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Network Design

Viceroy Network Structure

Performance Evaluation

## The Viceroy Network Algorithms for Modern Communication Networks

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http://www.ferienakademie.eu/

#### September 21 - October 3, 2008



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#### Introduction

#### Previous Peer2Peer Networks

- Single peer linkage cost not constant or fair, or,
- Suboptimal lookup efficiency

#### Viceroy Design Goals

- Uniformly distribute minimal linkage cost on every peer
- Avoid bottlenecks
- Maximize Lookup Efficiency for Huge Networks



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|---------------------------|------------------------|---------------------------|------------------------|---------|--|--|
| Natural, Obaus stavistica |                        |                           |                        |         |  |  |

#### Network Characteristics

#### Network Degree deg

Maximum number of outgoing links out of a single peer

#### Network Diameter dia

Longest of all shortest distances between two peers



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- Within a distance *d* of a peer there are at most *deg<sup>d</sup>* peers reachable.
- The Definition of Diameter and Degree thus yield for the number of peers *n*:

$$deg^{dia} \ge n$$

and thus

$$\Rightarrow dia \geq \frac{\log(n)}{\log(deg)}.$$

• Optimum:

$$deg = \text{const}, dia \propto \log(n).$$





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## Butterfly-Networks: Level 1





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## Butterfly-Networks: Level 2





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| Butterfl     | v-Networks     | : Level 3                 |                        |         |





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Network Characteristics

3 Viceroy Network Structure Butterfly-Networks

> Level Selection Routing

Trade-Off in Network Design

Viceroy: Emulation of Butterfly Networks

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| Vicerov      |                |                           |                    |



#### Limenitis archippus (Viceroy Butterfly)



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| Vicerov      | : Basics       |                           |                        |         |

- Viceroy implements a 1-dimensional distributed hashtable
- Keys are mapped to [0, 1)
- Data is assigned to the clockwise-closest successor



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## Viceroy: Network Structure

At this point, we assume that each peer s

- features a *s.position* that is determined by its ID, and,
- a level (s.level).
- Links are established to...



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## Best Case Emulation - Ring Links



... the first successor and predecessor of s on the Interval [0, 1), regardless of the level...

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|              |                |                           |                        |      |

## Best Case Emulation - Level Links



... the first successor and predecessor of s on s.level...



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## Best Case Emulation - Up Links



... the clockwise-closest peer on level *s.level* -1, if *s.level* > 0...



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## **Best Case Emulation - Butterfly Links**



... the clockwise-closest peer on *s.level* + 1 to *s.position* and  $(s.position + (1/2)^{s.level}) \mod 1...$ 

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## Viceroy Outdegree

The outdegree is given by counting:

- 2 ring links
- 2 level links
- 1 up link
- 2 butterfly links

 $\Rightarrow$  Constant network degree of 7.



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| Level S      | election       |                           |  |         |

Performance is proportional to the maximum level

Level selection is key in bounding performance:

- Assume uniform distribution of the peers
- Expected number of nodes is <sup>k</sup>
   distance to the k-th node
- The estimation for the number of peers  $\hat{n}$  is

$$\log\left(\frac{n}{c\log(n)}\right) \le \lfloor \log(\hat{n}) \rfloor \le c'\log(n)$$

with high probability.



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| Routing      |                |                           |   |         |

#### Step 1 - Route up to level 1

Follow up-links. Their number is  $O(\log(n))$ .

#### Step 2 - Route down to target

Is the target in between the left and the right down-link, route left, else right.  $O(\log(n))$ 

#### Step 3 - Traverse level and outer rings

If there are no down links anymore

- Try level-links in direction of target
- 8 Route along the outer ring



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 $\Rightarrow$  Logarithmic complexity with high probability.





## **Routing Example**





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## Routing Example - Step 2





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| Peer Ins     | sertion        |                           |                        |         |

• Find peer responsible for SystemID.  $O(\log(n))$ 

- 2 Reassign keys according to successor relationship. O(1)
- Setimate number of peers  $\hat{n}$  through distance to *k*-successing peers ( $\hat{n} = \frac{k}{dk}$ ). O(1)
- Choose Butterfly-Level uniformly out of  $1 \le l \le \lfloor \log(\hat{n}) \rfloor$ . O(1)
- Update links. O(1) in expectation, O(log(n)) with high probability
- Solutional to plain Butterfly, link peers on each level and create uplink. O(1)



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Ensuring Constant Indegree

Although the expected indegree is constant, it can still be logarithmic for some node.

- local coordination on "buckets" with  $O(\log(n))$  peers
- position and level selection is not random any more
- good and sane distribution of peers over stretches and levels
- really complex procedure



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## Peer Failure / Leaving Peer

# The successing peer has to take over the data. O(1) Every former link has to find a replacement. O(log(n))



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## Peer Failure / Leaving Peer

- The successing peer has to take over the data. O(1)
- 2 Every former link has to find a replacement.  $O(\log(n))$



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## Viceroy features

- constant degree
- Iogarithmic diameter
- quite complex implementation



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## Thank you





## Additional Literature I



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Dahlia Malkhi and Moni Naor and David Ratajczak Viceroy: A Scalable and Dynamic Emulation of the Butterfly Proceedings of the twenty-first annual symposium on Principles of distributed computing, 2002.



The picture of the Viceroy Butterfly is by Namek Piccolo

The picture of the Monarch Butterfly is by April M. King

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