Resource Pooling for the Future Internet

NOKIA

Lars Eggert
Nokia Research Center &
Helsinki University of Technology

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Premise

we need a more robust Internet than we can get from simply making better individual components

most hosts will be mobile, with multiple radios in use concurrently

applications are becoming more demanding & important

we don't have a clean slate = incentives are more critical than ever!

incentive misalignment kills many technically viable proposals

partial benefit from partial deployment

change is easiest where pain is felt

SPEED ZONE AHEAD

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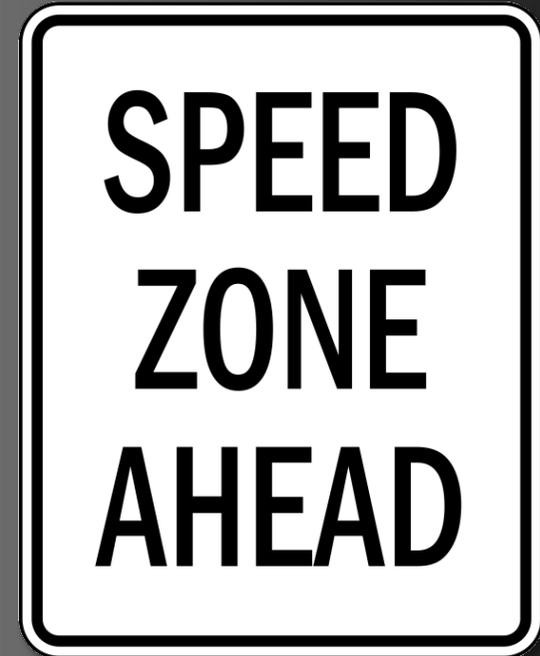
Resource Pooling for the Future Internet

make the network resources behave like a **single, pooled** resource

increase reliability, flexibility and performance

by exploiting **parallelism** and **redundancy** in the network

through an **evolution** of the current Internet protocols

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Components of a Resource Pooling Architecture

Multipath Transport

transmit the data of a single transport connection along multiple paths

coupled congestion control loops are critically important (Kelly/Voice, etc.)

Resource Accountability

expose the impact of its resource usage to an end system (and "charge" for it)

creates the correct incentives to behave smartly

Multipath Routing

make multiple, disjoint paths available between two endpoints

the only real way to robustness is via diversity

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Multipath Transport Overview

multipath transport treats multiple end-to-end paths as a single pooled resource

both in terms of robustness and bandwidth

linked congestion control for bottleneck fairness

traffic moves away from congested paths naturally

larger bursts can be accommodated

traditional Internet:
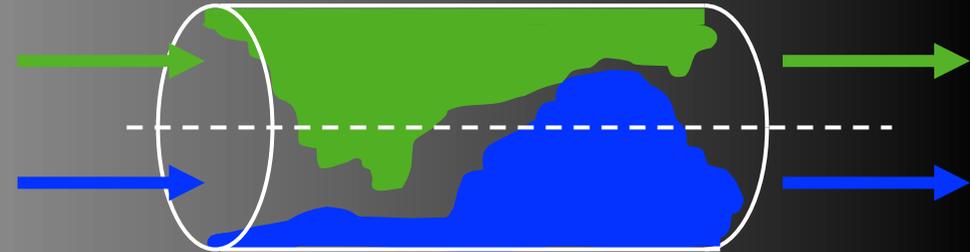
multipath resource pooling:

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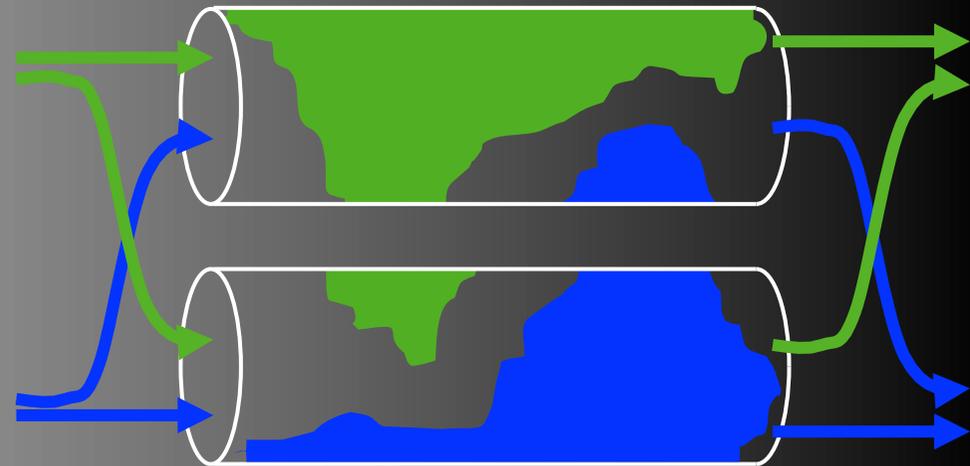
# Multipath Transport Allows a Wider Range of Traffic Matrices
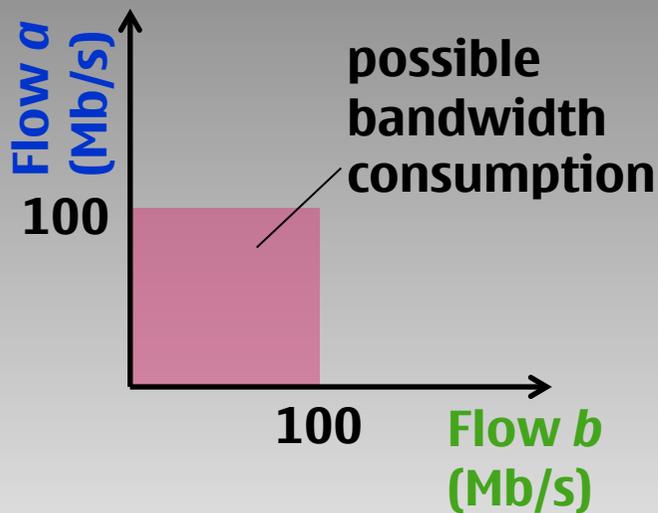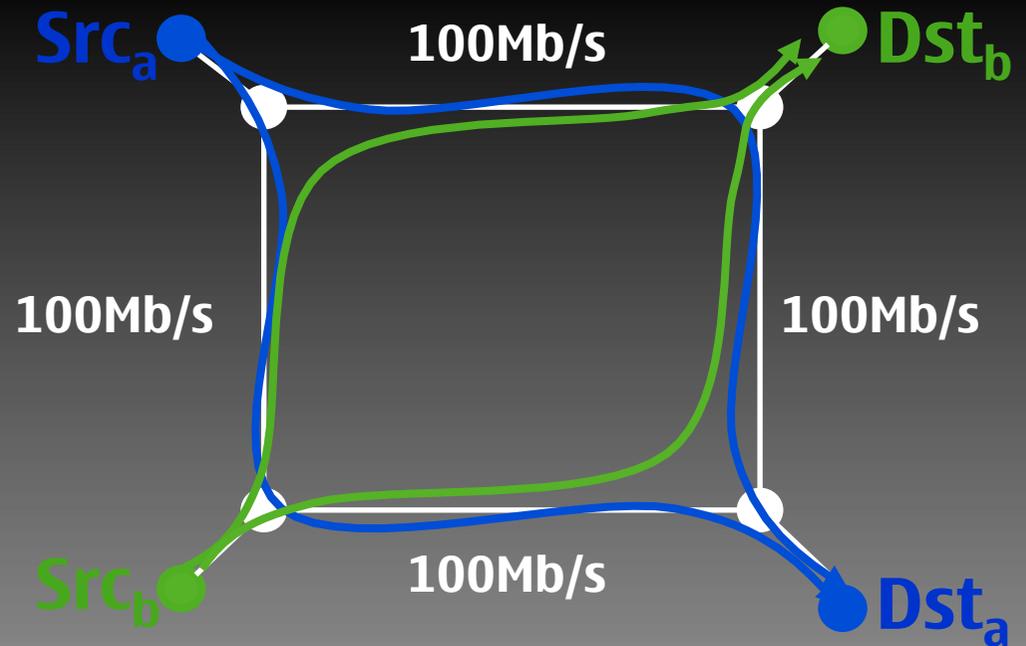
no multi-path flows
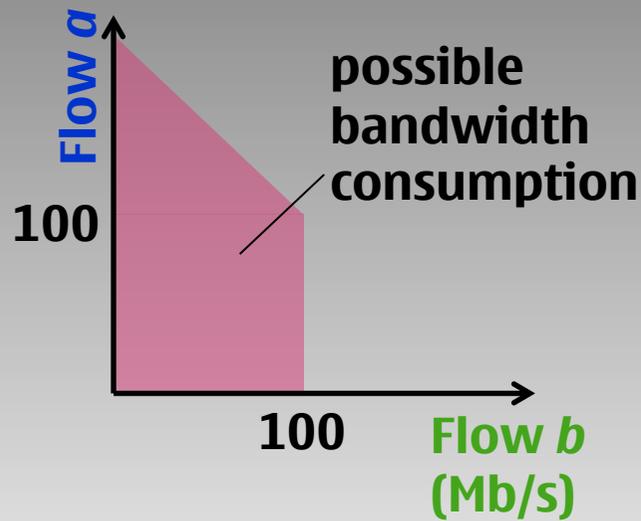
only flow *a* is multi-path
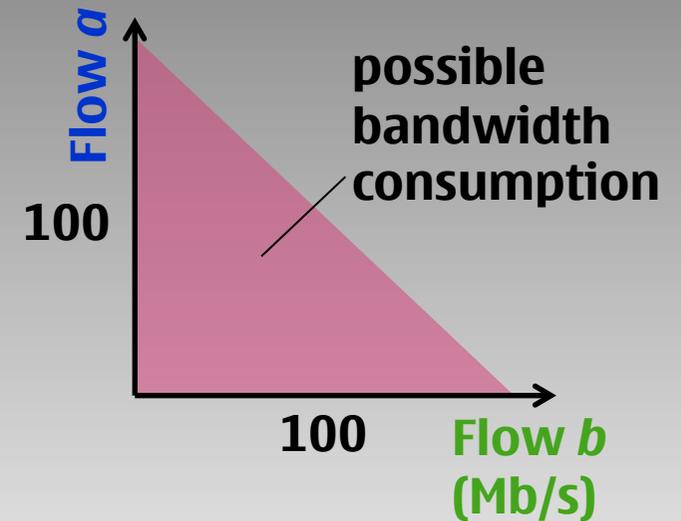
both flows are multi-path

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Internet Transport means TCP

applications and higher-layer protocols use TCP to transmit data across the Internet

this is unlikely to change anytime soon (quite the opposite)

so any other transport protocol is a non-starter (incentives!)

but standard TCP only transmits along a single path...

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Resource Pooling + TCP = Multipath TCP

extend TCP to allow one connection to send data along multiple paths between the same two end systems

concurrently, or changing over the lifetime of the TCP connection

flexibility, performance, robustness

must be fully backwards compatible
    same socket API for apps
    looks like standard TCP (+ options) to network

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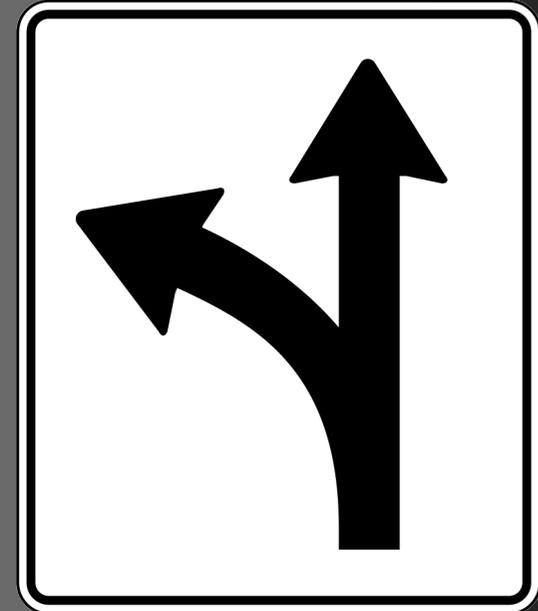
Current Status

initial research is complete

protocol engineering is underway

IETF standardization starts 2H2009
  "Multipath TCP" Working Group

strong interest from Apple, Google, Microsoft
    Windows 8 roadmap?

prototype code available

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Resource Accountability

the current Internet does not adequately account for whose sessions use which fraction of its communication resources

example: ISPs account for traffic volume when they should be accounting for "congestion caused"

a Future Internet must have more useful accounting & reporting

so users of the network have the information & incentives to behave smartly

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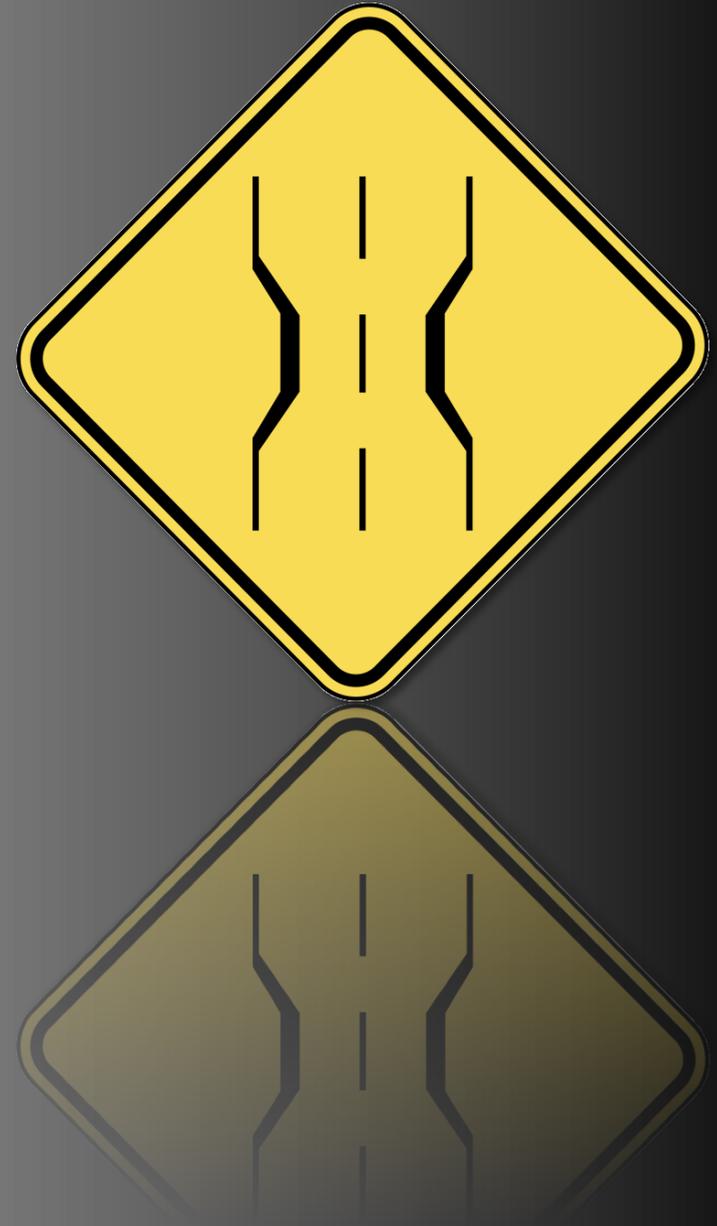
Congestion Exposure

a mechanism for exposing how much a user's traffic is contributing to current path congestion

to the user himself and the ISPs

ISPs charge for "congestion caused"

users have an incentive to use applications & protocols that are smart about avoiding congestion

or they can decide to pay a premium

creates flexibility, choice & incentives

proposed protocol: Re-Feedback

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Re-Feedback

1 Congested queue debit marks some packets

2 Receiver feeds back debit marks

3 Sender re-inserts feedback (re-feedback) into the forward data flow as credit marks

Feedback path

Networks

Routers

Data packet flow

Sender

Receiver

+1 +1 +1 −1 +1 −1

4 Outcome: End-points still do congestion control
But sender has to reveal congestion it will cause
Then networks can limit excessive congestion

5 Cheaters will be persistently in debt
So network can discard their packets
(In this diagram no-one is cheating)

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Current Status

research/engineering on congestion exposure ("re-feedback") has progressed farthest

"Congestion Exposure" BOF in Nov 2009 at IETF-76 in Hiroshima, Japan

resource accounting & control ideas for other communication resources are being investigated

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Multipath Routing

how can we bring the benefits of multipath transports to hosts that only have one single network interface?

> when the ISP they connect to is multihomed

> or when multiple paths exist "deeper" in the network

(multipath theory says that complete path disjointness is not required, as long as there is no shared path bottleneck)

Internet routing = BGP

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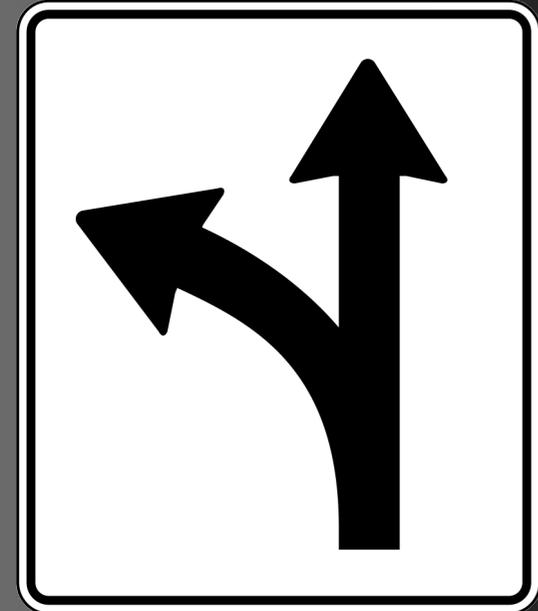
Resource Pooling + BGP = Multipath BGP

computing & using multiple BGP paths
at the same time

- potentially better traffic engineering
- better resilience + convergence
- increase utilization of the network

challenges

- incremental deployment
- loop-freeness
- end-to-end consistency

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Work in Progress

loop-freeness & incremental deployment

    only propagate a single path to avoid loops

    longest used (not longest known)

first result: understand the dynamics

    slightly faster convergence in some chosen topology

many more results needed to understand resulting path diversity

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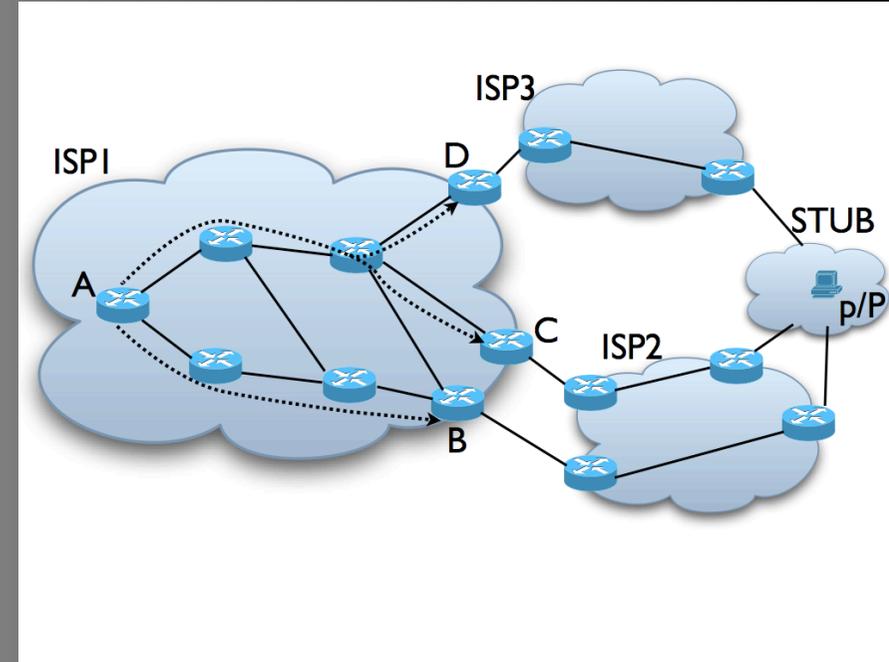
The trilogy Project

Develop a unified control architecture for the Future Internet that adapts in a scalable, dynamic & robust manner to local operational and business requirements.

Develop and evaluate new technical solutions for key Internet control elements: reachability & resource control.

Assess commercial and social control aspects of the architecture & technical solutions, including internal & external strategic evaluation

Funded by the EU under FP7 for 3 years (2008-10)
http://www.trilogy-project.eu/

Reachability, Topology Discovery

Load-Dependent Multipath Transport

Traffic Engineering

Congestion Control

Re-Feedback

Routing Policy

Economic Drivers