



# Computer Networks

## Foundation Concepts

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# Interaction Points

- **How would the course be conducted?**
- **Introduction to Computer Networks**
- Types of Networks & Internetworks
- **Basic elements of a Computer Network**
- Interconnection of basic elements
- **Architecture of Computer Networks & Internetworks**
- Concluding remarks



# How would be the course conducted?

- Course handout is already with you and a copy has been also uploaded at the course home page at <http://discovery.bits-pilani.ac.in/rahul/CompNet/>
- IntraBITS page of the course shall be enabled as soon as ID and ARCD make the data available to the SDET-Unit that manages the Course Management Tool (CMT) for teachers and IntraBITS facilities for students.
- Quizzes: One per month, surprise, the best two quiz-marks shall be taken for computation.
- Assignments: Three: one theoretical and two experimental assignments, scheduled for submission on Feb. 7, Feb. 28, March 30, 2008 respectively.
- Two closed-book of 20 marks each on March 3 and April 14 respectively
- The Comprehensive Exam. of 40% on May 2, 2008
- Tests & Comprehensive Examination shall be evaluated by Rahul Banerjee and Quizzes and Assignments shall be evaluated by Murali P



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# Defining a Computer Network

- Defining a Computer Network
  - A Computer Network is an interconnected group of autonomous computing nodes which:
    - Use a well-defined, mutually-agreed set of rules and conventions known as Protocols,
    - Interact with one-another, if duly authenticated and authorized, meaningfully;
    - Allow resource-sharing preferably in a predictable and controllable manner.
- Autonomous computing node
  - A computer / node that has its own processing capabilities and that does not act under the control of any other computer / is known as an Autonomous Computer or an Autonomous Computing Node.
  - It should NOT be confused with the traditional Dumb Terminals in centralized computing environments.



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# Types of Computer Networks

- Spread, size, inter-node-distance and purpose based classification:
  - Personal Area Networks (PANs): Often Wireless: WPANs
  - Local Area Networks (LANs): Wireline LANs: LANs & Wireless LANs: WLANs
  - Metropolitan Area Networks (MANs): Wireline and Wireless MANs
  - Wide Area Networks (WANs): Wireline / Wireless, Fixed / Mobile, Planet-wide / Interplanetary
  - Sensor Networks (SNs) & Wireless Sensor Networks (WSNs)
  - Storage Area Networks / System Area Networks (SANs)
- Virtualization-based classification:
  - Virtual Local Area Networks (VLANs)
  - Virtual Private Networks (VPNs)
- Organization based classification
  - Mobile Ad-hoc Networks
  - Regular Mobile Networks



# Types of Computer Internetworks

- **Intranet:** Completely private network of networks
  - Wireline
  - **Wireless**
    - Fixed
    - **Mobile**
  - Hybrid
- **The Internet:** Global public network of networks
  - Wireline
  - **Wireless**
    - Fixed
    - **Mobile**
  - Hybrid
- **Extranet:** Intranets interconnected via the Internet



# Classes of Computer Networks <sup>1</sup>

of 2

- Class One: **Function-based classification**
  - Data Networks
  - Voice Networks
  - Multimedia Networks
- Class Two: **Location-and-Distance-based classification**
  - Personal Area Networks (**PANs**)
  - Local Area Networks (**LANs**)
  - Metropolitan Area Networks (**MANs**)
  - Wide Area Networks (**WANs**)



# Classes of Computer Networks 2 of 2

- Class Three: **Forwarding-based classification**
  - Switched Networks
    - Circuit-Switched Networks
    - Packet-Switched Networks
  - Shared Networks
  - Hybrid Networks
- Class Four: **Ownership-based classification**
  - Public Networks
  - Private Networks
  - Virtual Private Networks



# Classes of Computer Networks 1 of 2

- Class One: **Function-based classification**
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  - Voice Networks
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  - Virtual Private Networks



# LANs

- The term **LAN** stands for **Local Area Network**.
- The term 'local area' in the world of networking usually refers to a **geographically contiguous area** in which the **inter-computer distance** is **lesser than or equal to one kilometer**.



# Local Area Networks ...

- It is wholly owned by a single organization / entity, is locally installed (i.e. in a single contiguous geographic location like an office, a laboratory, a building or a campus) is called a Local Area Network (LAN).
- Although, normally, in a LAN, the inter-node distance does not exceed a kilometer; in most of the real-life situations, it is far less than this ceiling.



# PANs

- The term **PAN** stands for **Personal Area Network**.
- Typically these networks are **small in size**, **belong to a single person** and are **limited to his / her environment** within a small area *like* his room, body or garden etc.
- PANS mostly use short-range wireless technologies for interconnecting various nodes that comprise them.



# MANs

- The term **MAN** stands for **Metropolitan Area Network**.
- A computer network that is not usually owned by a single organization / entity and that is spread over a metropolitan city area is called a **Metropolitan Area Network**.
- Normally, in a MAN, the **inter-node distance does not exceed ten kilometers**. This, however, is not a hard-and-fast rule.



# WANs

- The term **WAN** stands for **Wide Area Network**.
- A computer network that is **not usually owned by a single organization / entity** and that is spread over an area larger than that of any city of operation is called a **Wide Area Network** .
- *A WAN may be spread over several cities / towns, a state, a country or even a continent.*
- In many a cases, when people say WAN, they actually mean **Wide Area Internetwork (WAI)**, however!



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# Elements involved in a Network / Internetwork

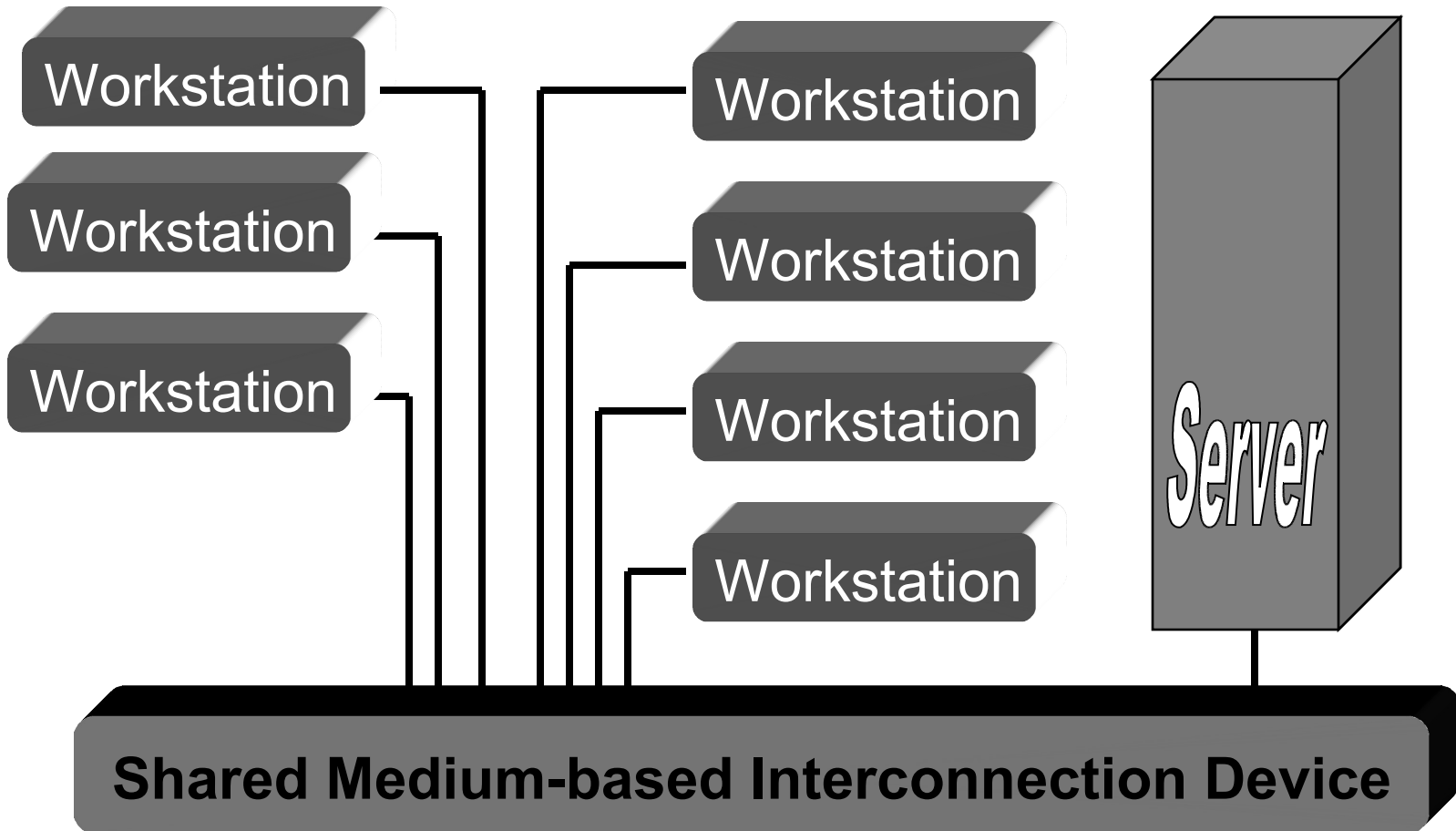
- **Nodes**
  - Regular computing nodes
  - Network extension / interconnection devices
- **Network Interfaces**
  - NICs / On-board Chips
  - Wireless interfaces
  - Wireline interfaces
- **Links**
  - Wireline links
  - Wireless links
- **Strategies, Algorithms & Protocols: H/W, S/W, F/W level implementations**

Nodes: where processing and communication capabilities co-exist

Hosts: end / intermediate nodes where all levels / layers including those belonging to applications exist



# An Example of a Computer Network





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# Interconnection of nodes / interfaces / networks

- **Media-based interconnection perspective**
  - Guided / Unguided
  - Noisy / Noiseless
  - Broadcast / Non-broadcast
- **Link-based interconnection perspective**
  - Secure / Insecure
  - Logical / Physical
  - Point-to-Point / Multi-point
- **Physical Links: those entities that provide physical path (direct paths between neighbouring nodes (point-to-point / point-to-multi-point) for data delivery over guided or unguided media**
- **Logical Links: an abstraction showing the logical path of data delivery at layers higher than the physical layer**



# Network Building Blocks

- Bridges: where L1 and L2 layers / levels exist with L2-protocol data unit (frame) processing and forwarding
- Hubs: where L1 and L2 layers / levels exist with ability to handle and deliver L2-protocol data unit (frame) over a shared medium
- Switches: where L1 and L2 and / or L3 (sometimes even higher) layers / levels exist with L2 and / or L3-protocol data unit (frame / packet) processing, switched routing / forwarding



# Network Building Blocks

- Repeaters: where L1 layer / level exist with L1-protocol data unit (raw bits) regeneration and onward transmission
- Gateways: where two or more different networks meet and may require protocol / message translation capabilities
- Routers: where L1, L2 and L3 layers / levels exist with L3-protocol data unit (packet) processing, routing and forwarding
- Clouds: abstraction of node connectivity in the networking context <details hidden>



# Some More Terms Related to Networks

- Channel <application-level logical communication path>
- Services: Functionalities provided by a layer / protocol / entity
- Interfaces: Peer-to-Peer / Layer-to-Layer / entity-to-entity
- Service Access Points: defined addresses / ports through which data / parameters are passed
- Interoperability <applies to different implementations of the same specification>
- Compatibility <applies to independent implementations of the different specifications>
- Tunneling <Encapsulation & Decapsulation>



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# Network Architecture & Reference Models

- **Architecture versus Reference Model: A simplistic perspective:**
  - Architecture: It may be seen as a detailed generic blueprint with unambiguous definitions of services, interfaces, organization and defined protocols that helps in design and implementation of a set of relevant protocol stack / suite based network / internetwork
  - Reference Model: It is the same as the architecture minus the specifically defined readily usable protocols.



# Network Architecture & Reference Models

- Examples:
  - TCP/IP Architecture & TCP/IP Reference Model
  - OSI Reference Model & OSI Architecture
  - IBM's SNA Architecture
  - ATM Reference Model & ATM Architecture



# Network Architectures & Network Reference Models

- **Network Architecture:**
  - **Definition:** Model is often specific in nature, valid, interfaces and services of each layer defined in the generic sense, protocols / protocol-definitions must exist at the time of definition of the network architecture.
  - **Purpose:** Guiding the designers and implementers
  - **Example:** TCP/IP Architecture, IBM's SNA Architecture
- In the literature, the terms *reference model* and *architecture* have been used in a variety of ways (at times, interchangeably as well!).



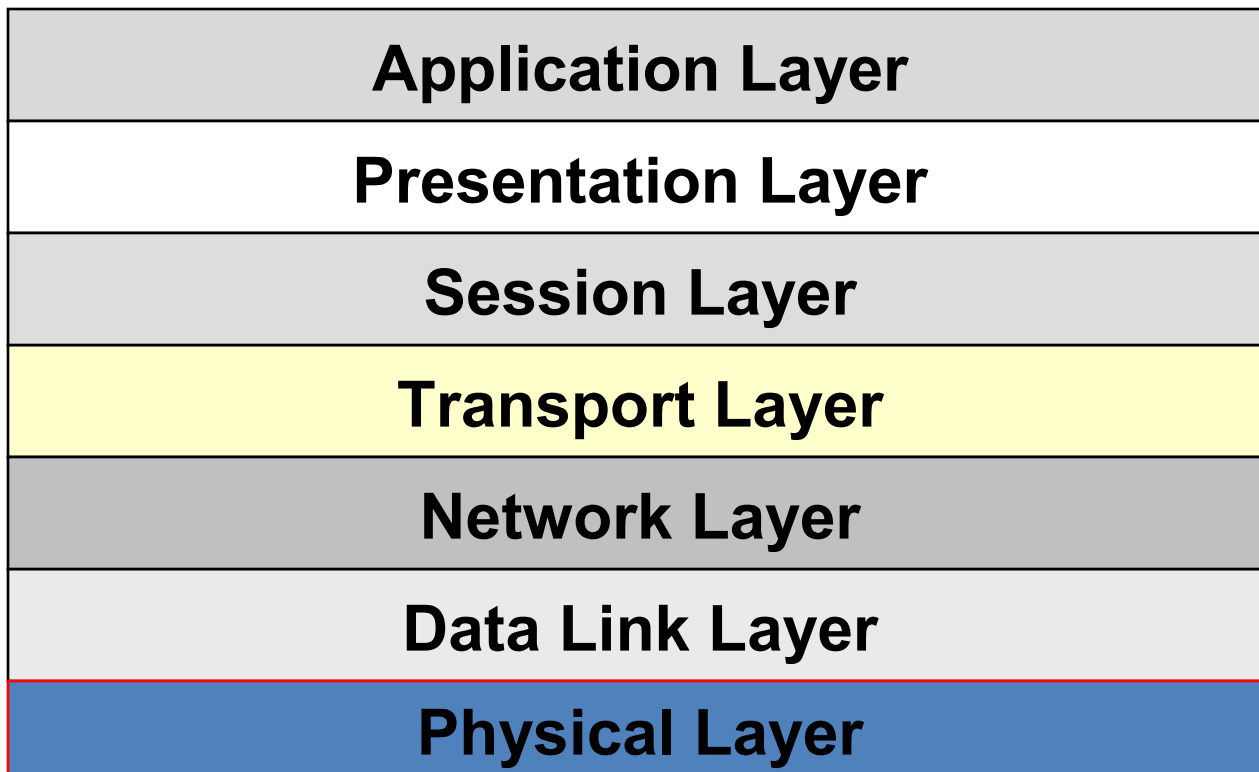
# Network Architectures & Network Reference Models

- Network Reference Model:
  - Definition: Model is generic in nature, valid, interfaces and services of each layer defined in the generic sense, protocols / protocol-definitions need not exist at the time of definition of the model, (ready-to-use implementation may not be necessarily available at the time of standardization)
  - Examples: ISO OSI Reference Model, TCP/IP Reference Model (?)



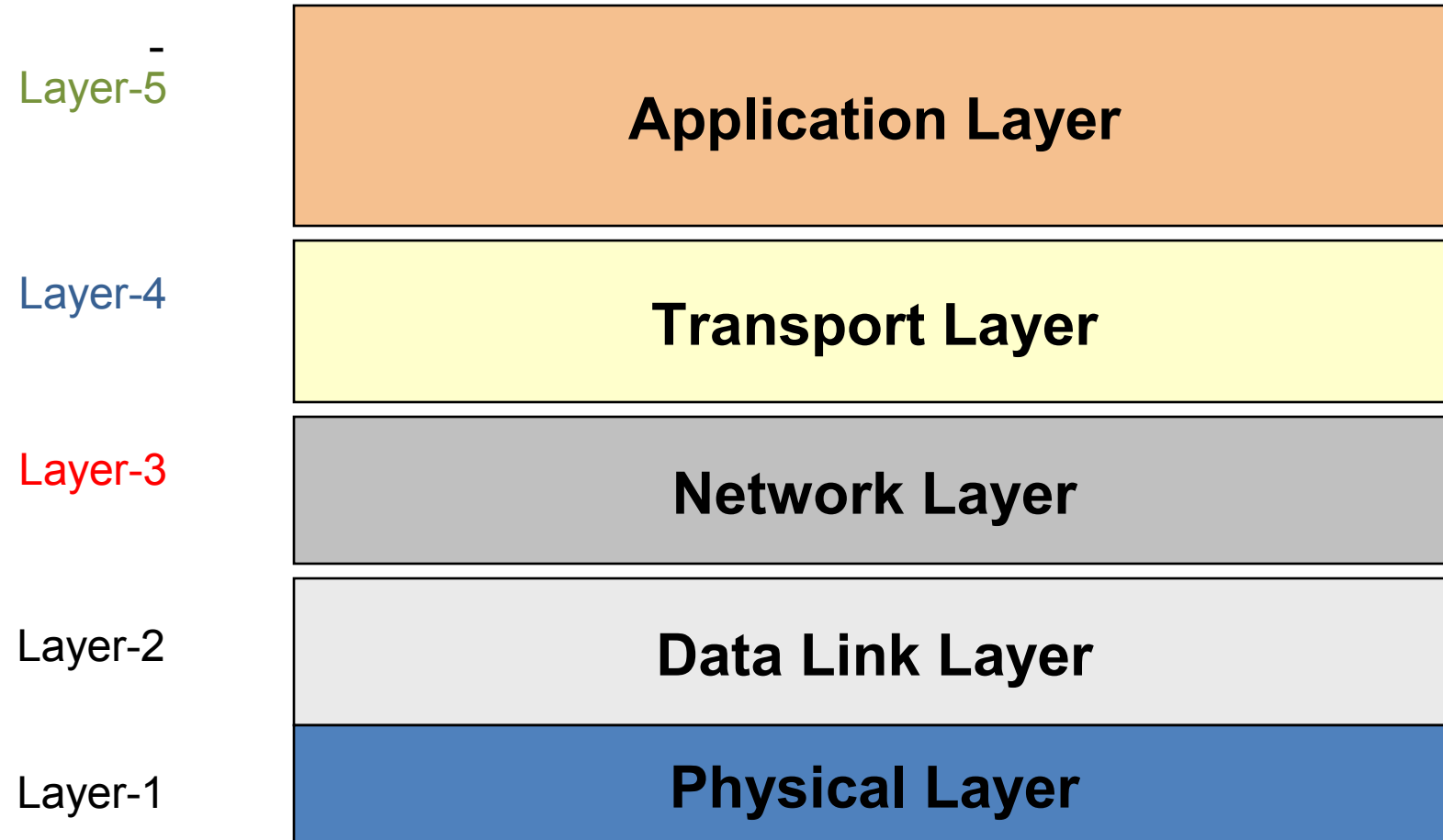
# The ISO OSI Reference Model

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# A Hypothetical Network Architecture for Easy Conceptual Understanding





# Application Layer

- Application Layer is a layer of the Network Architecture that is primarily concerned with getting TPDUs from the lower layer (**usually Transport Layer**) and delivering it to the Application and vice-versa (**with or without explicit presentation and session management support**).
- Examples: HTTP, DHCP, DNS, SNMP, FTP (in the context of the TCP/IP Architecture).
- **Web-services, Video-on-Demand over the network, Video/Voice-conferencing over the network etc. are examples of Applications that reside atop the protocols belonging to this layer.**



# Application Layer Responsibilities

(1 of 2)

- It primarily deals with:
  - Accepting messages from the Application Layer through the APIs
  - Processing these messages and generating APDUs
  - Deciding transport connection requirements (for further transmitting this DU after encapsulating it within an APDU)
  - Passing this packet through the SAP to the lower layer (TL)



# Application Layer Responsibilities

(2 of 2)

- It also deals with ...
  - Accepting APDU from the lower layer through the SAP
  - Processing the APDU
  - Removing the encapsulation and passing the messages to the respective destination application
  - Provide diagnostic support for network monitoring, configuration, management and trouble-shooting at the Application Layer or lower layer



# QoS Considerations in the AL

<for a detailed discussion on a later date!>

- Per-Flow or Aggregate Flow QoS suitability
- Priority of Service
- Maximum Acceptable Delays
- Minimum Acceptable Throughput
- MTBF
- Maximum Acceptable AL-initiated Abnormal Termination of Service
- Security Specifications



# Transport Layer: What is it?

- Transport Layer is a layer of the Network Architecture that is primarily concerned with:
  - getting TPDUs from the upper layer (usually Application Layer) and
  - delivering it to the same layer at the intended destination node (through the underlying Network Layer).
- Converse is also true of the targeted set of responsibilities of this layer.



# Transport Layer Responsibilities

<another perspective>

- It primarily deals with:
  - Accepting APDU from the Application Layer through the Service Access Point (SAP)
  - Processing these APDU
  - Deciding transport connection requirements (for further transmitting this DU after encapsulating it within a TPDU)
  - Passing this packet through the SAP to the lower layer (NL)



# TL Responsibilities ...

- It also deals with ...
  - Accepting TPDU from the lower layer through the SAP
  - Processing the TPDU
  - Removing the encapsulation and passing the APDU through the SAP to the upper layer (Application Layer)
  - Providing support for connection-oriented / connectionless services as the case may be (depending upon the protocol stack and need)
  - Provide diagnostic support for:
    - network monitoring,
    - configuration,
    - management and
    - trouble-shooting at the Transport Layer or higher layer.



# Network Layer

- Network Layer is primarily concerned with getting NLDU / Packets from the source node and delivering it to the intended destination node (through none or many intermediate nodes).
- Additional responsibilities of this layer include:
  - Providing support for connection-oriented / connectionless services as the case may be (depending upon the protocol stack and need)
  - Provide diagnostic support for network monitoring, configuration, management and trouble-shooting at the Network Layer or higher layer.
- Packet handling, packet management, Routing are its major responsibilities.



# Network Layer Design Goals

- In the context of packet routing, network layer structural design goals include:
  - Ensuring the shortest possible delay and thereby the highest throughput at the least possible cost
  - Ensuring acceptably reliable packet delivery (may be optional in some cases)
  - Ensuring secure packet delivery (may be optional in some cases)



# Network Layer Design Issues <1 Of 4>

- Choice of the Services to be provided by the Network Layer to the Transport Layer and their nature:

## The primary issue:

- Choice of any one of the Connection-oriented or Connectionless types of service to be provided by the Network Layer.



# Network Layer Design Issues <2 Of 4>

- Services to be provided by the Network Layer to the Data Link Layer and their nature:
  - **The primary issue:**
    - The format and size of the Network Layer Data Unit (e.g. Packet or Cell) in which the data is to be passed to the Data Link Layer (if it does exist) with or without encapsulation and additional information.
  - **It needs to be noted here that in practice, the Network Layer and the lower layers (e.g. DLL and PL) are not really totally transparent to one-another.**
  - Degree of transparency is, therefore, another major issue, which is seldom discussed in literature.



# Network Layer Design Issues <3 of 4>

- Architecture and internal organization of the Network Layer so as to be able to meet the N.L. design goals:
  - **Primary Issue:**
    - In this case, the real issue is ‘how to provide the mechanism that would satisfy the primary design goals of the designated Network Layer.
  - **A possible example involves making choice of PVMs or SVMs or Datagrams (again reliable ones or the default unreliable ones?) or a mix of them in a given situation.**



# Network Layer Design Issues <4 Of 4>\_

- Choice of Interior and Exterior Routing and Protocol Translation schemes.
- Choice of Security to be provided at the subnet level.
- Choice of conventional / mobile / hybrid routing support.
- Choice of support for QoS, FTRT etc. for the intended class of applications.



# The Layer-2: Data Link Layer

- **Data Link Layer consists of two sub-layers:**
  - Media Access Control (MAC) sub-layer &
  - Logical Link Control (LLC) sub-layer.
- **Major Issues involved in the design of the Data Link Layer include:**
  - Which services are to be provided to each of the adjacent layers?
  - Exactly when to provide these services?
  - How to provide them?
  - To whom should they be provided?\_



# The Layer-1: Physical Layer

- Physical Layer's primary responsibilities include acceptable communication of data using appropriate signalling mechanism between various network nodes directly connected <with or without guided medium>.
- Major Issues involved in the design of the Data Link Layer include:
  - Which services are to be provided to each of the higher layer?
  - Exactly when to provide these services?
  - How to provide them?
  - To whom should they be provided?\_
  - What signalling scheme (electrical / optical / electromagnetic etc.) to be used?
  - What mechanical / electrical / optical considerations etc. are to be made with respect to connectivity, signalling, transmission, reception, coding, decoding, modulation, demodulation, frequency choices, voltage and current levels, clock speeds etc.



# Physical Layer

- Physical Layer deals with transmission of raw digital data using analog or digital signal.
- This layer is concerned with the logic type (negative or positive), amplitude of the signal, signal representation, bit-length, direction of transmission etc.
- It deals with connection-establishment and termination.



# More on Physical Layer

- This layer is, in a nutshell, a layer that deals with various electrical and mechanical characteristics of every physical component of a computer network.
- Exact electrical, mechanical and procedural Interface Definition is therefore its responsibility.
- Choice and use of the physical medium are the Physical Layer Design Issues.



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# Concluding remarks

- A network is ...
- An internetwork is ...
- A vertical Layer 'n' to Layer 'm' service is ...
- A horizontal Layer 'n' to Layer 'n' service is ...
- A Service Access Point is ...
- A Protocol is ...
- A Protocol Stack is ...
- A Protocol Family / Suite is ...
- A Cloud is ....



# Applications of Computer Networks

- Numerous applications of computer networking are possible.
- Some of the most popular ones include:
  - Electronic Mail
  - Web-browsing
  - Digital Libraries
  - Video-on-Demand
  - File Transfer
  - Video / Audio Conferencing



# Internetworks

- An Internetwork may be defined as a network of computer networks any authorized node of which could directly or indirectly communicate with any other member node.
- It may consist of several PANs, LANs, MANs or WANs interconnected via LAN / MAN / WAN oriented communication technology.



# Local Area Internetwork

- Traditionally, a Campus Internetwork is a campus-wide internetwork of individual LANs which may be geographically spread over the part or whole of a single campus. This sometimes called campus intranet.
- In common practice, the entire campus internetwork including its communication subnet is wholly owned by a single organization or institution.
- Usually, the campus internetworks use LAN technology; however, it is possible to use WAN technology, when so desirable.
- The latter may be desirable in some cases when the campus is very large and comprises of a vast set of buildings spread over it. Protocols used in both of these cases at the lower layers, are, generally, different.



# Of the Internet, Intranet and Extranet

- The Global Public Internetwork: **The Internet**
- The Wholly Owned / Private Internetwork:  
**Intranet**
- The Hybrid Internetwork-- private networks /  
internetworks connected through the Internet:  
**Extranet**

*In the early stages of development, technologies used for the internetworks of all type were essentially the same, except probably at the lowest level. This situation is rapidly changing.*



# Comparing Computer Networks with Distributed Systems

- Terms Computer Network and Distributed System must NOT be used interchangeably since:
  - In the former, locations and elements of network remain visible to the user; *whereas*
  - in the latter, the underlying network remains transparent to the user who sees the system as a uni-processor.
- Similar differences can be cited in case of Network Operating Systems and Distributed Operating Systems.



# Multiplexing: What and why?

- **Multiplexing:**
  - Purpose: Capacity sharing for cost-effective delivery
  - Mechanism: Division / partitioning of the resource / capacity based on one or more parameters of physical medium or representation scheme or statistical / probabilistic estimate of usage
  - Examples: Time Division Multiplexing, Statistical Time Division Multiplexing, Frequency Division Multiplexing and many more ...



# Switching Fabric, Network Processors and the Semantic Gap <recap>

- **Switching Fabric**
  - High-speed Physical mechanism that allows the backplanes to execute low-latency switching
- **Channels**
  - Process-to-Process abstraction / view
  - Request-Response abstraction / view
  - Message-Stream abstraction / view
- **Network Processors**
  - Specialized network nodes optimized for functions like switching / routing / forwarding / provisioning etc.
- **Semantic Gap**
  - Gap between services / functionalities / features expected by applications and the capabilities of the networking technology



# Any questions?

***Thank you!***