New routing schemes for highly meshed networks

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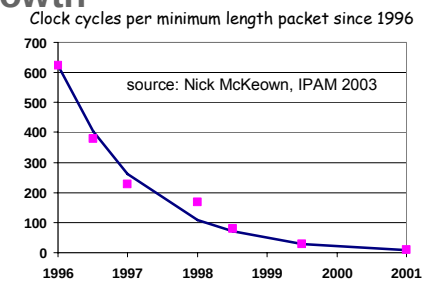
Outline

- Traffic growth
- Meshed networks
- Experiments
- Conclusions

Future Internet and traffic growth

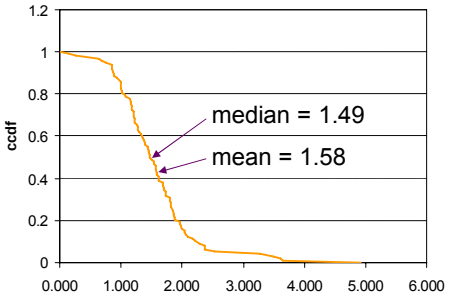


- let's look at today's Internet
- traffic is growing by 50-60% per year
- even more growth in some areas
  - Internet exchanges
  - mobile networks (but still at less total volume)
- the Internet at large will not be able to support highly sophisticated per-packet (or whatever it is called then) processing at each node
- or can traffic be drastically reduced in future
  - is this desirable at all?
- network protocols, nodes and mechanisms will have to cope with real traffic levels

- future Internet(s) will have to support current traffic growth

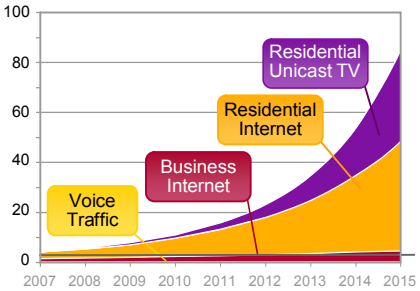
Traffic Growth

annual growth factor 2002–2008



source: http://www.dtc.umn.edu/mints/2002-2008/

Global FIXED traffic (ExaByte/month)

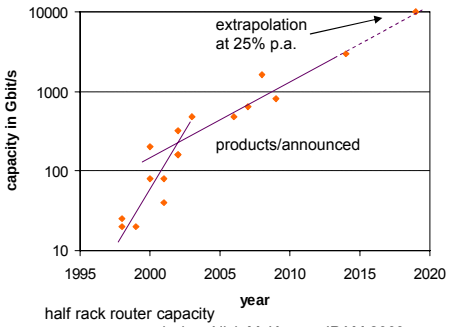


source: internal analysis

- traffic has been growing exponentially over the past years
- growth rate of 50–60% per year
- residential Internet and unicast video delivery are supporting further growth
- no reason seen why growth should suddenly stop

Current multi-hop architectures will face challenges with growing traffic

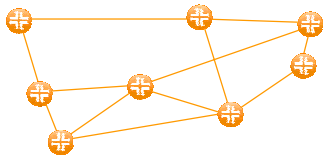
- half-rack router capacity grows by ca. 25% per year
- at constant cost per router, core network capacity will become a bottleneck
- solution approaches
  - use multi-chassis routers
    - expensive
    - high power dissipation and power dissipation density
  - change network architecture to more dense mesh
    - could save interfaces
    - need to reduce number of edge sites



half rack router capacity
source: own analysis + Nick McKeown, IPAM 2003

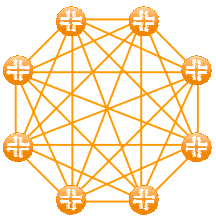
Meshed networks have higher total capacity due to lower hop count

hierarchical, loosely meshed network (example)



- average hop count = 1.75
- total traffic cost ~ 1.75 * total offered traffic

fully meshed network



- average hop count = 1
- total traffic cost ~ 1.0 * total offered traffic

Current IGP routing is sub-optimal for highly meshed networks

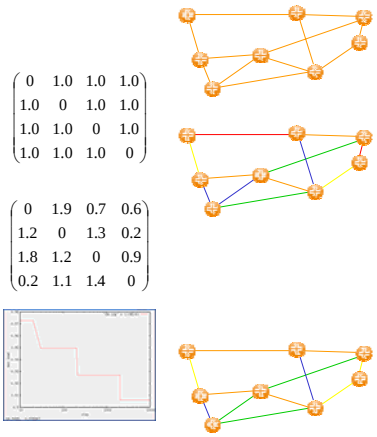
- OSPF, IS-IS have focus on finding shortest path connectivity
  - trivial in full mesh
- traffic engineering via interface metric optimization works well in loosely meshed networks
  - nearly impossible in full mesh
- need new IGPs for fully or densely meshed networks!?

A traffic engineering experiment

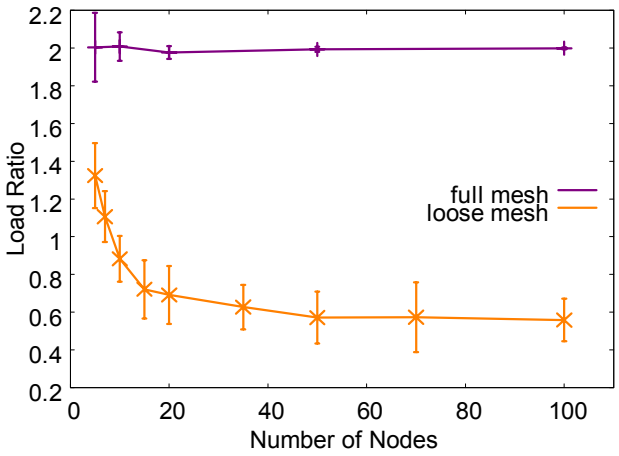
- generate random n node network
- compute load for homogeneous traffic matrix and homogeneous link metrics
- record maximum link load L1
- produce new traffic matrix
  - random, uniform distribution on [0,2]
  - same mean traffic
- optimize interface metrics
  - genetic optimization
- record maximum link load L2
- compute mean and c_v of L2/L1 for 10 networks
  - low value → network can adapt well to load changes
  - high value → network cannot adapt to load changes

$$\begin{pmatrix} 0 & 1.0 & 1.0 & 1.0 \\ 1.0 & 0 & 1.0 & 1.0 \\ 1.0 & 1.0 & 0 & 1.0 \\ 1.0 & 1.0 & 1.0 & 0 \end{pmatrix}$$

$$\begin{pmatrix} 0 & 1.9 & 0.7 & 0.6 \\ 1.2 & 0 & 1.3 & 0.2 \\ 1.8 & 1.2 & 0 & 0.9 \\ 0.2 & 1.1 & 1.4 & 0 \end{pmatrix}$$



Result of traffic engineering experiment



Conclusions

- future Internet will have to cope with massively growing traffic
- new IGP routing schemes required for future Internet
  - capacity scaling will require densely meshed routers
  - OSPF et al solve the wrong problem for densely meshed networks
- further work required
  - new mechanisms for simple and flexible load balancing on IP
    - including full mesh and hierarchical networks
    - react to short term overload while maintaining efficiency
  - investigations on heterogeneous architectures, traffic demands and dynamic loads