OpenDHT: A Shared, Public DHT Service

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OASIS Retreat

January 10, 2005

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Distributed Hash Tables (DHTs)

- Introduced four years ago
  - Original context: peer-to-peer file sharing
- Idea: put/get as a distributed systems primitive
  - Put stores a value in the DHT, get retrieves it
  - Just like a local hash table, but globally accessible
- Since then:
  - Good implementations available (Bamboo, Chord)
  - Dozens of proposed applications

DHT Applications

- Storage systems
  - file systems: OceanStore (UCB), Past (Rice, MSR), CFS(MIT)
  - enterprise backup: hivecache.com
  - content distribution networks: BSlash(Stanford), Coral (NYU)
  - cooperative archival: Venti-DHASH (MIT), Pastiche (UMich)
  - web caching: Squirrel (MSR)
  - Usenet DHT (MIT)

DHT Applications

- Storage systems
- Indexing/naming services
  - Chord-DNS (MIT)
  - OpenDHT (Intel, UCB)
  - pSearch (HP)
  - Semantic Free Referencing (ICSI, MIT)
  - Layered Flat Names (ICSI, Intel, MIT, UCB)

DHT Applications

- Storage systems
- Indexing/naming services
- DB query processing
  - PIER (UCB, Intel)
  - Catalogs (Wisconsin)

DHT Applications

- Storage systems
- Indexing/naming services
- DB query processing
- Internet data structures
  - SkipGraphs (Yale)
  - PHT (Intel, UCSD, UCB)
  - Cone (UCSD)

DHT Applications

- Storage systems
- Indexing/naming services
- DB query processing
- Internet data structures
- Communication services
  - i3 (UCB, ICSI)
  - multicast/streaming: SplitStream, MCAN, Bayeux, Scribe, …

Deployed DHT Applications

- Overnet
  - Peer-to-peer file sharing
  - 10,000s of users
- Coral
  - Cooperative web caching
  - Several million requests per day

Why the discrepancy between hype and reality?

A Simple DHT Application: FreeDB Cache

- FreeDB is a free version of the CD database
  - Each disc has a (mostly) unique fingerprint
  - Map fingerprints to metadata about discs
- Very little data: only 2 GB or so
  - Trick is making it highly available on the cheap
  - Existing server: 4M reqs/week, 48 hour outage
- A perfect DHT application
  - One node can read DB, put each entry into DHT
  - Other nodes check DHT first, fall back on DB

Deploying the FreeDB Cache

- Download and familiarize self with DHT code
- Get a login on a bunch ($\approx$100) of machines
  - Maybe convince a bunch of friends to do it
  - Or, embed code in CD player application
  - PlanetLab, if you're really lucky
- Create monitoring code to keep up and running
  - Provide a service for clients to find DHT nodes
- Build proxy to query DHT before DB
- After all this, is performance even any better?
  - Is it any wonder that no one is deploying DHT apps?

An Alternative Deployment Picture

- What if a DHT was already deployed?
  - How hard is it to latch onto someone else's DHT?
- Still have build proxy to query DHT before DB
- After that, go direct to measuring performance
  - Don't have to get login on a bunch of machines
  - Don't have to build infrastructure to keep it running
- Much less effort to give it a try

OpenDHT

- Insight: *a shared DHT would be really valuable*
  - Could build/deploy FreeDB cache in a day
  - Dumping DB into DHT: $\approx$ 100 semicolons of C++
  - Proxy: 58 lines of Perl
- But it presents a bunch of research challenges
  - Traditional DHT APIs aren't designed to be shared
    - Every application's code must be present on every DHT node
    - Many traditional DHT apps modify the DHT code itself
  - A shared DHT must isolate applications from each other
    - Clients should be able to authenticate values stored in DHT
    - Resource allocation between clients/applications

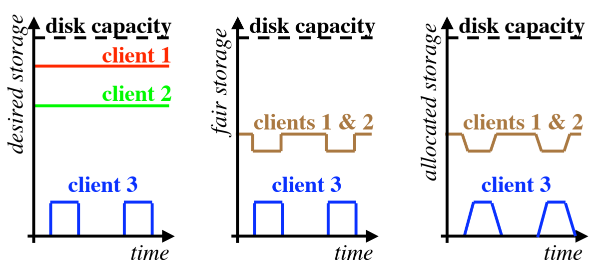
Protecting Against Overuse

- PlanetLab has a 5 GB per-slice disk quota
  - "But any *real* deployment will be over-provisioned."
- Peak load may be much higher than average load
  - A common problem for web servers, for example
- Malicious users may deny service through overuse
  - In general, can't distinguish from enthusiastic users
- Research goals:
  - Fairness: stop the elephants from trampling the mice
  - Utilization: don't force the elephants to become mice

Put/Get Interface Assumptions

- Make client code and garbage collection easy
  - Puts have a time-to-live (TTL) field
  - DHT either accepts or rejects puts "immediately"
  - If accepted, must respect TTL; else, client retries
- Accept based on fairness and utilization
  - Fairness could be weighted for economic reasons
- All decisions local to node
  - No global fairness/utilization yet
  - Rewards apps that balance puts, helps load balance

Fair Allocation Example

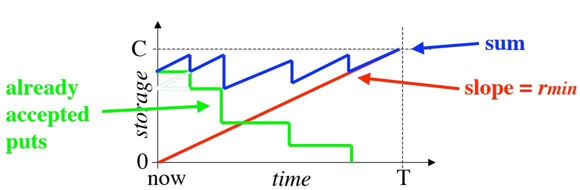


Starvation

- A motivating example
  - Assume we accept 5 GB of puts in very little time
  - Assume all puts have maximum TTL
- Result: starvation
  - Must hold all puts for max TTL, and disk full
  - Can't accept new puts until existing ones expire
- Clearly, this hurts fairness
  - Can't give space to new clients, for one thing

Preventing Starvation

- Fairness: must be able to adapt to changing needs
  - Guarantee storage frees up as some minimum rate, $r_{min} = C/T$
  - T is maximum TTL, C is disk capacity
- Utilization: don't rate limit when storage plentiful



Efficiently Preventing Starvation

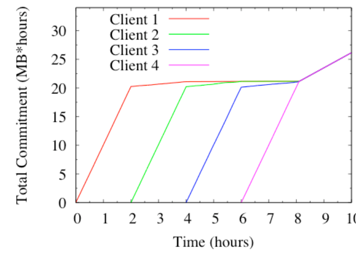
- Goal: before accept put, guarantee sum $\leq C$
- Naïve implementation
  - Track values of sum in array indexed by time
  - $O(T/\Delta t)$ cost: must update sum for all time under put
- Better implementation
  - Track inflection points of sum with a tree
  - Each leaf is an inflection point (time, value of sum)
  - Interior nodes track max value of all children
  - $O(\log n)$ cost: where n is the number of puts accepted

Fairly Allocating Put Rate

- Another motivating example
  - For each put, compute sum, if ≤ C, accept
  - Not fair: putting more often gives more storage
- Need to define fairness
  - Critical question: fairness of *what* resource?
  - Choice: storage over time, measured in bytes × seconds
  - 1 byte put for 100 secs same as 100 byte put for 1 sec
  - Also call these “commitments”

Candidate Algorithm

- Queue all puts for some small time, called a slot
  - If max put size is m, a slot is m/r_{min} seconds long
- At end of slot, in order of least total commitments:
  - If sum ≤ C for a put, accept it
  - Otherwise, reject it
- Result:
  - Starvation

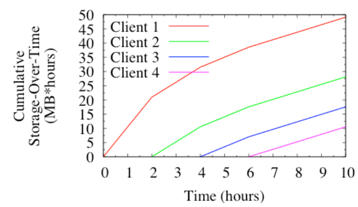


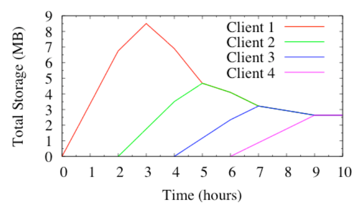
Preventing Starvation (Part II)

- Problem: we only prevented global starvation
  - Individual clients can still be starved periodically
- Solution: introduce *use-it-or-lose-it* principle
  - Don’t allow any client to fall too far behind
- Easy to implement
  - Introduce a minimum total commitment, s_{sys}
  - After every accept, increment client commitment, s_{client}, and s_{sys} both
  - When ordering puts, compute

    effective $s_{client} = \max(s_{client}, s_{sys})$

Revised Algorithm Performance





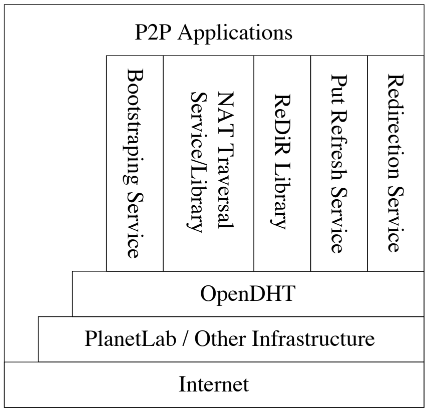
Fair Storage Allocation Notes

- Also works with TTL/size diversity
  - Not covered here
- Open Problem 1: can we remove the queuing?
  - Introduces a delay of 1/2 slot on average
  - Working on this now, but no firm results yet
- Open Problem 2: how to write clients?
  - How long should a client wait to retry rejected put?
  - Can it redirect the put to a new address instead?
  - Do we need an explicit refresh operation?

Longer Term Future Work

- OpenDHT makes a great common substrate for:
  - Soft-state storage
  - Naming and rendezvous
- Many P2P applications also need to:
  - Solve the bootstrap problem
  - Traverse NATs
  - Redirect packets within the infrastructure (as in *i3*)
  - Refresh puts while intermittently connected
- We need *systems software* for P2P

A System Architecture for P2P



For more information, see
http://opendht.org/