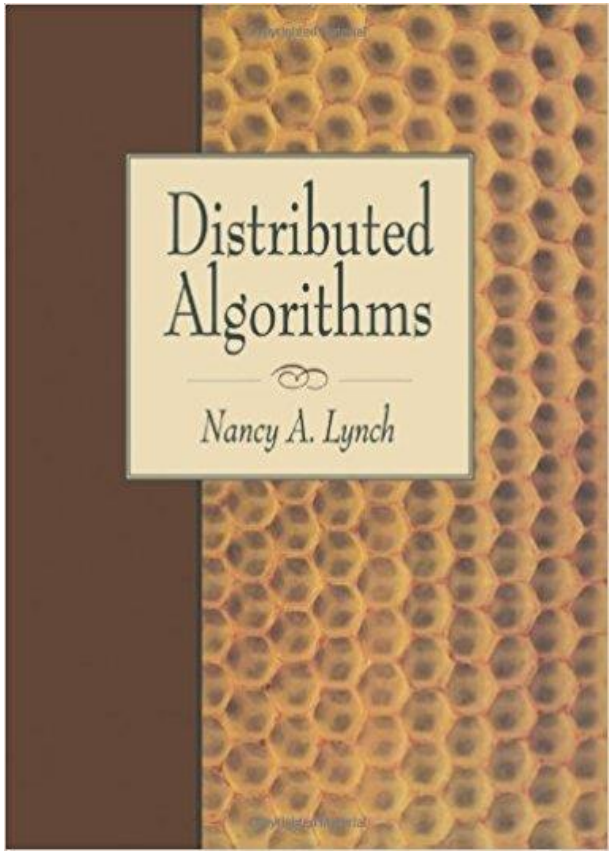
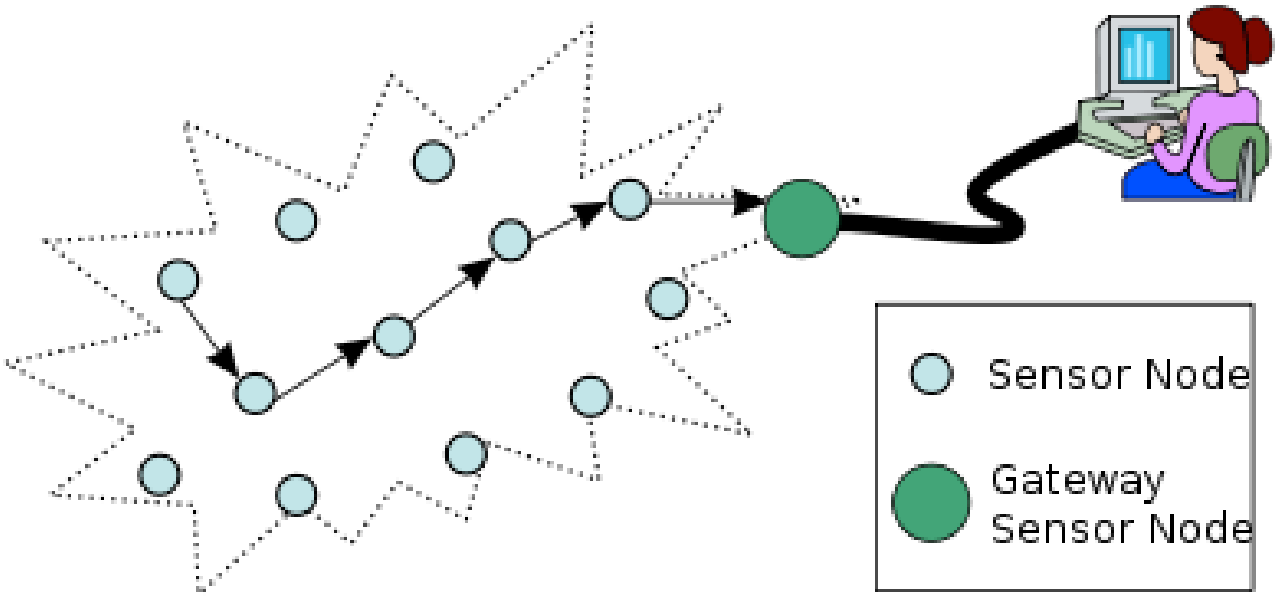
References

Nancy A. Lynch, Distributed Algorithms. **Morgan Kaufmann Publishers Inc., First edition.**



What is a distributed system?

It is a network of computing elements interacting with one another to achieve a goal.



(The nodes are processes/processsors, and the edges are communication channels.)

A channel may be physical (wired, wireless) or logical

Examples

- **The World Wide Web runs on the Internet and provides service**
- **eBay for internet-based auction**
- **Sensor networks for monitoring environmental data**
- **BitTorrent (P2P network) for downloading video / audio**
- **Skype, FaceTime for making audio and video communication**
- **Facebook, Twitter, Google (the oxygen of many people)**
- **Process control networks in engineering factories**
- **Network of mobile robots collectively doing a job**
- **Distance education, net-meeting etc.**
- **Netbanking**
- **Applications on Vehicular networks (VANET)**

More Examples

- **Domain Name System (DNS)**
  - **Distributed lookup table of hostname to IP address**

- **Email servers (SMTP)**
- **Phone networks: Land line and cellular**
- **Cars network electronic components via CANbus**
- **Traffic light controllers**
- **Train control networks**

- **Airplanes**
  - **Avionics use RS232 serial links**
  - **Air traffic control uses verbal communication**

What is Distributed System?

There is no universally accepted definition of distributed system.

Distributed Systems

- From “Distributed algorithms”
  - N. A. Lynch
  - Morgan Kaufman, ISBN 1-55860-348-4

- *“Distributed algorithms* are algorithms designed to run on hardware consisting of many interconnected processors. Pieces of a distributed algorithm run concurrently and independently, each with only a limited amount of information. The algorithms are supposed to work correctly, even if the individual processors and communication channels operate at different speeds and some components fail.”

Distributed Systems

- From “Distributed computing”
  - H. Attiya, J. Welch
  - Wiley, ISBN 978-0-471-45324-6

- “A *distributed system* is a collection of individual computing devices that can communicate with each other. This very general definition encompasses a wide range of modern-day computer systems, ranging from a VLSI chip, to a tightly-coupled shared memory multiprocessor, to a local area cluster of workstations, to the Internet.”

Distributed Systems

- From “Distributed algorithms”
  - G. Tel
  - Cambridge U. Press, ISBN 0-521-47069-2

- “By *distributed system* we mean all computer applications where several computers or processors cooperate in some way. This definition includes wide-area computer communication networks, but also local-area networks, multiprocessor computers in which each processor has its own control unit, and systems of cooperating processes.”

Distributed Systems

- From “Distributed systems”
  - A. S. Tanenbaum, M. Van Steen
  - Pearson, ISBN 0-13-239227-5

- “A *distributed system* is a collection of independent computers that appears to its users as a single system.”

Distributed Systems

- Good reasons for using them
  - Information exchange
  - Resource sharing
  - Increased reliability (replication)
  - Increased performance (parallelization)
- Wide range of applications
  - Telecommunications
  - Distributed information processing
  - Scientific computing
- Real life examples
  - Telephone systems
  - Airline reservation systems
  - Banking systems

Classification

- Models
  - Interprocess communication
  - Timing assumption
  - Failures
- Uncertainty and independence
  - Unknown number of processors, topology
  - Independent inputs at different locations
  - Programs started at different times, different speeds
  - Uncertain message delivery time

Inter-process Communication

- How process communicate?

- Commonly
  - Sending point-to-point or broadcast messages
  - Remote procedure calls
  - Shared memory

- Computer networks
  - messages

Timing Model

- Synchronous
  - Processors and communication work at perfect lock-step synchrony
- Asynchronous
  - Processors and communication take arbitrary time
- Partially synchronous
  - Wide range of assumptions about timing

Distributed System Models

- Synchronous model
  - Message delay is bounded and the bound is known.
  - E.g., delivery before next tick of a global clock.
  - Simplifies distributed algorithms
    - "learn just by watching the clock"
    - absence of a message conveys information.
- Asynchronous model
  - Message delays are finite, but unbounded/unknown
  - More realistic/general than synchronous model.
    - "Beware of any model with stronger assumptions." - Burrows
  - Strictly harder/weaker than synchronous model.
    - Consensus is not always possible

Failures

- Distributed systems without failures
  - … piece of cake
- Failures are always possible
  - Harder problem solutions, sometimes impossible
  - f-failure resilient algorithms
    - wait-free algorithms
- Common type of failures
  - Process stop or Byzantine failures
  - Duplication, loss or reordering of messages

Distributed System

Thanks!