Multipath Transport Challenges and Solutions

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I. MULTIPATH TRANSPORT IN THE INTERNET

Multipath transport is a promising new paradigm that enables the concurrent use of different paths and resource pooling of their capacity. Ongoing research and standardization activities extend the Transmission Control Protocol (TCP) towards a Multipath TCP solution. The objective of the MPTCP protocol [1] by the IETF Multipath TCP is to aggregate multiple subflows between two endpoints into a session that can be accessed by an application like a TCP connection. Promising use cases include mobile devices with multiple interfaces or bandwidth aggregation inside data centers.

This contribution analyzes the capacity sharing implications of multipath transport. We analyze the resulting challenges and present selected solutions. As an alternative to MPTCP we developed Multi-Connection TCP (MCTCP) [2][3]. We will present our solutions for some of the multipath transport challenges and compare it to existing ones. Finally, we will discuss remaining open capacity sharing issues.

II. CHALLENGES

Capacity sharing in the Internet is a complex problem with remaining open issues, e. g., regarding congestion control [4]. Multipath transport has to deal with specific challenges:

(1) *Multiple addresses vs. multiple paths*: In the Internet architecture, transport protocols only deal with addresses and are unaware of the paths between them. As a result, it is impossible to develop a Multipath TCP solution that will work perfectly in all possible situations.

(2) *Subflow selection, scheduling, and congestion control*: Compared to TCP, multipath transport has additional degrees of freedom how to send data. A subflow control function has to determine whether and when subflows shall be established. Scheduling mechanisms have to assign data chunk to these subflows. And congestion control and fairness constraints have to be taken into account, too. As a result, multipath transport may not outperform single path transport in all cases.

(3) *Interactions with policies and routing*: The forwarding in the Internet is governed by routing protocols and policy functions, which typically do not exchange information with endsystems. There is no simple way for a network to announce the availability of paths, and there is no way for endsystems to ensure that a network is indeed multipath-friendly.

(4) *Protocol design*: There are further functional and algorithmic challenges, ranging for instance from the protocol design aspects to the end-to-end flow control design issues.

III. SOLUTIONS

There have been significant research efforts to address these challenges. We will consider as one example our own TCP-based multipath protocol MCTCP [2][3]. MCTCP consists of a shim layer on top of several TCP connections and encodes control information, as far as possible, in their payload, while being transparent in the single path case. We report lessons learnt from a Linux prototype. Furthermore, measurement results demonstrate that MCTCP can dynamically aggregate the capacity of several paths, either without or with congestion control coupling [5]. We also proof its robustness, e. g., in combination with effects such as reverse path congestion.

In addition, we discuss potential implications of multipath transport on the interface to applications, since some features require extensions of the Application Programming Interface (API) [6], different to the normal TCP operation.

IV. MULTIPATH TRANSPORT: QUO VADIS?

As a final contribution, we will address the question how multipath transport will evolve in the Internet. We argue that multipath transport will most likely not fundamentally affect the overall capacity sharing. For instance, due to the Quality-of-Service and traffic isolation mechanisms both in fixed and mobile access networks (e. g., [7]), congestion control and load distribution algorithms in endsystems do not necessarily really impact how resources are shared.

While mobile networks are a promising use case for multipath transport, we also question whether there is a fundamental difference between capacity sharing in the mobile and the fixed Internet, given that per-subscriber and per-application schedulers and policies are possible in both cases. Insofar we argue against the design of transport protocol mechanisms specifically for mobile access networks.

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