Introduction to Telecommunications
EN1052

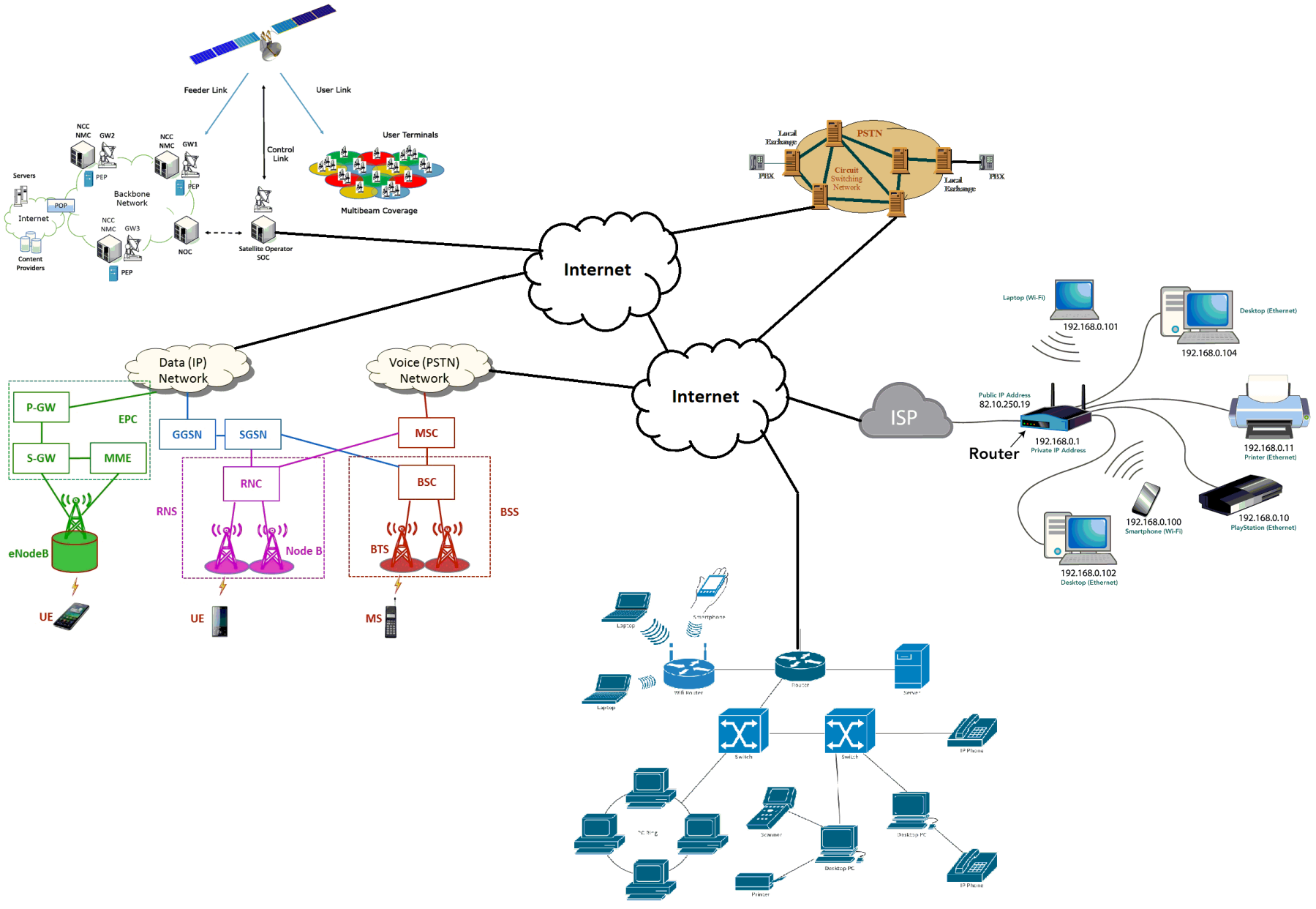
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March 2021

Lecture 7: Networking Principles II

Layered Architecture to Data Network Design

Networks


Feeder Link
User Link
Control Link
User Terminals
Multibeam Coverage
NCC NMC
GW1
GW2
GW3
PEP
POP
Servers
Backbone Network
Internet
Content Providers
NOC
Satellite Operator SOC
Local Exchange
PSTN
Circuit Switching Network
PBX
Internet
Data (IP) Network
Voice (PSTN) Network
P-GW
S-GW
MME
EPC
GGSN
SGSN
MSC
RNC
BSC
RNS
BSS
Node B
BTS
eNodeB
UE
MS
ISP
Router
Public IP Address
82.10.250.19
192.168.0.1
Private IP Address
Laptop (Wi-Fi)
192.168.0.101
Desktop (Ethernet)
192.168.0.104
192.168.0.11
Printer (Ethernet)
192.168.0.100
Smartphone (Wi-Fi)
192.168.0.10
PlayStation (Ethernet)
192.168.0.102
Desktop (Ethernet)
Laptop
Smartphone
Wifi Router
Router
Server
Switch
IP Phone
Scanner
Desktop PC
Printer

Concept of Layering

- the required network operations for communication between nodes are indeed intricate
- a modular approach is adopted
- in fact a hierarchical modularity is central to network design
- this leads to the idea of layered architecture of networks

Layering

- a form of hierarchical modularity that is central to data network design
- the word module is used to refer either to a device or to a process within some computer system

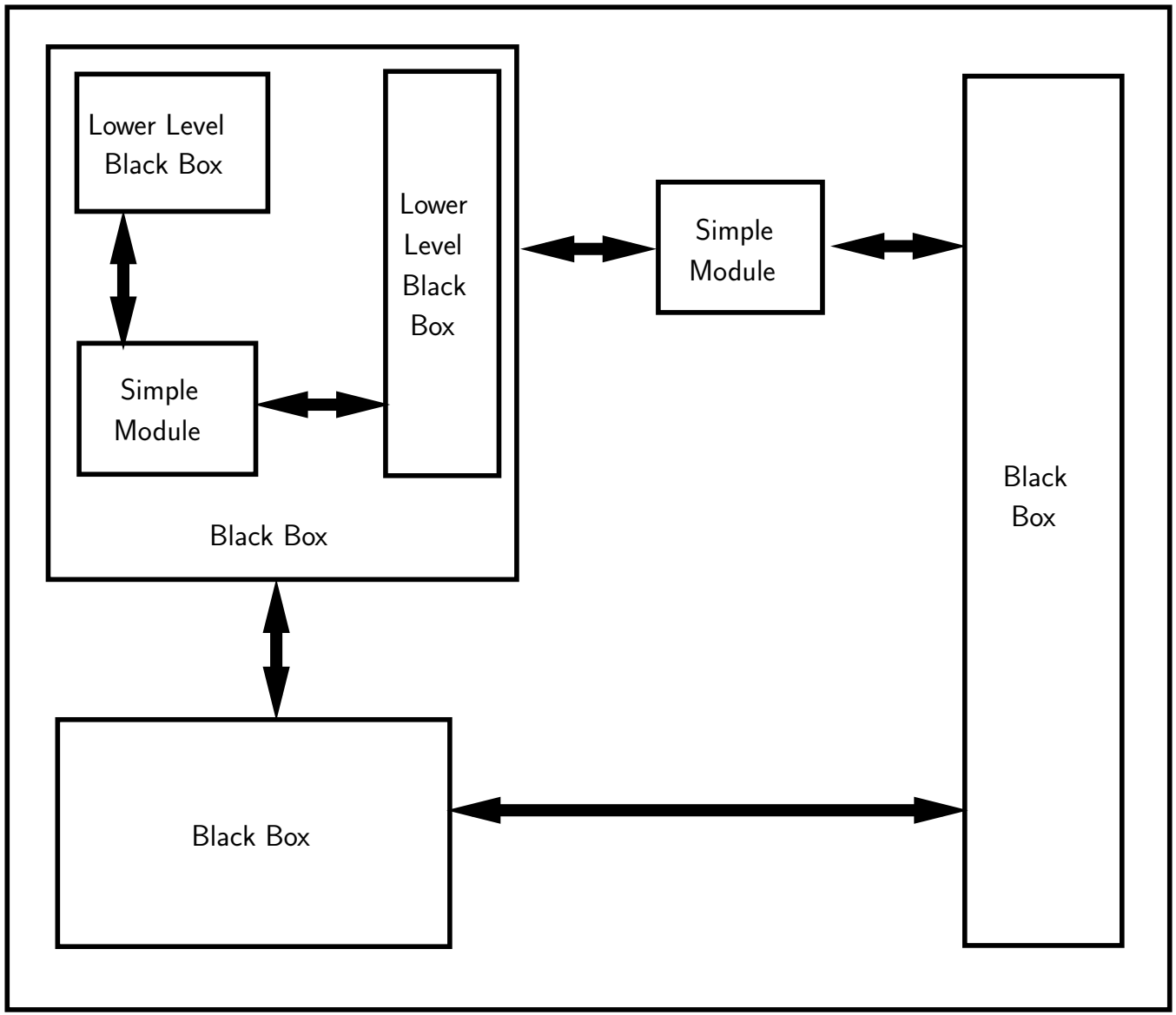
Module

- the module performs a given function in support of the overall function of the system
- such a function is often called the service provided by the module
- the designers of a module are aware of the internal details and operation of that module
- for others who uses the module it is a black box
- the user is uninterested in the internal workings

Module

- however, for the user, the inputs, the outputs, and the relation of outputs to inputs are important
- the user is concerned with the service provided by the module
- thus, a module is a black box viewed in terms of its input-output description
- modules are used to construct a more complex module, which is a bigger black box
- a module can contain simple modules, which does not require further splitting

Nested Black Boxes



Advantages of Modularity

- simplicity of design
- understandability
- possibility of standardization
- interchangeability

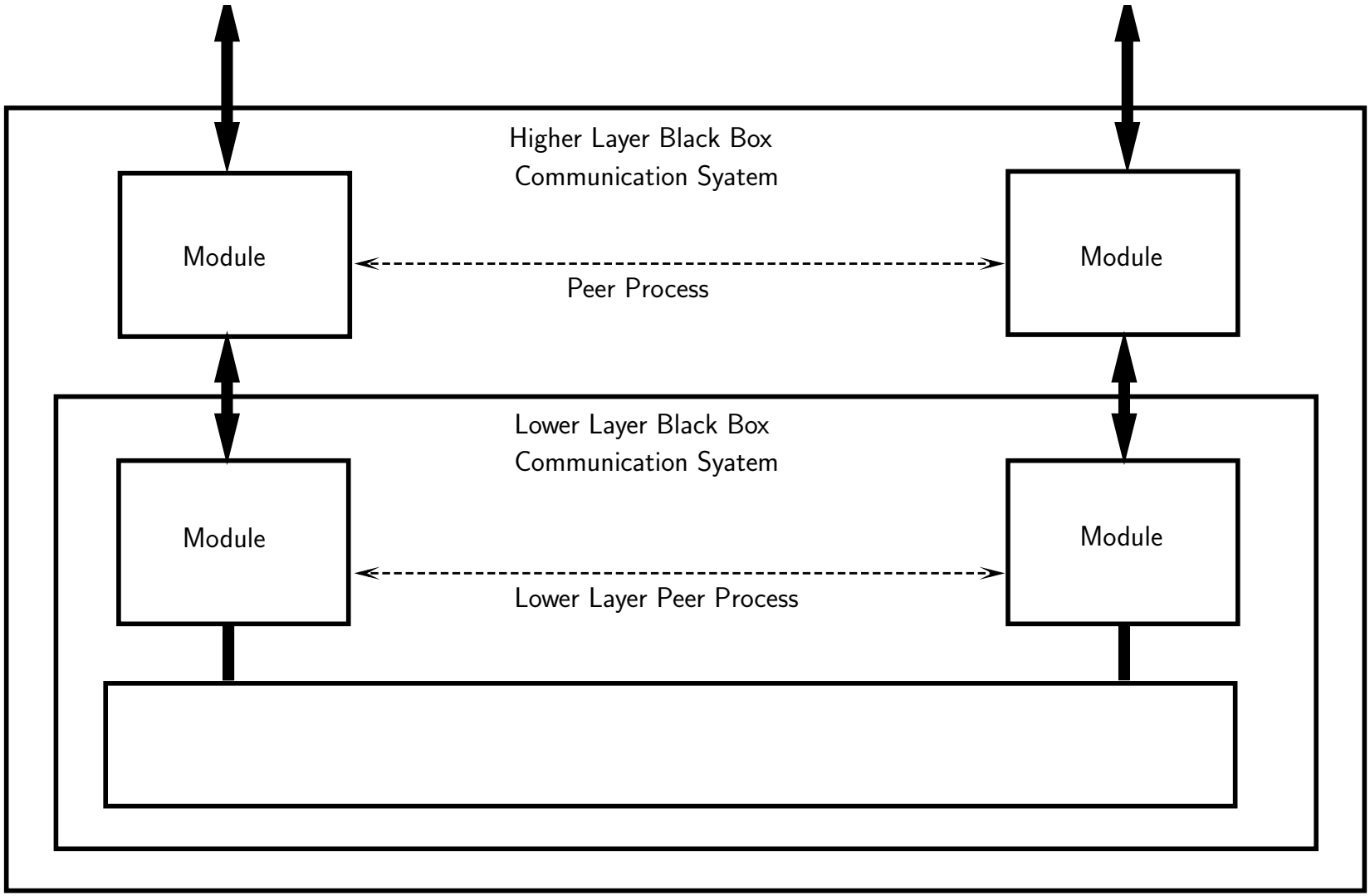
A Layered Architecture

- hierarchy of nested modules or black boxes
- each given layer in the hierarchy regards the next lower layer as one or more black boxes
- lower layers provide a specified service to their immediate higher layers

Unique Features in Data Networks

- the black boxes at various layers are in fact distributed black boxes
- the bottom layer of the hierarchy consists of the physical communication links
- each black box consists of
  - a lower-layer black box communication system
  - a set of modules, one at each end of the lower-layer communication system

Black Box Communication Sys.



Communication between Peers

- one peer module (associated with a peer process) can communicate with its peer at the other node
- to this end, it places a message into the lower-layer black box communication system
- the lower-layer black box, consist of lower-layer peer processes, and a modules at each of the two nodes
- those modules, connected again by lower-layer black box communication system

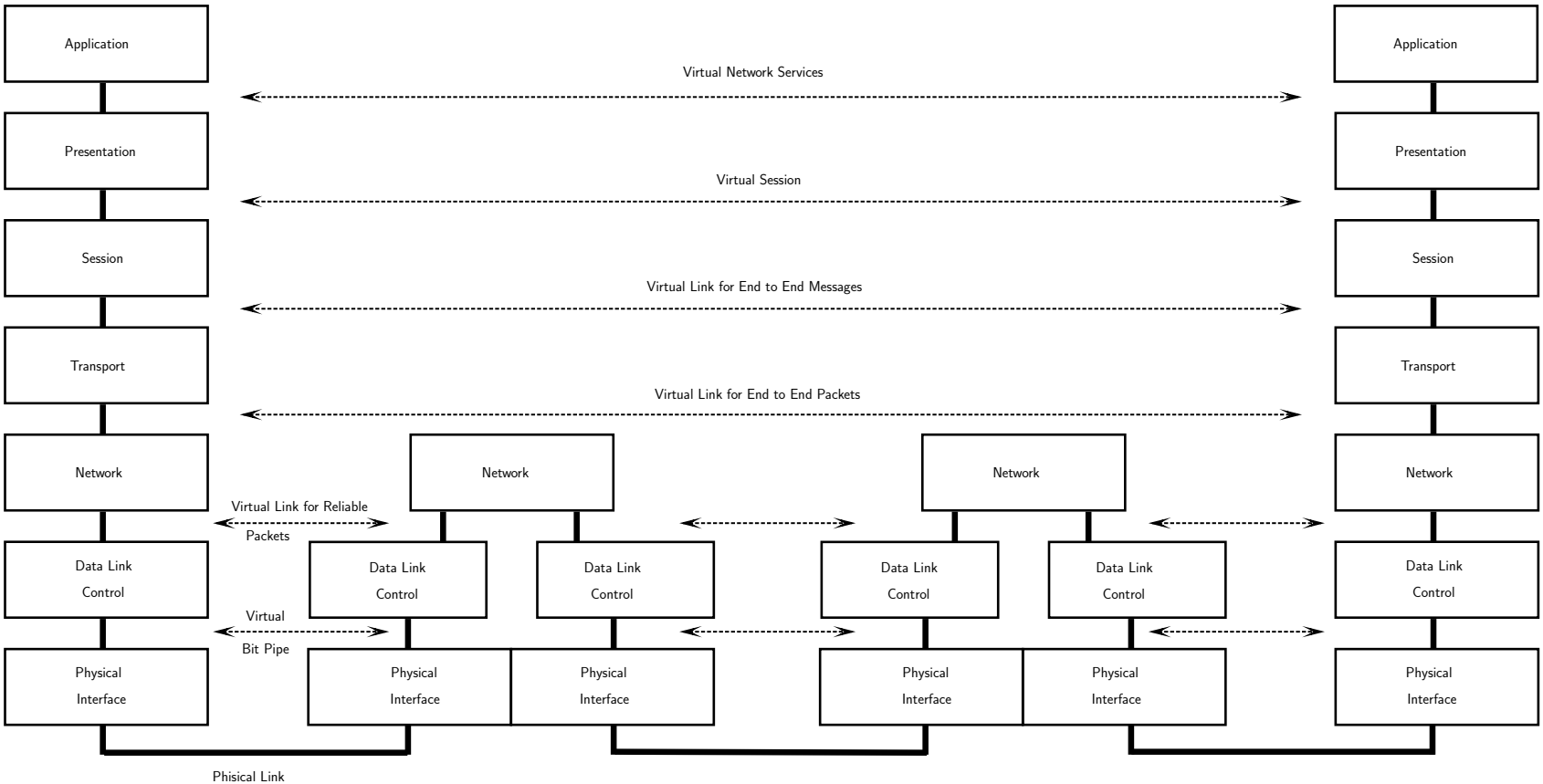
Communication between Peers

- important aspects:
  - protocol the peer modules use in exchanging messages or bit strings so as to provide the required functions or service to the next higher layer
  - the specification of the precise interface between the layer n module at one node and the layer $n-1$ module at the same node through which the messages above are actually exchanged

Reference Model of OSI

- OSI: open system interconnection
- a guideline based on which the practical systems are designed
- an international standard for data networks by the international standards organization (ISO)

Seven-Layer OSI Network Architecture



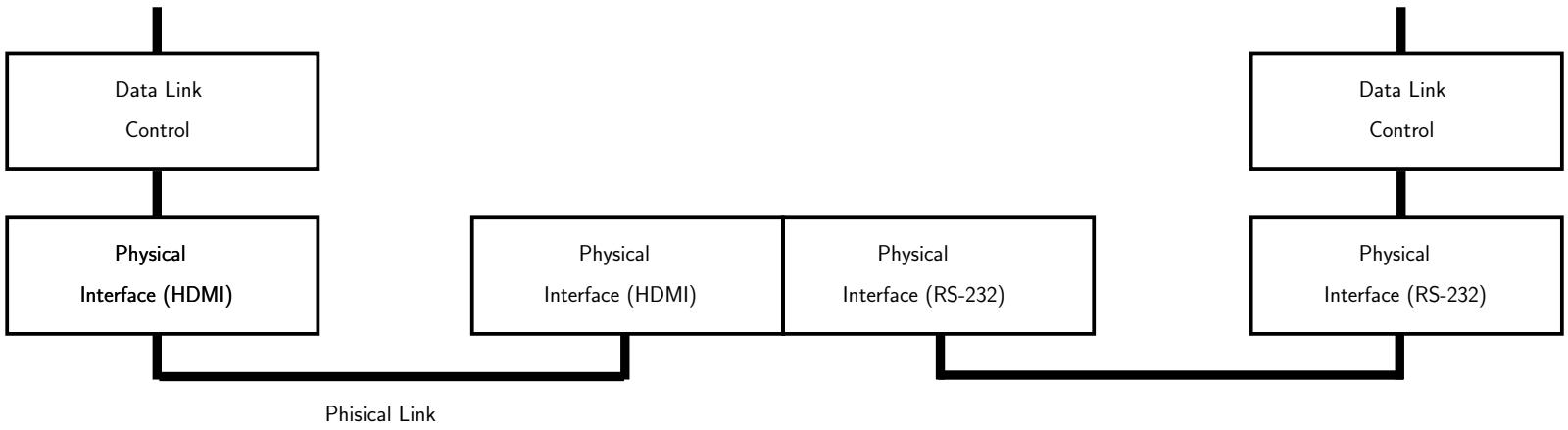
Physical Layer

- provide a virtual link for transmitting a sequence of bits between any pair of nodes
- such a virtual link is called a virtual bit pipe
- physical interface modules on each side the communicationchannel
  - map the incoming bits from the next higher layer into signals appropriate for the channel
  - map the signals from channel back into bits to be delivered to upper layers at Rx

Physical Layer

- such interface modules (loosely speaking)
  - Ethernet card
  - MODEMS (old telephony systems)
  - the USB (serial, HDMI, etc.,) port and the cct, to which a USB (serial, HDMI, etc.,) cable is connected
- communication is either synchronous, intermittent synchronous, or asynchronous

Interface Over a Physical Medium



Data Link Control (DLC) Layer

- convert the unreliable bit pipe in to a error-free virtual communication link for sending packets
- communication is asynchronous due to variable delay from start to end
  - need to detect/correct the errors that occur at the physical layer
  - packets can be of variable length

Data Link Control Layer

- communication is asynchronous also due variable time between subsequent entries
  - higher layer has no packets to be sent
  - unable to accept new packets when too many old packets are being retransmitted due to transmission errors

Data Link Control Layer

- an overhead is added to the packets from the upper layer before sending to the physical (PHY) layer, e.g., headers, trailer $\rightarrow$ frames
- some of these determine if errors have occurred in the transmitted frames
- some request retransmissions when errors occur
- some delineate the beginning and ending of frames

Data Link Control Layer

- reverse operation: header and trailer of those from PHY is removed and pushed to the upper layer

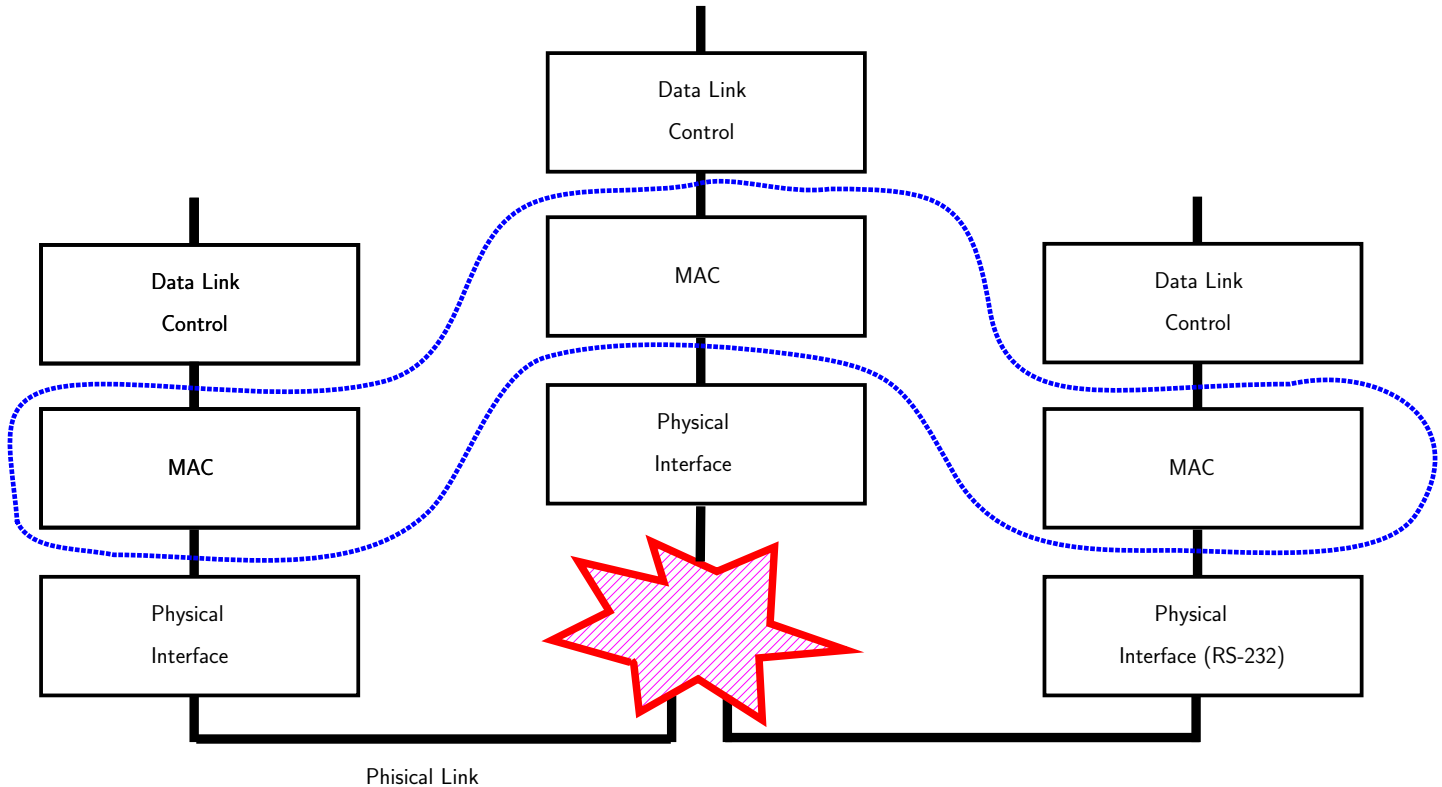
MAC Sublayer

- still the the DLC layer exits for a virtual error-free packet link to higher layers
- still the PHY layer to provide a bit pipe
- MAC sublayer resides between PHY and DLC layers

MAC Sublayer

- a need for an intermediate layer to manage the multiaccess links
- frames can be sent by each node without constant interference from the other nodes
- i.e., multiaccess of the channel is enabled
- called medium access control (MAC)

Layering for a Multiaccess Channel



Network Layer

- one network layer process associated with each node and with each external site
- underlying peer processes work together to implement
  - routing
  - flow control

Network Layer

- suppose a frame enters a node or site from a communication link
- the bits of the frame pass through the physical layer to the DLC layer
- DLC layer determines where the frame begins and ends
- if the frame is correct, the DLC strips off the DLC header and trailer
- the resulting packet is passed up to the network layer module

Network Layer

- packet consists of packet header and the packet body
- the network layer module uses
  - the packet header of an incoming packet
  - stored information at the module

  to accomplish its routing and flow control functions

Network Layer

- reverse operation: data coming from transport layer are packaged to be sent to the DLC layer

Network Layer

- in addition to routing, flow control is also done

Network Layer

- if no flow control
  - traffic at bottleneck links grows
  - delays will increase, i.e., violation of delay spec
  - traffic grows indefinitely
  - the buffer space at some nodes may be exhausted
  - some of the traffic arriving at these nodes will be discarded
  - those are to be retransmitted later
  - thus, waste of communication resources

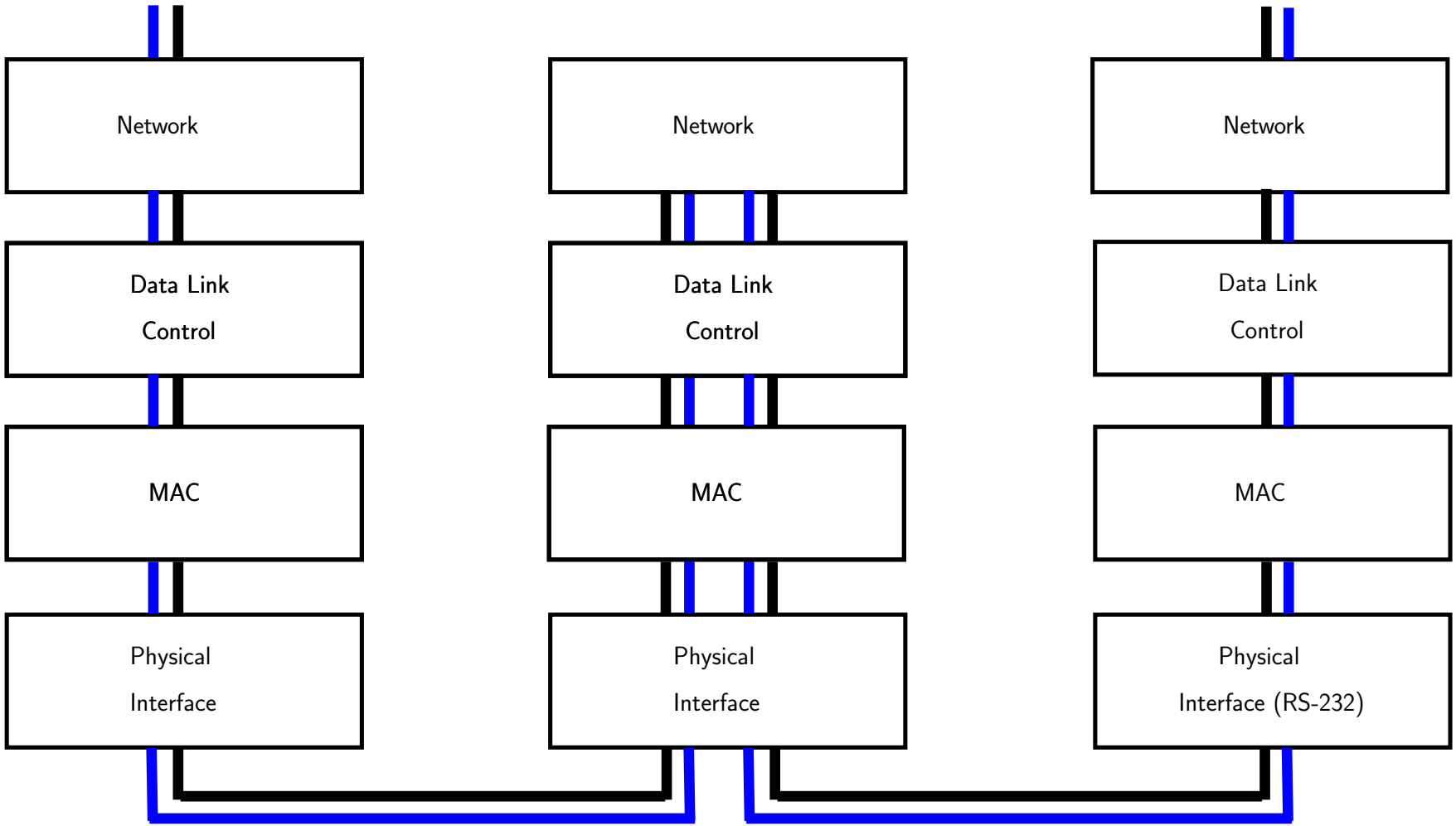
Network Layer

- measures are there to restrict the traffic into the network
  - one has to prevent some of the offered traffic from entering the network
  - this is why flow control

Network Layer

- the most complex of the layered hierarchy
- this is because all the peer processes at this layer must work together
- the overall algorithms are distributed between many geographically separated processes

The Network Layer at a Node



Transport Layer

- for each virtual end-to-end link provided by the network layer, there is a pair of peer processes, one at each end of the virtual end-to-end link
- the transport layer has a number of functions, not all of which are necessarily required in any given network

Transport Layer

- breaks messages into packets at the transmitting end
- reassembles packets into messages at the receiving end

Transport Layer

- the transport layer might multiplex several low-rate sessions
- those are from the same source site and are going to the same destination site
- create a one session at the network layer

Transport Layer

- split one high-rate session into multiple sessions at the network layer
- facilitate flow control with guaranteed rate
- instead, the network layer itself would have performed rate adjustments

Transport Layer

- if unreliable network layer $\rightarrow$ achieve reliable end-to-end session communication
- this is required for example
  - one or the other end site fails
  - the network becomes disconnected due to communication link failures

Transport Layer

- end-to-end flow control is usually done ar this layer

Session Layer

- one function is akin to the directory assistance service in the telephone network
- this layer provides the transport layer with the information needed to establish the session
- deals with access rights in setting up sessions
  - authentication
  - permissions
  - session restorations

Presentation Layer

- data encryption
- data compression
- code conversion (e.g., between ASCII and EBCDIC)

Application Layer

- familiar software that we use, e.g.,
  - paint
  - word
  - excel
  - chat
  - zoom