Mapping a Dynamic Prefix Tree on a P2P Network

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Outline

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Context

- Resource discovery in grid context
- New needs facing the development of grids
  - large scale
  - no central infrastructure
  - dynamic joins and leaves of nodes
- Adopt peer-to-peer technologies
  - Pure decentralized algorithms
  - Scalable algorithms to retrieve objects
  - Fault-tolerance

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P2P technologies

- Unstructured P2P approaches
  - flooding based
  - non-exhaustive researches
- Distributed Hash Tables
  - key-based routing
  - exhaustive search
  - scalable :
    - logarithmic local state
    - logarithmic number of hops
  - fault-tolerance
    - periodic scanning
    - replication
  - drawbacks
    - no locality awareness
    - assumptions of homogeneity
    - only exact match queries

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Trie Based Lookup (2/2)

- Range queries
  - automatic completion
  - logarithmic Latency
- Approaches
  - Skip Graphs (complexities)
  - Nodewiz (no fault-tolerance)
  - Prefix Hash Tree (static trie)
  - P-Grid (static trie)
  - locality awareness issue
  - DLPT (load balancing)

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A two layer architecture

- **Logical indexing structure**
- On-line building of a Greatest Common Prefix (GCP) Tree
- Distributed traversal algorithms
- **Mapping on a dynamic network**
  - random DHT-based mapping (no load balancing)
  - each physical node maintains one or more logical nodes
- Replication based fault-tolerance
- Greedy locality awareness

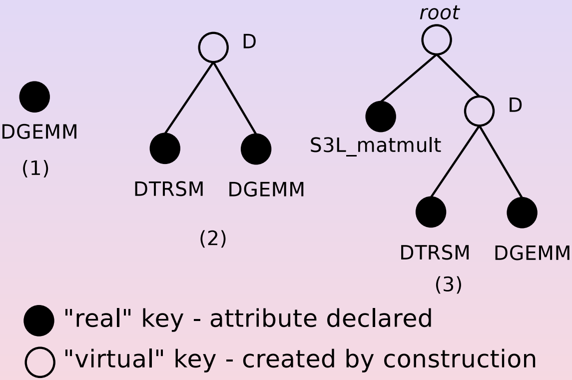
GCP Tree - Preliminaries

- Alphabet A finite set of letters
- $\prec$ an order on A
- Word w finite set of letters of A, $w = a_1, \ldots, a_i, \ldots, a_l$, $l > 0$
- u, v two words, uv *concatenation* of u and v
- $|w|$ length of w
- ϵ the empty word, $|\epsilon| = 0$

GCP Tree - Definition

- $u = prefix(v)$ if $\exists w$ s.t. $v = uw$
- $GCP(w_1, w_2, \ldots, w_i, \ldots, w_n)$ is the longest prefix shared by $w_1, w_2, \ldots, w_i, \ldots, w_n$
- Example :
  - DTR = $prefix$(DTRSM)
  - GCP(DTRSM, DTRMM) = DTR
- GCP Tree labeled rooted tree s.t.
  - The node label is a proper prefix of any label in its subtree
  - The node label is the Proper Greatest Common Prefix of all its son labels

GCP Tree - Dynamic construction



- Contact
- Routing
- Inserting

GCP Tree - worst case complexities

- Number of hops bounded by twice the depth of the tree
- Depth of the tree bounded by the size osf the words
- Local state bounded by the number of characters
- Constant time local decision of routing
- Range query, replication/locality process
  - latency bounded by the depth of the tree
  - linear number of messages

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Current mapping

- Random
- No Load balancing
- Cost of maintaining both physical and logical level
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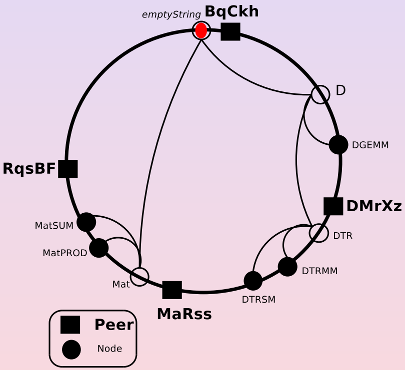
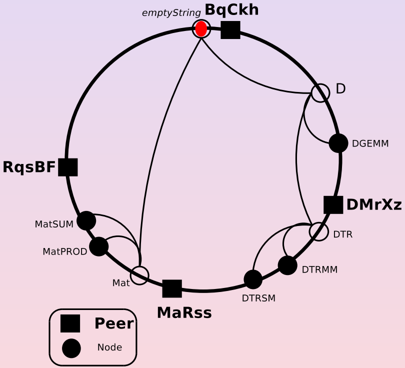
General design (1/2)

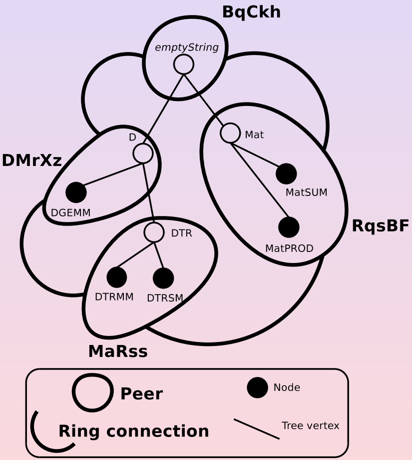
- **The physical layer**
  - Structured as a ring dynamically growing
  - Each *peer* is placed by a *lexicographic* hash function
  - Each peer maintains a *predecessor* and a *successor*
- **The logical layer**
  - Dynamic GCP Tree (built as objects are declared)
  - Each node is mapped on its *successor peer*

General design (2/2)



General design (2/2)





Inserting a physical node - principle

- Finding the successor peer $\equiv$ finding the target node (labeled by the greatest ID smaller than the new peer ID)
- 3 phases
  - 0. Not in the right branch : going up
  - 1. In the right branch : routing down
  - 2. Inserting : the successor searched is
    - the peer hosting the target node
    - the succesor of the peer hosting the target node

Inserting an object

- Routing according to the object's key
- Potential creation of new nodes
- Finding peers to host new nodes

Load balancing heuristics - related work

- Karger and Ruhl
  - periodic random item balancing
  - homogeneity of peer capacities
- Godfrey et al.
  - periodic item redistribution
  - semi-centralized
- Ledlie and Seltzer
  - K-choices
  - Chooses the best location for a new peer among k

Load balancing - Max Local Throughput

- C_p capacity of the peer p
- l_n load of the node n
- considering two adjacent peers s and p
- $\mathcal{I}_s$ set of nodes currently managed by s
- $\mathcal{I}_p$ set of nodes currently managed by p
- $T = T_p + T_s$
- Considering n nodes, $n = |\mathcal{I}_s| + |\mathcal{I}_p|$
- Find k such that

$$min(\sum_{i \in \{0,\ldots,k\}} l_i, C_p) + min(\sum_{i \in \{k+1,\ldots,n\}} l_i, C_s)$$

is maximum (algorithm linear in the number of nodes)

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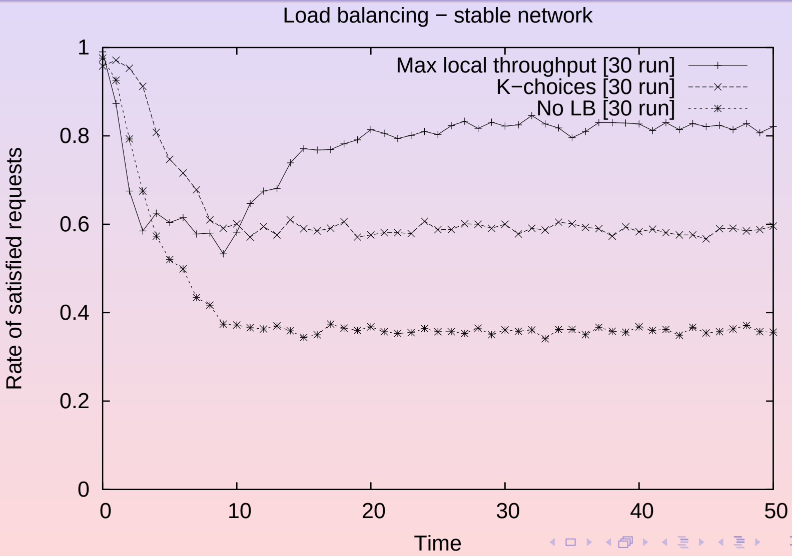

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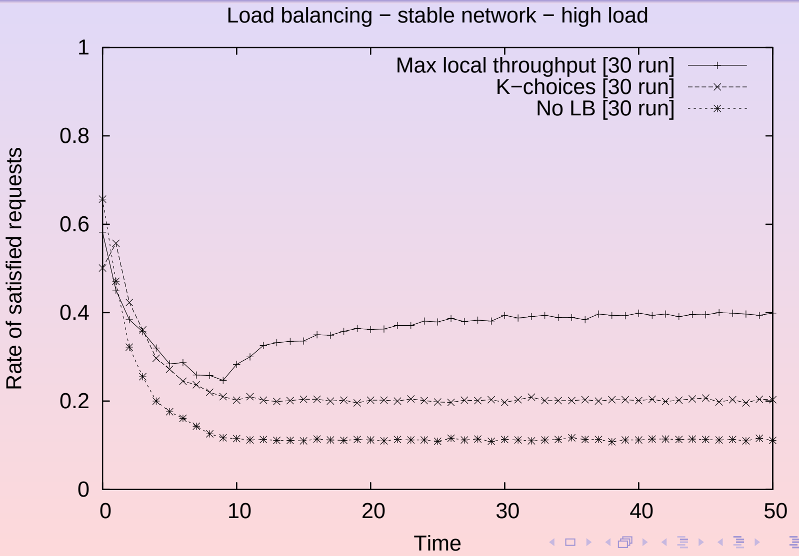

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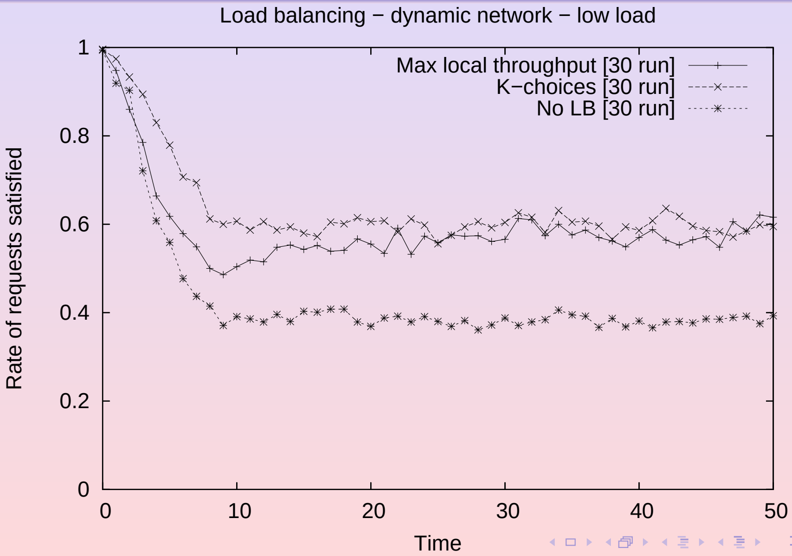

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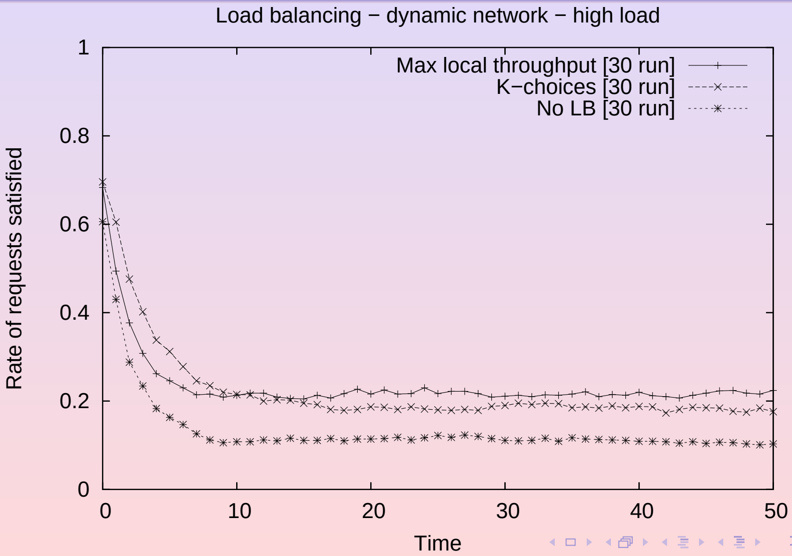

Simulation results

Load	Stable network		Dynamic network	
	Max local th.	K-choices	Max local th.	K-choices
5%	39,62%	38,58%	18.25%	32,47%
10%	103,41%	58,95%	46,16%	51,00%
16%	147,07%	64,97%	65,90%	59,11%
24%	165,25%	59,27%	71,26%	60,01%
40%	206,90%	68,16%	97,71%	67,18%
80%	230,51%	76,99%	90,59%	71,93%

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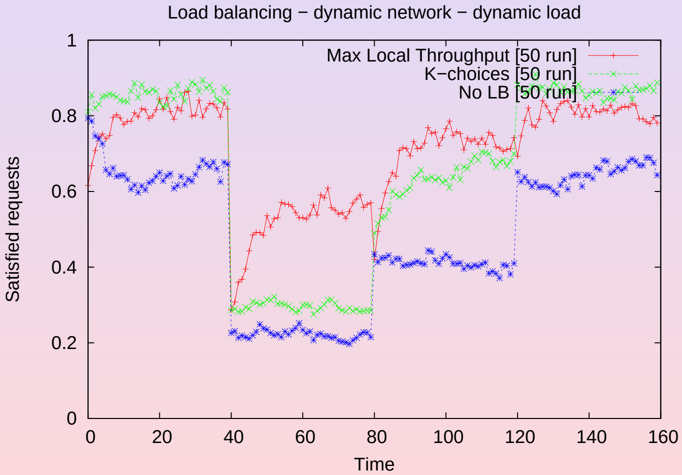

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Conclusion

- Algorithms to map a Prefix tree on a P2P network
- Reduction of maintenance cost of trie-based P2P systems
- New heuristic for load balancing