Distributed Information Processing

4th Lecture

Eom, Hyeonsang (엄현상)
Department of Computer Science & Engineering
Seoul National University
Outline

- Architectures and Algorithms
  - Matching the Architecture to the Algorithm
- Distributed Processing
  - Performance
  - Ability
  - Behavioral Principles
- Q&A
Principal Architectural Models

Client-Server

- Client Processes Interacting w/ Server Processes to Access Their Shared Resources Managed in a Centralized Manner
  - E.g., DNS Servers, Web Search Engines

![Diagram of Client-Server architecture]

Key:
- Process: 
- Computer: 

Not Scalable
Principal Architectural Models (Cont’d)

Peer-to-Peer

- Processes Interacting Cooperatively to Access Their Shared Resources Collectively-Managed in a Distributed Fashion
- E.g., Napster

![Diagram of Peer-to-Peer architecture]
Flynn’s Model for Architectures

- SISD (Single Instruction Stream, Single Data Stream)
  - Uniprocessor

- SIMD (SI, Multiple Data Streams)
  - Single Instruction Memory & Control Processor w/ Memory per Processor

- MISD (Multiple Instruction Streams, SD)

- MIMD
  - Centralized Shared-Memory Architectures
  - Distributed-Memory Architectures

E.g., UMA, Uniform Memory Access

E.g., NUMA, Non-Uniform Memory Access
MIMD Architectures

- E.g., SMP (Symmetric Multiprocessing) – Problem: Poor Scalability
- E.g., MPP (Massively Parallel Processing) – Problem: Explicit Data Distribution
- E.g., SMP (Symmetric Multiprocessing) – Problem: Poor Scalability
- E.g., NUMA
Characterizing the Algorithm [Kleinrock85]

To Exploit Its Potential for Concurrency at Different Granularity Levels:
- Job
- Task
- Process
- Instruction
- Register Transfer
- Logic Device

E.g., by Using a Graph Model
Matching the Architecture to the Algorithm [Kleinrock85]

- Considerations Regarding the Graph Model
  - Partitioning
    - Deciding granularity levels
    - Grouping
  - Scheduling
    - Assigning processors and memory modules
- Memory Access
- Interprocessor Communication
- Synchronization
  - Preserving dependency
Matching the Architecture to the Algorithm [Kleinrock85]

- Balance and Tradeoff among Communication, Processing, and Storage
  - Trading Processing for Communication
    - E.g., data compression prior to transmission
  - Trading Storage for Processing
    - E.g., storing a list of computational results
  - Trading Storage for Communication
    - E.g., storing data from a previous communication
- Failure Detection & Recovery
Parallel-Processing Performance

- **Speedup (S)**

  - **Serial Computation Time** $T_s$ **over Parallel Execution Time** $T_p$ ($S = \frac{T_s}{T_p}$)
    - $T_p = T_{COMP_p} + T_{COMM_p}$
    - $T_{COMP_p} = T_s(1-A)/P + T_sA$, where $A$ is the serial portion
      - E.g., if $T_s = 100$, $A = 0.2$, & $P = 10$, then $T_{COMP_p} = 28$
    - $T_p = T_s(1-A)/P + T_sA$, assuming that $T_{COMM_p} = 0$
    - $S = \frac{T_s}{T_p} = T_s/(T_{COMP_p} + T_{COMM_p}) = \frac{1}{A + (1-A)/P}$, assuming that $T_{COMM_p} = 0$
      - $1 \leq S \leq P$

Amdahl Portion – Speedup Will Be Limited by This Portion
Ability of Distributed Processing
Possibly Producing the Best Result

- Greedy Solutions with Unexpected Results:
  E.g., Goore Game [Kleinrock85] (Repeating Actions Preferentially by Trial and Error)
  - Many Players Being Asked to Vote YES or NO in Each Interval
    - Acting w/ sufficient memory in a probabilistic fashion
    - W/ each unaware of the others
  - Referee Rewarding Each Member Independently w/ a Probability Given by \( f(p) \) Unknown to It
    - \( p \): fraction of the player set that votes YES

Exactly 20% of the Players Will Vote YES with Probability 1
We May Be Able to Explain How the Colony of Ants Perform Its Tasks
Ability of Distributed Processing (Cont'd)

- Possibly Producing a Globally Suboptimal Solution

- Most Greedy Solutions: E.g., Prisoner’s Dilemma (Predicting the Behavior of the Other Players)
  - Two Men Being Held in Separate Cells for a Crime They Did
  - District Attorney w/ Hard Evidence Just for One-Year Penalty
    - Making the following offer to each prisoner:
      - Free if confessing w/ your partner remaining silent
      - In jail for 20 years in the opposite case
      - Five years in jail for each if both confess

Dilemma: Each Is Tempted to Confess, But If Both Confess, It Will Be Worse
Behavioral Principles
[Kleinrock85]

- Developing innovative architectures for parallel processing
- Providing better languages and algorithms for specification of concurrency
- More expressive models of computation
- Matching the architecture to the algorithm
- Understanding the trade-off among communication, processing, and storage
- Evaluation of the speedup factor for classes of algorithms and architectures
- Evaluation of the cost-effectiveness of distributed-processing networks
- Study of distributed algorithms in networks
- Investigation of how loosely coupled self-organizing automata
can demonstrate expedient behavior
- Development of a macroscopic theory of distributed systems
- Understanding how to average over algorithms, architectures,
  and topologies to provide meaningful measures of system performance