Part I Syllabus

Lecture	Date	Subject
1	10/08/2016	Introduction
2	**10/08/2016**	**Network layer & physical resilience**
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	24/08/2016	Data link layer – HDLC
6	24/08/2016	Local area network – introduction
7	31/08/2016	Local area network – MAC
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	07/09/2016	Packet switch network
11	14/09/2016	Network performance analysis
12	14/09/2016	Review and examples

Which one is more valuable?

NANYANG TECHNOLOGICAL UNIVERSITY

CE3005 Computer Networks

Lecture 2
Network Layers and Physical Resilience

Contents

- **Layered Network Architecture**
  - Motivations and Benefits
  - OSI 7-Layer Model
  - Internet 5-Layer Model
- **Physical Resilience**
  - Link Failure probability
  - Network resilience calculation

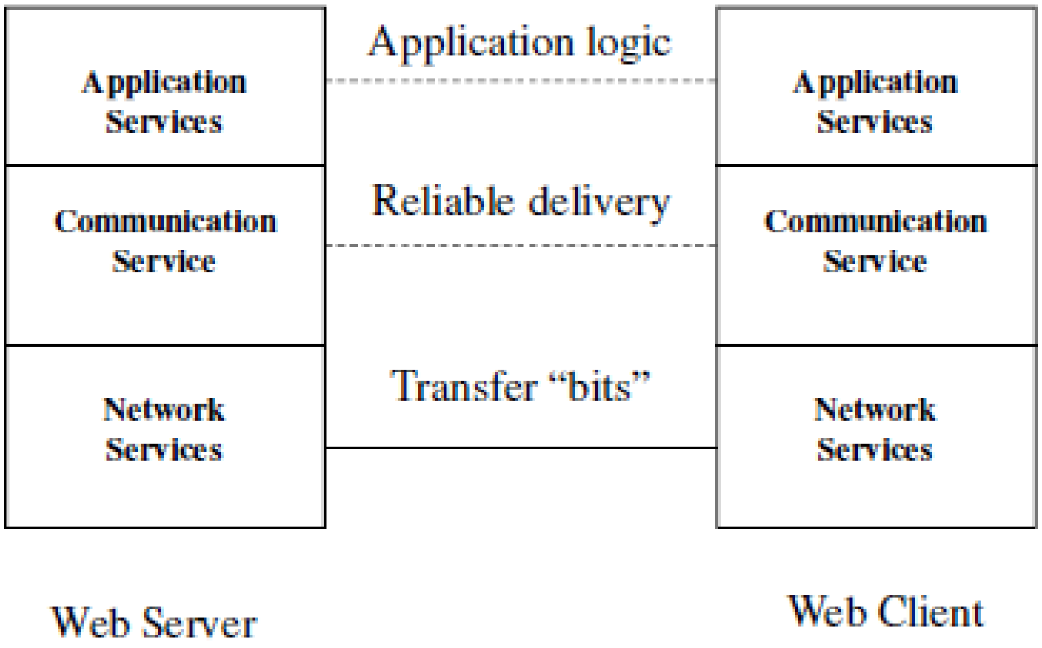
Layered Network Architecture

Motivations for Layered Network Architecture

- **Networks are complex with many pieces**
  - Hosts, routers, links, applications, protocols, hardware, software
- **Dealing with complex systems**
  - Explicit structure allowing identification, relationship of different pieces
    - Layered reference model for discussion
  - Modularization easing maintenance and updating
    - Change of layer's service transparent to rest of system
    - Change in network technology does not affect rest of system
  - Layering harmful? (design vs implementation)

A Layered Example for Web

- Brower requests web page from server
- Server determine if access is granted
- Reliable transfer page from server to client
- Physical transfer of bits from server to client



Layered Network Architecture

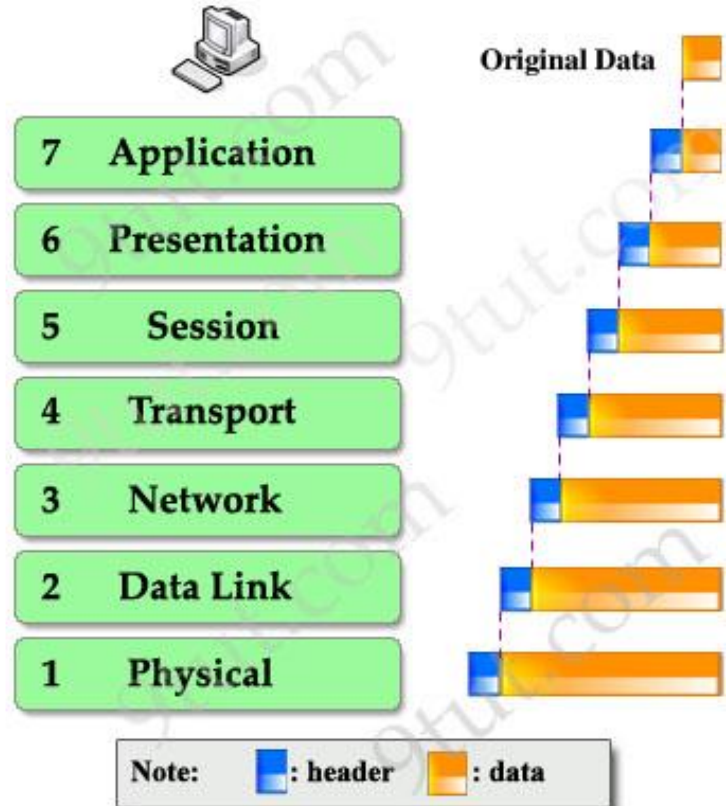
- **Network organized as a stack of layers**
  - Purpose of layer is to offer services to the layer above it and passes data & control information to the layer below, using a well-defined interface
  - Reducing design complexity
- **Protocols: a set of rules governing communication between two peering parties/computers**
  - define format, order of messages sent and received among network entities, and actions taken on message transmission & receipt.
- **Network Architecture: a set of layers and protocols with specifications enabling hardware/software developers to build systems compliant with a particular architecture**

Benefits of Layers

- **Simplicity**
  - Easy to design once layers and their interactions are defined clearly
- **Flexibility**
  - Easy to modify and develop networks by separate layers modifications
- **Incremental Changes**
  - Easy to add news layers, add new functions to a layer

OSI 7-Layer Model

- **Function Decomposition**
  - Weakly-decoupled stack
- **Encapsulation**
  - Each layer adding new headers
- **Peering**
  - Only peer layer communicating with each other

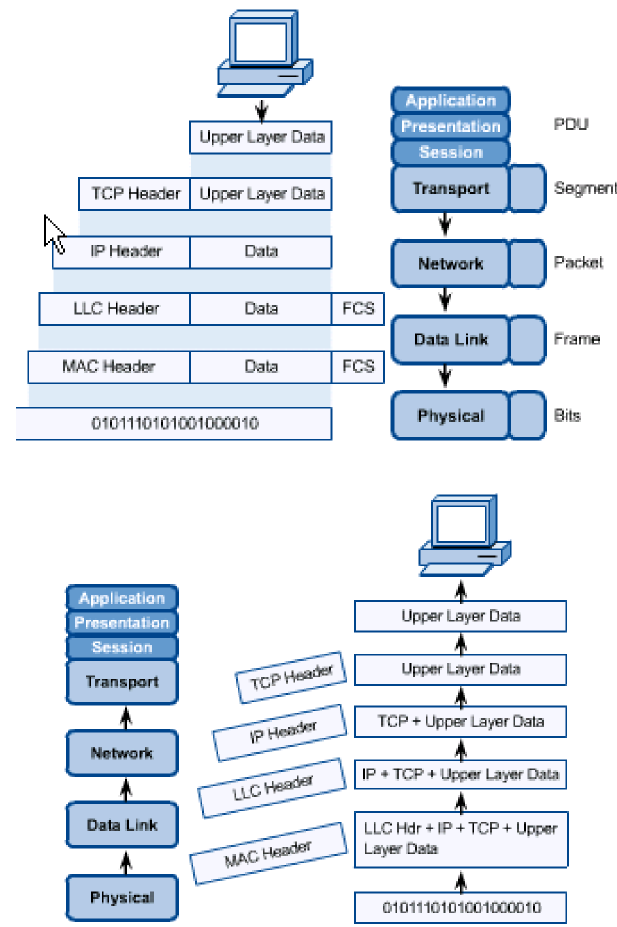


OSI Reference Model: 7 Layers (More on Supplementary Materials)

OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Inter-host communication, managing sessions between applications
	Segment	4. Transport	End-to-end connections, reliability and flow control
Media layers	Packet	3. Network	Path determination and logical addressing
	Frame	2. Data link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

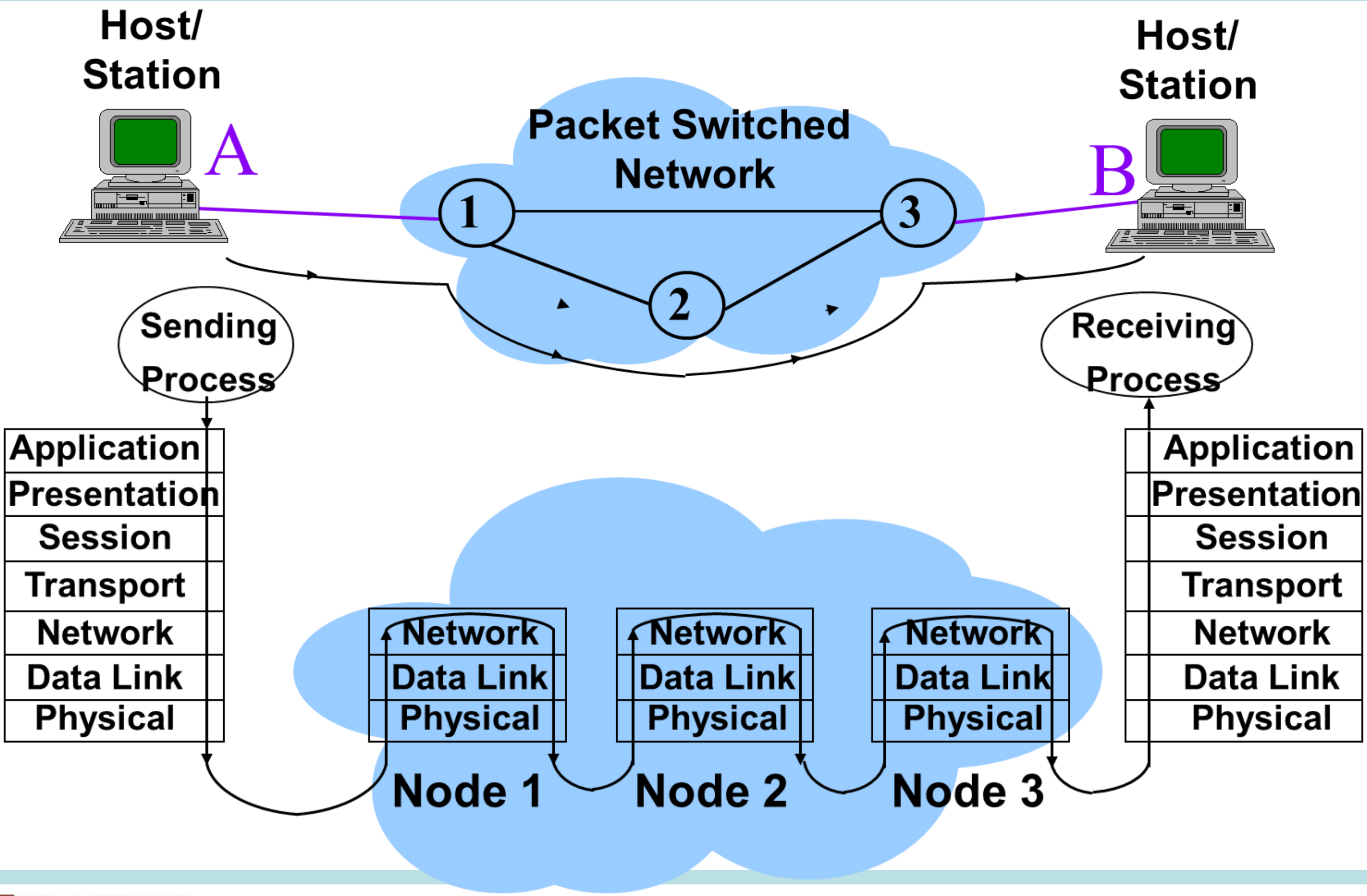
OSI in Action

- A message begins at the top application layer and moves down the OSI layers to the bottom physical layer
- As the message descends, each successive OSI model layers adds a header to it
- A header is layer-specific information that basically explains what functions the layer carries out
- Conversely, at the receiving end, headers are stripped from the message as it travels up the OSI layers.



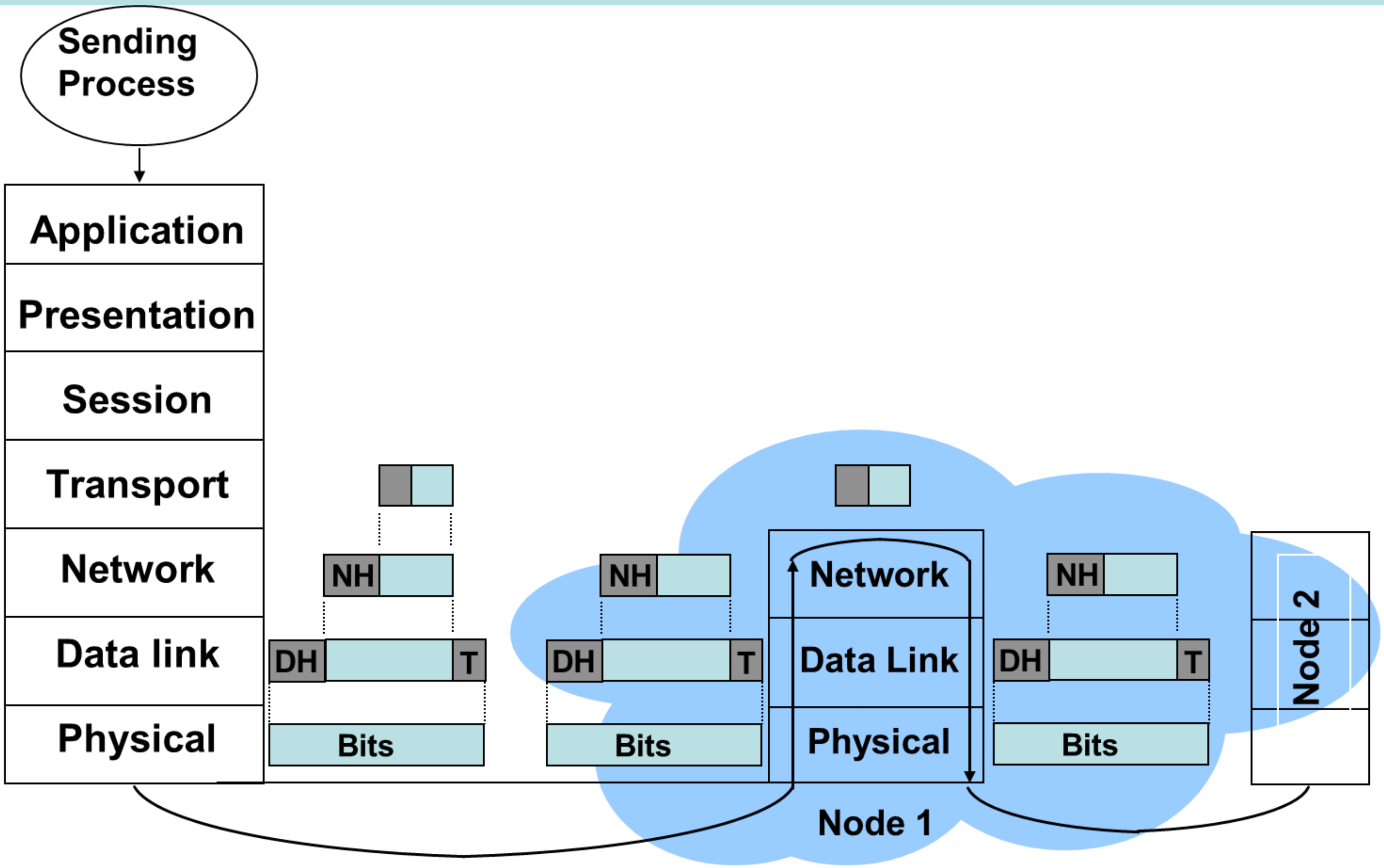
NANYANG TECHNOLOGICAL UNIVERSITY

A Simple Computer Network



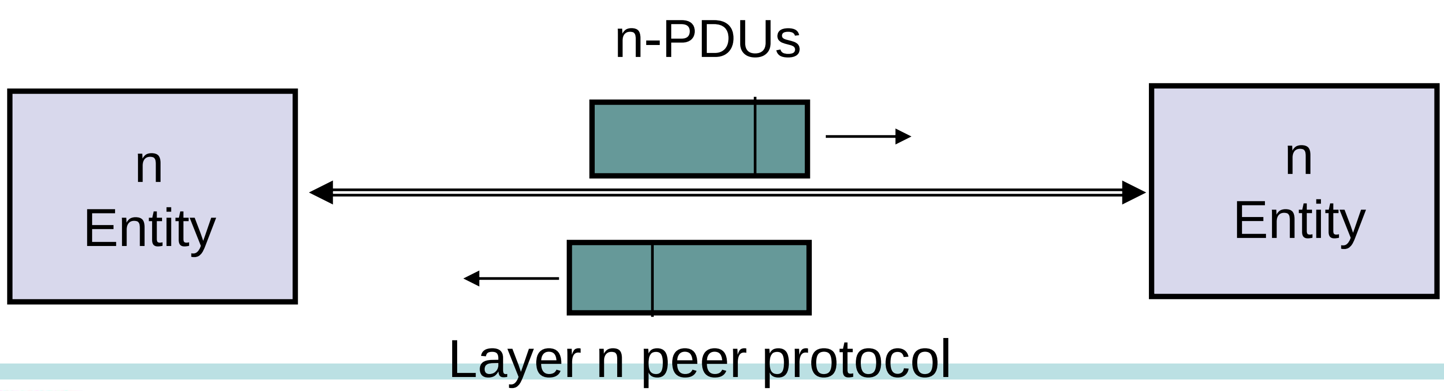
NANYANG TECHNOLOGICAL UNIVERSITY

Header Processing at Switch Node



OSI Unified View: Protocols

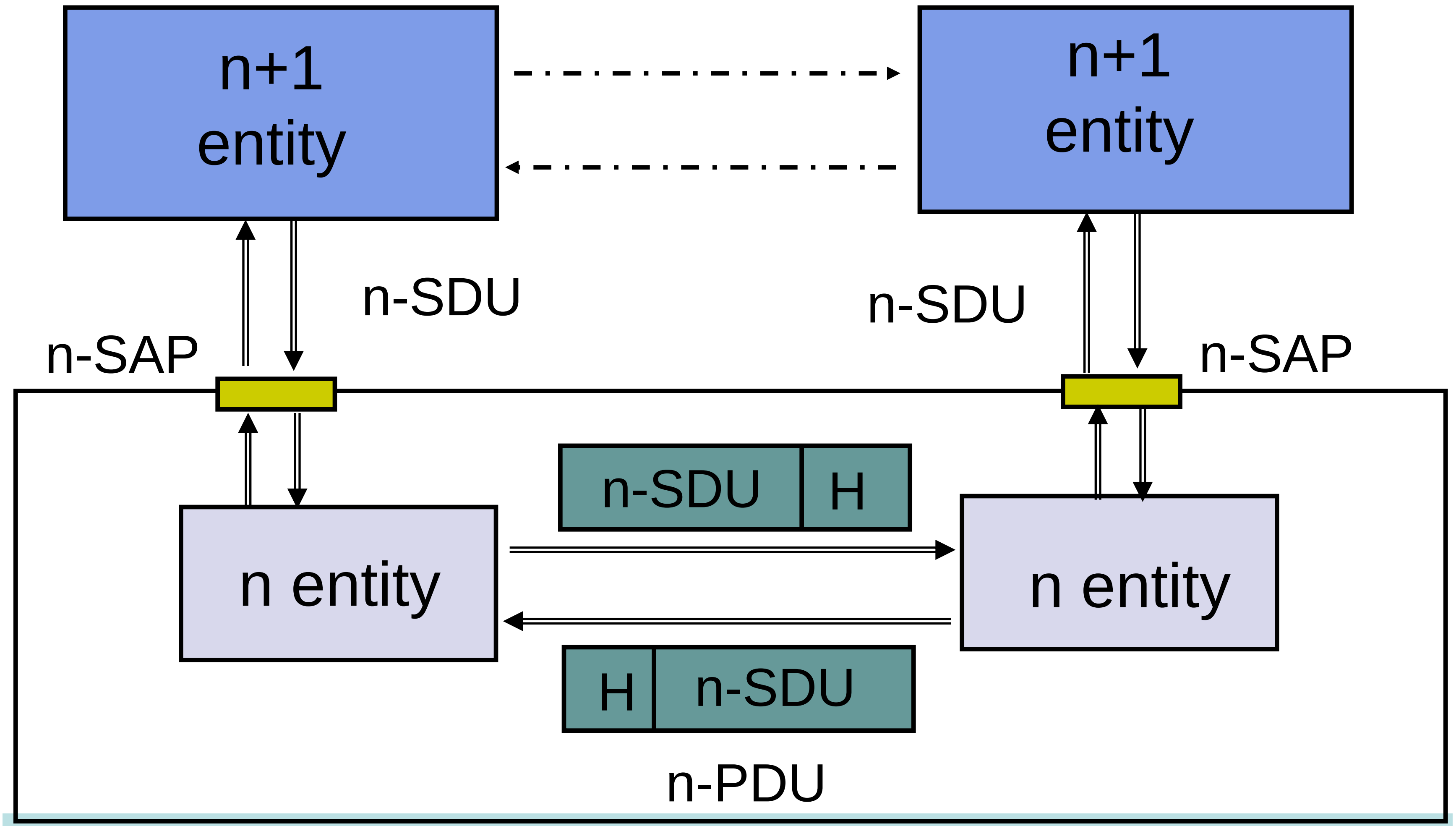
- **Layer *n* in one machine interacts with layer *n* in another machine to provide a service to layer *n* +1**
- **The entities comprising the corresponding layers on different machines are called *peer processes.***
- **The machines use a set of rules and conventions called the *layer-n protocol*.**
- **Layer-n peer processes communicate by exchanging *Protocol Data Units* (PDUs)**



OSI Unified View: Services

- Communication between peer processes is virtual and actually indirect
- Layer *n*+1 transfers information by invoking the services provided by layer *n*
- Services are available at *Service Access Points* *(*SAP's)
- Each layer passes data & control information to the layer below it until the physical layer is reached and transfer occurs
- The data passed to the layer below is called a *Service Data Unit* (SDU)
- SDU's are *encapsulated* in PDU's

Layers, Services & Protocols



OSI Model in a Nutshell

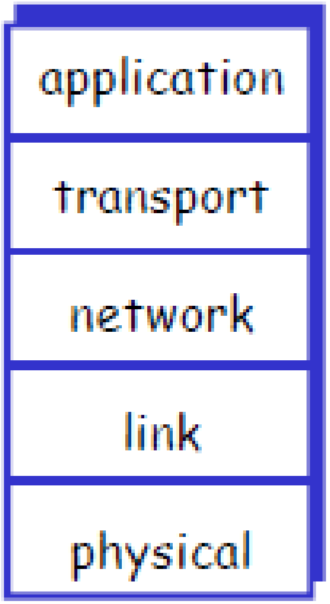
OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example		Central Device/ Protocols		DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management		**User Applications** SMTP	**GATEWAY** Can be used on all layers	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**		JPEG/ASCII EBDIC/TIFF/GIF PICT		
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.		**Logical Ports** RPC/SQL/NFS NetBIOS names		
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	PACKET FILTERING	TCP/SPX/UDP		Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		**Routers** IP/IPX/ICMP		Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control		**Switch** **Bridge** **WAP** PPP/SLIP Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts		**Hub**		

NANYANG TECHNOLOGICAL UNIVERSITY

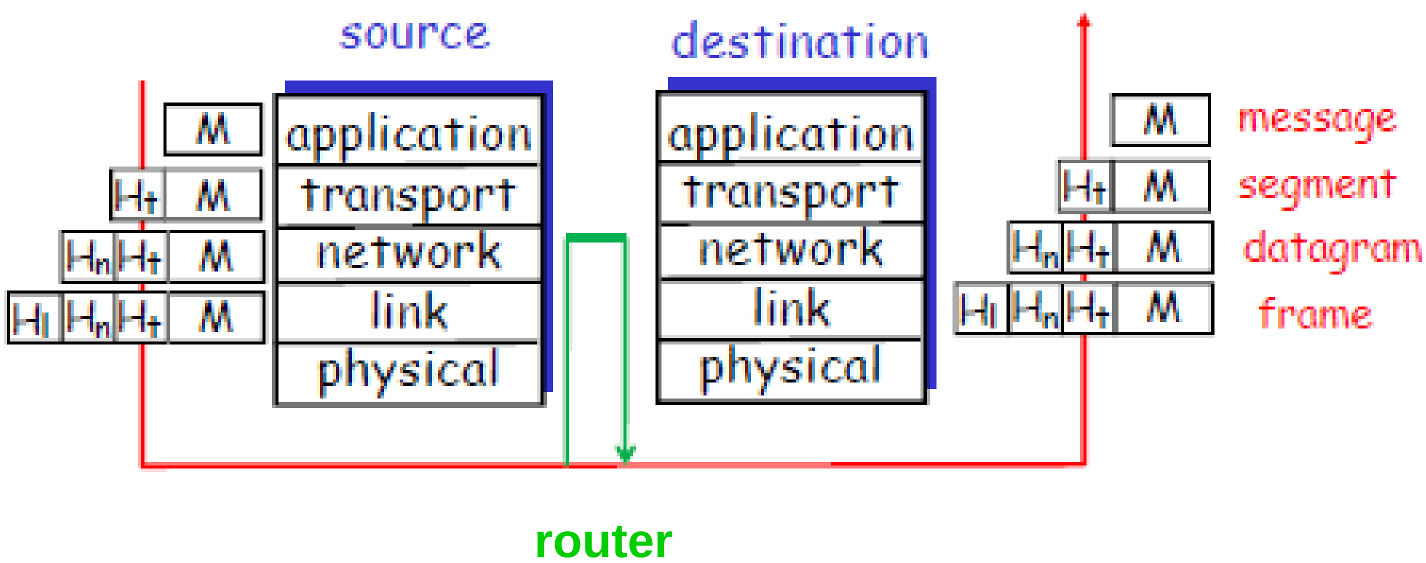
TCP/IP Model: 5 Layers

- **Application**: supporting network applications
  - FTP, SMTP, HTTP
- **Transport:** host-host data transfer
  - TCP, UDP
- **Network**: routing of datagrams from source to destination
  - IP, routing protocols
- **Link**: data transfer between neighboring network elements
  - PPP, Ethernet
- **Physical**: bits on the wire

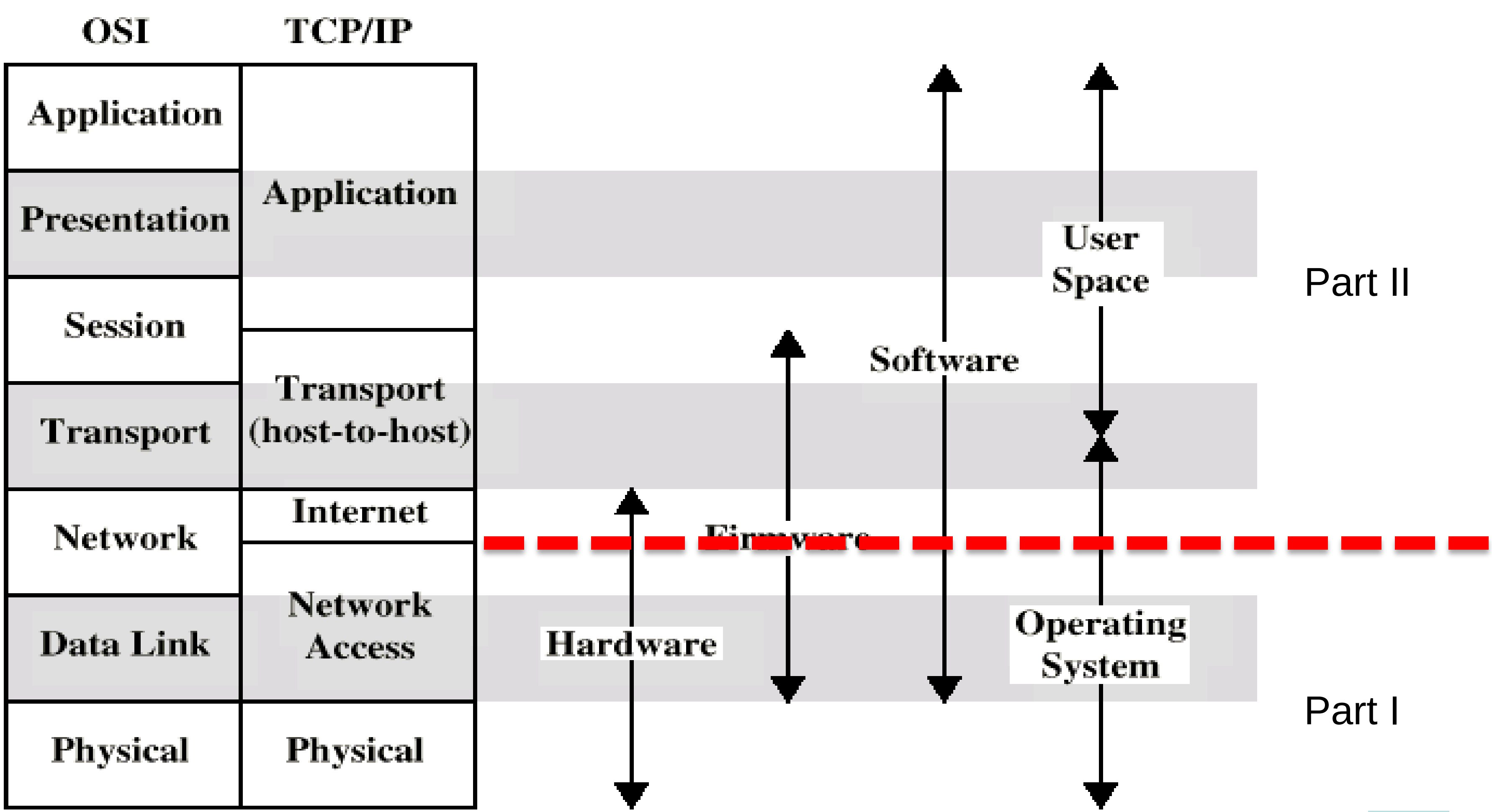


TCP/IP Internetworking

- **Each layer takes data from above**
  – Adds header information to create new data unit
  – Passes new data unit to layer below



TCP/IP vs OSI Models



Part I Syllabus – Fundamental Underlying Layers

Lecture	Date	Subject
1	10/08/2016	Introduction
2	10/08/2016	Network layer & physical resilience
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	24/08/2016	Data link layer – HDLC
6	24/08/2016	Local area network – introduction
7	31/08/2016	Local area network – MAC
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	07/09/2016	Packet switch network
11	14/09/2016	Network performance analysis
12	14/09/2016	Review and examples

CE3005/CPE302 – Part II

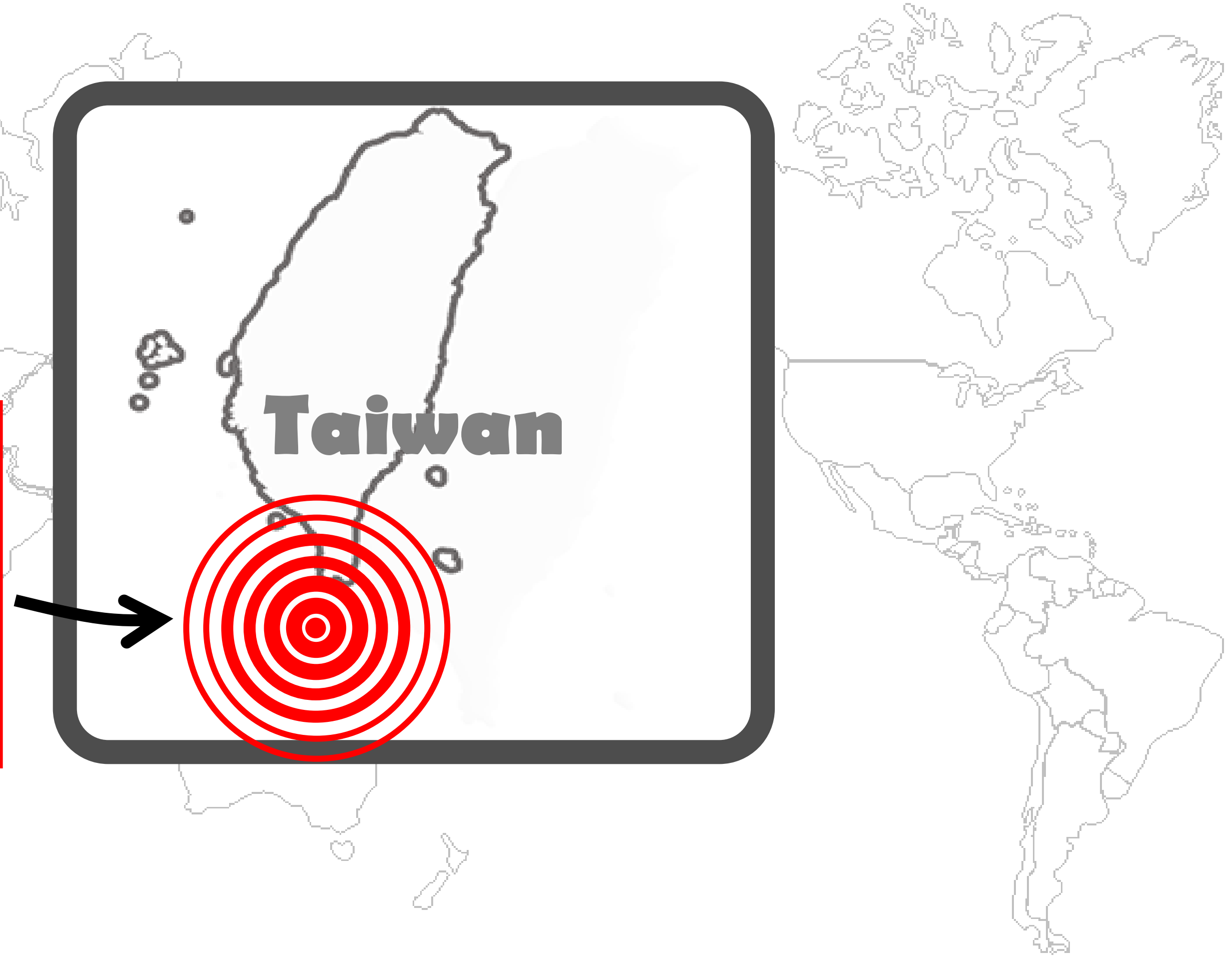
- **Covering Higher-Level Layers**
  - Applications
  - TCP protocol
  - IP protocol (main emphasis)
  - Routing process

Physical Layer: Network Resilience

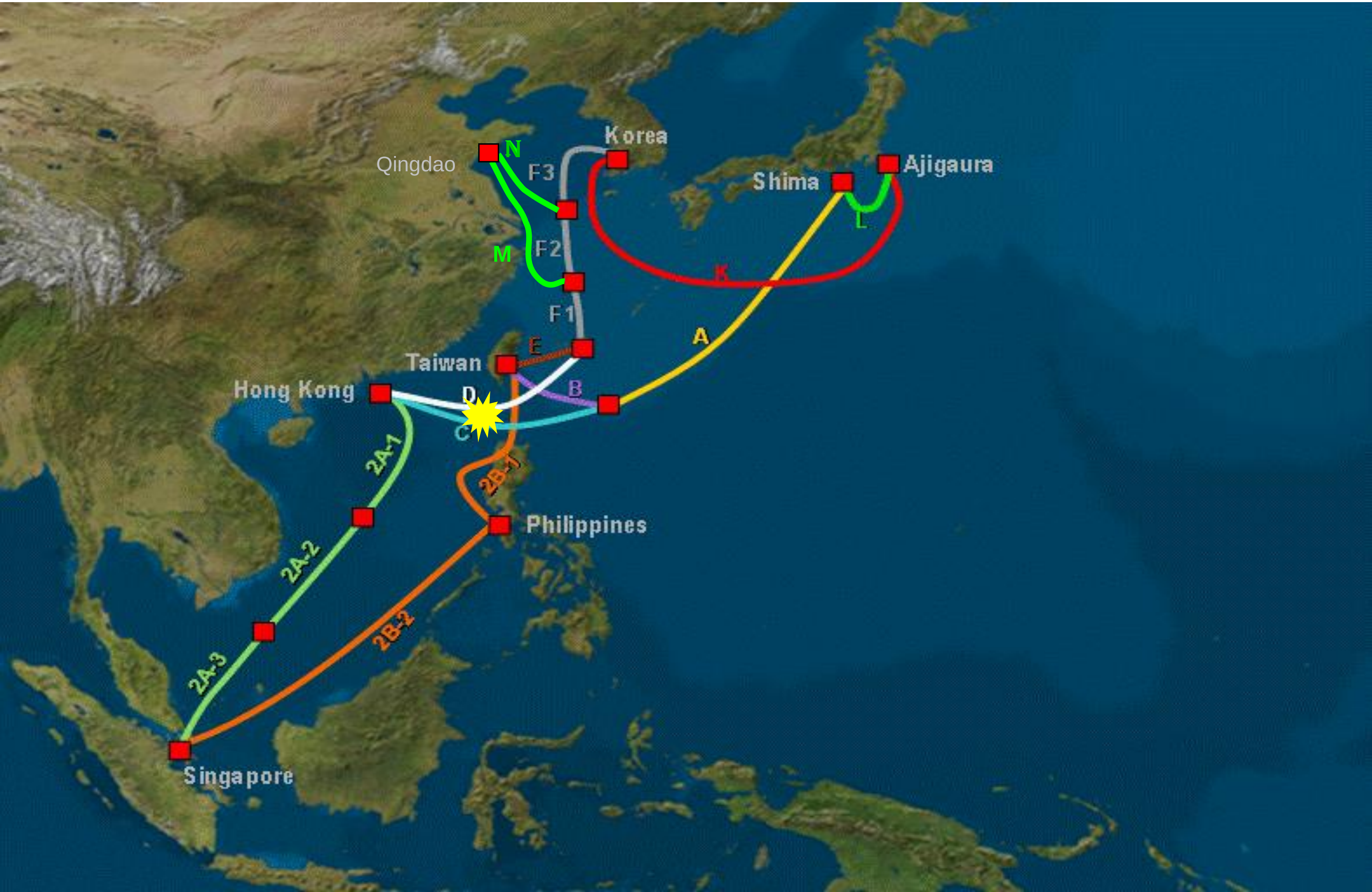
ASIA COVERAGE

GMT 12:26:01, 26 December 2006

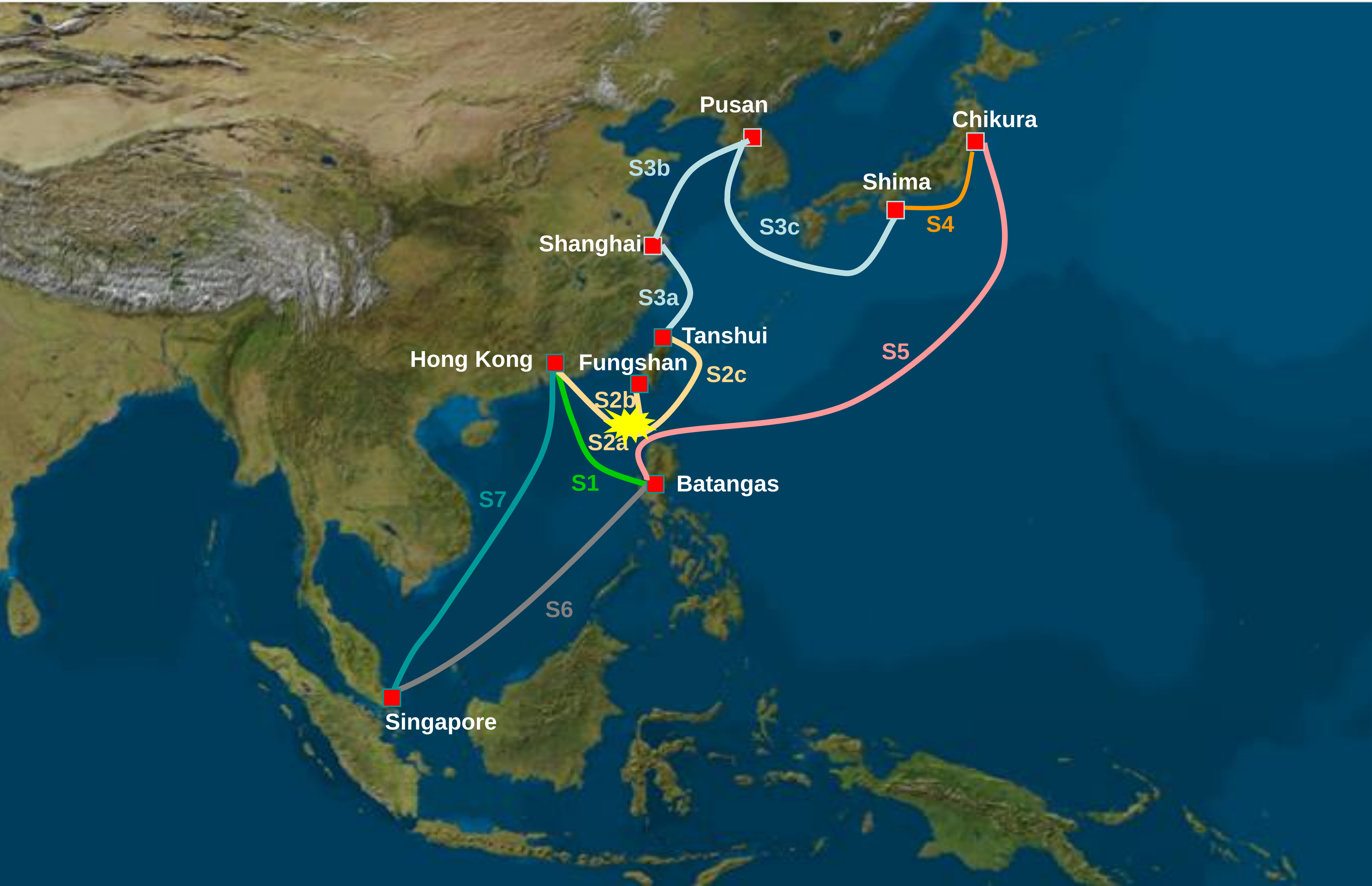
- **7.1** magnitude quake
- Multiple aftershocks
- **6** cable systems effected



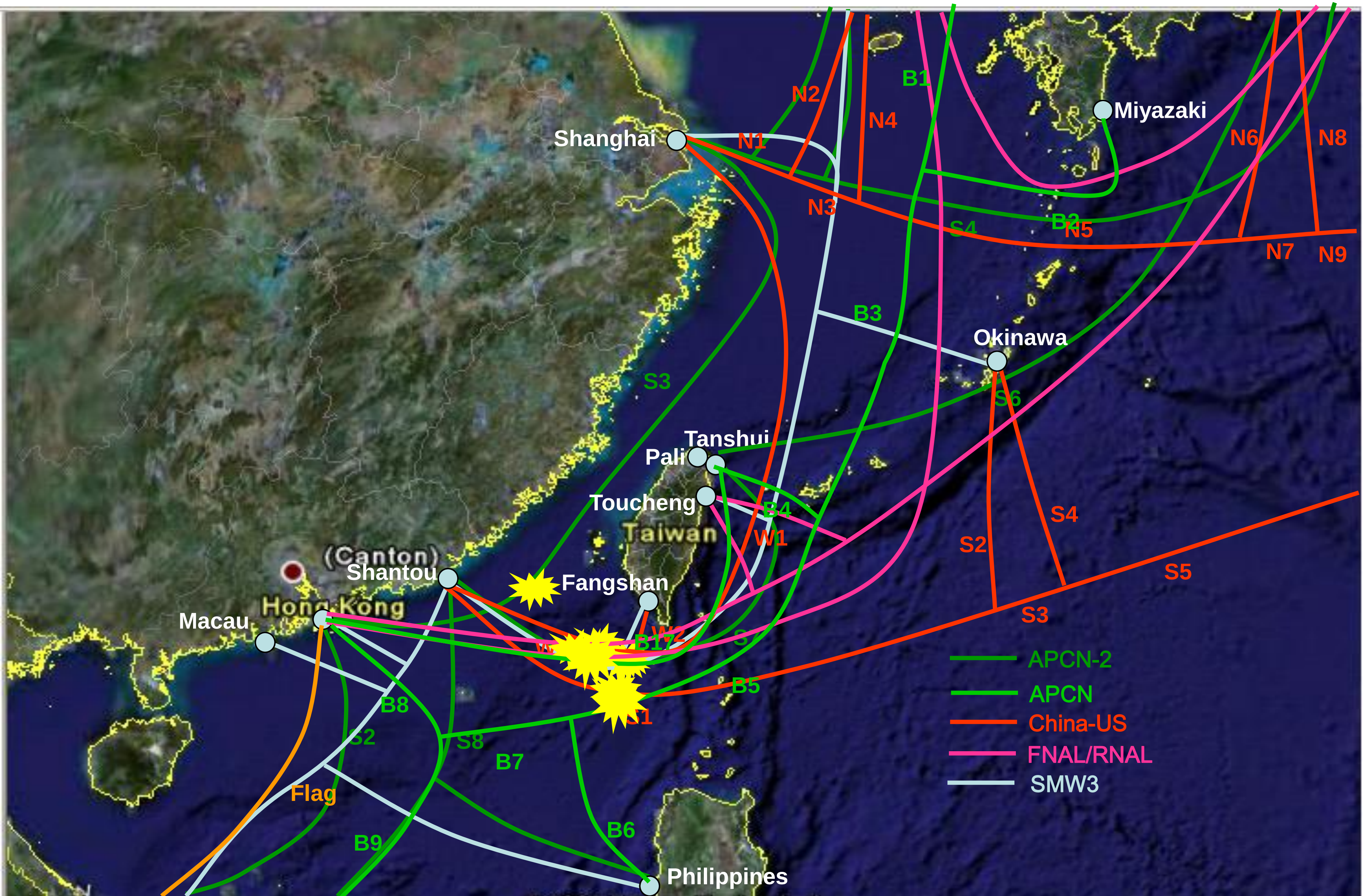
EAC Cable Network



C2C Cable Network



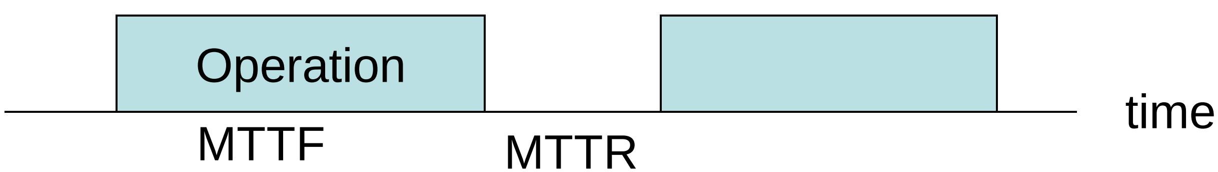
Other Cable Network



Network Reliability

- **Probability that a network performs satisfactorily over a period of time**
- **Parameters:**
  - Mean Time Between Failures(MTBF)
  - Mean Time to Repair(MTTR)
  - Mean Time to Failure (MTBF)

MTBF = MTTF + MTTR



Link Failure Probability

- **Link Failure Probability: percentage of time during which the link is dysfunctional**
- **Link Availability: percentage of time during which the link is functional**

Availability %	Downtime per year	Downtime per month*	Downtime per week
90% ("one nine")	36.5 days	72 hours	16.8 hours
95%	18.25 days	36 hours	8.4 hours
97%	10.96 days	21.6 hours	5.04 hours
98%	7.30 days	14.4 hours	3.36 hours
99% ("two nines")	3.65 days	7.20 hours	1.68 hours
99.5%	1.83 days	3.60 hours	50.4 minutes
99.8%	17.52 hours	86.23 minutes	20.16 minutes
99.9% ("three nines")	8.76 hours	43.8 minutes	10.1 minutes
99.95%	4.38 hours	21.56 minutes	5.04 minutes
99.99% ("four nines")	52.56 minutes	4.32 minutes	1.01 minutes
99.999% ("five nines")	5.26 minutes	25.9 seconds	6.05 seconds
99.9999% ("six nines")	31.5 seconds	2.59 seconds	0.605 seconds
99.99999% ("seven nines")	3.15 seconds	0.259 seconds	0.0605 seconds

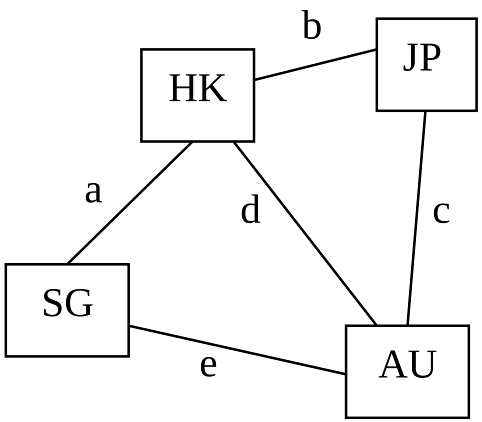
- **r_i : Probability link "i" is available, ie not broken**
- **b_i : Probability link "i" is broken**
- **$r_i = 1 - b_i$**

Network Resilience Issues

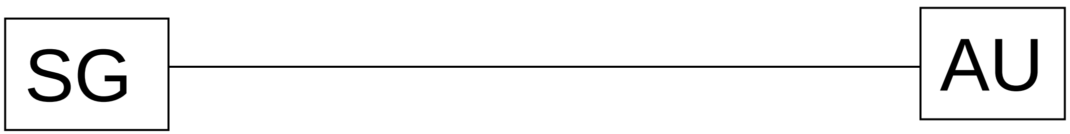
- What's the probability of a link failure ?
- Are there alternative paths?
- Is there a single point of failure ?
- What is the probability for two nodes to stay connected in a network?

Network Resilience

- **A measure of Network Fault Tolerance**
- **Express in terms of probability that the network remain connected.**
- **Assumptions**
  – The probability of link breaks are independent of each other.



Network Availability: Single Link



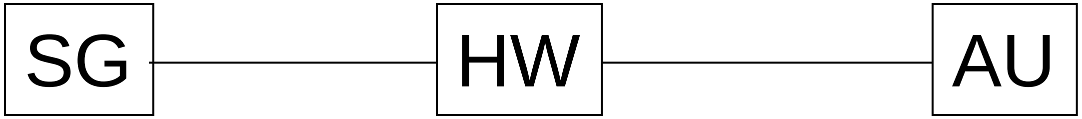
Given that the probability of a break is 0.05,

Link Break: $b_{SG\text{-}AU} = 0.05$

Link Avail: $r_{SG\text{-}AU} = 1-0.05$

$= 0.95$

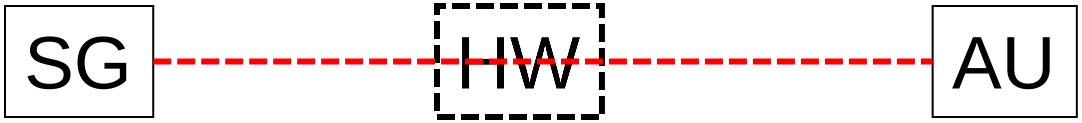
Network Availability: Series



Given that the probability of a break is 0.05, Prob that SG cannot communicate with AU

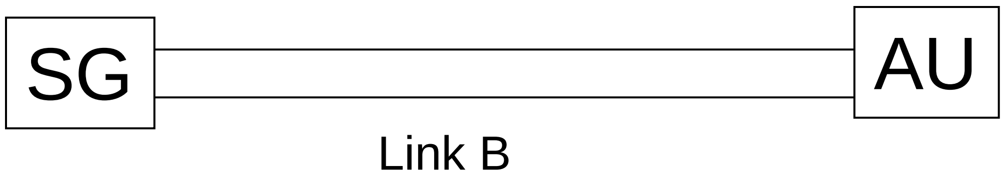
$r_{SG\text{-}AU}$ =Pr [**both links survive**]
= $r_{SG\text{-}HW} * r_{HW\text{-}AU}$
= (1-0.05)*(1-0.05)
=0.9025

$b_{P(SG\text{-}HW\text{-}AU)}$ = 1-0.9025
= 0.0975



$b_{P(SG\text{-}HW\text{-}AU)}$ = 0.0975

Network Availability: Parallel



Given that the probability of a break is 0.05,
What is the probability that SG is isolated from AU ?

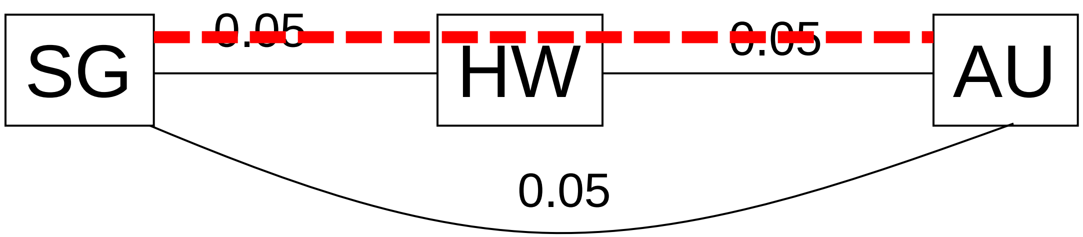
Prob(break) = **Pr[both links break]**

$= b_A * b_B$

$= 0.05 * 0.05 = 0.0025$

$b_{P(SG\text{-}AU)} = 0.0025$

Hybrid Graphs: Path-Based Approach



Given that the probability of a break is 0.05, Calculate the Prob that SG is isolated from AU.

$$\begin{aligned} r_{P(SG\text{-}HW\text{-}AU)} &= r_{SG\text{-}HW} * r_{HW\text{-}AU} \\ &= (1-0.05)*(1-0.05) \\ &= 0.9025 \end{aligned}$$

$$\begin{aligned} b_{P(SG\text{-}HW\text{-}AU)} &= 1- r_{P(SG\text{-}HW\text{-}AU)} \\ &= 1-0.9024 \\ &= 0.0975 \end{aligned}$$

$$\begin{aligned} \text{Prob. SG Disconnected from AU} &= b_{P(SG\text{-}HW\text{-}AU)} * b_{P(SG\text{-}AU)} \\ &= 0975 * 0.05 \\ &= 0.045125 \end{aligned}$$

NANYANG TECHNOLOGICAL UNIVERSITY

Rules for Network Availability

- **Link in series**
  - Calculate that probability that all links in the series are working
- **Link in parallel**
  - Calculate the probability that all links are broken.
- **Combination of series and parallel**
  - Decompose them into paths
  - Calculate network availability using path-based approach

Learning Objectives

- **Layered Network Architecture**
  - Why layering?
  - OSI model and its functions
  - TCP/IP model and its functions
  - Mapping between OSI and TCP/IP Models
- **Physical Layer Resilience**
  - Definition of link availability and calculation
  - Calculation of network availability

Supplementary Materials

Physical Layer

- **Provides physical interface for transmission of information**
- **Defines rules by which bits are passed from one system to another on a physical communication medium**
- **Covers all – mechanical, electrical, functional and procedural – aspects for physical communication**
- **Such characteristics as voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, physical connectors, and other similar attributes are defined by physical layer specifications**

Data Link Layer

- Data link layer attempts to provide reliable communication over the physical layer interface
- Breaks the outgoing data into frames and reassemble the received frames
- Create and detect frame boundaries
- Handle errors by implementing an acknowledgement and retransmission scheme
- Implement flow control
- Supports points-to-point as well as broadcast communication
- Supports simplex, half-duplex or full-duplex communication

Network Layer

- Implements routing of frames (packets) through the network
- Defines the most optimum path the packet should take from the source to the destination
- Defines logical addressing so that any endpoint can be identified
- Handles congestion in the network
- Facilitates interconnection between heterogeneous networks (Internetworking)
- The network layer also defines how to fragment a packet into smaller packets to accommodate different media

Transport Layer

- Purpose of this layer is to provide a reliable mechanism for the exchange of data between two processes in different computers
- Ensures that the data units are delivered error free
- Ensures that data units are delivered in sequence
- Ensures that there is no loss or duplication of data units
- Provides connectionless or connection oriented service
- Provides for the connection management
- Multiplex multiple connection over a single channel

Session Layer

- Provides mechanism for controlling the dialogue between the two end systems. It defines how to start, control and end conversations (called sessions) between applications
- Requests for a logical connection to be established on an end-user's request
- Any necessary log-on or password validation is also handled by this layer
- Session layer is also responsible for terminating the connection
- This layer provides services like dialogue discipline which can be full duplex or half duplex
- Session layer can also provide check-pointing mechanism such that if a failure of some sort occurs between checkpoints, all data can be retransmitted from the last checkpoint

Presentation Layer

- **Presentation layer defines the format in which the data is to be exchanged between the two communicating entities**
- **Also handles data compression and data encryption (cryptography)**

NANYANG TECHNOLOGICAL UNIVERSITY

Application Layer

- **Application layer interacts with application programs and is the highest level of OSI model**
- **Application layer contains management functions to support distributed applications**
- **Examples of application layer are applications such as file transfer, electronic mail, remote login etc**