

oueees-202106 topic 01:  
Latency and laws of physics  
Centralized Communication  
Multiplexing

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On the internet

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# Lecture notes and reporting

- <https://github.com/jj1bdx/oueees-202206-public/>
- Check out the README.md file and the issues!
- Keyword at the end of the talk
- URL for submitting the report at the end of the talk

# Latency and laws of physics

Speed of light in vacuum  $c$   
299 792 458 [m/s]

This is a definition, *not* a measured value

# Refractive indices of materials

- $v$ : speed of light in a material
- Refractive index  $n = c/v$ , always  $n \geq 1$ !
- Air: 1.000279 for  $\lambda=0.50 \mu\text{m}$ <sup>1</sup> -> 299709 km/s
- Water: 1.3330 for  $\lambda=589.3 \text{ nm}$ <sup>1</sup> -> 224901 km/s
- Silica glass (optic fiber): 1.45<sup>2</sup> -> 206753 km/s

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<sup>1</sup> 「光学の性質」、理科年表2022、丸善、ISBN: 978-4-621-30648-2, pp. 477-479

<sup>2</sup> <https://apniphysics.com/classroom/optical-fiber-refractive-index/>

# Distance latency and timing

- Osaka to Tokyo:  $\sim 400\text{km} = \sim 1.3\text{ms}$  (in vacuum/air)
- Tokyo, Japan to San Francisco, CA, USA:  $\sim 8300\text{km} \sim 28\text{ms}$  (in vacuum/air),  $41\text{ms}$  (in silica glass)
- Japan  $\leftrightarrow$  USA in optic fiber, round trip:  $\sim 100\text{ms}$  or more
- *Synchronization is hard*
- A question: can you play a network real-time game in the global scale, e.g., between Tokyo, New York, and Paris?



# Light traveling time and distance wiring and wavelength matter

- ~300km in 1ms aka 1kHz
- ~300m in 1 $\mu$ s aka 1MHz
- ~30cm in 1ns aka 1GHz
- ~3mm in 1ps aka 1THz

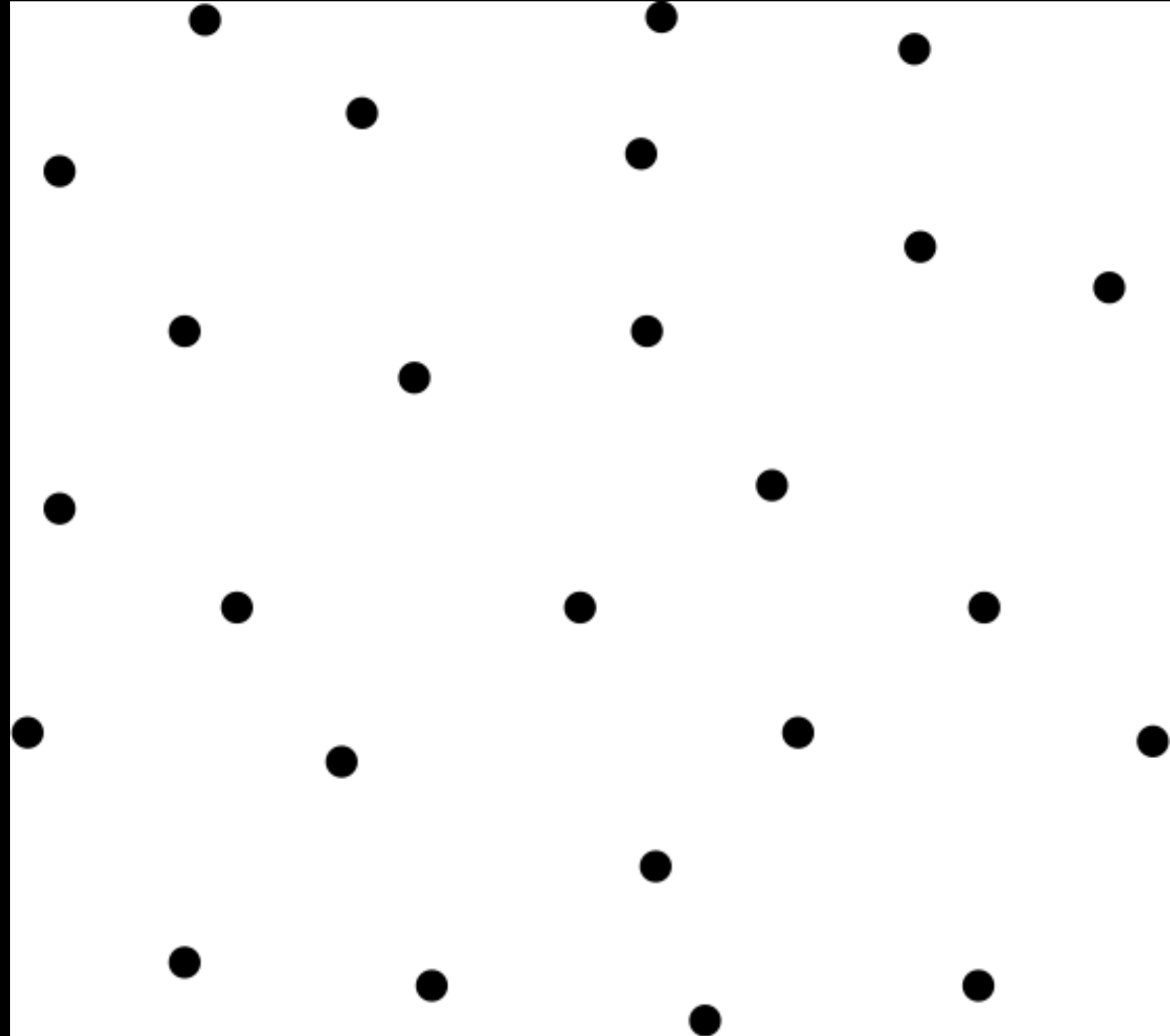
# Centralized communication

# Communication: sharing a medium

- Sharing a physical link between two or multiple parties
- *The physical layer*
- A medium could be: electric wires, optic fibers, radio airwaves, sound, flying birds like pigeons

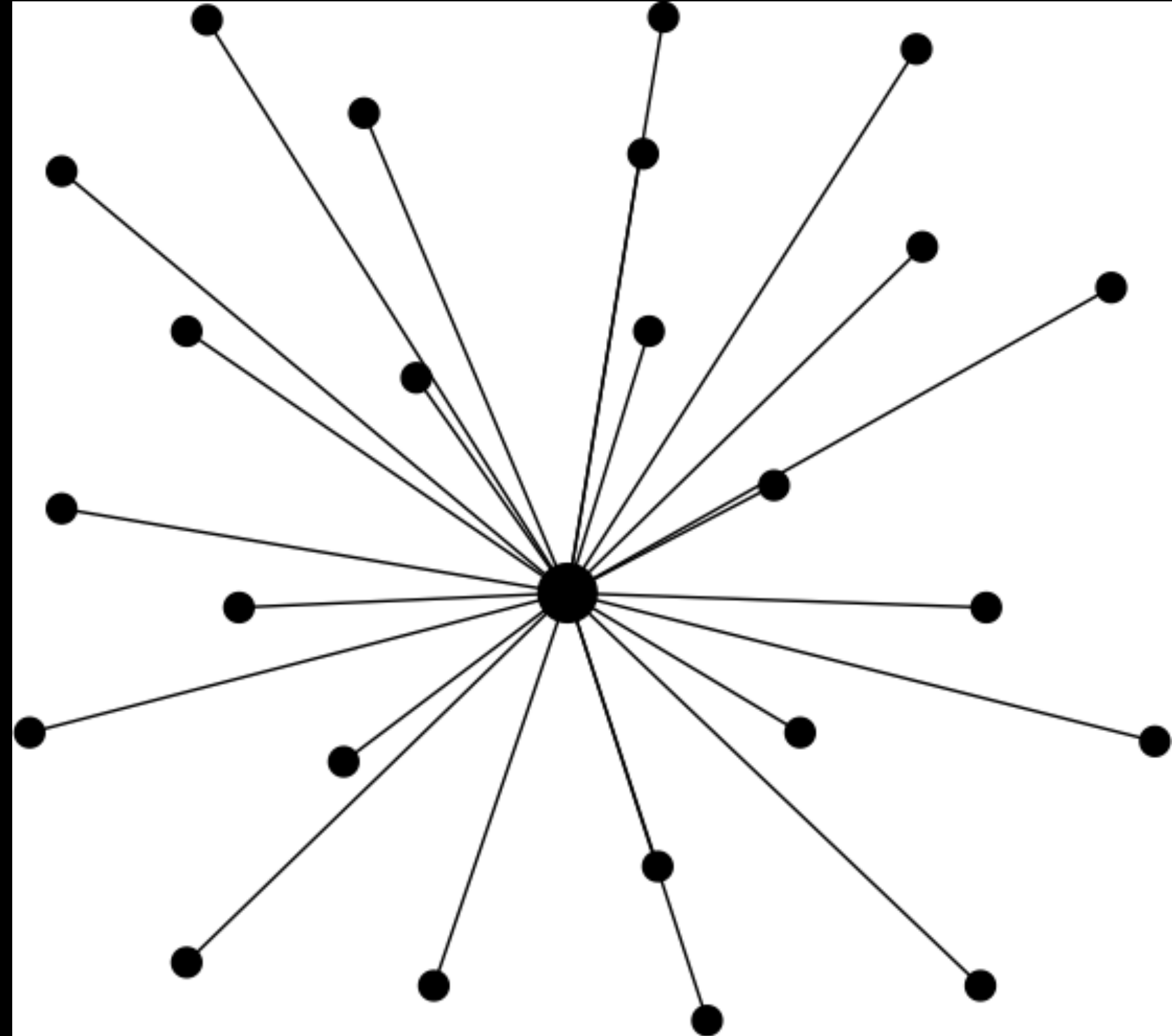
# Connecting unconnected nodes

There are many ways to connect the dots in this picture



# Simplest way: star/ centralized connection

- Centralized connection was the easiest way to connect the nodes
- Very much susceptible to network link failures
- Links should stay connected during the connection





# The old Stockholm telephone tower in 1890





# Fallen telephone lines by frost at Jönköping, Sweden, 1929





# Tekniska museet in Stockholm

(June 2018)



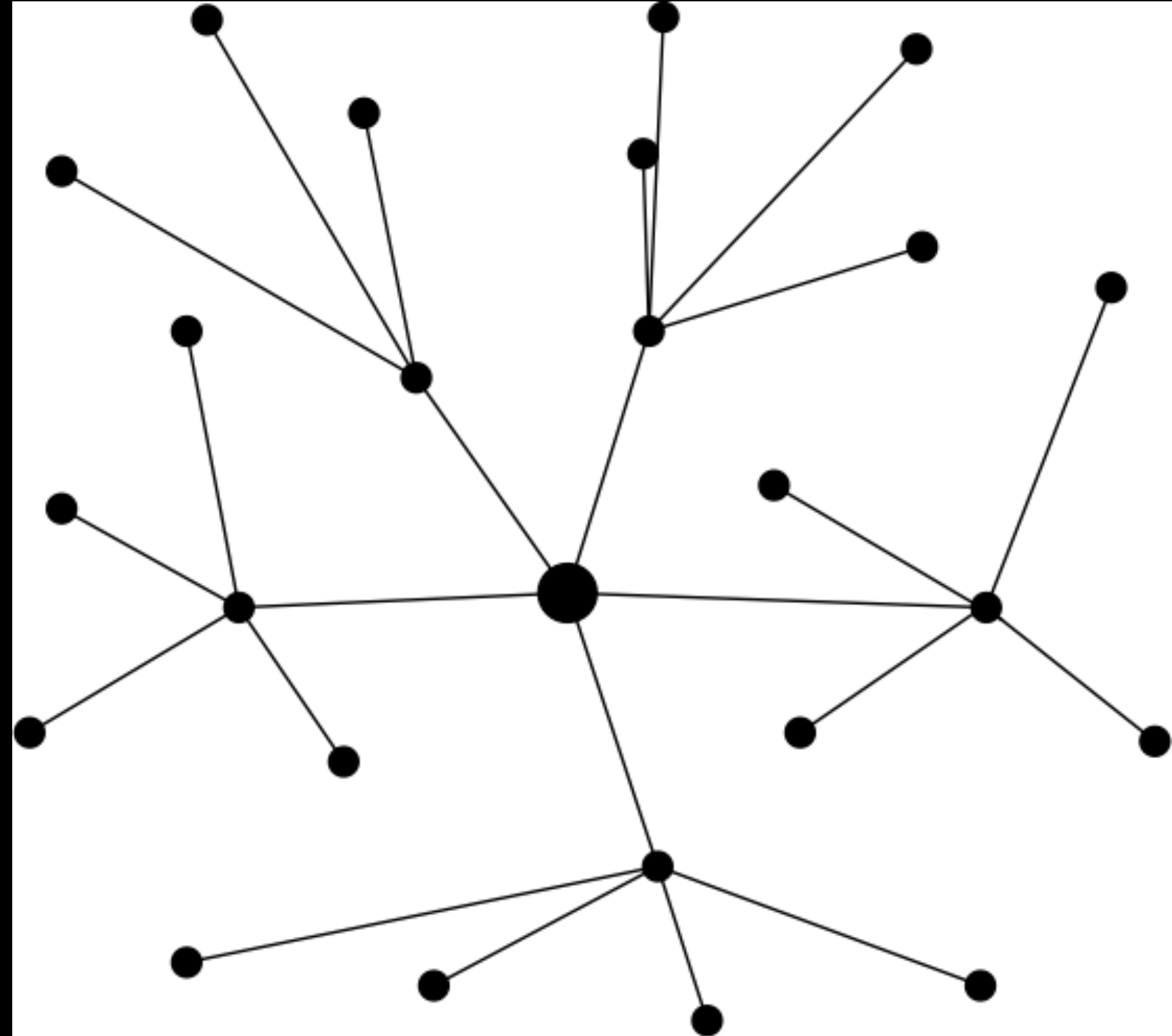


# Multiplexing

Multiplexing: sharing the same link  
by multiple nodes and  
communication devices

# Multiplexing enables decentralization

- Some links carry shared traffics for many different nodes



How to multiplex different types of information, and put them together for sharing a same medium?

# Signal characteristics used for multiplexing

- Space division (multiple lines or multiple beam-formed antennas)
- Time division
- Frequency/wavelength division
- Polarization division
- Code division (multiple codes of very small cross-correlation)

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