# Resource Pooling and the Trilogy Project

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(with thanks to Mark Handley, Damon Wischik and Marcelo Bagnulo)

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trilogy

Develop a **unified control architecture for the Future Internet** that can adapt in a scalable, dynamic and 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 our architecture & technical solutions, including internal & external strategic evaluation

reachability mechanisms

topology discovery, reachability

load-dependent multi-path

traffic engineering

congestion control

re-feedback

routing policy

economic drivers

resource control

business
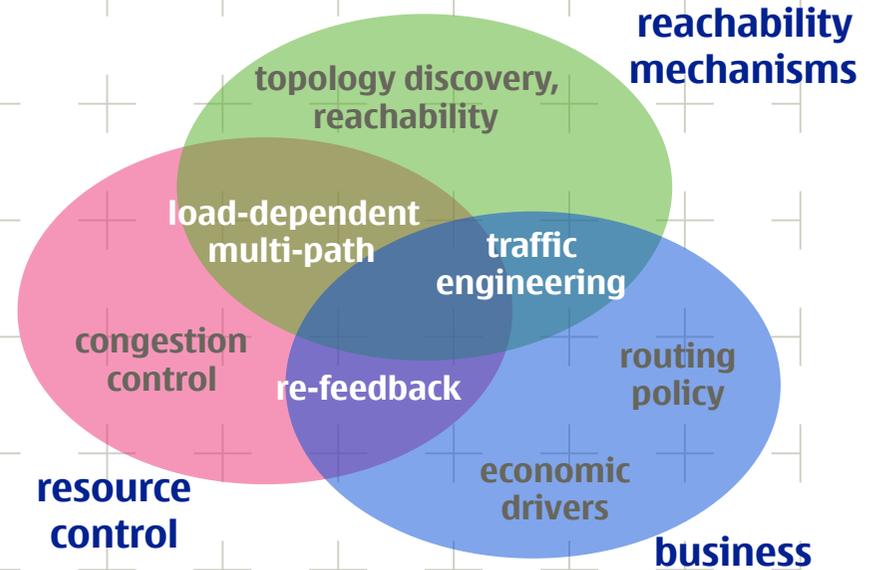
Funded by the EU under FP7 for 3 years (2008-10)

Total volume: 9.15M€

EU: 5.82M€

~60 person-years total

http://www.trilogy-project.eu/

SEVENTH FRAMEWORK PROGRAMME

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The architectural requirements have changed

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

traditional routing can't solve this in a scalable way

applications are becoming more demanding (VoIP, TV, Games)

most of the end-systems will be mobile, with multiple radios that can be used simultaneously

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Resource pooling

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

the aim is to increase reliability, flexibility and efficiency

the method is to build mechanisms for shifting load between the various parts of the network on the fly
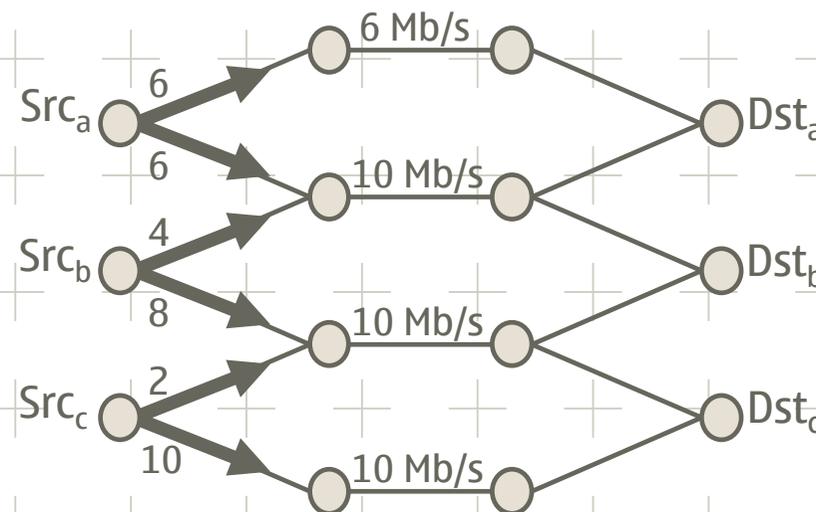
Resource pooling is not new...

Routing

BGP traffic engineering
    slow, manual process to pool
    resources across peering links

OSPF/MPLS traffic engineering
    slow, mostly manual process
    to pool resources across
    internal ISP links

BT, AT&T and others
    dynamic alternative routing

Elsewhere

multi-homing
    pool reliability & capacity

Google, Akamai, CDNs
    pool reliability & bandwidth

BitTorrent
    pool capacity & reliability

Theoretical foundations

Kelly and Voice

Key, Massoulié and Towsley

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Resource pooling for the Internet

multipath
> the only real way to get robustness is redundancy

multihoming – via multiple IP addresses for a system
> allows to still aggregate routing information

mobility – via adding and removing addresses to a system
> no need to involve the routing system
> (or use non-aggregatable addresses or identifiers)

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Approach

multipath-capable transport layers

> use multiple subflows within one transport connection
>
> control perform congestion control for each subflow independently
>
> effect: traffic automatically moves to the less congested paths

note: the involvement of congestion control is crucial

> link the back-off parameters for stability and fairness (Kelly/Voice)
>
> you can't solve this problem at the IP layer alone (no feedback)

this approach moves some of the stresses out of the routing system

> might be able to converge slowly and no-one cares

(eventually, the routing system should expose in-network multipath availability, so single-homed end systems benefit, too)

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Multipath transport

multipath transport allows multiple paths to be treated as a single pooled resource

both in terms of robustness and bandwidth

traffic moves away from congested paths naturally

larger bursts can be accommodated

better performance and fault tolerance

ARPAnet resource pooling:
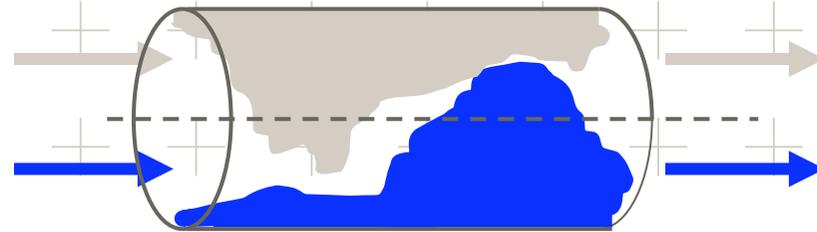
multipath resource pooling:

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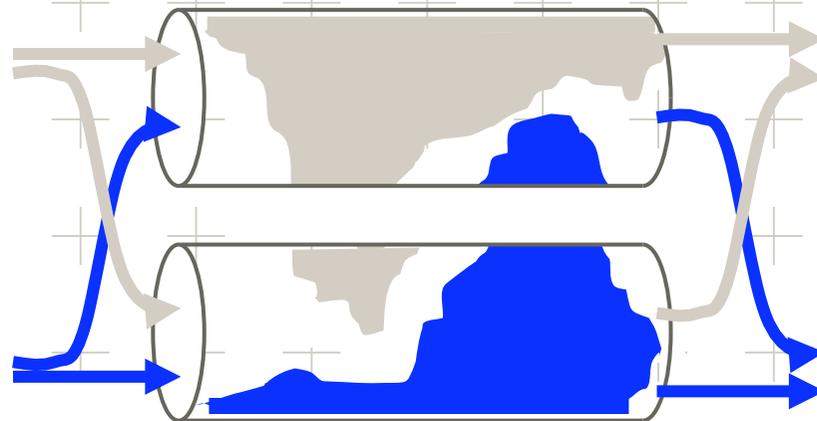
Resource pooling allows a wider range of traffic matrices

Src$_a$ ○ —— 100Mb/s —— ○ Dst$_b$

100Mb/s   100Mb/s

Src$_b$ ○ —— 100Mb/s —— ○ Dst$_a$

Flow a (Mb/s)

100

possible bandwidth consumption

100   Flow b (Mb/s)

no multi-path flows

Flow a

100

possible bandwidth consumption
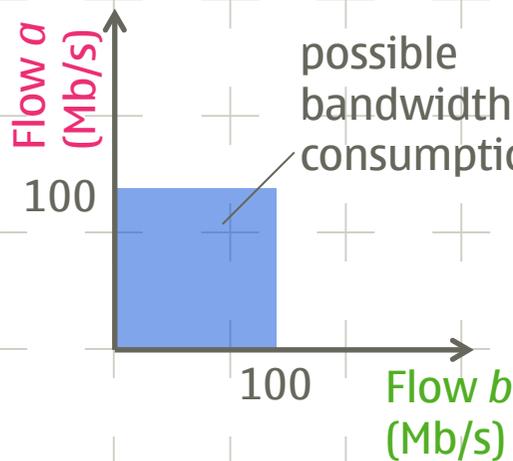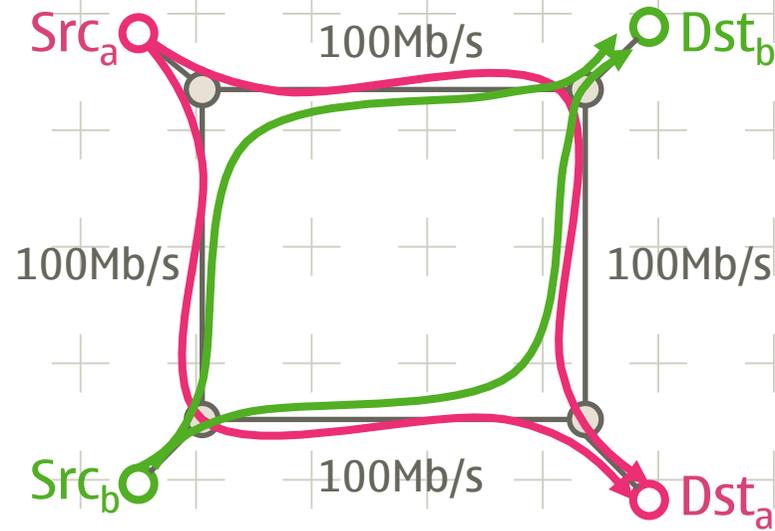
100   Flow b (Mb/s)

only flow a is multi-path

Flow a

100

possible bandwidth consumption

100   Flow b (Mb/s)
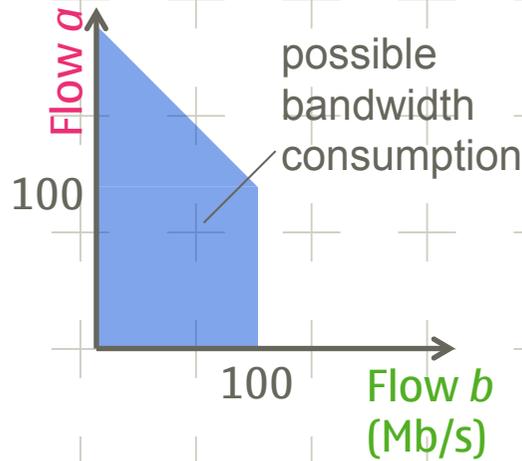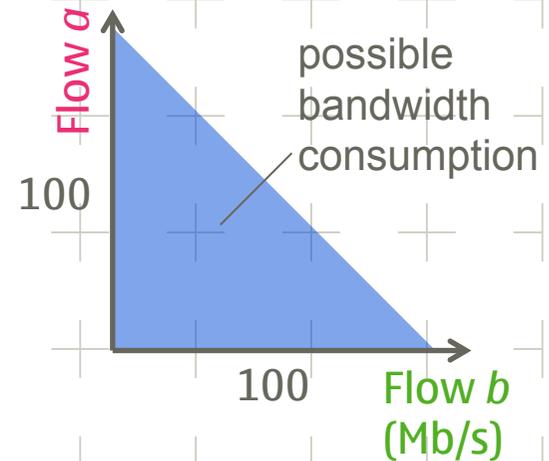
both flows are multi-path

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Multipath traffic engineering

Balancing across links of dissimilar speed

Balancing across links of dissimilar cost

Src

Src

Add congestion marking

$$$

Dst

Dst

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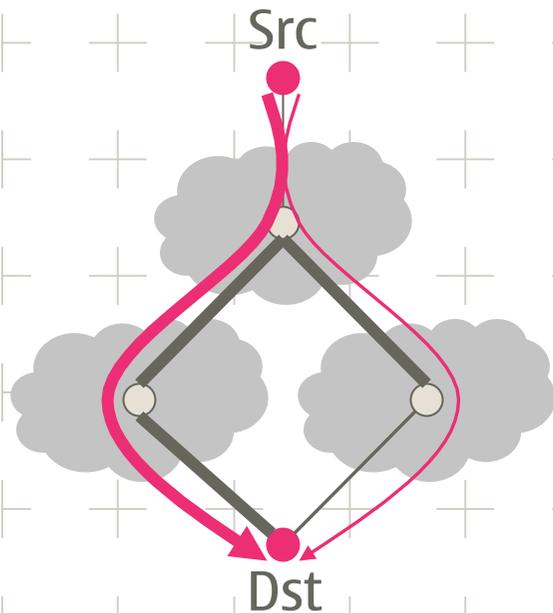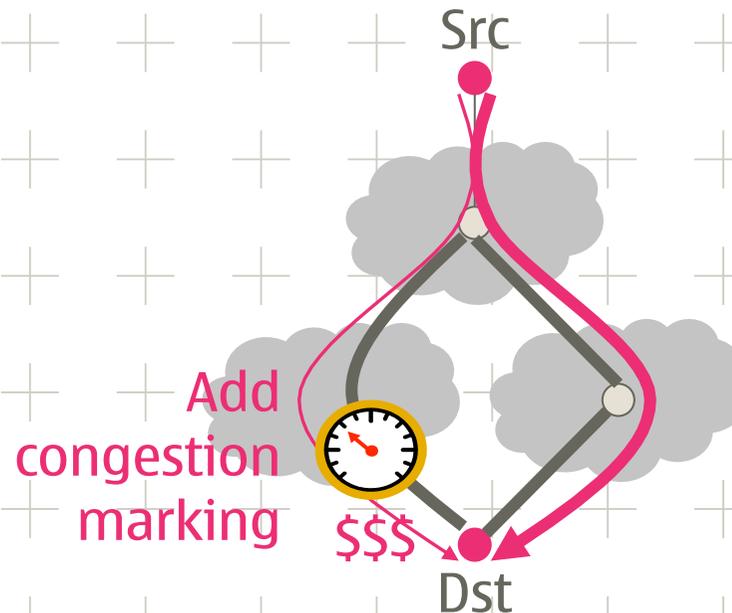
# End-systems can optimize globally (often ISPs cannot)

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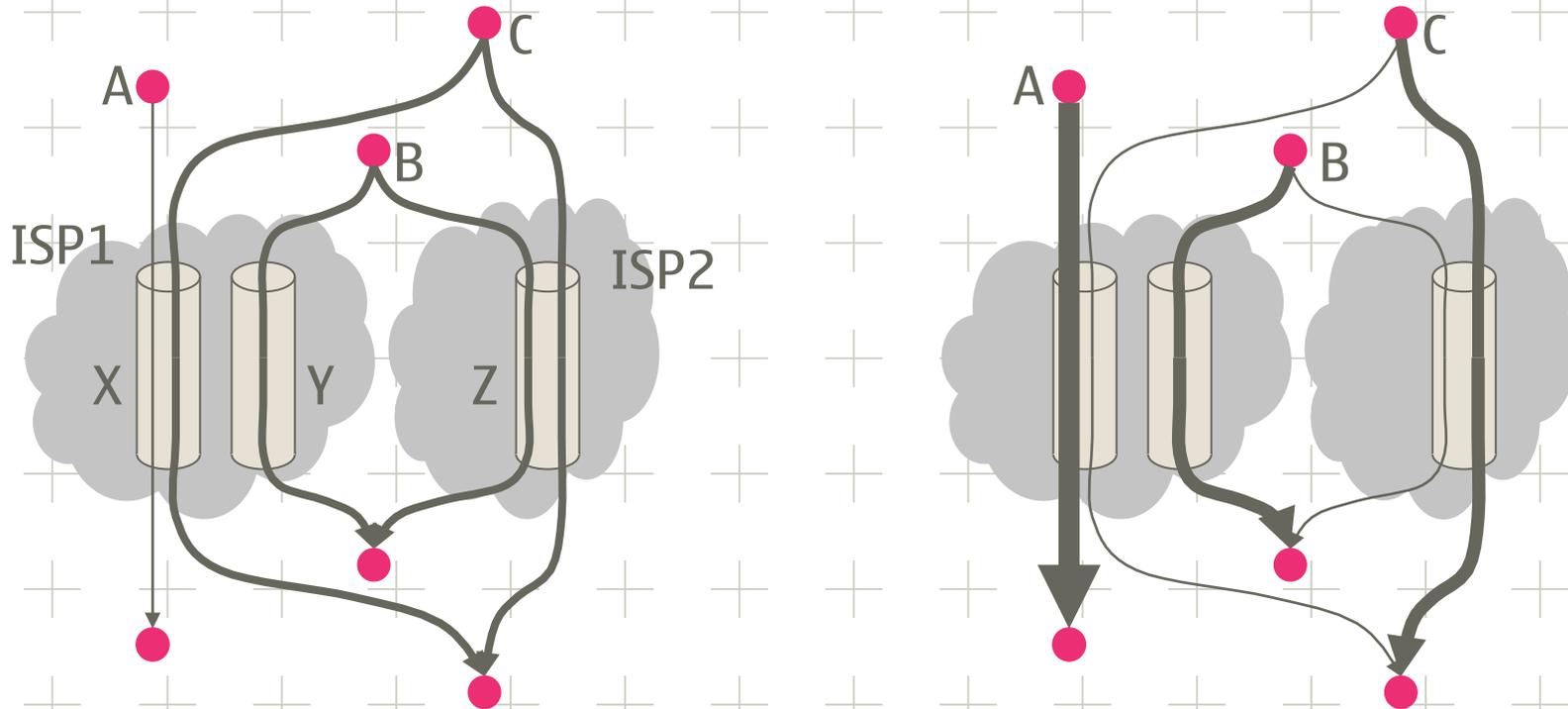
Where are we today?

good theoretical understanding of the issues (past work by others)

    Kelly and Voice; Key, Massoulié and Towsley

Trilogy is working on the details for TCP & BGP

    how well does this work in practice?

    are there cases where multipath does worse?

    how much of the traffic engineering problems does this solve?

    how much remains to be done in routing?

    how to manage such dynamic networks?

(Trilogy is also investigating other topics)

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Next Steps: IETF

Multipath TCP (MPTCP) BOF

proposed for IETF-75 in Stockholm, Sweden (approval pending)

mailing list: multipathtcp@ietf.org

related Internet Drafts
    draft-ford-mptcp-multiaddressed   ("2-ended variant")
    draft-van-beijnum-1e-mp-tcp   ("1-ended variant")

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Next Steps: Keio University

Michio Honda worked in Trilogy during his internship at Nokia

interest from both sides to continue this collaboration

Trilogy and Keio are investigating how an ongoing collaboration could be formalized (NDA, etc.)

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