Chapter 2
Principles of Distributed Computing

Mastering Cloud Computing

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(based on materials from Paul Talaga)

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Elements of Distributed Computing

A distributed system is a collection of independent computers that appears to its users as a single coherent system - Tanenbaum et al

A distributed system is one in which components located at networked computers communicate and coordinate their actions by passing messages. - Coulouris et al

Message passing!!!!

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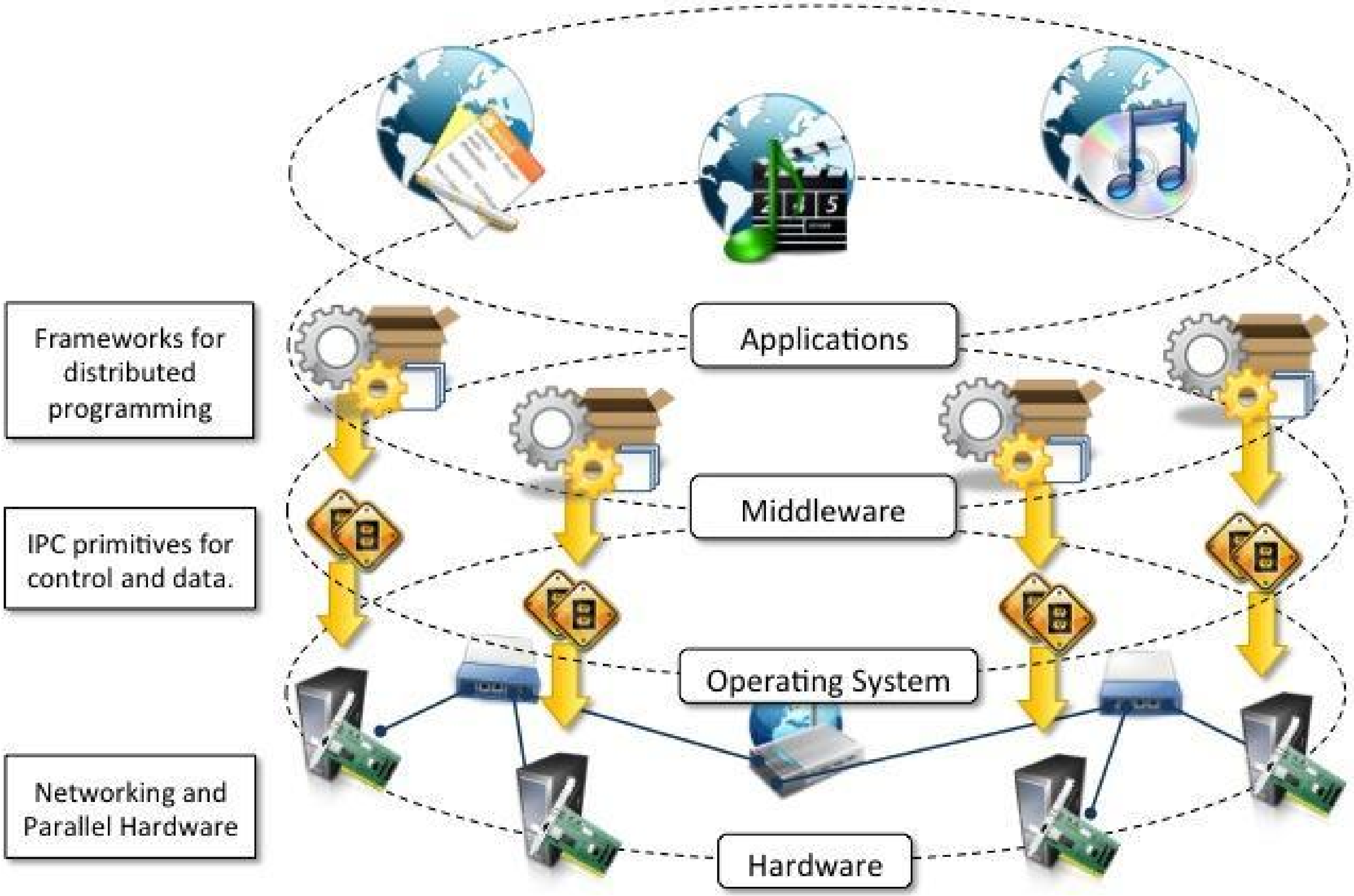
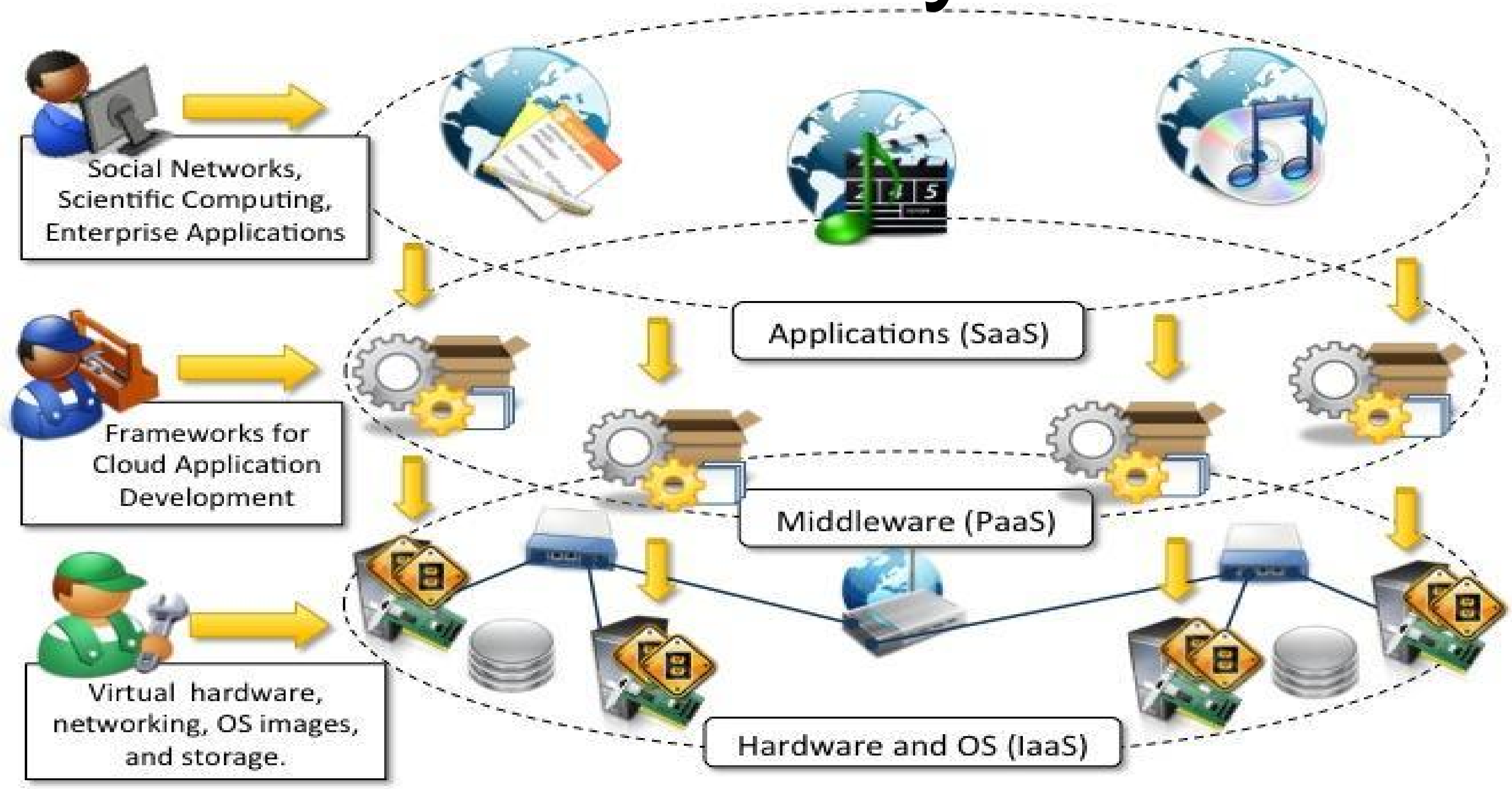
Distributed System Layers



Abstraction!

Cloud Computing as a distributed system



Middleware enables distributed computing

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Architectural Styles for Distributed Computing

Architectural styles are mainly used to determine the vocabulary of components and connectors that are used as instances of the style together with a set of constraints on how they can be combined.

Like design patterns for a program, but for an entire software system.

- Software architectural styles (software organization)
- System architectural styles (physical organization)

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Components and Connectors

- Component - software that encapsulates a function or feature of the system: programs, objects, processes.
- Connector - communication mechanism between components, can be implemented in a distributed manner.

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Software Architectural Styles

Category	Common Architectural Styles
Data-centered	Repository
	Blackboard
Data flow	Pipe and filter
	Batch sequential
Virtual Machine	Rule-based system
	Interpreter
Call and return	Main program and subroutine/top down
	Object-oriented systems
Independent components	Communicating processes
	Even systems

Data centered architectures

- Data is core, and access to shared data
  - Data integrity is goal
  - Ex: Gmail, Flickr, Google search
- *Repository style -*
  - central data structure - current state
  - independent components - operate on data
  - 2 subtypes:
    - database systems - components called & act on data
    - blackboard systems - data-structure is trigger - if/then or expert-system feel - updates itself

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Data-Flow architectures

- Availability of data controls, data flows through system
- For when data size exceeds storage capacities, or when long-term storage is not needed
- 2 styles:
  - Batch Sequential - sequence of programs - must wait for previous to finish before next
  - Pipe-and-Filter - sequence of programs, but FIFO queues to start processing before previous has finished.
  - Unix shell pipes and tools are good examples:
    - grep, sed, awk

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Batch Sequential vs. Pipe-and-Filter

Batch Sequential	**Pipe-and-Filter**
Coarse grained	Fine grained
High latency	reduced latency due to incremental processing
External access to input	localized input
No concurrency	Concurrency possible
Noninteractive	Awkward, but possible

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Virtual Machine architectures

- Abstract execution environment - rule-based systems, interpreters, command-language processors. 2 types:
- **Rule Based:**
  - Inference engine - AI - process control - network intrusion detection
  - Examples includes some of the Predix IoT analytics systems - https://github.com/PredixDev/predix-analytics-sample
- **Interpreter:**
  - Interprets pseudo-program - abstracts hardware differences away - Java, C#, Perl, PHP
  - Examples include the "*try it*" features in the Python/Java tutorials I gave you

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Call & Return architectures

- Components connected via method calls
- 3 styles:
  - **Top-Down**: imperative programming - tree structure - hard to maintain
  - **Object-Oriented**: coupling between data and manipulation operations - easier to maintain - method calling requires object - consistency an issue
  - **Layered Style**: Abstraction layers - modular design - hard to change layers
    - Ex: OS kernels, TCP/IP stack, web applications

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Independent Components Architectures

- Life cycles to components
- 2 styles:
  - Communicating Processes: good for distributed systems - concurrent - service based - IPC
  - Event Systems: components have data and manipulation, but add event registering/triggering - callbacks - like layered, but looser connections - hard to reason about correctness of interactions

Apple's ObjectiveC/C++ is a good example

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System Architectural Styles

- Describe physical layout
- 2 styles:
  - Client/Server
  - Peer-to-peer

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Client/Server

- Very Popular
- *request, accept (client)*
- *listen, response (server)*
- Suitable for many-to-one situations

Types of Clients

- Thin-client: (nearly) all data processing done on server (plain HTML)
  - presentation on client
  - app logic and data storage on server
- Fat-client: client processes and transforms data, server just gateway to access data (AJAX-like)
  - presentation and app logic on client
  - data storage on server

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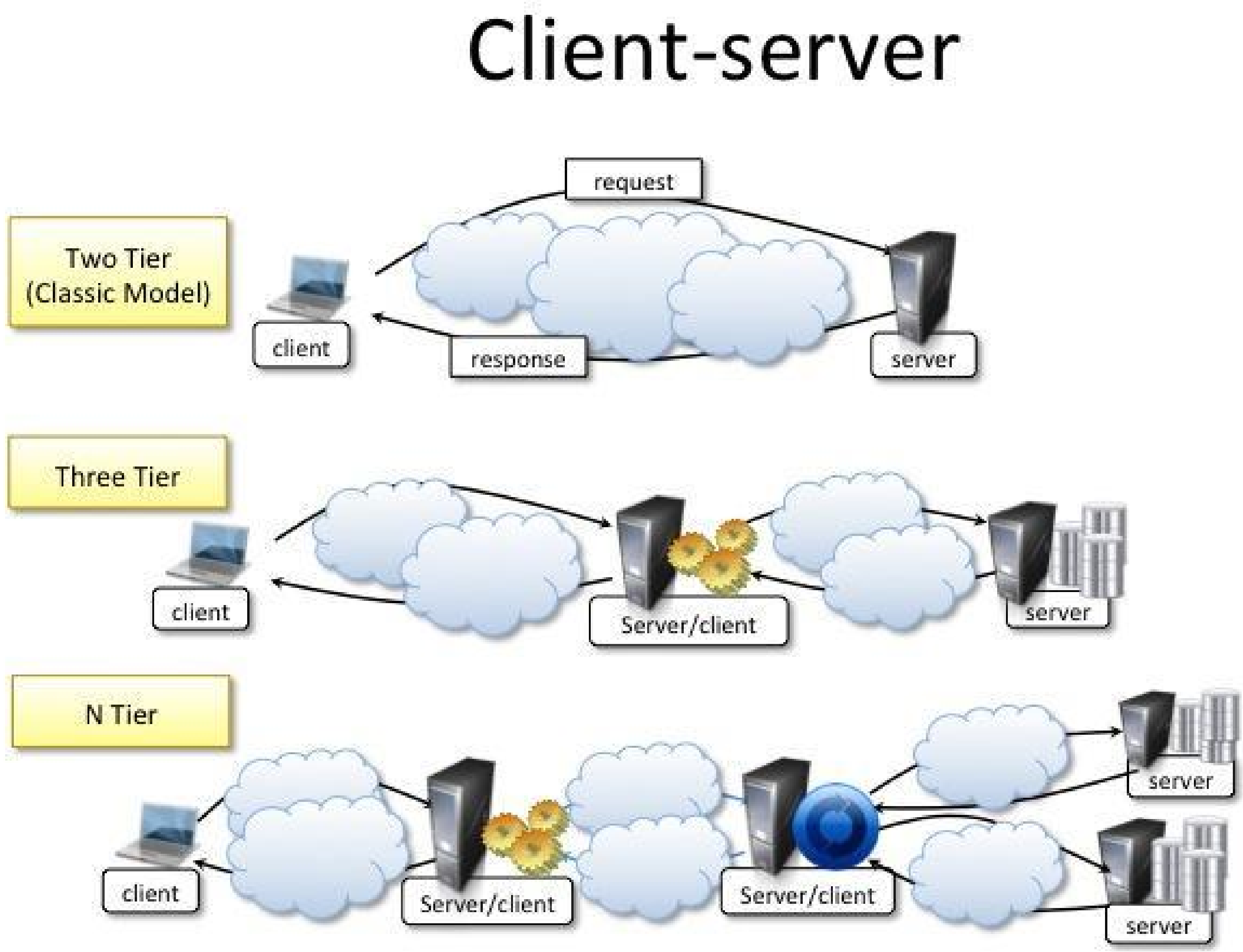
Layered Approach



Layer Types

- Two Tier
  - Pros: Easier to build
  - Con: Doesn’t scale well
  - Ex: Small dynamic web applications
- Three Tier/N Tier
  - Pros: Scales better (add more servers to layer)
  - Con: Harder to maintain
  - Ex: Medium-Large dynamic web applications

Peer-to-Peer

- Symmetric - everyone client and server
- Scales very well!
- Hard to build
- Used in data centers to distribute data!
- Ex: Gnutella, BitTorrent, Kazaa, Skype, Tor
- Multi-level roles possible: Kazaa

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