
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

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■ In the past

- Single-path dominated network
- Fairness restrictions
 - TCP-friendly

■ Actually

- Multi-path transfer is becoming more and more important
 - Congestion Control (CC) assuring
 - Effective use of the resources
 - Fairness
- But what is „fair“ here?

■ 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)

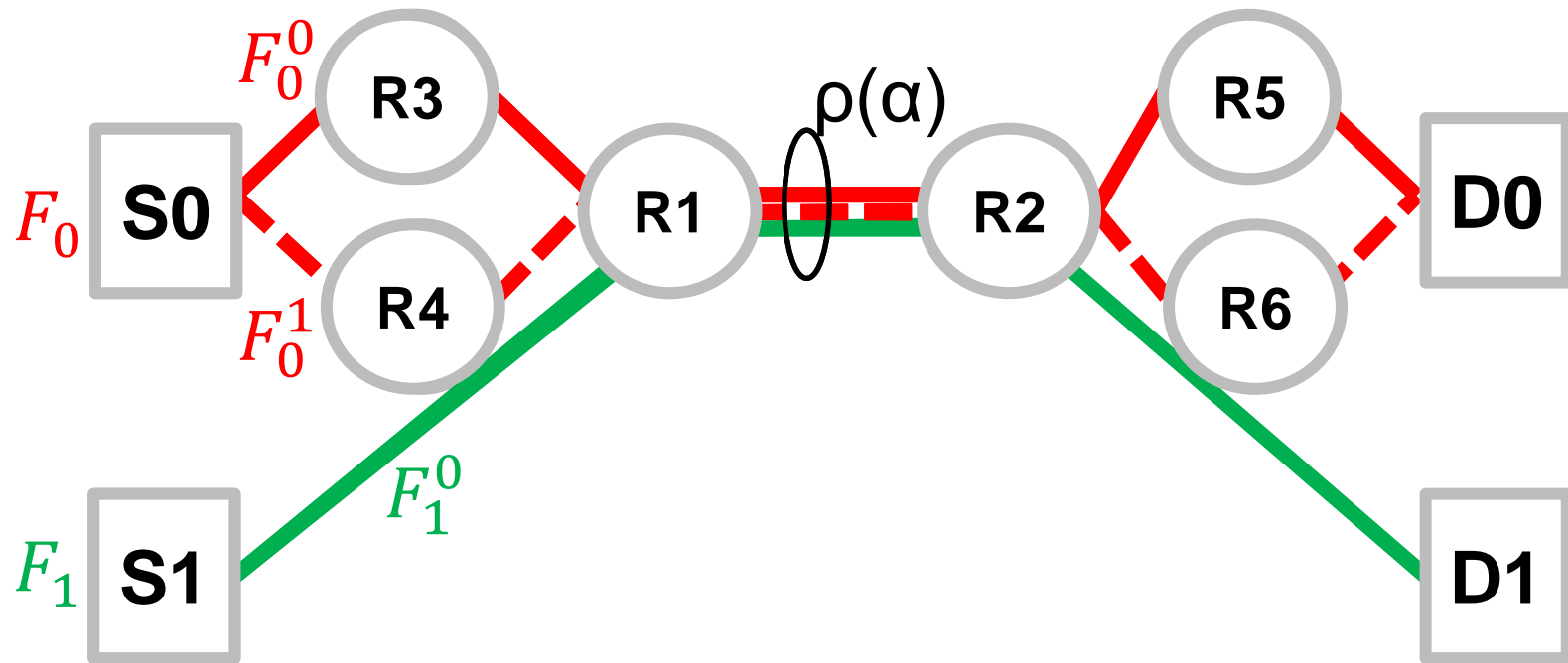
■ Problem statement

- 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

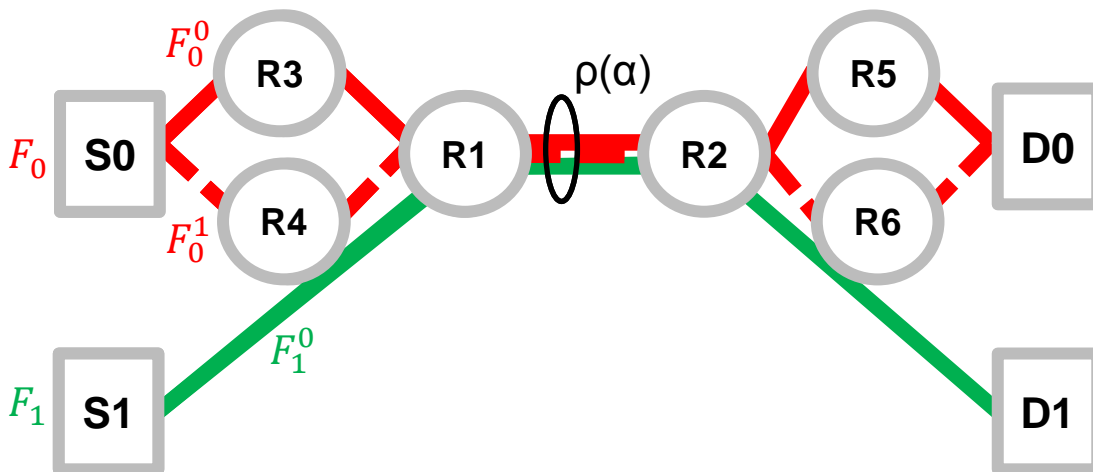
Link-Centric Flow Fairness

Expected behavior

- Goal 2 (Do no harm) [RWH09]

→ Link-Centric Flow Fairness

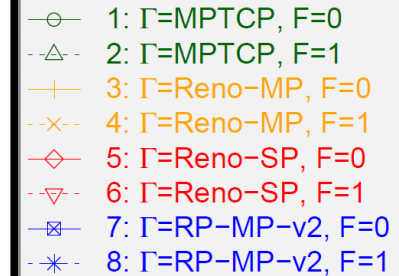
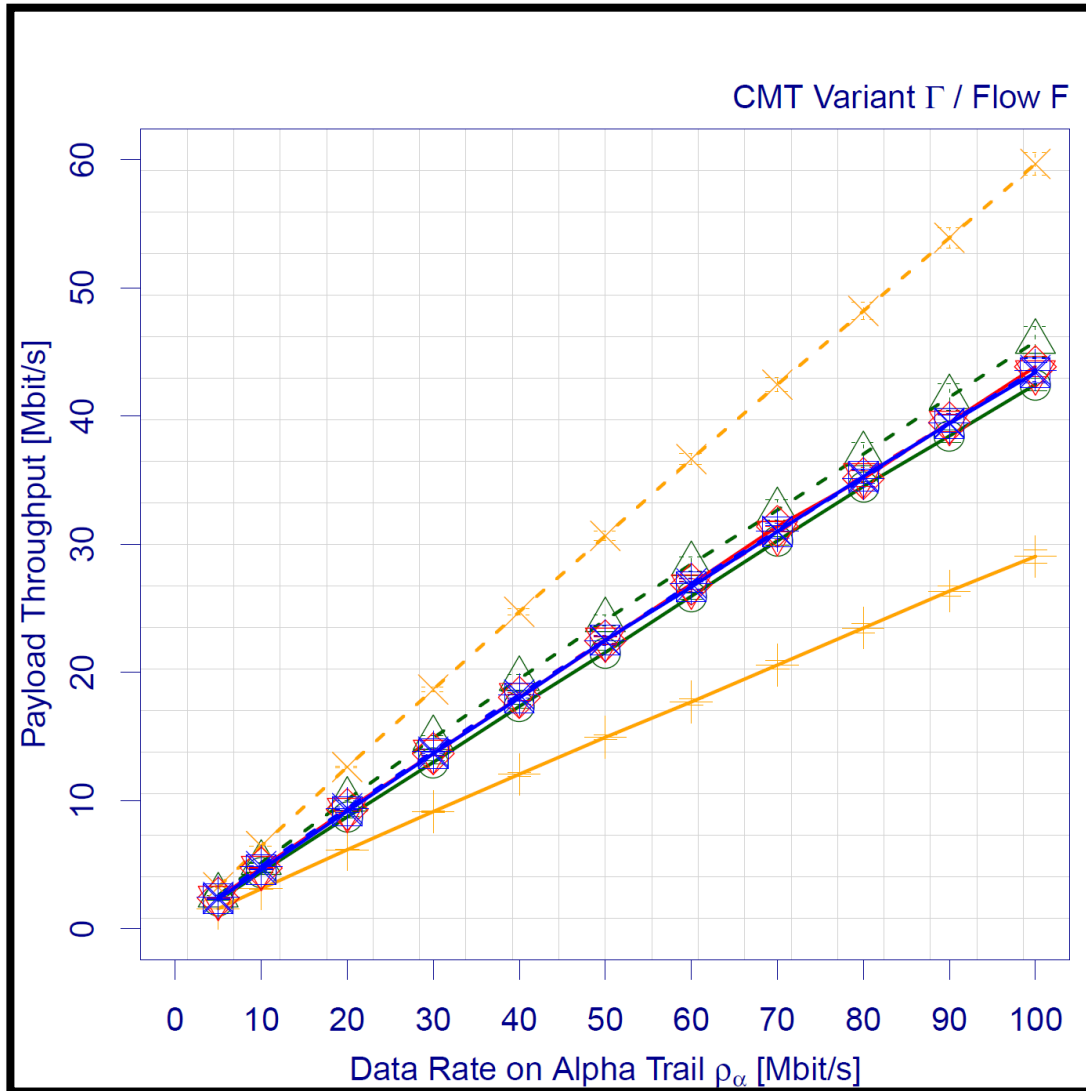
- ratio of flows to sub-flows
 - 1:1 → 1:x
 - For n different flows sharing a link l
 - $\rho(l)/n$ for each of the n flows



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

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

Bottleneck Topology Simulation Results



■ RENO-MP

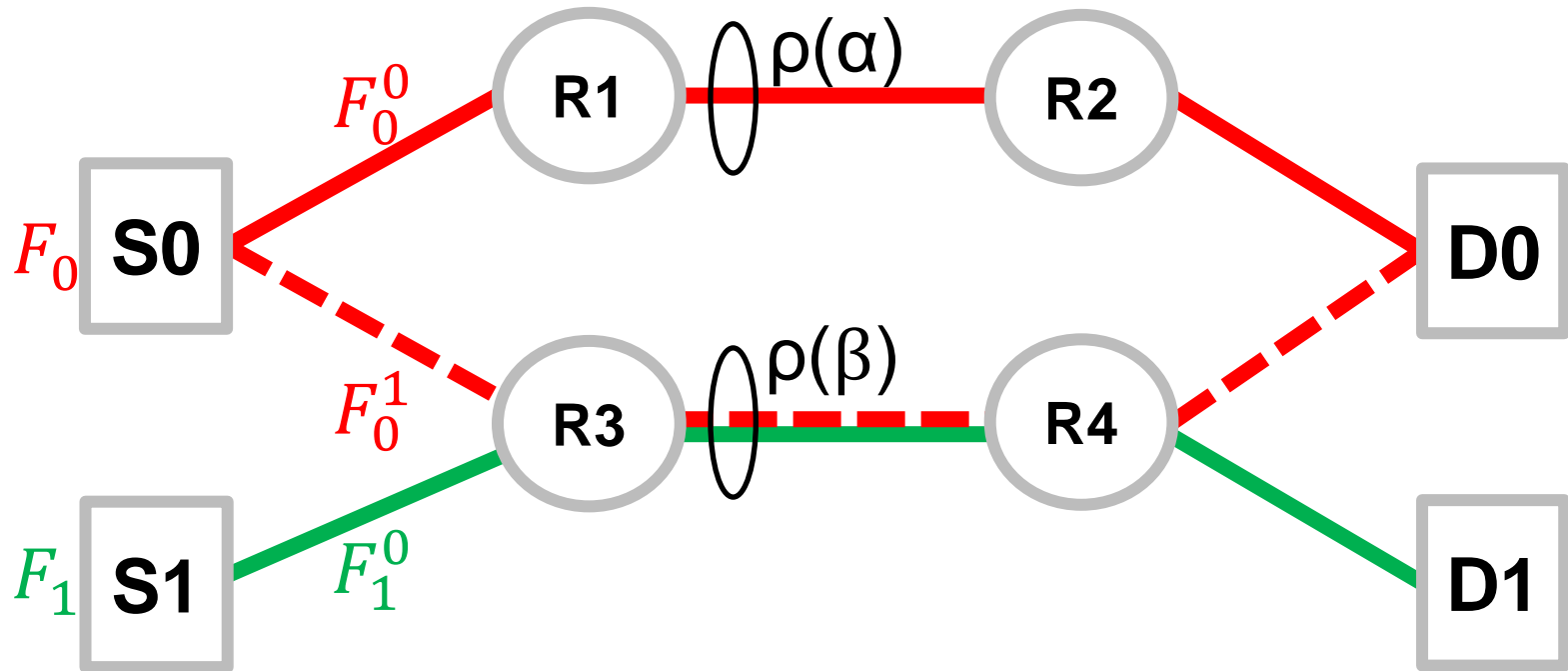
– 2/3 vs 1/3

■ 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

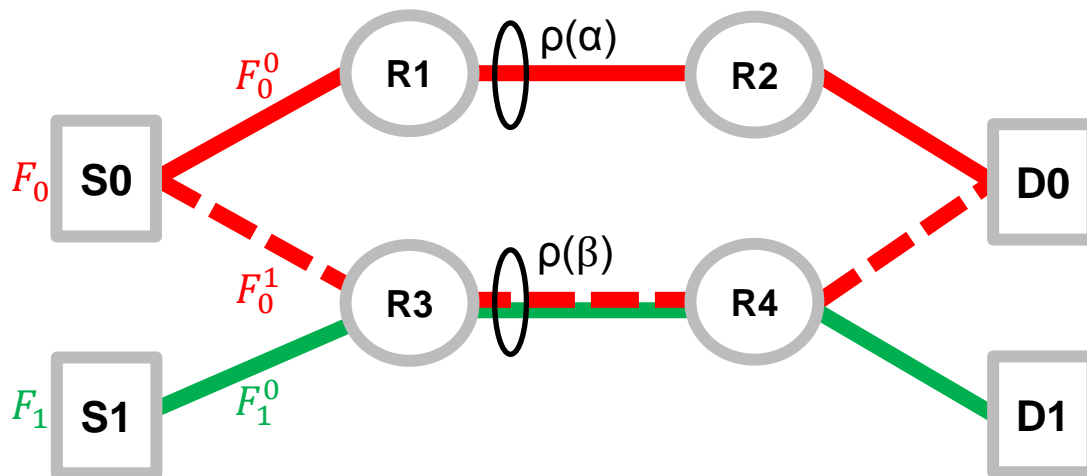
Network-Centric Flow Fairness

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

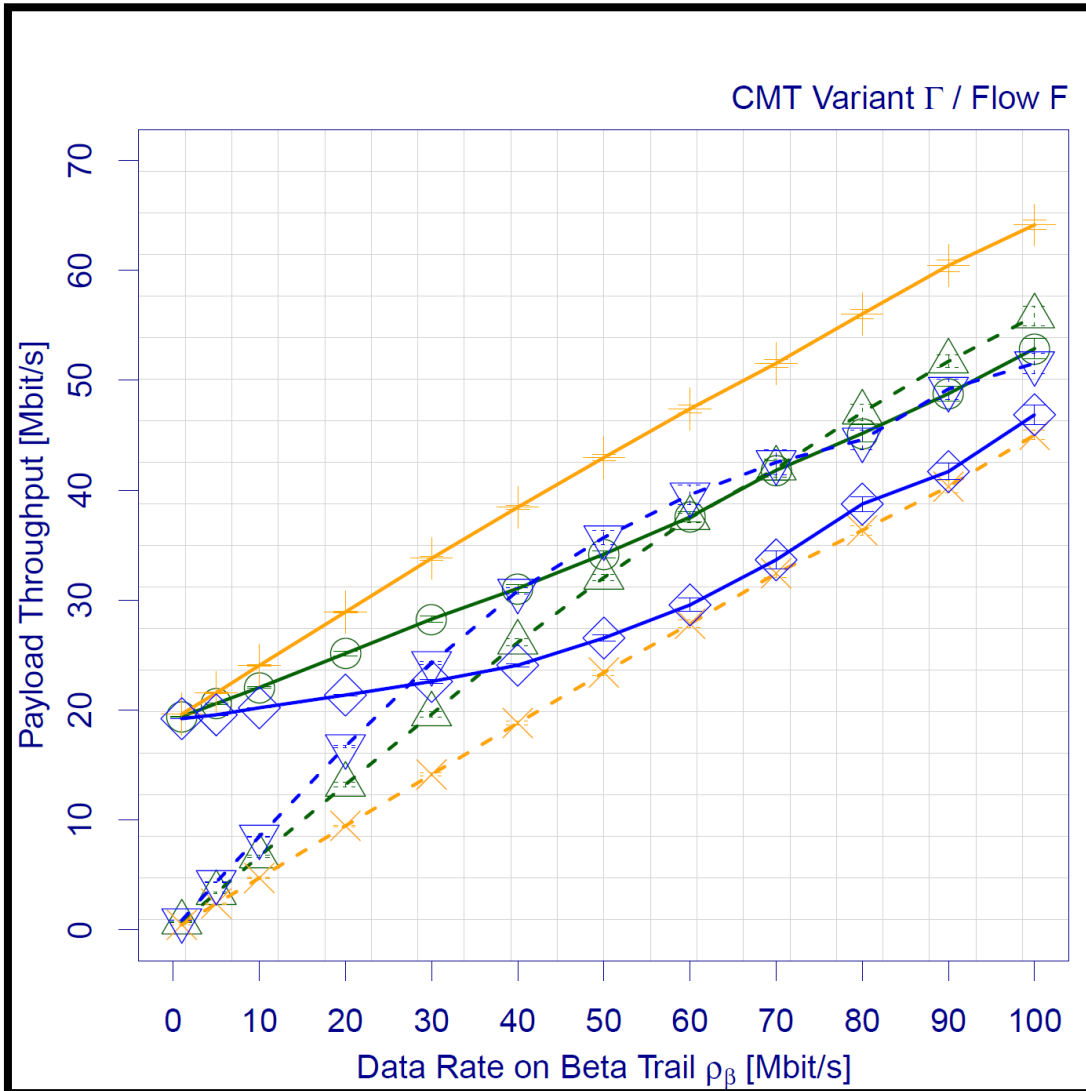


→ $B_0^0 = \rho(\alpha)$

→ $B_0^1 = \rho(\beta)/2$

→ $B_1^0 = \rho(\beta)/2$

Disjoint Paths Topology Simulation Results

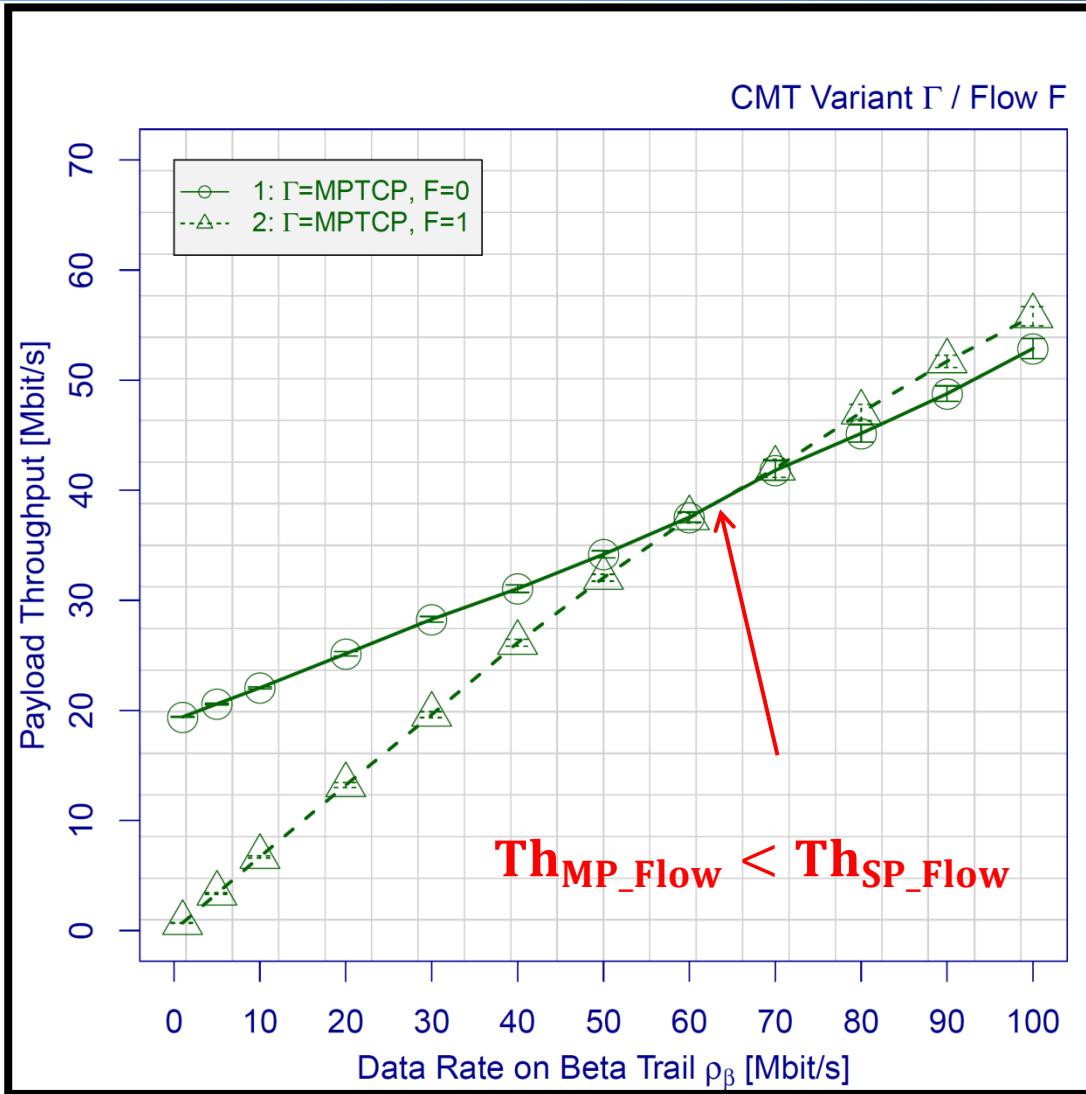


- 1: Γ =MPTCP, F=0
- △- 2: Γ =MPTCP, F=1
- + 3: Γ =Reno-MP, F=0
- ×- 4: Γ =Reno-MP, F=1
- ◇- 5: Γ =RP-MP-v2, F=0
- ▽- 6: Γ =RP-MP-v2, F=1

- 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?

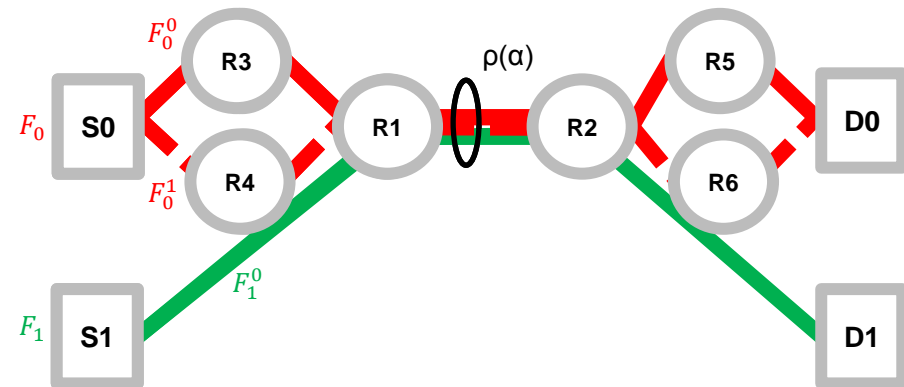
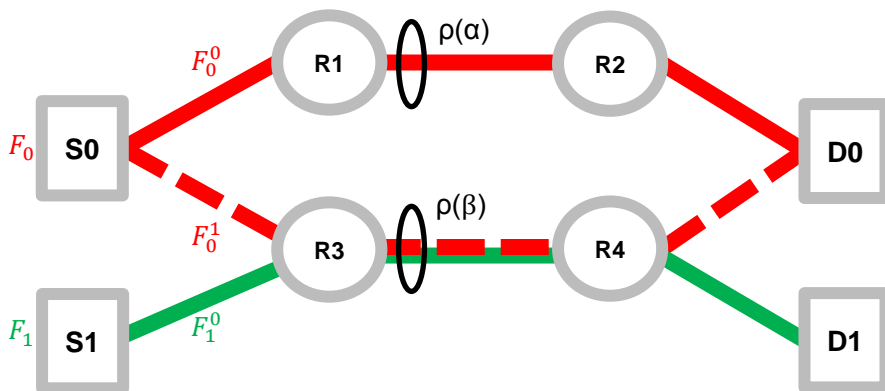
■ Example

- 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?

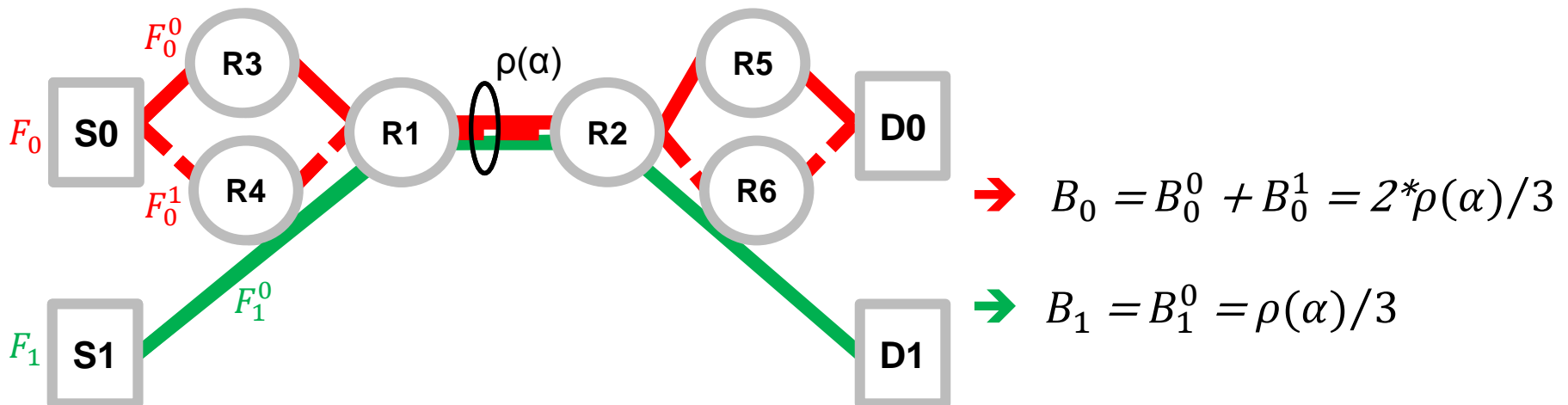
- Consumer view
- Provider view



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



Summing up

Views on “fair” Resource Allocation

■ We define three 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

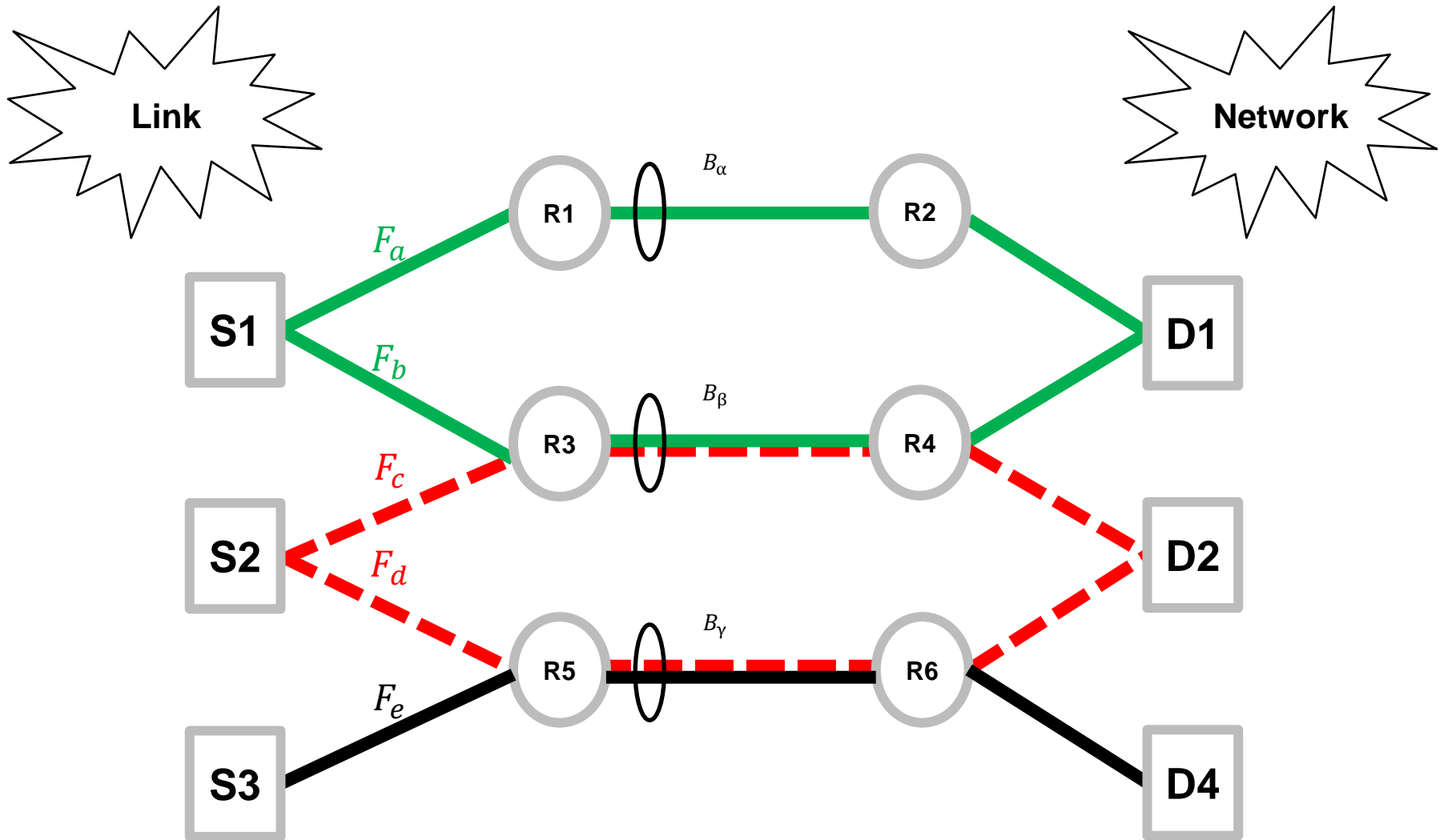
■ Until now:

- Dominating single-path transfer
- Multipath CCs
 - Fair coexistence of multi- and single-Path flows
 - Extension of the single-path CC
- 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 / correction 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“?

■ What is about the „Link-Centric Sub-Flow Fairness“?

- Is the bottleneck problem so important?

Any Questions?

■ Our Team

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■ 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.
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<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).
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- **[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>