Distributed Systems: Architectural Issues

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Outline for Today’s Talk

- Distributed Systems: Architectural Issues
Readings for Today’s Lecture

- Chapter 2 of “Distributed Systems: Principles and Paradigms”
Definition of a Distributed System

- From previous lecture

- A more precise definition:

  A distributed system consists of a collection of autonomous computers, connected through a network and distribution middleware, which enables computers to coordinate their activities and to share the resources of the system, so that users perceive the system as a single, integrated computing facility.
## A Taxonomy of Distributed Systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Distributed OS</th>
<th>Network OS</th>
<th>Middleware-based OS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multiproc.</td>
<td>Multicomp.</td>
<td></td>
</tr>
<tr>
<td>Degree of transparency</td>
<td>Very High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Same OS on all nodes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of copies of OS</td>
<td>1</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Basis for communication</td>
<td>Shared memory</td>
<td>Messages</td>
<td>Files</td>
</tr>
<tr>
<td>Resource management</td>
<td>Global, central</td>
<td>Global, distributed</td>
<td>Per node</td>
</tr>
<tr>
<td>Scalability</td>
<td>No</td>
<td>Moderately</td>
<td>Yes</td>
</tr>
<tr>
<td>Openness</td>
<td>Closed</td>
<td>Closed</td>
<td>Open</td>
</tr>
</tbody>
</table>

A comparison between multiprocessor operating systems, multicomputer operating systems, network operating systems, and middleware based distributed systems.
Architectural Styles

- Logical organization of software components in distributed systems

- The notion of architectural style:
  - Formulated in terms of components
    - How the components are connected each other
    - How and what data exchanged between them
    - How the components are jointly configured into a system

- Component and Connector
Architectural Styles (2)

Important styles of architecture for distributed systems

- Layered architectures
  - Network model: OSI & TCP/IP

- Object-based architectures
  - Client/Server

- Data-centered architectures
  - Web-based DS

- Event-based architectures
  - Publish/Subscribe systems

- Shared Data Spaces
Architectural Styles (3)

Layered architectural style

Object based architectural style
Architectural Styles (4)

Event-based architectural style

Shared data-space architectural style
System Architectures

- Centralized vs Decentralized organizations
- Client – Server Model
A Vanilla Network OS
(Remote Access System [Goscinsky ‘83])

Issues:
• Performance! (local and remote)
• Where is the state?
• Serialization of operations.
• Blocking operations
C/S Model: Application Layering

- Issue: How to draw a distinction between client and server

- Considering database apps, people have advocated a three-level distinction (following the layered architectural styles):
  - The user-interface level
  - The processing level
  - The data level

- Example: A simplified organization of an Internet search engine
C/S Model: Multi-tiered Architecture

The distinction into three levels suggests various possibilities for physically distributing a C/S application across several machines.

Alternative Client-Server Organizations (a-e)
C/S Model: Multi-tiered Architecture

Three-tiered Architecture:

An example of a server acting as client.
Decentralized Architecture

- Vertical Distribution
  - Distributed processing is equivalent to organizing a C/S application as a multi-tiered architecture

- Horizontal Distribution
  - A client or server may be physically split up into logically equivalent parts, but each part runs on its own share of complete data set, thus balance the load.
  - An example of horizontal distribution of a Web service
  - Peer-to-peer systems
  - Overlay Network
    - Structured
    - Unstructured
Structured Peer-to-Peer Architectures

- Distributed Hash Table (DHT)

- Example 1: Chord System
  - The mapping of data items onto nodes in Chord.

![Chord System Diagram]

- Actual node
- Associated data keys
- "{8,9,10,11,12}"
- "{5,6,7}"
Structured Peer-to-Peer Architecture (2)

Example 2: CAN System
(a) The mapping of data items onto nodes in CAN. (b) Splitting a region when a node joins.
Unstructured Peer-to-Peer Architecture

- Randomized Algorithms

- Resemble Random Graph

- Framework for Overlay Construction (Jelasity 2004 and 2005)
  - Active Thread
  - Passive Thread
Framework for Overlay Construction

Actions by active thread (periodically repeated):

select a peer P from the current partial view;
if PUSH_MODE {
    mybuffer = [(MyAddress, 0)];
    permute partial view;
    move H oldest entries to the end;
    append first c/2 entries to mybuffer;
    send mybuffer to P;
} else {
    send trigger to P;
}
if PULL_MODE {
    receive P’s buffer;
}
construct a new partial view from the current one and P’s buffer;
increment the age of every entry in the new partial view;

(a)
Framework for Overlay Construction (2)

Actions by passive thread:

receive buffer from any process Q;
if PULL_MODE {
    mybuffer = [(MyAddress, 0)];
    permute partial view;
    move H oldest entries to the end;
    append first c/2 entries to mybuffer;
    send mybuffer to P;
}
construct a new partial view from the current one and P’s buffer;
increment the age of every entry in the new partial view;

(b) The steps take by the passive thread
Overlay Networks: Topology Management

- One key observation: By carefully exchanging and selecting entries from partial views, it is possible to construct and maintain certain topologies of overlay networks.

A two-layered approach for constructing and maintaining specific overlay topologies using techniques from unstructured peer-to-peer systems
Overlay Networks: Topology Management

- If the lowest layer periodically executes the protocol in Fig. 2-9, the topology will evolve into a torus.
- Examples of a torus include the surfaces of doughnuts and inner tubes.
Overlay Networks: Superpeers

Nodes such as those maintaining an index or acting as a broker are Superpeers.

A hierarchical organization of nodes into a superpeer network
Hybrid Architectures

- Edge-Server Systems
  - Viewing the Internet as consisting of a collection of edge servers
Middleware

General structure of a distributed system as middleware.
In an open middleware-based distributed system, the protocols used by each middleware layer should be the same, as well as the interfaces they offer to applications.
**Middleware (3)**

- Interceptors: A software construct that breaks the usual flow of control and allows other application specific code to be executed.

- Using interceptors to handle remote-object invocations.
**Middleware (4)**

- Interceptors: A software construct that breaks the usual flow of control and allows other application specific code to be executed.

- Using interceptors to adapt the middleware

- Three basic approaches to adaptive software:
  - Separation of concerns
  - Computational reflection
  - Component-based design
Questions?

Thanks and See you next time
Self-Management in Distributed Systems

- Organizing DSs as high-level feedback-control systems allowing automatic adaptations to changes
  - Autonomic computing and Self-star systems
- Feedback Control Model

![Feedback Control Model Diagram]

- Uncontrollable parameters (disturbance / noise)
- Initial configuration
- Corrections
- Core of distributed system
- Observed output
- Reference input
- Metric estimation
- Adjusted measures
- Analysis
- Measured output
- Adjustment triggers
Example 1: Systems Monitoring with Astrolabe

Data collection and information aggregation in Astrolabe

<table>
<thead>
<tr>
<th>avg_load</th>
<th>avg_mem</th>
<th>avg_procs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06</td>
<td>0.55</td>
<td>47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IP-addr</th>
<th>load</th>
<th>mem</th>
<th>procs</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.1.2</td>
<td>0.03</td>
<td>0.80</td>
<td>43</td>
</tr>
<tr>
<td>192.168.1.3</td>
<td>0.05</td>
<td>0.50</td>
<td>20</td>
</tr>
<tr>
<td>192.168.1.4</td>
<td>0.10</td>
<td>0.35</td>
<td>78</td>
</tr>
</tbody>
</table>
Example 2: Differentiating Replication Strategies in Globule

- The edge-server model assumed by Globule

- Dependency between prediction accuracy and trace length