BDCAT: Balanced Dynamic Content-Addressing in Trees

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BDCAT in a nutshell

What do we want to do?

- *Build a secure, low-delay darknet*

Why is that difficult?

- Publish/access without fear of retribution/censorship
- -> Routing/content addr. in restricted environments

What‘s this paper about?

log

polylog

- Content addressing on a
- tree-shaped (efficient routing!) overlay
- with fair load balancing

log

Content Addressing 101

- Derive identifier from resources that map to a (zone within the) network address

- Register and retrieve information at respective node

A bit more formal, in a network G=(V,E) with resources O:	
id: V -> ID	map: O -> ID
store: O -> V	retrieve: ID -> O

  - *First-term CS students: Hash tables*
  - *Cloud/datacenter people: memcached*
  - *P2P people: DHT*
  - *Everybody else: DNS*

Routing 101

Find a path of links to a destination (store, retrieve)

1. Assign node addresses and connectivity
2. Disseminate connectivity information
3. Calculate distances via neighbors *(DV/LS)*
4. Minimize distance to destination (greedy)

2 degrees of freedom: addresses / connections

- IP: centralized addressing, strategic connections
- DNS: centralized addressing, connect to tree
- DHT: random addresses, connect to routable structure

Information is restricted, connections are fixed! [1]

[1] Vasserman et al. 2009

Meet Embeddings

Single degree of freedom

1. *Adapt addresses*
2. Estimate distances
3. Minimize distance

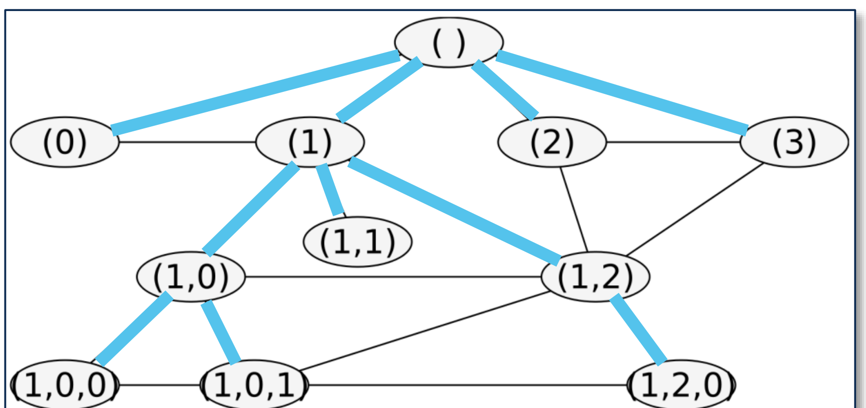
A bit more formal, let *ID(v)* be address of v ∈ V.
A *network embedding* on graph G is a function

$$ID : V \rightarrow M$$

to metric space *M* equipped with a distance

$$d : M \times M \rightarrow \mathbb{R}+ .$$

(1): Approx. routable structure *(greedy?)*, eg a **tree**



PIE embedding[1,2]

$$d(s, t) := |s|+|t| - 2(\mathrm{cpl}\ (s,t))$$

[1] Herzen et al. 2011
[2] Hoefer et al. 2013

Map resources to nodes, *map : O -> M*

Assume max depth of tree to be *L:*

Define metric space to be vectors (of *L* components):

$$map(o) = \left(h_1(o), h_2(o), h_3(o),\ldots,h_L(o)\right)$$

distance measured as above.

Maps uniform into components -> overall namespace

Balanced Dynamic Content Addressing

Trees determined by social graph, unbalanced, ***static.***

Task is to guarantee (f,δ)-balance:

for all v ϵ V less than $f \frac{1}{|V|} + \delta$ assigned.

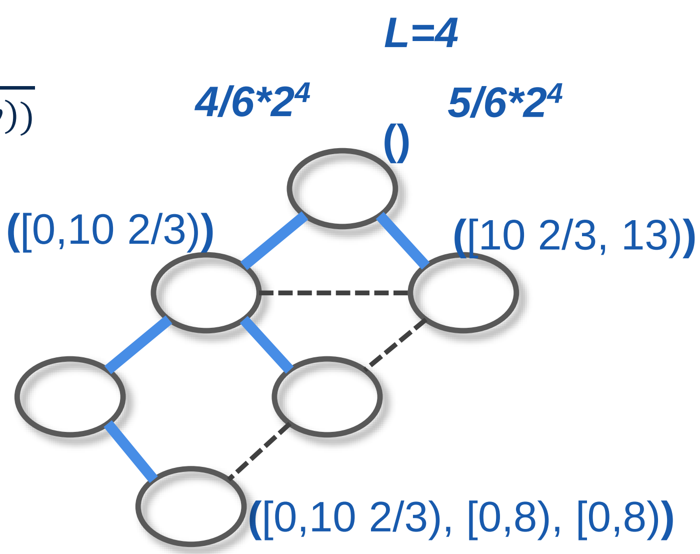
Intervals (zones) assigned to each component:

1. Estimate #nodes in branch *succ(v)*
2. Allocate zones *z(v)* accordingly:

   assign, width: $|z(v)| = 2^L \frac{succ(v)}{succ(parent(v))}$

Distance metric considering zones:

- d(x,y)=|x|+|y|-2con(x,y)
- with: con(x,y)=max{i:x_j ϵ y_j ∀ j≤i}



Balanced ***Dynamic*** Content Addressing

Churn: nodes are unreliable, *trees are delicate*

monitoring ***embedding*** ***content reassignment***

Guarantee polylog stabilization complexity *(+ balance)*

- Tree: Stabilize underlying branches locally
  - Join (or: depart/reconnect)
  - a: local reassignment possible
  - b: escalate to parent

Paper: slightly different algorithm, disseminating estimate of |V|

Results:

- logarithmic *f*: O($\log^3$ n E(S))
- polylog f: O($\log^6$ n)

Churn: nodes are unreliable, *trees are delicate*

content reassignment

Guar… n complexity *(+ balance)*

- Tre… ranches locally

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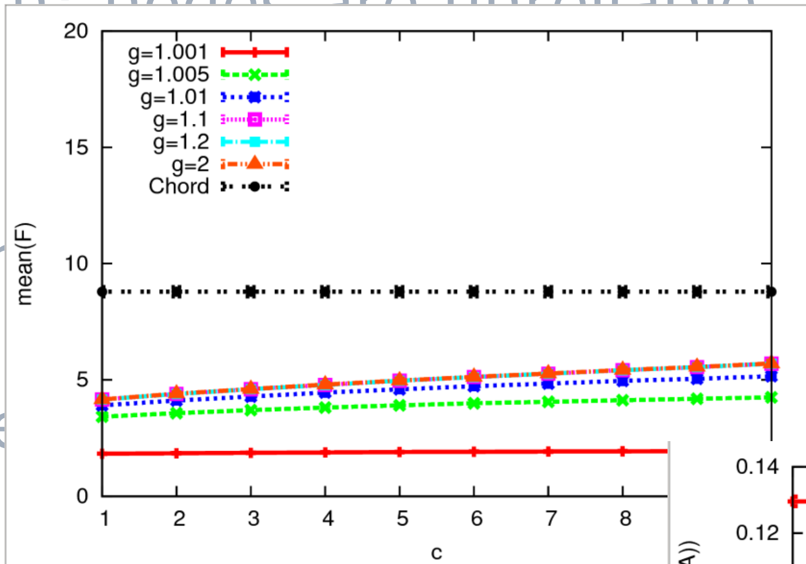
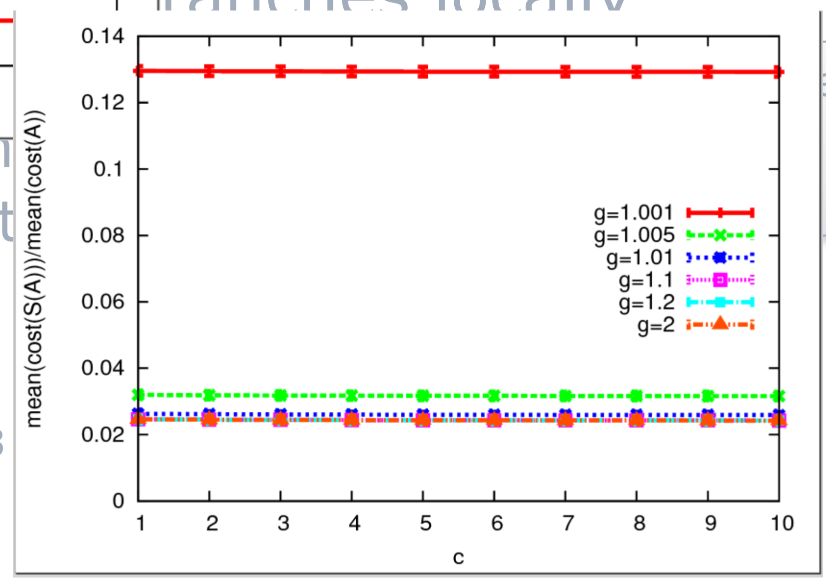


- a: local reassignmen…
- b: escalate to parent…



Results:

- logarithmic *f*: O($\log^3$…
- polylog f: O($\log^6 n$)

[1] Paul et al. 2012

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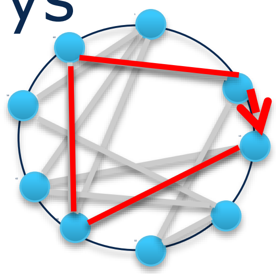
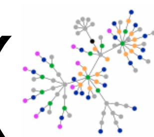
Standing on the Shoulders of Giants

Virtual Overlays



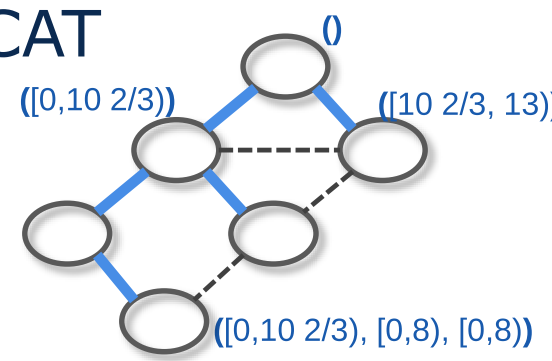
- Long routes
  - Voute: polylog [1]
  - Others: > polylog [2]

Topology-aware hashes [5]

h( , )

- Churn:Reassign everything

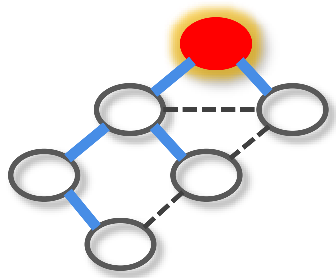
BDCAT



- log / log / polylog

Kleinberg, Prefix Emb. [3,4]

- Unfair load:



[1] Roos et al., INFOCOM 16
[2] Mittal et al., NDSS 12
[3] R. Kleinberg, INFOCOM 07
[4] Hoefer et al., NetSys 2013
[5] Roos et al., MobiArch 2014

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