Internet Resource Pooling for Mobile Devices

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The requirements have changed

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

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

mobile applications are becoming more demanding & important
  VoIP, TV, Games, always-on services

the deployment 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"
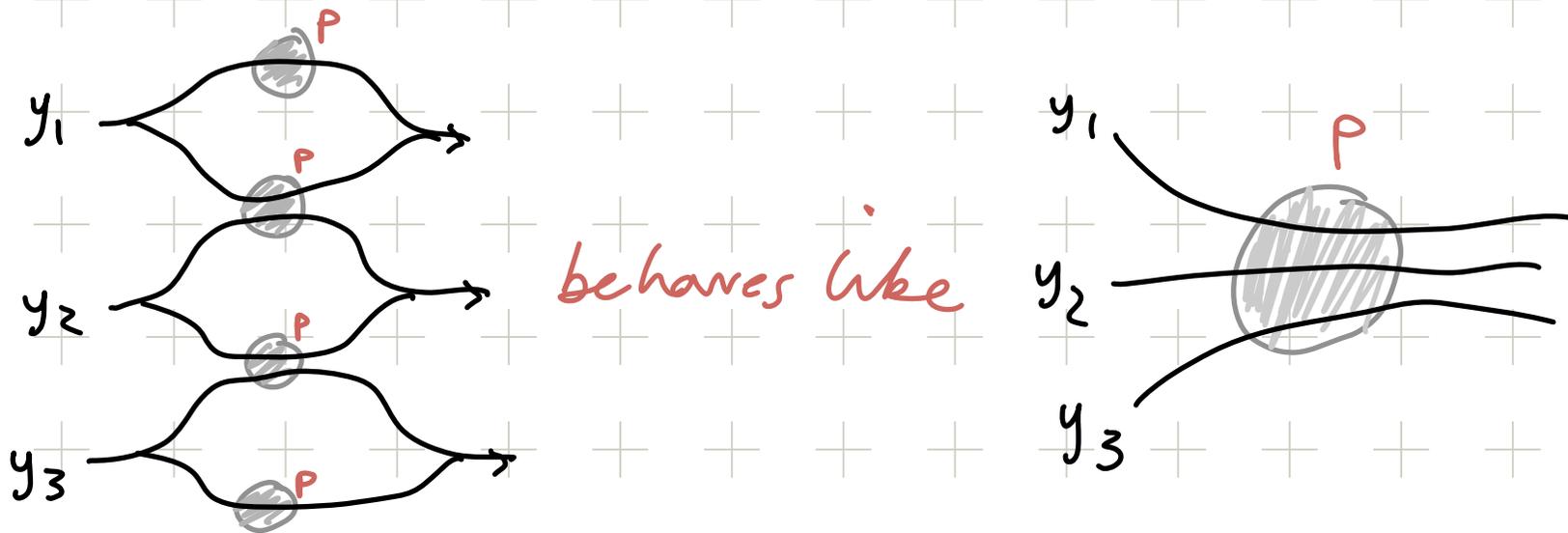
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Resource pooling

make the resources of a network 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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Resource pooling for the Internet

Multipath routing

make multiple, disjoint paths available between two endpoints

the only real way to robustness if through diversity

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 the end system (and "charge" for it)

creates the incentives to behave smartly

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Short-term resource pooling for the Internet

Multipath routing

make ~~points~~

the only real way to robustness if through diversity

Multiple IP addresses/ interfaces per host

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 ~~for it)~~

Evolution of standard end-to-end congestion control

creates the incentives to behave smartly

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Multipath transport in a nutshell

multipath transport treats multiple end-to-end paths as a single pooled resource
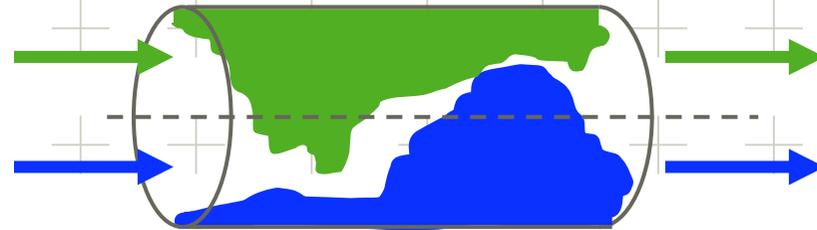
both in terms of robustness and bandwidth
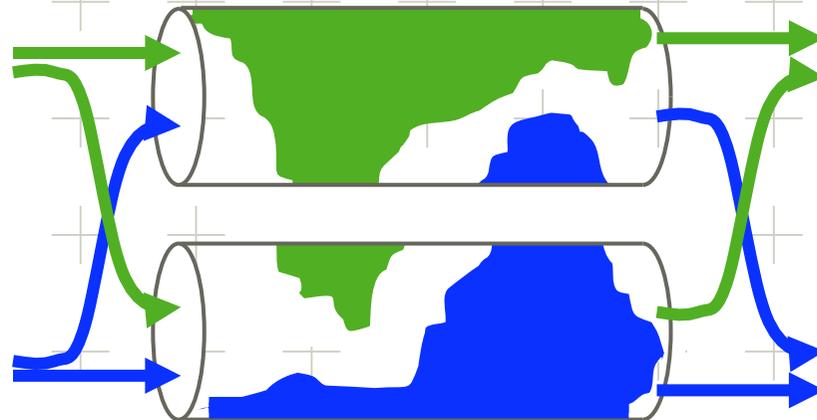
per-path congestion control

traffic moves away from congested paths naturally
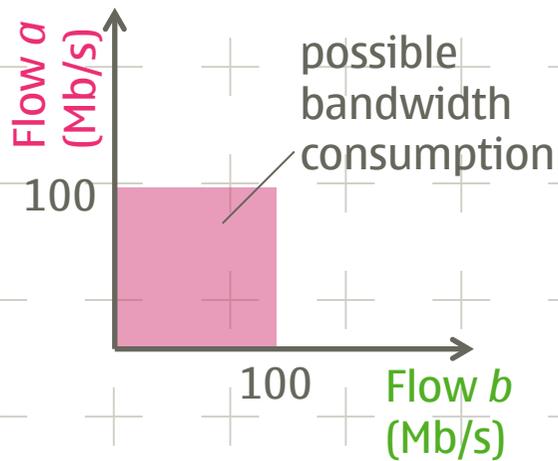
larger bursts can be accommodated

traditional Internet:

multipath resource pooling:

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Multipath transport allows a wider range of traffic matrices

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
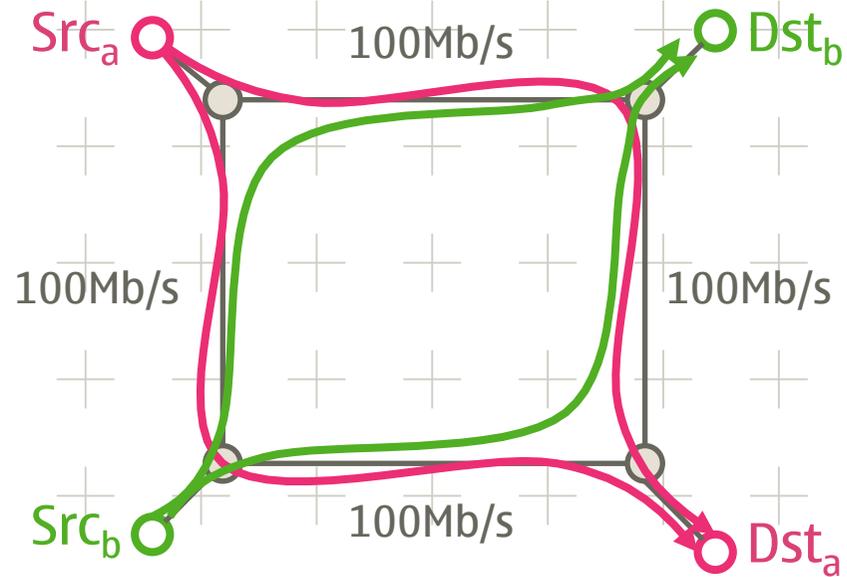
100   Flow b (Mb/s)

only flow a is multi-path

Flow a

100

possible bandwidth consumption

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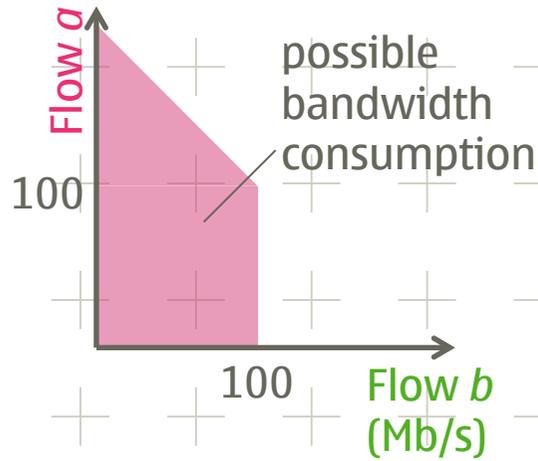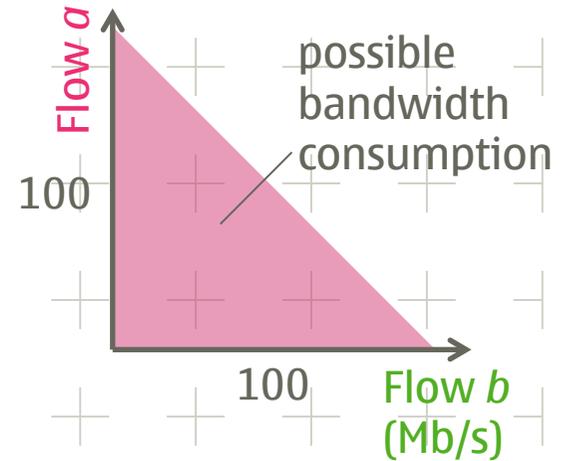
both flows are multi-path

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Multipath transport can optimize across ISPs
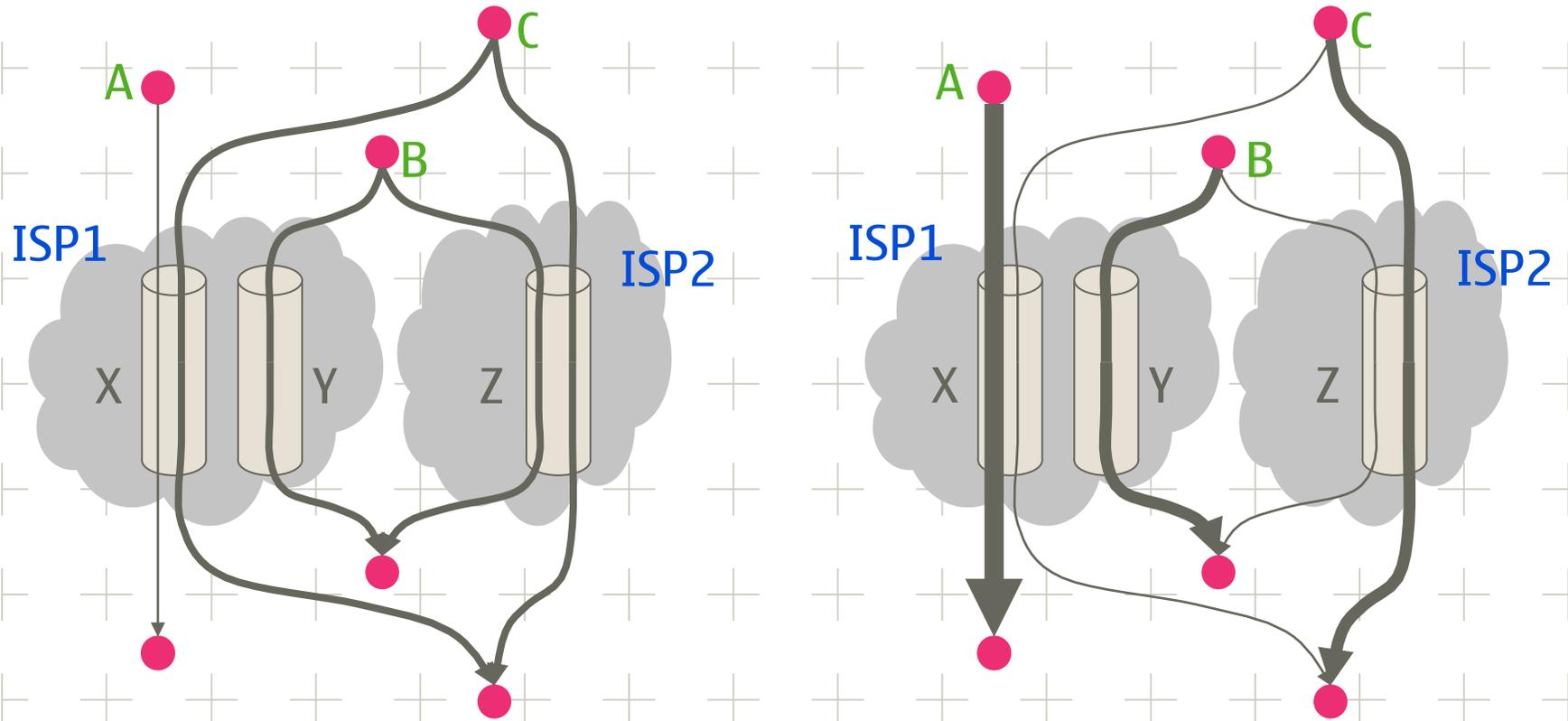
Internet resource pooling for mobile devices

mobile devices are an ideal target for short-term resource pooling

multiple radios = multiple ISPs = natural path diversity

even stronger incentives for stakeholders that control both ends

multipath transport = mobility "light"

connections stay up even when some radios become disconnected

no need to deploy heavyweight mobility or routing solutions

potential improvements in energy efficiency

multipath uses more radios (= more energy) but for a *shorter* time

depending on the hardware, there this can be more efficient

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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; etc.

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 account for pooled resource usage? create incentives?

how to manage such dynamic networks?

(Trilogy is also investigating other topics)

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Related standardization activities
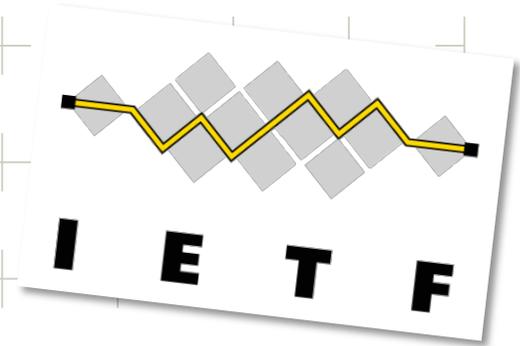
Multiple Interfaces WG chartered April 2009

Multipath TCP BOF at IETF-75 (Stockholm) in July 2009

Congestion Exposure bar BOF at IETF-75 (Stockholm) in July 2009

individual related involvement in many other IETF & IRTF groups

Trilogy IETF/IRTF Participation
(as of IETF-74)

Internet Architecture Board (IAB)
13 Members

Internet Engineering Steering Group (IESG)
15 Area Directors

General Area
R. Housley

ipr
pre8prob***

Internet Area
J. Arkko
R. Droms

16ng
6ai***
6lowpan
6man
ancp
autoconf
csi
dhc
dna
dnsext
hip
intarea***
ipdvb
l2tpext
l2vpn
lisp***
magma
mext
mif***
mip4
mipshop
netext***
netlmm
ntp
pana
pppext
pwe3
savi
shim6
softwire
tictoc
trill

Internet Research Task Force
A. Falk

asrg
cfrg
dtnrg
end2end
hiprg
iccrg
mobopts
nmrg
p2prg
rrg
samrg
tmrg

Applications Area
L. Dusseault
A. Melnikov

alto
apparea***
calsify
crisp
eai
httpbis
idnabis
lemonade
ltru
mmox***
morg
oauth***
sieve
usefor
vcarddav
yam***

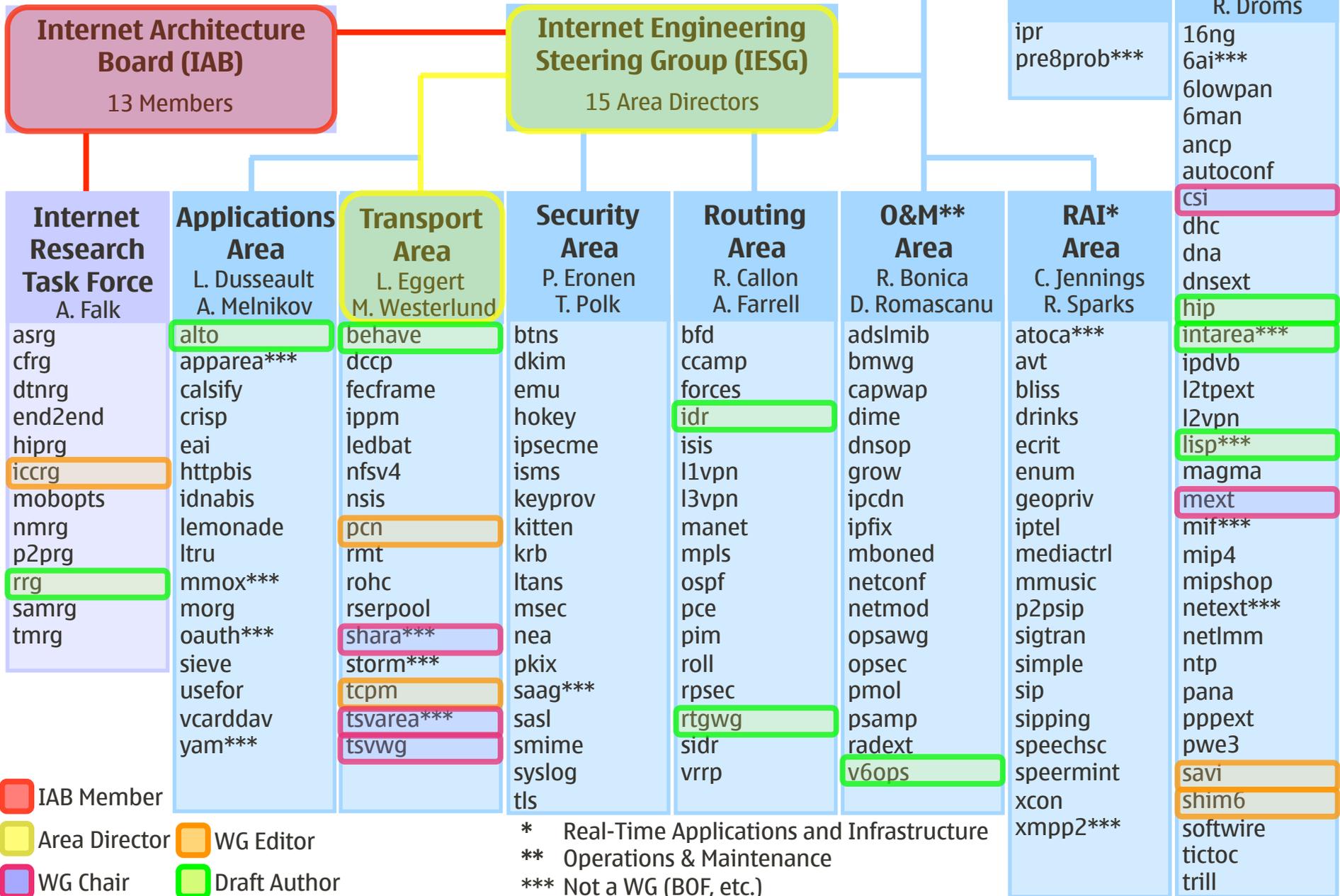**Transport Area**
L. Eggert
M. Westerlund

behave
dccp
fecframe
ippm
ledbat
nfsv4
nsis
pcn
rmt
rohc
rserpool
shara***
storm***
tcpm
tsvarea***
tsvwg

Security Area
P. Eronen
T. Polk

btns
dkim
emu
hokey
ipsecme
isms
keyprov
kitten
krb
ltans
msec
nea
pkix
saag***
sasl
smime
syslog
tls

Routing Area
R. Callon
A. Farrell

bfd
ccamp
forces
idr
isis
l1vpn
l3vpn
manet
mpls
ospf
pce
pim
roll
rpsec
rtgwg
sidr
vrrp

O&M Area**
R. Bonica
D. Romascanu

adslmib
bmwg
capwap
dime
dnsop
grow
ipcdn
ipfix
mboned
netconf
netmod
opsawg
opsec
pmol
psamp
radext
v6ops

RAI* Area
C. Jennings
R. Sparks

atoca***
avt
bliss
drinks
ecrit
enum
geopriv
iptel
mediactrl
mmusic
p2psip
sigtran
simple
sip
sipping
speechsc
speermint
xcon
xmpp2***

Legend:
- IAB Member
- Area Director
- WG Editor
- WG Chair
- Draft Author

* Real-Time Applications and Infrastructure
** Operations & Maintenance
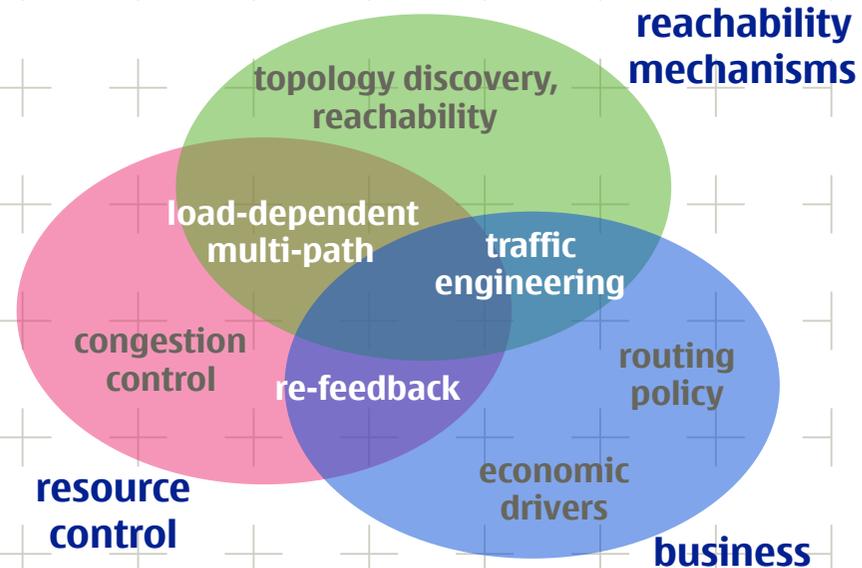*** Not a WG (BOF, etc.)

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

SEVENTH FRAMEWORK PROGRAMME

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

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