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Distributed Systems

Chapter 3 System Models

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3.1: Introduction

Difficulties and threats to distributed systems

- Widely varying modes of use
  - millions of accesses to a web-page
  - multimedia access versus e-mail

- Wide range of system environments
  - heterogeneous hardware, operating systems and networks

- Internal problems
  - non-synchronized clocks
  - conflicting data updates
  - software/hardware failures

- External threats
  - attacks on data integrity and security
  - denial of service
3.2: Architectural Models

Description of the general structure of a DS

- Placement of the components
- Interrelationship between components

Processes may be classified as

- Server processes
- Client processes
- Peer processes

Usually, variations of these classifications are used
3.2.1: **Software Layers**

**Platform**
- Lowest-level hardware and software layers
- Provide services to the layer above
- E.g. Intel x86/Windows, Intel x86/Solaris, Intel x86/Linux

**Middleware**
- Layer of software which masks the heterogeneity
- Useful building blocks for the construction of software components
- E.g. CORBA, Java RMI, web services, Microsoft DCOM, ISU/ITU RM-ODP
3.2.2: System Architectures

- Prevalent architecture
- Server process and client processes
- E.g. Web servers with database, search engines using web crawlers

from Distributed Systems – Concepts and Design, Coulouris, Dollimore, Kindberg
3.2.2: System Architectures

Peer-to-Peer

- All processes play similar roles
- Interacting as peers (equals)
- Large number of peer processes on separate computers
- Individual servers hold only a small quantity
- E.g. File-sharing, Skype

→ more difficult
Peer-to-Peer Architecture
3.2.2: System Architectures: Variations

- Services provided by multiple servers (based on replicas)
  e.g. Sun NIS (Network Information Service)
- Proxy server and caches
- Mobile code
  e.g. applets
- Mobile agent
  a running program (code and data) that travels from computer to another one
- Network computers
  downloads OS from remote file server; also files are managed there
- Thin clients
  an graphical interface to a remote computer system,
  e.g. terminal to mainframe computer
- Mobile devices and spontaneous interoperation
  e.g. smart phones interacting using GSM, UMTS, Bluetooth
3.2.2: System Architectures: Design Requirements

- **Performance issues**
  - Responsiveness
  - Throughput
  - Balancing computational loads

- **Quality of service**
  - Reliability
  - Security
  - Performance

- **Dependability issues**
  - Correctness
  - Security
  - Fault tolerance
3.3.1: Interaction Model

Performance of communication channels

- **Delay (latency)**
  - includes time for transmission, accessing the network, time by the operation systems

- **Bandwidth**
  - number of bits that can be transmitted in a given time

- **Jitter**
  - variation of the delay

Computer clocks

- **Clock drift rate**
  - relative amount that a computer clock differs from a perfect clock
3.3.1: Interaction Model

Synchronous Distributed Systems [Hadzilacos, Toueg, 1994]

- the time to execute each step of a process has known lower and upper bounds
- each message transmitted over a channel is received within a known bounded time
- each process has a local clock whose drift rate has a known bound

Asynchronous Distributed System

No bounds on
- process execution speeds
- message transmission delays
- clock drift rates
3.3.1: Interaction Model

Event ordering

1. X sends a message with the subject: Meeting
2. Y and Z reply, send a message with subject: Re: Meeting

User A’s inbox:

<table>
<thead>
<tr>
<th>Item</th>
<th>From</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Z</td>
<td>Re: Meeting</td>
</tr>
<tr>
<td>24</td>
<td>X</td>
<td>Meeting</td>
</tr>
<tr>
<td>25</td>
<td>Y</td>
<td>Re: Meeting</td>
</tr>
</tbody>
</table>
3.3.2: Failure Model

- Process omission failures
  - e.g. crash: can only detected by timeouts
  - e.g. fail-stop: detected crash

- Arbitrary (Byzantine) failures
  - worst possible failure: anything can happen
  - omits steps, takes unintended processing steps, returns wrong values, corrupted messages . . .
  - are rare
  - check sums can detect corrupted messages
  - message sequence number can detect omitted data
3.3.2: Failure Model

- **Timing failures**
  - internal clock too late or too early
  - process is too slow or too fast
  - messages take longer than wanted

- **Masking failures**
  - A service masks a failure by hiding it or by converting it into a more acceptable type of failure
3.3.2: Failure Model

- Communication omission failures
  - *dropping messages*: lost messages on the communication channel
  - *send-omission failure*: between send process and outgoing buffer
  - *receive-omission failure*: between incoming buffer and receive process
  - e.g. fail-stop: detected crash

- Reliability of one-to-one communication
  - validity: any message in the outgoing buffer is eventually delivered to the incoming message buffer
  - integrity: the message received is identical to the one sent, no messages are delivered twice

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from *Distributed Systems – Concepts and Design*, Coulouris, Dollimore, Kindberg
3.3.2: Failure Model

Defeated army problem

- Two confederated armies on two hills separated by the enemy army in the valley
- Dark Blue and Blue communicate via messengers

Problem: In the asynchronous model Dark Blue cannot distinguish whether
- Blue has been attacked and defeated by Red or
- the messenger with the "everything is fine" message from Blue is late.

![Diagram of communication between processes](image-url)

from Distributed Systems – Concepts and Design, Coulouris, Dollimore, Kindberg
3.3.2: Failure Model

Agreement Problem

- **Two confederated armies** on two hills separated by the **enemy army** in the valley
- **Dark Blue** and **Blue** communicate via messengers.
- **Red** can delete any message (by killing the messenger)
- **Dark Blue** and **Blue** want to agree on whether to attack **Red** the next morning **or not**

Problem:

*Red can prevent Dark Blue and Blue from an agreement by erasing the right messages.*
3.3.2: Failure Model: Agreement Problem
### 3.3.2: Failure Model

#### Omission and Arbitrary Failures

<table>
<thead>
<tr>
<th>Class of failure</th>
<th>Affects</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail-stop</td>
<td>Process</td>
<td>Process halts and remains halted. Other processes may detect this state.</td>
</tr>
<tr>
<td>Crash</td>
<td>Process</td>
<td>Process halts and remains halted. Other processes may not be able to detect this state.</td>
</tr>
<tr>
<td>Omission</td>
<td>Channel</td>
<td>A message inserted in an outgoing message buffer never drives at the other end’s incoming message buffer.</td>
</tr>
<tr>
<td>Send-omission</td>
<td>Process</td>
<td>A process completes a send, but the message is not put in its outgoing message buffer.</td>
</tr>
<tr>
<td>Receive-omission</td>
<td>Process</td>
<td>A message is put in a process’s incoming message buffer, but that process does not receive it.</td>
</tr>
<tr>
<td>Arbitrary (Byzantine)</td>
<td>Process or channel</td>
<td>exhibits arbitrary behavior: sends/transmits arbitrary message at arbitrary times, omissions, process may stop or may take an incorrect step</td>
</tr>
</tbody>
</table>
### 3.3.2: Failure Model

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<tr>
<td>Clock</td>
<td>Process</td>
<td>Process’s local clock exceeds the bounds on its rate of drift from real time</td>
</tr>
<tr>
<td>Performance</td>
<td>Process</td>
<td>Process exceeds the bounds on the interval between two steps.</td>
</tr>
<tr>
<td>Performance</td>
<td>Channel</td>
<td>A message’s transmission takes longer than the stated bound.</td>
</tr>
</tbody>
</table>
3.3.3: Security Model

The security of a distributed system can be achieved by securing the processes and the interaction channels and by protecting the objects they encapsulate against unauthorized access.

- Protecting objects
  - access rights
  - an authority (user or process), called *principal*, grants the access to the objects

- securing processes and interactions
  - messages are exposed to attacks
  - processes expose their interfaces
  - enable invocations
3.3.3: Security Model: The enemy

- threats to processes
  - e.g. IP lacks the reliable knowledge of the source of messages
  - Servers, e.g. mail-server delivers e-mail to attacker
  - Clients, e.g. fake GSM radio station captures secret phone calls

- threats to communication channels
  - enemy copies, alters, injects messages
  - enemy saves copies of messages and replays them later
  - such attacks can be defeated by the use of secure channels

- denial of service

from *Distributed Systems – Concepts and Design*, Coulouris, Dollimore, Kindberg
3.3.3: Security Model: Defeating Security Threats

- Cryptography: the science of keeping messages secure
  - symmetric encryption
  - public-key encryption
  - challenge-response protocols

- Authentication
  - shared secrets
  - public-key encryption

- Secure channels
  - process know reliably the identity of the principle
  - ensure privacy and integrity of the data
  - include physical or logical time stamps

- Other threats: denial of service and mobile code
End of Section 3