École Pour l'Informatique et les Techniques Avancées – EPITA

BSc L1 – 27 April 2024

Course: Introduction to Computer Networks

Course instructor: M Salman Nadeem

mohammad-salman.nadeem@epita.fr

Introduction to Computer Networks

Course schedule (tentative)

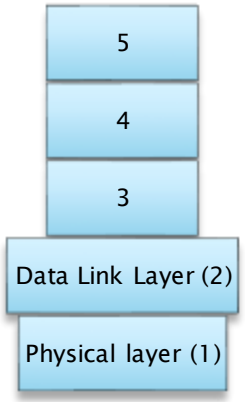
Date & Time	No.	Topics	Duration (hours)
Fri 19/04/24 – 10:00–13:00	1	Primer, Network protocols, types, topology, architecture	3
Fri 26/04/24 – 10:00–13:00	2	Network models, TCP/IP model, Packet switching	3
Sat 27/04/24 – 10:00–13:00	3	Physical Layer (Function, Signals, Modulation, Multiplexing, Transmission media & Hardware, Optical networks)	3
Sat 27/04/24 – 14:00–17:00	**4**	**Data Link Layer (Function, Framing, Protocols, Flow control, Access control, Error correction, Hardware)**	**3**
Fri 03/05/24 – 14:30–17:30	5	Network Layer (Function, IP addressing and subnets)	3
Sat 04/05/24 – 10:00–13:00	6	Network Layer (Routing algorithms and protocols), Internet Control Message Protocol	3
Fri 17/05/24 – 14:00–17:00	7	Network Layer (IGP & EGP), Autonomous System, Border Gateway Protocol	3
Fri 18/05/24 – 14:00–17:00	8	Transport Layer (Function, Flow and congestion controls, Protocols)	3
Fri 24/05/24 – 10:00–13:00	9	Application Layer (Function, Protocols)	3

Lecture 4 Outline

- Data Link Layer (TCP/IP)
  - Functions
  - Framing
  - MAC Address
  - ARP
  - Class exercise 6

- Data Link Layer (TCP/IP)
  - Flow Control
  - Access control
  - Error detection & correction
  - Hardware
  - Class exercise 7

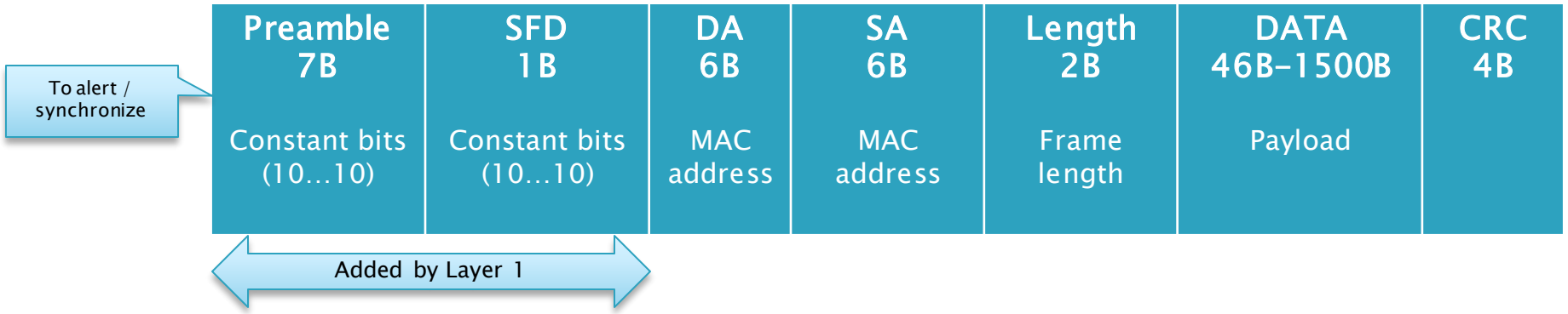
Data Link Layer (Function)



- Layer-2 of TCP/IP model
  -> also known as link layer
- Primary function is **hop-to-hop data transfer** using **Frames**
- Performs:
  - Flow control by regulating data between two nodes
  - Access control (CSMA/CD, Aloha, Token) by regulating access to the shared physical medium by multiple nodes
  - Error detection (using Parity, Checksum, CRC) and correction (using Hamming codes)

Framing

- Data is divided into smaller units called frames that contains:
  - Header (including source/destination addresses)
  - Trailer (including error detection and correction codes)
  - Ethernet Frame format (IEEE 802.3):



- Types of Ethernet:
  - 10 Base 2 – Thin, 10 Base 5 – Thick, …
    10 Base T – Twisted, 100 Base FX – Fiber optic, …

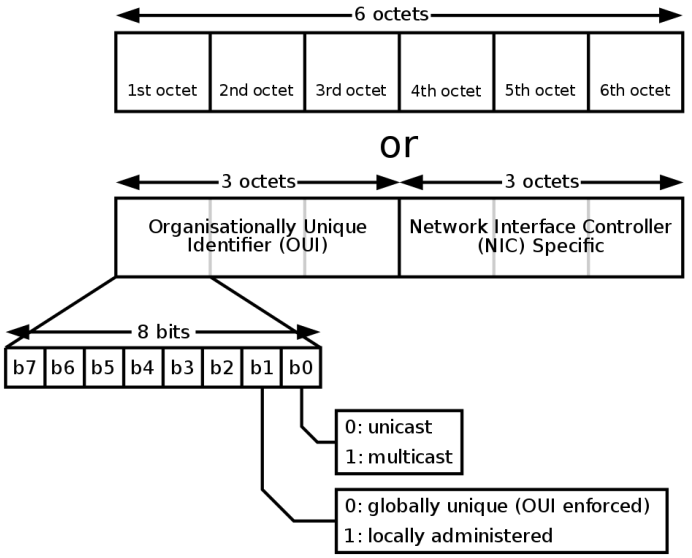
Framing protocols

- Point-to-Point Protocol (PPP)
  - Commonly used protocol for establishing a direct connection between two nodes e.g., for internet connectivity over telephone lines, DSL, and other types of WAN connections
- Ethernet
  - Default protocol for local area networks (LANs)
  - It is a packet-oriented protocol that uses a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access control method

Can you find frames based on PPP protocol?

MAC Address

- Media Access Control (MAC) address (also known as Physical address) is a unique identifier assigned to a network interface controller (NIC)
  - Used in the medium access control protocol sublayer
  - Formed using numbering spaces managed by IEEE
    - Uses 6 bytes (48 bits)
  - Typically represented as six groups of two hexadecimal digits E.g., 00:50:fc:70:10:4d



https://en.wikipedia.org/wiki/MAC_address#/media/File:MAC-48_Address.svg

ARP Protocol (to discover MAC)

- Address Resolution Protocol (ARP) protocol allows getting a physical address (MAC) from logical address (IP) and vice versa
- Devices store MAC-IP bindings:
  - Switch maintains a Forwarding Table
  - Router maintains a MAC Table
  - End-devices/hosts maintains ARP cache
- This allow hosts, connected to the same LAN, to communicate without passing the gateway (the destination MAC is already present in ARP cache)

How ARP works?

- Scenario: Host A wish to talk to host B, ARP cache is empty:
  1. Host ‘A’ sends a broadcast request in order to get the host ‘B’ (192.168.0.2) MAC address
  2. Host ‘B’ receives the request, recognizes its IP address and then sends a response containing its MAC address to host ‘A’
  3. Host ‘A’ updates its ARP cache and can now communicate with host ‘B’

ARP Tables

- Two entries types:
  - Dynamic: That's the default way ARP works and correspondences are temporary stored (depending on the OS)
  - Static: In this case, the correspondence is manually registered without any duration limit
- ARP Table (router)

```
R0#show arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  165.132.9.126           -   0060.70AE.2B92  ARPA   FastEthernet0/0
Internet  165.132.9.190           -   0060.709B.7D49  ARPA   FastEthernet6/0
Internet  165.132.9.222           -   00E0.A339.846C  ARPA   FastEthernet1/0
```

- Forwarding Table (switch)

```
Switch#show mac-address-table dynamic
          Mac Address Table
-------------------------------------------

Vlan    Mac Address       Type        Ports
----    -----------       --------    -----

   1    0060.70ae.2b92    DYNAMIC      Fa0/1
```

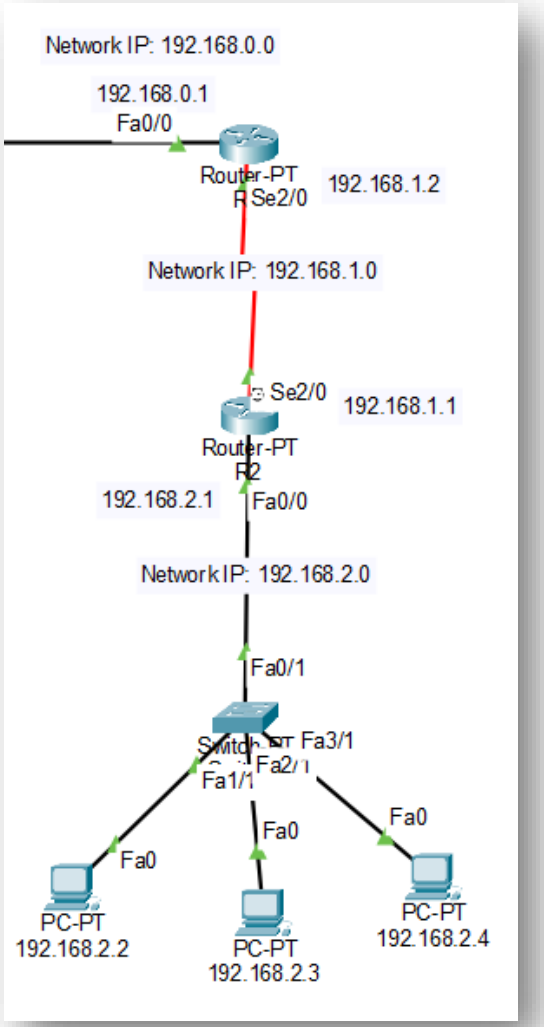
- ARP cache (host)

```
C:\>arp -a
No ARP Entries Found
C:\>arp -a
  Internet Address      Physical Address      Type
  192.168.4.1           0001.6407.7820        dynamic
```

Exercise 6: Practical work

- Using your last cisco packet tracer file:
  1. Add two new networks: 192.168.1.0 and 192.168.2.0
  2. Attach 3 PCs to 192.168.2.0 network (ref. check network diagram)
  3. Check arp table (should be empty)
  4. Initiate PING from 1 PC to another to set-up the ARP – and simulte the connection
  5. Verify ARP setup (using arp -a)

Save your cpt file with your 'First_Last name'



Deadline: See 'Teams' Assignment section

Lecture 4 Outline

- Data Link Layer (TCP/IP)
  - Functions
  - Framing
  - MAC Address
  - ARP
  - Class exercise 6

- Data Link Layer (TCP/IP)
  - Flow Control
  - Access control
  - Error detection & correction
  - Hardware
  - Class exercise 7

Data Link Layer (Flow Control)

- Flow control is used to regulate the flow of data between two (network) nodes
- There are two types of flow control:
  - **Stop-and-wait**: The sending node sends one frame at a time and waits for an acknowledgment from the receiving node before sending the next frame
  - **Sliding window**: The sending node can send multiple frames before waiting for an acknowledgment. The receiving node maintains a window of acceptable frames and sends an acknowledgment for all frames within the window

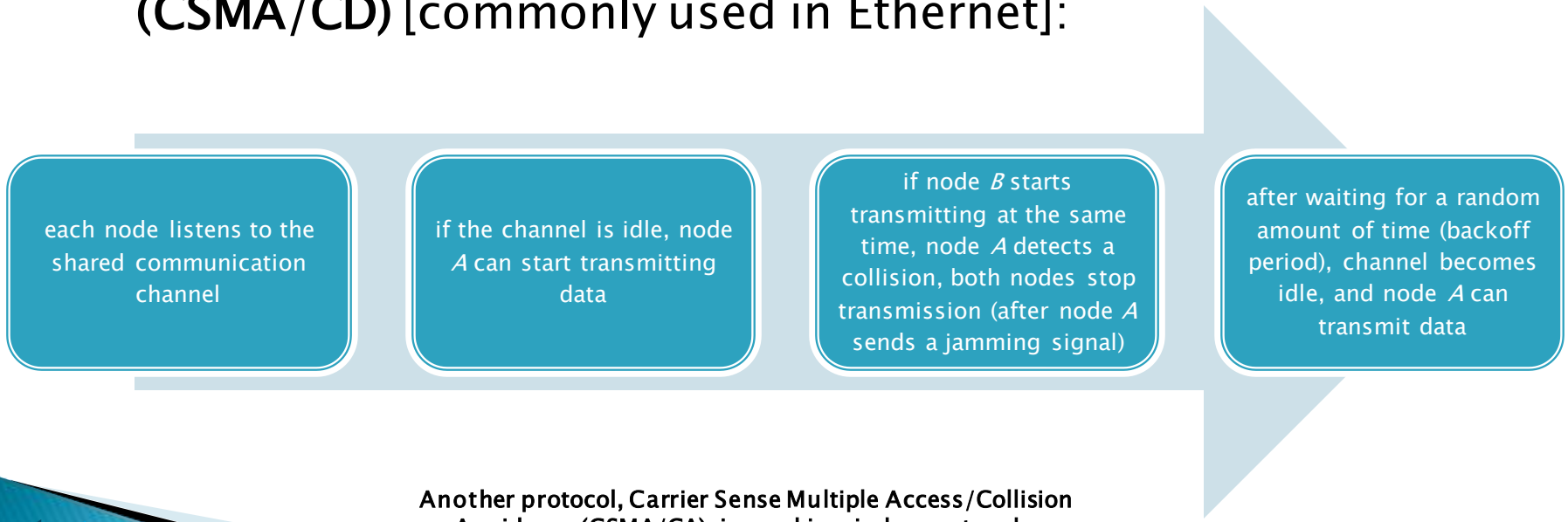
Data Link Layer (Flow Control protocols)

Stop & Wait	Sliding (Go back N)	Sliding (Selective Repeat)
1 frame per unit of time	Multiple frames per unit of time	Multiple frames per unit of time
Sender Window=1	Sender Window=$2^k - 1$	Sender Window=2^{k-1}
Receiver Window=1	Receiver Window=1	Receiver Window=2^{k-1}

Increase in efficiency and window size

Data Link Layer (Access Control)

- Access control is used to regulate access to the shared physical medium by multiple nodes e.g.
  - Token Ring: Uses a token that pass access control method, allowing nodes to transmit data only when they have the token, in local area networks (LANs), not much used now
  - **Carrier Sense Multiple Access / Collision Detection (CSMA/CD)** [commonly used in Ethernet]:



Another protocol, Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA), is used in wireless networks

Data Link Layer (Error correction)

- Error (types)
  - Single bit error
  - Burst error
- Detection (e.g., by sending extra bits)
  - Simple Parity (Even, Odd): A single (parity) bit value is used to detect single-bit errors
  - 2D Parity check: Extension of single parity by dividing data into blocks and adding 2 parity bits (calculated for each block in horizontal & vertical directions)
  - Checksum: A sum of all data bytes is calculated, and result is added as a checksum value
  - Cyclic Redundancy Check (CRC): A value is calculated using a polynomial division algorithm
- Correction using Hamming codes (by XORing parity bits)

Hardware (boxes)

Name	Function	Duplexity	Ports	Collision domain	Network type
Switch 	Connects devices together and forwards frames	Half-duplex, Full-duplex	5, 8, 16, 24, 48, or more ports	No (separates collision domains of connected segments)	LAN
Bridge 	Connects network segments together and forwards frames	Half-duplex	2 (input/output)	Yes (combines collision domains of connected segments)	LAN
Wireless Access Point 	Connects wireless devices to a wired network and forwards frames	Half-duplex, Full-duplex	1 or more	No (wireless transmissions use a different collision avoidance mechanism)	LAN

Exercise 7: Practical work

- Using your last cisco packet tracer file:
  1. Setup shared secret in local database (used by default in PPP) for CHAP (defined in RFC1994):

     R1(config)# username *R2* password *Secret*

     R2(config)# username *R1* password *Secret*

     ***Note**: Passwords (shared secret) should be identical at both ends, and credentials (username and password) must follow same case (i.e. they are case-sensitive.*
  2. Setup PPP (to change default HDLC encapsulation) in serial interfaces of both R1 and R2 :

     R?(config)# interface ?

     R?(config-if)# encapsulation ppp
  3. Configure PPP authentication method on both router interfaces to enable two-way authentication:

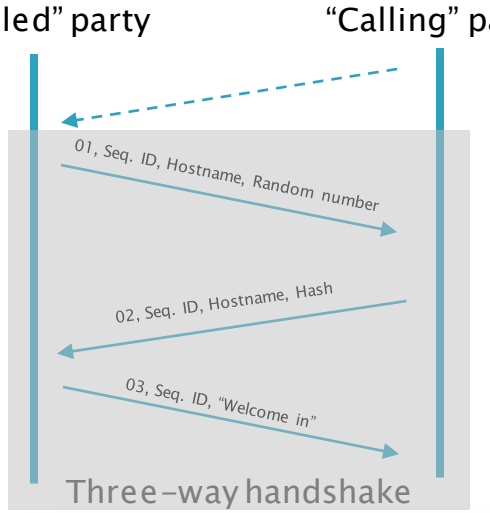
     R?(config-if)# ppp authentication chap
  4. Confirm e.g.

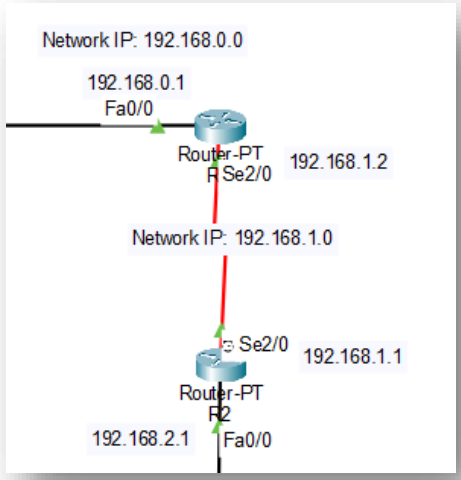
     R?#show interfaces ?

     > …Encapsulation PPP…LCP Open…

     Observe Layer 2 frames in simulation mode

Save your cpt file with your 'First_Last name'





Deadline: See 'Teams' Assignment section

Lecture 4 ends here

- Course Slides: Go to MS Teams:
  'Introduction to Computer Networks - Spring 2024 | BSc'
  -> Files section

- Send your questions by email:
  mohammad-salman.nadeem@epita.fr
  OR via direct message using MS Teams

- Thank You!