

# Computer Networks

## -An Introduction

Lecture-2

January 10, 2011

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# Interaction Points

- **Classes / types of Computer Networks**
- Introduction to Internetworks
- **Classes / types Internetworks**
- Select References to the literature
- **Summary**

# Types of Computer Networks (1 of 2) <recap>

- Spread, size, inter-node-distance and purpose based classification:
  - Personal Area Networks (PANs): Often, Wireless: Wireless Personal Area Networks (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)
  - Body Area Networks (BANs)
  - Car Area Networks (CANs)

# Types of Computer Networks (2 of 2)

- **Virtualization-based classification:**
  - Virtual Local Area Networks (VLANs)
  - **Virtual Private Networks (VPNs)**
  - Overlay Networks

# Conventional Classification of Computer Networks

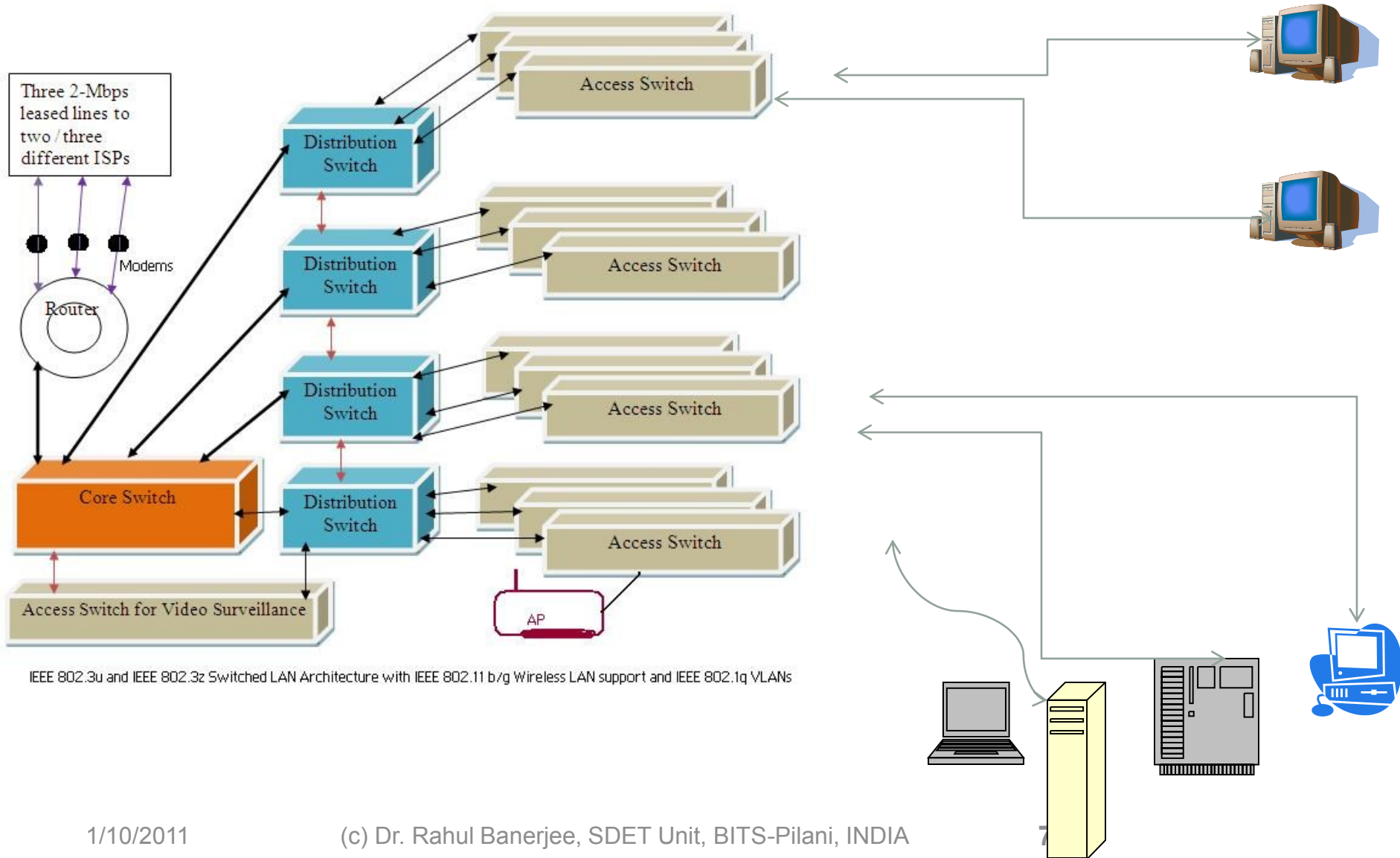
- **Class One: Function-based classification**
  - Data Networks
  - **Voice Networks**
  - Multimedia Networks .....
- **Class Two: Location-and-Distance-based classification**
  - Personal Area Networks (PANs)
  - **Local Area Networks (LANs)**
  - Metropolitan Area Networks (MANs)
  - **Wide Area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

# 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



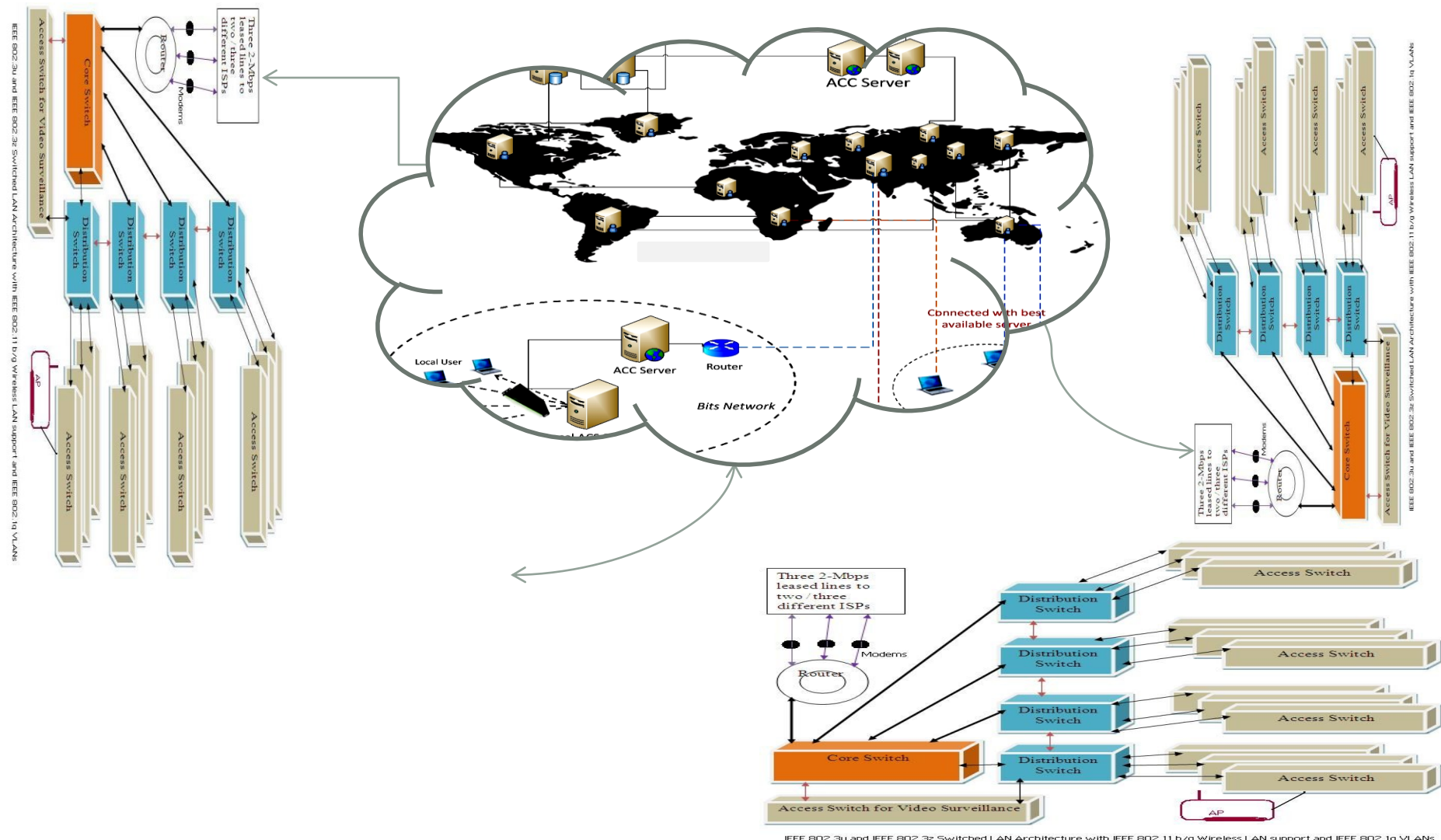
# An Example of a Computer Network



# Introduction to Internetworks

- What is an Internetwork?
  - Simply, a network of networks
- Types of Internetworks:
  - Intranet
    - Local, Metropolitan & Wide area types
  - The Internet
    - Wide area
  - Extranet

# What is an Internetwork?



# Local Area Internetwork / Intranet

- 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.

# Wide Area Networks (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!

# What is the Internet today?

- Wide Area Network of variety of networks
- Global
- Public
- Not transparent, as yet
- Hybrid topology but largely hierarchical
- No single controller
- Internet Society (ISoc) oversees, assists --- does not control
- QoS, Security continue to have issues – partly at least
- Web, mail, commerce, education, entertainment, sharing continue to dominate its application space

# Architecture of the Internet

- Originally, it was a point-to-point WAN.
- Original architecture that led to ARPANET has evolved over the years that have passed by.
- It is loosely hierarchical.
- Currently, Internet architecture is largely governed by the IAB of the ISoc.
- Has many sub-organs which facilitate evolution and coordinated maintenance of the Internet.
- IESG steers the ISoc in a general way the engineering issues are resolved.
- IETF workgroups do the ground work and by a democratic process helps community in building up engineering solutions through IETF drafts and standards (RFCs) etc.

# 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.*



# Some Terms Related to Networks

- Channel <application-level logical / virtual 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
- Tunneling <Encapsulation & Decapsulation>



# Of Protocols & Protocol Graphs

- **Definition of Protocol**

- **Perspective-1:** A set of rules and conventions leading to a set of pre-defined requests / commands and responses for any meaningful communication / exchange of control / information / both
- **Perspective-2:** Abstract interfaces in terms of operations associated with an interface definition in the context of one or more services on offer along with the set of parameters, form, forma, message types, meanings associated with the messages and even mechanism of handling select kinds of possible failures.
- **Perspective-3:** A pair of modules implementing the interfaces between two layers or peers



# Protocol Graphs

- A graph showing interrelation of various collaborating protocols at different levels is called a Protocol Graph.
- In a protocol graph, each protocol is represented as a node.



# Protocol Representation

- There exist numerous schemes of representation of a given Protocol.
- One common way to specify a Protocol is to represent it as a State Transition Diagram.

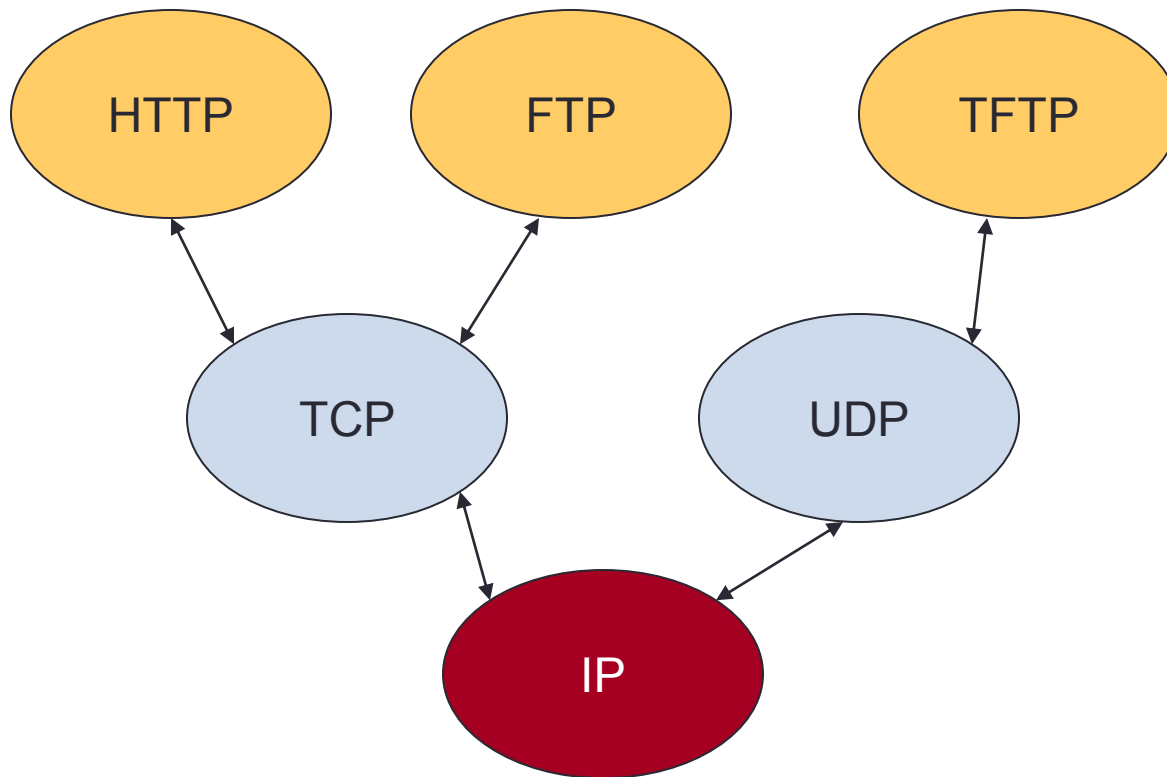


# Protocol Validation

- A Protocol needs to be proven correct before it is implemented.
- There exist quite a few ways of formal and semi-formal verification of Protocols.
- One common technique is to first represent a protocol a State Transition Diagram and then examine it for its 'completeness', 'reachability' and / or points of weakness etc.



# Example of a Simple Protocol Graph as applicable to the Internet





# An Example Protocol

- Let's take one of the simplest situations in which there exist two network nodes N1 and N2 interconnected through a bi-directional communication link.
  
- Let's assume that that it is required that primarily N1 would be sending the data to N2 using a simple mechanism over this link and only one unit of data (frame) would travel at a time over the link.



# A Few Measures of Network Performance

- *Performance Measures*
  - *Available Performance*
  - *Measured Performance*
- *Bandwidth:*
  - *Width of the usable / allotted Frequency band*
  - *Rate of data transfer in bits per second*
    - *Throughput: Actual measured rate of achievable data transfer in bits per second*
    - *Bandwidth has often a value greater than that of the Throughput*
- *Round-Trip Time (RTT)*
- *Latency: Delays of various kinds*
- *'Delay x Bandwidth' metric*
- *Quality of Service*



# 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.

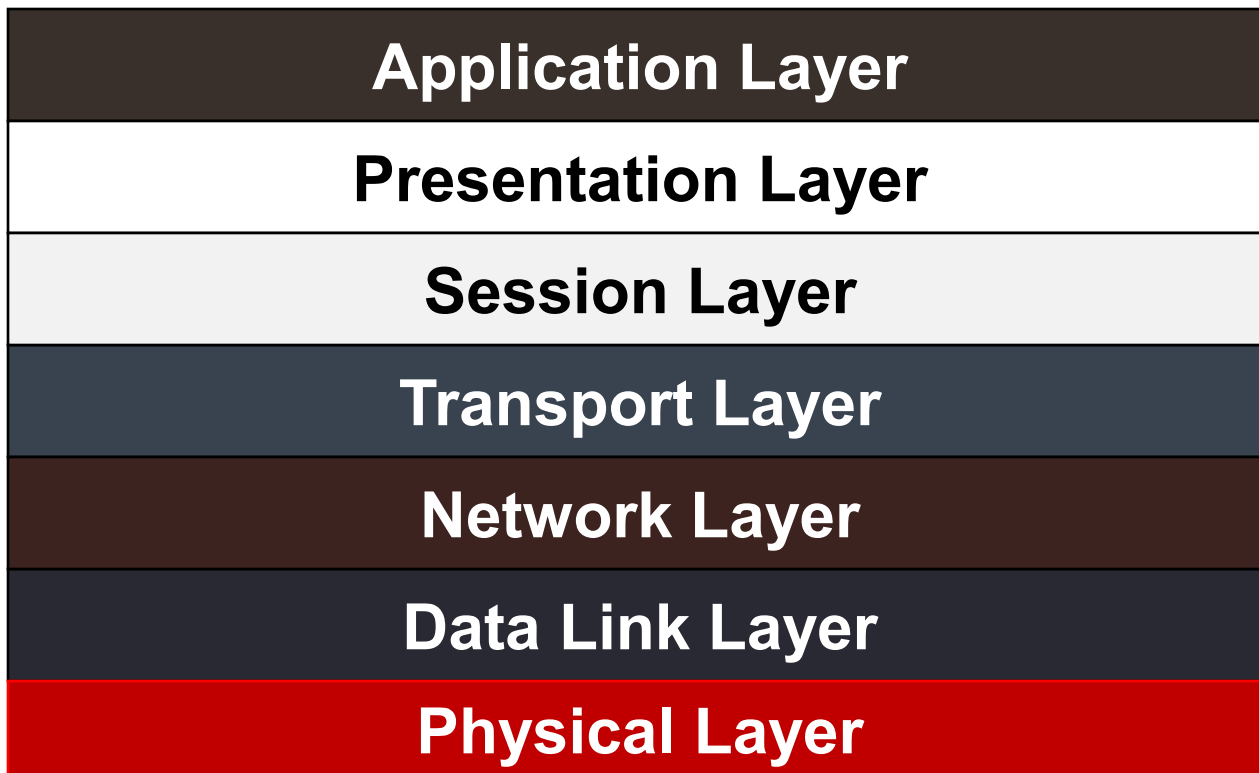


# Network Architecture & Reference Models

- Examples:
  - **TCP/IP Architecture**
  - OSI Reference Model & OSI Architecture

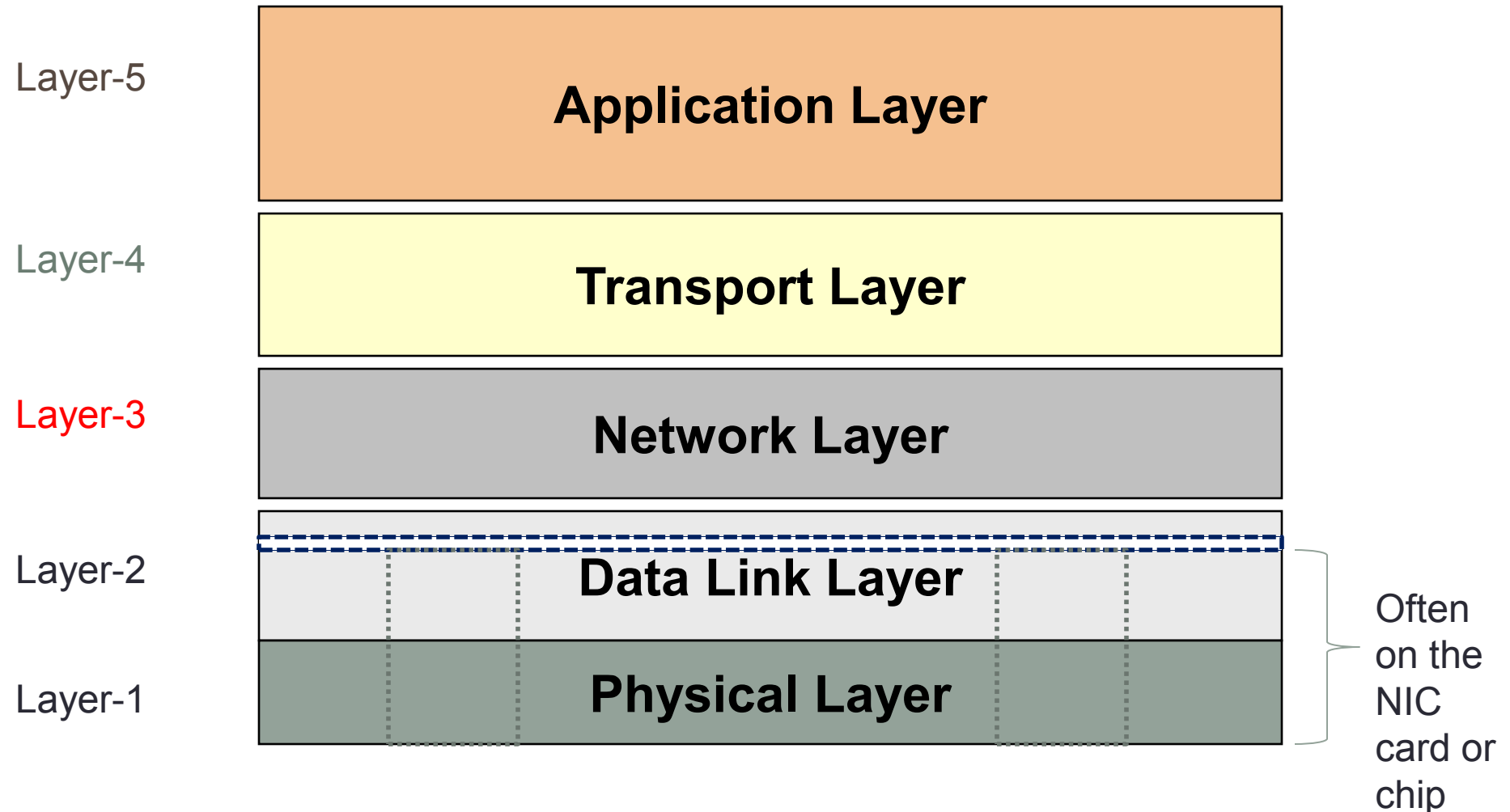


# The ISO OSI Reference Model





# A Hypothetical Network Reference Model for Easy Conceptual Understanding



# 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;
  - **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.

# Summary of the Concepts learnt so far:

Definition and applications of networks

Types / Classes of Networks

Physical & Logical / Virtual links

Need for Network Protocols

How networks facilitate distributed & mobile computing

# Concluding remarks

- Networking support of some kind is already inside most of the operating systems we use today in variety of forms on Notebooks, Laptops, Workstations and Servers. All Smartphones and several set-top boxes support it too.
- **Subsequent lectures shall introduce you to the following topics:**
  - Internetworks
  - Network Architectures
  - Performance
  - Quality of Service
  - Reliability
  - Security

Any question please?

*Thank you for your kind attention!*

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**or visit:**

Home: <http://www.bits-pilani.ac.in/~rahul/>

# References

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- *Thomas G. Robertazzi: Computer Networks and Systems: Queuing Theory and Performance Evaluation, Third Edition, Springer-Verlag, New York, 2000. <Analytical approach>*

# Next Interaction Points

- **Examples of Types of Applications benefitting from Networking**
  - hard real-time, soft real-time, non-real-time / best-effort / delay-tolerant applications / services <with examples>
  - **case-study movie**
  - Constituent networking components of a smart room setup
- **The Internet & its Evolution**
- About Internet Architecture
- **Who decides about the Internet?**
- The Internet versus the World-Wide Web
- **Protocols, Layers, Interfaces, Virtual Communication and Services**
- Select References to the literature
- **Questions and Answers / Summary**



# Examples of Types of Applications benefitting from Networking

- **Types of applications & services:**
  - hard real-time applications & services,
  - **soft real-time applications & services,**
  - non-real-time / best-effort / delay-tolerant applications / services
- **Examples of each kind of applications and services**
- About the significance of application-driven and economics-constrained nature of network system design approaches
- **Case-study of the Networking aspects of the *Microsoft Easy Living Research Experiment***



# Summary

- **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