System Design #largeScale

https://workat.tech/system-design/article/best-engineering-blogs-articles-videos-system-design-tvwa05b8bzzr

https://github.com/Akshay-Iyangar/system-design

https://github.com/donnemartin/system-design-primer

https://github.com/codekarle/system-design/tree/master/system-design-prep-material/architecture-diagrams

https://sites.google.com/site/includemak/system-design

https://github.com/imujjwalanand/Grokking-the-System-Design

https://github.com/donnemartin/system-design-primer

System Requirements:
1. **Functional requirements**:

These are requirements that define specific behavior or functions, often represented by use cases.

- **How to Define**: Start with user needs and business goals. Outline the primary tasks users should accomplish.
- **Working Backwards Approach**: Begin with the end goal and trace steps backwards to identify requirements.

2. **High Availability**:

Availability is a measure of system uptime.

- **Time-based**: E.g., 99.9% (or "three nines") uptime.
- **Count-based**: E.g., 1 failure allowed in 1 million requests.
- **Design Principles**: Redundancy, failover, replication, monitoring, and regular testing.
- **Processes**: Regular maintenance, backup procedures, disaster recovery planning.
- **SLO vs SLA**: Service Level Objective (SLO) is the target level of service. Service Level Agreement (SLA) is the contract with the customer promising certain SLOs.

3. **Fault Tolerance, Resilience, Reliability**:
- **Error**: An incorrect internal state.
- **Fault**: A component's incorrect behavior.
- **Failure**: When a system as a whole stops providing the required service.

- **Fault Tolerance**: Ability of a system to behave in a well-defined manner once a fault occurs.
- **Resilience**: Ability to return to a normal state after a failure.
- **Game Day vs Chaos Engineering**: Game Day is a planned simulation. Chaos Engineering is introducing random failures.
- **Reliability**: Probability a system will fail in a given period.

4. **Scalability**:

- **Vertical Scaling**: Increasing the resources of a single node.
- **Horizontal Scaling**: Adding more nodes.
- **Elasticity vs Scalability**: Elasticity is the ability to scale automatically based on demand.

5. **Performance**:

- **Latency**: Time taken to process a single operation.
- **Throughput**: Number of operations processed in a given time period.
- **Percentiles**: E.g., 95th percentile latency = under which 95% of the request latencies fall.
- **How to Increase**: Optimize algorithms, caching, distributed systems.

6. **Durability**:

Ensuring data is safely stored and retrievable.

- **Backup Types**:
  - **Full**: Everything is backed up.
  - **Differential**: Only changes since the last full backup.
  - **Incremental**: Only changes since the last backup of any type.
- **RAID**: Redundant Array of Independent Disks. A method for redundant storage.
- **Replication**: Copying data to ensure durability and availability.
- **Checksum**: A computed value to detect errors in data.

7. **Consistency**:

Ensuring all users see the same data.

- **Eventual Consistency**: Data will become consistent over time.
- **Linearizability**: Real-time consistency.
- **Monotonic Reads**: If a process reads the value of a data item, any successive reads by that process will always return that value or a more recent one.
- **Read-Your-Writes**: Guarantees that a write by a process is visible to a subsequent read by the same process.
- **Consistent Prefix Reads**: Guarantees that every read receives a prefix (some initial segment) of the writes, in order.

8. **Maintainability, Security, Cost**:

- **Maintainability**: Ease with which a system can be maintained. Includes monitoring, testing, and deployment strategies.

- **Security**:
  - **CIA Triad**: Confidentiality, Integrity, Availability.
  - **Identity and Permissions Management**: Who can do what.
  - **Infrastructure Protection**: Protecting physical and virtual resources.
  - **Data Protection**: Ensuring data confidentiality, integrity, and availability.
- **Cost Aspects**: Engineering, maintenance, hardware, and software costs.

9. **Summary of System Requirements**:
  - **Most Popular Non-Functional Requirements**: Availability, Scalability, Performance, Security, Maintainability.
10. **Regions, Availability Zones, etc.**:
  - **Regions**: Geographic areas that consist of multiple, isolated data centers.
  - **Availability Zones**: Isolated locations within a region.
  - **Data Centers**: Physical facilities housing servers.
  - **Racks**: Structures holding multiple servers.
  - **Servers**: Physical machines running software.
11. **Physical Servers to Serverless**:
  - **Physical Servers**: Tangible hardware running software.
  - **Virtual Machines (VMs)**: Emulated computer systems.
  - **Containers**: Lightweight VMs that share the same OS kernel and isolate the application processes from each other.
    - **Pros**: Lightweight, fast, consistent environment, scalable.
    - **Cons**: Less isolation than VMs.
  - **Serverless**: Cloud-computing model which can run individual functions in response to events. Resources are fully managed by the cloud provider.
    - **Pros**: Scalability, no infrastructure management, cost-effective.
    - **Cons**: Cold starts, limited customization, statelessness.
12. **Synchronous vs. Asynchronous Communication**:
  - **Synchronous**: Sender waits for the receiver to respond.
  - **Asynchronous**: Sender sends the message and proceeds without waiting for a response.
13. **Asynchronous Messaging Patterns**:
  - **Message Queuing**: Temporarily storing messages to be processed later.
  - **Publish/Subscribe**: Senders (publishers) send messages to channels without specifying receivers. Receivers (subscribers) subscribe to channels they're interested in.
  - **Competing Consumers**: Multiple consumers process messages from a single channel, distributing load.
  - **Request/Response Messaging**: A two-way messaging pattern; a request is followed by a response.

- **Priority Queue**: Messages are processed based on priority rather than order of arrival.
- **Claim Check**: Large message is dropped off at a service and a claim check is provided to the requester, which can be used to get the full message later.

14. **Network Protocols**:
  - **TCP (Transmission Control Protocol)**: Reliable, connection-oriented protocol.
  - **UDP (User Datagram Protocol)**: Connectionless, no guarantee of message delivery.
  - **HTTP (Hypertext Transfer Protocol)**: Application protocol for distributed, collaborative, hypermedia systems.
    - **HTTP Request and Response**: Basic units of HTTP communication, where a client sends a request and a server responds.
15. **Blocking vs. Non-blocking I/O**:
  - **Blocking I/O**: The process is blocked until data is available.
  - **Non-blocking I/O**: The process continues even if the data is not available.
  - **Thread per Connection Model**: Each connection gets a dedicated thread.
  - **Thread per Request with Non-blocking I/O Model**: Threads are used only when processing a request.
  - **Event Loop Model**: Single thread handles multiple connections using events.
  - **Concurrency vs. Parallelism**: Concurrency is multiple tasks starting, running, and completing in overlapping time periods, while parallelism is multiple tasks running at exactly the same time.
16. **Data Encoding Formats**:
  - **Textual Formats (e.g., JSON, XML)**: Human-readable, more overhead.
  - **Binary Formats (e.g., Protobuf, Avro)**: Efficient, not human-readable.
  - **Schema Sharing Options**: How schema (structure) of data is shared between sender and receiver.
  - **Backward and Forward Compatibility**: Ensuring newer systems can read older data and older systems can read newer data, respectively.
17. **Message Acknowledgment**:
  - **Safe Acknowledgment Modes**: Receiver confirms safe receipt of a message.
  - **Unsafe Acknowledgment Modes**: Sender doesn't wait for a confirmation.
18. **Deduplication Cache**:
  - **Local vs. External Cache**: Storage close to the CPU vs. external storage systems.

- **Adding Data to Cache**: Can be added explicitly by the application or implicitly by the caching system.
- **Cache Data Eviction**: Removing data from cache, can be based on size, time, or other criteria.
- **Expiration vs. Refresh**: Time after which data is removed vs. updating data periodically.

19. **Metadata Cache**:
    - **Cache-aside Pattern**: Application is responsible for loading cache.
    - **Read-through and Write-through Patterns**: Cache controls the data load and update.
    - **Write-behind (Write-back) Pattern**: Data is written to cache and is asynchronously written back to the storage.
20. **Queue**:
    - **Bounded and Unbounded Queues**: Limited vs unlimited size.
    - **Circular Buffer (Ring Buffer)**: Fixed-size data structure that uses a single, continuous region of memory.
21. **Full and Empty Queue Problems**:
    - **Load Shedding**: Discarding excess traffic.
    - **Rate Limiting**: Limiting the rate of requests by users.
    - **Failed Requests Handling**: Strategies like retries or moving to dead-letter queues.
    - **Backpressure**: Signal to the producer to slow down.
    - **Elastic Scaling**: Dynamically adjusting resources based on demand.
22. **Start with Something Simple**:
    - **Single Machine vs. Distributed System Concepts**: Many concepts in distributed systems (like caching, load balancing) can be understood with the analogy of single-machine concepts.
    - **Interview Tip**: For system design interviews, start with a basic solution and then incrementally add complexity based on the requirements and constraints presented.
23. **Blocking Queue and Producer-Consumer Pattern**:
    - **Producer-Consumer Pattern**: Separate components that produce and consume data, often operating at different rates.
    - **Wait and Notify**: Mechanisms to synchronize between producers and consumers.
    - **Semaphores**: A synchronization primitive used to control access to a shared resource.
    - **Blocking Queue Applications**: Used in thread pooling, task scheduling, etc.
24. **Thread Pool**:
    - **Pros**: Efficient use of resources, controlled resource usage, quick task start-up.
    - **Cons**: Complexity, potential resource contention.
    - **CPU-bound vs. I/O-bound tasks**: CPU-bound tasks spend most of their time using the CPU, while I/O-bound tasks spend time waiting for

external operations (like disk or network operations).
- **Graceful Shutdown**: Properly terminating threads and releasing resources when shutting down a pool.

25. **Big Compute Architecture**:
- **Batch Computing Model**: Processing high volumes of data where a group of transactions is collected over a period.
- **Embarrassingly Parallel Problems**: Problems where little or no effort is needed to separate the problem into tasks to run in parallel.

26. **Log**:
- **Memory vs. Disk**: Storing logs in volatile memory (faster, but not persistent) vs. non-volatile disk storage (slower but persistent).
- **Log Segmentation**: Splitting logs into segments to manage them more efficiently.
- **Message Position (Offset)**: The position of a message within a log.

27. **Index**:
- **How to Implement an Efficient Index for a Messaging System**: Use data structures like B-trees or Hash Indexes to allow for quick lookups and writes.

28. **Time Series Data**:

Storing and retrieving data points indexed in time order.

- **How to Store and Retrieve**: Use databases optimized for time series data, like InfluxDB, to ensure efficient storage and fast queries.

29. **Simple Key-Value Database**:
- **How to Build**: Utilize hash tables for quick lookups. Address issues like collision resolution.
- **Log Compaction**: Reducing the size of logs by removing redundant data.

30. **B-tree Index**:
- **Usage in Databases and Messaging Systems**: B-trees allow for efficient data storage and retrieval in databases and are used to index data in messaging systems.

31. **Embedded vs. Remote Database**:
- **Embedded Database**: Runs within the same address space as the application. E.g., SQLite.
- **Remote Database**: Separate from the application and is accessed over a network. E.g., PostgreSQL, MySQL.

32. **RocksDB**:

A high-performance embedded database for key-value data.

- **Memtable**: In-memory data structure where RocksDB writes are inserted.
- **Write-ahead Log (WAL)**: A log that stores changes to data, ensuring

durability.

- **Sorted Strings Table (SSTable)**: Persistent, ordered immutable map of key-value pairs.

33. **LSM-tree vs. B-tree**:
    - **Log-Structured Merge-Tree (LSM-tree)**: Optimized for systems that write data more often than reading.
    - **Write Amplification vs. Read Amplification**: Trade-offs between the cost of writing data vs. reading data.
34. **Page Cache**:
    - **Increasing Disk Throughput**: Techniques like batching and zero-copy read can help in efficiently reading/writing to disks.
35. **Push vs. Pull**:
    - **Push**: Server initiates sending data to the client.
    - **Pull**: Client requests data from the server.
36. **Host Discovery**:
    - **DNS**: The Domain Name System translates domain names to IP addresses.
    - **Anycast**: Routing strategy where a single destination address has multiple routing paths to two or more endpoint destinations.
37. **Service Discovery**:
    - **Server-side and Client-side Discovery Patterns**: Mechanisms where services find each other's network locations.
    - **Service Registry**: A database containing the network locations of service instances.
38. **Peer Discovery**:
    - **Peer Discovery Options**: How nodes in a network find each other.
    - **Gossip Protocol**: Nodes randomly exchange information, which gradually propagates through the system.
39. **Choosing a Network Protocol**:
    - **TCP, UDP, and HTTP**: Decision depends on use case requirements like reliability, speed, and connection state.
40. **Video over HTTP**:
    - **Adaptive Streaming**: Adjusting video quality in real-time based on the viewer's network and playback conditions.
41. **CDN (Content Delivery Network)**:
    - **How to Use & Benefits**: CDNs distribute content across multiple servers to optimize access for users globally. They reduce latency and protectagainst traffic surges.
    - **Point of Presence (POP)**: Physical locations or access points that connect to the internet and host servers, acting as the local source for cached content.

42. **Push and Pull Technologies**:
    - **Short Polling**: Client frequently asks the server for new data.
    - **Long Polling**: Client requests information and waits for the server to respond.
    - **Websocket**: Protocol that allows two-way communication with a server over a single, long-lived connection.
    - **Server-Sent Events**: Server pushes updates to the client over an HTTP connection.
43. **Push and Pull Technologies in Real-Life Systems**:
    - **Quiz**: Real-life examples would be chat applications (like Slack) using Websockets for real-time messaging, or stock trading apps using long polling for updating stock prices.
44. **Large-scale Push Architectures**:
    - **C10K and C10M Problems**: Challenges of handling 10,000 and 10 million concurrent connections respectively.
    - **Large-Scale Push Architectures**: Techniques like event-driven programming to handle large numbers of simultaneous connections.
    - **Problems of Long-Lived Connections**: Resource management, detecting stale or "dead" connections, and handling dropped connections.
45. **Building Reliable, Scalable, and Fast Systems**:
    - **Common Problems in Distributed Systems**: Network failures, machine failures, performance bottlenecks.
    - **System Design Concepts**: Caching, load balancing, sharding, replication, and partitioning.
    - **Three-Tier Architecture**: Presentation, logic, and data tiers.
46. **Timeouts**:
    - **Fast Failures vs. Slow Failures**: Quickly failing a request vs. taking a long time before failing.
    - **Connection and Request Timeouts**: Time limits set for establishing a connection or waiting for a response.
47. **Handling Failed Requests**:
    - **Strategies**:
        - **Cancel**: Terminate the request.
        - **Retry**: Attempt the request again.
        - **Failover**: Redirect the request to another system or component.
        - **Fallback**: Use an alternate backup solution.
48. **When to Retry**:
    - **Idempotency**: Ensuring that operations can be repeated without side effects.
    - **AWS API Failures**: Not all API failures should be retried. For instance, validation errors shouldn't be retried.
49. **How to Retry**:
    - **Exponential Backoff**: Increase the wait time between retries

exponentially.
- **Jitter**: Adding randomness to retry intervals to spread out the load.

50. **Message Delivery Guarantees**:
    - **At-most-once**: Messages are delivered once or not at all.
    - **At-least-once**: Messages are delivered one or more times.
    - **Exactly-once**: Messages are delivered precisely once.
51. **Consumer Offsets**:
    - **Log-Based Messaging Systems**: Systems where messages are stored in order and consumers track their position using offsets.
    - **Checkpointing**: Periodically saving the state of a process.
52. **Batching**:
    - **Pros and Cons**: Batching can improve efficiency but may introduce latency.
    - **Handling Batch Requests**: Ensuring that all items in a batch are processed, even if some fail.
53. **Compression**:
    - **Pros and Cons**: Reduces data size but adds computational overhead.
    - **Compression Algorithms**: Techniques like GZIP, Brotli, and LZ4, each with their trade-offs.
54. **Scaling Message Consumption**:
    - **Single Consumer vs. Multiple Consumers**: One consumer can ensure order but is limited in throughput. Multiple consumers can increase throughput but introduce complexity in message ordering.
    - **Problems with Multiple Consumers**: Ensuring order, handling duplicate processing, etc.
55. **Partitioning in Real-Life Systems**:
    - **Pros and Cons**: Helps in horizontal scaling and distributing loads but can introduce complexities.
    - **Applications**: Databases, messaging systems, etc.
56. **Partitioning Strategies**:
    - **Lookup Strategy**: Direct lookup.
    - **Range Strategy**: Based on a range of data values.
    - **Hash Strategy**: Using a hash function for uniform distribution.
57. **Request Routing**:
    - **Physical and Virtual Shards**: Actual data partitions vs logical partitions.
    - **Routing Options**: Methods for directing a request to the appropriate server or data partition.
58. **Rebalancing Partitions**:

Ensuring data is evenly distributed across systems, especially when adding or removing nodes.

59. **Consistent Hashing**:
    - **Implementation**: Uses a circular keyspace.

- **Advantages and Disadvantages**: Reduces the number of re-mapped keys when scaling but can lead to non-uniform data distribution.
- **Virtual Nodes**: Multiple hash values for a single node to ensure a more uniform distribution.

60. **System Overload**:
   - **Importance**: Protecting against system overload ensures continued availability and prevents cascading failures across dependent systems.
   - **Protection Mechanisms**: Load shedding, rate limiting, backpressure, and queuing.
61. **Autoscaling**:
   - **Scaling Policies**:
     - **Metric-based**: Scale based on metrics like CPU utilization or memory usage.
     - **Schedule-based**: Scale based on known usage patterns or times.
     - **Predictive**: Scale based on predicted future traffic patterns.
   - **Autoscaling System Design**: Involves metrics collection, decision-making algorithms, and mechanisms to add or remove resources.
62. **Load Shedding**:
   - **Implementation**: Prioritize and process only the most critical tasks, while dropping or delaying non-essential tasks.
   - **Considerations**: Decide which requests to drop, how to notify clients, and when to trigger load shedding.
63. **Rate Limiting**:
   - **Purpose**: To prevent any single user or client from overloading the system.
   - **Implementation**: Token buckets, leaky buckets, and fixed window counters are popular methods.
64. **Synchronous and Asynchronous Clients**:
   - **Admission Control Systems**: Mechanisms to decide whether to process a request immediately or defer it.
   - **Blocking I/O vs. Non-Blocking I/O Clients**: Synchronous vs. Asynchronous client operations.
65. **Circuit Breaker**:
   - **Finite-State Machine**: Mechanism where the circuit breaker maintains states (Closed, Open, Half-Open) to decide whether to process or deny requests.
   - **Considerations**: Setting thresholds, reset intervals, and monitoring the health of downstream services.
66. **Fail-Fast Design Principle**:
   - **Problems with Slow Services**: Slow services can cause chain reactions leading to larger system outages.
   - **Solutions**: Implementing timeouts, circuit breakers, and other mechanisms to quickly fail and return control to the caller.
67. **Bulkhead**:

- **Implementation**: Isolating parts of a system so that if one fails, it doesn't bring down the whole system.
- **Applications**: Can be applied at various levels, from processes to servers to data centers.

68. **Shuffle Sharding**:
- **Implementation**: Combining sharding and redundancy to reduce the blast radius of failures.
- **Applications**: Reducing the impact of failures in multi-tenant systems.

69. **Host Discovery**:
- **DNS**: Translates domain names to IP addresses, enabling clients to discover hosts.
- **Anycast**: Uses DNS to route to the nearest or best-performing physical location.

70. **Service Discovery**:
- **Server-side and Client-side Discovery Patterns**: Mechanisms where services find each other's network locations, either with a central server or clients querying a service registry.
- **Service Registry**: Stores locations of service instances, allowing for service discovery.

71. **Peer Discovery**:
- **Peer Discovery Options**: Mechanisms like bootstrap lists or centralized directories.
- **Gossip Protocol**: Nodes share information about their peers, allowing for decentralized discovery.

72. **Choosing a Network Protocol**:
- **TCP vs. UDP vs. HTTP**: Depending on the requirements (reliability, connection setup, data size), one might be chosen over the other.

73. **Network Protocols in Real-Life Systems**:

Analyzing different scenarios and challenges to choose the best protocol. For example, streaming services might prefer UDP, while banking transactions would use TCP.

74. **Video Over HTTP**:
- **Adaptive Streaming**: The video quality is dynamically adjusted based on the viewer's network conditions.

75. **CDN**:
- **Benefits**: Faster content delivery by caching content closer to the end-users and reducing origin server load.
- **How It Works**: Content is distributed and stored across a network of servers. When a user requests content, it's served from the nearest cached server.

76. **Push and Pull Technologies in Real-Life Systems**:

Real-world applications like social media updates or live sports updates may use push technologies like WebSockets, while email clients might use pull technologies to check for new mails.

77. **Large-Scale Push Architectures**:

Design considerations for building systems that can handle millions of simultaneous connections.

78. **Timeouts**:
  - **Importance**: Ensure that a system doesn't hang indefinitely.
  - **Types**:
    - **Connection Timeouts**: Time a task will wait while attempting to establish a connection.
    - **Read/Write Timeouts**: Time a task will wait for a read or write operation to complete.
  - **Handling**: Opt for graceful degradation of service, provide feedback to users, and use retries judiciously.
79. **Handling Failed Requests**:
  - **Logging**: Essential for diagnostics. What failed, where, and why?
  - **Retry Logic**: Implementing algorithms like exponential backoff.
  - **Notifications**: Inform stakeholders or trigger systems about persistent failures.
80. **When to Retry**:
  - **Transient vs Permanent Failures**: Temporary glitches (network blip) vs. consistent failures (invalid credentials).
  - **Safety**: Ensuring retries don't exacerbate the problem.
81. **How to Retry**:
  - **Immediate vs Delayed**: Waiting between retry attempts can be crucial.
  - **Exponential Backoff**: Increasingly long waits between retries.
  - **Jitter**: Introducing randomness to retry intervals.
82. **Message Delivery Guarantees**:
  - **Importance**: Ensuring data isn't lost or seen multiple times.
  - **Strategies**: Acknowledgments, transaction logs, checkpoints.
83. **Consumer Offsets**:
  - **Checkpointing**: Storing position in a stream or log.
  - **Benefits**: Allows consumers to pick up where they left off after failures.
84. **Batching**:
  - **Benefits**: Can significantly reduce overheads and increase throughput.
  - **Challenges**: Introducing latency, complexity in error handling.
85. **Compression**:
  - **Trade-offs**: CPU time vs. bandwidth.
  - **Use Cases**: Important in bandwidth-constrained environments or for storage savings.

86. **Scaling Message Consumption**:
   - **Parallelism**: Distributing load across multiple consumers.
   - **Ordering**: Ensuring that the sequence is maintained, if necessary.
87. **Partitioning in Real-Life Systems**:
   - **Consistency vs Availability**: Deciding trade-offs based on system requirements.
88. **Partitioning Strategies**:
   - **Consistency Hashing**: Minimizing reorganization of data when nodes are added or removed.
89. **Request Routing**:
   - **Load Balancers**: Distributing incoming requests to prevent any single resource from being overwhelmed.
   - **Content-based Routing**: Directing traffic based on the content of the request.
90. **Rebalancing Partitions**:
   - **Importance**: Ensuring data and load are evenly distributed across nodes.
   - **Strategies**: Manual interventions, algorithmic rebalancing.
91. **Consistent Hashing**:
   - **Virtual Nodes**: A mechanism to ensure a more uniform distribution of data.
92. **System Overload**:
   - **Monitoring and Alerts**: Real-time insights into system health.
   - **Throttling**: Limiting user or service requests.
93. **Autoscaling**:
   - **Cloud Services**: Many cloud providers offer autoscaling services that can automatically add or remove resources based on rules or machine learning.
94. **Load Shedding**:
   - **Dynamic Adjustments**: Dropping non-critical tasks when the system is under heavy load.
95. **Rate Limiting**:
   - **API Gateways**: Many come with built-in rate limiting features.
   - **Client Feedback**: Informing clients when they're exceeding limits.
96. **Synchronous and Asynchronous Clients**:
   - **Trade-offs**: Responsiveness vs. resource usage.
   - **Use Cases**: Asynchronous operations for long-running tasks.
97. **Circuit Breaker**:
   - **Resilience Patterns**: Preventing system failures from cascading.
98. **Fail-Fast Design Principle**:
   - **Health Checks**: Regular checks to ensure services are operational.
   - **Fallbacks**: Having backup systems or data sources in place.
99. **Bulkhead**:
   - **Isolation**: Making sure failures in one part don't impact others.
100. **Shuffle Sharding**:

- **Resilience**: Improving system reliability by reducing the impact radius of failures.

if relational databases
are not suitable for your specific use cases, it is critical to explore beyond relational
databases. Non-relational databases might be the right choice if:
• Your application requires super-low latency.
• Your data are unstructured, or you do not have any relational data.
• You only need to serialize and deserialize data (JSON, XML, YAML, etc.).
• You need to store a massive amount of data.

A stateful server and stateless server has some key differences. A stateful server remembers
client data (state) from one request to the next. A stateless server keeps no state information.

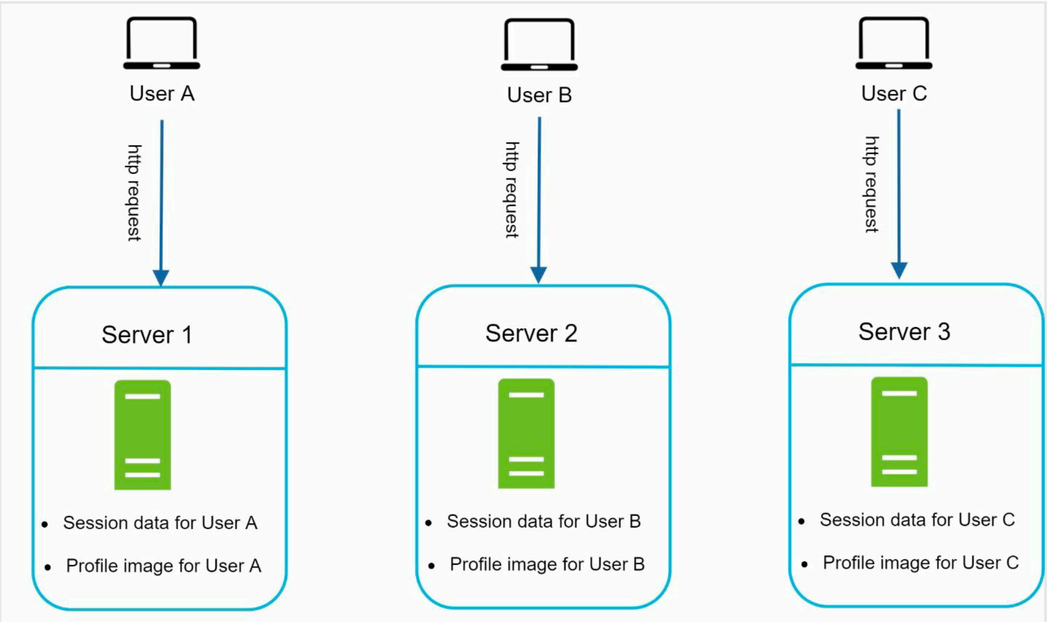

Figure 1-12

Sharding is a great technique to scale the database but it is far from a perfect solution. It
introduces complexities and new challenges to the system:

Resharding data: Resharding data is needed when 1) a single shard could no longer hold
more data due to rapid growth. 2) Certain shards might experience shard exhaustion faster
than others due to uneven data distribution. When shard exhaustion happens, it

requires
updating the sharding function and moving data around. Consistent hashing, which will be
discussed in Chapter 5, is a commonly used technique to solve this problem.

Celebrity problem: This is also called a hotspot key problem. Excessive access to a specific
shard could cause server overload. Imagine data for Katy Perry, Justin Bieber, and Lady
Gaga all end up on the same shard. For social applications, that shard will be overwhelmed
with read operations. To solve this problem, we may need to allocate a shard for each
celebrity. Each shard might even require further partition.

Join and de-normalization: Once a database has been sharded across multiple servers, it is
hard to perform join operations across database shards. A common workaround is to denormalize
the database so that queries can be performed in a single table.
In Figure 1-23, we shard databases to support rapidly increasing data traffic. At the same
time, some of the non-relational functionalities are moved to a NoSQL data store to reduce
the database load. Here is an article that covers many use cases of NoSQL [14].

When to use NOSql
http://highscalability.com/blog/2010/12/6/what-the-heck-are-you-actually-using-nosql-for.html

- **Massive write performance**. This is probably the canonical usage based on Google's influence. High volume. Facebook needs to store 135 billion messages a month. Twitter, for example, has the problem of storing 7 TB/data per day with the prospect of this requirement doubling multiple times per year. This is the data is too big to fit on one node problem. At 80 MB/s it takes a day to store 7TB so writes need to be distributed over a cluster, which implies key-value access, MapReduce, replication, fault tolerance, consistency issues, and all the rest. For faster writes in-memory systems can be used.

- **Fast key-value access**. This is probably the second most cited virtue of NoSQL in the general mind set. When latency is important it's hard to beat hashing on a key and reading the value directly from memory or in as little as one disk seek. Not every NoSQL product is about fast access, some are more about reliability, for example. but what people have wanted for a long time was a better memcached and many

NoSQL systems offer that.
- **Write availability**. Do your writes need to succeed no mater what? Then we can get into partitioning, CAP, eventual consistency and all that jazz.
- **No single point of failure**. Not every product is delivering on this, but we are seeing a definite convergence on relatively easy to configure and manage high availability with automatic load balancing and cluster sizing. A perfect cloud partner.
- Managing large streams of non-transactional data: Apache logs, application logs, MySQL logs, clickstreams, etc.
- Fast response times under all loads.
- Soft real-time systems where low latency is critical. Games are one example.
- Real-time inserts, updates, and queries.
- Voting.
- Real-time page view counters.
- User registration, profile, and session data.
-

1. String comparisons are expensive try to store Data in int form.
2. When storing the created_at data in date-time stamp try to store in epoc time as it is faster for comparison because date time get serialized and then store in disk and when we query it again deserialised it.

Handle Murphy's law
This is something that most people skip but this is one of the most important things that you must cover which talks about how resilient your system is. In the real world, things break, and when they do, you need to make sure you are in full control of your system.
Talk about how you monitor the system. What kind of alerting mechanism do you have in place? What are your KPIs (Key Performance Indicators) and how do you track them? What happens when things break, when your service crashes, your DB's master node goes down or even when one of your datacentres goes down?

What's App System Design Insights:
https://www.cometchat.com/blog/whatsapps-architecture-and-system-design

Facebook System Design
https://www.codekarle.com/system-design/facebook-system-design.html
https://www.youtube.com/watch?v=9-hjBGxuiEs
http://highscalability.com/blog/2011/12/6/instagram-architecture-14-million-users-terabytes-of-photos.html

Twitter System Design

https://www.codekarle.com/system-design/Twitter-system-design.html

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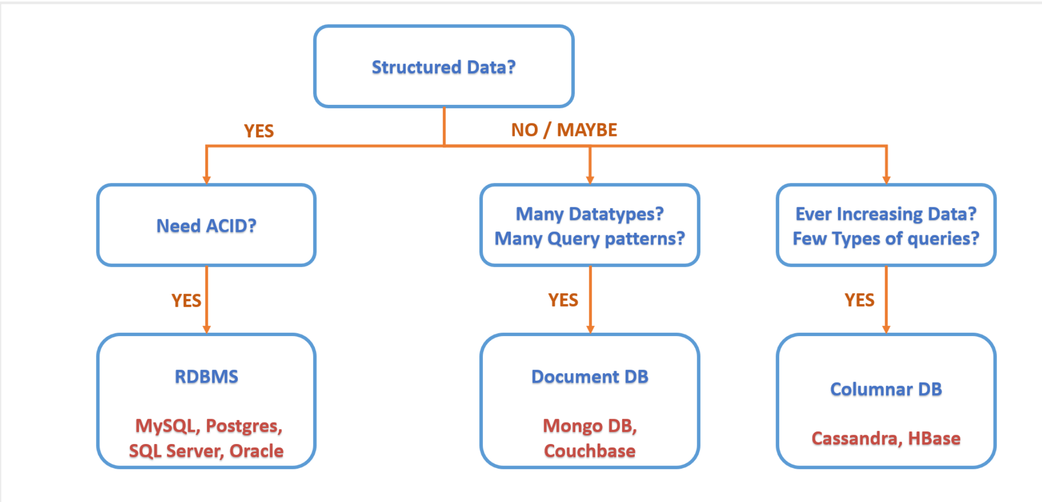
How to select DB's and other stuffs

https://www.codekarle.com/system-design/Database-system-design.html

Redis - Caching
Blog - Amazon s3 + CDN

Search -> Elastic Search

Metric Tracking system -> Time series DB(Influx , Open TSDB)



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Whenever you are designing a read heavy intensive platform you should be able to compute data before hand or make sure you cache the data.

Cache & its three main problems & solutions
While caching is great, but its careless use can raise 3 main issues 👇

ISSUE 1️⃣ : Cache penetration

The case when the data queried is neither present in database nor in cache. As

a result, the request will be directed from cache to database eventually, penetrating the cache layer and defeating the whole purpose of caching. It can be due to some malicious attack.
Solution:
💡 Cache keys with null value. Prefer short TTL (Time to Live) for keys with null value.
💡 Use Bloom filters. Basically it can tell whether a key is present in a set or not very quickly. Then if not present, ignore that calls completely, i.e. such calls should neither hit cache nor database.

ISSUE 2️⃣ : Cache avalanche

If the cache goes down for some reason, the massive query request that was originally blocked by the cache will flock to the database like a mad dog. At this point, if the database can’t withstand this huge pressure, it will collapse.
Solution:
💡 Ensure high availability of cache cluster as preventive measure.
💡 Use Hystrix, so in case a call fails, it returns default result so as to avoid cascaded failures.

ISSUE 3️⃣ : Hotspot data set is invalid

For very hot data, after expiry of cache TTL, the requests will bombard database between the time of expiry of TTL and re-cache.
Solution:
💡 When a hotspot data fails, only the first database query request is sent to the database, and all other query requests are blocked, thus protecting the database. That can be achieved with cache locks (mutex).
💡 Set different TTLs to avoid simultaneous failures.

We all consume a lot of content daily on various platforms like Instagram, Netflix etc. All the content delivery websites use a CDN. CDNs function by caching the content at the edge servers and then providing it from the nearest edge server to the client.

1. Mostly this is static content like images to be displayed on a webpage, some static text, or movies in case of websites like Netflix.
All content is static because it does not change. But, I recently came across a term called dynamic content caching.

2. Dynamic content is content that changes based on factors specific to the user such as time of visit, location, and device. A dynamic webpage will not

look the same for everybody, and it can change as users interact with it – like if a newspaper could rewrite itself as someone is reading it. This makes web pages more personalized and more interactive.

3. Dynamic webpages are not stored as static HTML files. Instead, server-side scripts generate an HTML file in response to events, such as user interactions or user logins, and send the HTML file to the web browser. Because dynamic content is generated server-side, it is typically served from origin servers, not a cache.

4. Now, as this content is generated using scripts from servers, will you load it every time for every user? The website experience would be pretty bad. How will you cache this type of content?

5. One of the ways can be to run the scripts on the CDN cache servers, rather than running the script on the origin server. A lot of CDNs allow this feature to run the scripts on edge nodes to serve the content.

6. One another way can be to cache the static content on the CDN edge servers and compress the dynamic content which is brought on run time from the origin server. This can significantly reduce the website load time.

- If you need a high ingestion rate where read latency is manageable then go for Cassandra, ScylaDB.

- If you need to build an analytics application then go to Clickhouse, Druid … These DB is specially built for OLAP use cases.

- If you want to track app-specific events then choose click house.

- If your use case is small like e-commerce then go for PostgreSQL/MongoDB. These two DB does not guarantee High availability if you compare them with Cassandra in terms of availability.

- For caching use cases go for Redis / Memcache. Again if you want to choose availability over consistency then go for Memcache.

- If your use case is similar to a graph. Example: friend list, common friends then go for graph database ie Neptune, Neo4j, Janus Graph. Even you can build a layer like Tao which Internally uses MySQL.