Peer-to-Peer networks

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‘Dark matter’ of the Internet

Potential for P2P

Computers (and other devices) at the edges of the Internet

- Cycles
- Storage
- Bandwidth

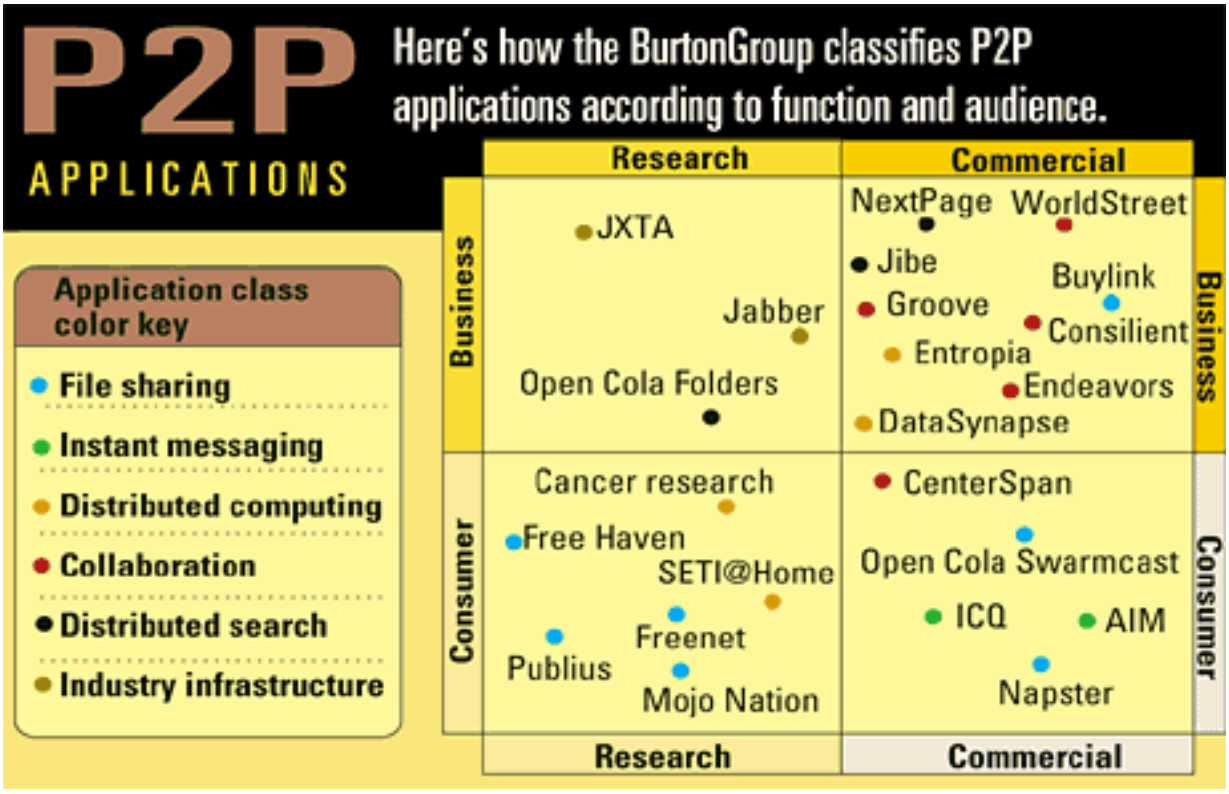
History - future ?

	'Great wiring'	'Great rewiring' ?
	Web	P2P
1980s	1994-1999	2000-
Internet	Internet	PC
PC	PC	PC PC
	(client-server)	

P2P- a new ‘killer application’? P2P traffic is already massive

- If so, it will have great effect on network architecture
- several prototypes and projects
- vendors like Intel are joining

http://www.nwfusion.com/research/2001/0730feat.html



Topology of data networks

nodes:

- routers (IP)
- autonomous systems (IP)
- computers (P2P)

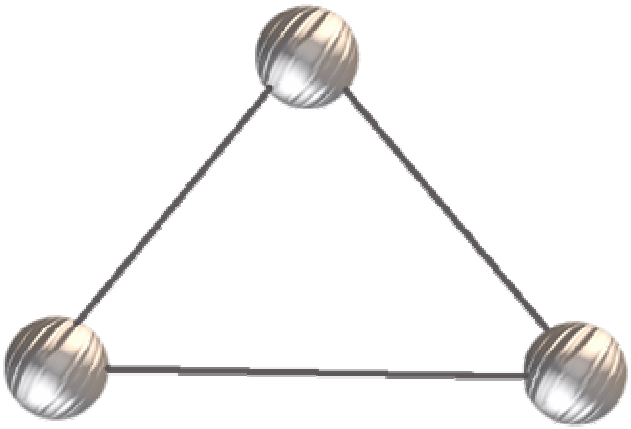
etc….

links between:

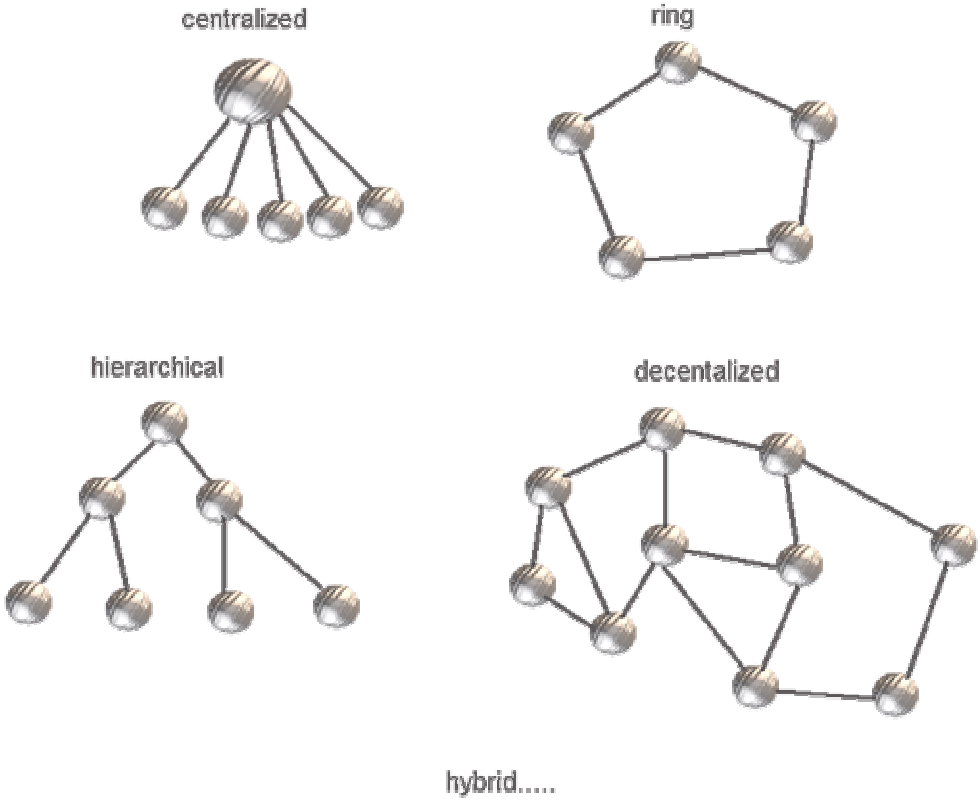
- routers one IP hop away
- peering autonomous systems
- peering computers

etc….

A graph:



Customary topologies



Some data networks are quite different from these

- IP router graph
- Internets autonomous systems (AS) graphs
- some P2P graphs

massive graphs with low hop-distances

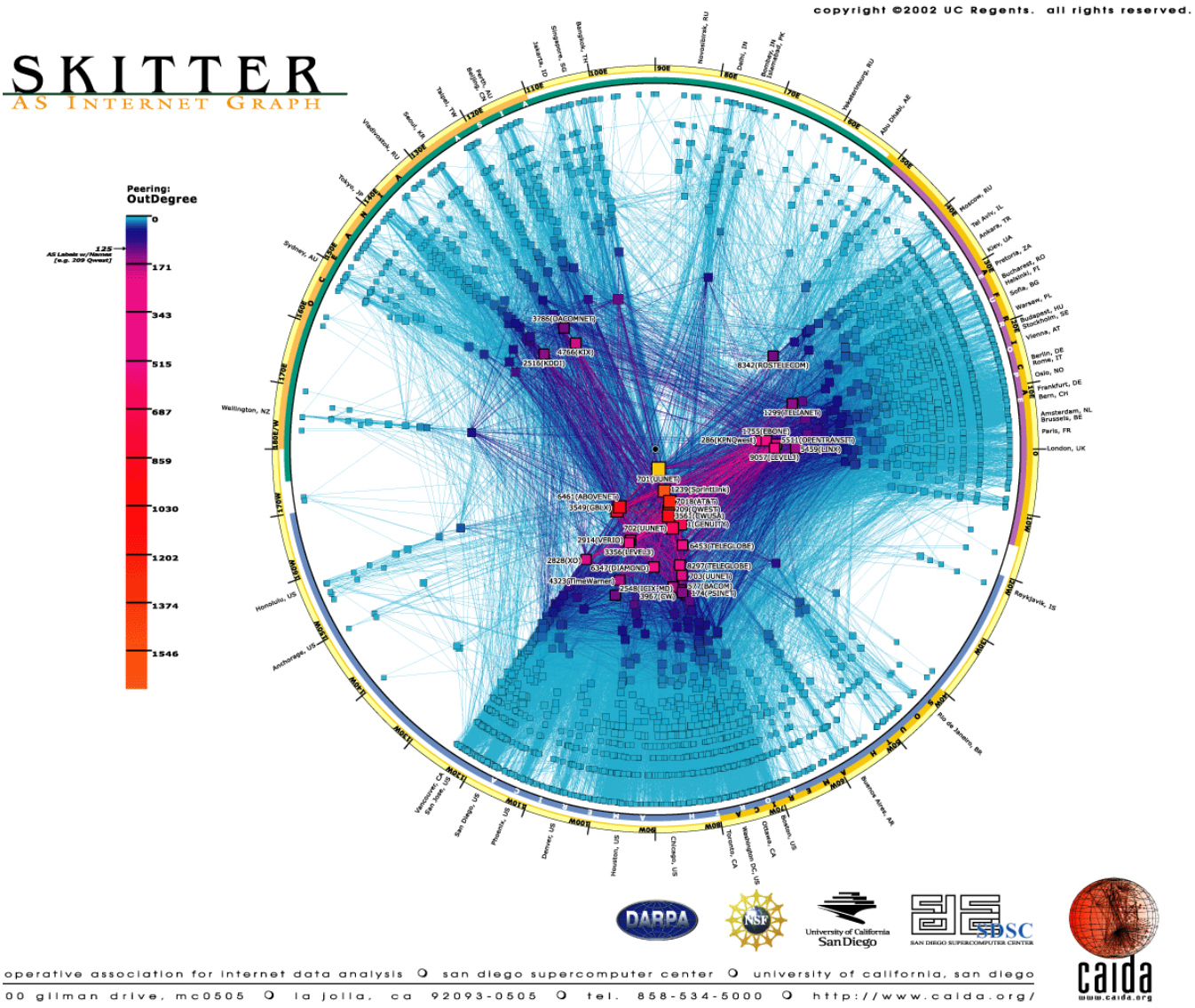
power law degree distributions

☞ nodes with very large degrees (AS graph: 10 thousand nodes, top-node degree 2000)

see AS graph:

AS-Graph (2002)

http://www.caida.org/analysis/topology/as_core_network/historical.xml



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CAIDA is a program of the University of California's San Diego Supercomputer Center (UCSD/SDSC)
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Few very large-degree nodes form a core that is crucial in connectivity

- Largest nodes well exceed

⌦ N, N-number of nodes

top degree 2000

- top nodes are located in USA
- Eu's and Asia's ASs are not peering with each others, instead with large ASs in USA

Why power laws?

http://www.shirky.com/writings/powerlaw_weblog.html

- New understanding: Barabasi, Watts, Huberman…
- Emergence of power laws in natural and social networks

Secret of succes

- Choose among big number of items (diversity)
- random choice with respect to content (freedom)
- choosing some item increases its popularity for forthcoming actions

This results in power law of ranking the items!

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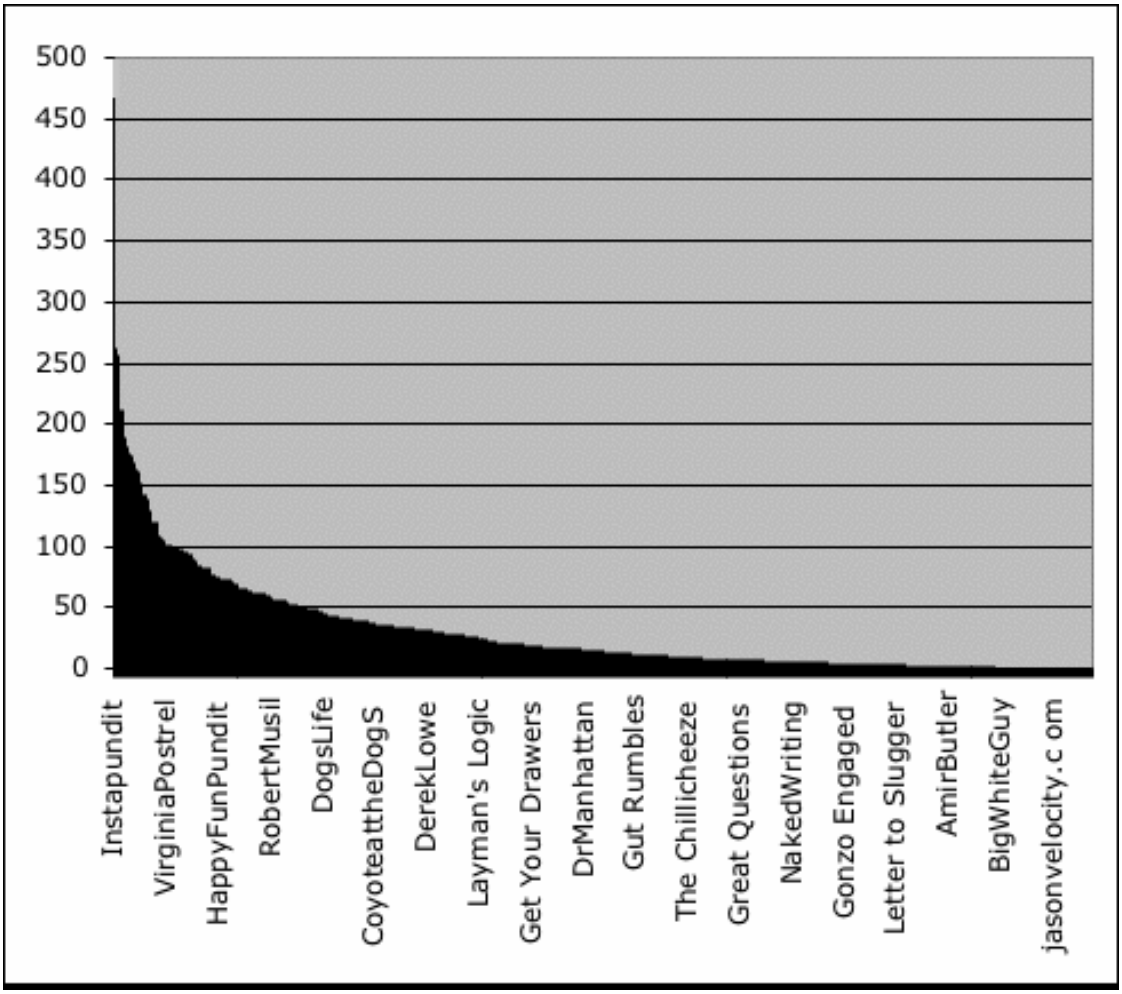


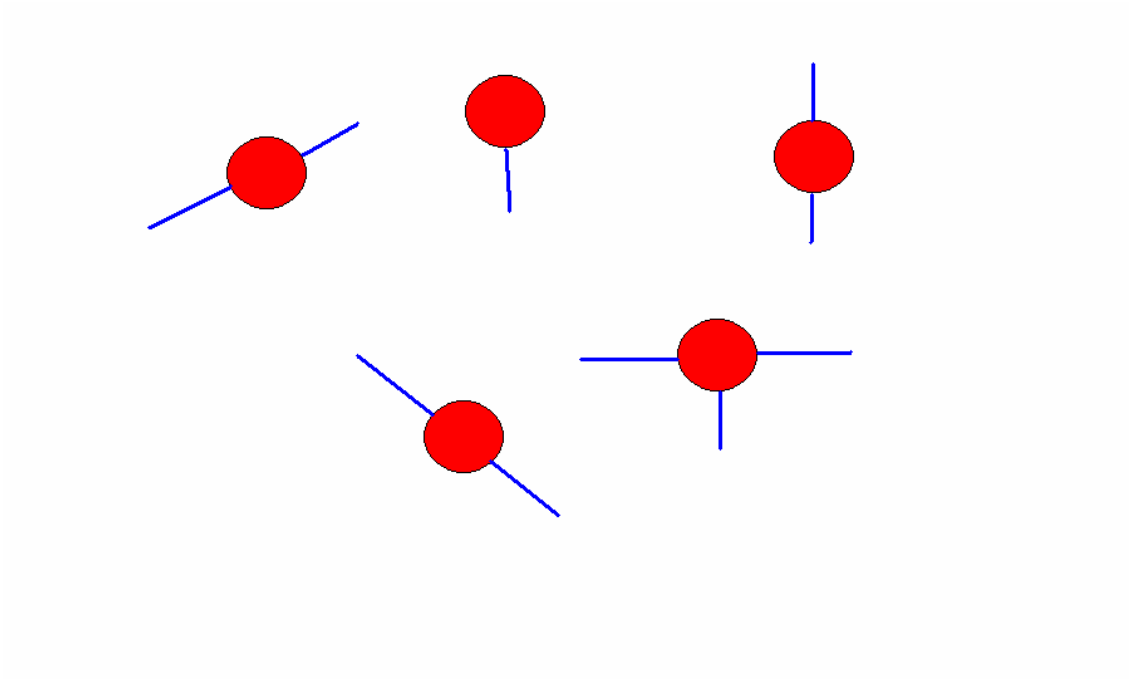
Models

- Take power law as granted
- simple rules for graph evolution that result in power law graph

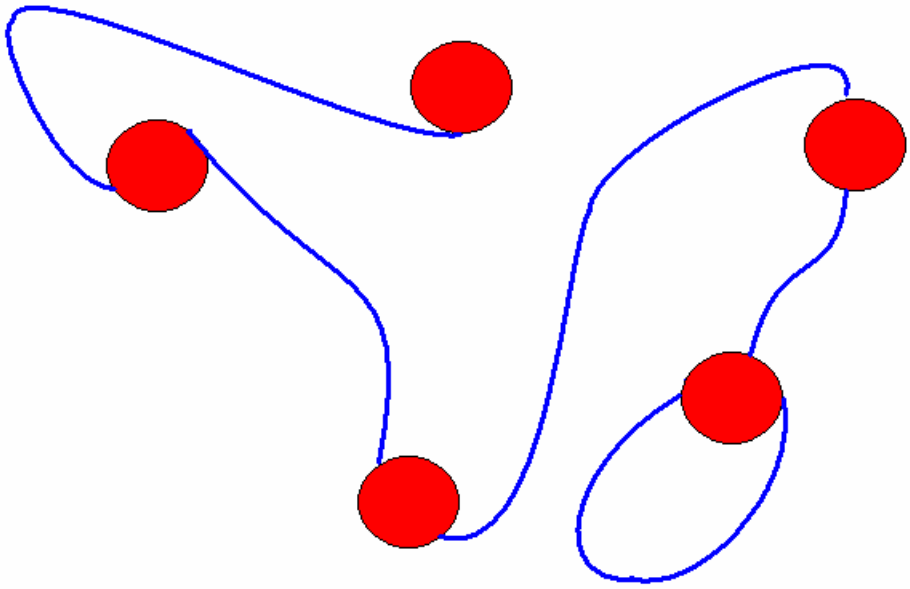
First approach:

- M. Newman, S. Strogatz, D. Watts: Random graphs with arbitrary degree distribution and their applications, *Phys. Rev. E, 64, 026118, 2001*
- F. Chung, L. Lu, The average distance in a random graph with given expected degrees, *Internet Mathematics, 2003, Vol. 1*
- H. Reittu, I. Norros, On the power law random graph model of massive data networks, *Performance Evaluation, to appear*

A random power law degree sequence



A random graph



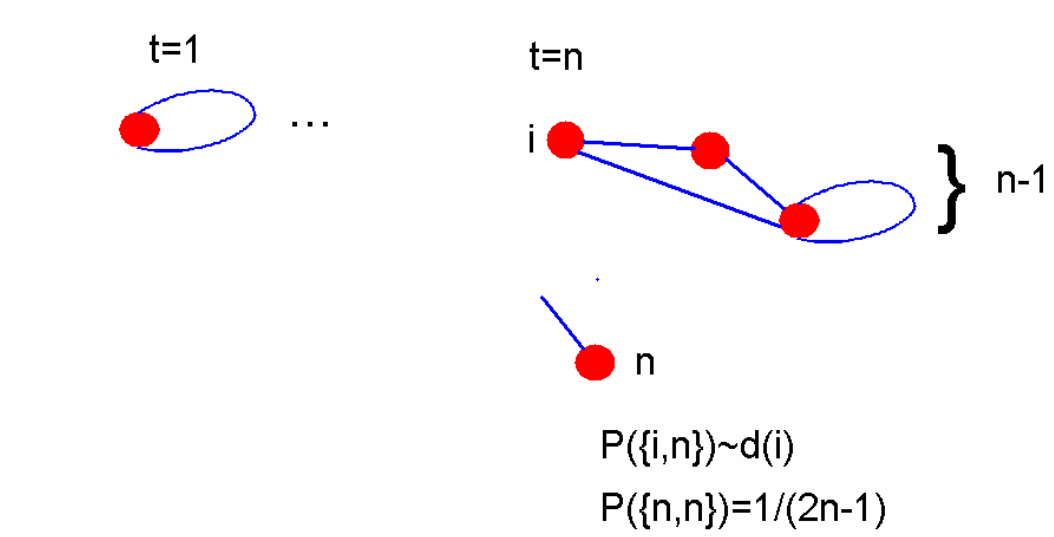
Some results so far, P(degree>d)=d$^{-\blacklozenge}$, 2<♦

- A core network self-organizes
- It consists of large nodes
- soft hierarchy
- typical distance scales as *log log(N)*
- a typical node is outside the core ->
- robustness to random failures of nodes
- like ‘living network’ not like techno-network

The second approach, a graph process

- R. Albert, A. Barabasi, Emergence of scaling in random networks, *Science, **286**, 509-512,1999*
- B.Bollobas, O. Riordan, The diameter of scale-free random graph, to appear

A popularity based random graph process, G(1), G(2),…,G(n),...



For a massive graph degree distribution is with ♦=3

- Can be modified to produce any power law degree distribution 📄 ⭘ ♦
- S.Dorogotsev, J.Mendes, A. Samukhin, Phys. Rev. Lett., 85 (21) 4633-4636 (2000)
- P. Buckley, D. Osthus, to appear
- change P({i,n})~d(i) with d(i)-1+a, where 0 ⭘ a is a ‘popularity parameter’
- then ♦ =2+a, a=1, Barabasi et. al result

P2P network

- Topology matters
- local algorithms -> ‘good topology’
- ????