Photonic Networks: ELG 5381

Module 1: Introduction

Course Objectives

❖ Learning the principles of operation of modern optical networks

❖ Evolution of optical networks and technological state-of-the-art in the field

❖ New paradigms in optical communications

❖ Understanding the principles of operation of optical fibre and optical network elements

❖ Optical signal transmission

uOttawa

Course Evaluation

❖ **Homework – 20%**
(4 ≤ x ≤ 7 assignments)
Questions? – Contact your TA (Jungmin Hwang).

❖ **Quizzes – 40%**
(assigned at random,
~15 min, 5 ≤ y ≤ 7 assignments)

❖ **Project – 40%**

❖ **No Final Exam**

uOttawa

Course Instructor

❖ **Hussein T. Mouftah**
   Tier 1 Canada Research Chair & Distinguished Univ. Professor
   School of EECS

❖ Office: SITE 5078 (However, Virtual)

❖ Phone: +1 (613) 562-5800 (Ext. 2173)

❖ E-mail: mouftah@uottawa.ca

❖ Teaching Assistant: **Jungmin Hwang**
   jhwan091@uottawa.ca jhwan091@uottawa.ca

Course Textbooks

Optical Network Design and Planning
<u>Author:</u> Jane M. Simmons

2nd edition, *Springer*, 2015.

Optical Networks: A Practical Perspective
<u>Authors:</u> Rajiv Ramaswami, Kumar N. Sivarajan, Galen H. Sasaki

3rd edition, *Elsevier*, 2008.

uOttawa

Bright Space Accounts

❖ **All students:** If there is a technical issue with your account, please contact support@genie.uottawa.ca or call **6555**.

Outline

❖ Optical Networks

❖ Network Layers
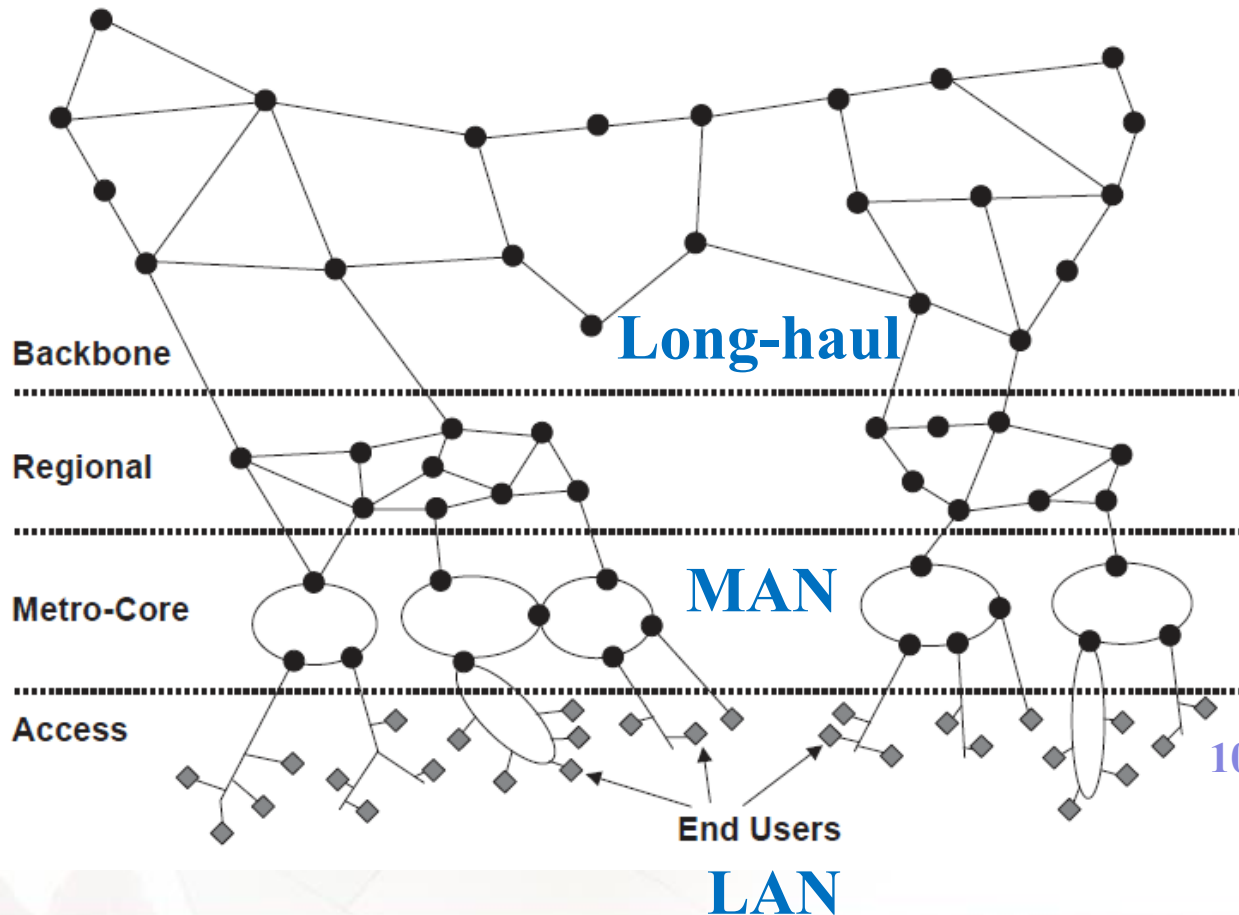
Outline

❖ Optical Networks

❖ Network Layers

uOttawa

Communication Networks

❖ Public and private;

❖ Underground, hung-up on overhead poles, terrestrial, undersea, buried beside oil and gas pipes;

❖ Local-area, access, metropolitan, long-haul

uOttawa

Networks: Geographic Hierarchy

Carries interregional traffic, spans 1,000s of km, serves 1,000,000s of customers

Long-haul

Backbone

Carries the traffic spanning multiple metro-core areas, 100s-1,000s customers, 100s-1,000s km

Regional

MAN

Metro-Core

Aggregates traffic from access networks, 1000s of customers, 10s-100s km

Access

10s-100s customers, spans a few km

End Users

LAN

Different tiers require different technologies

American and European Networks

North American
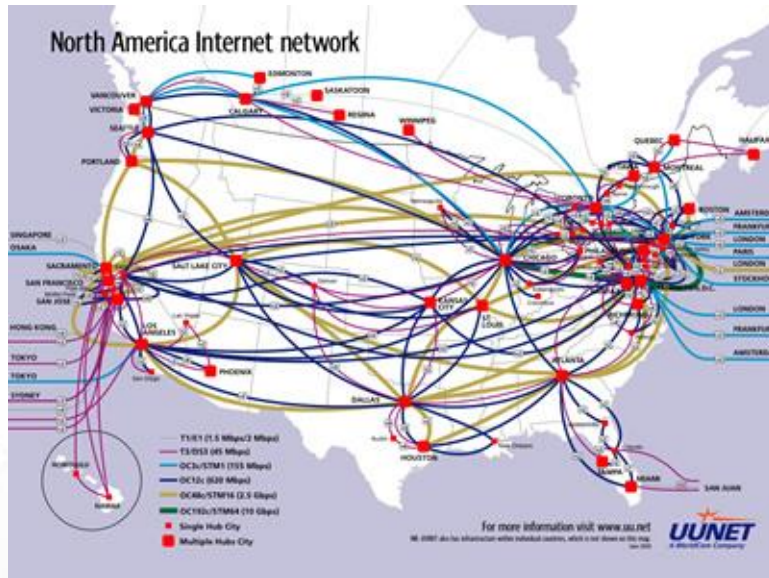
www.visualcomplexity.com

European
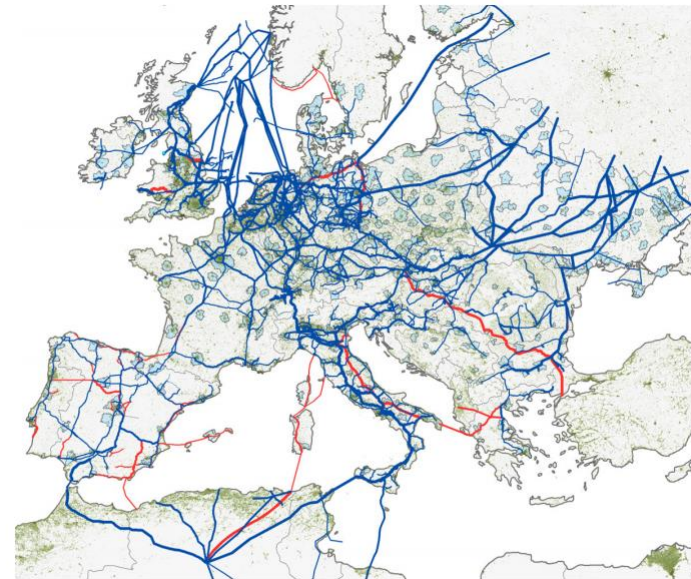
www.technologyreview.com

Undersea Network

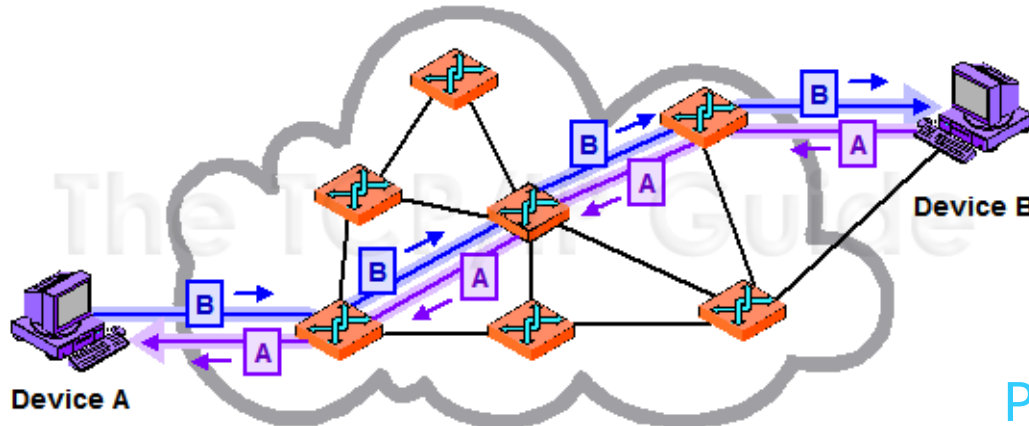http://thednetworks.com/2012/03/21/how-are-undersea-cables-laid-in-the-oceans-advantages-over-satellite/

uOttawa

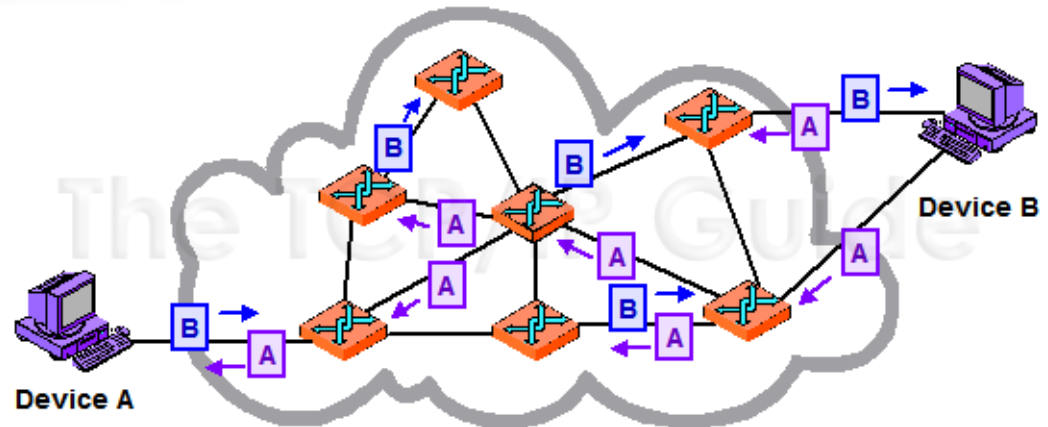**Module 1: Introduction**

Types of Network Infrasructure

Circuit-Switched

Before the communication between two devices can occur, circuit (connection) between them is established.

Packet-Switched

No circuit is set up prior to sending data. Blocks of data can take any paths around the network.
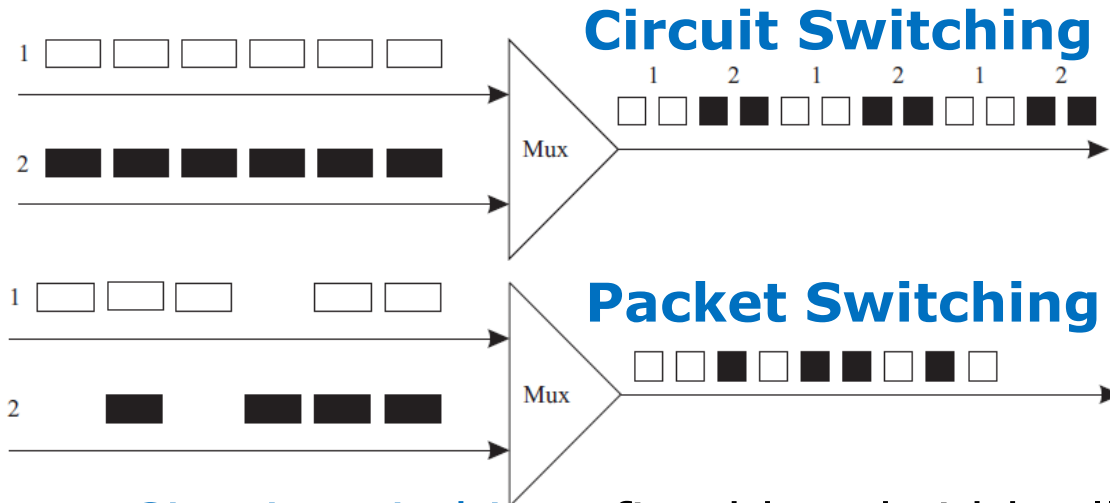
Circuit and Packet Switching

Circuit Switching

Packet Switching

- Circuit switching: fixed bandwidth allocated to the connection, guaranteed.
  E.g.: phone line, dial-up

- Packet switching: statistical switching, no guarantee, "best effort".
  E.g.: Internet Protocol (IP), it is connectionless;
  frame relay

Internet Service Today

❖ Service model changes rapidly

❖ Capacity increasing: 155 Mb/s – 2.5-100 Gb/s

❖ Availability 99.999 % (< 5 min down time per year)

❖ Fast restoration (< 50 ms)

❖ More variety of services, circuit- and packet-switched services delivered over separate overlay networks

uOttawa

Optical Networks

❖ Enormous capacity

❖ Common infrastructure for all services (fibre)

❖ Bandwidth delivery when and where needed

❖ Optical fibres: much higher bandwidth, less susceptible to various E&M interferences
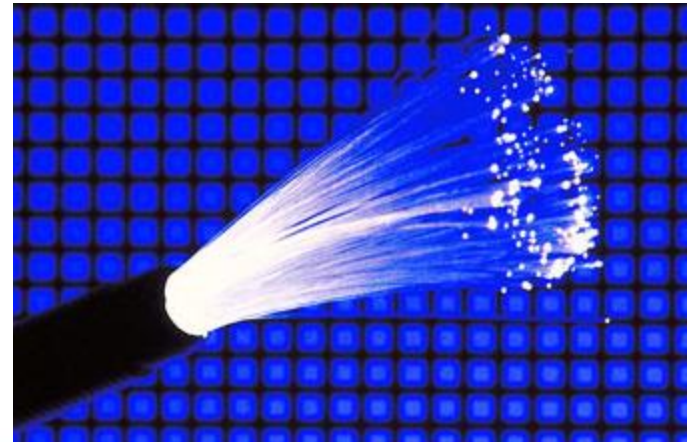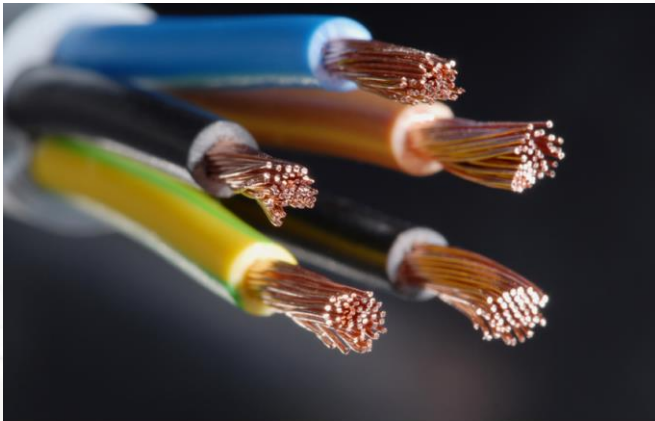
Optical Networks: Two Generations

- **1st generation**: optical fibre was used for transmission and capacity, and low bit error rate (BER). Electronics at the node must handle all the data intended for that node and all the data passed through that node.
  E.g.: SONET = Synchronous Optical Network;
  SDH = Synchronous Digital Hierarchy

- **2nd generation**: routing, switching and intelligence in optical layer. The data passing are routed through the optical domain.

uOttawa

# Second Generation Optical Networks
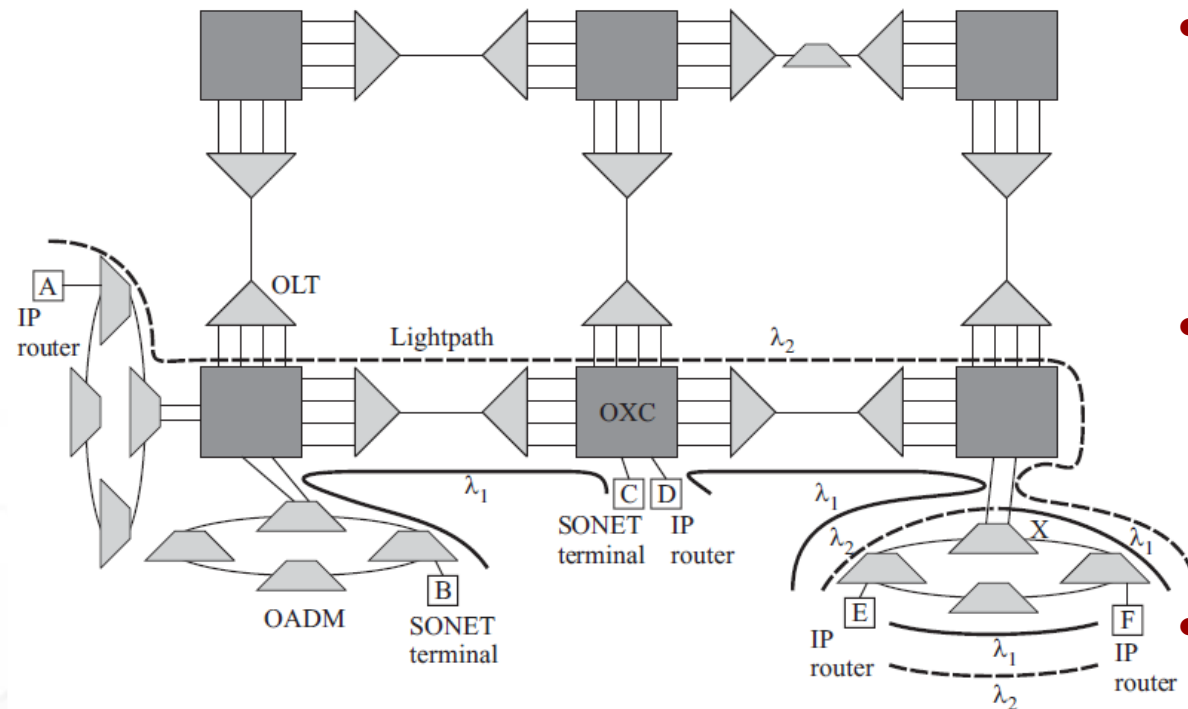
Actively Deployed

- OLT = Optical Line Terminal.
  Function: Multiplexing and de-multiplexing of optical wavelength.

- OADM = Optical Add-Drop Multiplexers.
  Function: Selective adding-dropping certain wavelength; transmitting

- OXC = Optical Cross-Connect.
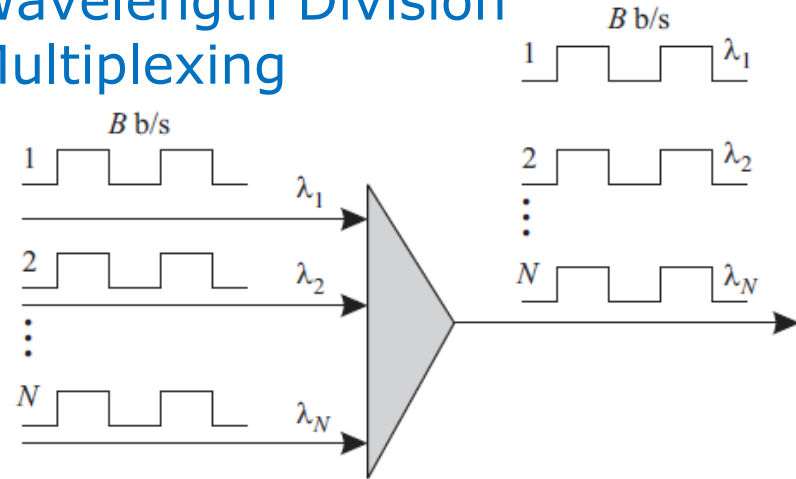 Function: same as OADM, but larger scale.

uOttawa

Multiplexing Techniques

**Time Division Multiplexing**
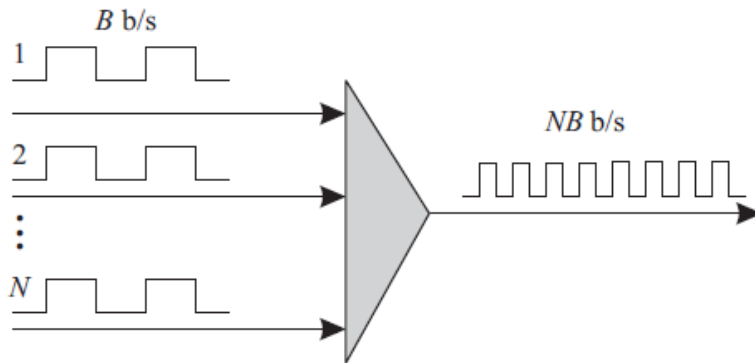
Wavelength Division Multiplexing

- ❖ TDM = Time Division Multiplexing: increasing bit rate, requires faster electronics

- ❖ WDM = Wavelength Division Multiplexing: transmitting many wavelength channels simultaneously; deployed in long-haul and undersea networks

- ❖ TDM + WDM allow to achieve capacities up to 1 Tb/s

uOttawa

Time Division Multiplexing
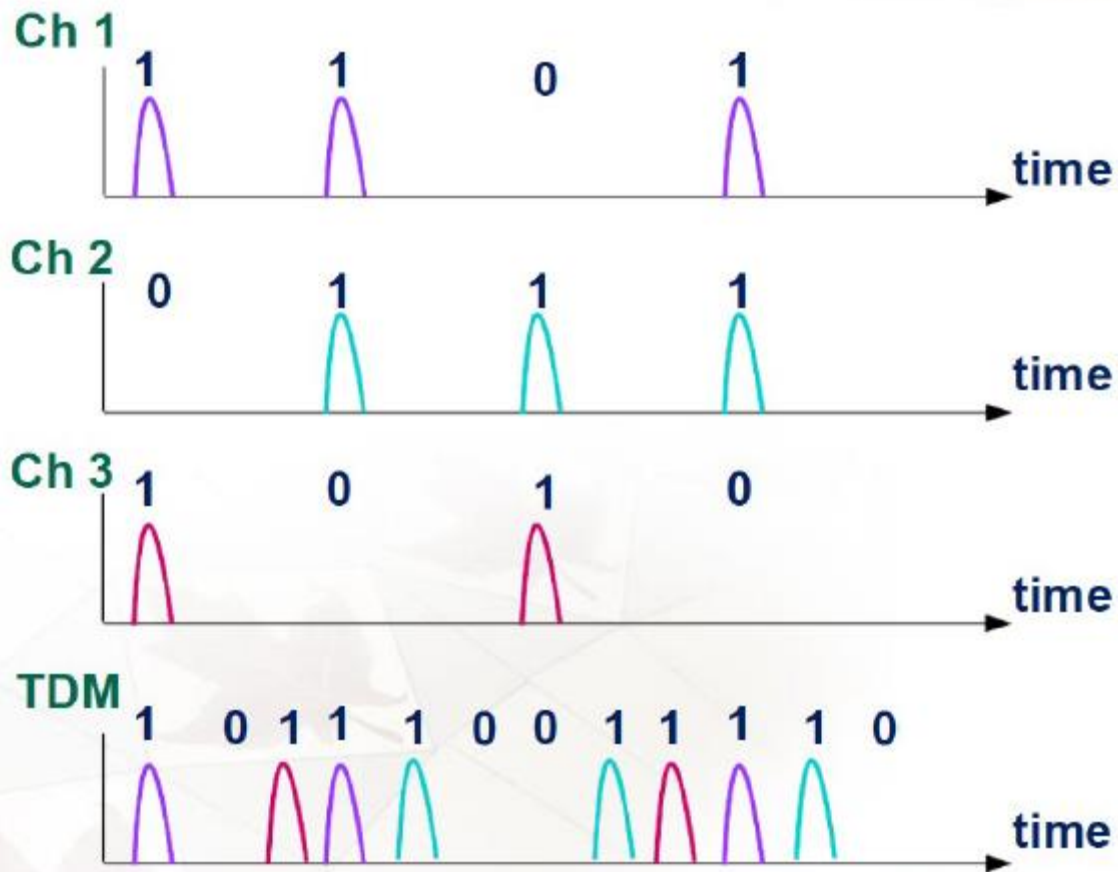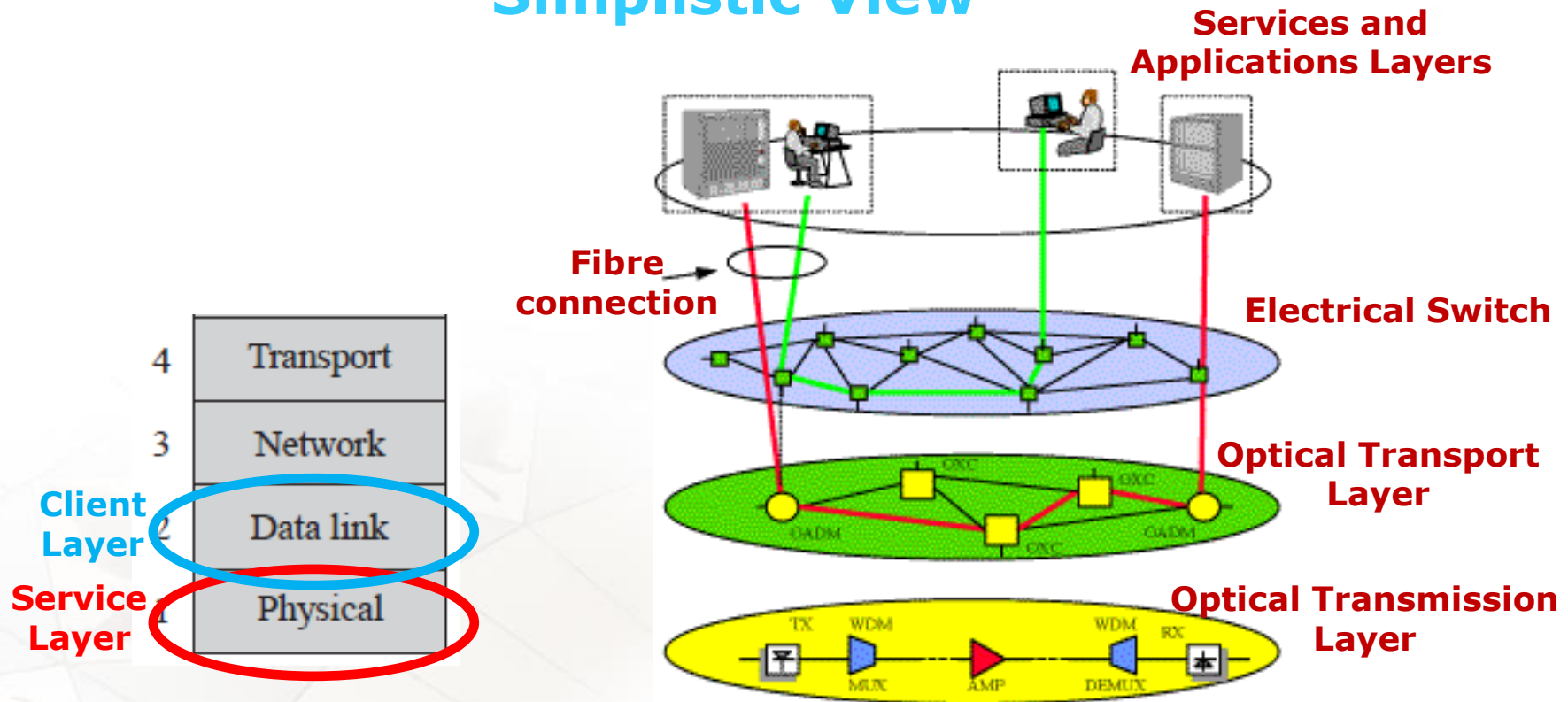
Wavelength Division Multiplexing
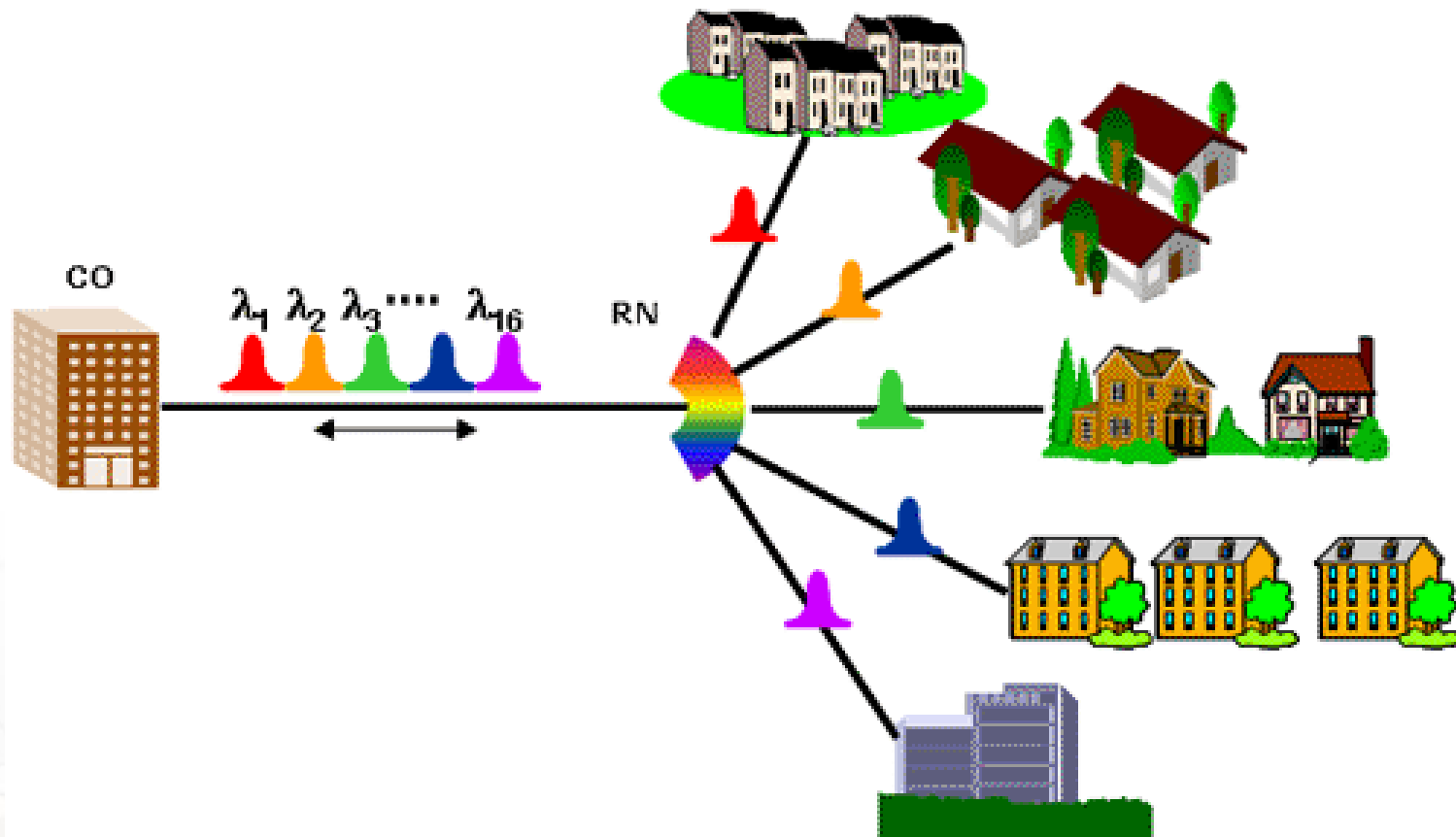
Outline

❖ Optical Networks

❖ **Network Layers**

❖ Transmission Basics

uOttawa

Network: Layered Perspective

Simplistic View

Services and Applications Layers

Fibre connection

Electrical Switch

4	Transport	
3	Network	
2	Data link	
1	Physical	

Client Layer

Service Layer

**Optical Transport Layer**

Optical Transmission Layer

Layered Network

❖ **Physical layer** – a "pipe" to the layers above.
  E.g.: optical fibre, wireless, wires, coaxial.

❖ **Data link layer** – framing, multiplexing, demultiplexing the data sent over the "pipe"
  E.g.: Ethernet, PPP (point-to-point protocol).

❖ **Network layer** – virtual circuit (VC) or datagram services to the higher layer. End-to-end routing of the message to destination.
  E.g.: Internet Protocol (IP) – provides a way to route packets in a packet-switched network. Provides simple mechanisms of network restoration.

❖ **Transport layer** – insuring end-to-end, in-sequence, error-free delivery of the messages.
  E.g.: TCP = transmission control protocol.

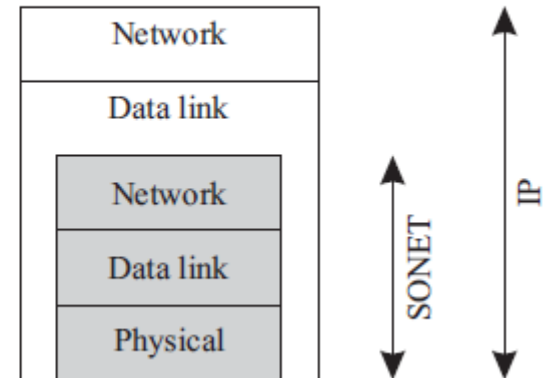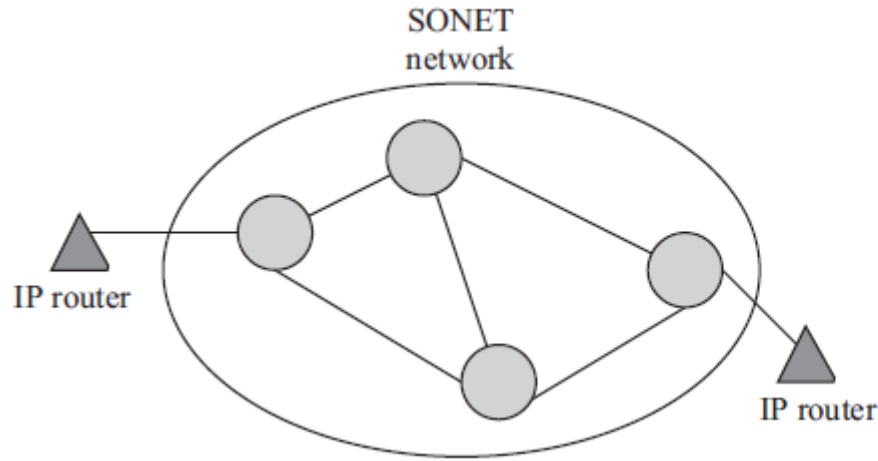|	
4	Transport
3	Network
2	Data link
1	Physical

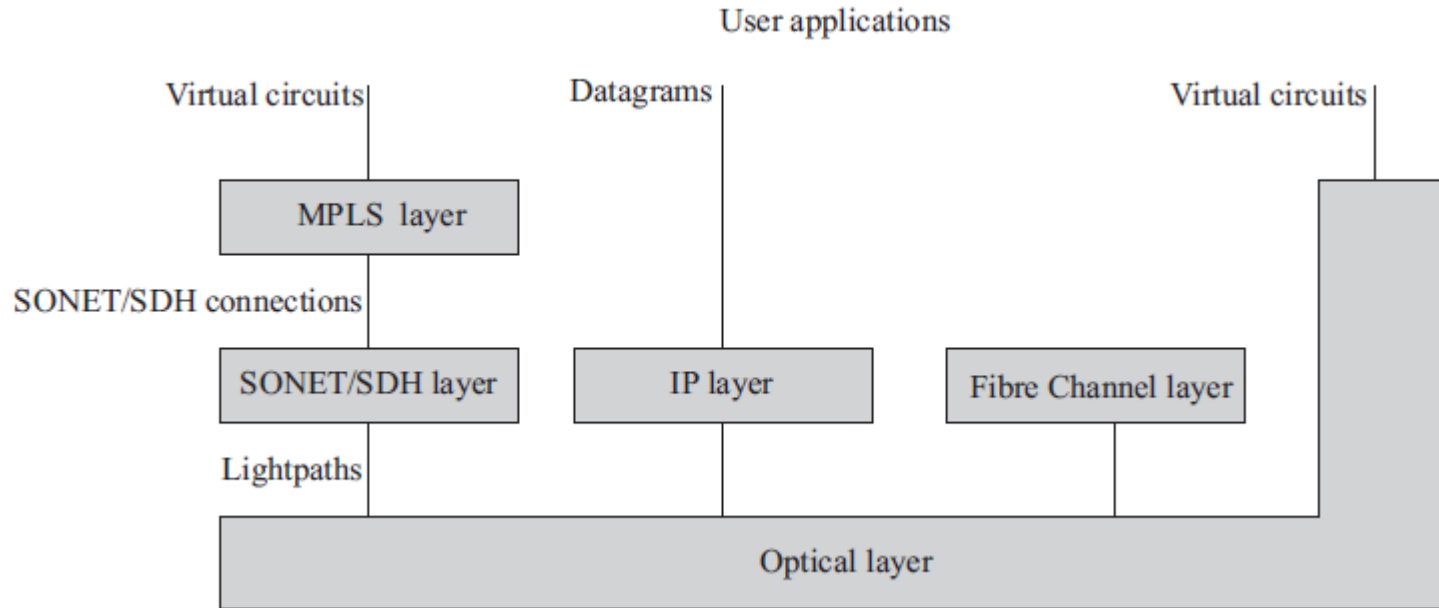uOttawa

Organizing Data Transmission
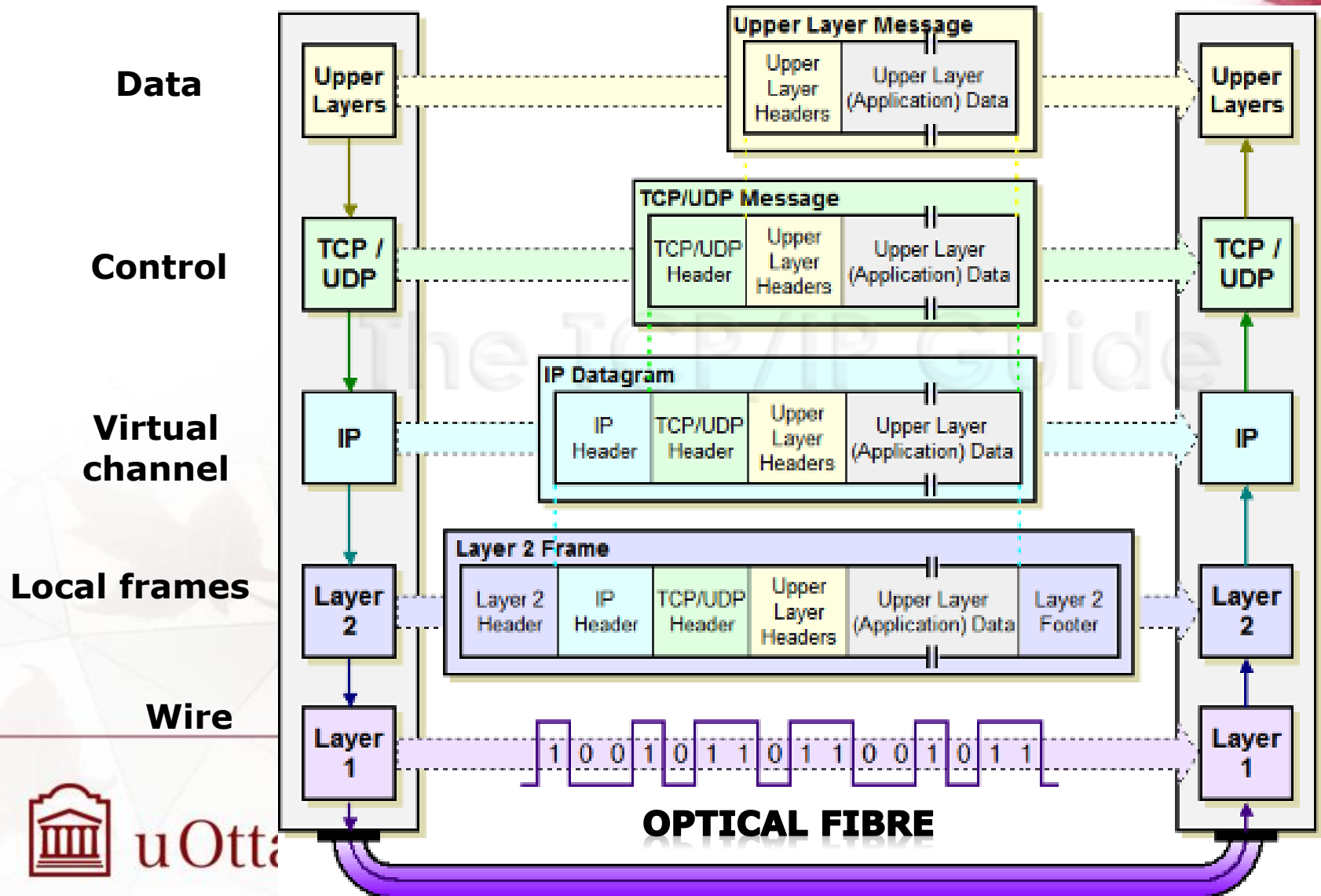
IP over SONET

- ❖ Classical layer view is simplistic.
- ❖ Realistic networks employ multiple protocol stacks
- ❖ E.g.: IP treats SONET as providing it with point-to-point link between IP routers
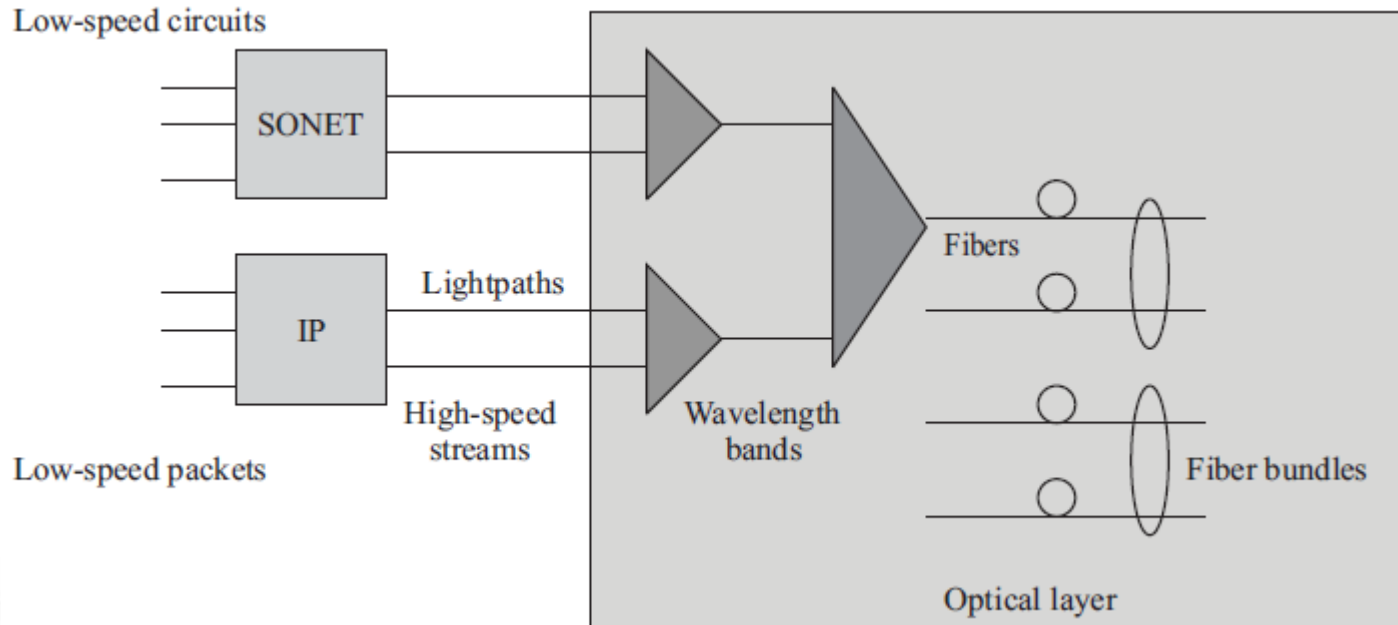- ❖ SONET itself is a network

Optical Layer

❖ Optical layer – server layer providing service to client layers.
❖ Can provide other services that may directly interface with user applications.

Multiplexing Layer Hierarchy

- ❖ Before OL, SONET was transmission layer.
- ❖ Now, SONET is built over OL.
- ❖ Functionalities of OL and SONET are similar, but at different bit rates.

Reading Material

Optical Networks: A Practical Perspective
<u>Authors:</u> Rajiv Ramaswami, Kumar N. Sivarajan, Galen H. Sasaki
3rd edition, *Elsevier*, 2008.

Chapter I: Sections 1.1-1.7

uOttawa