Characterization of Distributed Systems

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Cpt. S 464/564 Lecture

Textbook, Chapter 1, plus extras

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Administrative Items

- Handouts today
  - Syllabus
  - Student Survey
  - Paper "A Note on Distributed Computing"
  - Paper "Interview: Fred B. Schneider on Distributed Computing"
    - Testable for 564 students only
  - Lecture slides for first two lectures (this document!)
- Textbooks are not in yet! (Hopefully by Wednesday.)
- Conventions in these slides
  - Key terms defined are underlined
  - Items for extended discussion are in red
    - Or URLs underlined and in red by PowerPoint
  - `Code fragments or something else you might type are in a typewriter font (Courier New)`

Outline of Topics

1. **Introduction**
2. Examples of Distributed Systems
3. Resource Sharing and the Web
4. Challenges
5. Example Local vs. Remote Procedure Call

Introduction

- A distributed system is "one in which hardware or software components located at networked computers communicate and coordinate their actions only by message passing"
  - Very broad definition
  - Lots of examples
  - Lots of kinds
  - Note: I abbreviate "Distributed System" by "DS"
- "You know you have one when the crash of a computer you've never heard of stops you from getting any work done." Leslie Lamport
- Examples of DSs:
  -
  -
  -
  -
  -
  -

Advantages of Distributed Systems

- Share resources (key)
- Share devices
- Better hardware cost/performance than supercomputers, multiprocessors
- Allows access from many remote users using their simple PCs
- Allows for incremental growth (if done right)
- Increases reliability and availability (if done right)
- Some applications and services are inherently distributed
- Can spread the load of a given service much more easily
- Can potentially increase security (!!!???)

Consequences of Distributed Systems

- Concurrency
  - Concurrent use of low-level resources: processing, storage (memory+disk), communications
  - Mutual exclusion and other synchronization required
  - Access to resources for a given user often best-effort
- No global clock
  - Cannot often know the exact ordering of events: which happened first
- Independent failures
  - No longer “all or none” failures for your program!
  - Some computers still running, while others failed or partitioned
  - Failure of a component you are using may not be a clean failure
- “I don’t think we’re in Kansas anymore, Toto!”

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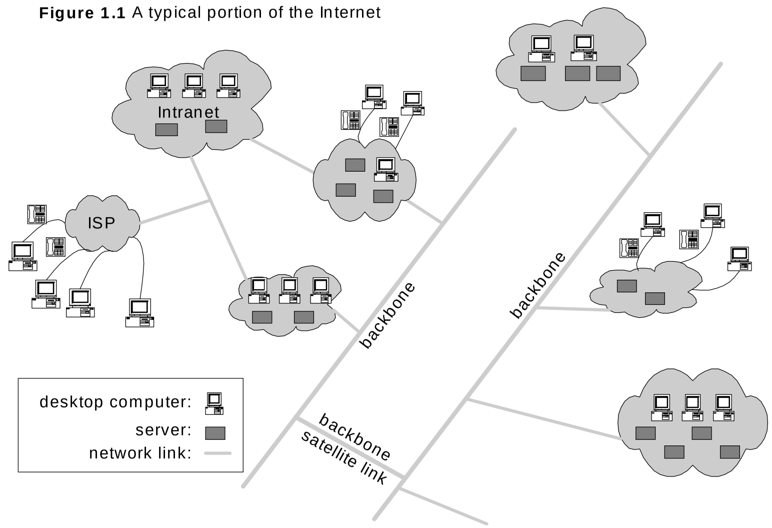
DS Example 1: The Internet

- Large number of connected computers
- Common protocols
- Common addressing
- Common set of basic services
- It is a very large distributed system!
- Q: What defines “The Internet”

The Internet (cont.)

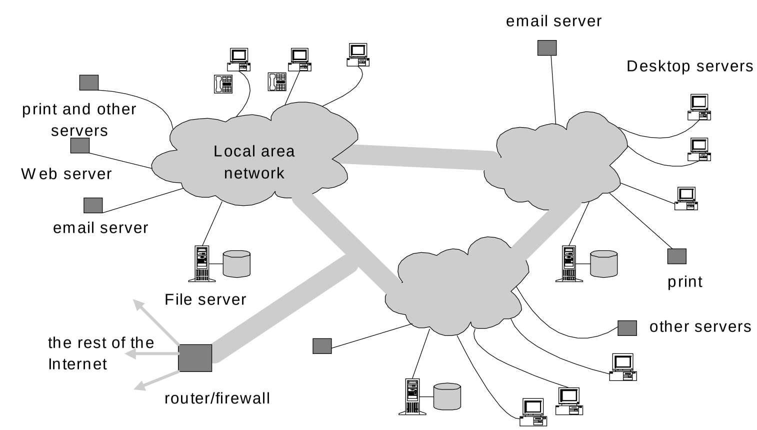
Figure 1.1 A typical portion of the Internet



DS Example 2: Intranets

- Intranet == "a portion of the Internet that is separately administered and has a boundary that can be configured to enforce local security policies"

Figure 1.2 A typical intranet



Intranets (cont.)

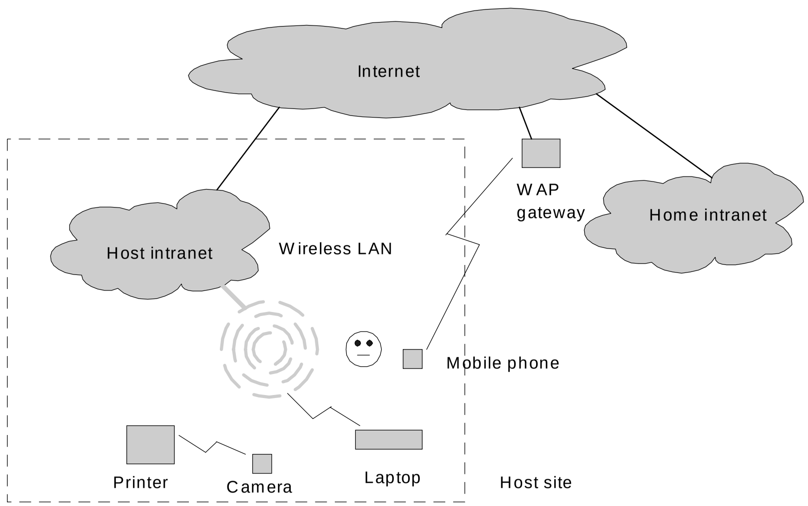
- Usually protected by a firewall
- Issues involving design of components in an intranet
  - File services are needed
  - Firewalls tend to impede legitimate access to services
    - Need finer-grained security mechanisms
  - Cost of software installation and support is very important!

DS Example 3: Mobile and Ubiquitous Computing

- Lots of small and/or portable computing devices are networked
  - Laptop computers
  - Personal Digital Assistants (PDAs) like a Palm Pilot
  - Mobile phones
  - Video cameras
  - Wearable devices (smart watch, "Dick Tracy" ring)
  - Devices embedded in appliances
- Mobile computing
  - Ability to perform computing tasks when user is moving from his normal environment
  - Also known as (aka) "nomadic computing"
- Ubiquitous computing
  - Harnessing plentiful small and cheap computing devices that are (seemingly) everywhere
  - Only really useful if they
    - Are networked
    - Can easily be used in programs by novices
- Mobile and ubiquitous computing overlap, but not 100%

Mobile and Ubiquitous Computing (cont.)

Figure 1.3 Portable and handheld devices in a distributed system



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Resource Sharing and the Web

- Its easy to overlook benefits of resource sharing!
- Great to share low-level resources (storage, etc), services, and peripherals
- But more important to share higher-level services like databases, etc.
- Patterns of resource sharing vary quite widely in
  - Geographic scope
  - How closely users work together
- Service == "a distinct part of a computer system that manages a collection of related resources and presents their functionality to users and applications"
  - Examples of distributed services….
- Server == "a running program (a process) on a networked computer that accepts requests from programs running on other computers to perform a service and responds appropriately"
  - A <u>client</u> *invokes an operation* on a server; "remote invocation"
  - "Client" and "server" usually refer to processes, sometimes to objects, occasionally principals/users

The World Wide Web (WWW)

- System for publishing and accessing resources and services across the Internet
  - WWW is probably what >90% of non-techies think of as the Internet!
- Began at CERN in Switzerland in 1989 to share documents
- Uses idea of <u>hypertext</u>: non-linear ways to use a document via <u>links</u>
  - Hypertext has been around since 1945…
- The web is an <u>open system</u>: can be extended
  - Based on freely available standards for communication and documents
  - Can add new kinds of resources to the web
- Web is based on 3 technologies:
  - HyperText Markup Language (HTML)
  - Uniform Resource Locators (URLs)
  - HyperText Transport Protocol (HTTp)d

HyperText Markup Language (HTML)

- Used to specify
  - Text and images that make up contents of a web page
  - How these are laid out and formatted
- A simple but low-level language
  - Often not directly programmed but generated
- Contains structured items specified by <u>tags</u>
  - Headings: `<h1>, <h2>, …`
  - Paragraphs: `<p>`
  - Images: `<img…>`
  - Links: `<a href … >`
  - ….
- Stored on a web server

Uniform Resource Locators (URLs)

- Used to identify a resource so a browser can locate it
- Format: `scheme : scheme-specific-location`
- Scheme declares what type of URL this is
- Scheme-specific-location tells where that scheme can find it
- Examples
  - `mailto: bakken@eecs.wsu.edu`
  - `http://www.eecs.wsu.edu/~bakken`
  - `ftp://ftp.parc.xerox.com/Programs/ILU.exe`
  - Other schemes: `nntp`, `telnet`
- Extensible by
  - Adding a new scheme
  - Developing and disseminating <u>helper applications</u> or <u>plugins</u> for the scheme
- HTTP URL is most common…
  - `http://servername[:port][/pathNameOnServer][?arguments]`
  - Anchors — # — are part of HTLM spec., not URL spec.

HyperText Transfer Protocol (HTTP)

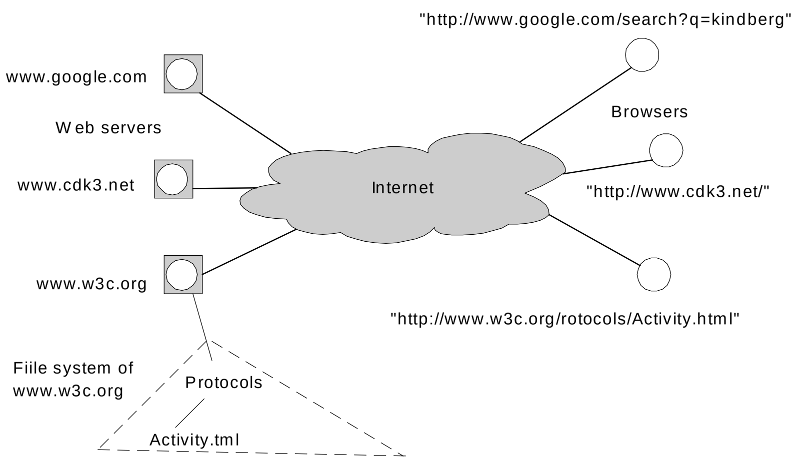
- HTTP is the protocol browsers and other clients interact with web servers
- Very low-level and dumb…. (version 1.0 anyway)
- Request-reply protocol
- Preferred content types (ones a browser can handle) sent with request
- One resource (html for the page, image, etc) per request
- Very simple access control
  - Configuration file to deny or allow access based on client's host or domain
  - Passwords

Advanced Features of the WWW

- Services and dynamic content
  - URL points to a program, not a file, that processes client's inputs
    - Often with input from a form
    - Often html is sent back for the client to present to the user
  - Program is often called a Common Gateway Interface (CGI)
- Downloaded code
  - JavaScript or Java applet to run on client machine
  - Can provide
    - Error checking locally before a request goes over the network
    - Much richer and quicker graphics than possible across web
- MetaData and the Web
  - Searching by an ASCII string is not always useful….
  - MetaData (data about data) is being developed and deployed
  - Resource Description Language standardized for this, not yet widely used
  - Semi-structured data (Prof. Curtis Dyreson)
- XML (later this course)
  - Meta-language for describing data
  - Helps make data portable between applications

WWW Example

Figure 1.4 Web servers and web browsers



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1. Introduction
2. Examples of Distributed Systems
3. Resource Sharing and the Web
4. **Challenges**
   1. **Heterogeneity**
   2. **Openness**
   3. **Security**
   4. **Scalability**
   5. **Failure Handling**
   6. **Concurrency**
   7. **Transparency**
5. Example Local vs. Remote Procedure Call

Heterogeneity

- Heterogeneity == variety or difference
- In DSs this is in a number of dimensions
  - Networks
  - Hardware
  - Operating Systems
  - Programming Languages
  - Different implementations of the same standard or protocol
- Dealing with this difference is very difficult!
- Middleware == a layer of software above the operating system which
  - Provides a programming abstraction (a higher-level building block) across the network
  - Masks the heterogeneity in above dimensions (some or all of them)
- Middleware examples
  - CORBA
  - DCOM/COM+
  - Java Virtual Machine (JVM)

Openness

- Openness == "the characteristic that determines whether the system can be extended and re-implemented in various ways"
- Key interfaces are published
- Hardware extensions: adding new computers to the DS
- Software extensions: adding new services or new implementations of existing services

Security

- Some information has high value to its owners (and others!)
- Dimensions of security
  - Confidentiality
  - Integrity
  - Availability
- Confidentiality
  - Protection of disclosure of information to unauthorized parties
  - I.e., lack of invalid reading of data
- Integrity
  - Protection against unauthorized alteration
  - I.e., lack of invalid writing of data
- Availability
  - Protection against valid users being able to access the data or service
  - I.e., lack of denial of service
- Denial of service attacks are an increasing problem
- Security of mobile code is crucial, too

Scalability

- System is scalable if it is still useable/effective with an increase in
  - Number of resources
  - Number of users
- Scalability challenge #1: controlling the cost of physical resources
  - Extending the system should be doable at reasonable cost
  - I.e, O(n)
- Scalability challenge #2: controlling the performance loss
  - The more resources, the more the cost to access one of them
  - But hopefully it can grown O(log n) at worst
- Scalability challenge #3: preventing software resources from running out
  - E.g,. 32-bit IP addresses
- Scalability challenge #4: avoiding performance bottlenecks
  - Centralized servers or "hot spots" in network do not scale
  - E.g., Domain Name Service (DNS) replicated and cached
- Scalability goal: design system so that system and existing application software do not need to change when growth occurs

Failure Handling

- Failures in a non-distributed system (a PC not networked) are often total failures (or can be treated as such)
- DS failures are often partial failures: some components fail while others remain in operation
- Technique #1: failure detection: Finding out one happened!
- Technique #2: failure masking: Hide or lessen impact of failure
  - Retransmit a message (redundancy in time)
  - Replicate the data (redundancy in space)
- Technique #3: failure toleration: write middleware and applications to explicitly deal with a partial failure (rather than ignoring the possibility)
- Technique #4: failure recovery: recover the state of the server after it has failed

Concurrency

- A DS has a lot of sharing happening (concurrently, not serially)
  - That is its *raison d'être*!
  - Sharing of applications
  - Sharing of servers
  - Sharing of low-level resources
  - ….
- Bottom line: any shared component must be written so that it operates correctly in a concurrent environment

Transparency

- Transparency == concealing distribution from the user and/or application
- Different kinds of transparencies:
  - Access transparency: local and remote resources can be accessed using an indentical operation
  - Location transparency: resources can be accessed without knowledge of their location
  - Concurrency transparency: several processes can operate concurrently using a shared resource or service without interference between them (or being aware of the concurrency in any other way)
  - Replication transparency: multiple copies can be deployed without the programmers or users having to be aware of it
  - Failure transparency: users and application programs can complete their activities despite hardware or software failures

Transparency (cont.)

- Different kinds of transparencies (cont.)
  - Mobility transparency: clients and systems resources can move within the system without users or applications being aware (or having to handle it)
  - Performance transparency: the system can be reconfigured to improve performance as loads vary, without the client or user having to be aware
  - Scaling transparency: the system and applications can expand in scale without the system structure or application programs being aware
- Note: middleware not only supports heterogeneity but also transparency
- Examples
  - GUI for file system (files and folders) which has same look and feel for local and remote files
  - Library for file operations where API is same for local and remote files
  - Library for file operations which makes you use ftp for remote files but procedure call for local ones
  - URLS
    - Location transparent?
    - Mobility trasparent?
    - Replication transparent?

Transparency (cont.)

- So, then, is transparency always
  - Feasable?
  - Desirable?
  - Free?
- Its always a tradeoff, usually against performance, and sometimes against other dimensions of transparency
- Understanding these tradeoffs is a key goal for this course!

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Example Local Call

Caller:
```
// declare and init stuff
x = new int [100];
Y = new util;
Flag = y.sort(x, 100);
```

Callee:
```
// declare and init stuff
Int util:sort(int [] a, int max) {
    // implementation of sort
    return status;
}
```

- Potential assumptions:
  - Procedure call conventions between caller ("client") and callee
  - In same address space (on same computer)
  - In same programming language (usually)
  - Written by same programmer (often, not always)
  - Can transfer data and control quickly, effectively in zero time
  - Both fail, or neither do (for the most part)
- None of these assumptions are true in a distributed system!

Example Remote Call

Caller:
```
// declare and init stuff
x = new int [100];
Y = new util.bind();
Flag = y.sort(x, 100);
…

// "proxy" or "stub"
// generated by middleware
int util:sort(int [] a, int max){
  // put a[], max into struct
  // send message with struct
  // receive message w/ struct
  // copy from struct to a[],
  // status
    return status;
}
```

Callee:
```
// declare and init stuff
int util_impl:sort(int [] a,
                   int max)        {
    // implementation of sort
    return status;
}

// "skeleton" generated
// by middleware compiler
  …
  // receive message with struct
  // copy from struct to a[], max
  flag = z.sort(a, max)
  // copy a[], flag into struct
  // send message with struct
  …
```


Many Assumptions do not Hold!

- Not a local procedure call, so need more help
- Not in same programming language (can't assume this)
- Not written by same programmer
- Not always in the same administrative domain
- Latency for transfer of control and data can be large and, worse, unpredictable
- Partial failures
- Membership of the system (the computers in its collection) can change
- Unreliable or insecure communication

- One more important item……