OPEN DHT
A Public DHT Service

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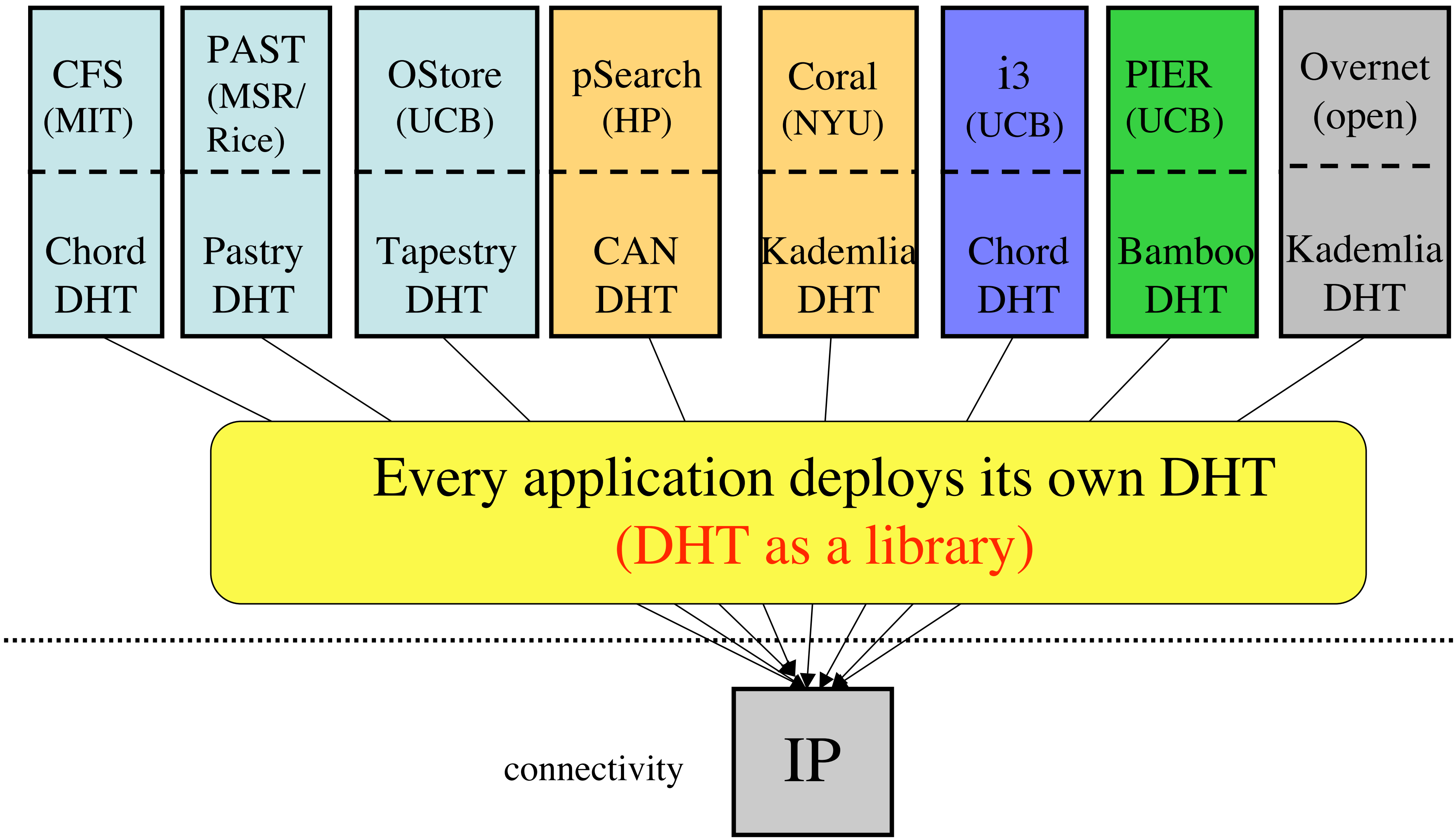
Two Assumptions

1. Most of you have a pretty good idea how to build a DHT
2. Many of you would like to forget

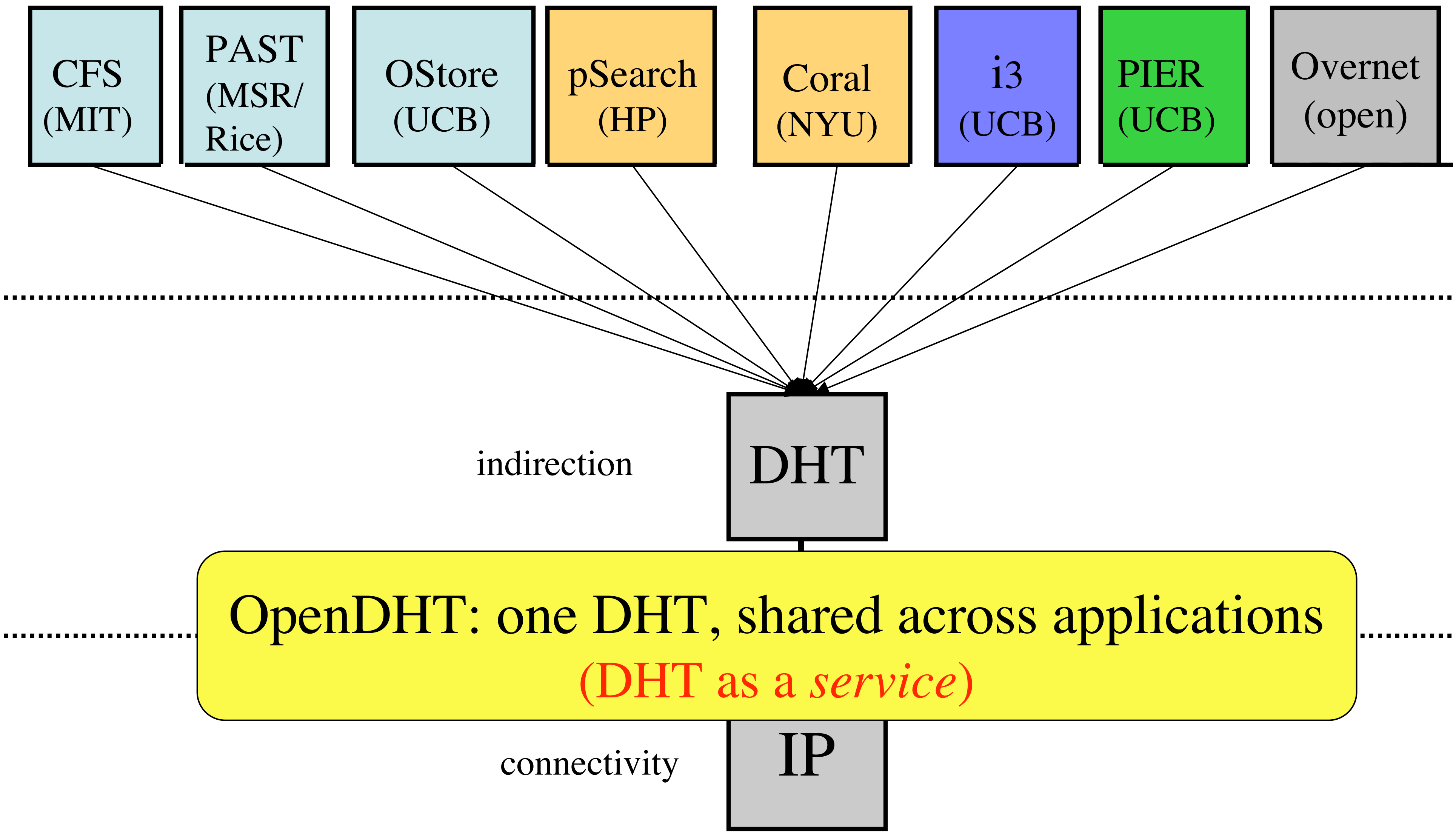
My talk today:

How to *avoid* building one

DHT Deployment Today



DHT Deployment Tomorrow?



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

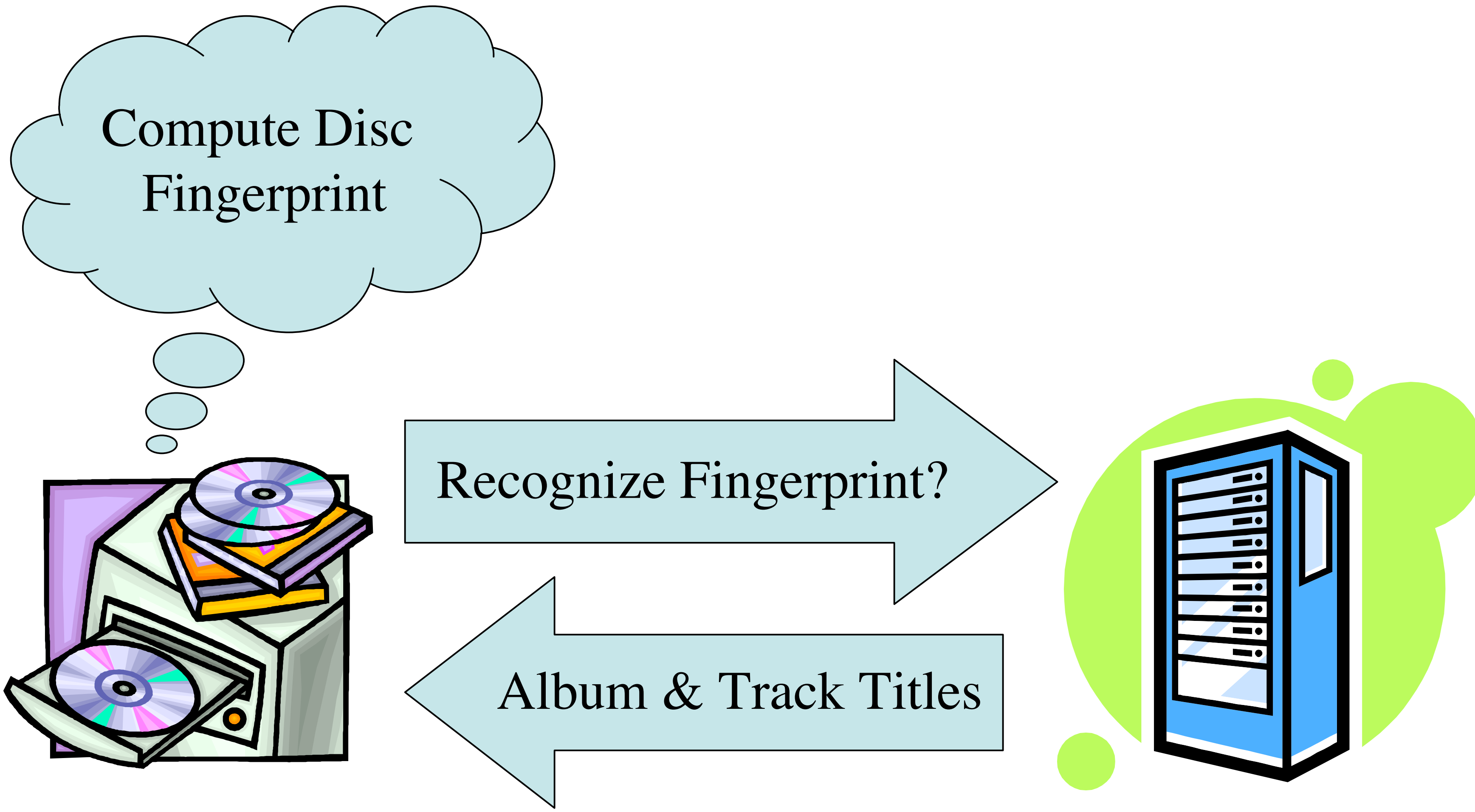
OpenDHT Applications

Application	*Uses OpenDHT for*
Croquet Media Manager	replica location
DOA	indexing
HIP	name resolution
DTN Tetherless Computing Architecture	host mobility
Place Lab	range queries
QStream	multicast tree construction
VPN Index	indexing
DHT-Augmented Gnutella Client	rare object search
FreeDB	storage
Instant Messaging	rendezvous
CFS	storage
*i*3	redirection

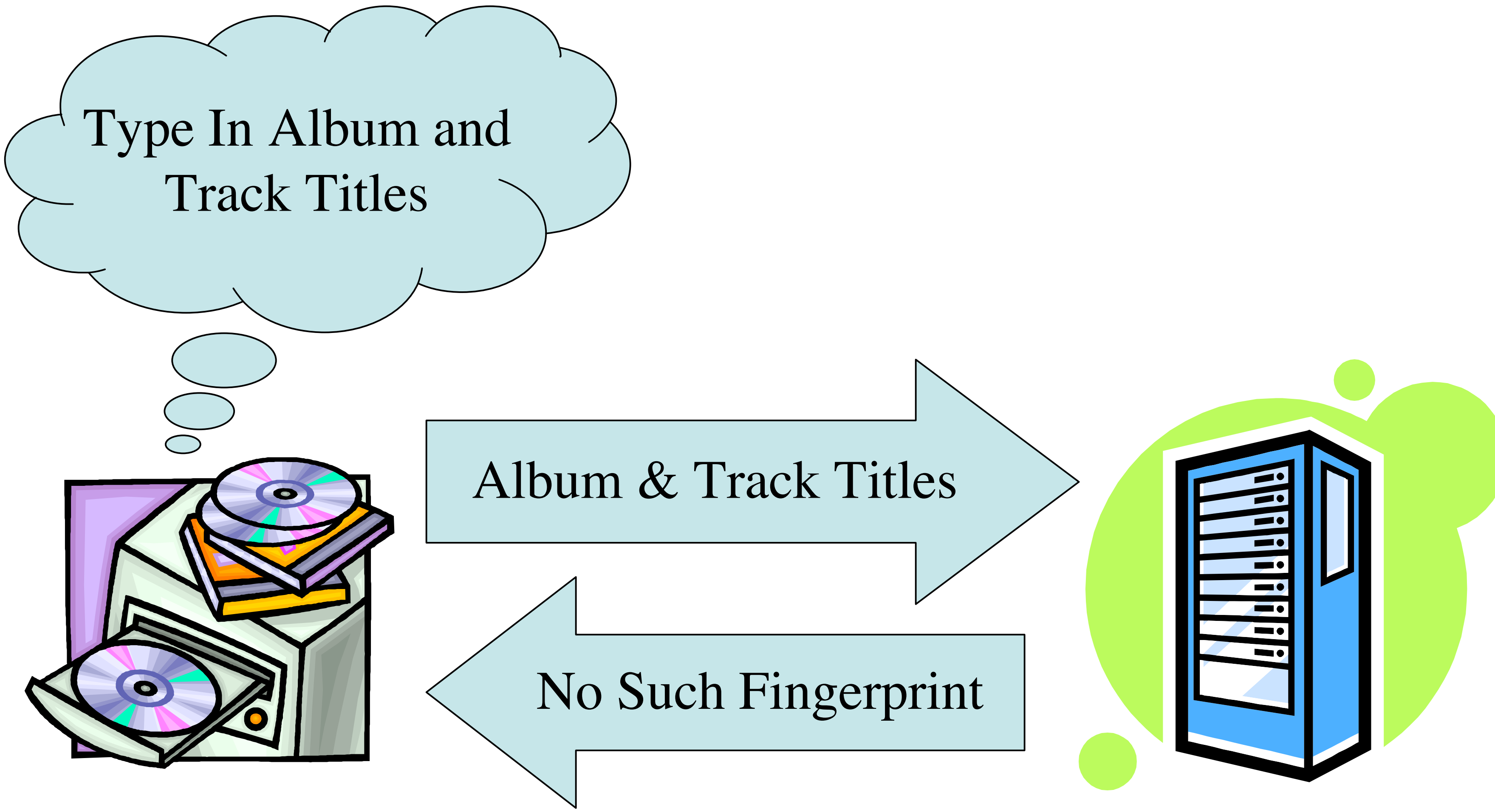
OpenDHT Benefits

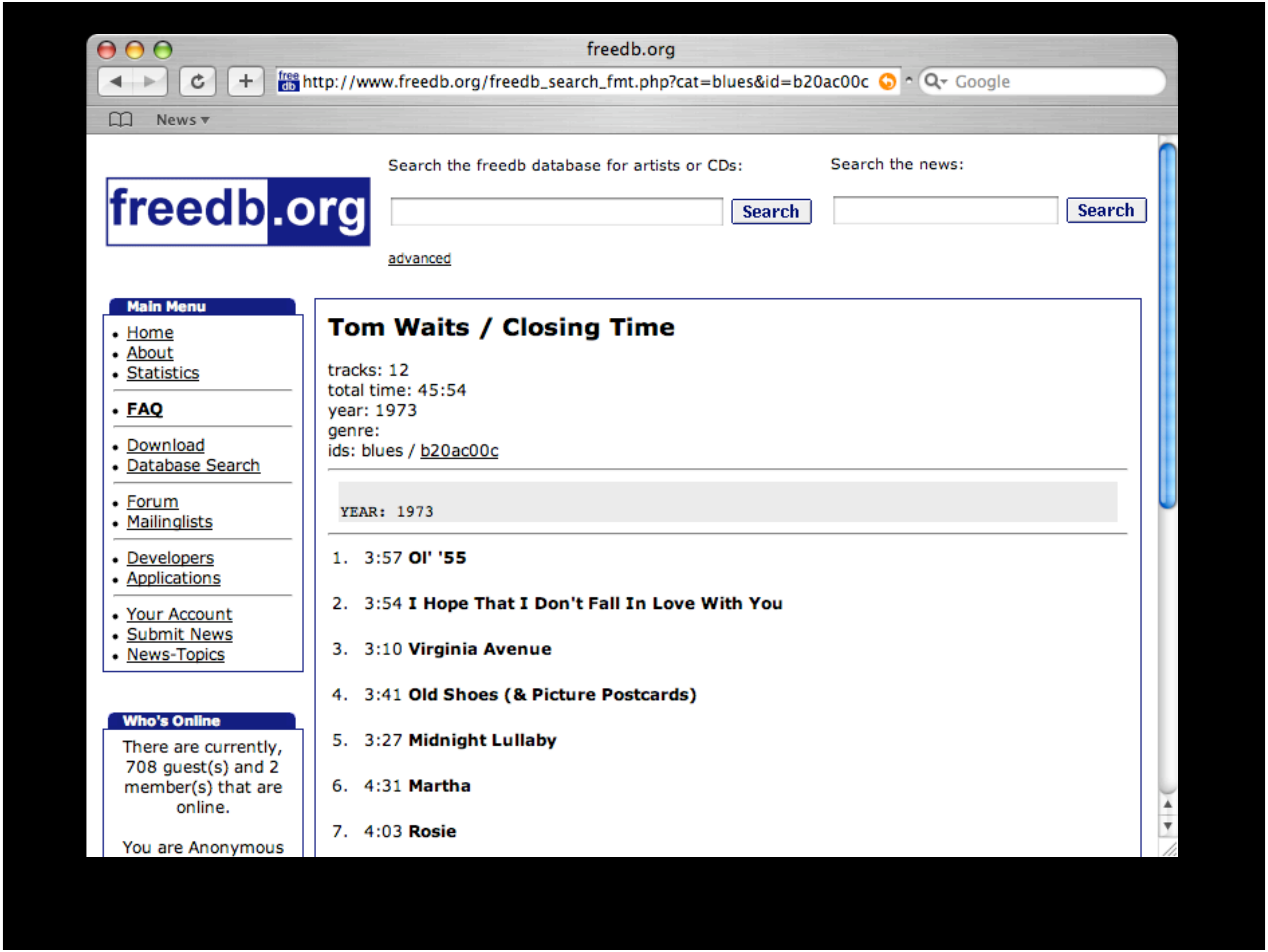
- OpenDHT makes applications
  - Easy to build
    - Quickly bootstrap onto existing system
  - Easy to maintain
    - Don't have to fix broken nodes, deploy patches, etc.
- Best illustrated through example

An Example Application: The CD Database



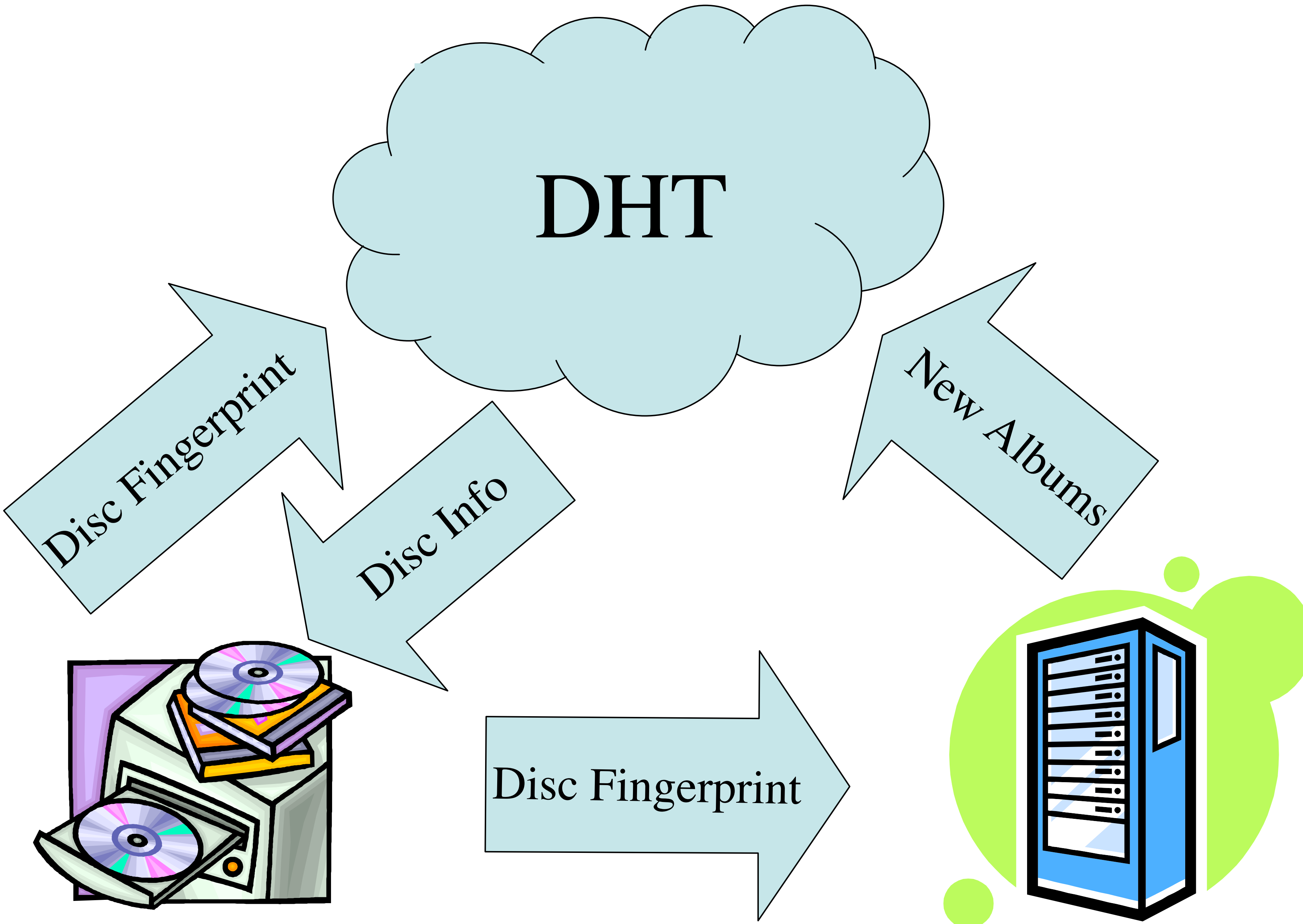
An Example Application: The CD Database




freedb.org
http://www.freedb.org/freedb_search_fmt.php?cat=blues&id=b20ac00c
Google
News
freedb.org
Search the freedb database for artists or CDs:
Search
advanced
Search the news:
Search
Main Menu
Home
About
Statistics
FAQ
Download
Database Search
Forum
Mailinglists
Developers
Applications
Your Account
Submit News
News-Topics
Who's Online
There are currently, 708 guest(s) and 2 member(s) that are online.
You are Anonymous
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


DHT
Disc Fingerprint
Disc Info
New Albums
Disc Fingerprint

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)

food.pl (~/Desktop) - VIM

File | Edit | Tools | Syntax | Buffers | Window | Help

```perl
#!/usr/bin/perl
use HTTP::Daemon; use HTTP::Status; use HTTP::Request; use Digest::SHA1;
use Compress::Bzip2; use MIME::Base64; require Frontier::Client;
$cl=Frontier::Client->new( 'url' => $ARGS[0], 'encoding' => 'ISO-8859-1' );
$d=HTTP::Daemon->new(LocalAddr => 'localhost', LocalPort => 4444, Reuse => 1,);
@cats=("blues","classical","country","data","folk","jazz","misc","newage",
"reggae","rock","soundtrack"); sub fm{($a,$b)=@_; if ($##$a==$##$b){
($i,$avg,$o,$aprev,$bprev)= (0,0,0,0,0);for($i=0;$i<=$##$a;$i++){
$o=abs(($$a[$i]-$aprev)-($$b[$i]-$bprev)); $avg+=$o; if($o>900){return 0;}
$aprev=$$a[$i]; $bprev=$$b[$i];} $avg/=($##$a+1); return ($avg<=(225))?1:0;}}
sub dp {($dd)=@_; @dlines=split /\n/,$dd; $inoffsets=0; $dlen=0; my @offsets;
$dd=~/DTITLE=(.*?)\n/; $dt=$1; foreach(@dlines){if(/Track\s+frame\s+offsets:/){
$inoffsets=1; next;} elsif($inoffsets){if (/Disc\s+length:\s+([0-9]+)/) {
$dlen=$1;last;} elsif(/([0-9]+)/){push @offsets, $1;}}} if($dlen==0){die($fn);}
return ($dt,$dlen,@offsets);} sub uri_parse{($uri)=@_; $r=HTTP::Response->new();
if($uri=~/cddb\+query\+([0-9a-f]+)\+([0-9]+?)\+/){@q=split /\+/,$',$2+1;
$#q=$2-1;$sha1=Digest::SHA1->new;$sha1->add($1);$hexkey=$sha1->clone->hexdigest;
$key=$sha1->b64digest.'='; $pmark=''; $found=0; do{$rpcresp=$cl->call('get',
$cl->base64($key),$cl->int(1024),$cl->base64($pmark),$cl->string('FOOD'));
foreach $disc (@{$$rpcresp[0]}){$foo=decode_base64($disc->value());
$p=Compress::Bzip2::decompress_init();$bar=substr($foo, 1);$dd=$p->finish($bar);
($dt,$dlen,@idx)=dp($dd);$cat=$cats[ord(substr($foo,0,1))];if(fm(\@q,\@idx)) {
$cache{$cat.$1}=$dd; $r->content("200 $cat $1 $dt\n"); return $r;}}
$pmark = $$rpcresp[1]->value(); last if ($found == 1);} while(length($pmark)>0);
$r->content("202 No match found\n");}
elsif ($uri =~ /cddb\+read\+([a-z]+)\+([0-9a-f]+)\&/) {$r->add_content(
"210 $1 $2 CD database entry follows (until terminating `.')\n");
$r->add_content($cache{$1.$2}); $r->add_content('.\n');} else{$r=0;}return $r;}
while ($c=$d->accept){while($r=$c->get_request){if ($r->method eq 'GET') {
$repl = uri_parse ($r->uri); if ($repl) {$c->send_response($repl);}
else {$c->send_error(RC_FORBIDDEN);}}} $c->close; undef($c);}
~
~
```

31,61 All

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

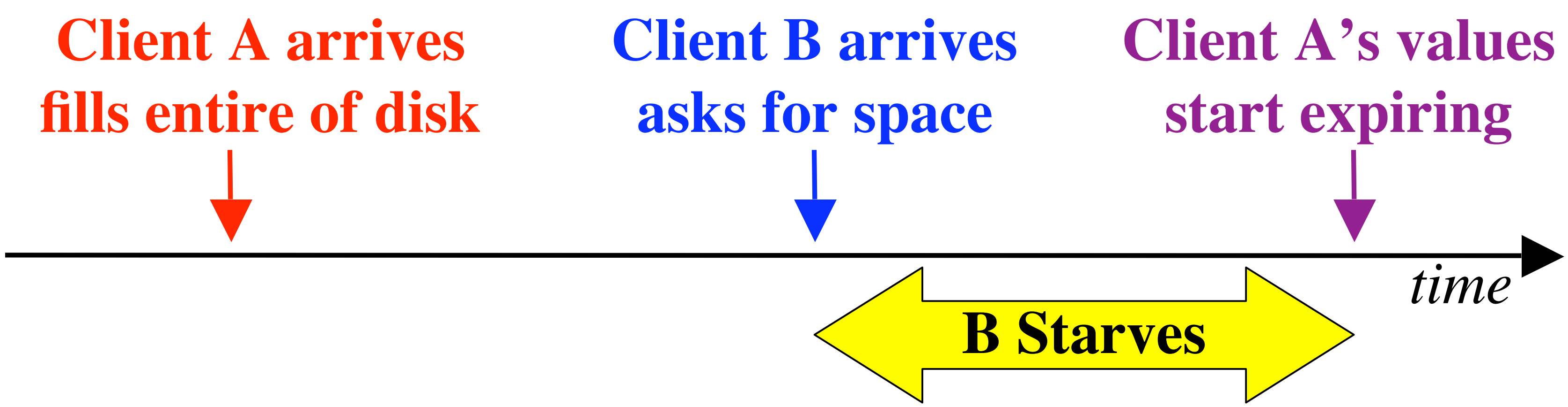
2. Allocating free disk fairly across clients
   – Adapt techniques from fair queuing

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

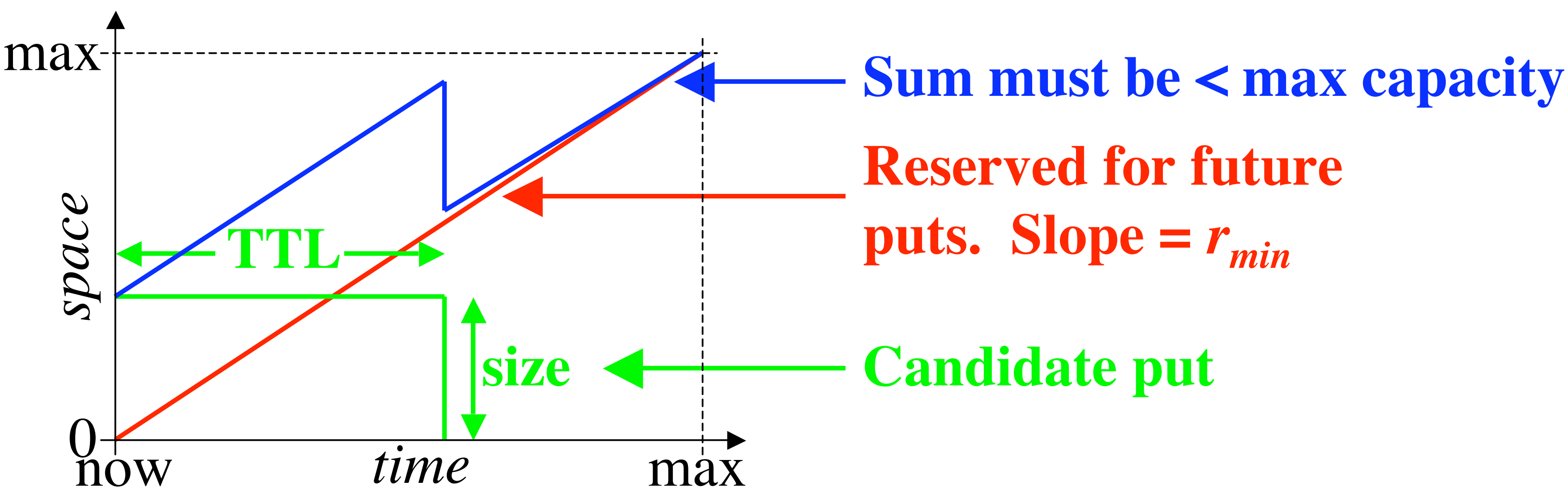
- TTLs prevent long-term starvation
  - Eventually all puts will expire
- Can still get short term starvation:



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

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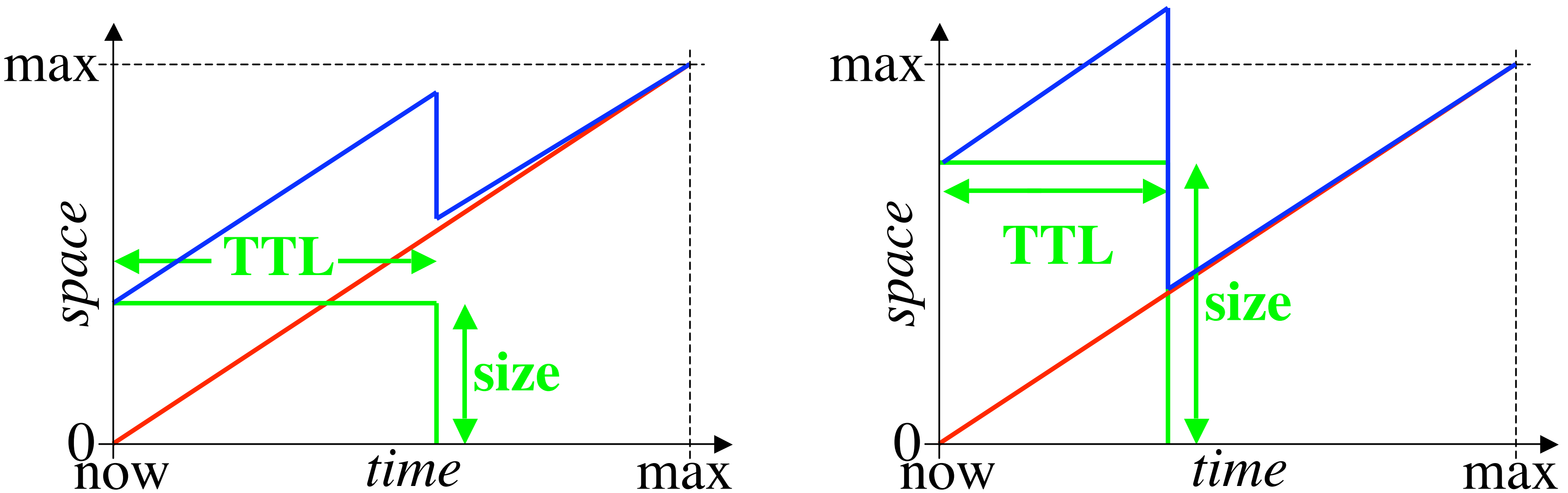


Making Sure Disk is Available

- Formalize graphical intuition:

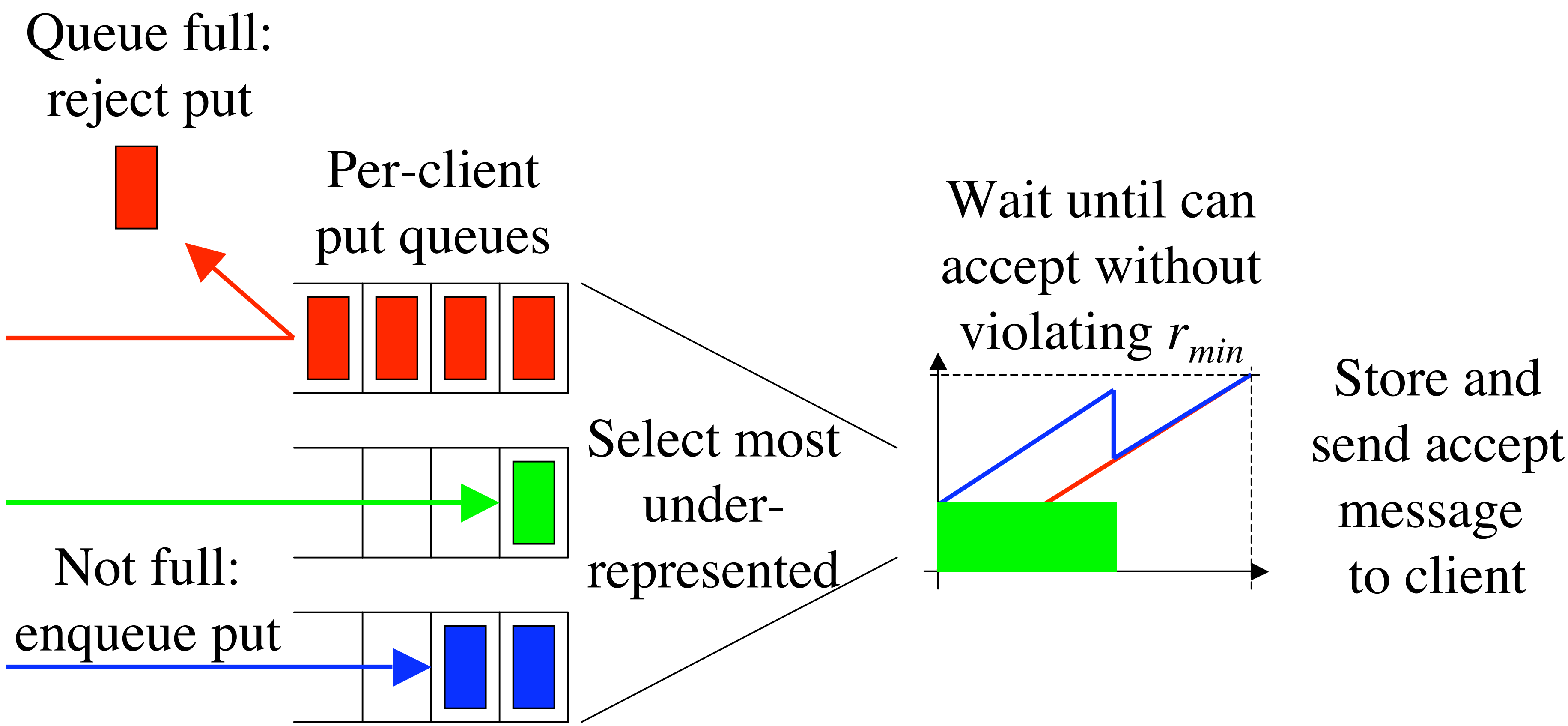
  $$f(\tau) = B(t_{now}) - D(t_{now}, t_{now} + \tau) + r_{min} \times \tau$$

- 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

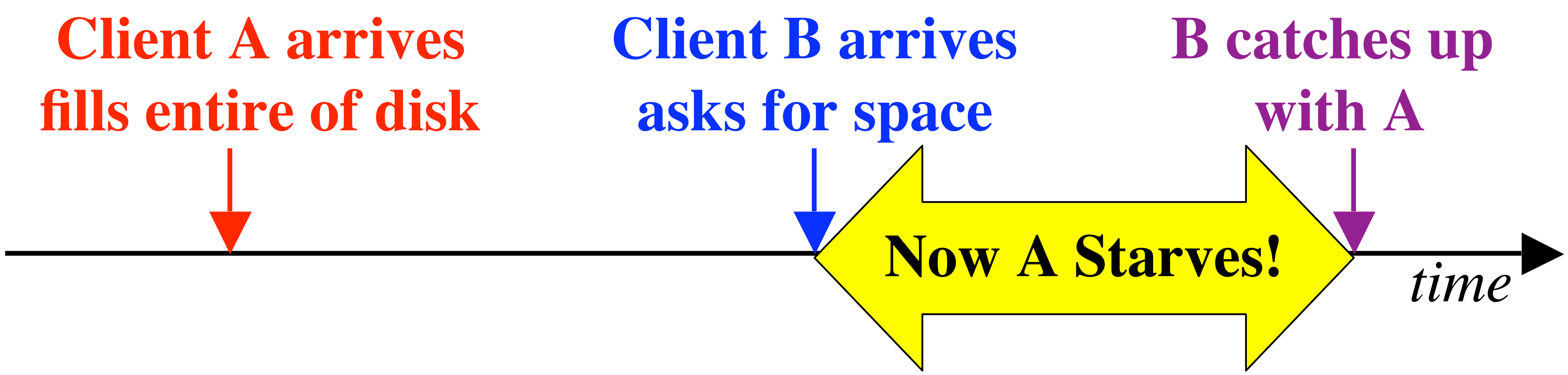
Fair Storage Allocation



The Big Decision: Definition of “most under-represented”

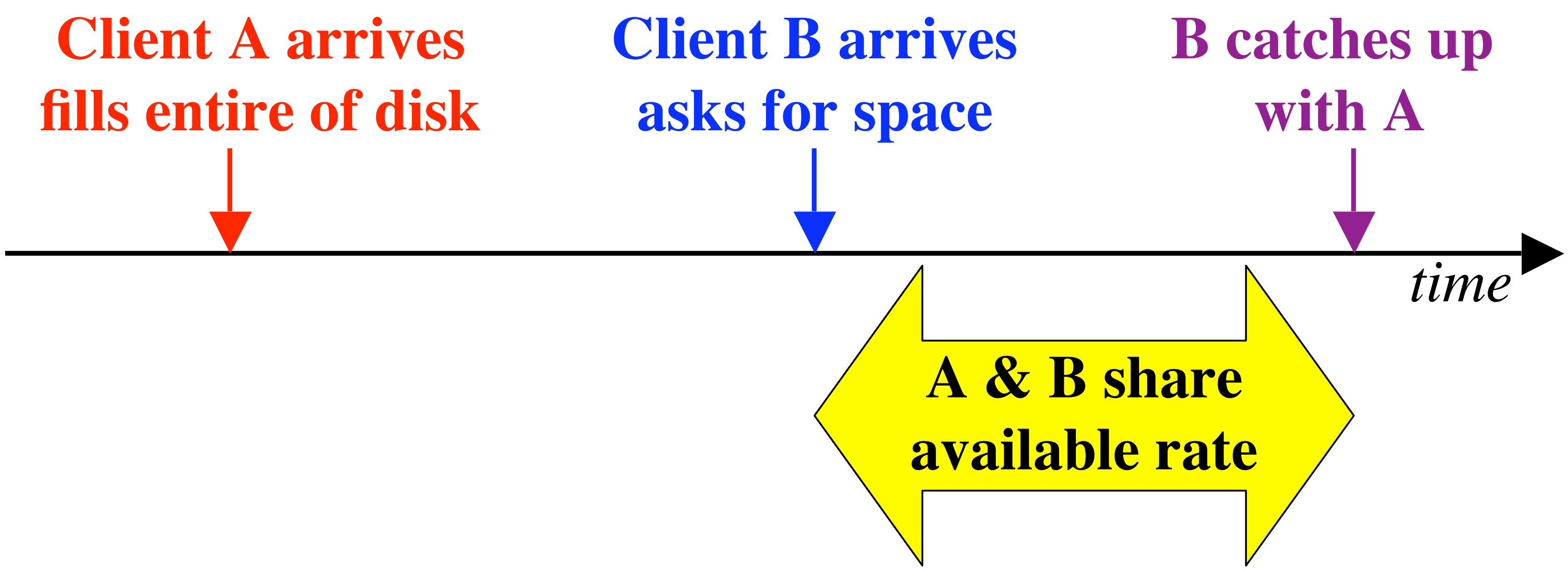
Defining "Most Under-Represented"

- 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



Defining "Most Under-Represented"

- Instead, equalize *rate* of commitments granted
  - Service granted to one client depends only on others putting "at same time"



Defining "Most Under-Represented"

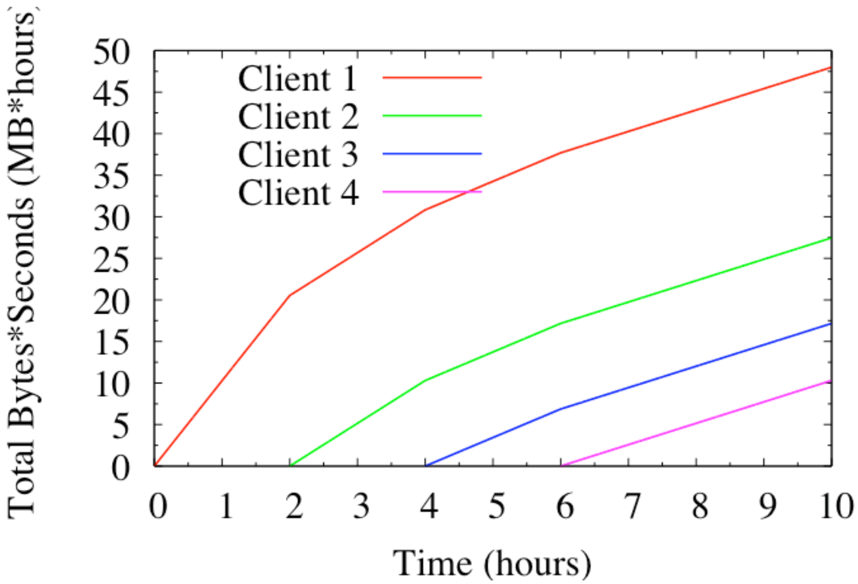
- Instead, equalize *rate* of commitments granted
  - Service granted to one client depends only on others putting "at same time"
- Mechanism inspired by Start-time Fair Queuing
  - Have virtual time, v(t)
  - Each put gets a start time $S(p_c^i)$ and finish time $F(p_c^i)$

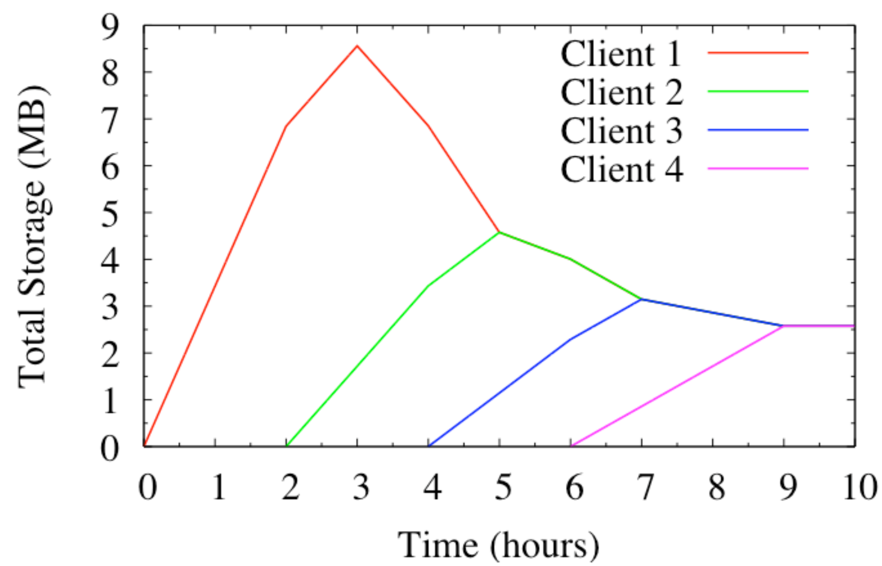
$$F(p_c^i) = S(p_c^i) + size(p_c^i) \times ttl(p_c^i)$$

$$S(p_c^i) = \max(v(A(p_c^i)) - \varepsilon, F(p_c^{i-1}))$$

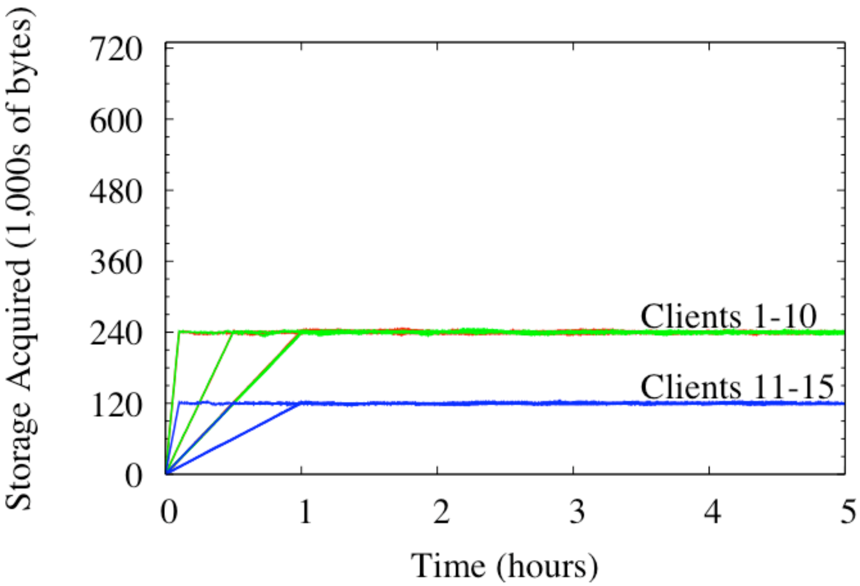
v(t) = maximum start time of all accepted puts

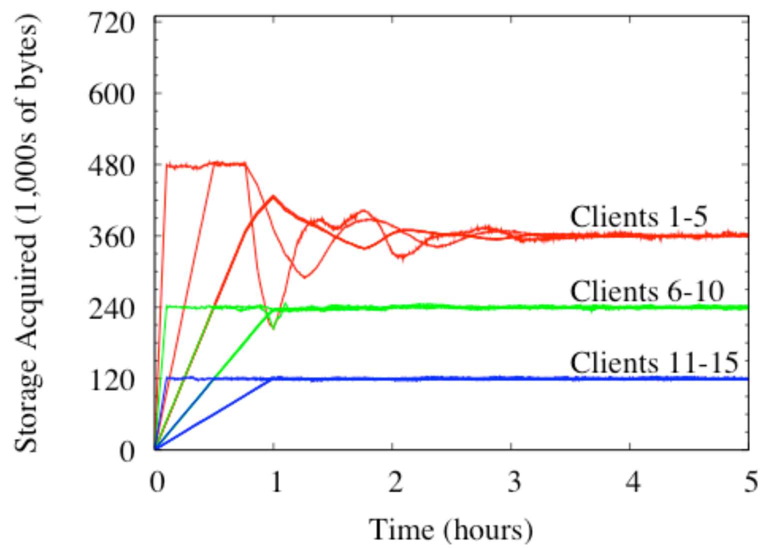
Fairness with Different Arrival Times





Fairness With Different Sizes and TTLs





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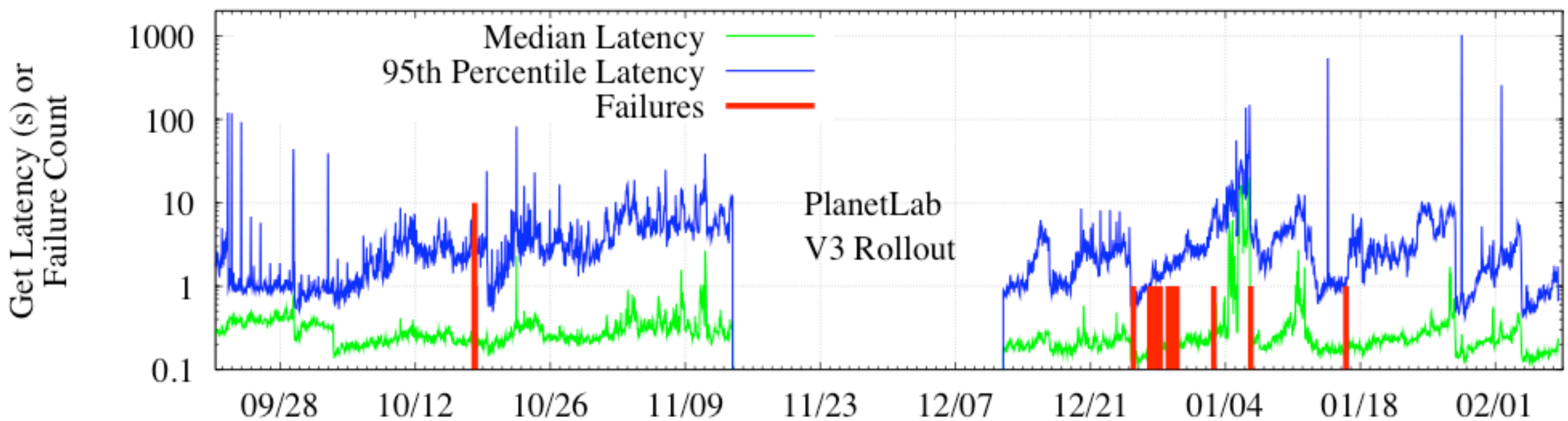
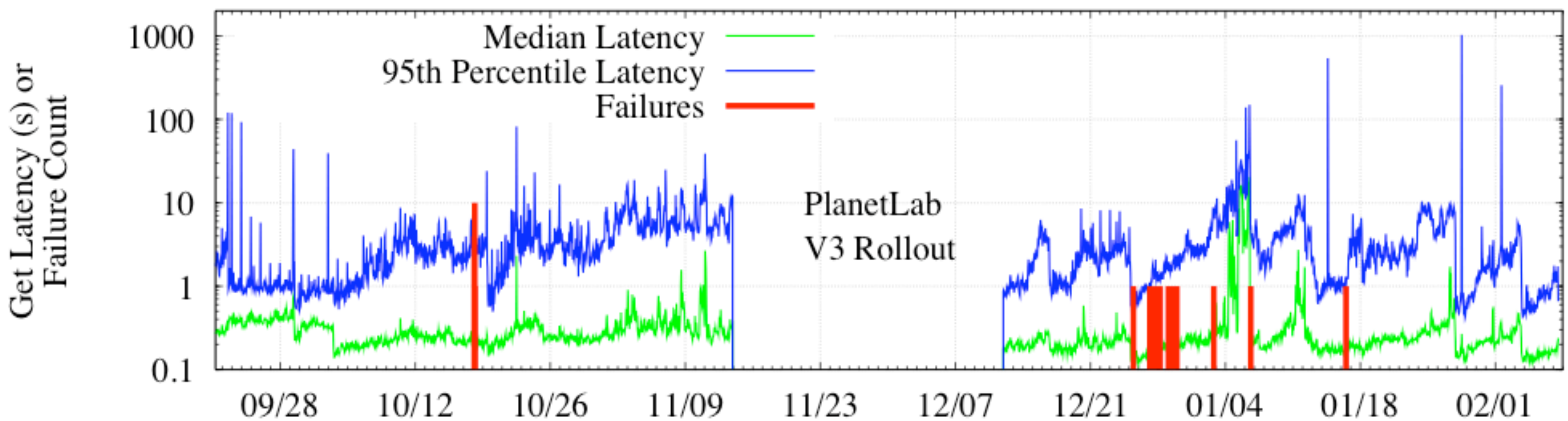
Current Work: Performance



- 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 → flexible interface
  - Across clients → 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