A Public DHT Service

Sean Rhea, Brighten Godfrey, Brad Karp, John Kubiatowicz, Sylvia Ratnasamy, Scott Shenker, Ion Stoica, and Harlan Yu

UC Berkeley and Intel Research
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Two Assumptions

1. Most of you have a pretty good idea how to build a DHT
2. Many of you would like to forget
My talk today:
How to *avoid* building one
DHT Deployment Today

Every application deploys its own DHT (DHT as a library)

connectivity

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OpenDHT: one DHT, shared across applications

(DHT as a *service*)

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Two Ways To Use a DHT

1. The Library Model
   - DHT code is linked into application binary
   - Pros: flexibility, high performance

2. The Service Model
   - DHT accessed as a service over RPC
   - Pros: easier deployment, less maintenance
The OpenDHT Service

• 200-300 Bamboo [USENIX’04] nodes on PlanetLab
  – All in one slice, all managed by us
• Clients can be arbitrary Internet hosts
  – Access DHT using RPC over TCP
• Interface is simple put/get:
  – put(key, value) — stores value under key
  – get(key) — returns all the values stored under key
• Running on PlanetLab since April 2004
  – Building a community of users
# OpenDHT Applications

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OpenDHT Benefits

• OpenDHT makes applications
  – Easy to build
    • Quickly bootstrap onto existing system
  – Easy to maintain
    • Don’t have to fix broken nodes, deploy patches, etc.

• Best illustrated through example
An Example Application: The CD Database

Compute Disc Fingerprint

Recognize Fingerprint?

Album & Track Titles
An Example Application: The CD Database

Type In Album and Track Titles

Album & Track Titles

No Such Fingerprint
Tom Waits / Closing Time

tracks: 12
total time: 45:54
year: 1973
genre:
ids: blues / b20ac00c

YEAR: 1973

1. 3:57 Ol' '55
2. 3:54 I Hope That I Don't Fall In Love With You
3. 3:10 Virginia Avenue
4. 3:41 Old Shoes (& Picture Postcards)
5. 3:27 Midnight Lullaby
6. 4:31 Martha
7. 4:03 Rosie
A DHT-Based FreeDB Cache

• FreeDB is a volunteer service
  – Has suffered outages as long as 48 hours
  – Service costs born largely by volunteer mirrors

• Idea: Build a cache of FreeDB with a DHT
  – Add to availability of main service
  – Goal: explore how easy this is to do
Building a FreeDB Cache Using the Library Approach

1. Download Bamboo/Chord/FreePastry
2. Configure it
3. Register a PlanetLab slice
4. Deploy code using Stork
5. Configure AppManager to keep it running
6. Register some gateway nodes under DNS
7. Dump database into DHT
8. Write a proxy for legacy FreeDB clients
Building a FreeDB Cache
Using the Service Approach

1. Dump database into DHT
2. Write a proxy for legacy FreeDB clients

• We built it
  – Called FreeDB on OpenDHT (FOOD)
#!/usr/bin/perl
use HTTP::Daemon; use HTTP::Status; use HTTP::Request; use Digest::SHA1;
use Compress::Bzip2; use MIME::Base64; require Frontier::Client;
use Cat::Class::XML; use File::Temp; use File::Pager; use XML::Twig;
use IO::File; use vars qw($stdin $stdout $stderr);

open my $in, '<', 'input.txt';
my $header = <$in>; print $header if scalar $header;
close $in;

""
Building a FreeDB Cache Using the Service Approach

1. Dump database into DHT
2. Write a proxy for legacy FreeDB clients

• We built it
  – Called FreeDB on OpenDHT (FOOD)
  – Cache has ↓ latency, ↑ availability than FreeDB
Talk Outline

• Introduction and Motivation

• Challenges in building a shared DHT
  – Sharing between applications
  – Sharing between clients

• Current Work

• Conclusion
Is Providing DHT Service Hard?

• Is it any different than just running Bamboo?
  – Yes, sharing makes the problem harder

• OpenDHT is shared in two senses
  – Across applications → need a flexible interface
  – Across clients → need resource allocation
Sharing Between Applications

• Must balance generality and ease-of-use
  – Many apps (FOOD) want only simple put/get
  – Others want lookup, anycast, multicast, etc.

• OpenDHT allows only put/get
  – But use client-side library, ReDiR, to build others
  – Supports lookup, anycast, multicast, range search
  – Only constant latency increase on average
  – (Different approach used by DimChord [KR04])
Sharing Between Clients

• Must authenticate puts/gets/removes
  – If two clients put with same key, who wins?
  – Who can remove an existing put?

• Must protect system’s resources
  – Or malicious clients can deny service to others
  – The remainder of this talk
Protecting Storage Resources

- Resources include network, CPU, and disk
  - Existing work on network and CPU
  - Disk less well addressed
- As with network and CPU:
  - Hard to distinguish malice from eager usage
  - Don’t want to hurt eager users if utilization low
- Unlike network and CPU:
  - Disk usage persists long after requests are complete
- Standard solution: quotas
  - But our set of active users changes over time
Fair Storage Allocation

• Our solution: give each client a fair share
  – Will define “fairness” in a few slides
• Limits strength of malicious clients
  – Only as powerful as they are numerous
• Protect storage on each DHT node separately
  – Global fairness is hard
  – Key choice imbalance is a burden on DHT
  – Reward clients that balance their key choices
Two Main Challenges

1. Making sure disk is available for new puts
   – As load changes over time, need to adapt
   – Without some free disk, our hands are tied

2. Allocating free disk fairly across clients
   – Adapt techniques from fair queuing
Making Sure Disk is Available

• Can’t store values indefinitely
  – Otherwise all storage will eventually fill

• Add time-to-live (TTL) to puts
  – put (key, value) → put (key, value, ttl)
  – (Different approach used by Palimpsest [RH03])
Making Sure Disk is Available

- TTLs prevent long-term starvation
  - Eventually all puts will expire
- Can still get short term starvation:

Client A arrives fills entire of disk
Client B arrives asks for space
Client A’s values start expiring

B Starves
Making Sure Disk is Available

- Stronger condition:
  Be able to accept $r_{\text{min}}$ bytes/sec new data at all times

![Diagram](image)

- Sum must be < max capacity
- Reserved for future puts. Slope = $r_{\text{min}}$
- Candidate put
Making Sure Disk is Available

- Stronger condition:
  Be able to accept $r_{\min}$ bytes/sec new data at all times
Making Sure Disk is Available

- Formalize graphical intuition:
  \[ f(\tau) = B(t_{now}) - D(t_{now}, t_{now} + \tau) + r_{min} \times \tau \]

- To accept put of size \( x \) and TTL \( l \):
  \[ f(\tau) + x < C \text{ for all } 0 \leq \tau < l \]

- This is non-trivial to arrange
  - Have to track \( f(\tau) \) at all times between now and max TTL?

- Can track the value of \( f \) efficiently with a tree
  - Leaves represent inflection points of \( f \)
  - Add put, shift time are \( O(\log n) \), \( n = \# \) of puts
Fair Storage Allocation

Queue full: reject put

Per-client put queues

Not full: enqueue put

Select most under-represented

Wait until can accept without violating $r_{min}$

Store and send accept message to client

The Big Decision: Definition of “most under-represented”
Defining “Most Under-Represented”

- Not just sharing disk, but disk over time
  - 1-byte put for 100s same as 100-byte put for 1s
  - So units are bytes × seconds, call them *commitments*

- Equalize total commitments granted?
  - No: leads to starvation
  - A fills disk, B starts putting, A starves up to max TTL

Client A arrives
fills entire of disk

Client B arrives
asks for space

B catches up with A

Now A Starves!
Defining “Most Under-Represented”

• Instead, equalize rate of commitments granted
  – Service granted to one client depends only on others putting “at same time”

- Client A arrives fills entire of disk
- Client B arrives asks for space
- B catches up with A
- A & B share available rate

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Defining “Most Under-Represented”

• Instead, equalize rate of commitments granted
  – Service granted to one client depends only on others putting “at same time”

• Mechanism inspired by Start-time Fair Queuing
  – Have virtual time, $v(t)$
  – Each put gets a start time $S(p_c^i)$ and finish time $F(p_c^i)$
    
    $$F(p_c^i) = S(p_c^i) + \text{size}(p_c^i) \times \text{ttl}(p_c^i)$$
    $$S(p_c^i) = \max(v(A(p_c^i)) - \epsilon, F(p_c^{i-1}))$$

    
    $$v(t) = \text{maximum start time of all accepted puts}$$
Fairness with Different Arrival Times

![Graph of Total Bytes x Seconds vs Time (hours) for Clients 1, 2, 3, and 4.]

![Graph of Total Storage (MB) vs Time (hours) for Clients 1, 2, 3, and 4.]

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Fairness With Different Sizes and TTLs
Talk Outline

• Introduction and Motivation
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  – Sharing between clients
• Current Work
• Conclusion
Current Work: Performance

- Only 28 of 7 million values lost in 3 months
  – Where “lost” means unavailable for a full hour
- On Feb. 7, 2005, lost 60/190 nodes in 15 minutes to PL kernel bug, only lost one value
Current Work: Performance

- Median get latency ~250 ms
  - Median RTT between hosts ~ 140 ms
- But 95th percentile get latency is atrocious
  - And even median spikes up from time to time
The Problem: Slow Nodes

• Some PlanetLab nodes are just really slow
  – But set of slow nodes changes over time
  – Can’t “cherry pick” a set of fast nodes
  – Seems to be the case on RON as well
  – May even be true for managed clusters (MapReduce)

• Modified OpenDHT to be robust to such slowness
  – Combination of delay-aware routing and redundancy
  – Median now 66 ms, 99th percentile is 320 ms
    (using 2X redundancy)
Conclusion

• Focusing on how to *use* a DHT
  – Library model: flexible, powerful, often overkill
  – Service model: easy to use, shares costs
  – Both have their place, we’re focusing on the latter

• Challenge: Providing for sharing
  – Across applications \(\rightarrow\) flexible interface
  – Across clients \(\rightarrow\) fair resource sharing

• Up and running today
To try it out:

(code at http://opendht.org/users-guide.html)

$ ./find-gateway.py | head -1
planetlab5.csail.mit.edu

$ ./put.py http://planetlab5.csail.mit.edu:5851/ Hello World 3600 Success

$ ./get.py http://planetlab5.csail.mit.edu:5851/ Hello World
Identifying Clients

- For fair sharing purposes, a client is its IP addr
  - Spoofing prevented by TCP’s 3-way handshake

- Pros:
  - Works today, no registration necessary

- Cons:
  - All clients behind NAT get only one share
  - DHCP clients get more than one share

- Future work: authentication at gateways