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A reliable power management scheme for consistent hashing based distributed key value storage systems

Key words: Consistent hash table (CHT), Replication, Power management, Key value storage system, Reliability

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Motivation

Current energy issues with key value storage systems

■ Key value storage systems

- Dynamo at Amazon, Cassandra at Facebook, and Voldemort at LinkedIn ...
- Consistent hash table (CHT)
 - High scalability
 - Load balance
 - Simplifying the lookup operations

■ Server energy conservation has become a priority

- With the increase in the sheer volume of digital data, storage and server demands are on a rapid increase.
- Server energy cost constitutes a significant part of a data center's power bill



Traditional replication under consistent hashing

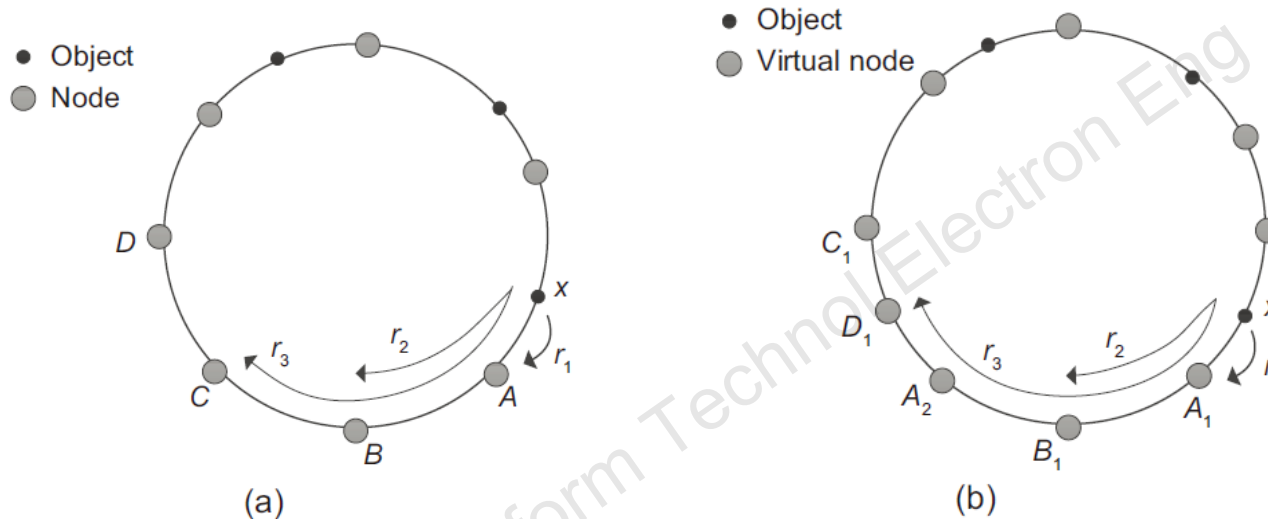


Fig. 1 Traditional replication under consistent hashing without (a) or with (b) virtual nodes

- The traditional replication strategy prevents subsets of nodes from powering down without violating data availability¹.

1 D. Harnik, D. Naor, and I. Segal. Low Power Mode in Cloud Storage Systems.

GreenCHT design

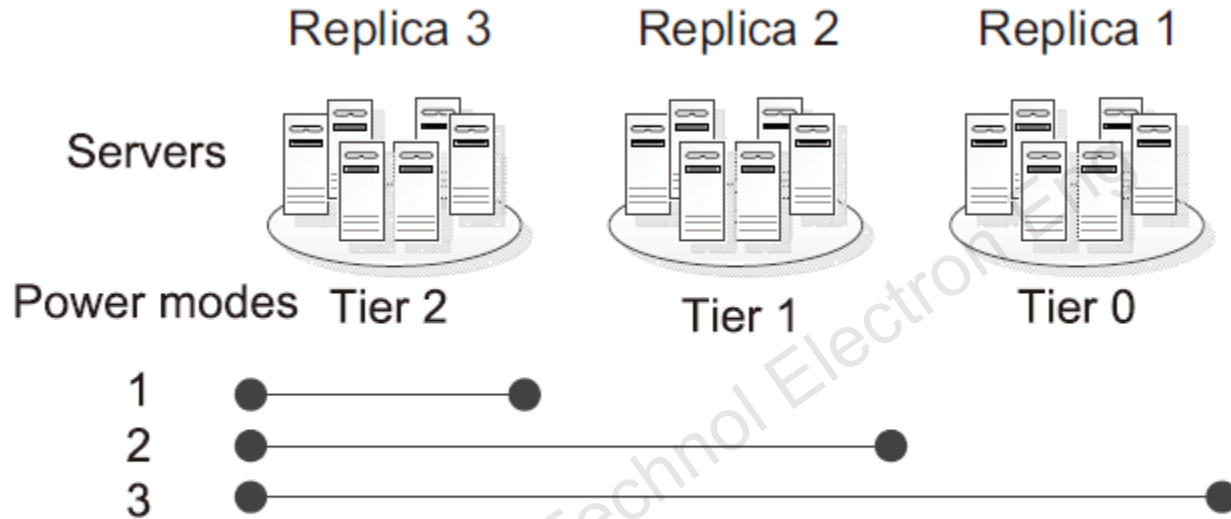


Fig. 2 Tiering and power modes with a replication factor of 3

■ Availability

- Allow $\frac{(R-t)N}{R}$ of the nodes to be powered down

■ Different power modes

- Sustain different workload levels

Multi-tier replication

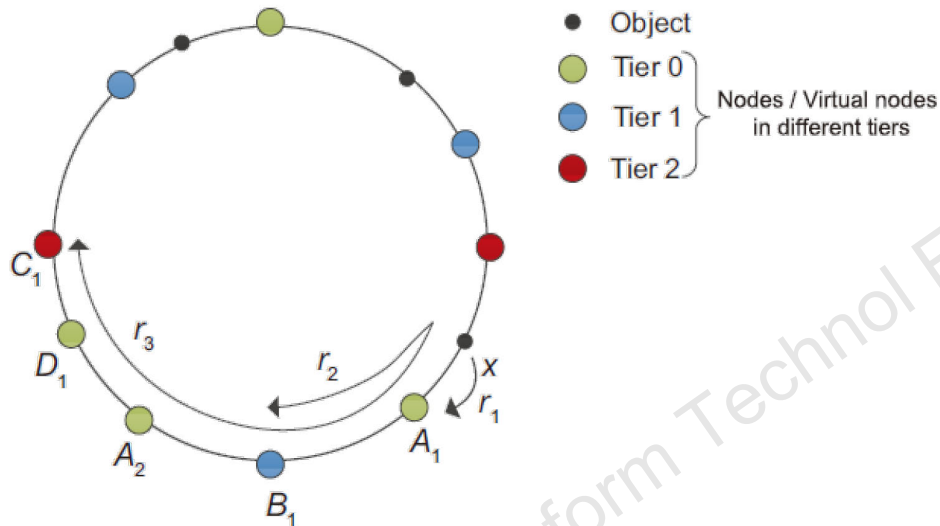


Table 1 Allocation of replicas

Object x	Successor 1
Tier 0	r_1
Tier 1	r_2
Tier 2	r_3

Fig. 3 Multi-tier consistent hash ring and replica layout (M-CHT)

■ Scalability

- When server n joins or leaves the system, certain objects will be migrated between server n and its successor in the same tier.

Log-store

Table 2 Log-replicas allocation

Object x	Successor_1	Successor_2	Successor_3		Successor_ R
Tier 0	r_1	-	-	-	-
Tier 1	r_2	Log r_1	-	-	-
Tier 2	r_3	Log r_1	Log r_2	-	-
... ..					
Tier $R-1$	r_R	Log r_1	Log r_2		Log r_{R-1}

■ Availability and reliability

- All the writes to standby replicas are offloaded to log-store, which exists in active nodes in higher tiers.

■ Parallelism of writes

- Replicas and log-replicas are stored in different nodes.

■ Scalability

- When a node enters or leaves, certain objects will be migrated between the node and its successor in the same tier. It will not influence other nodes.

Power mode scheduler

- Track the load

- Hour

- Predict the load

- ARMAX model

- Choose the power mode

- $$P = \left\lceil \frac{L_{predict}}{L_{tier}} \right\rceil$$

GreenCHT prototype

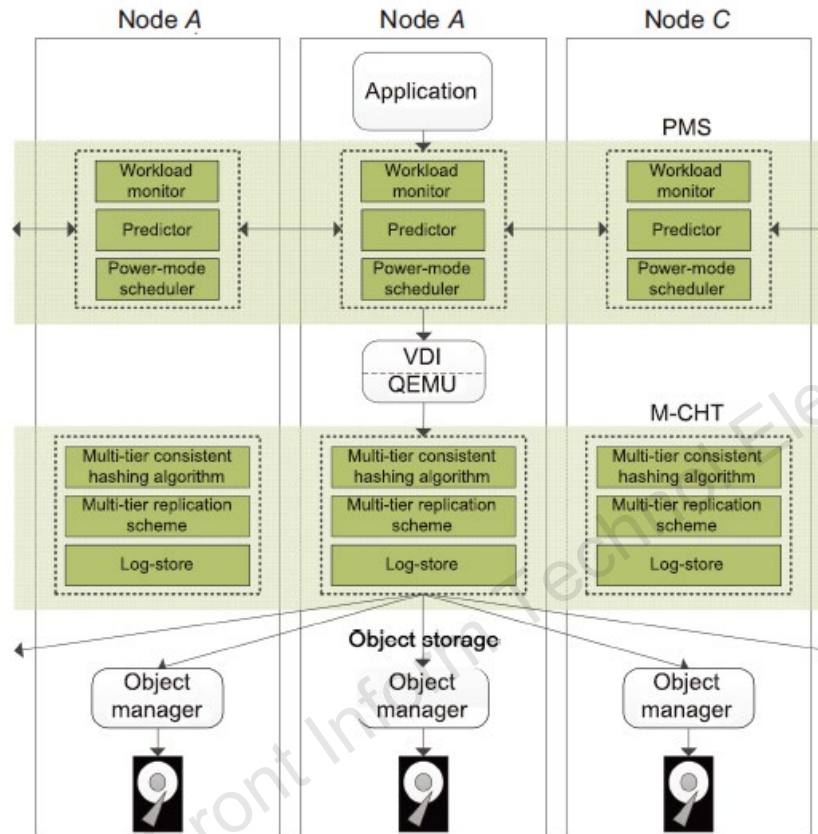


Fig. 6 GreenCHT system architecture

- We implemented our multi-tier replication scheme on Sheepdog
 - Modify its original data distribution and replication algorithm.
 - The power mode scheduler runs in the user space to schedule nodes to be powered-down and powered-up.

Evaluation

Power savings

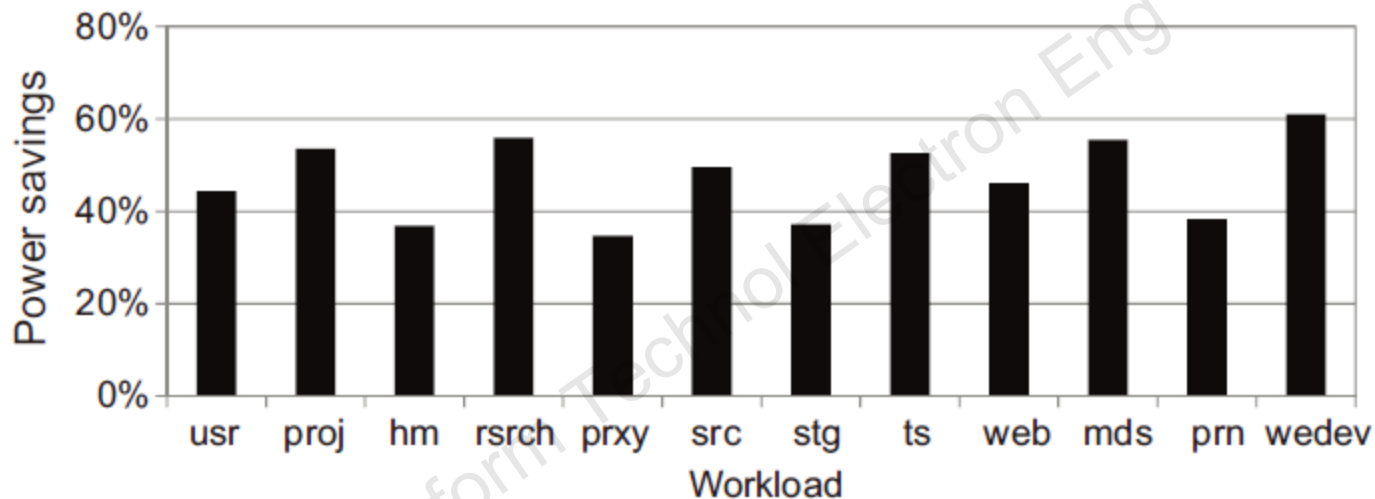


Fig. 12 Power savings for GreenCHT by using power mode scheduler's decisions

- **GreenCHT can reduce power consumption by up to 35%–61%**

Latency

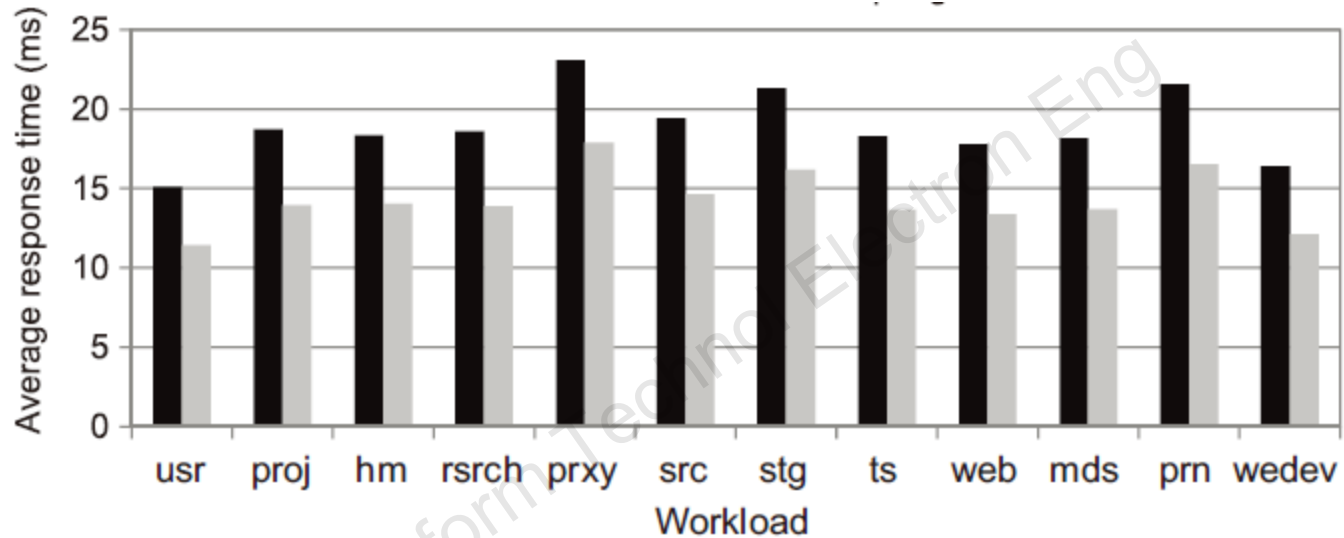


Fig. 14 Average response time for the two schemes under 12 traces

Conclusions

- We proposed a reliable power management scheme, GreenCHT, for consistent hashing based distributed key value storage systems.
- GreenCHT uses multi-tier replication to achieve considerable power savings while ensuring data availability and a reliable distributed log store to ensure reliability as well as fault tolerance of the whole system.
- To provide power proportionality and ensure good performance, GreenCHT dynamically adapts to workload variation under the required performance constraint by using a predictive power mode scheduler (PMS).
- GreenCHT was implemented based on the Sheepdog storage cluster by modifying Sheepdog's original data distribution and replication algorithm. By replaying 12 real-world traces, we observed that GreenCHT can reduce power consumption by up to 35%–61%.