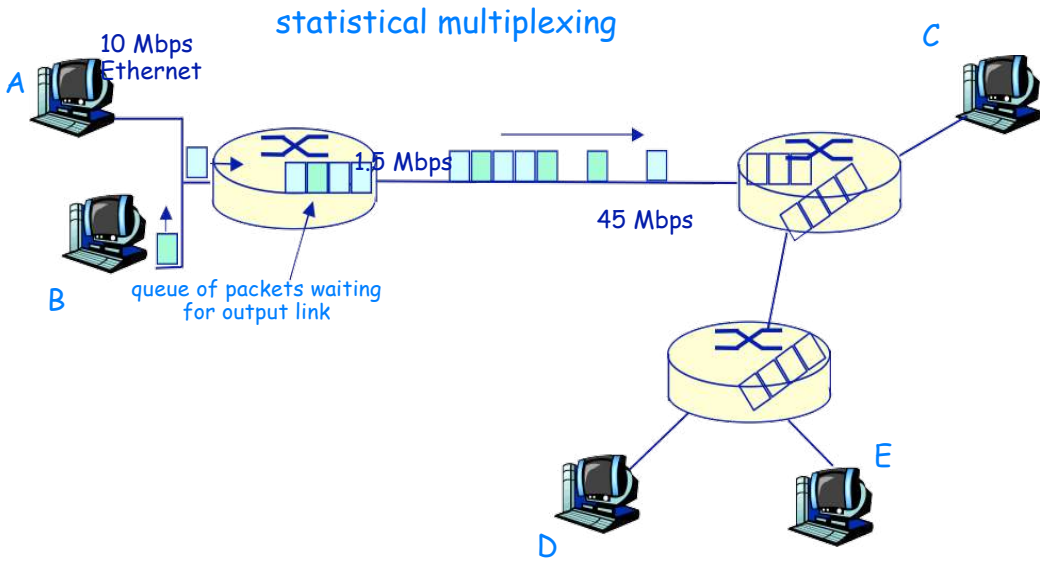
- Each sender divides its messages into *packets (sequence of bits)*
  - Senders' packets share (compete for) network resources
  - Each packet uses full link capacity until transmission completed
  - Resources allocated & used as needed

- But now we have resource contention!
  - Aggregate resource demand can exceed amount available
  - packets queue, wait for link availability
- Store and forward: packets move **one hop** at a time
  - Transmit over link
  - Wait turn at next link

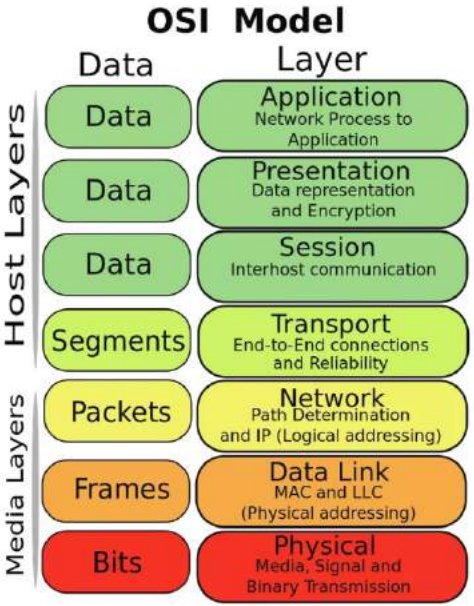


# Packet Switching

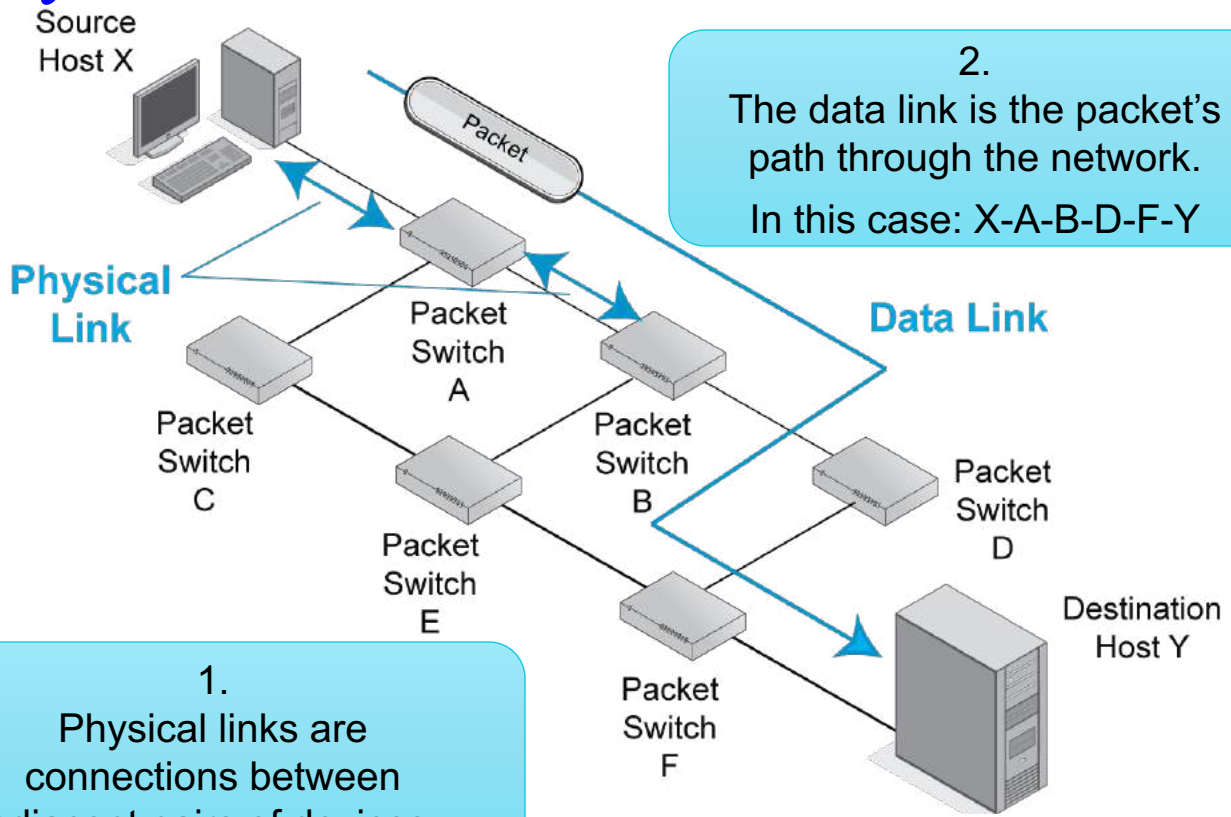
## Statistical multiplexing



# Bits, Frames, Segments, Data?



# Physical Links and Data Links

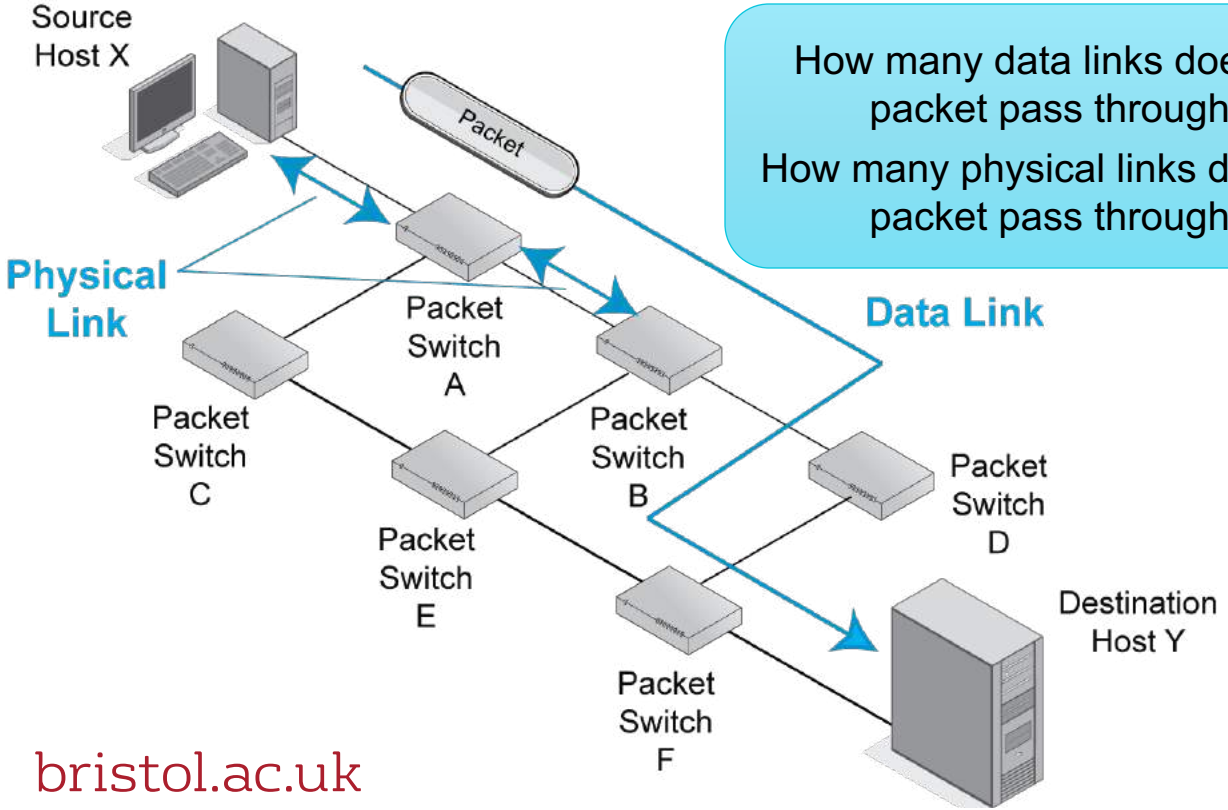



2.
The data link is the packet's path through the network.

In this case: X-A-B-D-F-Y

1.
Physical links are connections between adjacent pairs of devices.

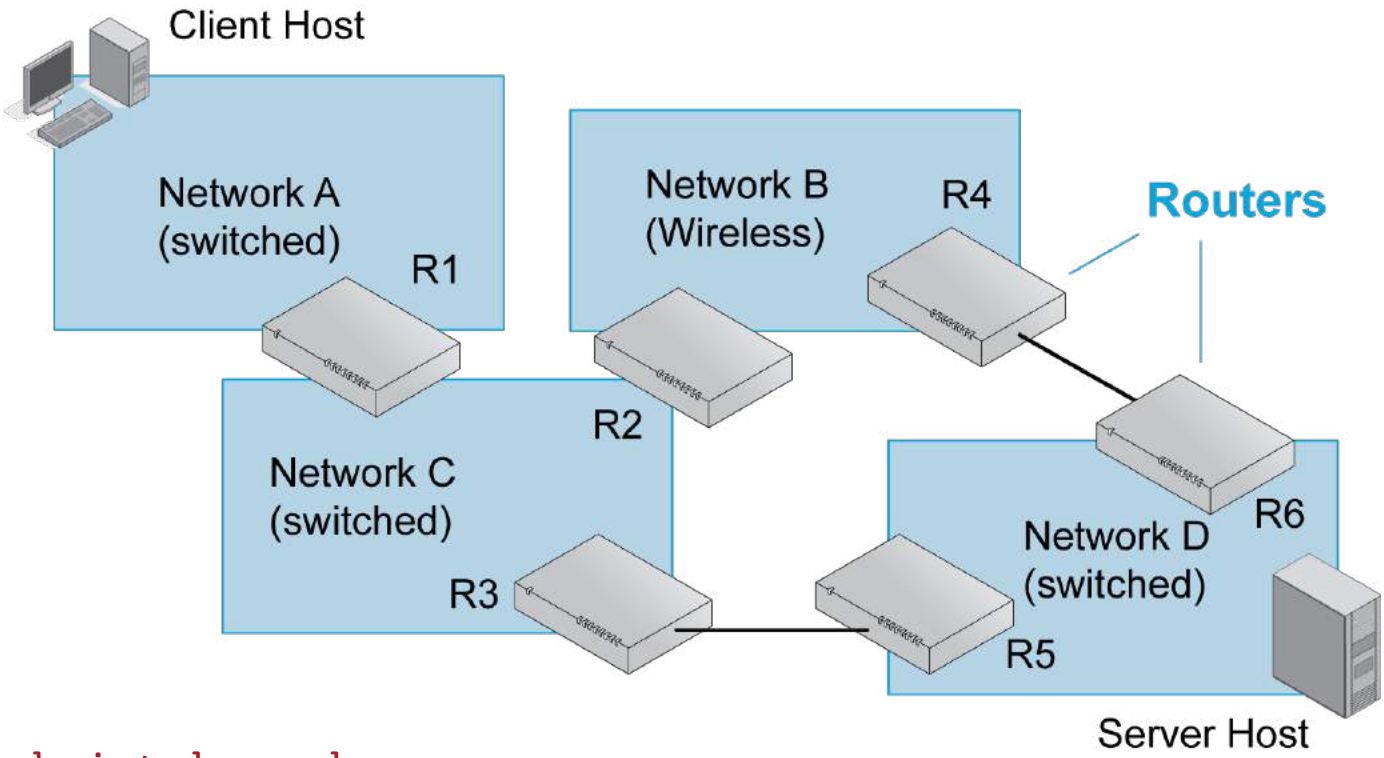
# Physical Links and Data Links




How many data links does the packet pass through?

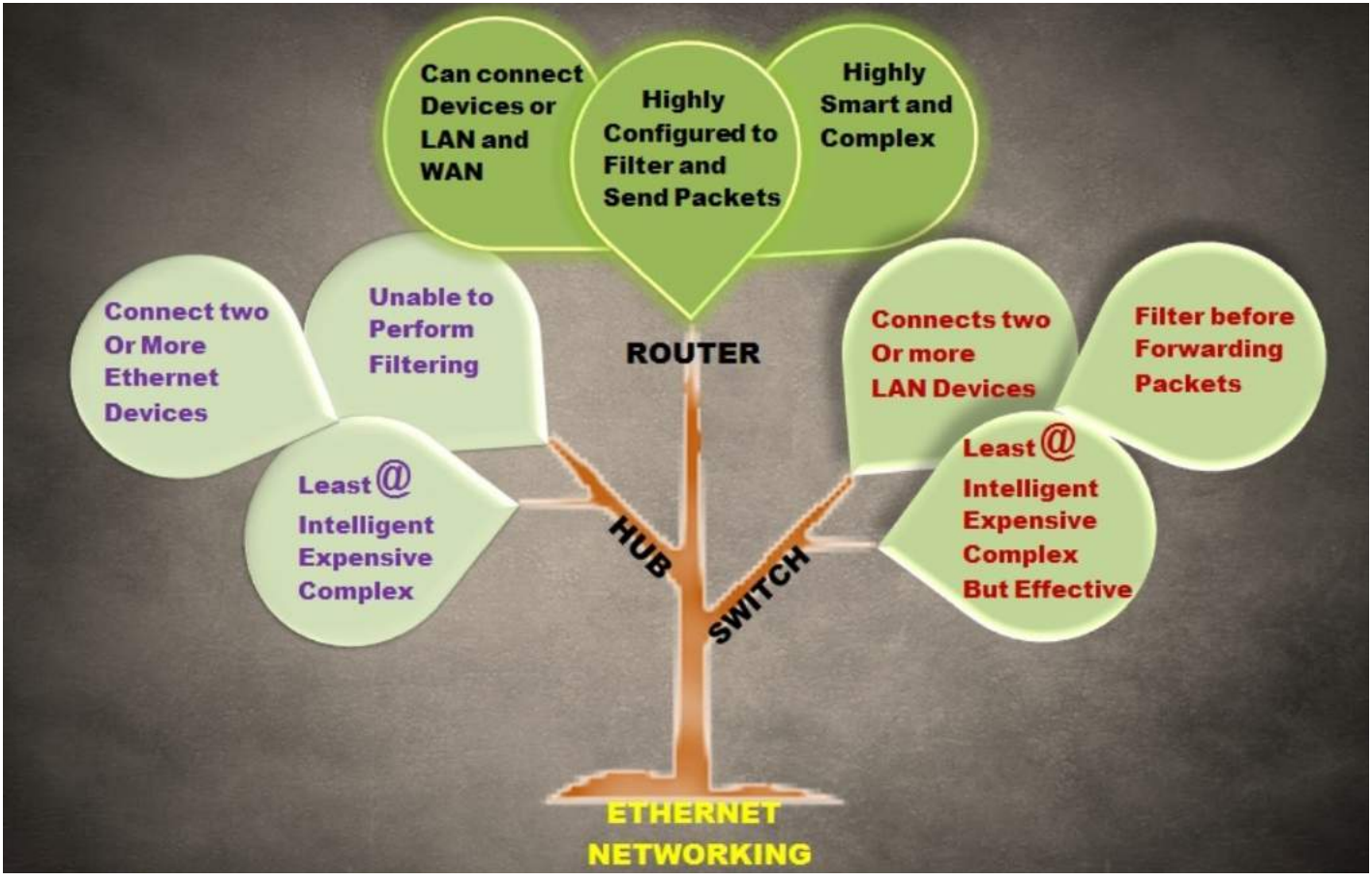
How many physical links does the packet pass through?

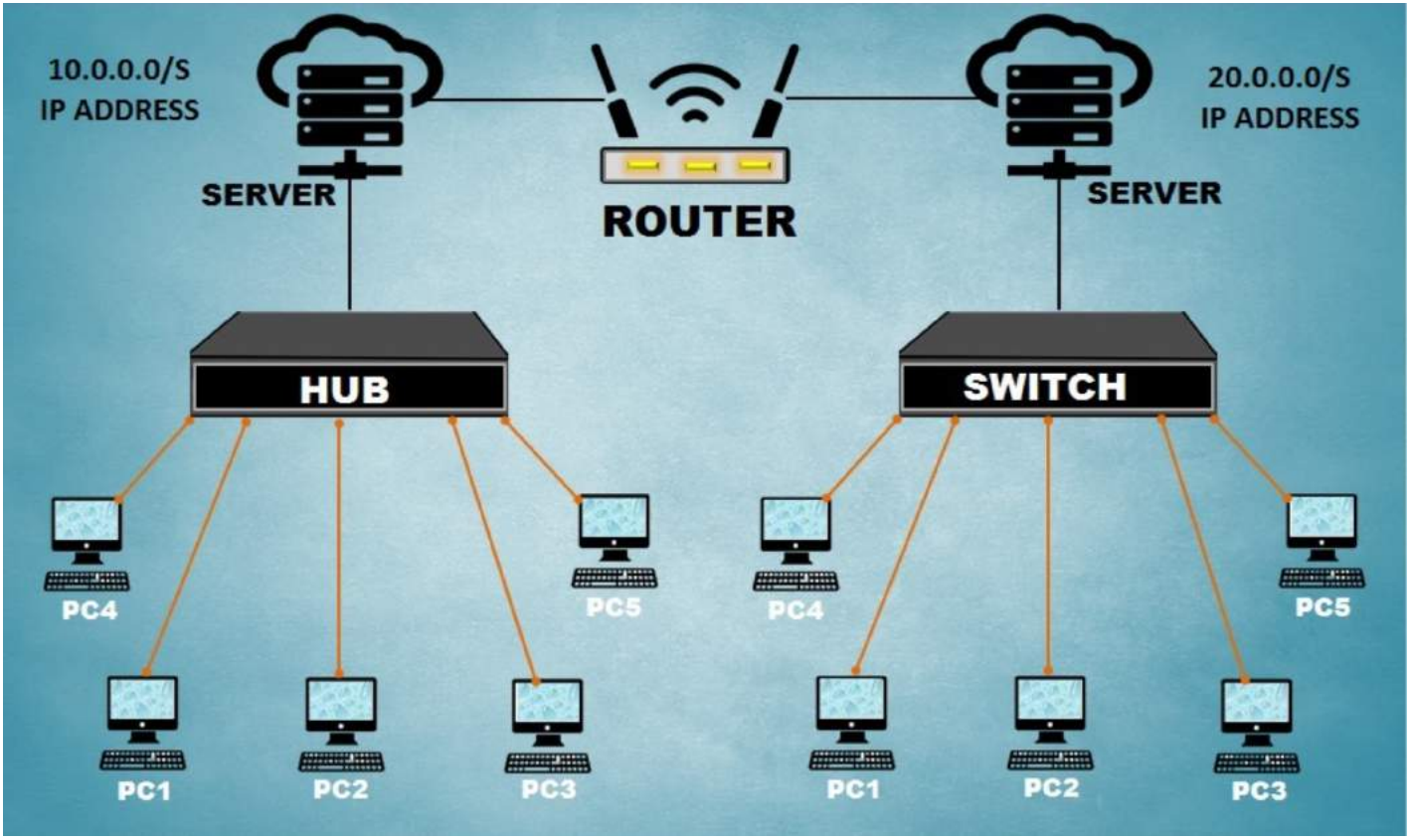
# Internetworking



# Router, Switch, Hub, Bridge?





Can connect Devices or LAN and WAN
Highly Configured to Filter and Send Packets
Highly Smart and Complex
Connect two Or More Ethernet Devices
Unable to Perform Filtering
ROUTER
Connects two Or more LAN Devices
Filter before Forwarding Packets
Least @ Intelligent Expensive Complex
HUB
SWITCH
Least @ Intelligent Expensive Complex But Effective
ETHERNET NETWORKING


10.0.0.0/S
IP ADDRESS
SERVER
ROUTER
20.0.0.0/S
IP ADDRESS
SERVER
HUB
SWITCH
PC4
PC5
PC1
PC2
PC3
PC4
PC5
PC1
PC2
PC3

# Packets and Frames

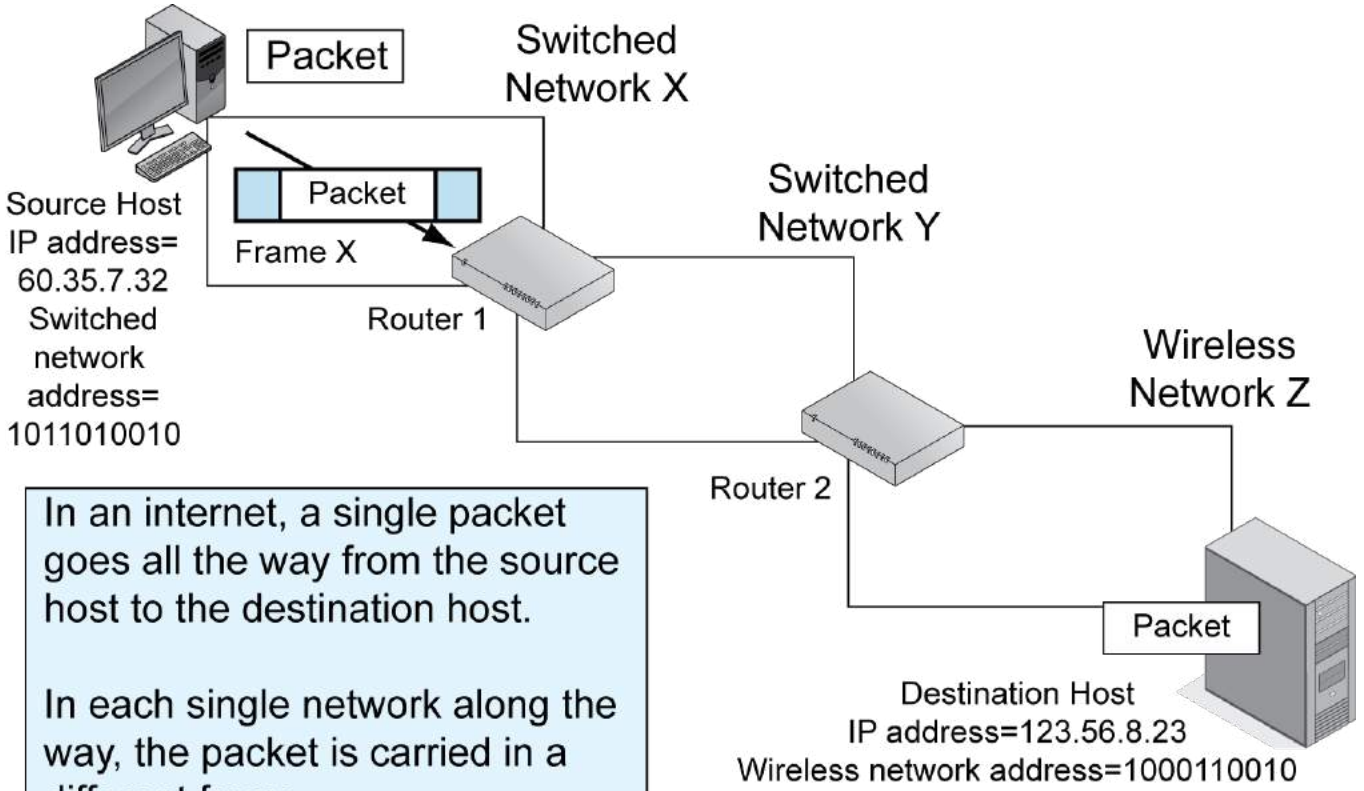
- **WHAT IS A FRAME?**
  - The term *frame* is most frequently used to describe a chunk of data created by network communication hardware such as a network interface cards (NIC cards) and router interfaces. Switch ports primarily forward existing frames and don't usually create frames of their own.

- **CONTENTS OF FRAMES**
  - Frames contain frame delimiters, hardware addresses, such as the source and destination MAC addresses, and data encapsulated from a higher layer protocol.

# Packets and Frames

- **WHAT IS A PACKET?**
  - The Request For Comments (RFC) documents frequently use the term *packet* to mean a stream of binary octets of data of some arbitrary length. It is typically used to describe chunks of data created by software, not by hardware. Internet Protocol (IP) creates packets. This term is NOT synonymous with the term *frame* even though many people make that mistake. Information that has been broken into packets is sometimes described as *packetized*.
- **Types of Packets**
  - Internet Protocol is often described as transmitting packets.
- **Contents of Packets**
  - Packets contain logical addressing information, such as an IP address, and data.

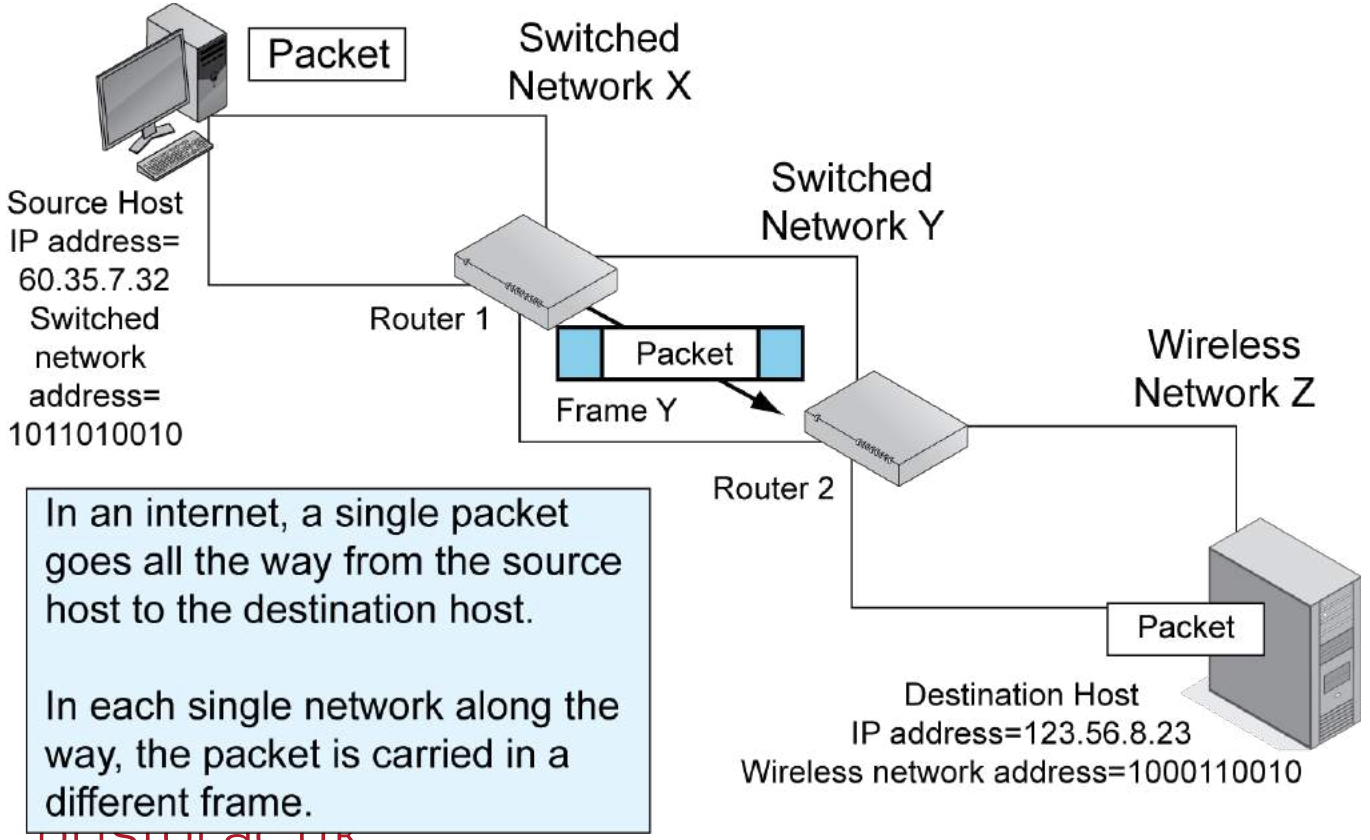
# Packets and Frames




In an internet, a single packet goes all the way from the source host to the destination host.

In each single network along the way, the packet is carried in a different frame.

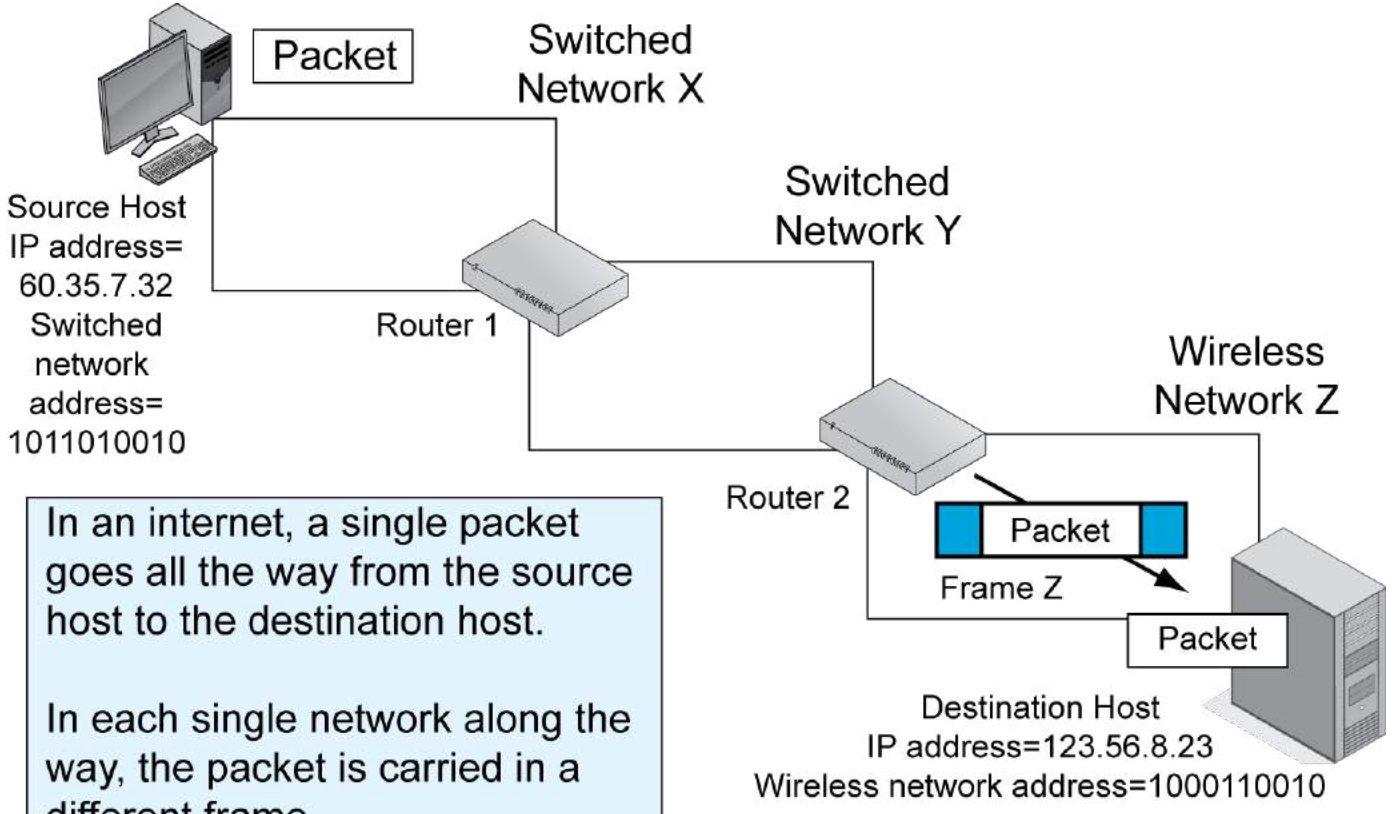
# Packets and Frames




In an internet, a single packet goes all the way from the source host to the destination host.

In each single network along the way, the packet is carried in a different frame.

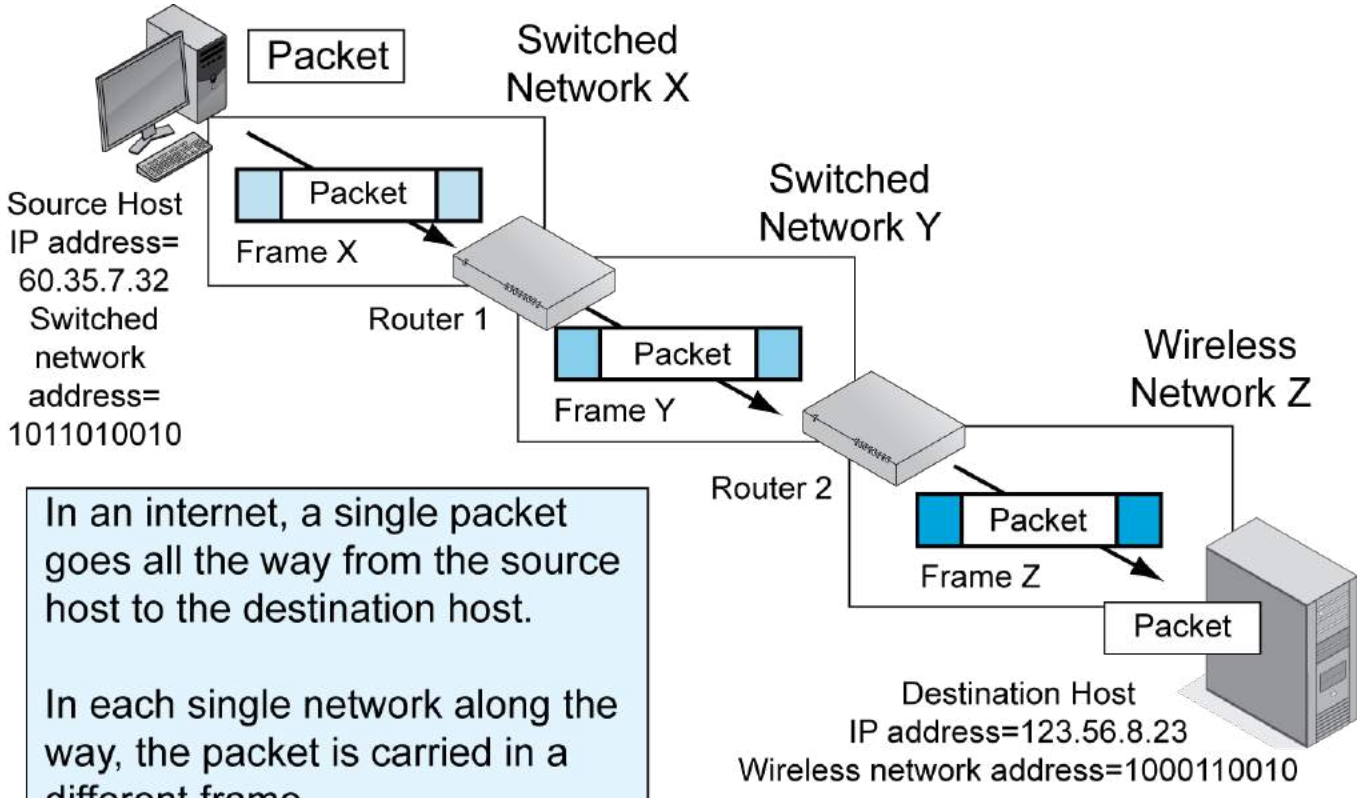
# Packets and Frames




In an internet, a single packet goes all the way from the source host to the destination host.

In each single network along the way, the packet is carried in a different frame.

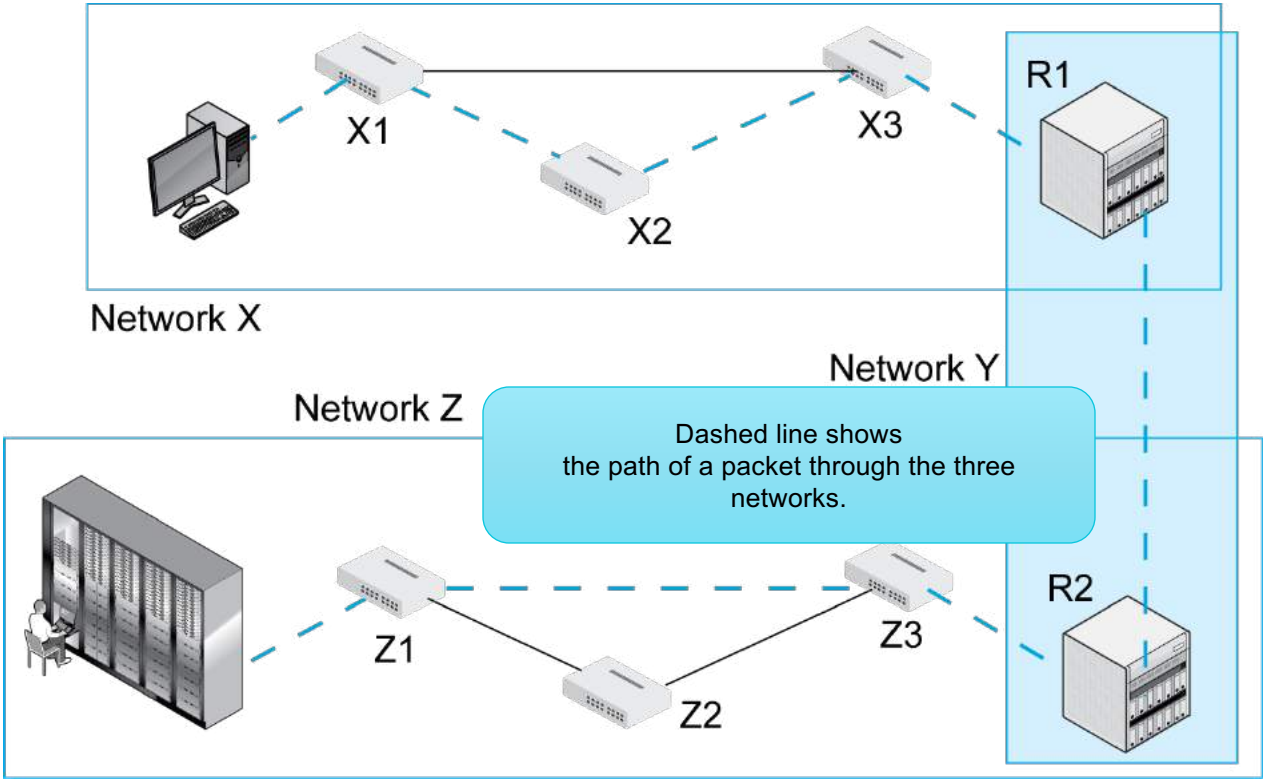
# Packets and Frames



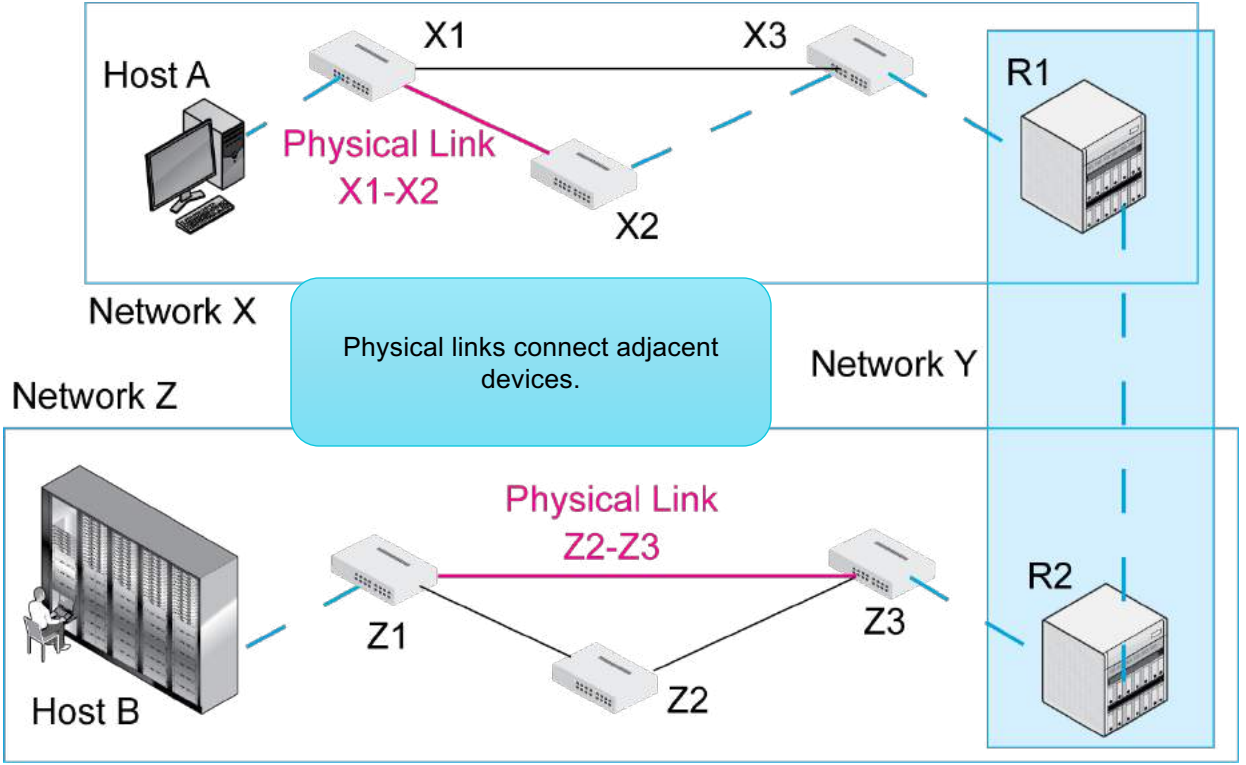

In an internet, a single packet goes all the way from the source host to the destination host.

In each single network along the way, the packet is carried in a different frame.

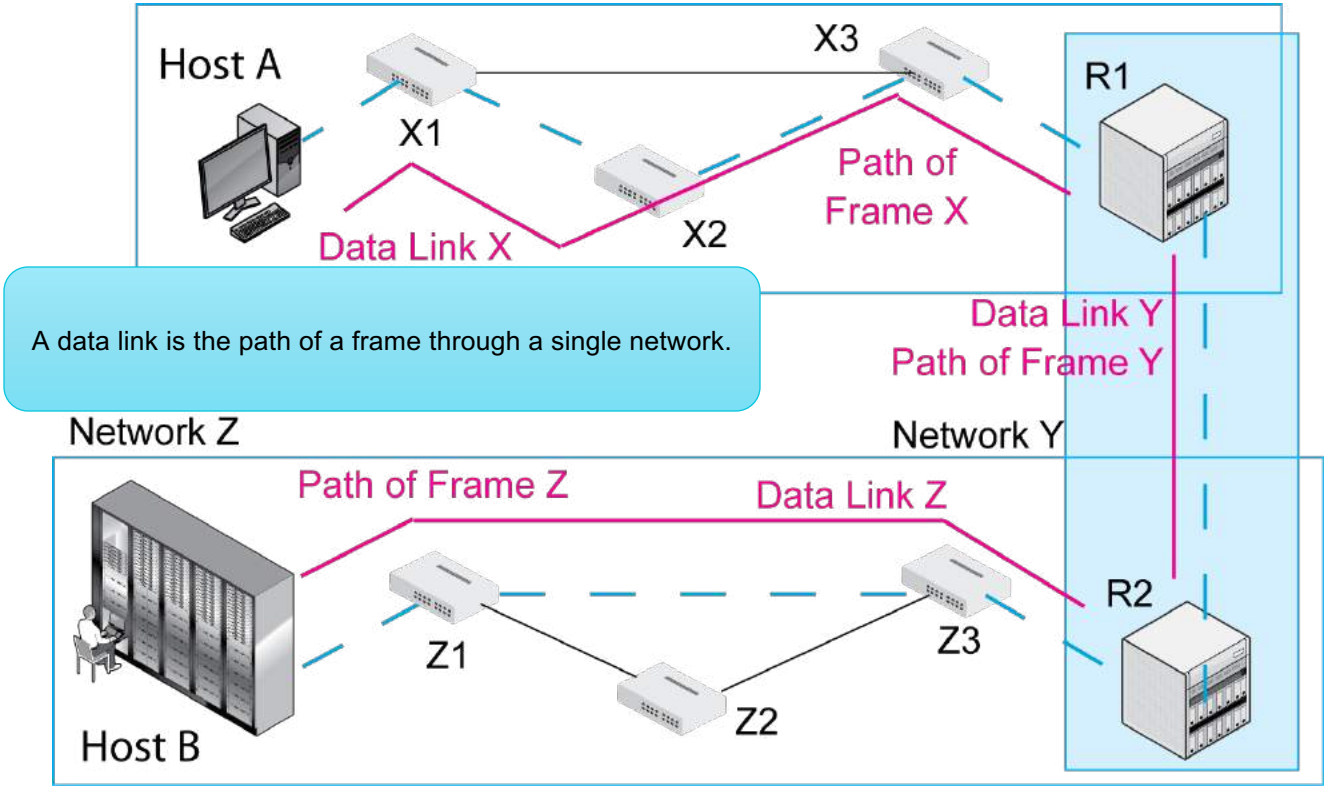
# Physical Links, Data Links, and Routes



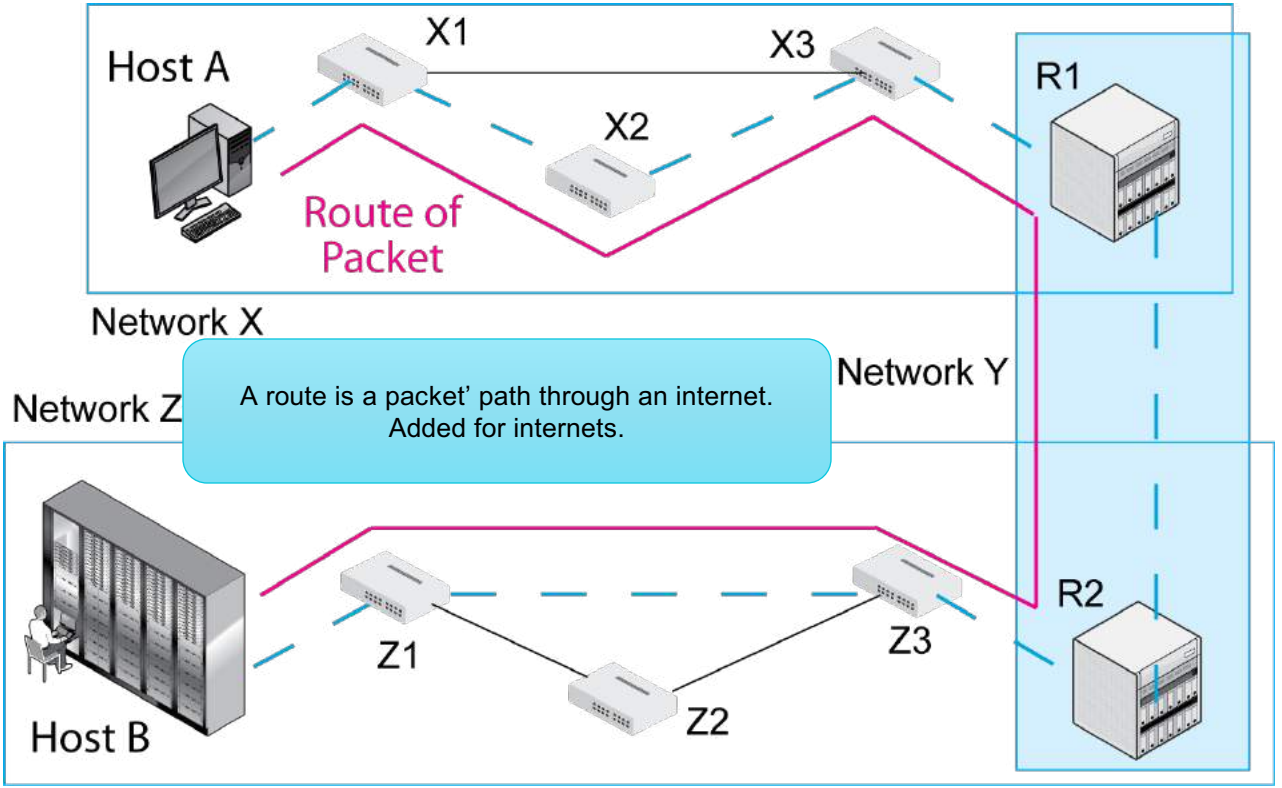
# Physical Links, Data Links, and Routes



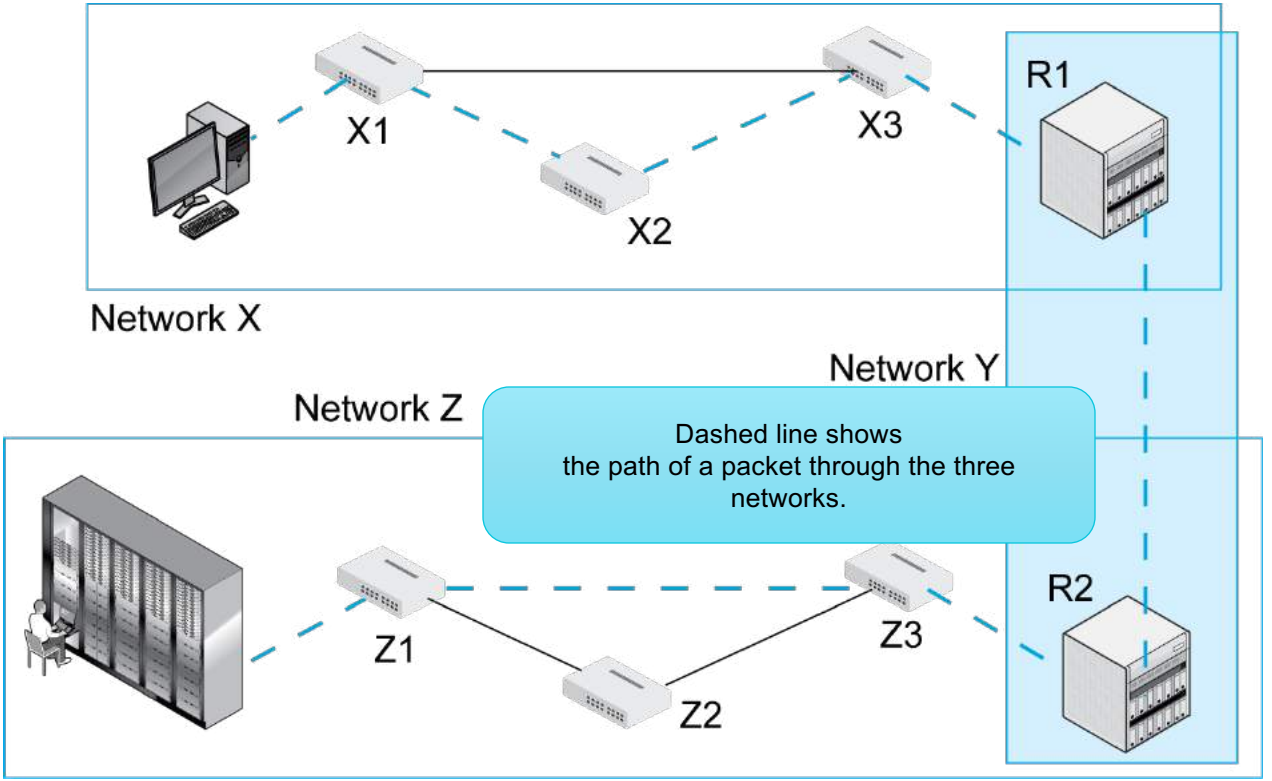
# Physical Links, Data Links, and Routes



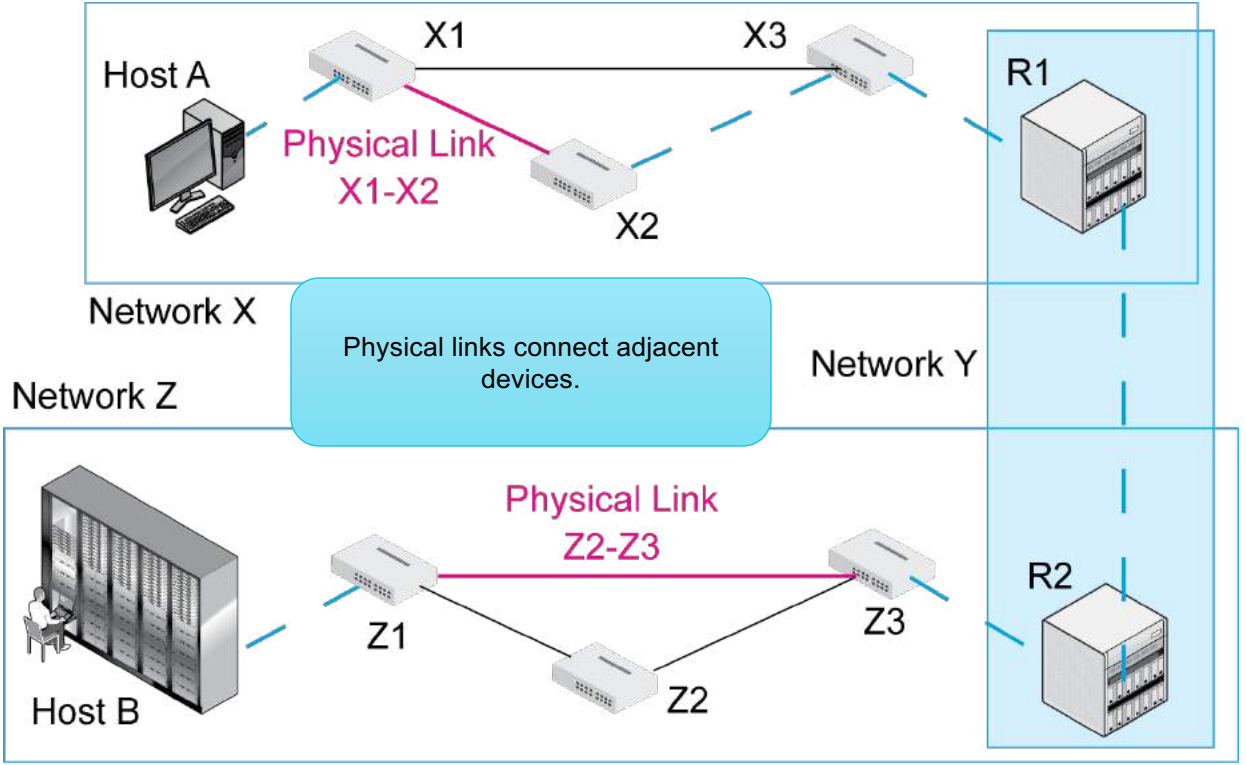
# Physical Links, Data Links, and Routes



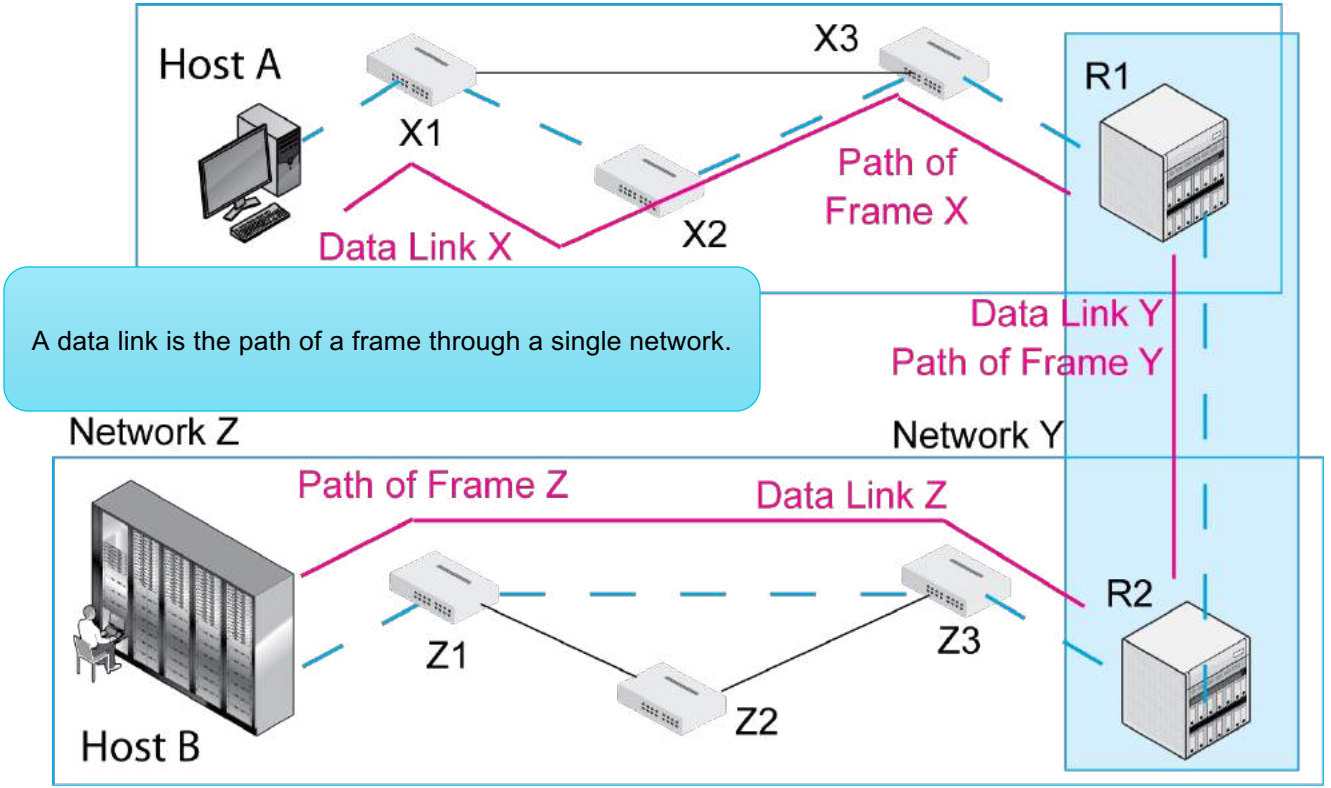
# Physical Links, Data Links, and Routes



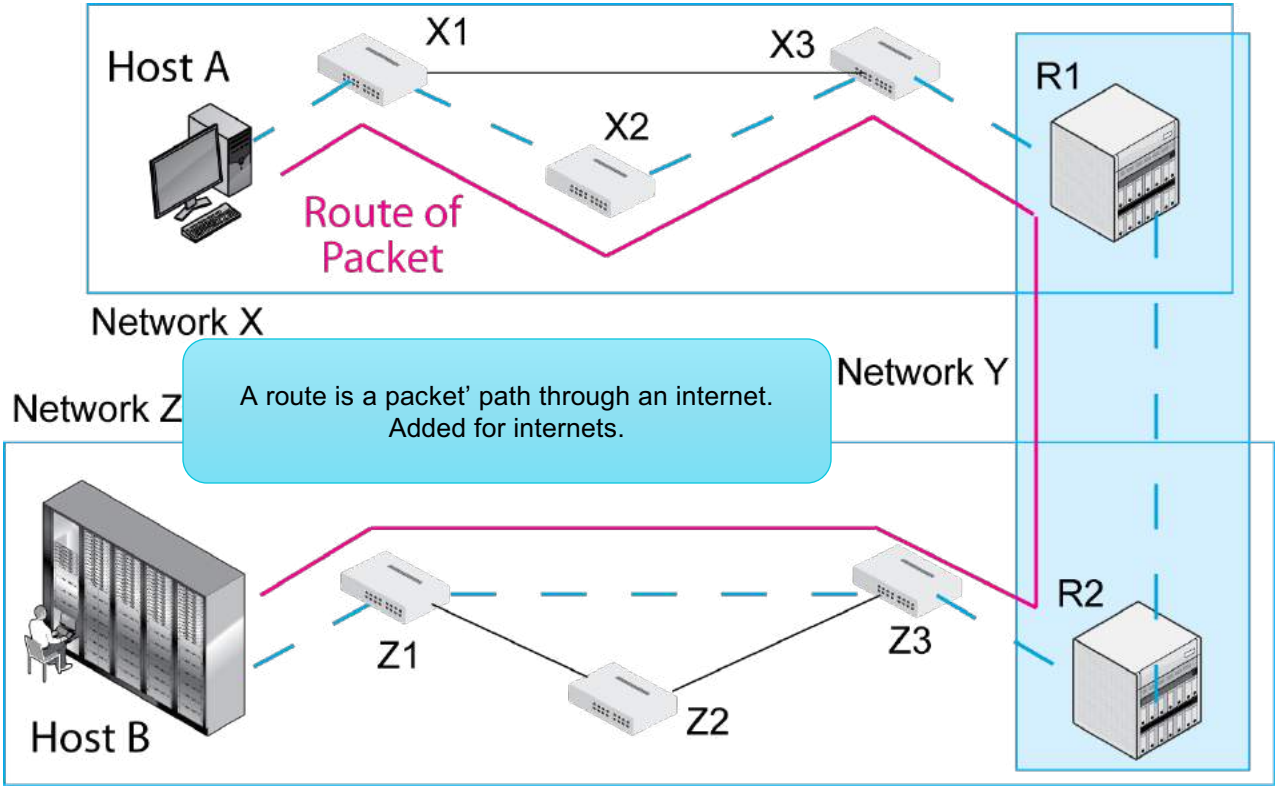
# Physical Links, Data Links, and Routes



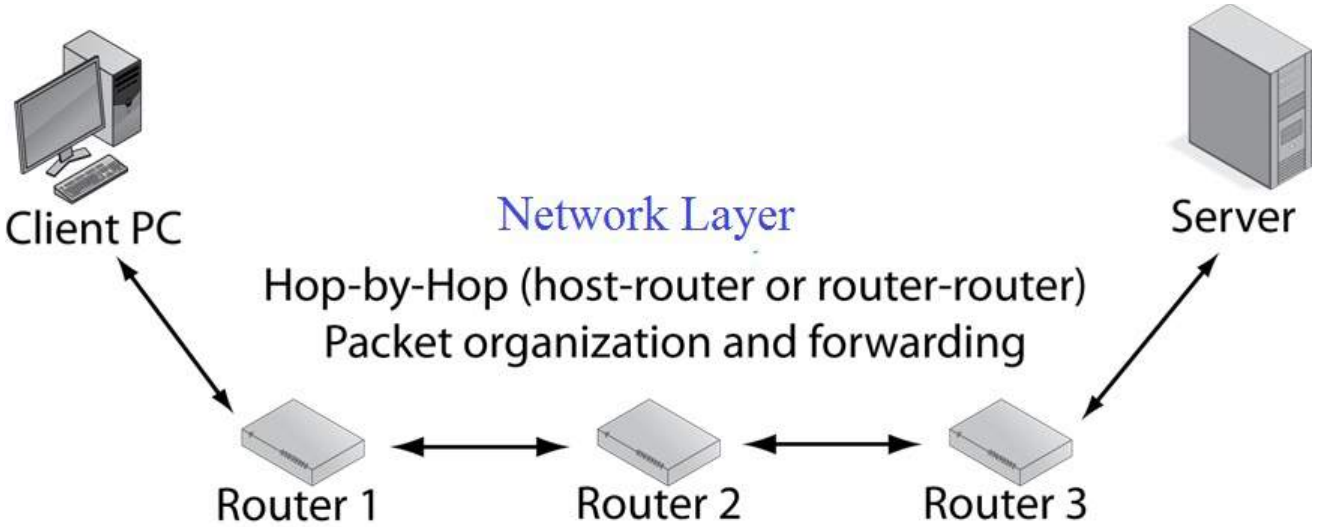
# Physical Links, Data Links, and Routes



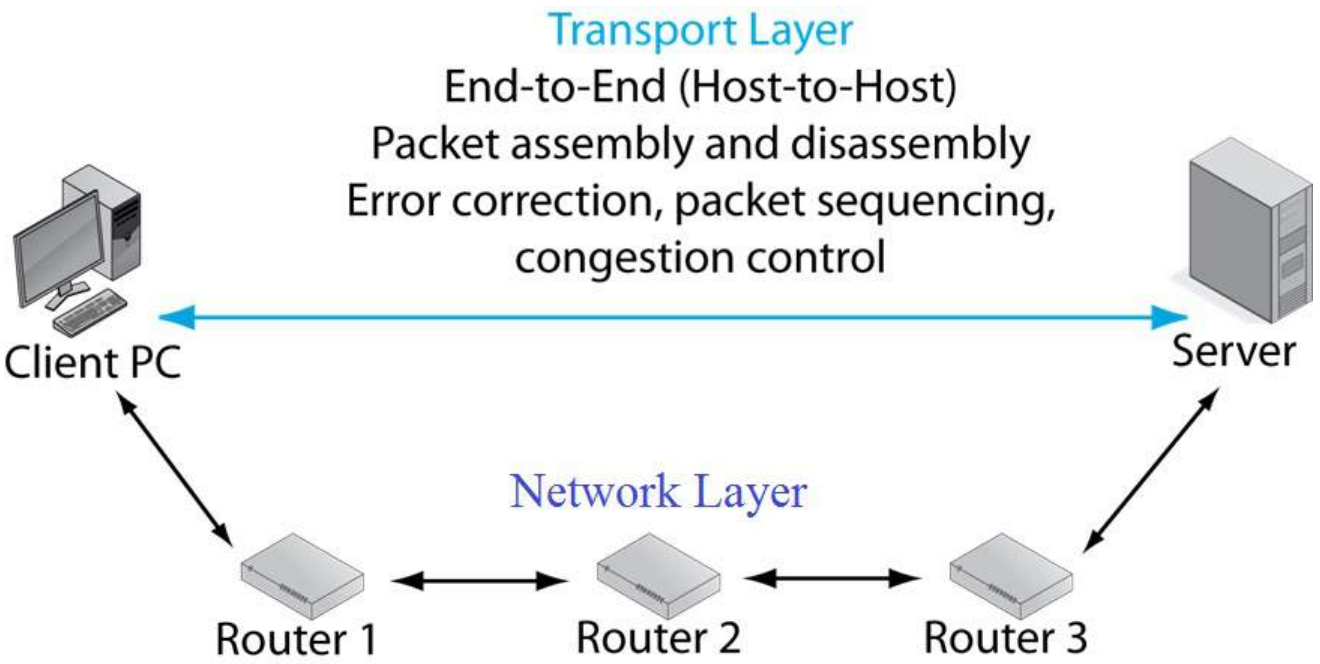
# Physical Links, Data Links, and Routes



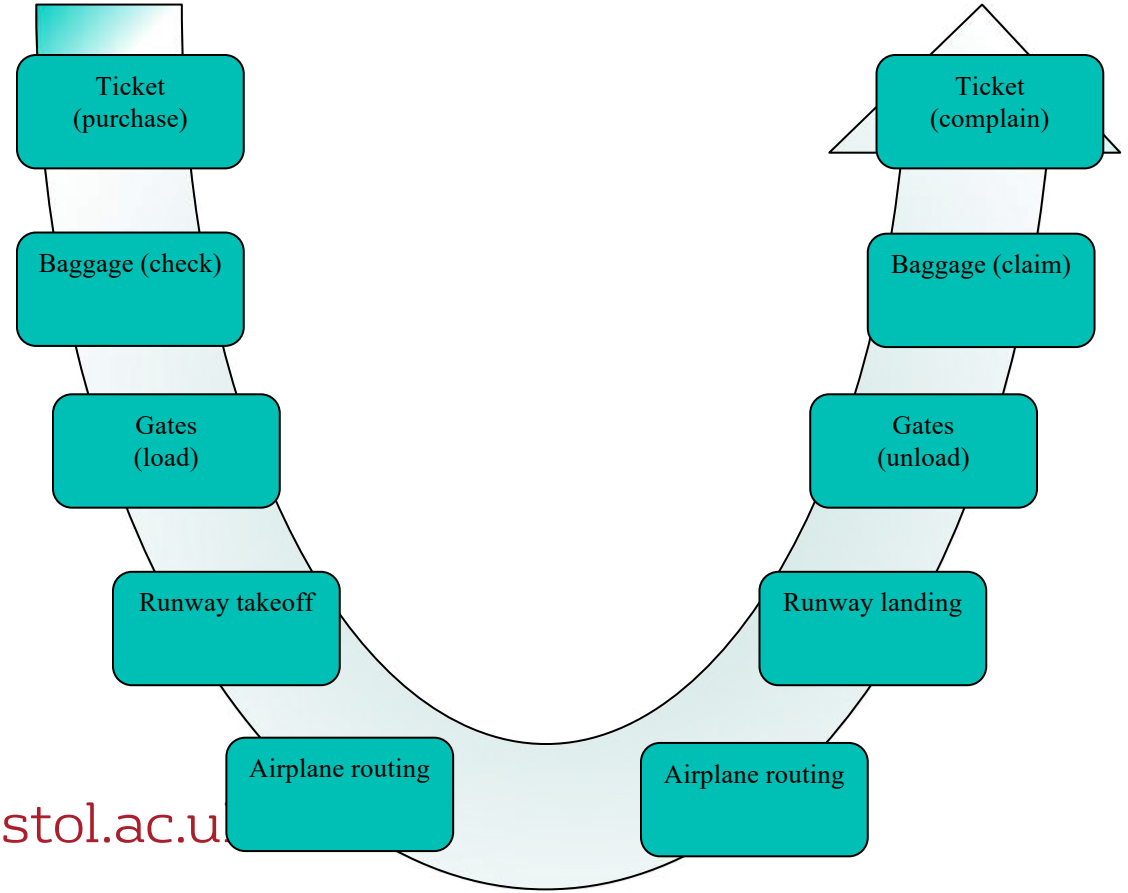
# The Network and Transport Layers



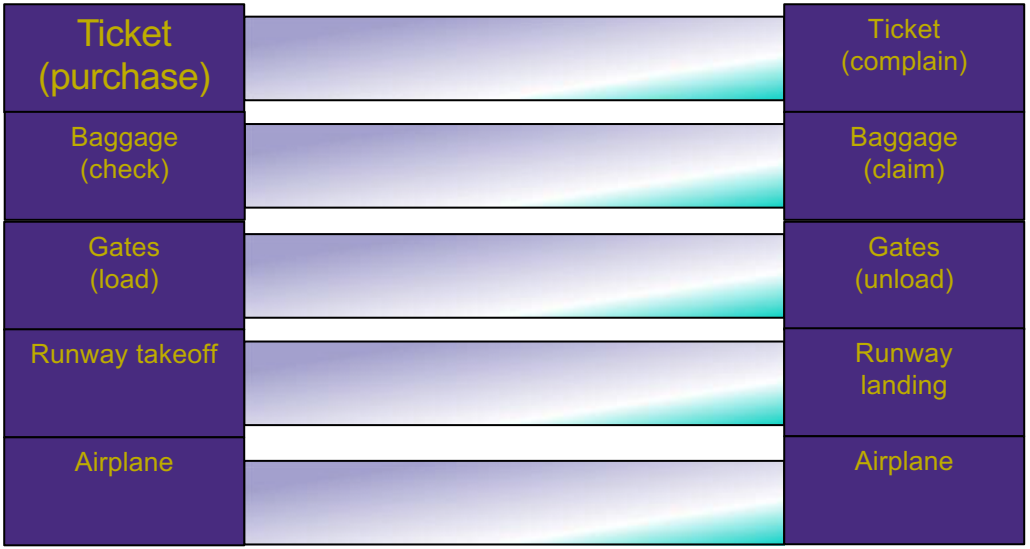
# The Network and Transport Layers



# Taking an airplane: actions



# Again – Airplane example



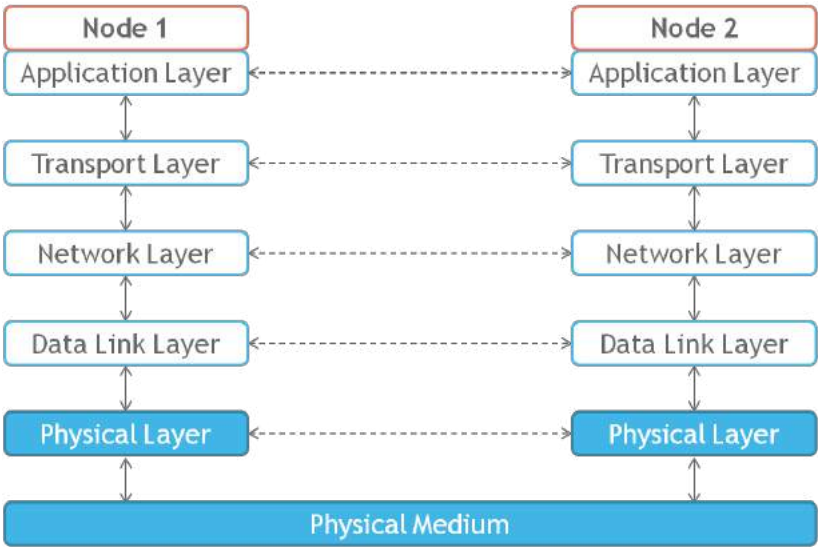

Departure airport

Arrival airport

# ISO/OSI model

| Layer | Description | Protocols |
|---|---|---|
| Application | This layer interfaces directly to applications and performs common application services for the application processes. | POP, SMTP, DNS, FTP, Telnet |
| Presentation | The presentation layer relieves the application layer of concern regarding syntactical differences in data representation within the end-user systems. | Telnet, Network Data Representation (NDR), Lightweight Presentation Protocol (LPP) |
| Session | The session layer provides the mechanism for managing the dialogue between end-user application processes. | NetBIOS |
| Transport | This layer provides end-to-end communication control. | TCP, UDP |
| Network | This layer routes the information in the network. | IP, ARP, ICMP |
| Data link | This layer describes the logical organization of data bits transmitted on a particular medium. The data link layer is divided into two sublayers: the Media Access Control layer (MAC) and the Logical Link Control layer (LLC). | SLIP, PPP |
| Physical | This layer describes the physical properties of the various communications media, as well as the electrical properties and interpretation of the exchanged signals. In other words, the physical layer is the actual NIC, Ethernet cable, and so forth. | IEEE 1394, DSL, ISDN |

# TCP/IP model


Node 1
Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Node 2
Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Physical Medium

# Five Layers in the Internet Network Model

## 1. Physical Layer:

- Is the physical connection between the sender and the receiver.
- It includes all the hardware devices (computers, modems, and hubs) and physical media (cables and satellites).
- This layer specifies the type of connection and the electrical signals, radio waves, or light pulses that pass through it.

# Five Layers in the Internet Network Model

## 2. Data Link Layer:

- Is responsible for moving a message from one computer to the next computer in the network path from the sender to the receiver. This layer has 3 functions:
  - Control the physical layer by deciding when to transmit messages over the media.
  - Format the messages by creating a frame to encapsulate packets and add a header to it.
  - Detects and recovers from errors that have occurred during transmission.

# Five Layers in the Internet Network Model

## 3. Network Layer:

- Routing, selecting the next computer to which the message should be sent.

- Find the address of that computer if it doesn't already know it.

# Five Layers in the Internet Network Model

## 4. Transport Layer:

- It performs three functions:
  - It is responsible for linking the application layer software to the network and establishing end-to-end connections between the sender and receiver when such connections are needed.
  - It breaks long messages into several smaller messages to make them easier to transmit.
  - Detect lost messages and request that they be resent.

# Five Layers in the Internet Network Model

## 5. Application Layer:

- This is the application software used by the network user.
- With this layer the user defines what messages are sent over the network.
- Examples of this layer are the internet explorer and outlook.

# Networking Layers

| Number | Name | Broad Purpose | Specific Purpose |
|---|---|---|---|
| 5 | Application | Communication between applications | Same |
| 4 | Transport | | |
| 3 | Network | | |
| 2 | Data Link | | |
| 1 | Physical | | |

# Networking Layers

| Layer | Name | Broad Purpose | Specific Purpose |
|---|---|---|---|
| 5 | Application | | |
| 4 | Transport | Internet Transmission | Application message fragmentation, error correction, congestion reduction, etc. |
| 3 | Network | | Transmission of packet across an internet. Packet formats, router operation. |
| 2 | Data Link | | |
| 1 | Physical | | |

# Networking Layers

| Layer | Name | Broad Purpose | Specific Purpose |
|---|---|---|---|
| 5 | Application | | |
| 4 | Transport | | |
| 3 | Internet | | |
| 2 | Data Link | Single-network transmission (switched or wireless) | Connection across a single network. Frame formats and switch operation. |
| 1 | Physical | | Physical connections between adjacent devices |

# Network Access Security Model

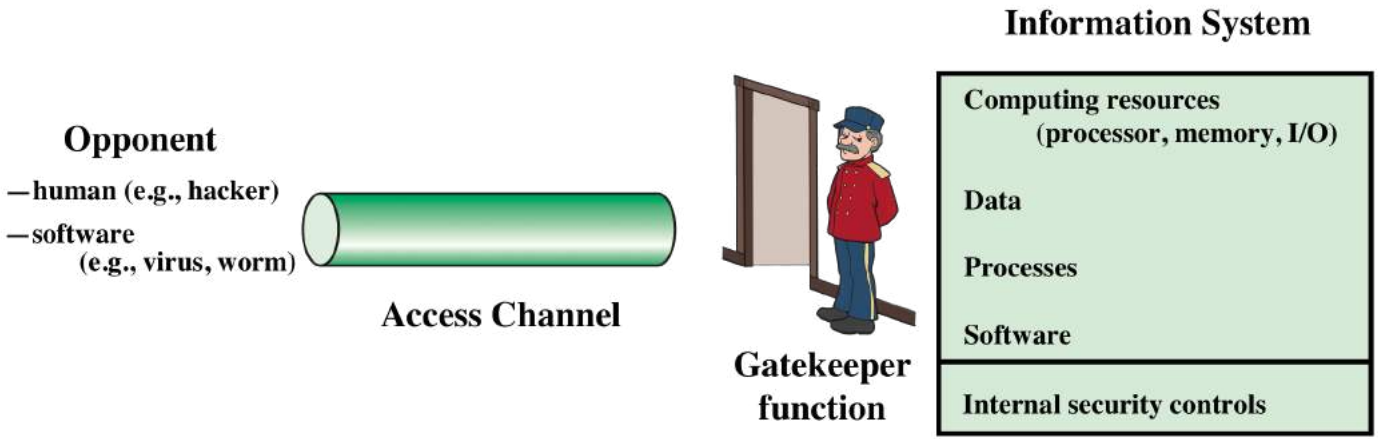
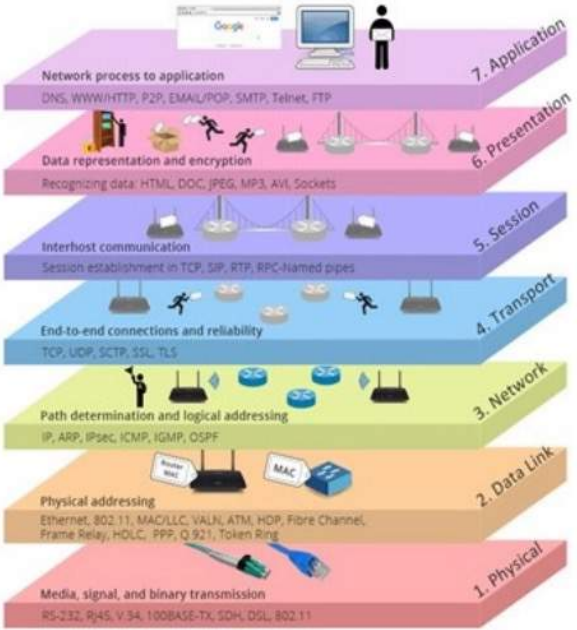



**Figure 1.3 Network Access Security Model**

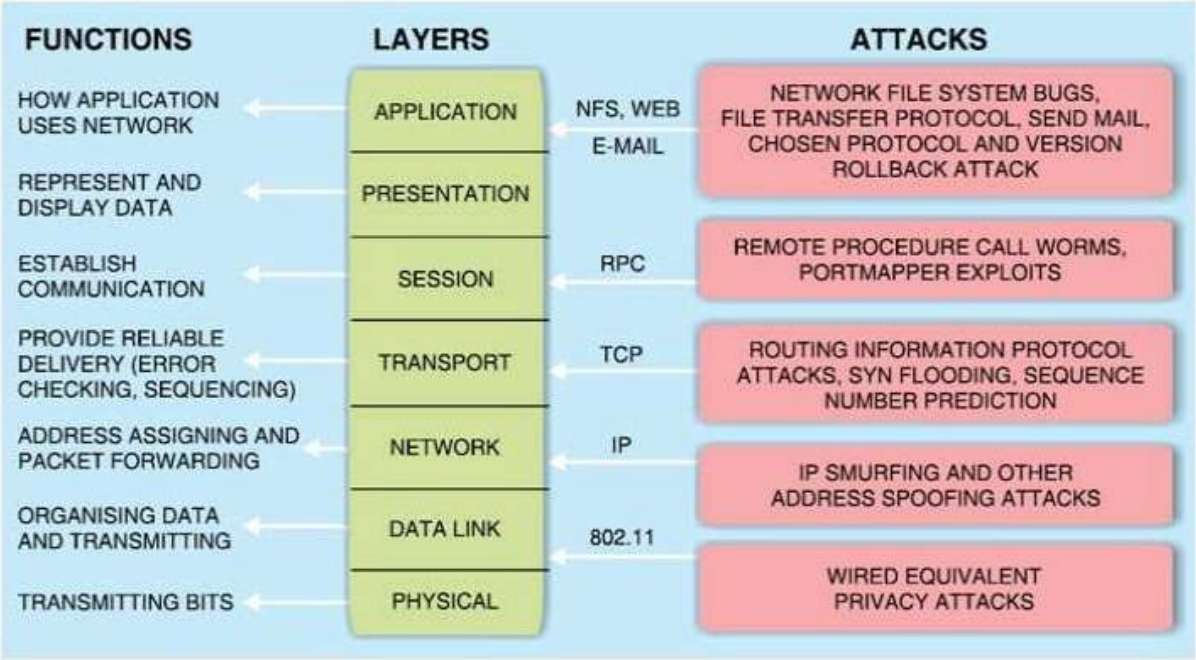
# Unwanted Access

- Placement in a computer system of logic that exploits vulnerabilities in the system and that can affect application programs as well as utility programs such as editors and compilers
- Programs can present two kinds of threats:
  - Information access threats
    - Intercept or modify data on behalf of users who should not have access to that data
  - Service threats
    - Exploit service flaws in computers to inhibit use by legitimate users

# ISO/OSI


7. Application
Network process to application
DNS, WWW/HTTP, P2P, EMAIL/POP, SMTP, Telnet, FTP
6. Presentation
Data representation and encryption
Recognizing data: HTML, DOC, JPEG, MP3, AVI, Sockets
5. Session
Interhost communication
Session establishment in TCP, SIP, RTP, RPC-Named pipes
4. Transport
End-to-end connections and reliability
TCP, UDP, SCTP, SSL, TLS
3. Network
Path determination and logical addressing
IP, ARP, IPsec, ICMP, IGMP, OSPF
2. Data Link
MAC
Physical addressing
Ethernet, 802.11, MAC/LLC, VALN, ATM, HDP, Fibre Channel,
Frame Relay, HDLC, PPP, Q.921, Token Ring
1. Physical
Media, signal, and binary transmission
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, 802.11

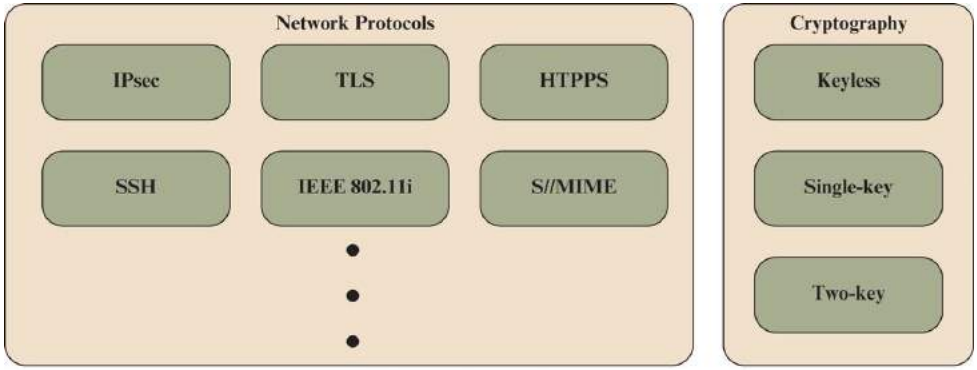
# Attacks on different layers



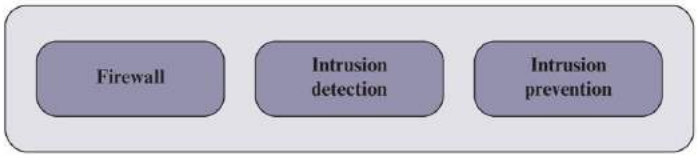
# Attacks on different layers

| Layers | Attacks |
|---|---|
| **Application layer** | Repudiation, Data Corruption |
| **Transport layer** | Session Hijacking, Sync flooding |
| **Network layer** | Warm-hole, Black-hole, Gray-hole, Byzantine, Flooding, Resource consumption, Location-disclosure, Sybil attack, Jelly-fish, Fabrication, Modification attack |
| **Data-Link layer** | Traffic analysis, Monitoring, Disruption MAC(802.11), WEP weakness, Selfish-node |
| **Physical layer** | Jamming, Interception, Eavesdropping |
| **Multi-layer Attacks** | Dos attacks, Impersonation, Replay, Man-in-the-middle |

# What we will learn next time?



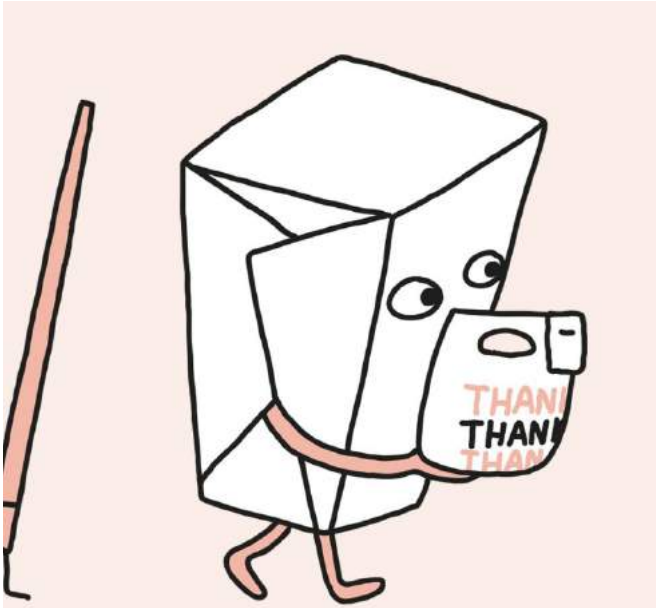

(a) Communications Security




(b) Device Security

# What did we learn today?

- Classical Encryption Techniques
- First virus
- What is network security?
- Model for network security
- Basics of networking!
- Attacks on different layers



bristol.ac.uk