

# RR-FS Status Report

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IETF-60

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# Outline

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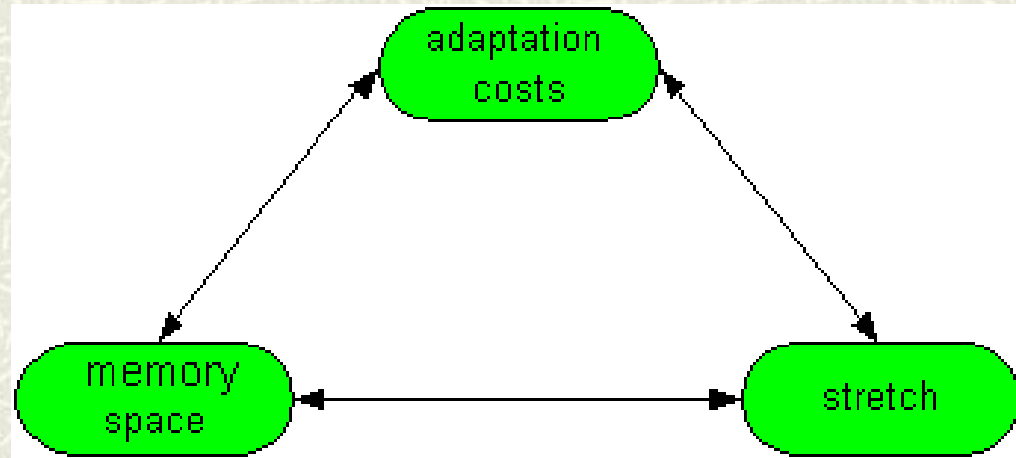
- # Progress in routing theory
  - # Applications to realistic topologies
  - # Future directions
  - # Recent advances
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# Inevitable trade-offs



Triangle of trade-offs:

- ✦ Adaptation costs = convergence measures (e.g. number of messages per topology change)
- ✦ Memory space = routing table size
- ✦ Stretch = path length inflation

# What's known

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# No recent progress on the dynamic case  
(adaptations costs are excluded)

- Lower bound  $\Omega(n/s)$
- Graph theory is a static theory

# Memory vs. stretch

- Shortest path ( $s=1$ )  $\Rightarrow O(n \log n)$
  - $1 \leq s < 1.4 \Rightarrow \Omega(n \log n)$
  - $1.4 \leq s < 3 \Rightarrow \Omega(n)$
  - $3 \leq s < 5 \Rightarrow \Omega(n^{1/2})$
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# Recent “*very static*” breakthroughs

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- # L. Cowen. Compact routing with minimum stretch. *Symposium on Discrete Algorithms (SODA) 1999*.
  - $s=3, \sim O(n^{2/3})$
- # M. Thorup and U. Zwick. Compact routing schemes. *Symposium on Parallel Algorithms and Architectures (SPAA) 2001*.
  - $s=3, \sim O(n^{1/2})$
  - On trees:  $s=1, \sim O(1)$  ( $= (1+o(1)) \log n$ )
  - All *forwarding* decisions are  $O(1)$  time

# Recent “*less static*” breakthroughs: name-independence

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- # M. Arias, et al. Compact routing with name independence. *SPAA 2003*.
  - $s=5, \sim O(n^{1/2})$
- # I. Abraham, et al. Compact name-independent routing with minimum stretch. *SPAA 2004*.
  - $s=3, \sim O(n^{1/2})$

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# Compact routing on Internet-like graphs

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- # D. Krioukov, et al. Compact routing on Internet-like graphs. *INFOCOM 2004*.
    - Average stretch of the TZ scheme on power-law graphs:
      - is *low* ( $\sim 1.1$ ,  $\sim 70\%$  paths are shortest)
      - does *not* depend on  $\gamma$
      - *decreases* with  $n$
    - Routing table size is well below its upper bounds (52 vs. 2,187 for  $n=10,000$ )
    - The average stretch function has a unique critical point and the Internet is located in its close neighborhood... (which is quite **surprising**)
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# Proposal to NSF

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**Title:** Toward mathematically rigorous next-generation routing protocols on realistic network topologies; **agenda:**

✦ Routing:

- Name-independent routing on realistic graphs
- Low average stretch routing on realistic graphs

✦ Topology (what *are* realistic graphs)

- Traceroute-based AS-level topology data
- Comparative analysis of Internet topologies obtained from different data sources

✦ Modeling of the Internet topology evolution

- Graph entropy-based extensions to existing methodologies
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# Work just started

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- # Comparative analysis of Internet topologies (with P. Mahadevan, UCSD)
- # Internet topology evolution modeling (with R. Liu, UCLA)

# Recent results

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- # Inference of business relationships between ASs (w/ X. Dimitropoulos, Georgia Tech)
  - # Why relevant
    - Routing  $\Leftarrow$
    - Topology  $\Leftarrow$
    - Modeling  $\Leftarrow$
    - Validation (real data)
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# AS relationship inference

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- # Node-degree based approach
  - produces many paths inconsistent with standard BGP import-export policies (*invalid* paths)
- # Invalid path minimization approach
  - produces unrealistic AS hierarchies
- # Our approach
  - uses multiobjective optimization of the two objective functions above
  - casts the problem as a semidefinite programming relaxation of MAX2SAT
  - resolves the issues associated with both approaches

# Last slide

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- # Homepage <http://rr-fs.caida.org/> will be updated soon (will send email to the list)
  - # Mailing list subscriptions requests, collaboration proposals, questions, comments, etc: [dima@caida.org](mailto:dima@caida.org)
  - # Thank you
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