CSC0056: Data Communication

Lecture 01: Introduction

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NATIONAL TAIWAN NORMAL UNIVERSITY

Course information

- Instructor: Chao Wang 王超
  - cw@ntnu.edu.tw
  - Office hours: Wednesdays and Fridays, 8-10am, or by appointment
- Teaching assistant: Shang Zhong 鍾尚值
  - 60847091s@gapps.ntnu.edu.tw

- Course meetings: Mondays 9:10-12:10 in B102, Gongguan Campus
- Course website: https://wangc86.github.io/csc0056/
- Homework submission via Moodle (https://moodle.ntnu.edu.tw/)

What is this course about?

- The 2020 theme: **messaging in cloud/edge computing systems**
  - classic data communication algorithms and protocols
  - data communication systems analytics (including basic queueing theory)
  - recent advances in data communication systems (e.g. Internet-of-Things)

- This course is for junior/senior undergraduate and graduate students
- Lectures will be in English
- Bring your pen and paper to take notes!

Textbooks and other references

- Required textbook:
  - Bertsekas, Dimitri and Gallager, Robert. *Data networks (2nd edition)*. Prentice Hall, 1992. ISBN 0132009161

  ✓a wonderful exposition to data networks fundamentals!

- Others (check out the course webpage for updates):
  - Harchol-Balter, Mor. *Performance modeling and design of computer systems: queueing theory in action.* Cambridge University Press, 2013. ISBN 9781107027503.

  ✓a great reference to queueing theory and its practice!

Grading policy

- Homework 40% (submit via Moodle https://moodle.ntnu.edu.tw/)
- First Exam 20%
- Final Exam 25%
- Participation 5%
- Attendance 5%

- No late homework submission and no make-up exam

Academic integrity

本校校訓由第三任劉真校長所訂，於民國41年2月20日第27次行政會議通過。劉校長希望同學們從內心的修養到生活的實踐，都能切切實實地做到這四個字，以樹立良好的學風，進一步達到改造社會的目的。

誠 不虛偽、不欺妄。
凡事能做到始終如一、擇善固執。

正 不偏私、不枉曲。
凡事能做到光明正大，貞固剛毅。

勤 不怠惰、不因循。
凡事能做到自強不息、鍥而不捨。

樸 不奢靡、不浮華。
凡事能做到質樸無華，闇然尚絅。

- Sincerity
- Integrity
- Diligence
- Simplicity

http://archives.lib.ntnu.edu.tw/c2/c2_1.jsp

The rest of today's lecture: a tour de data communication

- To give you some flavors of what will be covered in this course

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Data networks: a quick review

Data networks

- Network: a thing that interconnects devices together

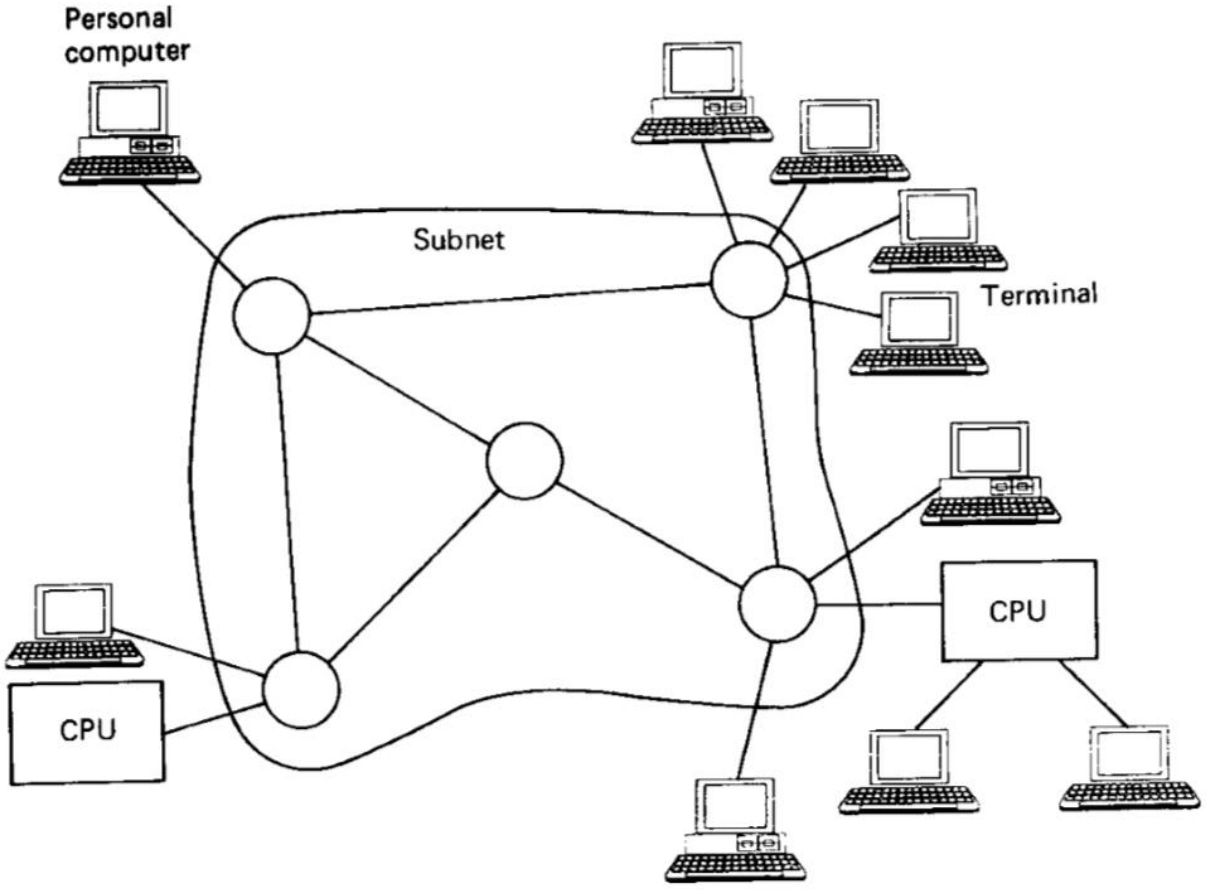


Image credit: Bertsekas, Dimitri and Gallager, Robert. *Data networks (2nd edition)*. Prentice Hall, 1992.

From point-to-point to a network of networks

- Adding intermediaries for
  - better scalability,
  - management,
  - Interoperability,
  - …

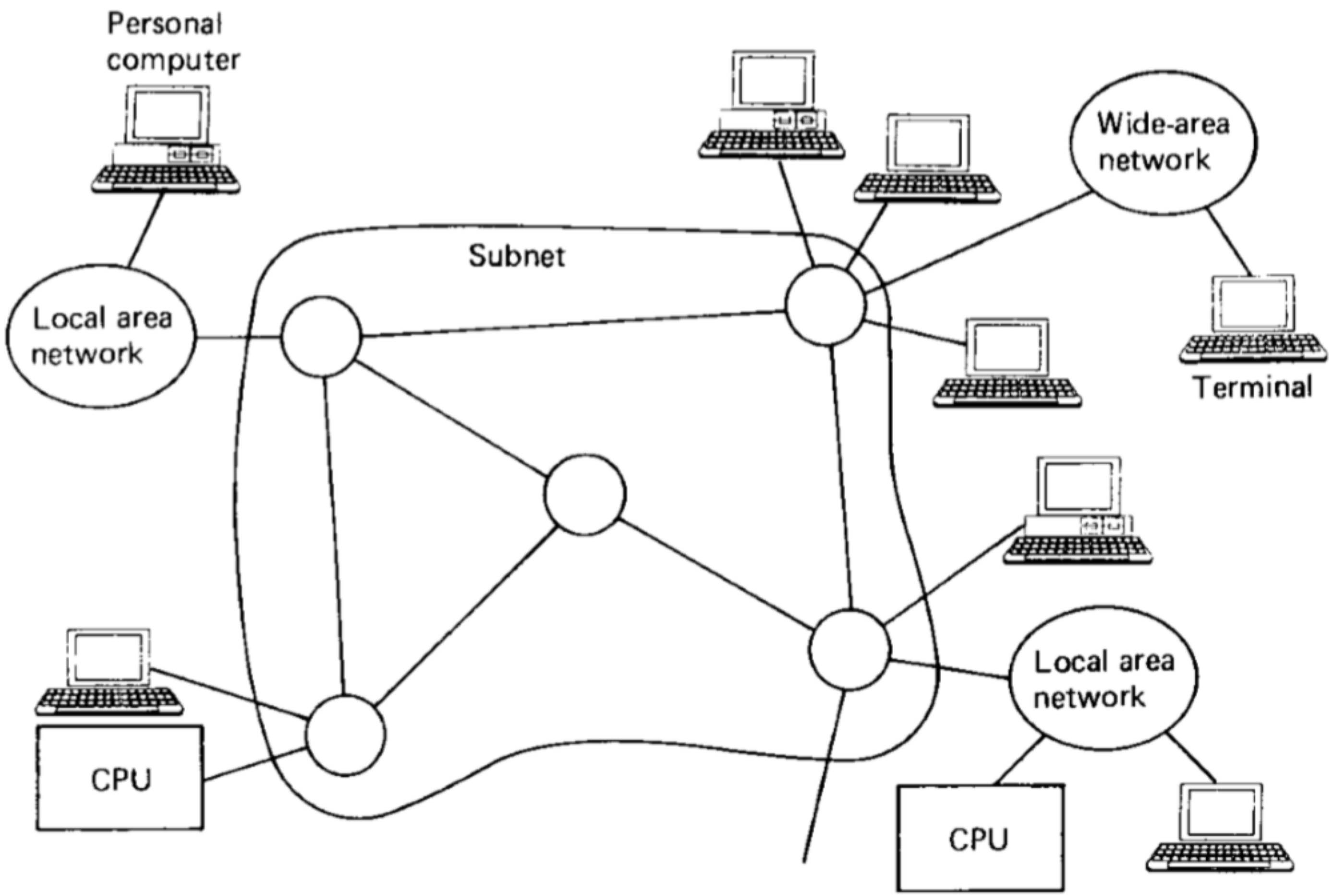
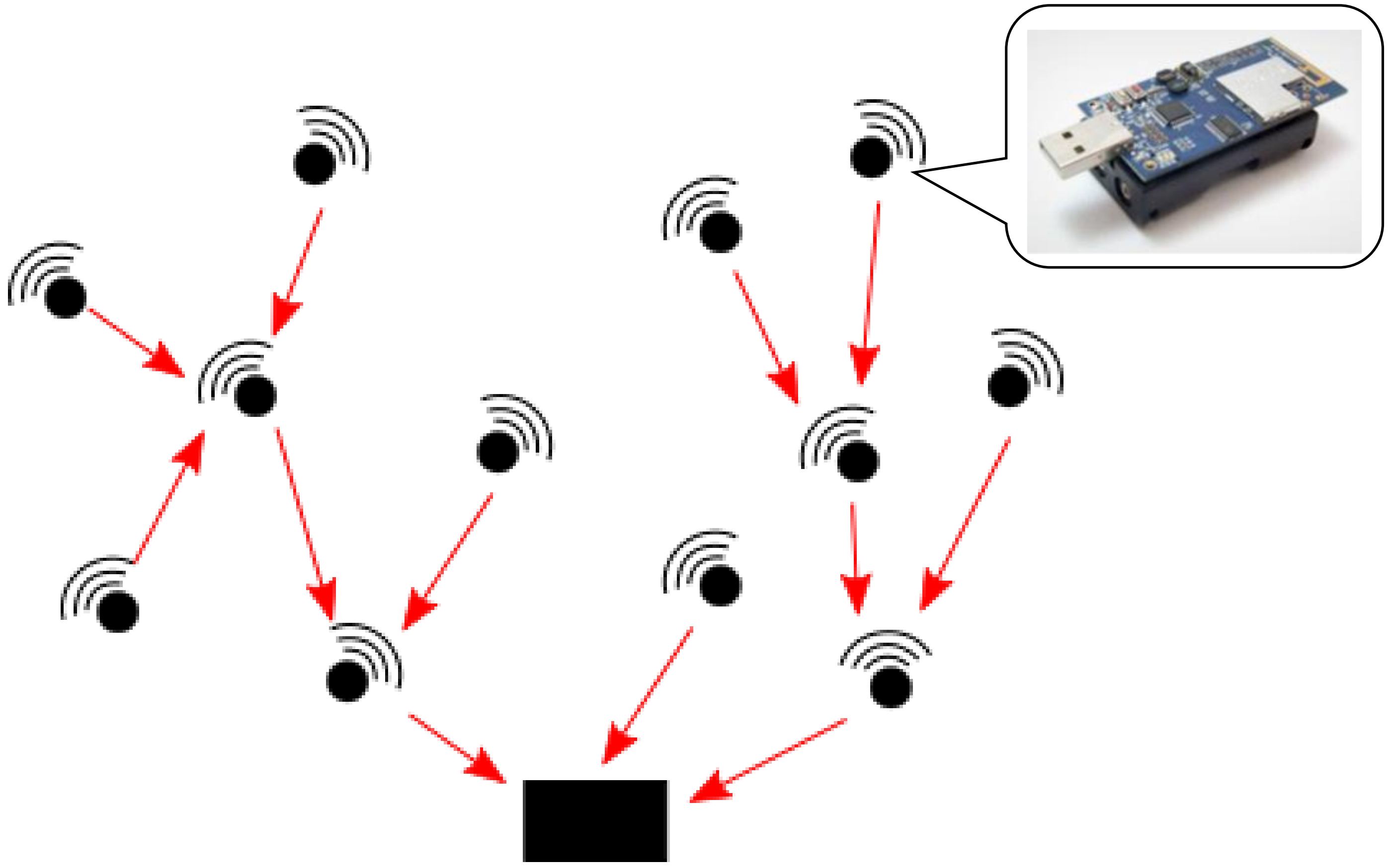


Image credit: Bertsekas, Dimitri and Gallager, Robert. *Data networks (2nd edition)*. Prentice Hall, 1992.

At the dawn of Internet of Things (IoT)

- Wireless sensor networks
  - Environment monitoring
  - Object tracking
  - Intrusion detection
  - …

https://wirelessmeshsensornetworks.wordpress.com/tag/tmote-sky/



At the dawn of IoT (cont.)

- There have been many research efforts aiming to utilize wireless sensor networks

- Attaching sensors to *things*…

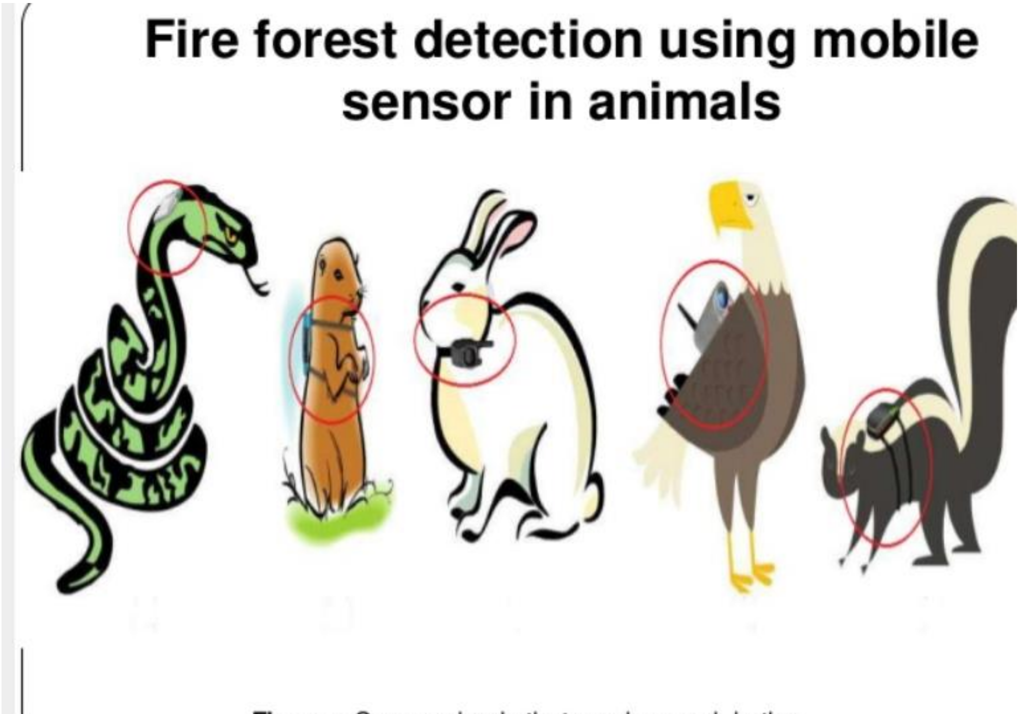
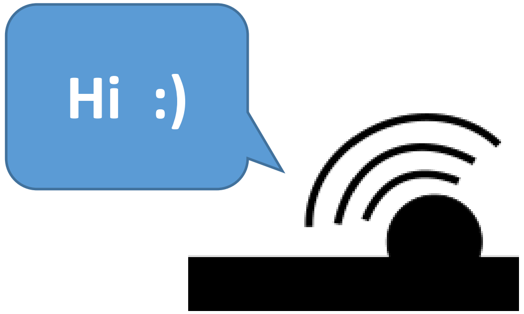


Figure : Some animals that can be used in the system

https://www.slideshare.net/mueenudheenshafaquat/wireless-sensor-networks-application-forest-fire-detection-74947510

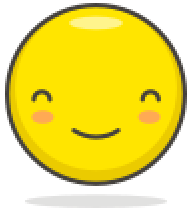
When things have there *voices*...



AIoT:
Artificial **I**ntelligence and **I**nternet **o**f **T**hings

This morning my lamp told my phone to call me and tell me that I've left my wallet at home. And it said that my wallet is *sad*.

My friend's car suggested me to take a MRT home as I was about to get off work, because it heard that there's high PM2.5 in the past hour around the factory area that I usually walked by.



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Elements of data communication

- "My friend's car **suggested** me to take a MRT home *as I was about to get off work*, because it **heard** that the factory area that I usually walked by has high PM2.5 *in the past hour*."

⇨ Data communication is about
giving and **getting** relevant information (data) in a *timely* manner

Data communication is _____

- An *essential* part of those intelligent systems that shape our lives
  - Public transportation ETA (estimation time of arrival)
  - Self-driving vehicles
  - Traffic control
  - Real-time streaming
  - Predictive maintenance
  - …

https://www.corrierecomunicazioni.it/digital-economy/smart-city/icity-rate-2017-milano-si-conferma-citta-piu-smart-d-italia/

A first look at messages and switching

- Message = a self-contained piece of data for communication
- Switching = a way to exchange messages between things
- Two general approaches for switching
  - Circuit switching
  - Packet switching
    (a.k.a. store-and-forward switching)

Circuit switching

- A classic example: a telephone network
- Each session is allocated a fixed fraction of the capacity on each link along its path
  - Dedicated resources
    - time-division multiplexing (TDM)
    - frequency-division multiplexing (FDM)
  - Fixed path
  - If capacity is used, calls are blocked

Circuit switching (cont.)

- Advantage
  - Fixed delays
  - Guaranteed continuous delivery
- Disadvantage
  - when the session is idle, circuits are *not used*
  - Inefficient for bursty traffic
    - Circuit switching usually done using a fixed rate stream (e.g., 64 kbps)

Packet switching

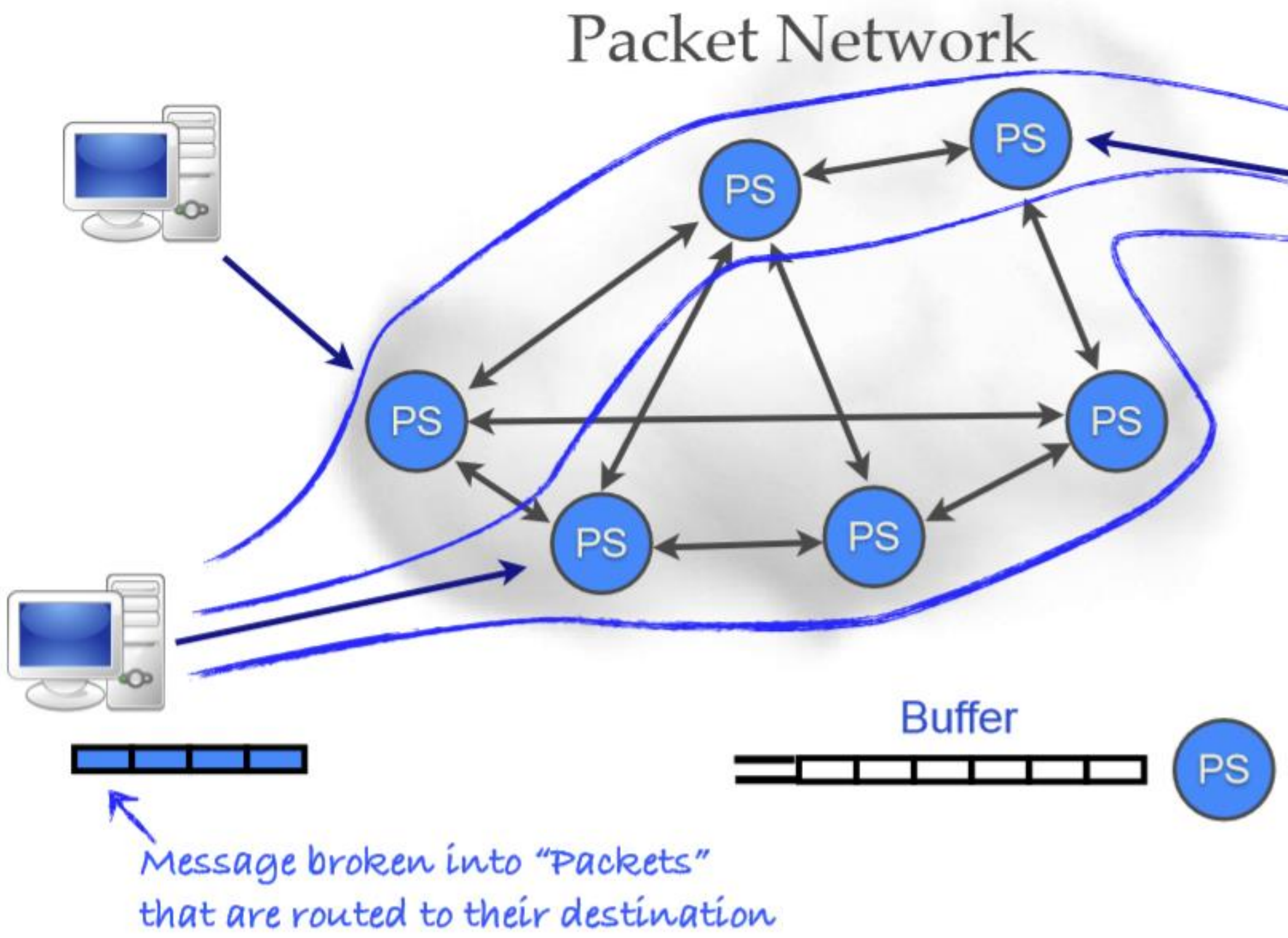


Figure borrowed from the 2014 edition of this course taught by Prof. Yao-Hua Ho

Packet switching (cont.)

- **Datagram** packet switching (or Dynamic routing)
  - Route chose on packet-by-packet basis
  - Different packets may follow different routes
  - Packets may arrive out of order at the destination
  - Example: IP (The Internet protocol)

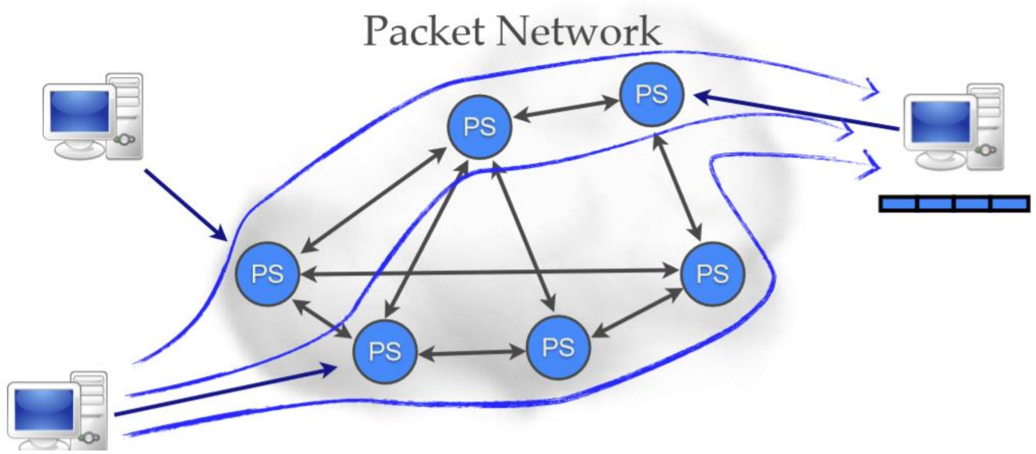
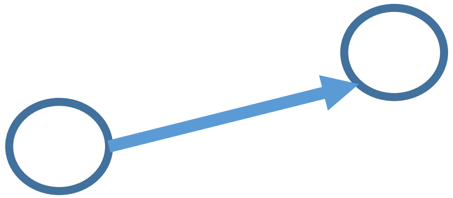


Figure borrowed from the 2014 edition of this course taught by Prof. Yao-Hua Ho

A first look at data network analytics

- Consider circuit switching on a single link:



$\overline{L}$: message lengths

λ : message arrival rate

r : allowable bit rate (example unit: bps (bits per second))

$\overline{X}$: expected message transmission time of a message

$$\overline{X} = \frac{\overline{L}}{r}$$

Link utilization = $\dfrac{\overline{X}}{1/\lambda} = \lambda\overline{X}$

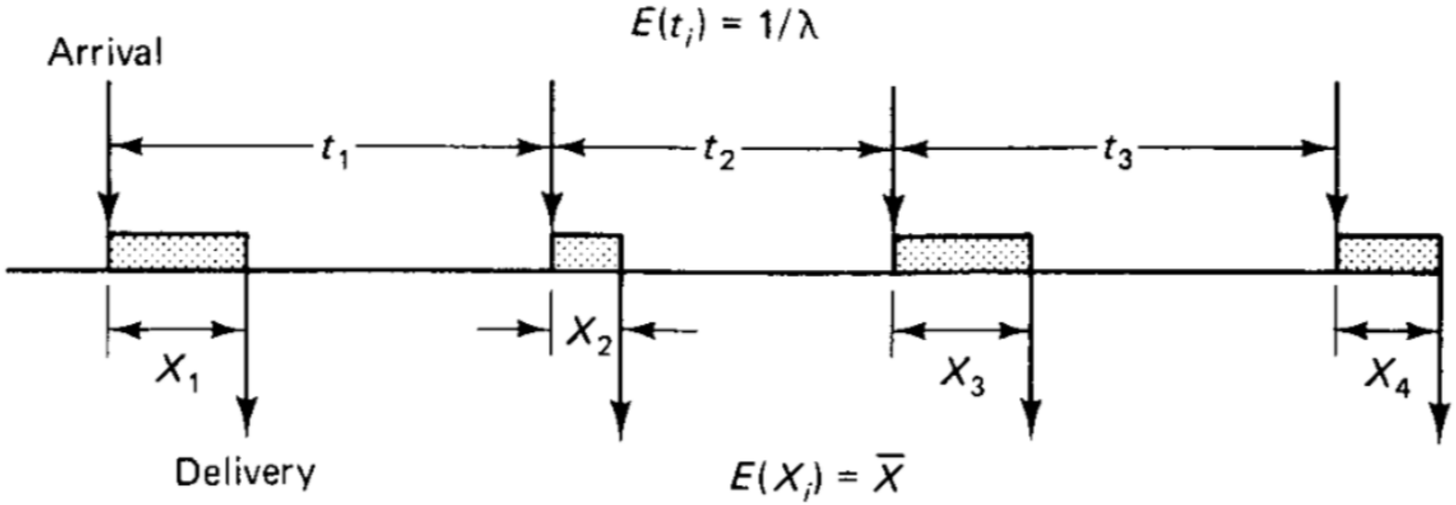


Image credit: Bertsekas, Dimitri and Gallager, Robert. *Data networks (2nd edition)*. Prentice Hall, 1992.

A first look at data network analytics (cont.)

- An exercise:
  - On a foggy Monday morning, you switched on your PM2.5 sensor to see if the current air quality is good enough for you to walk to a 7-11 for breakfast. The PM2.5 sensor is connected via a cable to a display. The sensor sends 16 bytes of air-quality data to the display every 10 seconds. The cable's bit rate is 80 bits per second. As you tried to wake yourself up, you wondered what is the cable's link utilization.
  - Answer:

$\overline{L}$: message lengths

λ : message arrival rate

r : allowable bit rate (example unit: bps (bits per second))

$\overline{X}$: expected message transmission time of a message

$$\overline{X} = \frac{\overline{L}}{r} = 16*8/80 = 1.6$$

Link utilization = $\frac{\overline{X}}{1/\lambda} = \lambda\overline{X}$ = (1/10)*1.6 = 0.16 = 16%

A first look at data network analytics (cont.)

- Situations where analysis skill can help you:
  - Following the previous example, suppose that now you want to know the air quality within the latest second. Can the current configuration offer that information? If you can get a better, faster cable, what bit rate is good enough for this purpose?
  - Suppose now that multiple sensors can share the same cable. Is there any constraint on the number of sensors?

Where there are many links in a data network

- Consider a network of links shared by sessions of different type
  - Each link has a fixed capacity for transmissions.
  - Each session uses a fixed route and reserves a fixed amount of transmission capacity on each link.
  - A session is blocked if any link on its path is loaded to the point that it can no longer accommodate the transmission capacity of the session.
- *Quality of service: what is the blocking probabilities for each session type?*

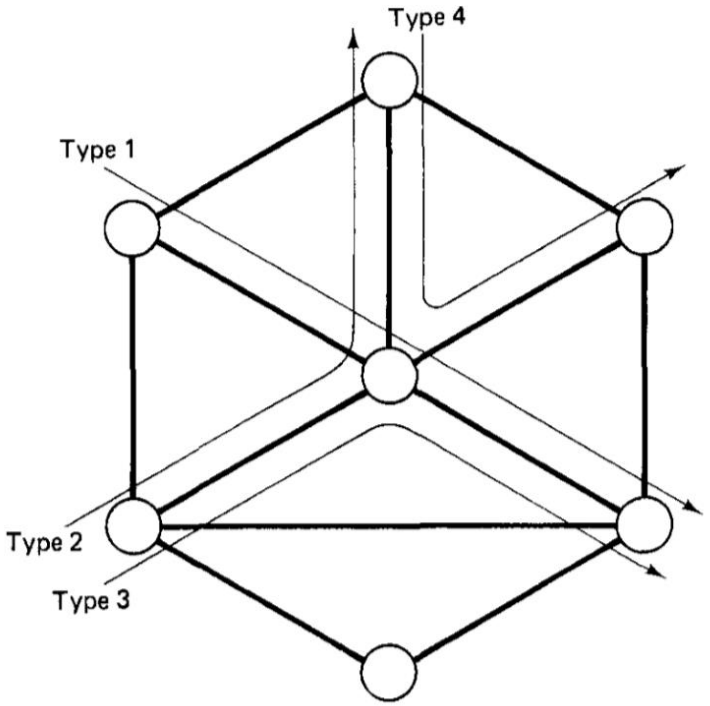
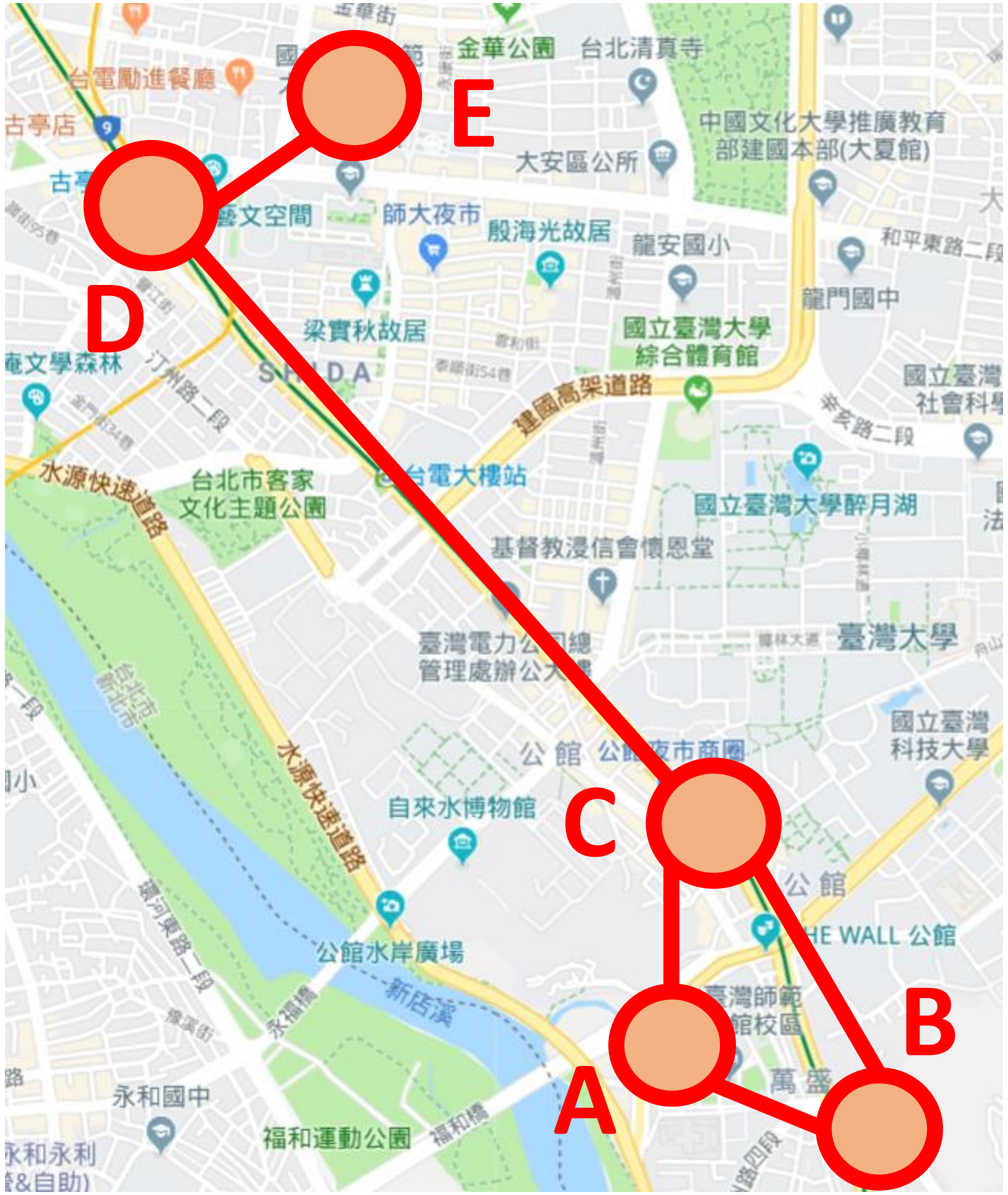


Image credit: Bertsekas, Dimitri and Gallager, Robert. *Data networks (2nd edition)*. Prentice Hall, 1992.

Data communication algorithms

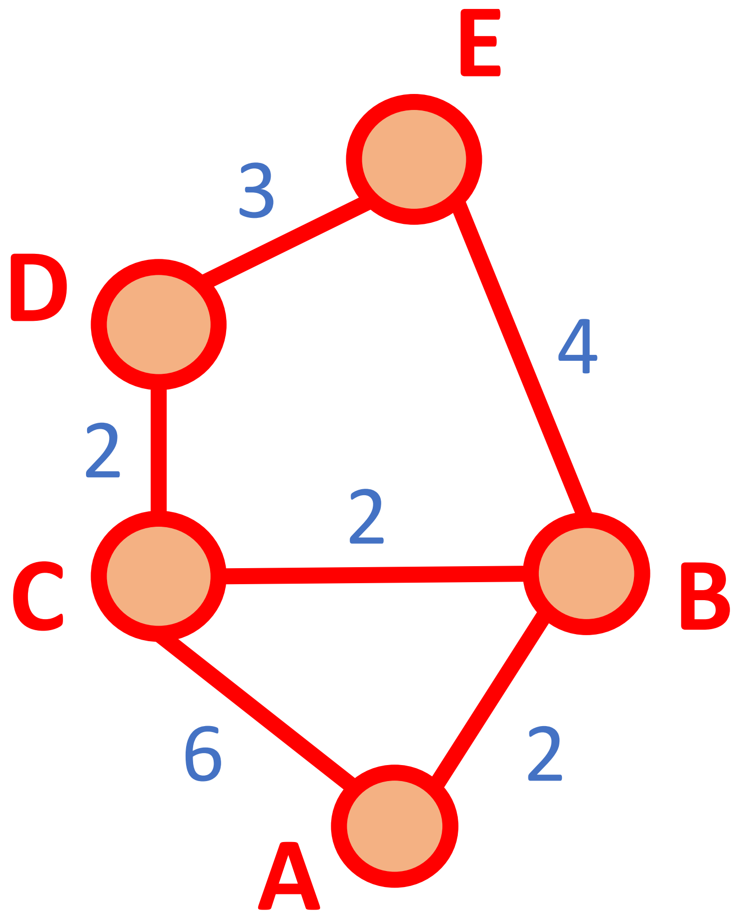
- Motivating example: We are travelling from **A** (Gongguan Campus) to **E** (Main Campus). If we take the MRT, shall we take
  - A → B → C → D → E ?
  - A → C → D → E ?

⇨ Design and analysis of data structures and network algorithms (e.g., finding a shortest path)



Data communication algorithms (cont.)

- Network flow problem:
  - A *flow* is a real-valued function on node pairs having the following three properties:
    - Skew symmetry: $f(v, w) = -f(w, v)$
    - Capacity constraint: $f(v, w)$ cannot be larger than the capacity of the link between v and w
    - Flow conservation: for every node other than the source and the destination, $\sum_w f(v, w) = 0$
  - Given a fixed capacity for each link, what is the maximum net flow from A to E?



Practical considerations in data communication: <u>physical constraints</u>

- Wireless communications
  - Range of communication for each wireless node
    - Noise and/or blockage
  - Energy consumption
    - Battery-powered smart IoT devices
  - Traffic congestion

- Emerging low-power wide-area technologies
  - LoRa and LoRaWAN

Practical considerations in data communication: **timing**

- Timing is important!
  - Example 1: stock trading AI
    - Learn from data and make timely trading decisions
  - Example 2: autonomous vehicles
    - Detect pedestrians and prevent accidents

- Low-latency communication
- Real-time communication
  - Given multiple data flows, which one to process first?

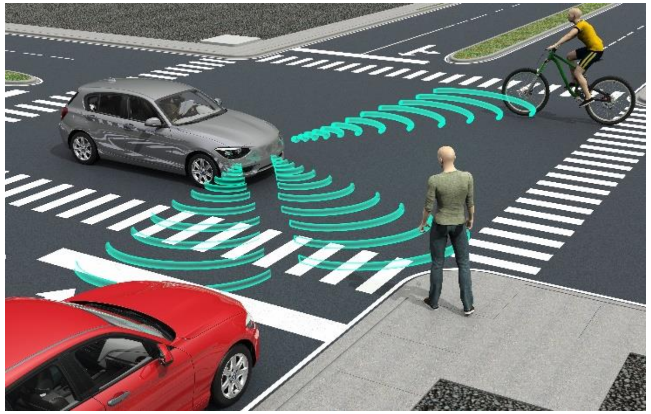


Image credit:
https://www.tradingacademy.com/financial-education-center/high-frequency-trading.aspx
https://www.com-magazin.de/news/internet-dinge/neues-gesetz-autonomes-fahren-in-deutschland-1220648.html

Practical considerations in data communication: dependability

- What if some of the network components may fail to work?
- How to keep applications running properly while fixing the underlying network problems?
- Will fault-tolerance affect the performance of a data network? In which ways? How to amend it?

Summary of lecture 01

- Course logistics
  - Visit and view the course website (e.g., via this QR code)
  - Homework access via NTNU Moodle

- Course overview
  - What data networks are
  - A first look at analyzing a data network (circuit switching over a single link)
  - How algorithms apply to data communications
  - A glimpse of some practical considerations in data networks
    - hardware, timing, dependability