

On the Fairness of Transport Protocols in a Multi-Path Environment

ICCRG meeting @ IETF 83

UNIVERSITÄT

D U I S B U R G
E S S E N

Hakim Adhari, Martin Becke, Thomas Dreibholz
Networking Technology Group
Institute for Experimental Mathematics
University of Duisburg-Essen

■ Multi-Path CC

- Three goals are targeted [RWH09]
 - (1) Improve throughput
 - (2) Do no harm
 - (3) Balance congestion

■ Considered mechanisms

- Multi-Path Reno (Reno-MP)
- CMT-Resource Pooling Version 2 (RP-MP-v2) [DBAR11]
- Multi-Path TCP (MPTCP)

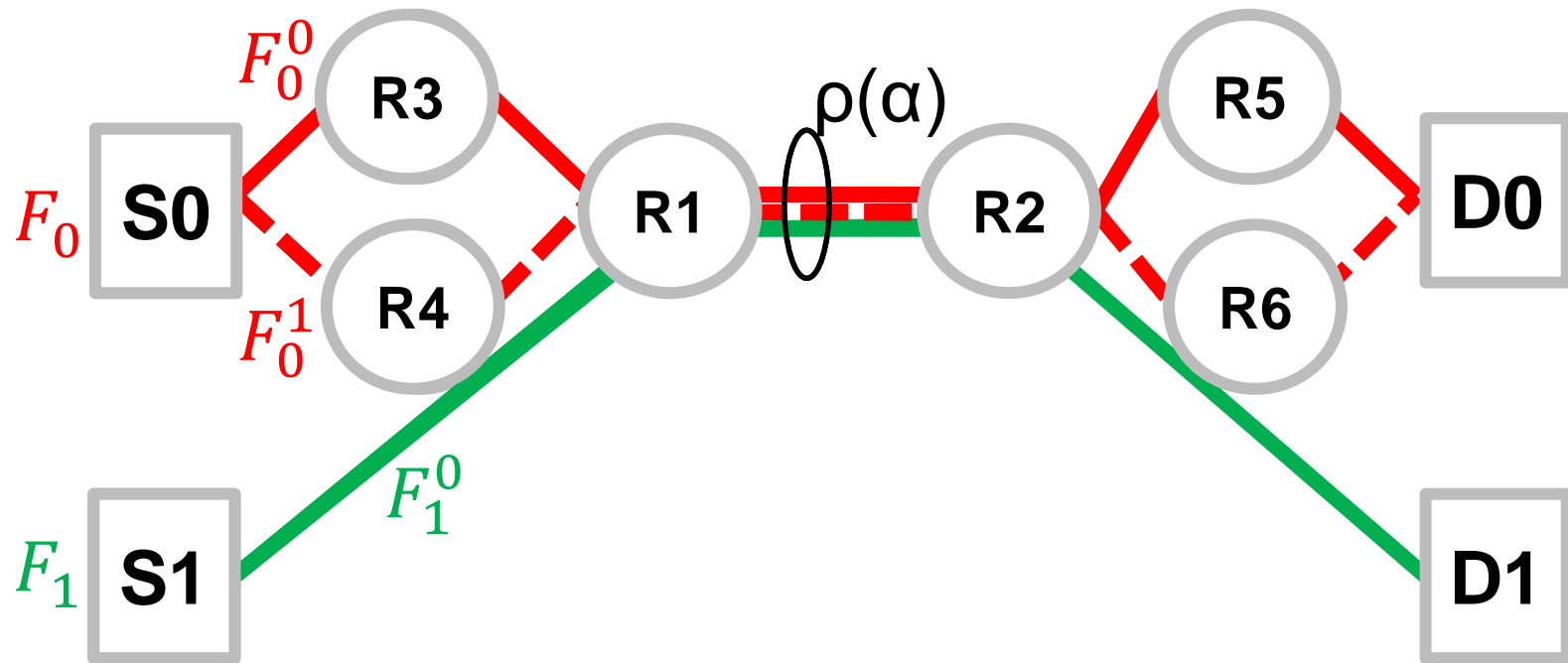
■ Problem statement

- Are these mechanisms TCP-friendly/fair?
- Is fair == TCP-friendly?

■ Approach

- Analysis of the behavior of the CC Mechanisms
 - Bottleneck topology
 - Disjoint paths topology

Bottleneck Topology Test Scenario



Bottleneck Topology

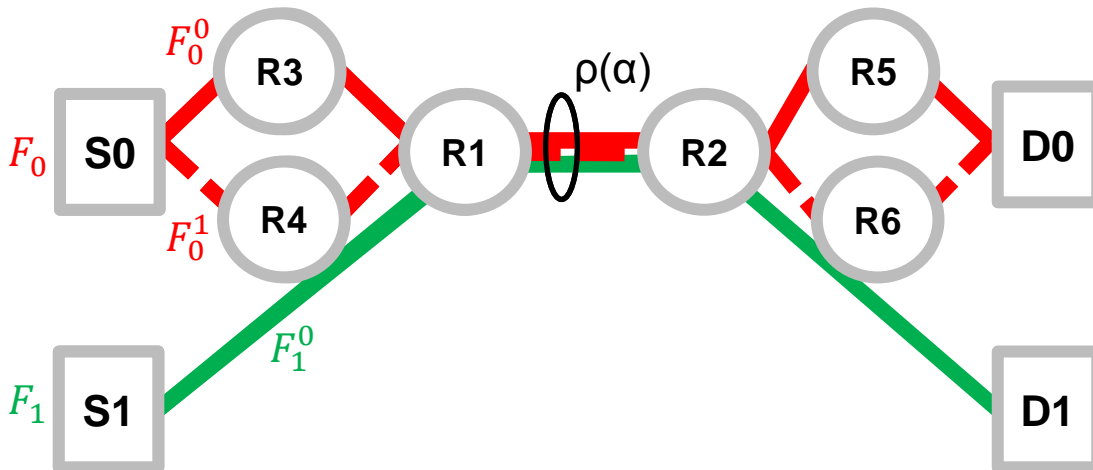
Link-Centric Flow Fairness

Expected behavior

- Goal 2 (Do no harm) [RWH09]

→ Link-Centric Flow Fairness

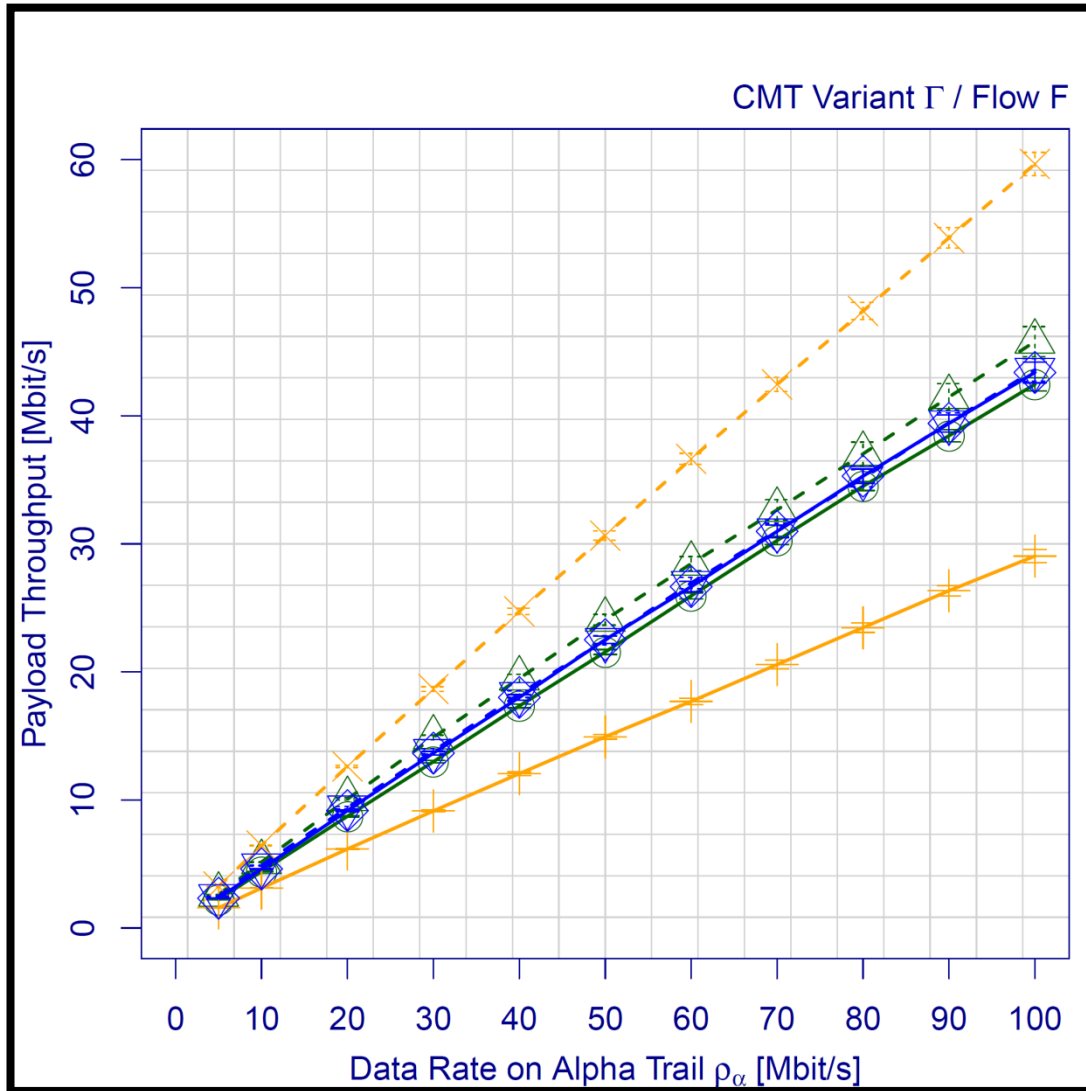
- ratio of flows to sub-flows
 - 1:1 → 1:x
 - For n different flows sharing a link l
 - $\rho(l)/n$ for each of the n flows



$$\rightarrow B_0 = B_0^0 + B_0^1 = \rho(\alpha)/2$$

$$\rightarrow B_1 = B_1^0 = \rho(\alpha)/2$$

Bottleneck Topology Simulation Results

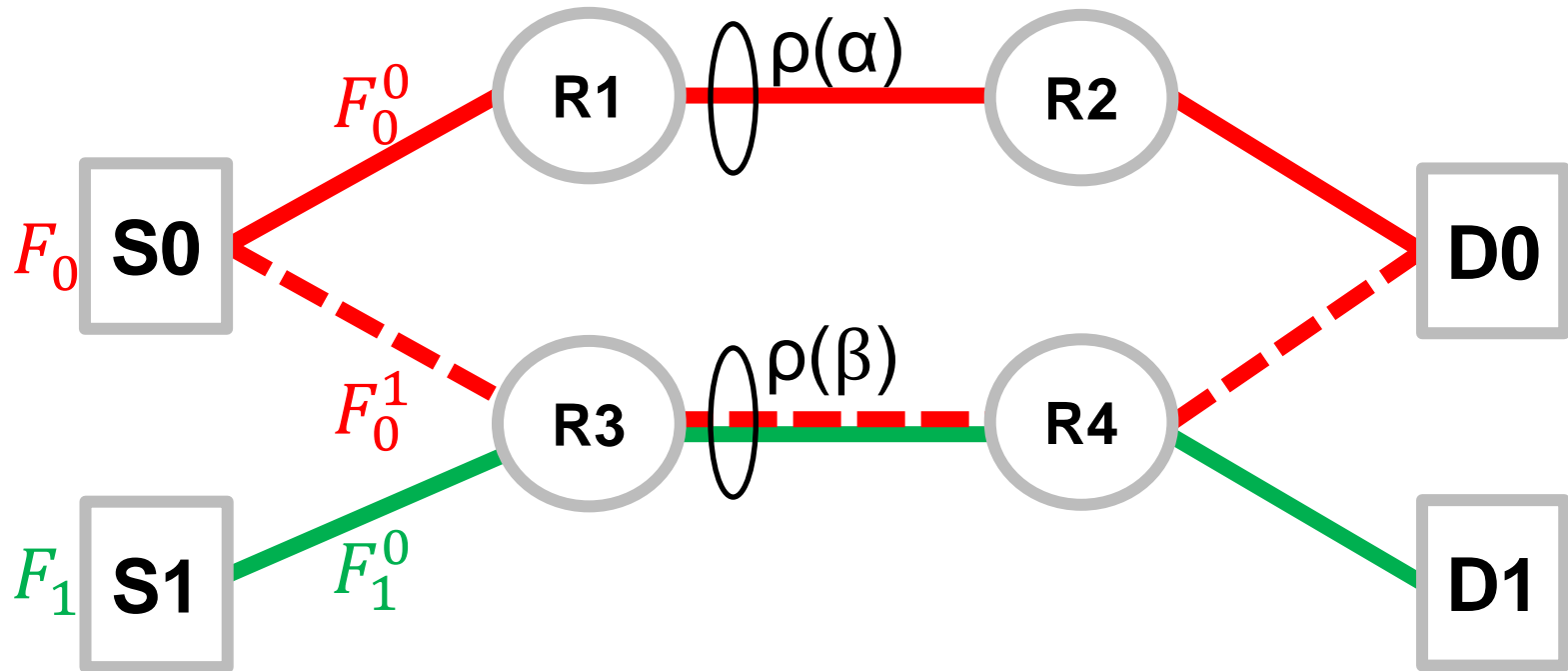


- 1: Γ =MPTCP, F=0
- -△- - 2: Γ =MPTCP, F=1
- -+ - - 3: Γ =Reno-MP, F=0
- -×- - 4: Γ =Reno-MP, F=1
- -◇- - 5: Γ =RP-MP-v2, F=0
- -▽- - 6: Γ =RP-MP-v2, F=1

- RENO-MP
 - 2/3 vs 1/3
- RP-MP-v2 and MPTCP
 - 1/2 vs 1/2

➔ The mechanisms behave as expected

Disjoint Paths Topology Test Scenario



$\rho(\alpha) = 20 \text{ Mbit/s}$

Bottleneck Topology

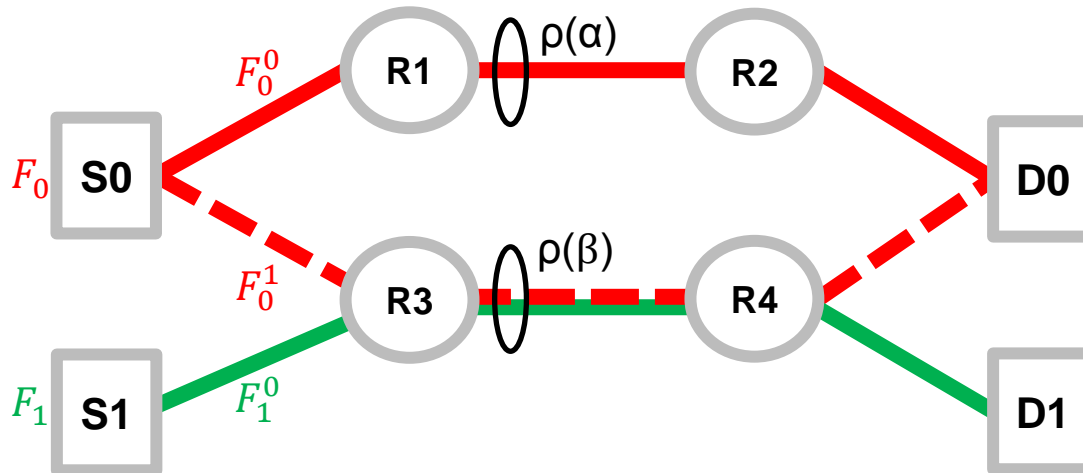
Network-Centric Flow Fairness

Expected behavior

- Link Centric Flow Fairness
 - Is this “fair”?

Link-Centric Flow Fairness?

- ratio of flows to sub-flows
 - 1:1 → 1:x
 - For n different flows sharing a link l
 - $\rho(l)/n$ for each of the n flows



→ $B_0^0 = \rho(\alpha)$

→ $B_0^1 = \rho(\beta)/2$

→ $B_1^0 = \rho(\beta)/2$

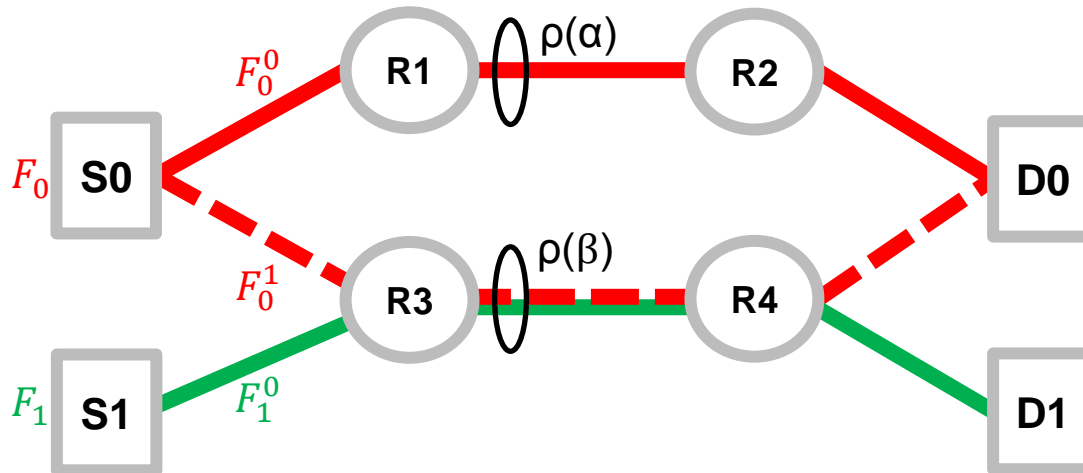
Bottleneck Topology

Network-Centric Flow Fairness

Expected behavior

- Goal 3 (Balance congestion)[RHW09] → **Network-Centric Flow Fairness**

- The whole network is considered

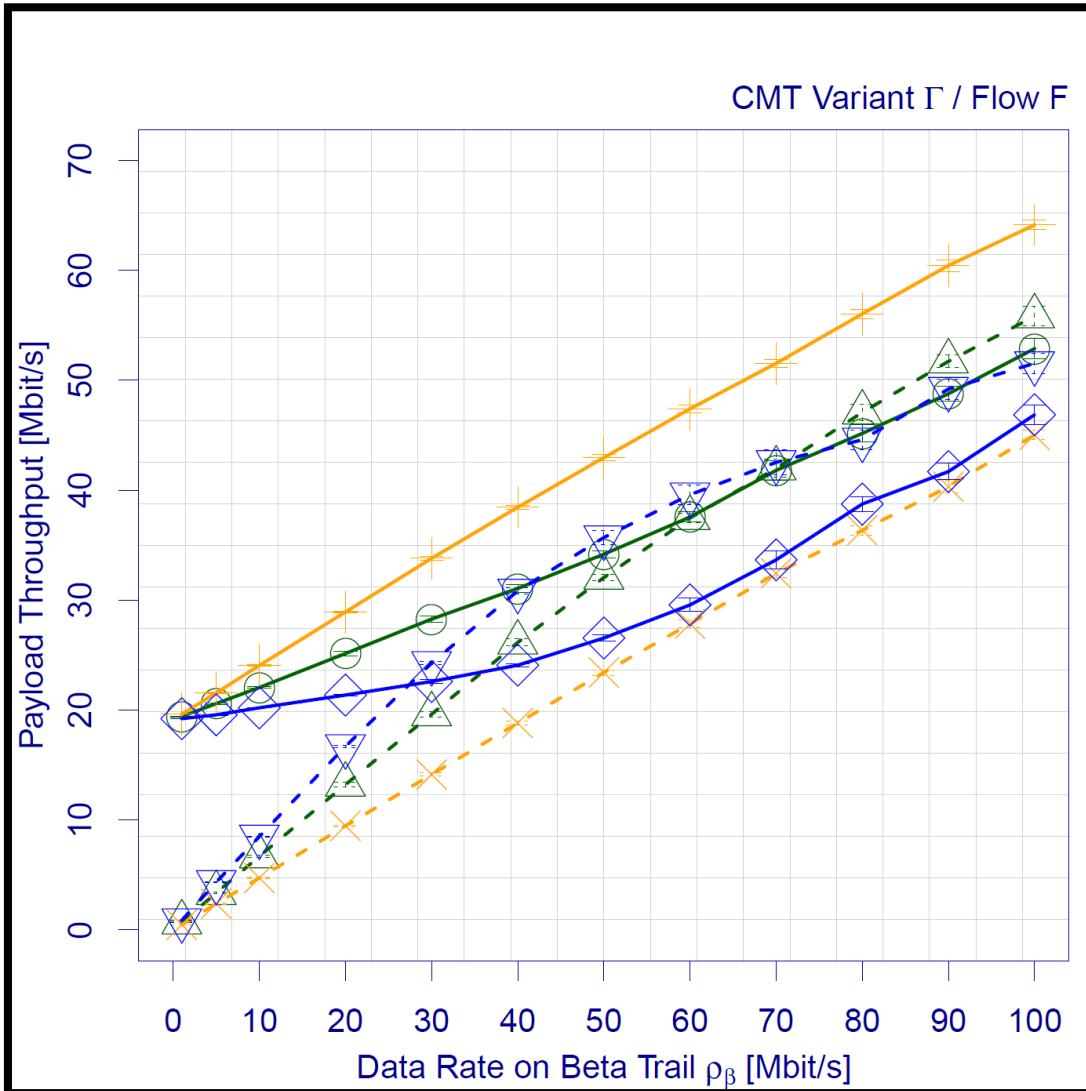


$$\rightarrow B_0^0 = \rho(\alpha)$$

$$\rightarrow B_0^1 = \max\{0, \rho(\beta) - B_0^0 / 2\}$$

$$\rightarrow B_1^0 = \rho(\beta) - B_0^1$$

Disjoint Paths Topology Simulation Results

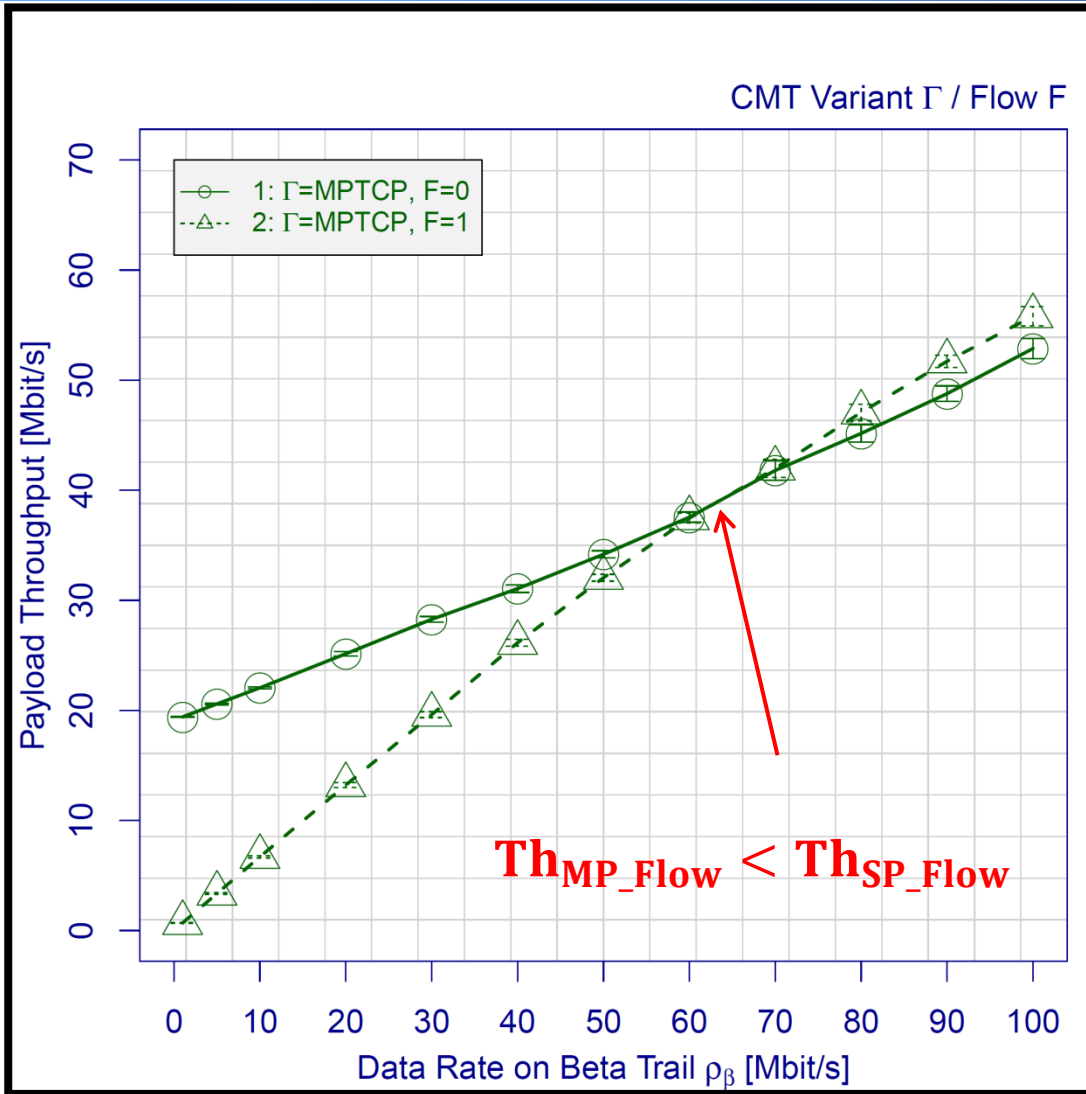


- 1: Γ =MPTCP, F=0
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- + 3: Γ =Reno-MP, F=0
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- ◇- 5: Γ =RP-MP-v2, F=0
- ▽- 6: Γ =RP-MP-v2, F=1

- RP-MP-v2 and MPTCP are approximating the Network-Centric Flow Fairness
 - First converging to the fairness line
 - For higher dissimilarity: the single-path flow acquires more bandwidth than the multi-path flow

$$\rho(\alpha) = 20 \text{ Mbit/s}$$

Disjoint Paths Topology Simulation Results



$$\rho(\alpha) = 20 \text{ Mbit/s}$$

Is this „fair“ what we actually call fair?

■ Example

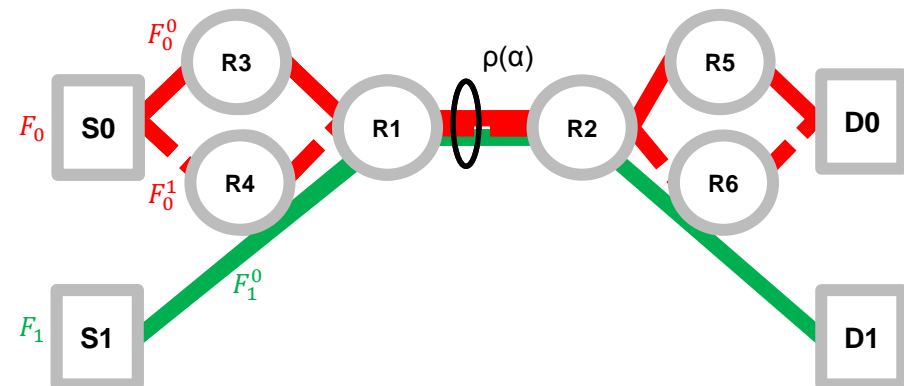
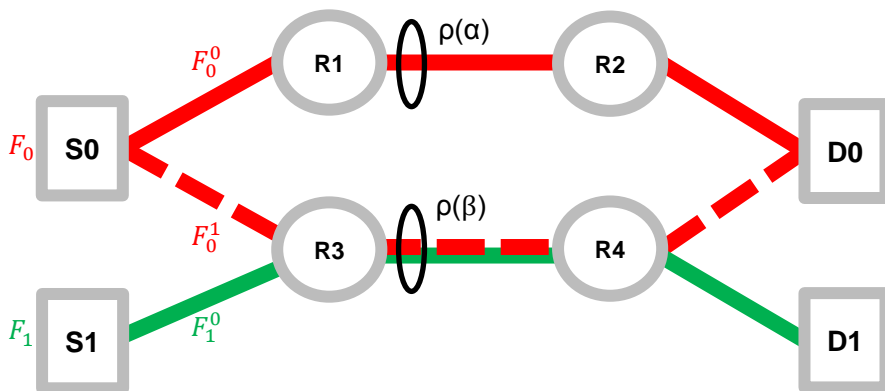
- A consumer S0 (paying for two high-speed Internet access lines)
- A consumer S1 (paying for one high-speed Internet access line)

→ Is it really “fair” if S1 gets more resources than S0?

→ Is it really “fair” if S1 gets as much resources as S0?

- Consumer view

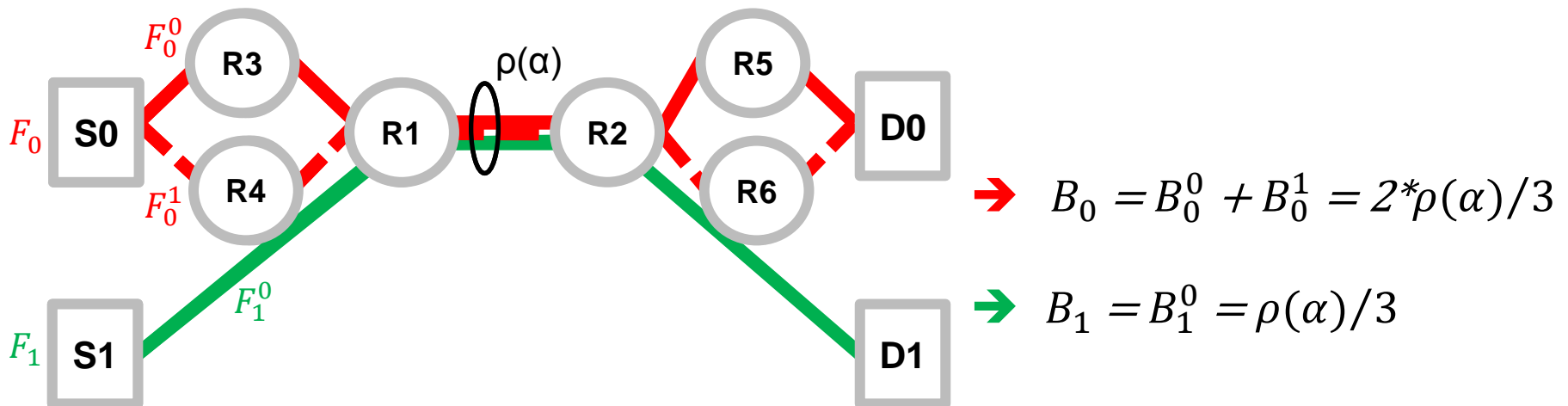
- Provider view



Is this „fair“ what we actually call fair?

■ Link-Centric Sub-Flow Fairness

- based on the number of the sub-flows on a link l
- $\rho(l)/m$ for each of the m sub-flows



Disjoint Paths Scenario Results

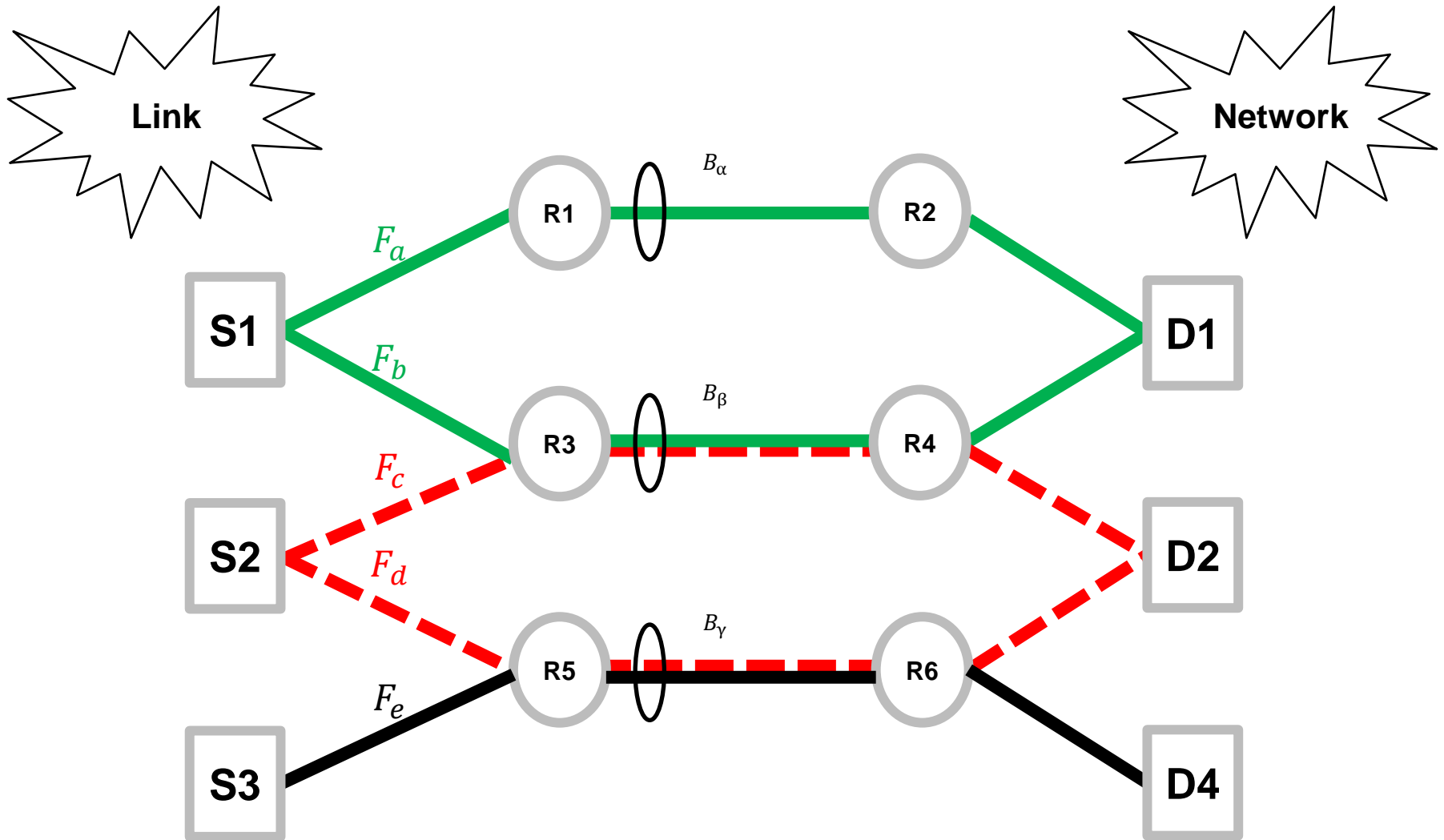
■ Until now:

- Dominating single-path transfer
- Multipath CCs
 - Extension of the single-path CC
 - Fair coexistence of multi- and single-Path flows
- No relationship between the brought-in resources and the final allocation
 - Disadvantage for Multi-Path flows
 - More resources for single-path than multi-path flows

■ With multi-path transfer

- Are the three goals defined in [RWH09] enough?
- Is an extension / adaptation of the goals needed?

How Should the Resources be allocated?



■ Which factors are important to reach the “Network-Centric Flow Fairness”?

- Bandwidth?
- Loss rate?
- MTU?
- Delay?
-

➔ is it possible to reach the „Network-Centric Flow Fairness“?

Views on “fair” Resource Allocation

What should we do?

■ Different views [BDAR12]

- Link-Centric Sub-Flow Fairness
 - based on the number of the sub-flows on a link l
 - $\rho(l)/m$ for each of the m sub-flows
- Link-Centric Flow Fairness
 - ratio of flows to sub-flows
 - 1:1 \rightarrow 1:x
 - For n different flows sharing a link l
 - $\rho(l)/n$ for each of the n flows
- Network-Centric Flow Fairness
 - the whole network is considered
-

Any Questions?

■ Our Team

- Hakim Adhari (hakim.adhari@iem.uni-due.de)
- Martin Becke (martin.becke@iem.uni-due.de)
- Thomas Dreibholz (dreibh@iem.uni-due.de)

■ Multi-path transfer project page

- <http://www.tdr.wiwi.uni-due.de/forschung/forschungsprojekte/sctp>

- **[BDAR12]** Martin Becke, Thomas Dreibholz, Hakim Adhari, and Erwin Paul Rathgeb. On the Fairness of Transport Protocols in a Multi-Path Environment. In Proceedings of the IEEE International Conference on Communications (ICC), Ottawa/Canada, June 2012.
<http://www.tdr.wiwi.uni-due.de/fileadmin/fileupload/I-TDR/SCTP/Paper/ICC2012.pdf>
- **[RWH09]** Costin Raiciu, Mark Handley, and Damon Wischik. Practical Congestion Control for Multipath Transport Protocols. Technical report, University College London, London/United Kingdom, 2009.
<http://nrg.cs.ucl.ac.uk/mptcp/mptcp-techreport.pdf>
- **[DBAR11]** Thomas Dreibholz, Martin Becke, Hakim Adhari, and Erwin Paul Rathgeb. On the Impact of Congestion Control for Concurrent Multipath Transfer on the Transport Layer. In Proceedings of the 11th IEEE International Conference on Telecommunications (ConTEL).
<http://www.tdr.wiwi.uni-due.de/fileadmin/fileupload/I-TDR/SCTP/Paper/ConTEL2011.pdf>
- **[DABR12]** Thomas Dreibholz, Hakim Adhari, Martin Becke, and Erwin Paul Rathgeb. Simulation and Experimental Evaluation of Multipath Congestion Control Strategies. In Proceedings of the 2nd International Workshop on Protocols and Applications with Multi-Homing Support (PAMS), Fukuoka/Japan, March 2012.
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- **[ADB+11]** Hakim Adhari, Thomas Dreibholz, Martin Becke, Erwin Paul Rathgeb, and Michael Tüxen. Evaluation of Concurrent Multipath Transfer over Dissimilar Paths. In Proceedings of the 1st International Workshop on Protocols and Applications with Multi-Homing Support (PAMS), Singapore, March 2011.
<http://www.tdr.wiwi.uni-due.de/fileadmin/fileupload/I-TDR/SCTP/Paper/PAMS2011.pdf>
- **[DB10]** Thomas Dreibholz, Martin Becke, Erwin Paul Rathgeb, and Michael Tüxen. On the Use of Concurrent Multipath Transfer over Asymmetric Paths. In Proceedings of the IEEE Global Communications Conference (GLOBECOM), Miami, Florida/U.S.A., December 2010.
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- **[Dre12c]** Thomas Dreibholz. Evaluation and Optimisation of Multi-Path Transport using the Stream Control Transmission Protocol. Habilitation treatise, University of Duisburg-Essen, Faculty of Economics, Institute for Computer Science and Business Information Systems, March 2012.
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- <http://www.tdr.wiwi.uni-due.de/forschung/forschungsprojekte/sctp>