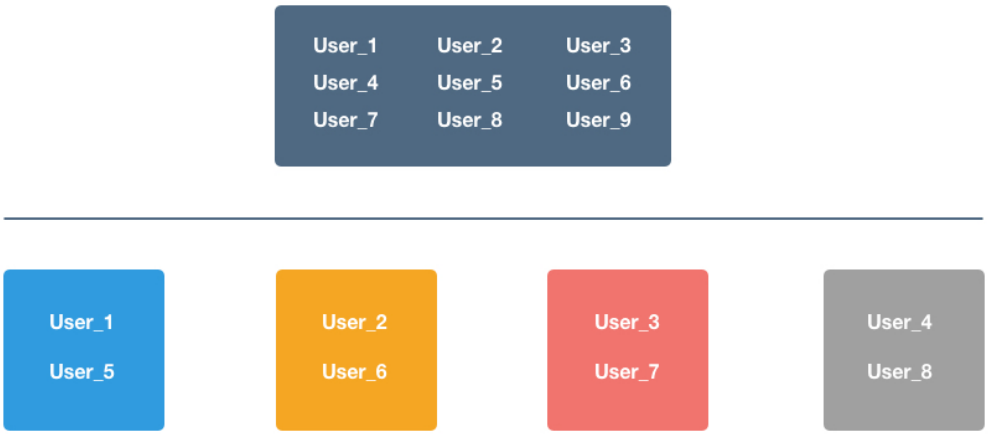
Sharding a Database

Bookmark

Let's design a sharding scheme for key-value storage.



Features:

> *This is the first part of any system design interview, coming up with the features which the system should support. As an interviewee, you should try to list down all the features you can think of which our system should support. Try to spend around 2 minutes for this section in the interview. You can use the notes section alongside to remember what you wrote.*

Q: What is the amount of data that we need to store?
A: Let's assume a few 100 TB.

Q: Will the data keep growing over time? If yes, then at what rate?
A: Yes. At the rate of 1TB per day.

Q: Can we make assumptions about the storage of machines available with me?
A: Let's assume that machines have a RAM of 72G and a hard disk capacity of 10TB.

Q: How many machines do I have to begin with?
A: Let's assume we have 20 machines to begin with. More machines will be available on request if need be.

Q: Are all key value entries independent?
A: Yes. A typical query would ask for value corresponding to a key.

Estimation:

> *This is usually the second part of a design interview, coming up with the estimated numbers of how scalable our system should be. Important parameters to remember for this section is the number of queries per second and the data which the system will be required to handle.*
> *Try to spend around 5 minutes for this section in the interview.*

Total storage size : 100 TB as estimated earlier
Storage with every machine : 10TB
Q: What is the minimum number of machines required to store the data?

A: Assuming a machine has 10TB of hard disk, we would need minimum of 100TB / 10 TB = 10 machines to store the said data. Do note that this is bare minimum. The actual number might be higher.
In this case, we have 20 machines at our disposal.

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Q: How frequently would we need to add machines to our pool ?

A: The data grows at 1TB per day. That means that we generate data that would fill the storage of 1 machine (10TB) in 10 days. Assuming, we want to keep a storage utilization of less than 80%, we would need to add a new machine every 8 days.

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Deep Dive:

> *Lets dig deeper into every component one by one. Discussion for this section will take majority of the interview time(20-30 minutes).*

> Note : In questions like these, the interviewer is looking at how you approach designing a solution. So, saying that I'll use a distributed file system like HDFS is not a valid response. It's okay to discuss the architecture of HDFS with details around how HDFS handles various scenarios internally.

Q: Can we have a fixed number of shards?

A: One qualification for a shard is that the data within a shard should fit on a single machine completely.
As in our case, the data is growing at a fast pace, if we have a fixed number of shards, data within a shard will keep growing and exceed the 10TB mark we have set per machine. Hence, we cannot have a fixed number of shards. The shards will have to increase with time.

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Q: How many shards do we have and how do we distribute the data within the shard?

A: Lets say our number of shards is S. One way to shard is that for every key, we calculate a numeric hash H, and assign the key to the shard corresponding to H % S.
There is one problem here though. As we discussed earlier, the number of shards will have to increase. And when it does, our new

number of shard becomes S+1.
As, such H%(S+1) changes for every single key causing us to relocate each and every key in our data store. This is extremely expensive and highly undesirable.

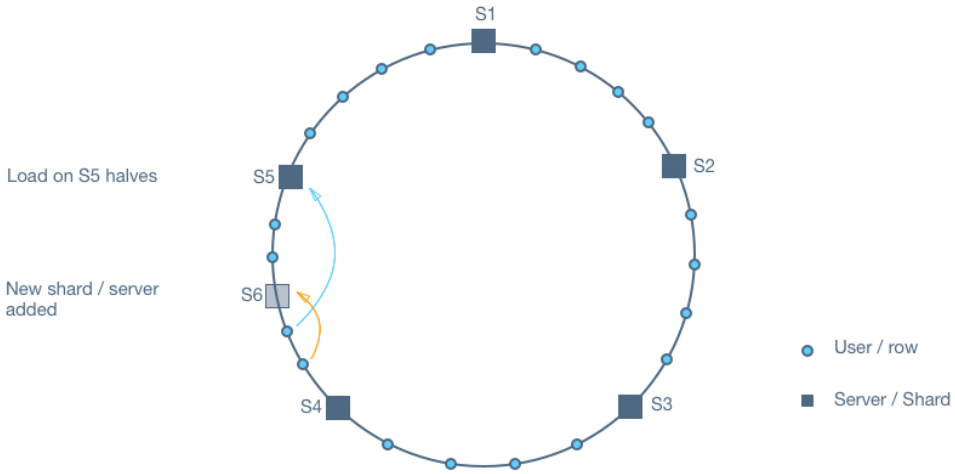
2 ()

Q: Can we think of a better sharding strategy?

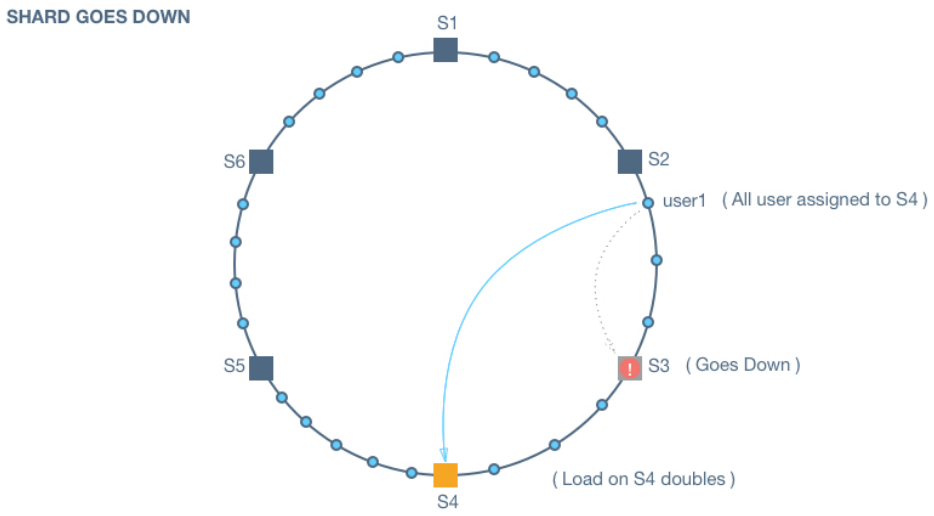
Hint: Consistent Hashing.

A: Consistent hashing is ideal for the situation described here. Lets explore consistent hashing here.
Let's say we calculate a 64 bit integer hash for every key and map it to a ring. Lets say we start with X shards. Each shard is assigned a position on the ring as well. Each key maps to the first shard on the ring in clockwise direction.

What happens if we need to add another shard ? Or what if one of the shard goes down and we need to re-distribute the data among remaining shards?

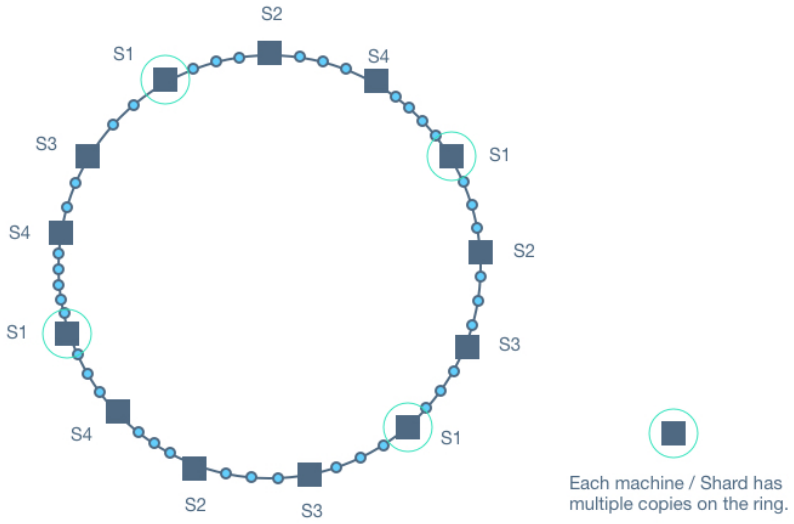


Similarily, there is a problem of cascading failure when a shard goes down.

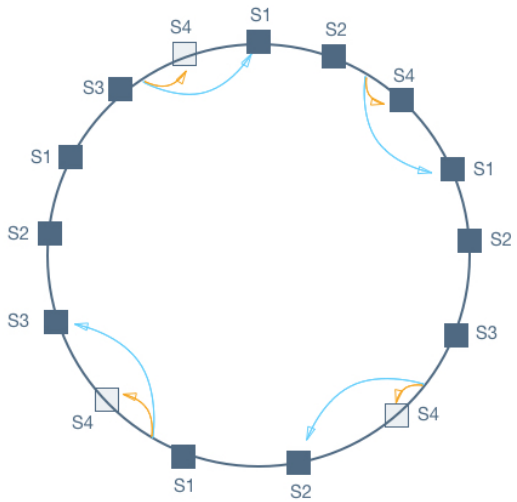


Modified consistent hashing

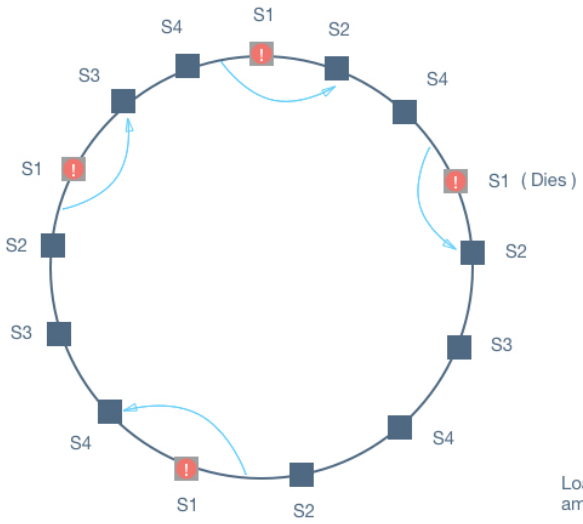
What if we slightly changed the ring so that instead of one copy per shard, now we have multiple copies of the same shard spread over the ring.



Case when new shard is added :



Case when a shard goes down : No cascading failure. Yay!



3 ()

You have now mastered this problem!

Discussion

vkb087 (/profile/vkb087) about 1 year ago
23 Great Doc. You can find more information about consistent hashing implementation and detail here.

http://www.tom-e-white.com/2007/11/consistent-hashing.html
reply

Ajit (/profile/Ajit) about 1 year ago
-11 Java implementation of Sharading
reply

Ajit (/profile/Ajit) about 1 year ago
-6 http://sleeplessinslc.blogspot.in/2008/09/hibernate-shards-maven-simple-example.html
reply

skcoder (/profile/skcoder) about 1 year ago
15 It looks like this is not addressing the question of how data is actually relocated. I would like to understand how data is physically moved onto the new node when it joins the cluster. Which part of the system does this? Similarly data would need to be relocated to all of the surviving nodes when a node leaves. Is this all done before the node comes online? Also when the node leaves, I suppose this is assuming there must be a redundant copy of data still online that can be moved to the surviving nodes. Would we be expected to come up with this as well in an interview?
reply

prakhar_jain_803 (/profile/prakhar_jain_803) 8 days ago
0 I think learning about internal architecture and design of a DB like Cassandra would address this.
reply

swapnil_marghade (/profile/swapnil_marghade) about 1 year ago
0 Storing data in multiple shards is same as replication factor. We can address this concern by using right term as "Replication factor" !
reply

karan3296 (/profile/karan3296) 11 months ago
1 Not sure they are replicating here. This is just distributing data. Replication is mentioned in the dynamo paper and is a feature of HDFS.

reply

AB_kyusak (/profile/AB_kyusak) about 1 year ago
0 I cant understand,what advantage we gain by maintaining the multiple copies of the shrad? wht advantage does modified consistent hashing has over consistent hashing.It might sound a dumb question but i am new to the topic :)
reply

Nivas (/profile/Nivas) 11 months ago
0 1.All I can think of about maintaining multiple copies per shard is it increases the availability.
reply

Nivas (/profile/Nivas) 11 months ago
2 With respect to modified consistent hashing, it makes sure that order in which shards follow each other is not deterministic. So if a shard fails the load will not be on a single shard, it will be shared by all subsequent shards that follow the failed instance at different places.
reply

karan3296 (/profile/karan3296) 11 months ago
0 It allows for heterogeneity too. Beefier nodes can be used to spread more virtually along the ring whereas weaker servers can be less prominent on the ring.
reply

kumar955 (/profile/kumar955) about 1 year ago
0 I think he needs to expand the answer, what happens if a user shared size increases - do we split the data or not? Do we need to support replicas? How data center to data center replication happens etc?
reply

kulkav (/profile/kulkav) about 1 year ago
0 http://www.project-voldemort.com/voldemort/design.html
reply

Srivathsan_Venkatavaradhan (/profile/Srivathsan_Venkatavaradhan) about 1 year ago
3 I think modified consistent hashing explained above is not correct. Please refer https://ihong5.wordpress.com/2014/08/19/consistent-hashing-algorithm/ . It has nothing to do with shards.
reply

ramanatnsit (/profile/ramanatnsit) 12 months ago
1 How does the system remain available during the time when a node failure occurs and redistribution of keys are in process. Is it sacrificing availability for consistency
reply

Nivas (/profile/Nivas) 11 months ago
0 Each shard will have a leader/master and some replicas. During failure or redistribution the leader will be changed. So availability is not sacrificed. But this may result in increased load in the machine where the elected replica is located if not managed at right time.
reply

eipie (/profile/eipie) 11 months ago
0 What is this obsession with 72GB RAM? Isn't is better / easier to pick powers of two? Or maybe perhaps 100GB treating 1GB = 1000MB for simplicity of calculations?
reply

sunnyk (/profile/sunnyk) 6 months ago
0 I had the same thought.. 64/128/256 makes so much sense.
reply

shaily_mittal (/profile/shaily_mittal) 9 months ago
0 Great doc, didn't know the concept of consistent hashing earlier
reply

ishtiaque_hussain (/profile/ishtiaque_hussain) 7 months ago
0 I found the following YouTube tutorial by Curtis on Consistent Hashing interesting, easy to understand:
reply

ishtiaque_hussain (/profile/ishtiaque_hussain) 7 months ago
1 I found the following YouTube tutorial by Curtis on Consistent Hashing interesting, easy to understand: https://www.youtube.com/watch?v=jznJKL0CrxM
reply

mohammed_alhfian (/profile/mohammed_alhfian) 5 months ago
0 yes

reply

cnachiketa07 (/profile/cnachiketa07) 3 months ago
0 Found this article to be good
reply

cnachiketa07 (/profile/cnachiketa07) 3 months ago
2 https://www.toptal.com/big-data/consistent-hashing
reply

> zonker (/profile/zonker) 3 months ago
> 0 Best article so far on explaining Consistent hashing.
> reply

shivendra_panicker (/profile/shivendra_panicker) 3 months ago
0 https://www.youtube.com/watch?v=--4UgUPCuFM
Easy to understand concept of consistent hashing!
reply

surabhi_gupta (/profile/surabhi_gupta) 3 months ago
0 I have a doubt, we can store 10 tb data per machine so we start with 10 machines, but each machine has only 72 gb ram, This means we can not load the complete data into ram and hence can not return data on o(1) time. So do you think with this soln we should implement an internal caching as well, so that data is retrieved at a very fast rate
reply

Write your comment here. Press Enter to submit.