Group Therapy for Systems:

Using link attestations to manage failure

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A little background…

Powered By PLANETLAB

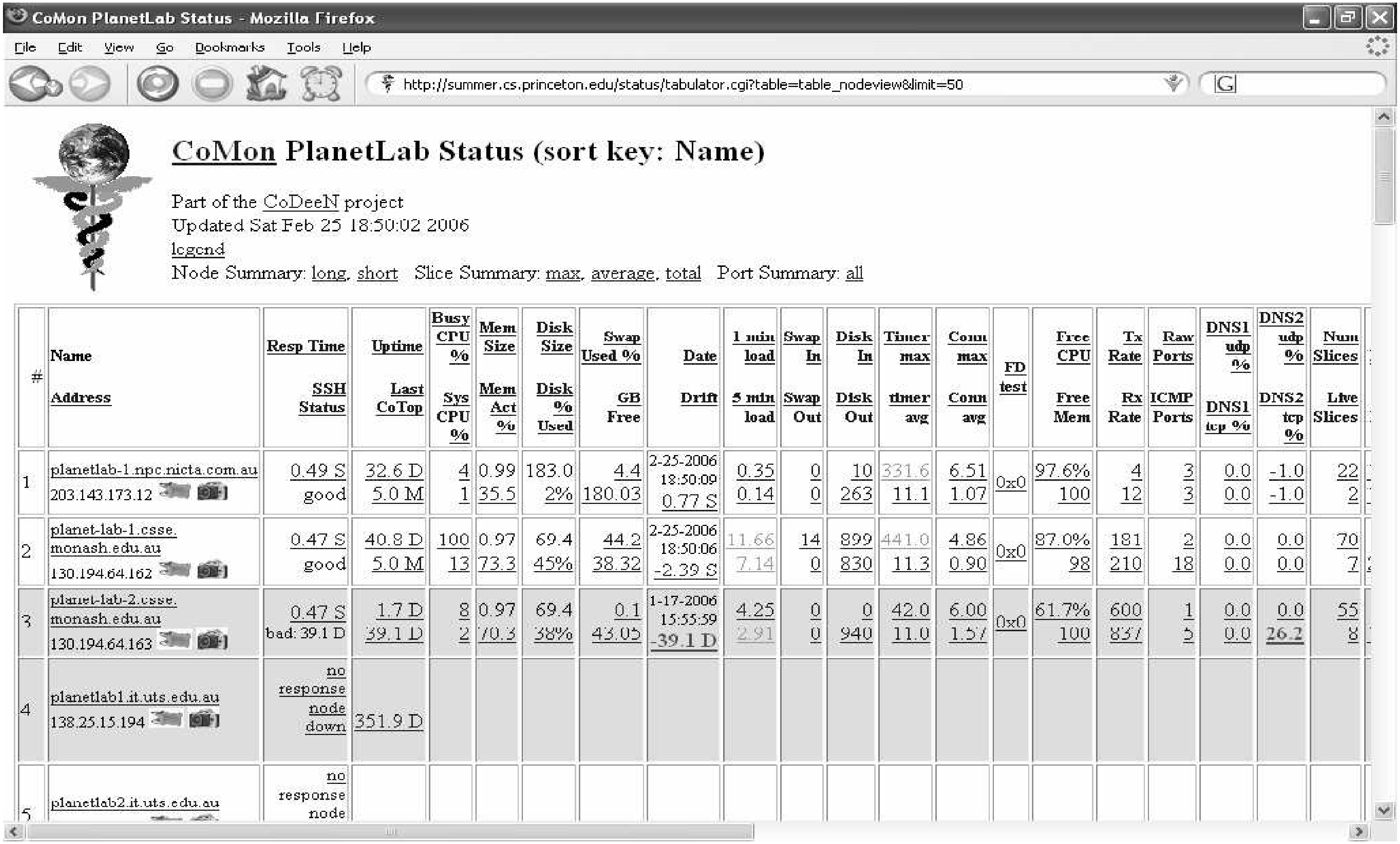
- I built and manage CORAL
  - CoralCDN is an open, P2P content distribution network
  - http://cnn.com/ → http://cnn.com.***nyud.net:8080***/
  - Publicly deployed for 2 years on PlanetLab
  - 25 M requests from 1 M clients for 2-3 TB daily
- Nodes rarely crash
- Nodes often don’t behave “correctly”
- How do I cope with this problem?

Problems running CoralCDN

- Non-transitive or asymmetric routing
  - Interdomain routing failures, I2-only peering, firewalls, egress filtering, proxies, …
- Performance faults
  - Network queuing and high packet loss, slow disks, long context switches, memory leaks, …
- Buggy code
  - File-descriptor leaks, race conditions, versioning issues, …
- File-system errors
  - Disk quota exceeded, disk corruption, wrong file perms, …

- Problem: Failures are not fail stop!

How do we manage today?

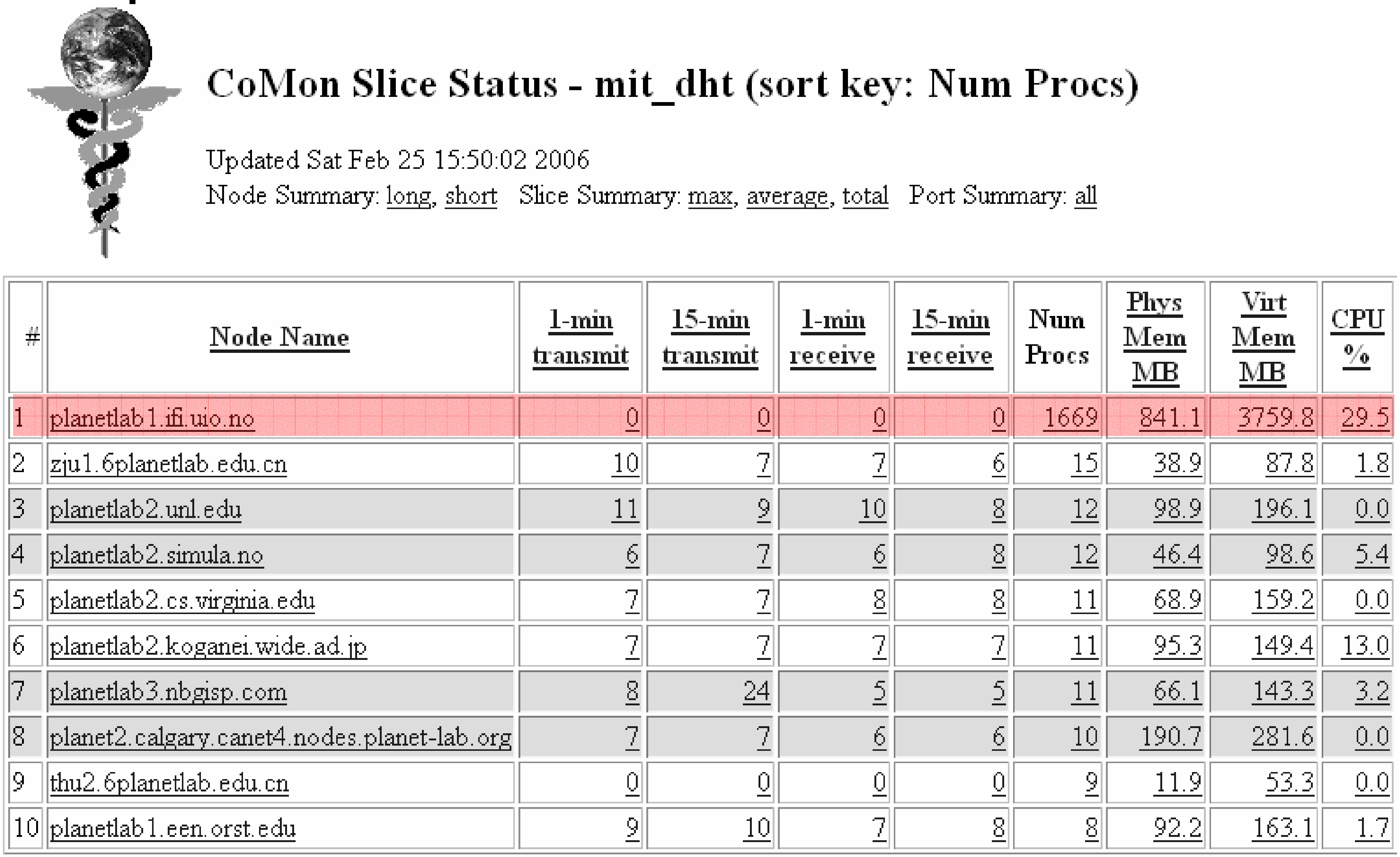

CoMon PlanetLab Status - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://summer.cs.princeton.edu/status/tabulator.cgi?table=table_nodeview&limit=50

CoMon PlanetLab Status (sort key: Name)

Part of the CoDeeN project
Updated Sat Feb 25 18:50:02 2006
legend
Node Summary: long, short   Slice Summary: max, average, total   Port Summary: all

#	Name	Resp Time	Uptime	Busy CPU %	Mem Size	Disk Size	Swap Used %	Date	1 min load	Swap In	Disk In	Timer max	Conn max	FD test	Free CPU	Tx Rate	Raw Ports	DNS1 udp %	DNS2 udp %	Num Slices
	Address	SSH Status	Last CoTop	Sys CPU %	Mem Act %	Disk % Used	GB Free	Drift	5 min load	Swap Out	Disk Out	timer avg	Conn avg		Free Mem	Rx Rate	ICMP Ports	DNS1 tcp %	DNS2 tcp %	Live Slices
1	planetlab-1.npc.nicta.com.au 203.143.173.12	0.49 S good	32.6 D 5.0 M	4 1	0.99 35.5	183.0 2%	4.4 180.03	2-25-2006 18:50:09 0.77 S	0.35 0.14	0 0	10 263	331.6 11.1	6.51 1.07	0x0	97.6% 100	4 12	3 3	0.0 0.0	-1.0 -1.0	22 2
2	planet-lab-1.csse.monash.edu.au 130.194.64.162	0.47 S good	40.8 D 5.0 M	100 13	0.97 73.3	69.4 45%	44.2 38.32	2-25-2006 18:50:06 -2.39 S	11.66 7.14	14 0	899 830	441.0 11.3	4.86 0.90	0x0	87.0% 98	181 210	2 18	0.0 0.0	0.0 0.0	70 7
3	planet-lab-2.csse.monash.edu.au 130.194.64.163	0.47 S bad: 39.1 D	1.7 D 39.1 D	8 2	0.97 70.3	69.4 38%	0.1 43.05	1-17-2006 15:55:59 -39.1 D	4.25 2.91	0 0	0 940	42.0 11.0	6.00 1.57	0x0	61.7% 100	600 837	1 5	0.0 0.0	0.0 26.2	55 8
4	planetlab1.it.uts.edu.au 138.25.15.194	no response node down	351.9 D																	
5	planetlab2.it.uts.edu.au	no response node																		

How do we manage today?



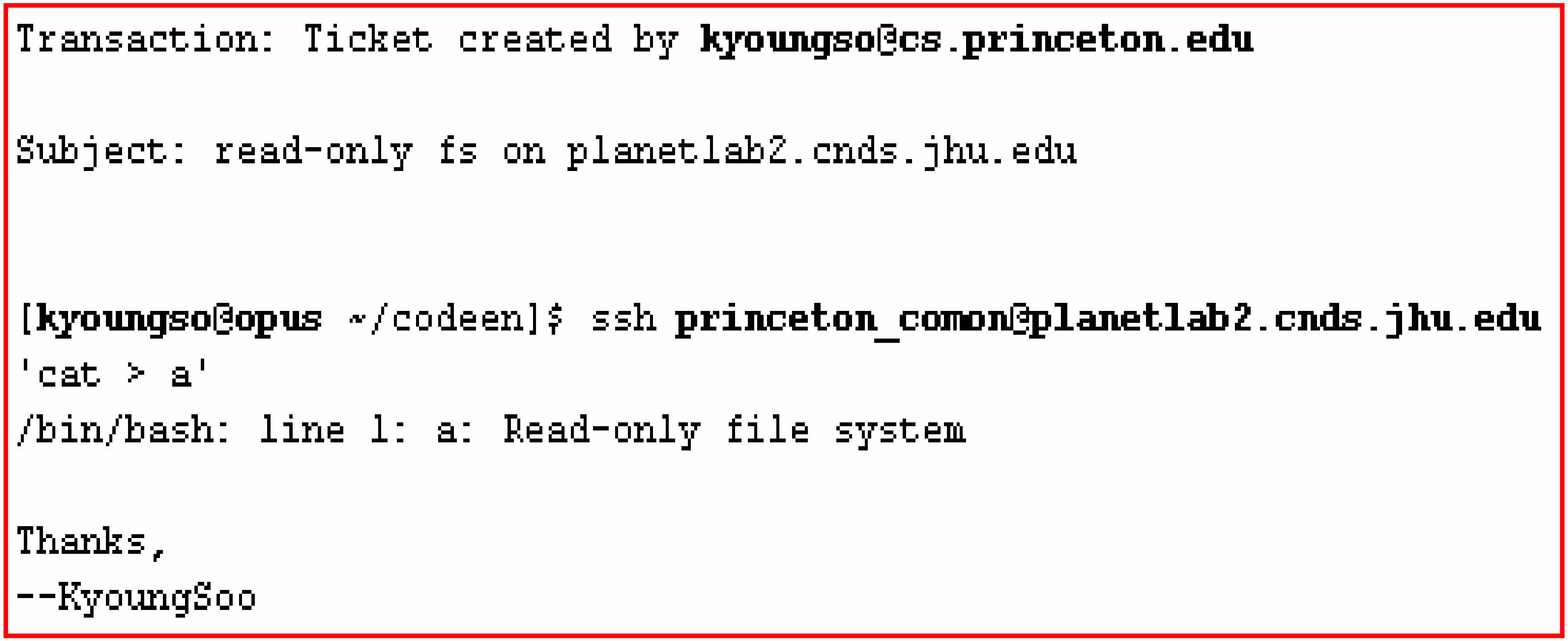
CoMon Slice Status - mit_dht (sort key: Num Procs)

Updated Sat Feb 25 15:50:02 2006

Node Summary: long, short   Slice Summary: max, average, total   Port Summary: all

#	Node Name	1-min transmit	15-min transmit	1-min receive	15-min receive	Num Procs	Phys Mem MB	Virt Mem MB	CPU %
1	planetlab1.ifi.uio.no	0	0	0	0	1669	841.1	3759.8	29.5
2	zju1.6planetlab.edu.cn	10	7	7	6	15	38.9	87.8	1.8
3	planetlab2.unl.edu	11	9	10	8	12	98.9	196.1	0.0
4	planetlab2.simula.no	6	7	6	8	12	46.4	98.6	5.4
5	planetlab2.cs.virginia.edu	7	7	8	8	11	68.9	159.2	0.0
6	planetlab2.koganei.wide.ad.jp	7	7	7	7	11	95.3	149.4	13.0
7	planetlab3.nbgisp.com	8	24	5	5	11	66.1	143.3	3.2
8	planet2.calgary.canet4.nodes.planet-lab.org	7	7	6	6	10	190.7	281.6	0.0
9	thu2.6planetlab.edu.cn	0	0	0	0	9	11.9	53.3	0.0
10	planetlab1.een.orst.edu	9	10	7	8	8	92.2	163.1	1.7

How do we manage today?



```
Transaction: Ticket created by kyoungso@cs.princeton.edu

Subject: read-only fs on planetlab2.cnds.jhu.edu


[kyoungso@opus ~/codeen]$ ssh princeton_comon@planetlab2.cnds.jhu.edu
'cat > a'
/bin/bash: line 1: a: Read-only file system

Thanks,
--KyoungSoo
```

How do we manage today?

A maze of twisty little passages, all *different*

Something is needed…

- When running systems, weird stuff happens
- Once identify class of problems, write tests for them
- Give application more information →

  System makes more intelligent decision to work around
  - Graceful degradation
  - Give us time to go back and fix problem
  - Right now we don’t utilize info systematically
- Today: Abstraction that collects and exposes information in structured way
- Goal: Simplify application design & implementation

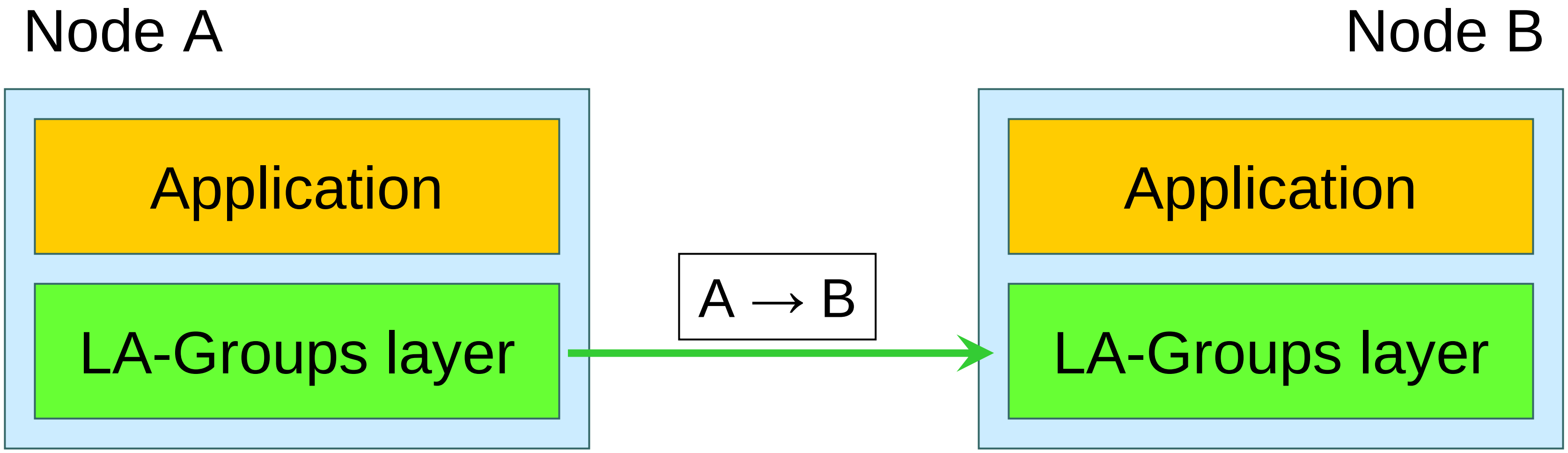
Towards better system manageability

- Propose Link-Attestation Groups abstraction
  - Software abstraction to aid in management
  - “Group membership” subsystem

- Applying LA-Groups
  - DHTs
  - Multicast
  - File-sharing

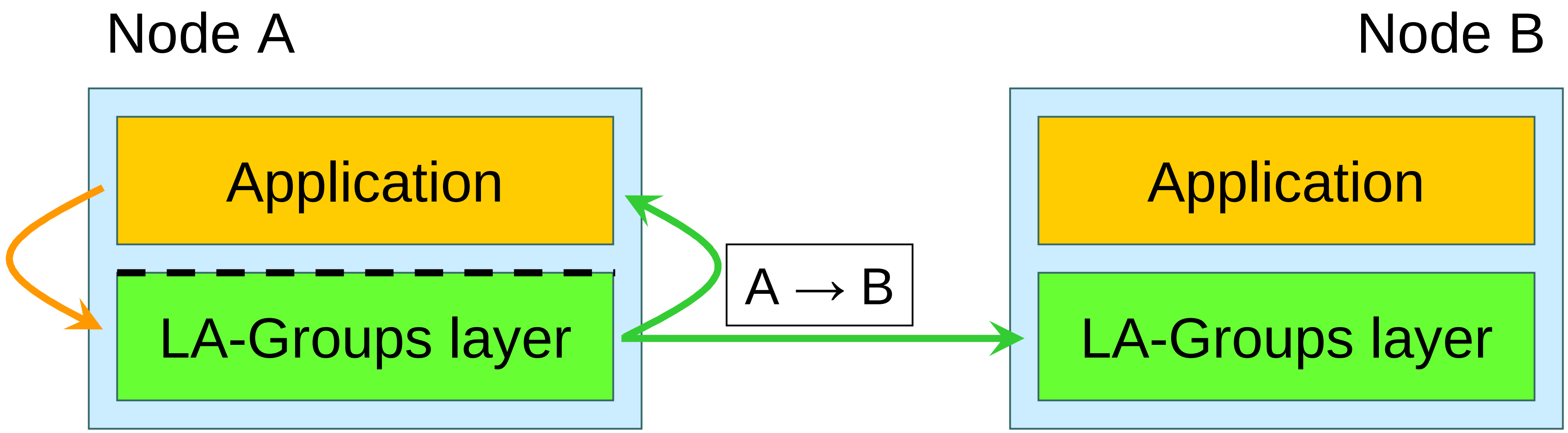
- Only one point in design space

Link attestations



- Attestation: “A.app says B.app is correct”
  - Group identifier
  - Identities of attester (A) and attestee (B)
  - Expiration time (now + *t* secs)
  - Signed by attester (A)

The LA-Groups API



GID create()

void join(GID, nodeID[ ])

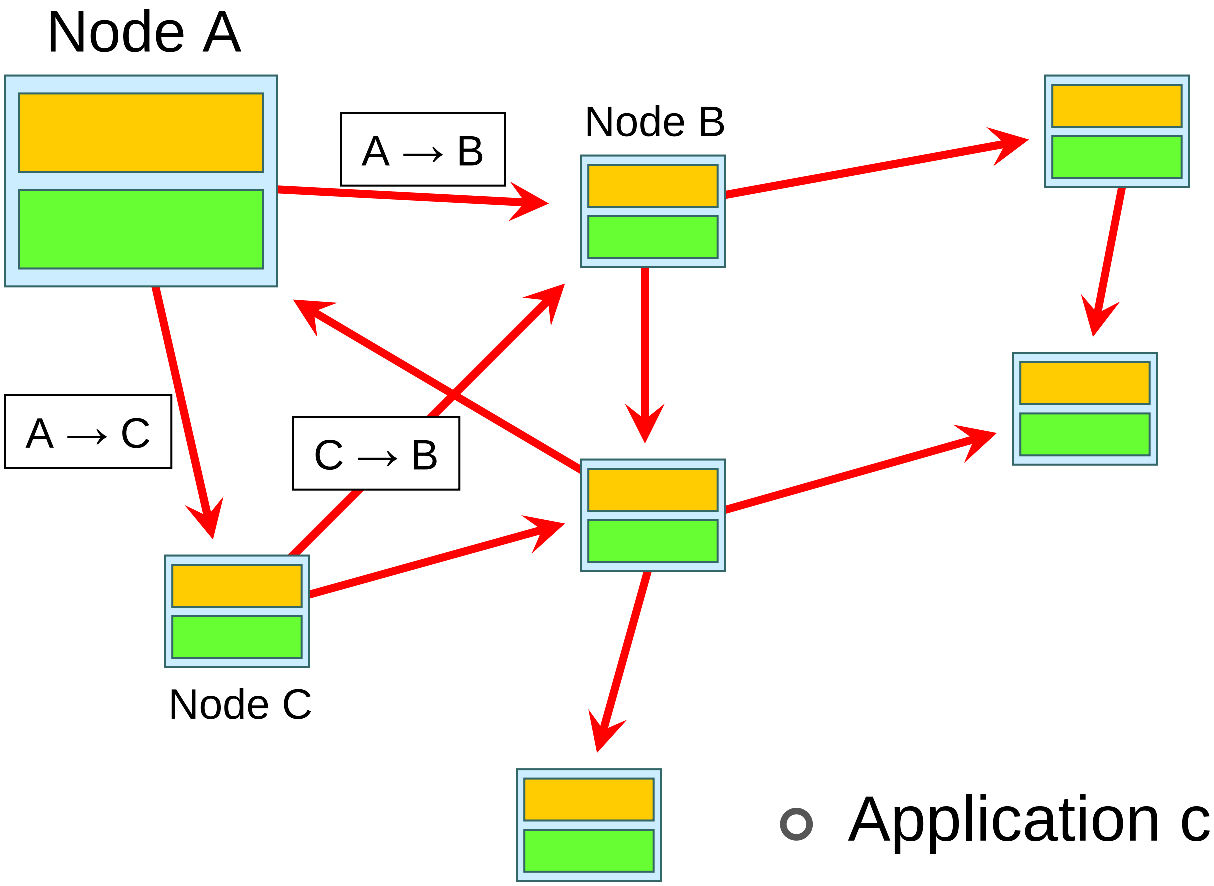
GID[ ] groups()

Graph attestations (GID)

void startAttest(GID, nodeID, info)

void stopAttest(GID, nodeID)

Graph of link attestations



A knows for GID:

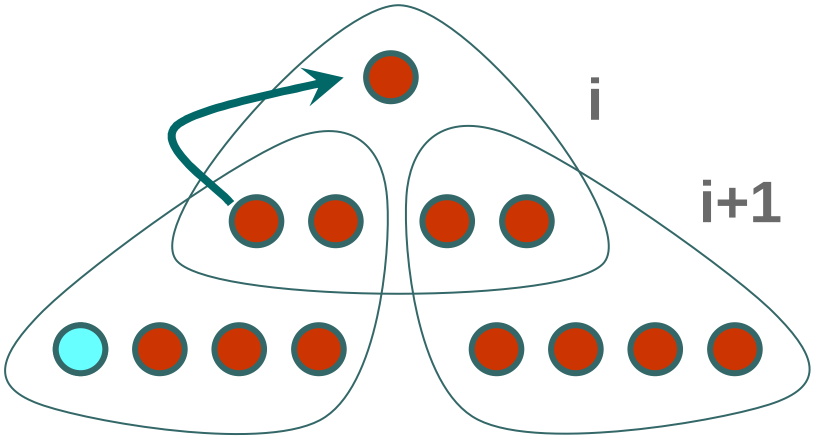
A → B
A → C
C → B
…

Think link-state

- Application calls startAttest()
- Subsystem generates, gossips, periodically refreshes attestations

LA-Groups for robust multicast

- Build fat multicast tree



- Goal:
  - Good nodes towards root
- LA-Group for parents and children
  - Correctness property:

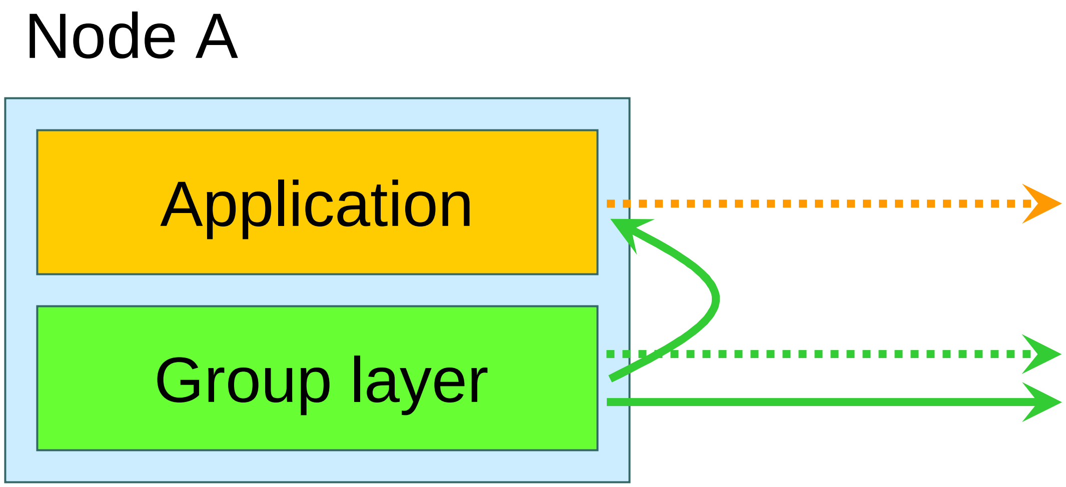
    Child says “Parent sent traffic at sufficient rate”
  - Level-i requires membership transcript from level i+1
  - If children fail to forward, must restart at bottom

When to startAttest() ?

- Unreliable failure detectors
  - Answers heartbeat: startAttest()
  - Fail to respond: stopAttest()
  - Yet applications aren’t fail-stop!

- Application performs own battery of tests
  - Stateful anomaly detection
    - Network latency, application thruput, DoS attacks
  - Voting-based verification
    - Name resolution (DNS, pub keys), HTTP responses

vs. traditional membership systems



Group membership

- Layer tests liveness
- Uses failure reports
- Exports membership list

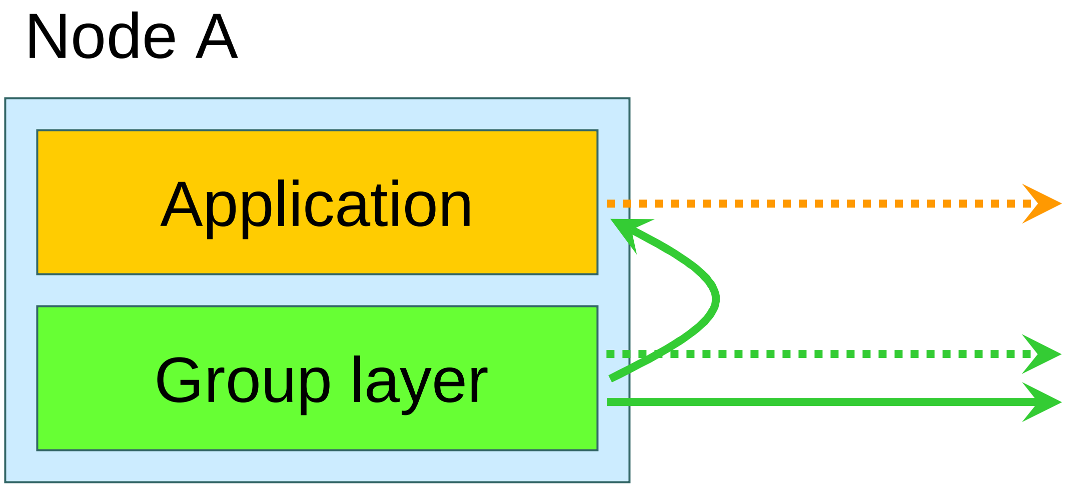
LA-Groups approach

- Application tests “correctness”
- Uses correctness attestations
- Exports attestation graph

Correctness, not failure, attestations

- Correctness attestations
  - Either both are correct or both are failed
  - More explicit that failure reports
    - Are failures per-link or global?
    - Either one or both are failed, but can’t differentiate
    - Failure to receive report does not imply correctness
- Attestations form membership transcript
  - Node can show membership to non-group member
  - Crypto optimizations for aggregating signatures

vs. traditional membership systems



Group membership

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LA-Groups approach

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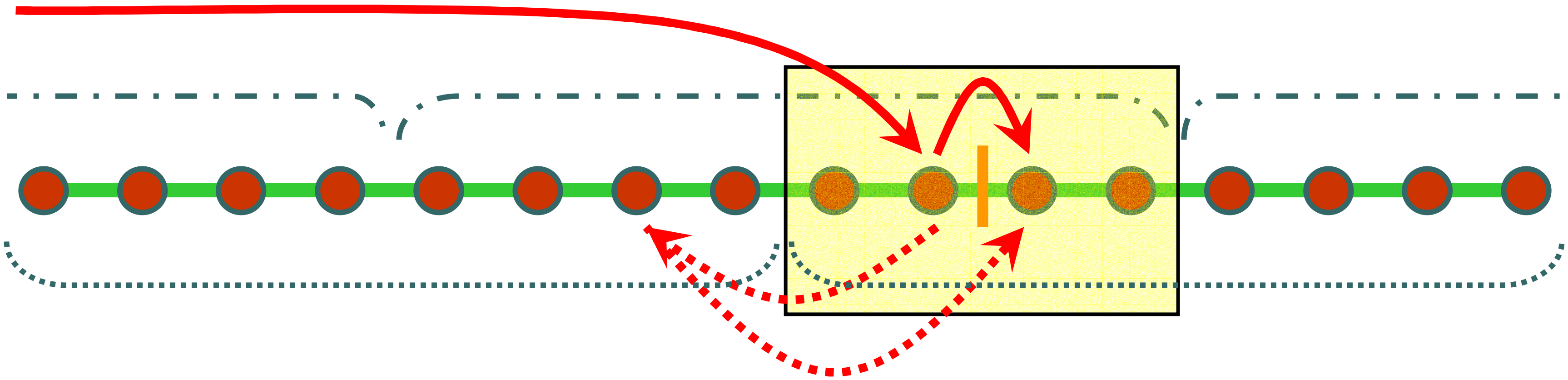
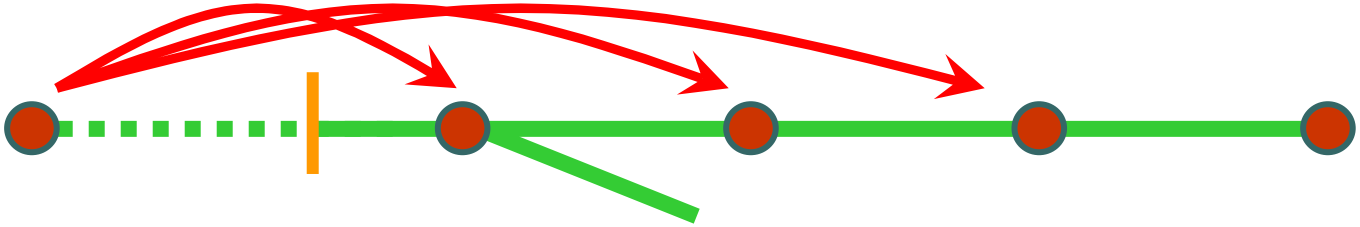
LA-Groups for robust routing



- Partition flat DHT ring into overlapping groups
  - Correctness test: heartbeats for link-level connectivity
  - Attestation graph gives topology at minimum

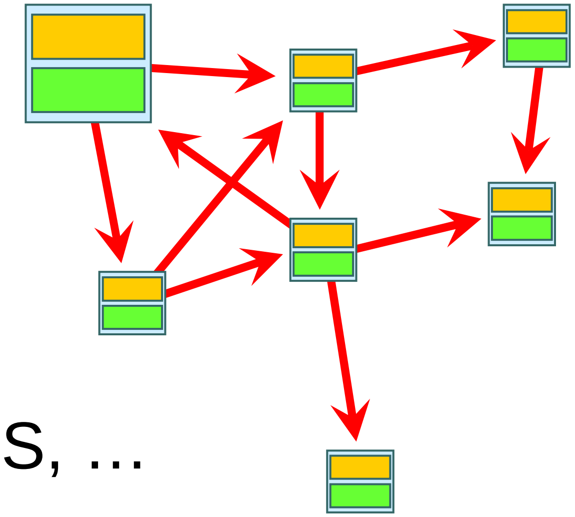
- Solves: Non-transitive routing
  - Use indirect hop to continue routing

LA-Groups for robust storage



- DHTs store key-values on multiple successors
- Say 🔵 only reachable via 🟡
  - If 🟡 fails, key-value is lost
  - Replicas experience correlated failures
- Attestation graph captures correlation
  - Tune replication for desired fault-tolerance

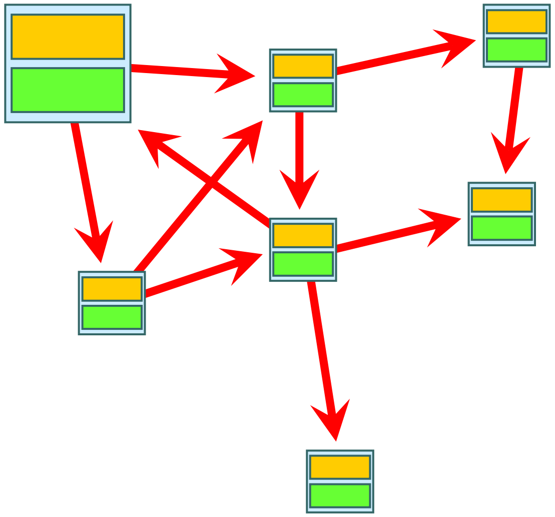
LA-Groups for f2f



- Trust in partitionable systems
  - Backup, file sharing, cooperative IDS, …
  - “Trust, but verify”

- Correctness test: successfully returns content
- Use attestation graph to:
  - Tune replication
  - Verify result from *k* disjoint paths upon failures

Using graph properties…



- Multiple vertex-disjoint paths
  - Secure gossiping protocols
  - Decentralized key distribution
- Minimum vertex cut
  - Quorum systems
- Strongly-connected components
  - Structured routing overlays
  - Multi-hop wireless protocols
- Shortest path or max-flow on link capacity
  - Optimizing multicast transmission
  - Handling selfish peers in BitTorrent swarms
- LA-Groups makes these properties explicit

What’s been traditional proposals?

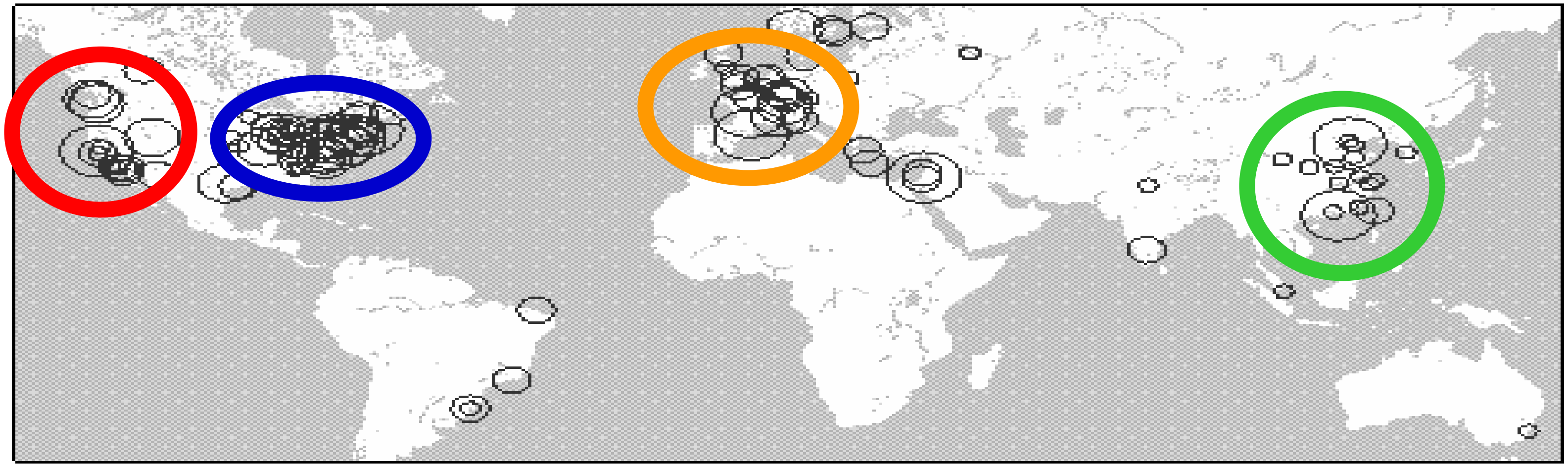
- Mask arbitrary failures
  - Virtual synchrony [Birman, …]
  - Replicated quorum systems [Malkhi/Reiter,…]
  - BFT replicated state machines [Liskov, …]

+ abstraction generality and correctness

– systems don’t experience uncorrelated failure:
> f nodes can fail simultaneously

– often no global notion of failure

Future work: LA-Groups for CoralCDN



- Move all testing code to testing module, e.g.,
  - Receives incoming and sends outgoing relevant pkts
  - Compare GET responses with others’ responses
- Group clusters of nearby proxies
- Redirect clients only to nodes with valid membership

Summary

- Presented LA-Groups
  - Software abstraction to simplify system design
  - Supports application-level notion of correctness
  - Exposes attestation graphs
  - Reason about system function vis-à-vis graph properties