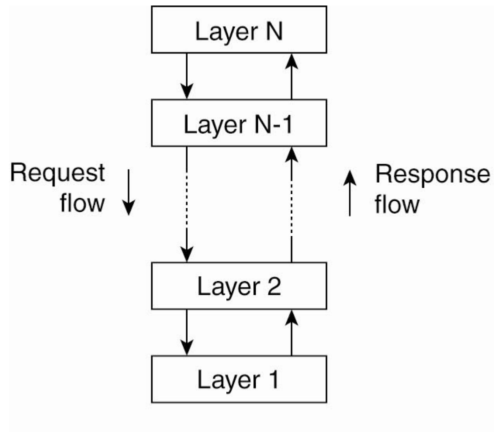
Distributed System Architectures

- Architectures for distributed systems
  - Module 1: Architectural styles
  - Module 2: Client-server architectures
  - Module 3: Decentralized, peer-to-peer, and other architectures

Module 1: Architectural Styles

- Important styles of architecture for distributed systems
  - Layered architectures
  - Object-based architectures
  - Data-centered architectures
  - Event-based architectures
  - Resource-based architectures

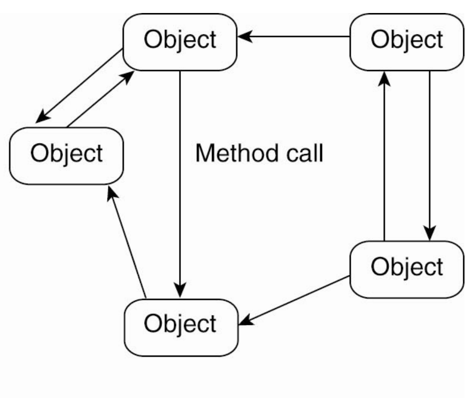
Layered Design



(a)

- Each layer uses previous layer to implement new functionality that is exported to the layer above
- Example: Multi-tier web apps

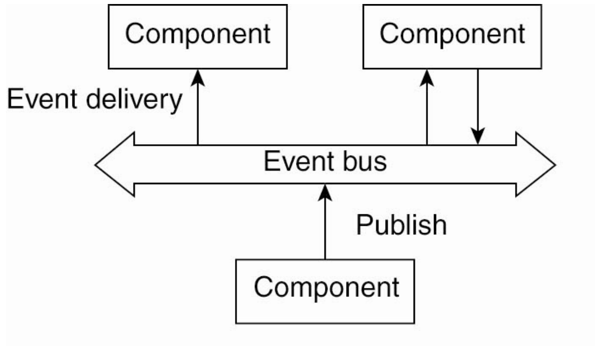
Object-based Architecture



(b)

- Each object corresponds to a components
- Components interact via remote procedure calls
  - Popular in client-server systems

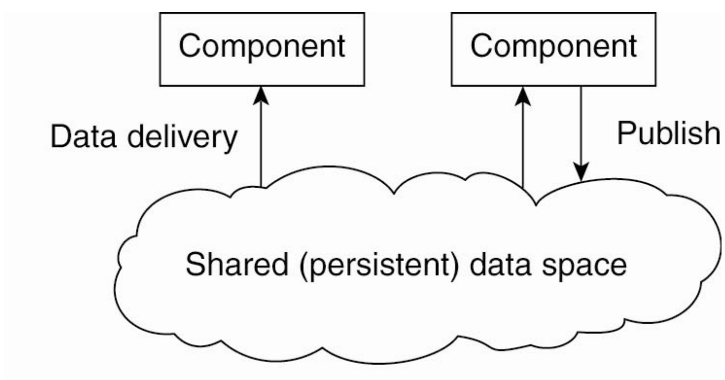
Event-based architecture



(a)

- Communicate via a common repository
  - Use a publish-subscribe paradigm
  - Consumers subscribe to types of events
  - Events are delivered once published by any publisher

Shared data-space



(b)

- "Bulletin-board" architecture
  - Decoupled in space and time
  - Post items to shared space; consumers pick up at a later time

Resource-oriented Architecture

- Example of ROA:Representational State Transfer (REST)
  - Basis for RESTful web services
  - Resources identified through a single naming scheme
  - All services offer same interface (e.g., 4 HTTP operations)
  - Messages are fully described
  - No state of the caller is kept (stateless execution)
  - Example: use HTTP for API
    - http://bucketname.s3.aws.com/objName
    - Get / Put / Delete / Post HTTP operations
  - Return JSON objects

{"name":"test.com","messages":["msg 1","msg 2","msg 3"],"age":100}

  - **Discuss**: Service-oriented (SOA) vs. Resource-oriented (ROA)

OOA vs. ROA vs. SOA

Attribute	Object-oriented	Resource-oriented	Service-oriented
Granularity	Object instances	Resource instances	Service instances
Main Focus	Marshalling parameter values	Request addressing (usually URLs)	Creation of request payloads
Addressing / Request routing	Routed to unique object instance	Unique address per resource	One endpoint address per service
Are replies cacheable?	No	Yes	No
Application interface	Specific to this object / class – description is middleware specific (e.g. IDL)	Generic to the request mechanism (e.g. HTTP verbs)	Specific to this service – description is protocol specific (e.g. WSDL)
Payload / data format description	Yes – usually middleware specific (e.g. IDL)	No – nothing directly linked to address / URL	Yes – part of service description (e.g. XML Schema in WSDL)

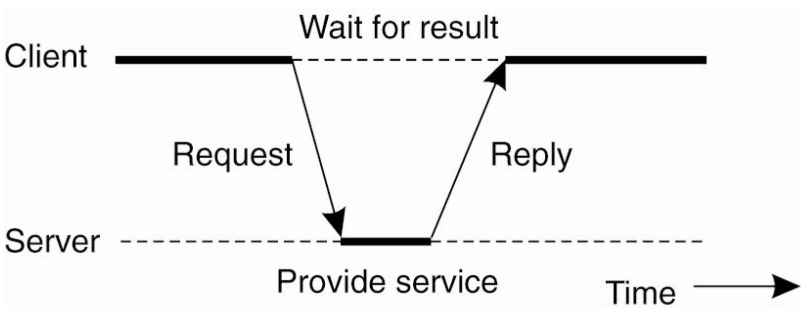
Courtesy: https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/3-arch-styles.pdf

End of Module 1

- Reminder: No laptop or phone use during class. Masks welcome.

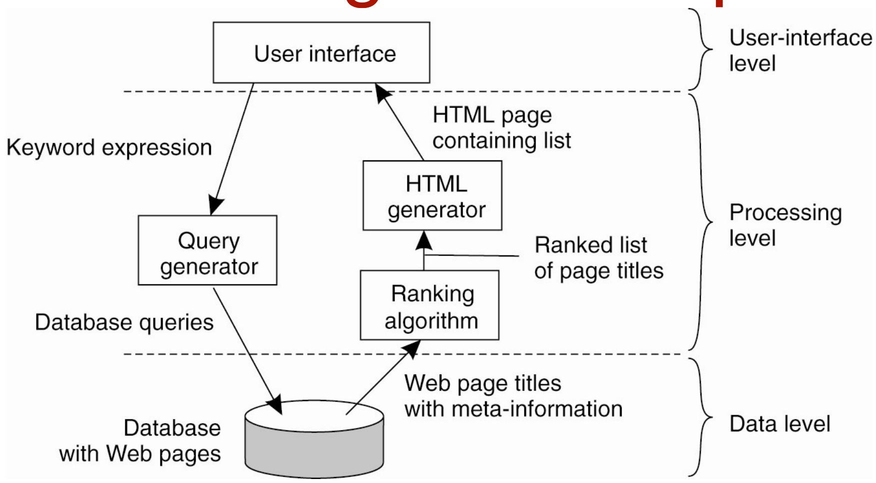
- Career Fair on Feb 28th

Module 2: Client-Server Architectures



- Most common style: client-server architecture
- Application layering
  - User-interface level
  - Processing level
  - Data level

Search Engine Example



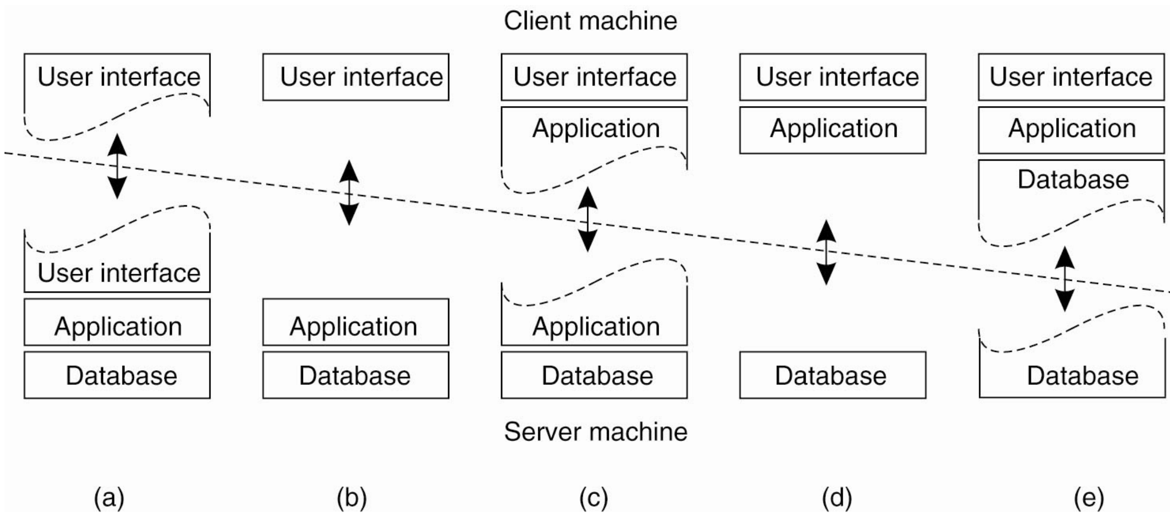
- Search engine architecture with 3 layers

Multitiered Architectures

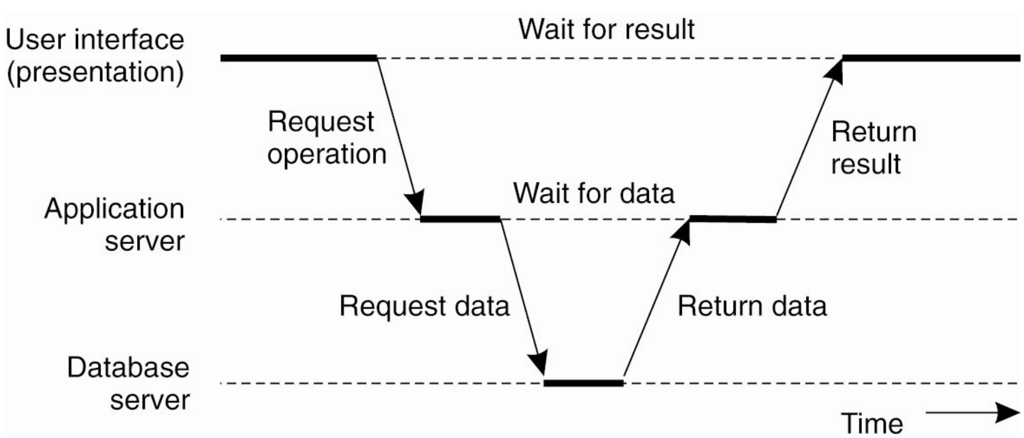
- The simplest organization is to have only two types of machines:
- A client machine containing only the programs implementing (part of) the user-interface level
- A server machine containing the rest,
  - the programs implementing the processing and data level

A Spectrum of Choices

- From browser-based to phone-based to desktop apps

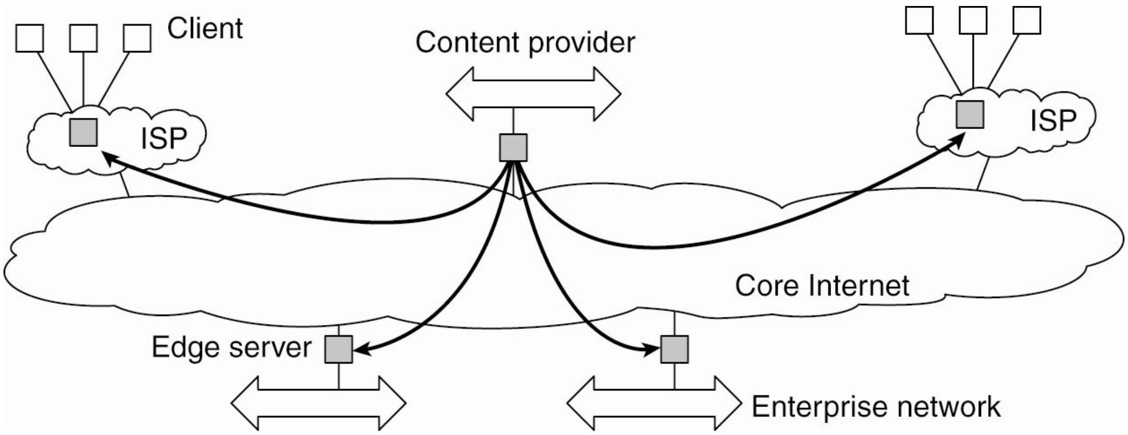


Three-tier Web Applications



- Server itself uses a "client-server" architecture
- 3 tiers: HTTP, J2EE and database
  - Very common in most web-based applications

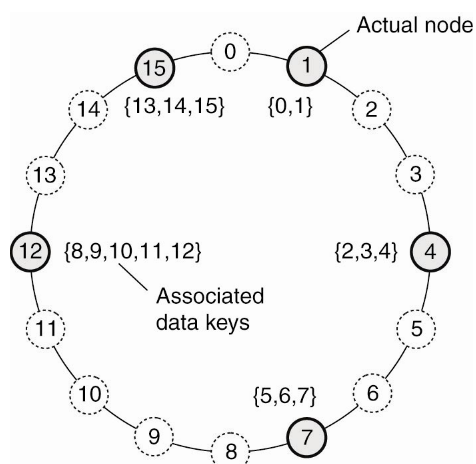
Edge-Server Systems



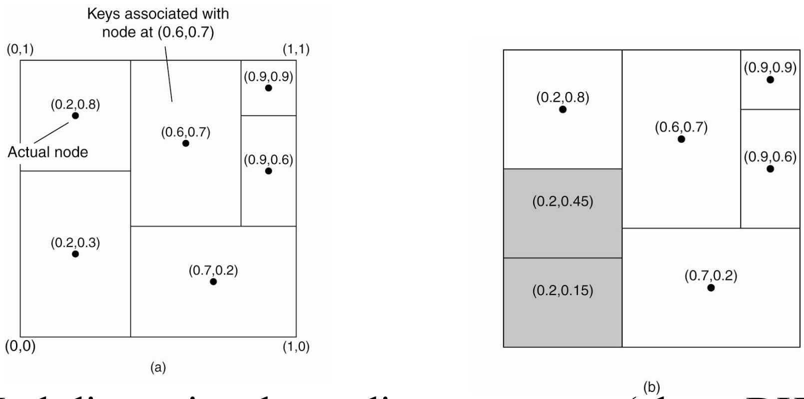
- Edge servers: from *client-server* to *client-proxy-server*
- Content distribution networks: proxies cache web content near the edge
- Evolved into edge computing model

Module 3: Decentralized Architectures

- Peer-to-peer systems
  - Removes distinction between a client and a server
  - Overlay network of nodes
- Chord: structured peer-to-peer system
  - Use a distributed hash table to locate objects
    - Data item with key *k* -> smallest node with id >= k
- P2P concepts with broader applicability:
  - **Distributed hash tables** (DHTs)
    - Distributed key-value stores, memcached, Apache Cassandra
  - Consistent Hashing



Content Addressable Network (CAN)

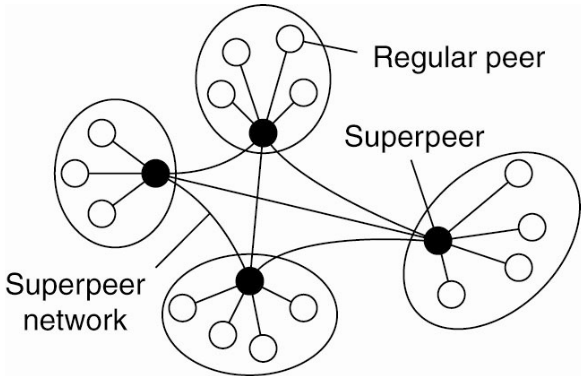


- CAN: d-dimensional coordinate system (also a DHT)
  - Partitioned among all nodes in the system
  - Example: [0,1] x [0,1] space across 6 nodes
    - Every data item maps to a point
    - Join: pick a random point, split with node for that point
    - Leave: harder, since a merge may not give symmetric partitions
- Beyond P2P: CAN => Information-centric networking (ICN), Named data networking (NDN)

Unstructured P2P Systems

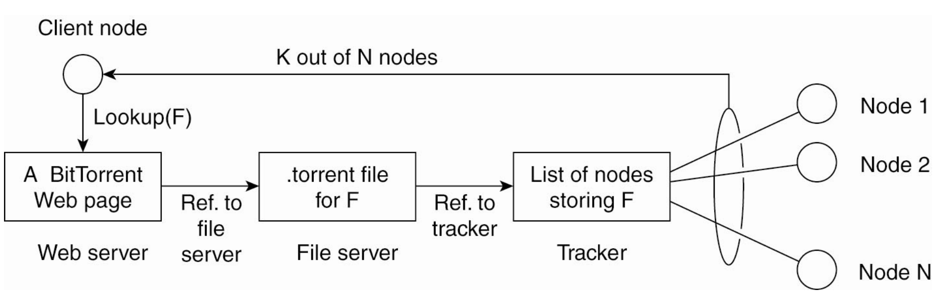
- Topology based on randomized algorithms
  - Each node pick a random set of nodes and becomes their neighbors
    - Gnutella
  - Choice of degree impacts network dynamics

SuperPeers



- Some nodes become "distinguished"
  - Take on more responsibilities (need to have or be willing to donate more resources)
  - Example: Skype super-peer in early Skype

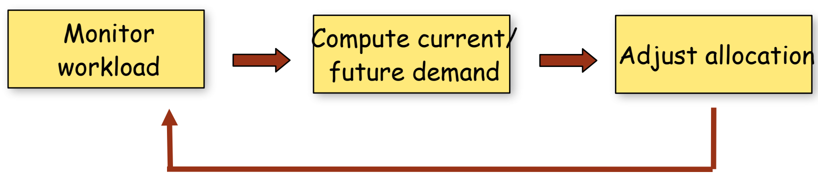
Collaborative Distributed Systems



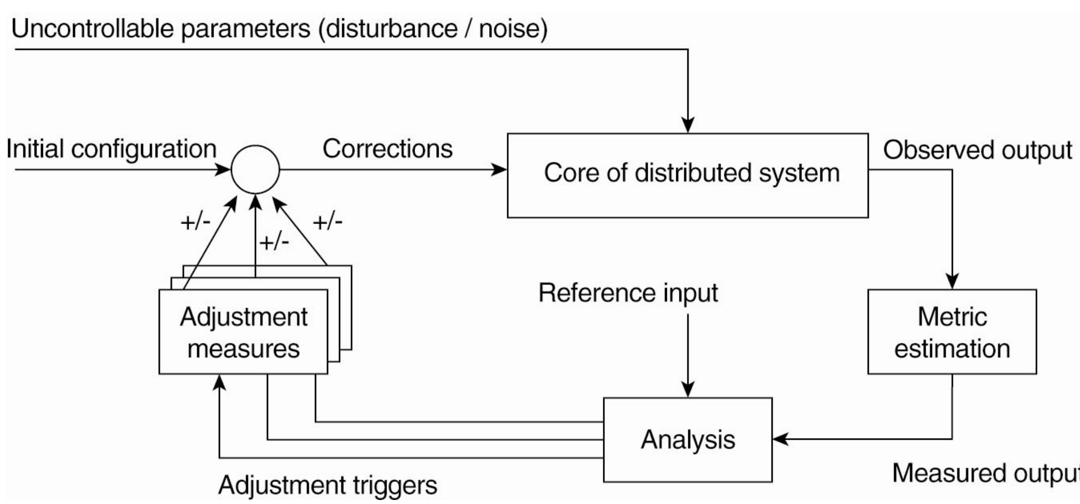
- BitTorrent: Collaborative P2P downloads
  - Download chunks of a file from multiple peers
    - Reassemble file after downloading
  - Use a global directory (web-site) and download a .torrent
    - .torrent contains info about the file
      - Tracker: server that maintains active nodes that have requested chunks
      - Force altruism:
        - » If *P* sees *Q* downloads more than uploads, reduce rate of sending to Q

Autonomic Distributed Systems

- System is adaptive - self-managing systems
  - Monitors itself and takes action autonomously when needed
    - Autonomic computing, self-managing systems
- Self-*: self-managing, self-healing
- Example: automatic capacity provisioning
  - Vary capacity of a web server based on demand



Feedback Control Model



- Use feedback and control theory to design a self-managing controller
  - Can also use machine learning or reinforcement learning