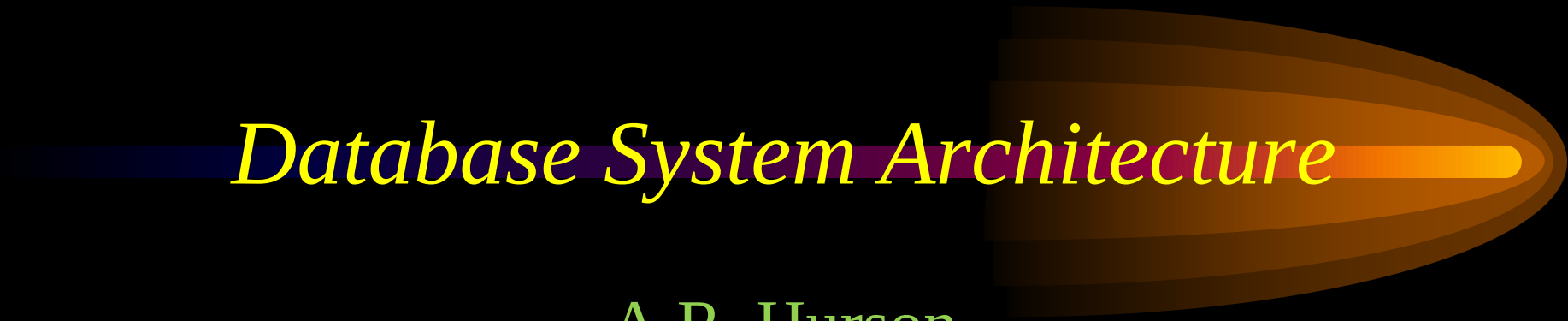
CS5300
Database Systems



Database System Architecture

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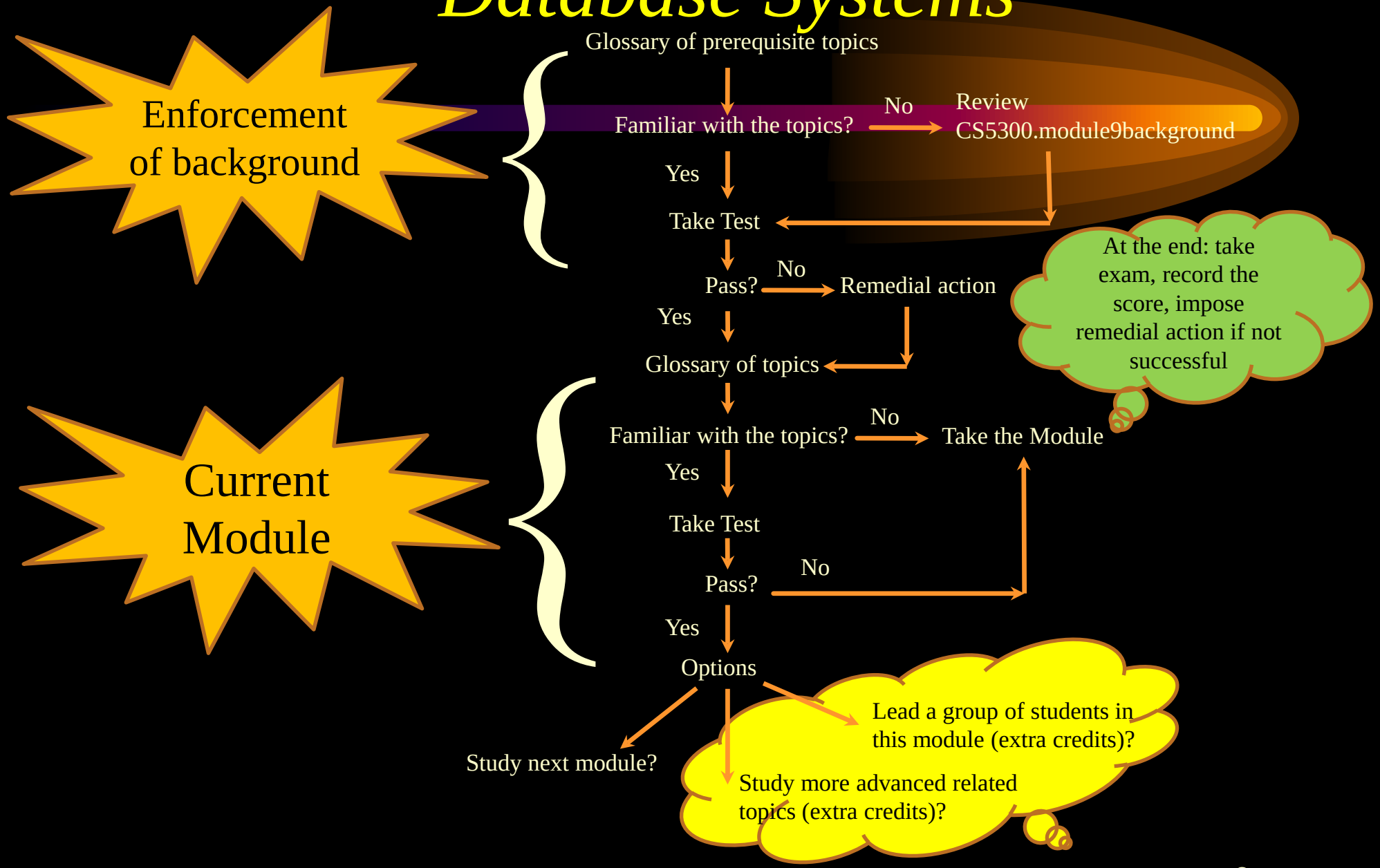
Database Systems

Note, this unit will be covered in three lectures. In case you finish it earlier, then you have the following options:

1) Take the early test and start CS5300.module10
2) Study the supplement module (supplement CS5300.module9)
3) Act as a helper to help other students in studying CS5300.module9

Note, options 2 and 3 have extra credits as noted in course outline.

Database Systems



Database Systems

- You are expected to be familiar with:
  - Centralized database configuration
- If not, you need to study CS5300.module9.background

Database Systems

- In this module, we will:
  - Define a simple database space,
  - Base on the parameters of this space, define:
    - Centralized data bases,
    - Client-server environment,
    - Peer-to-peer configuration,
    - Distributed databases, and
    - Parallel databases

Database Systems

- Different parameters can be used to classify the architecture of data base systems.
- We classify data base systems along the following three parameters:
  - Physical infrastructure
  - Services
  - Distribution

Database Systems

- Physical infrastructure
  - This dimension refers to the underlying platform composed of access devices (homogeneous/heterogeneous) interconnected through different communication medium:
    - Processing devices
      - Powerful Machines
      - Portable Devices
    - Network Architecture
      - Land-based Connection
      - Wireless Connection

Database Systems

- Services
  - Along this dimension we can distinguish two approaches:
    - There is no distinction between services,
    - Distinction between User processes and Data Processes.
  - For example, in a client-server model, some tasks are executed on the server system and some tasks are executed on client systems.

Database Systems

- Distribution
  - Along this dimension we can distinguish :
    - Distribution of data
    - Distribution of control, and
    - Distribution of processes

Database Systems

- Physical infrastructure
  - As noted earlier, two elements constitute this dimension;
    - Underlying computing platform, and
    - The communication medium that allows computers to communicate with each other.

Database Systems

- Physical Infrastructure: Networking
  - Networking represents the interconnectivity among the elements of the system. It also shows the division of work.

Database Systems

- Physical Infrastructure: Parallelism
  - Parallelism within a system allows activities to be sped up — faster response time, higher through put. Note, here we used term “parallelism” as a generic term that refers to the ability of executing more than one tasks at a time, also note that, we did not define the granularity of the task at this point.
  - Requests can be processed in a way that exploits the parallelism offered by the underlying system.

Database Systems

- Increased use of parallelism and data/processing distribution are the important trends in database design and implementation. There are several motivations for this:
  - Performance,
  - Distributed access to data,
    - Increased availability,
    - Increased reliability.

Database Systems

- Performance metrics
  - Response Time (Execution time, Latency) – The time elapse between the start and the completion of an event.
  - Throughput – The number of tasks that can be completed during a given time interval.

Database Systems

- Performance metrics
  - Scaleup – Handling large task by increasing the degree of parallelism. It is the ability to process larger tasks in the same amount of time by providing more resources.
  - Speedup – Running a task in less time by increasing the degree of parallelism.

$$S = \frac{\text{Execution time on Original Machine}}{\text{Execution time on Larger Machine}}$$

Database Systems

- Performance metrics
  - Power Consumption – Becomes an important performance metric when we use mobile wireless access devices.
  - Network Connectivity – Becomes of interest when connectivity is through wireless medium.
  - Data reliability and integrity – Becomes even more of concern at the presence of mobility and wireless communication.

Database Systems

- Distribution
  - Along this dimension we can distinguish distribution of:
    - Data,
    - Processing, and
    - Control

    spanning over multiple geographically separated sources.
  - Distribution of control is also referred to as the autonomy.
  - Data resides where it is generated or needed most:
    - Distributed data should be accessible by other sites.
    - Data distribution also implies data duplication/data replication.

Database Systems

- Centralized database systems
  - Centralized database systems are those that run on a single computer platform and do not interact with other computer systems.
  - The underlying platform could range from a single-user database system running on personal computer to high-performance database system running on high-end server systems.

Database Systems

- Centralized database systems
  - Within the scope of a centralized database systems we distinguish two configurations:
    - Single-user configuration
    - Multi-user configuration
  - Database systems designed for single-user configuration do not provide many facilities needed for a multi-user system – e.g., concurrency control, security, privacy.

Database Systems

Client-Server topology

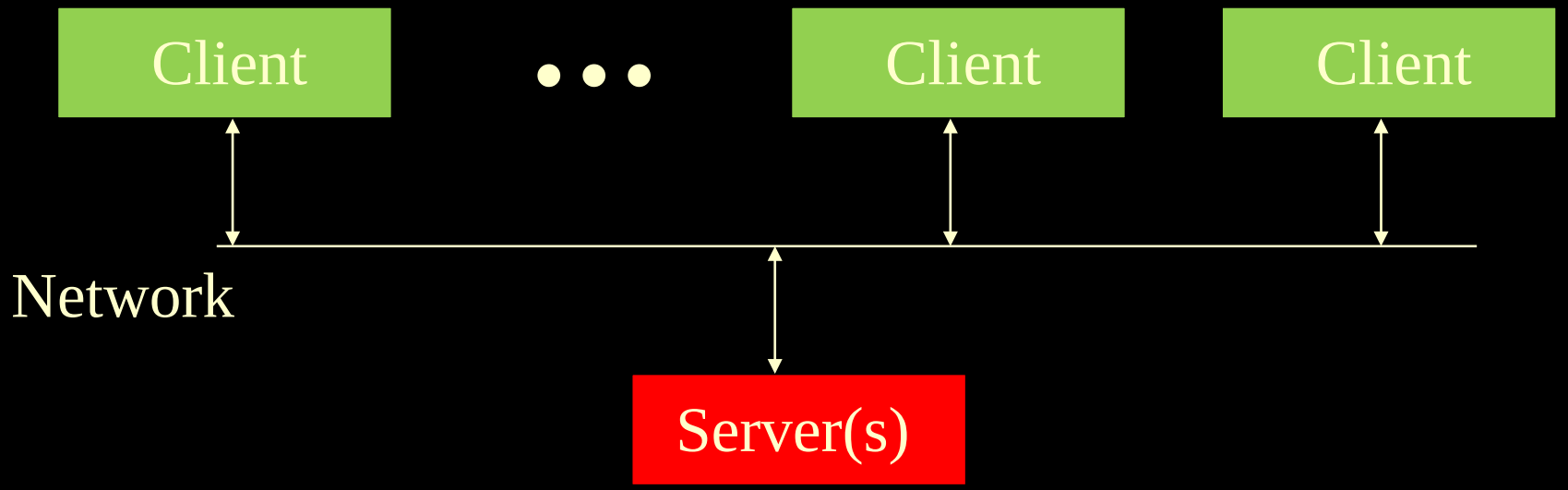
- Client-Server topology is the direct result of the advances in technology and a step towards distributed topology.
- It is a two-level topology based on a simple general idea: distinguish the needed functionalities and divide them into two coarse groups:
  - Server functions (The back end functions) – Query processing, Query optimization, concurrency control, recovery.
  - Client functions (The front end functions) – Report writer, Graphical User Interface facilities.

Database Systems

- Client-Server topology
  - In comparison to the centralized configuration:
    - The personal computer (Client) assumes the user-interface functionality.
    - Centralized system (Sever) satisfies requests generated by the clients.

Database Systems

- Client-Server topology
  - Client-Server topology has functionality split between a server and multiple clients.



Database Systems

- The client parses a query and decomposes it into a number of independent site queries. Each site query is sent to the appropriate server site.
- Each server processes the local query and sends the result to the client site.
- The client site combines the results of the sub-queries to generate the final result.

Database Systems

- Client-Server topology
  - Popularity of this topology is due to many factors, including:
    - Simplicity of implementation – distinct separation of functionality,
    - Higher degree of hardware utilization at the server side, and
    - Offering a user friendly environment.

Database Systems

- Summary (last lecture)
  - Database space
  - Performance metrics
  - Centralized Databases
  - Client-server platform
- Read Database System Architecture — A Walk through Time: From Centralized Platform to Mobile Computing (Keynote Address -ISSADS05)

Database Systems

- Client-Server topology
  - It can be further grouped into:
    - Multiple client-single server, and
    - Multiple client-multiple server
      - A client is communicating with a unique "home server", or
      - A client manages its communication to the appropriate server(s).

Database Systems

- Client-Server topology
  - Server system can be categorized as:
    - Transaction Server – thin client, and
    - Data Server – fat client

Database Systems

- Choice between thick client *and* thin client
  - The very same application may run at many client sites,
  - Large amount of trust is required between the server and the client,
  - Scalability:
    - number of clients,
    - number of databases.
  - Trend of technology (discussion and justification).

Database Systems

- Client-server topology – Transaction servers
  - A typical transaction server consists of multiple processes accessing data in shared memory:
    - Server processes – these are processes that receive user queries, execute them, and send the result back.
    - Lock manager process – this process implements lock manager functionality, lock grant, lock release, and deadlock detection.
    - Database writer process – These are processes that output modified buffer blocks back to disk.

Database Systems

- Client-server topology – Transaction servers
  - Log writer process – this process outputs log records from the log record buffer to a stable storage.
  - Checkpoint process – this process performs periodic checkpoints.
  - Process monitor process – this process monitors other processes and if any of them fails, takes recovery actions for the process.

Database Systems

- Client-server topology – Transaction servers
  - The shared memory contains all shared data:
    - Buffer pool
    - Lock Table
    - Log buffer
    - Cached query plans
  - Since multiple server processes may access shared memory, mutual exclusion must be ensured on the lock table.
  - If a lock cannot be obtained, the lock request code keeps monitoring the lock table to check when the lock has been granted.

Database Systems

- Client-server topology – Data Servers
  - This configuration is used, where:
    - There is a high-speed connection between clients and server (why?) – Local area network,
    - The client machines are powerful, and
    - Task being executed are computation intensive.
  - Note, this configuration requires full back end functionality at the client side.

Database Systems

- Client-server topology – Data Servers
  - In this configuration communication cost between clients and server is not much higher than memory references in transaction server configuration. This brings out several interesting issues:

Database Systems

- Client-server topology – Data Servers
  - Data granularity – coarse vs. fine granularity
    - For communication
    - For locking
  - Data Caching – Cache coherency
  - Lock Caching

Database Systems

- Client-server topology – Data Servers
  - Data Granularity – Size of data communicated between clients and server
    - Communication overhead of message passing justifies coarse data granularity. Specially, in applications with high data locality.
    - Coarse data granularity may have adverse effect on throughput – Lock on a coarse data block may block other clients, unnecessarily.

Database Systems

- Client-server topology – Data Servers
  - Data Caching – data that are transferred to a client can be cached for future use. As a result, successive transactions at the same client may be able to make use of the cached data.
  - Data Caching brings out the issue of cache coherency. As a result, it should be guaranteed that all copies of the same data items are synchronized.

Database Systems

- Summary
  - Parameters influencing architecture of a database.
  - Performance metrics
  - Centralized databases.
  - Client/server models
    - Thin client
    - Fat client
    - Comparative analysis

Database Systems

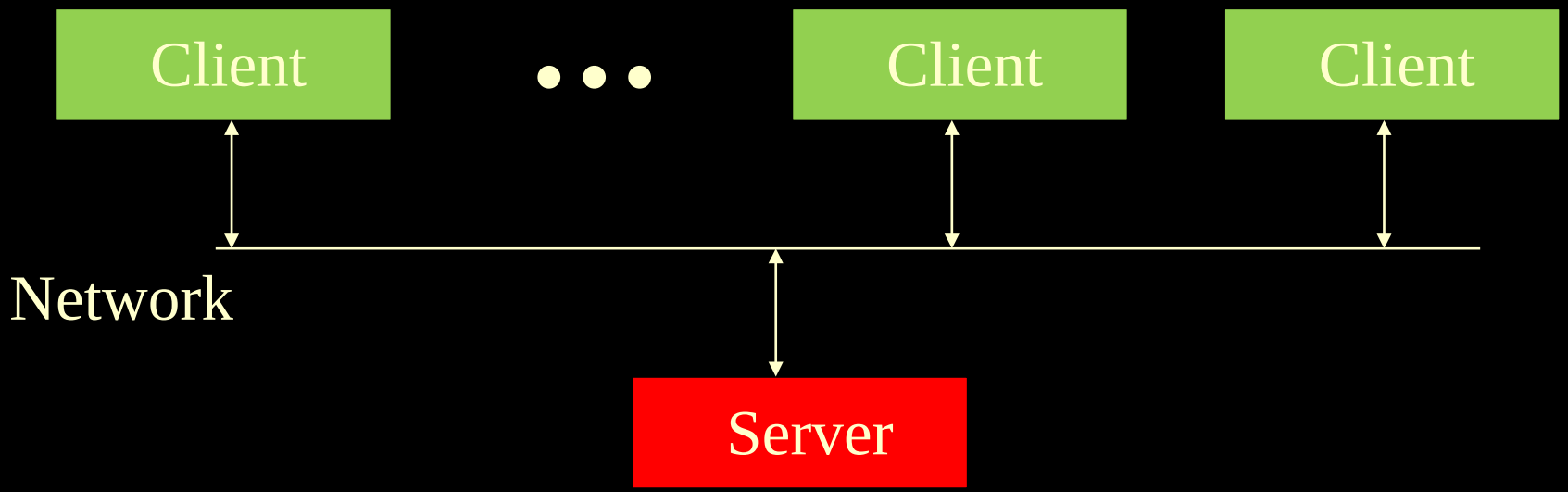
- Single-tier
- Two-tier client-server architecture
- Three-tier client-server architecture

Database Systems

- Single-tier
  - Application typically runs on a main frame and users access it through “dumb terminals”.
  - It is easy to maintain by a central administrator, however, it is not scalable.

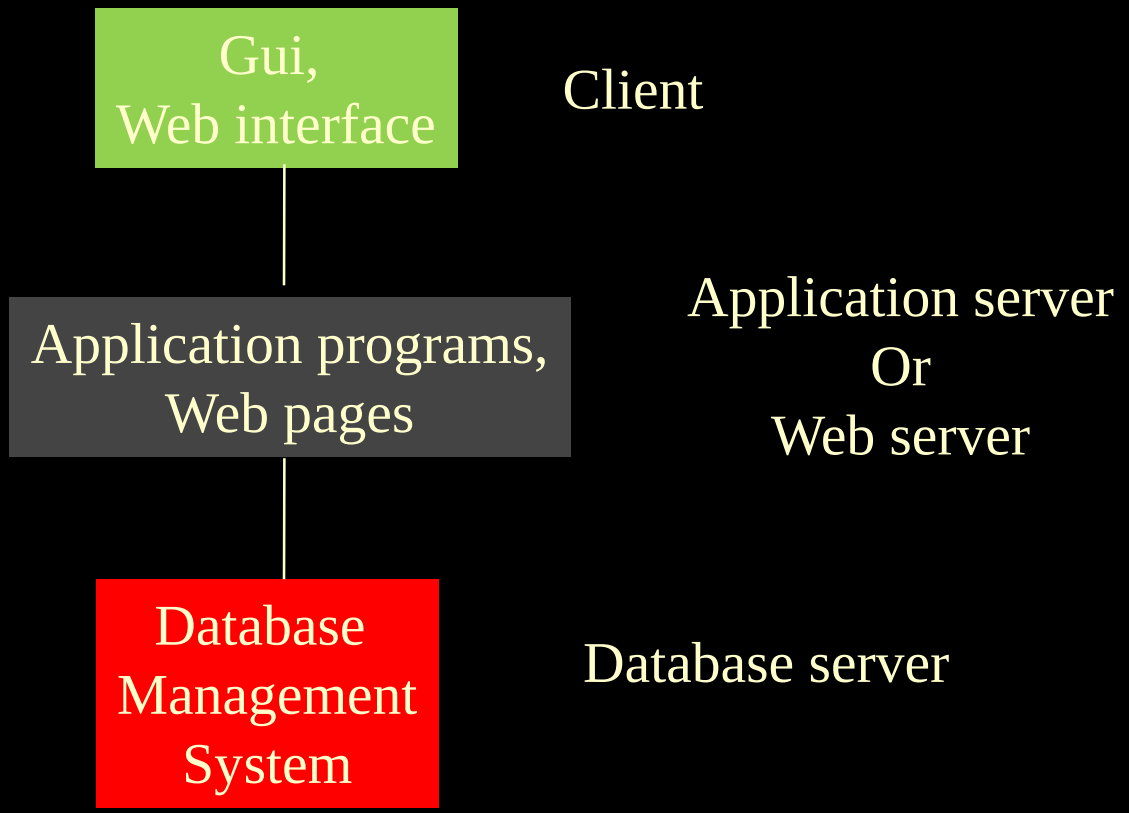
Database Systems

- Two-tier client-server architecture
  - At the client site then there is no “dumb terminal”.



Database Systems

- Three-tier client-server architecture



Database Systems

- Three-tier client-server architecture
  - Client tier (presentation tier) – natural interface with user (thin client),
  - Middle tier – application logic executes here,
  - Database server tier (Data management tier) – data base management system resides.

Database Systems

- In an internet shopping scenario:
  - The customer should be able to browse the catalog and make a purchase,
  - Before the sale, the customer has to go through several steps:
    - Add an item into shopping cart,
    - Provide shipping address and credit card number,
    - Confirm the sale.
    - Controlling the flow among these steps and remembering already executed steps is done at the middle tier level.

Database Systems

- Advantages of three-tier architecture:
  - Accommodates heterogeneous systems,
  - Supports thin clients (technology),
  - Allows integrated data access,
  - It is scalable with the number of clients.

Database Systems

- Peer-to-Peer topology
  - This is the direct evolution of the client-server topology. Note that in a Client-server topology functionality is split into user processes and data processes.
  - User processes handle interaction with the user and data processes handle interaction with data.
  - In a Peer-to-Peer topology, one should expect to find both class of processes placed on every machines.

Database Systems

- Peer-to-Peer topology
  - From a data logical perspective, Client-server topology and Peer-to-Peer topology provide the same view of data — data distribution transparency. The distinction lies in the architectural paradigm that is used to realize this level of transparency.

Database Systems

- Parallel Systems
  - Parallel configurations are aimed at improving the processing and I/O speeds by using multiple processing units and I/O devices in parallel.
  - Distribute task among several processors at a finer granularity, say relative to client-server paradigm.
  - Within the scope of parallelism, we can talk about:
    - Coarse grain parallelism
    - Fine grain parallelism

Database Systems

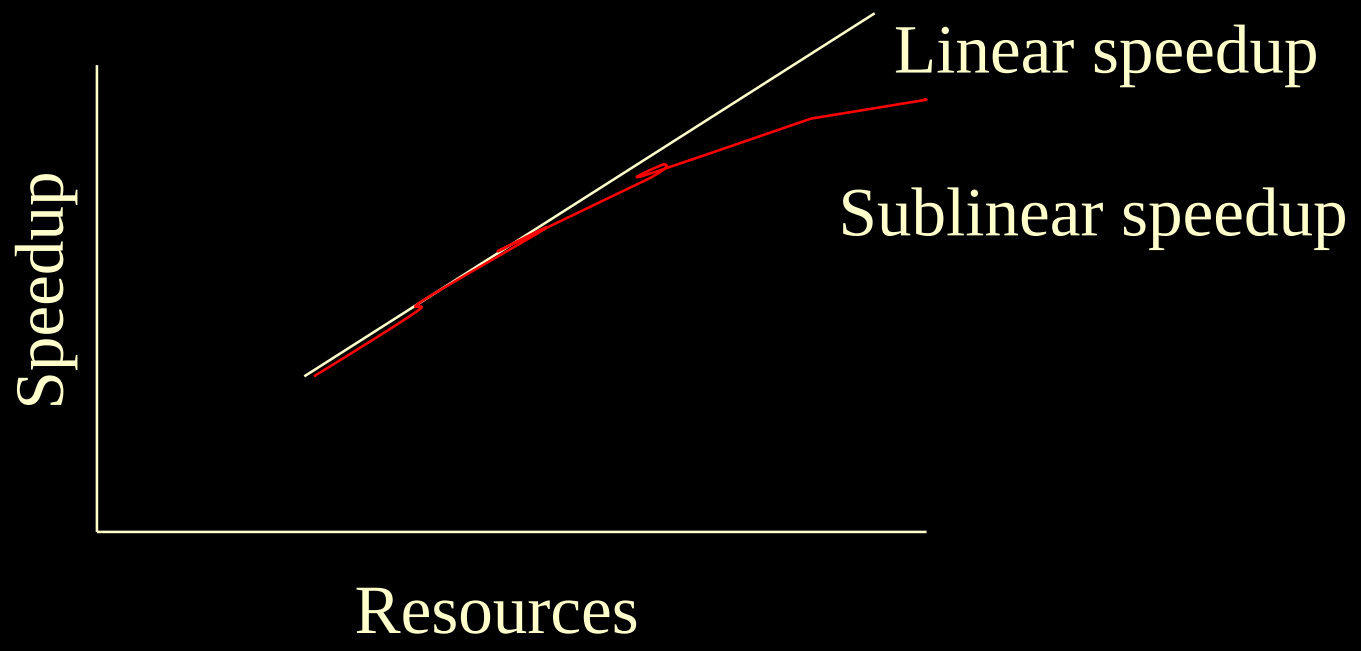
- Parallel Systems
  - Increase throughput by processing many small tasks in parallel,
  - Decrease response time by breaking out a task into subtasks and parallel execution of subtasks.

Database Systems

- Questions
  - Define linear speedup.
  - Define sublinear speedup.
  - Define linear scaleup.
  - Define sublinear scaleup.
  - Is there any relationship between speedup and scaleup?
  - For a database application, which one is of more important speedup or scaleup.

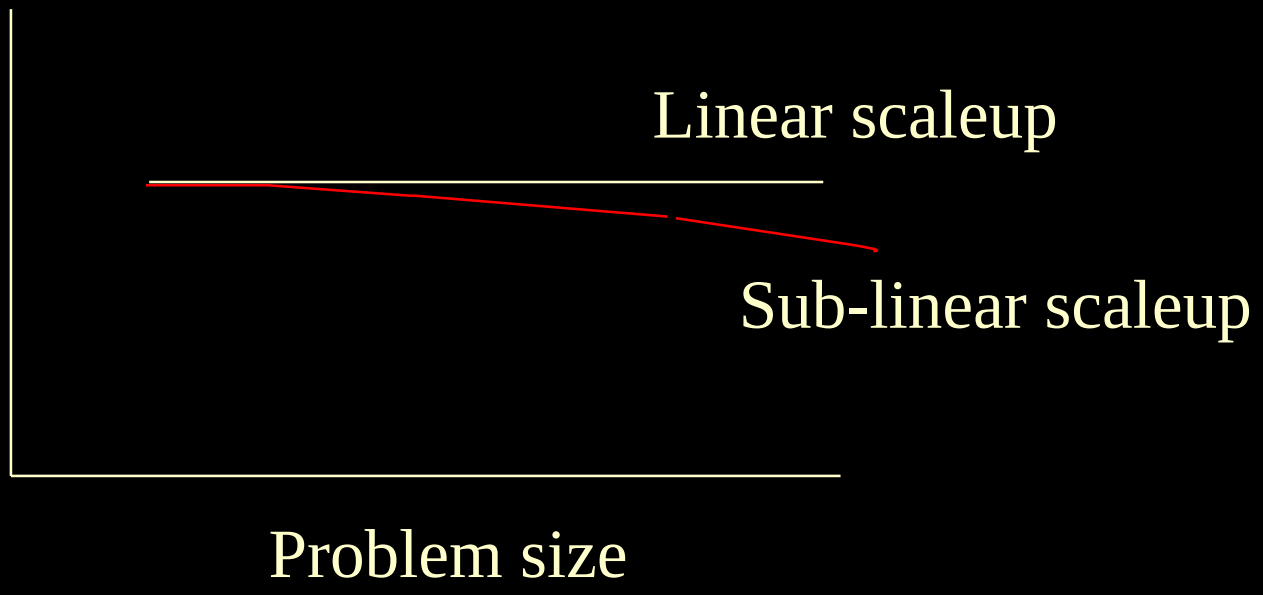
Database Systems

- Parallel Systems



Database Systems

- Parallel Systems

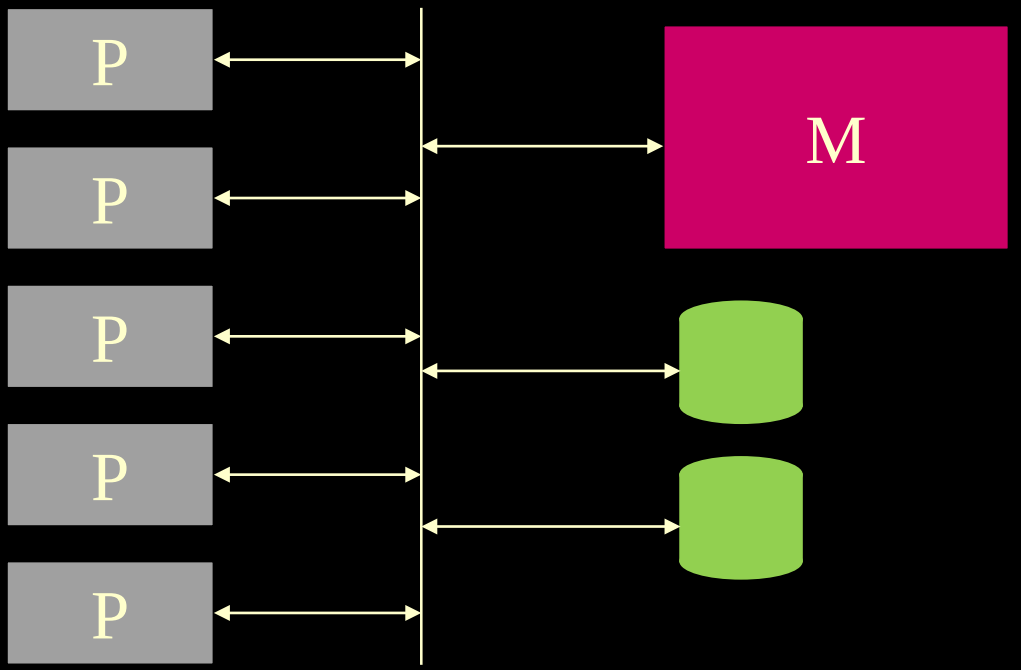


Database Systems

- Parallel Systems
  - There are several architectural models for parallel systems:
    - Shared Memory (tightly coupled)
    - Shared Disk (loosely coupled)
    - Shared nothing
    - Hierarchical

Database Systems

- Parallel Systems – Shared Memory
  - All processors share a common global memory

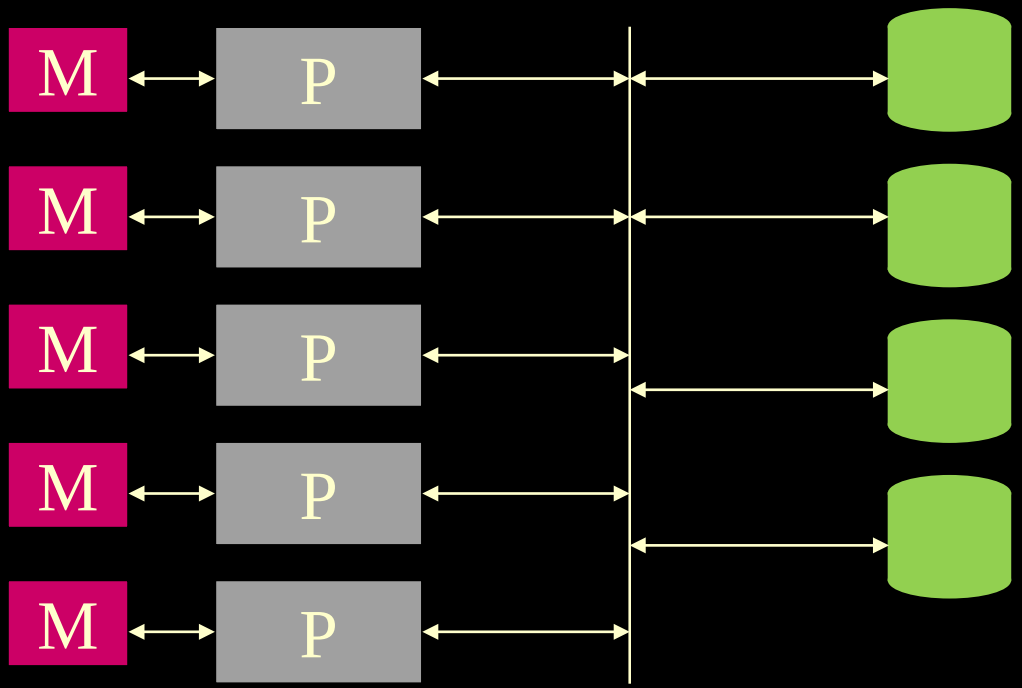


Database Systems

- Parallel Systems – Shared Memory
  - Processors and disks have access to a common memory, via a bus or an interconnection network.
  - In general, each processor has a private cache.
  - Efficient communication between processors, via common memory address space.
  - Not scalable, communication network becoming the bottleneck.

Database Systems

- Parallel Systems – Shared Disk
  - All processors share a common set of disks



Database Systems

- Parallel Systems – Shared Disk
  - Processors have direct access to all disks via an interconnection network.
  - Each processor has its own private memory.
  - Relative to shared memory organization, this configuration offers:
    - More fault tolerance and
    - Higher memory bandwidth
  - Disk subsystem can become more fault tolerance and faster by application of RAID architecture.

Database Systems

- Parallel Systems – Shared Disk
  - System is more scalable than the shared memory configuration.
  - Degree of scalability is limited due to the bottleneck at the interconnection network between disk subsystem and processor.
  - Communication among processors is slow – message passing.

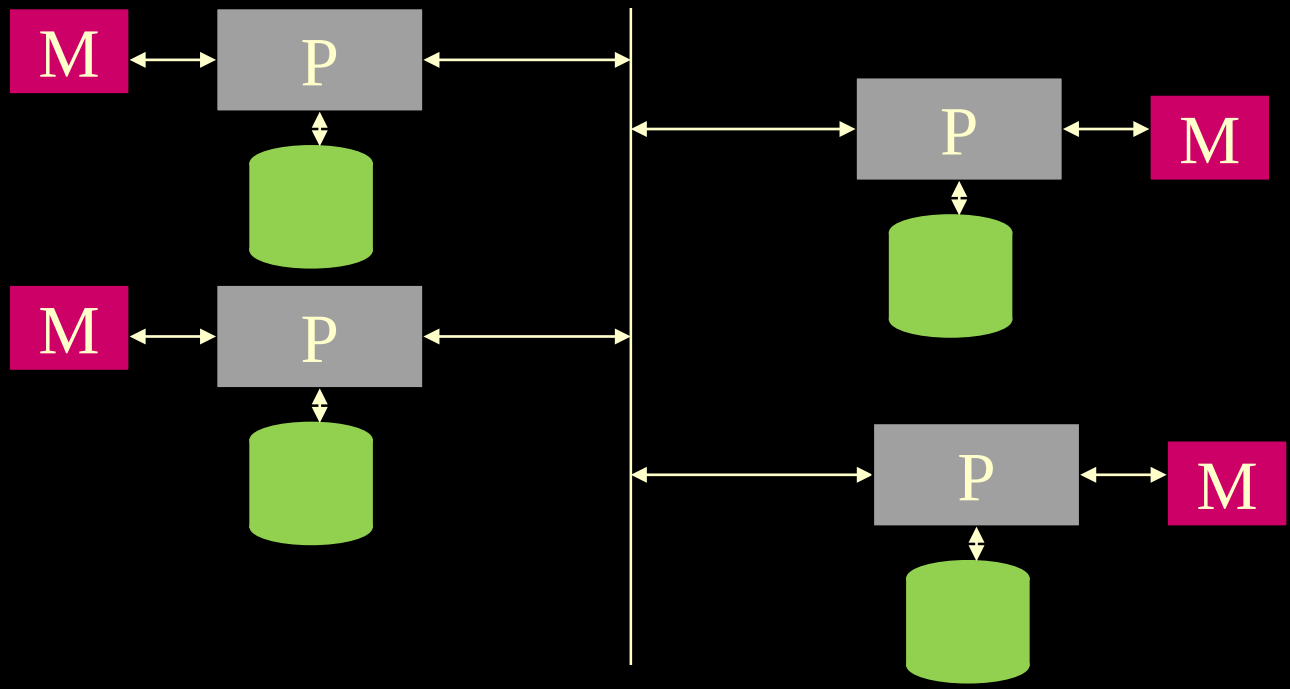
Database Systems

- Summary (last lecture)
  - Different classes of client-server topology
  - Peer-to-Peer topology
  - Parallel systems
    - Shared Memory
    - Shared Disk
  - Final exam

Database Systems

Parallel Systems – Shared Nothing

- The processors share neither a common memory nor common disks

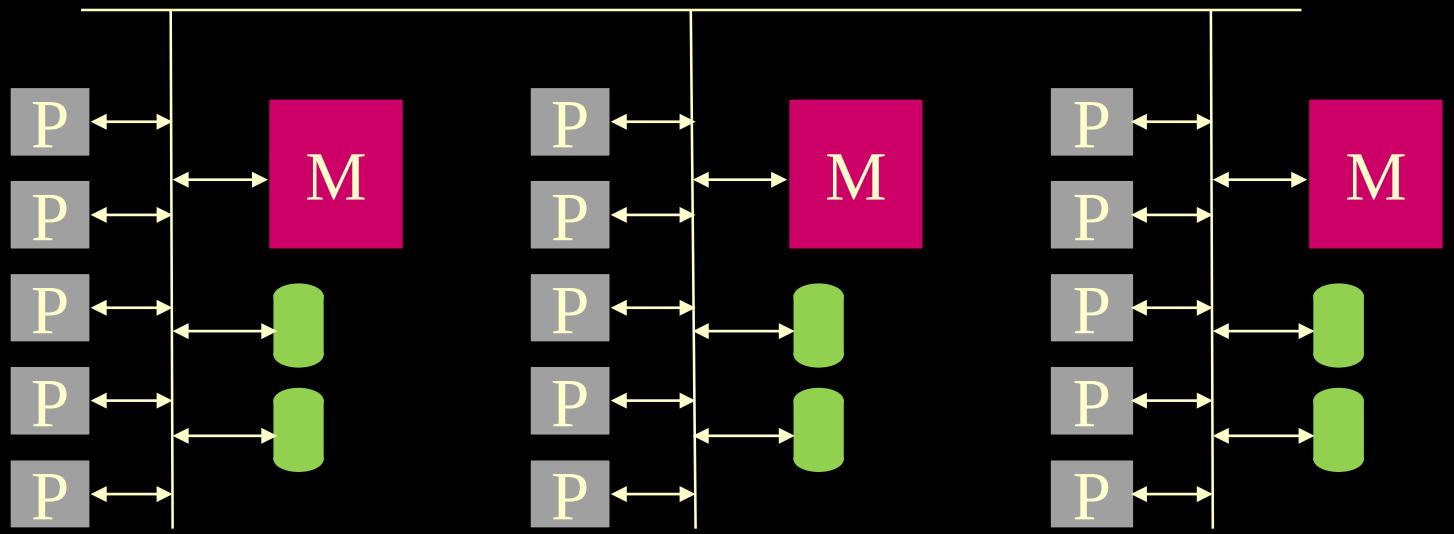


Database Systems

- Parallel Systems – Shared Nothing
  - This configuration is scalable.
  - Communication among processors and non-local disk accesses are expensive.

Database Systems

- Parallel Systems – Hierarchical
  - A hybrid of the other models



Database Systems

- Parallel Systems – Hierarchical
  - At higher level system acts as a shared nothing organization.
  - Each node of the system at the lower level can be a shared memory and/or shared disk system.

Database Systems

- Parallel Database Management Systems
  - Database management systems developed on parallel systems are called parallel database management system.

Database Systems

- Parallel database system seeks to improve performance through parallelization of operations. In another words, parallel database system is motivated by performance improvement.

Database Systems

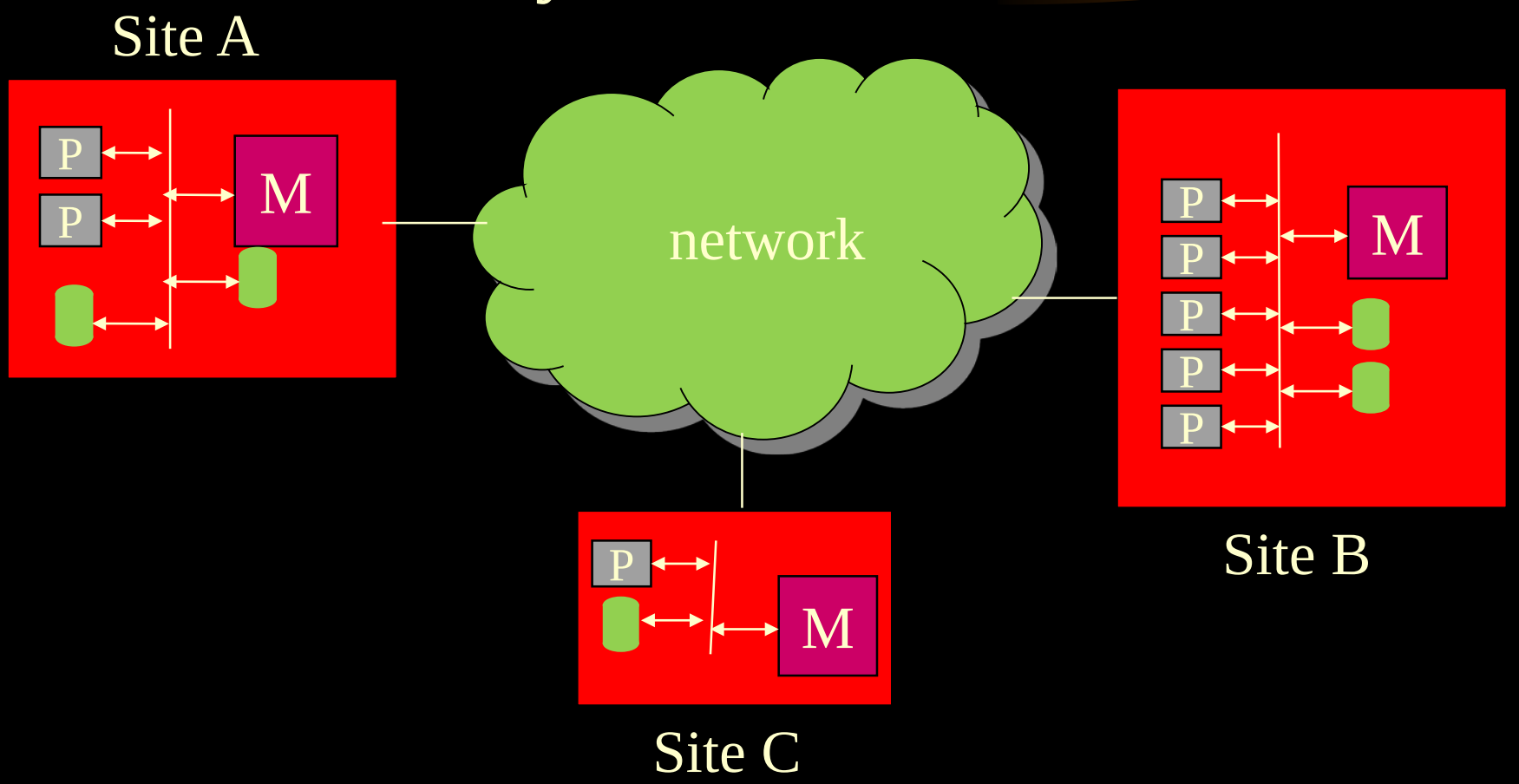
- Distributed Systems
  - Distributed databases bring the advantages of distributed computing to the database management domain.
  - A distributed system is a collection of processors, not necessarily homogeneous, interconnected by a computer network.

Database Systems

- Distributed Database Systems
  - Database is stored on several computers and computers communicate with each other through various communication media.
  - Computers do not share resources — disks, memory, processor, …

Database Systems

- Distributed Systems



Database Systems

Distributed Database Systems

- A distributed database is a collection of multiple logically interrelated databases distributed over a computer network – related data sources:
  - Are closer to the application domain (s) that uses it.
  - Might be replicated – to improve performance.
  - Are split (Fragmented), horizontally and/or vertically, and distributed – to balance the load and improve performance.
- A distributed database management system is a software system that manages a distributed database while making the distribution transparent to the user.

Database Systems

- Questions
  - What is the RAID?
  - What are the major differences between shared nothing and distributed configurations.
    - Distributed systems are typically geographically separated, are separately administrated, have slower interconnection, and there is a distinction between local processes and global processes.
    - With respect to the databases, in distributed databases, data is distributed while in shared nothing configuration, data is not distributed.

Database Systems

- Distributed Database Systems
  - In comparison to parallel systems in which processors are tightly coupled and constitute a single data base system, a distributed data base system is a collection of loosely coupled systems that share no physical components.
  - In general distributed databases can be classified as:
    - Homogeneous databases
    - Heterogeneous databases

Database Systems

- Distributed Database Systems
  - There are several reasons for building distributed database systems:
    - Sharing data
    - Autonomy
    - Increased reliability and availability
    - Improved performance
    - Ease of expansion

Database Systems

- Distributed Database Systems
  - Data distribution is an effort to improve performance:
    - To reduce communication costs and hence to reduce response time,
    - To maintain more control and enforce better security,
    - To improve quality of service in case of network failure.

Database Systems

- In a distributed database system, data is physically stored across several sites and each site is typically managed by a database management system capable of running independent of the other sites.
- Data distribution is motivated by:
  - Increased availability, and
  - Distributed access to data – locality in access patterns

Database Systems

- Distributed Database System :
  - Increased reliability and availability – reliability means probability that a system is running at a certain time point, availability means probability that a system is continuously available during a time interval.
  - Improved performance, and
  - Ease of expansion.