overload breakdown in evolving networks

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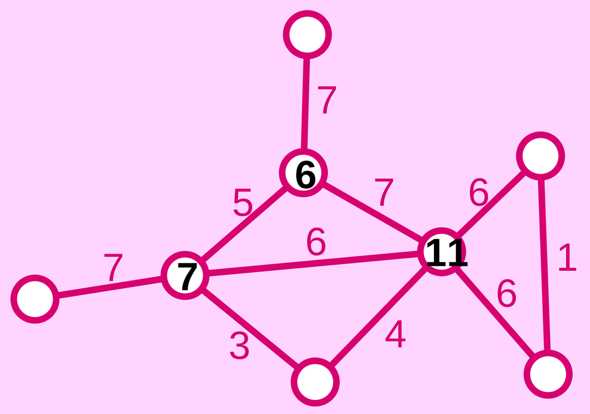
motivation

- Avalanching breakdowns do occur in (communication power distribution etc.) networks.
- Little work has been done on overload avalanches and cascading failures.
- The redistribution and increase of load in a growing network might trigger overload avalanches.

the load

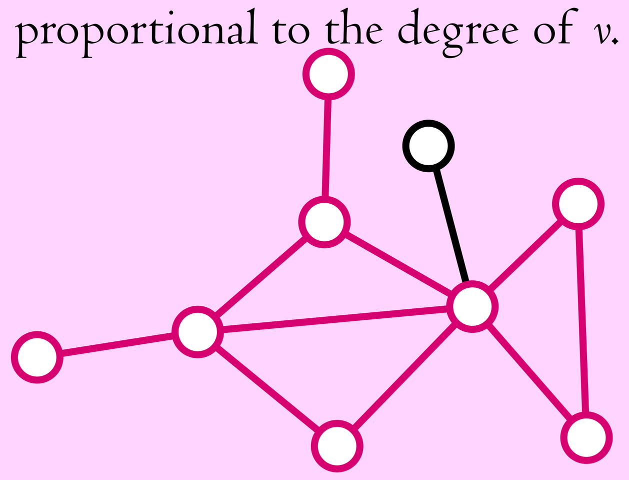
We use betweenness centrality C_B as principle load measure for both vertices and edges. C_B is count of the geodesics passing a specific vertex or edge:



the growth

The network is grown according to the Barabási-Albert model:

1. Initial condition: Start with m_0 vertices.
2. Growth: Add one vertex and m edges at each iteration.
3. Preferential attachment: The probability of a new vertex to attach to a specific vertex v is proportional to the degree of v.



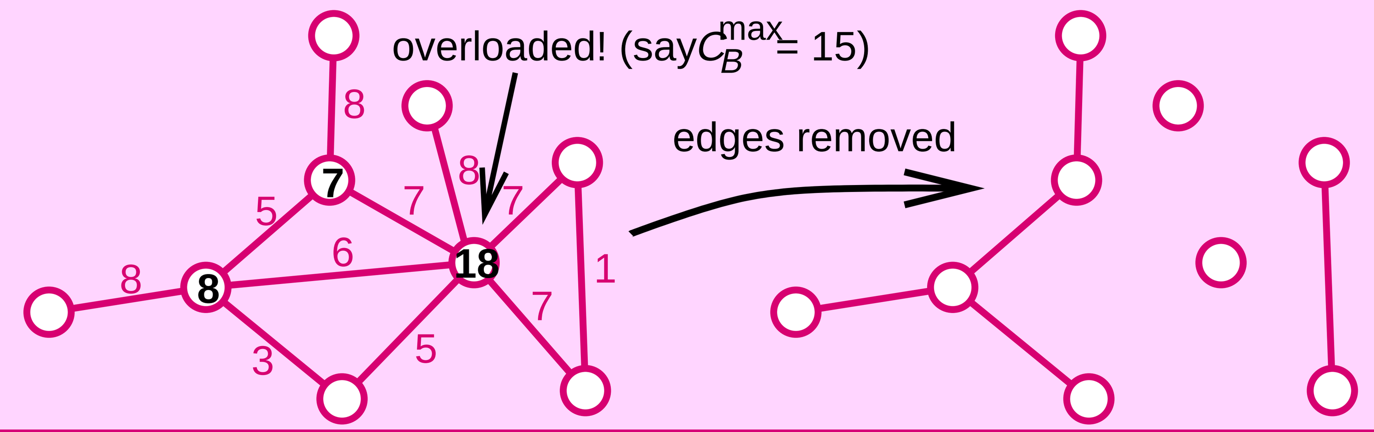
the breakdowns

vertices:

If the betweenness of one vertex exceeds a fixed C_B^{max} all adjacent edges are removed and the betweenness recalculated.

edges:

If the betweenness of one edge exceeds a fixed C_B^{max} that edge is removed and the betweenness recalculated.



different load cases

We distinguish between different load cases:

1. Extrinsic source activity (ECA) corresponding to that the average number of connections per vertex is increasing with the network's size.
2. Intrinsic source activity (ICA) corresponding to a constant average number of connections per vertex.

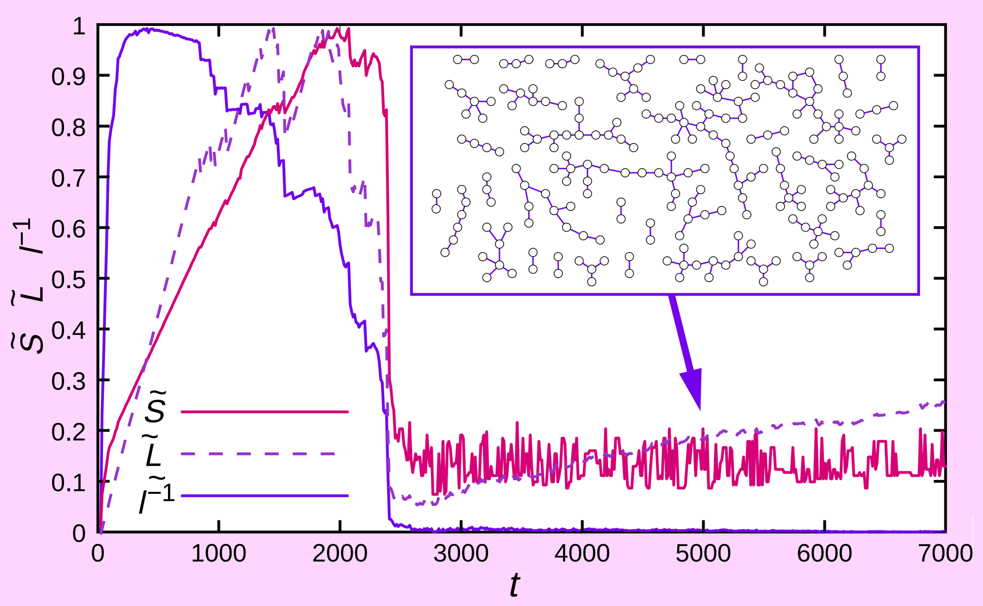
Real communication networks can be supposed to lie between the ECA and ICA extremes.

time evolution:

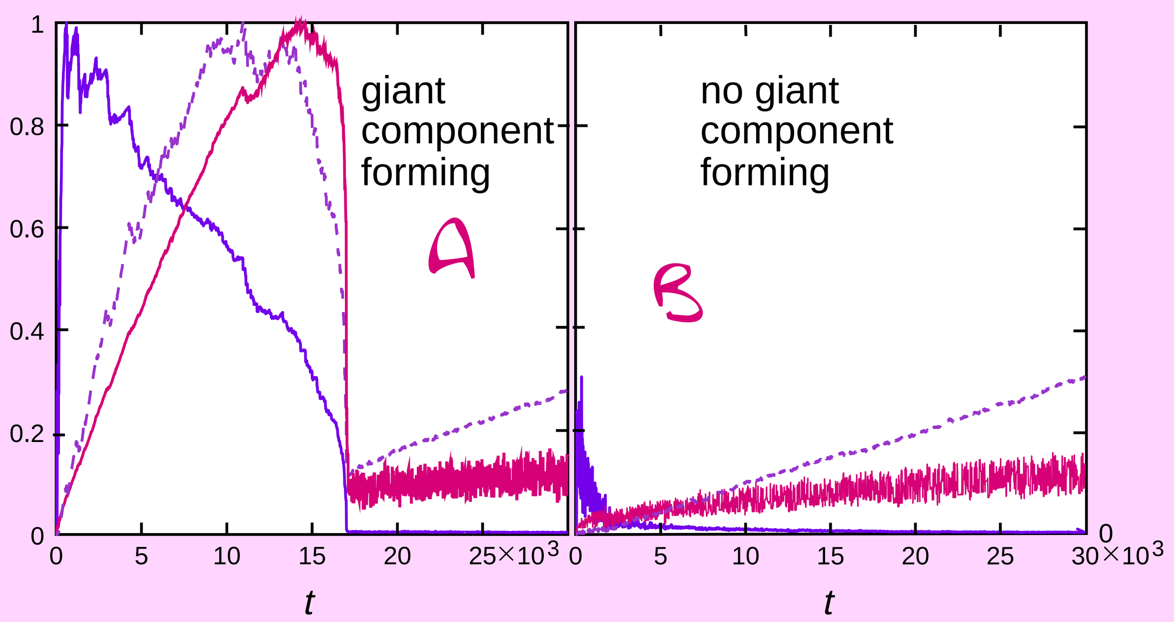
Here we measure (for one run):

- The size of the largest cluster S.
- The average inverse geodesic length l^{-1}
- The number of edges L.

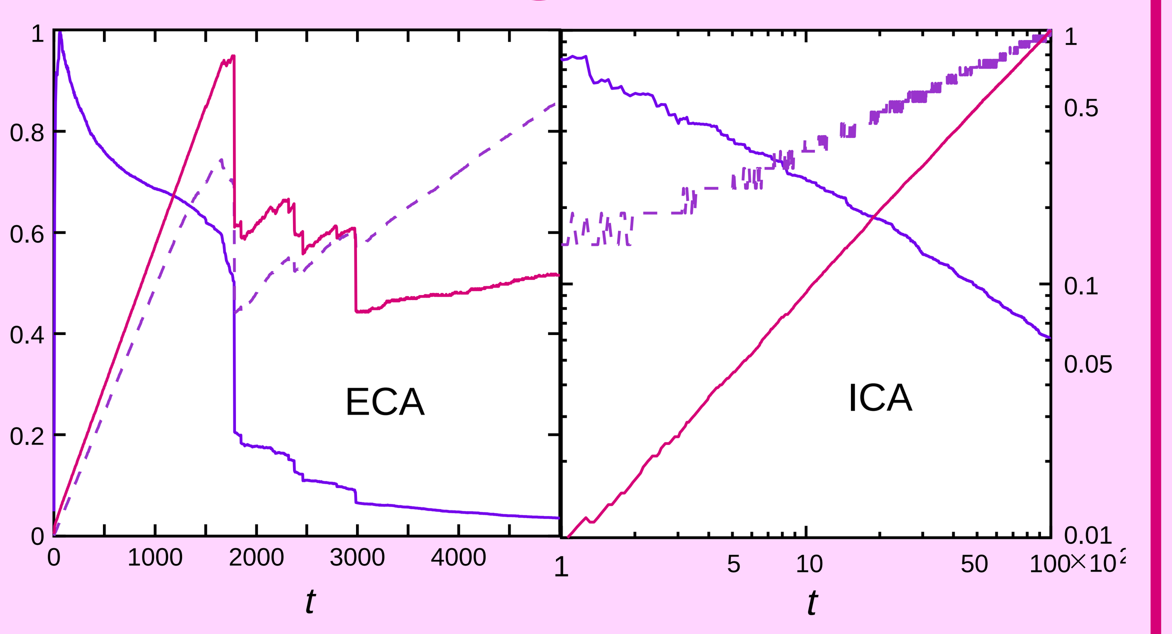
vertices (ECA)



vertices (ICA)

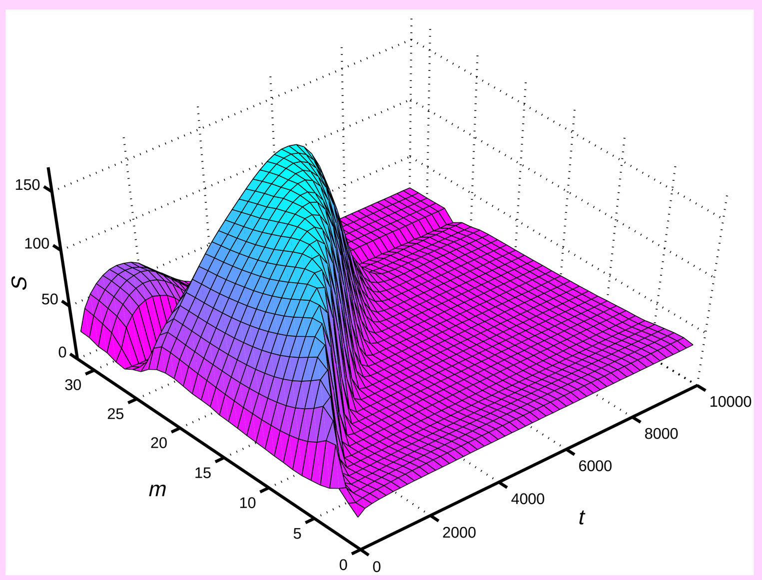


edges

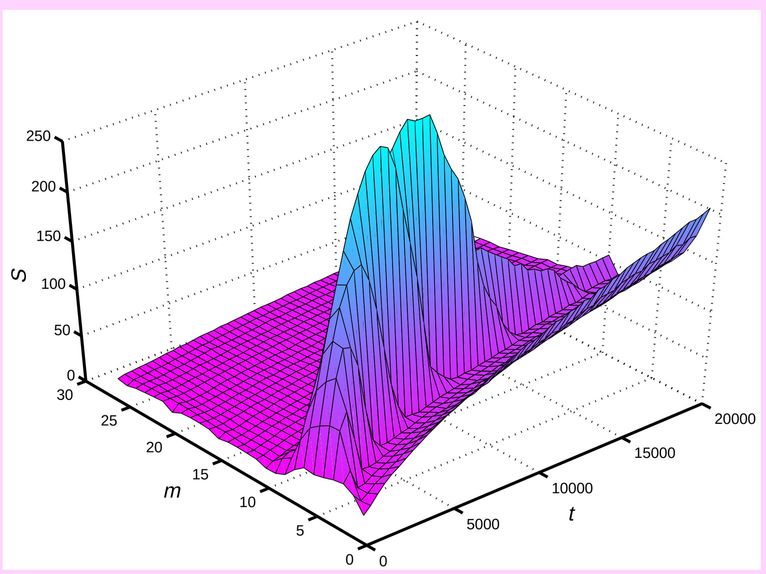


m scaling of S:

vertices (ECA)

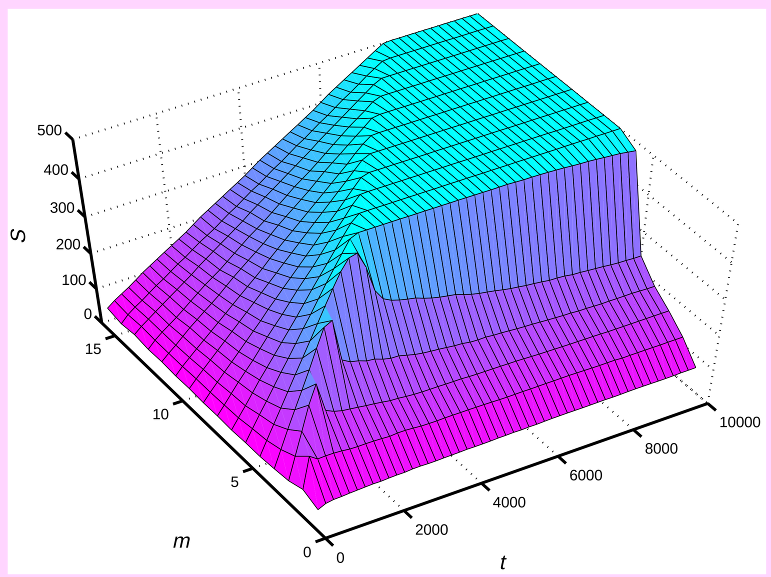


vertices (ICA)



These graphs are averaged over 50 runs.

edges (ECA)

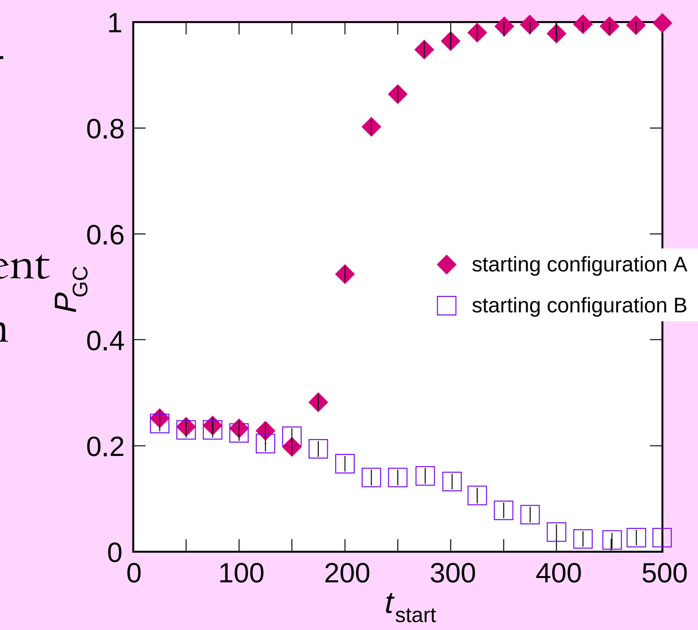


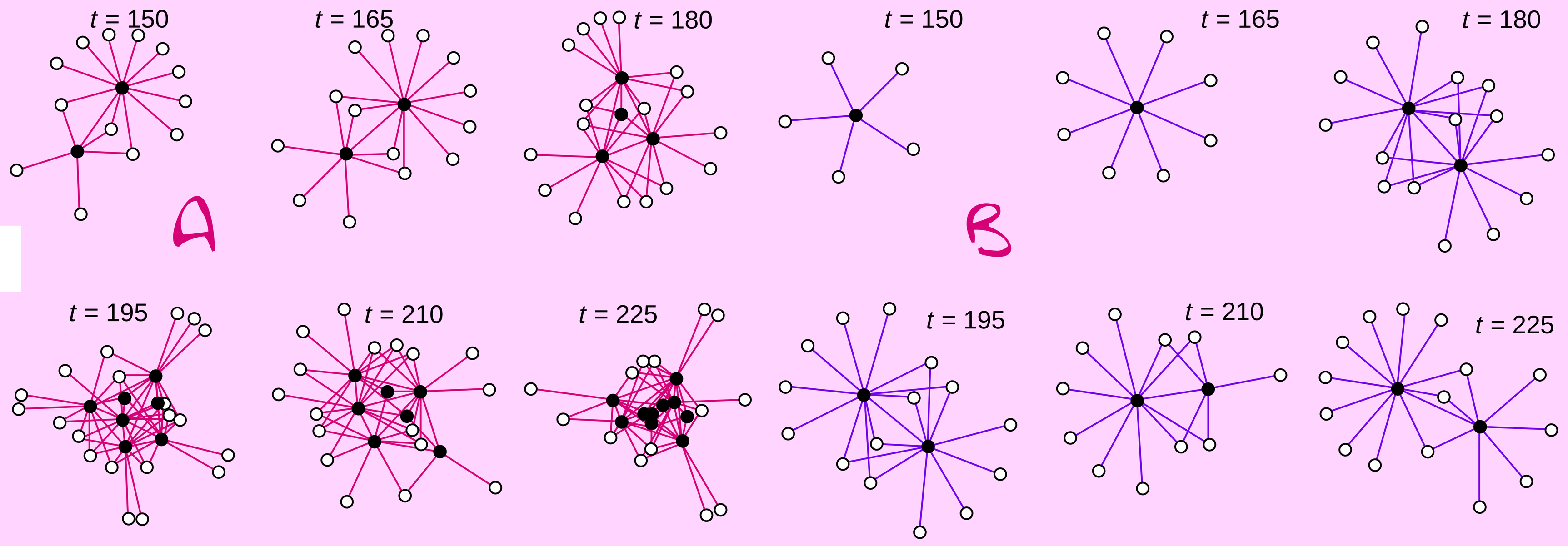
irregular dynamics:

In the ICA load case for vertices (for some parameter values): A giant component forms only a fraction of the runs.

Here we test the probability for a giant component to form, starting at time t with the network as in run A (where a g.c. forms) and run B (where no g.c. forms).

(Black vertices has nonzero betweenness.)



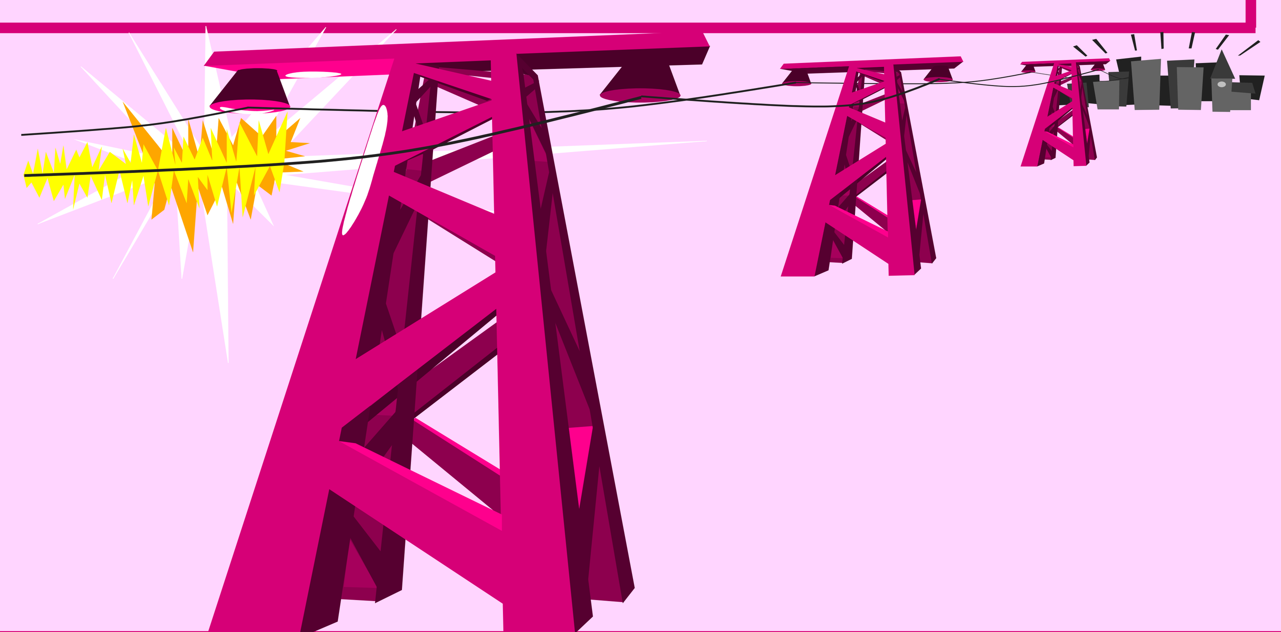


conclusions:

- Avalanching breakdowns occurs for both vertices and edges in the ECA load case.
- In the ICA load case vertex (but not edge) breakdown avalanches can occur.
- For Internet this suggests (if C_B is a relevant load measure) that the server capacity has to grow with the size of the network (even in the ICA scenario).
- For vertices, the networks are most robust at intermediate m.
- Interesting dynamics of giant component formation in the ICA case for vertices.

the future:

- More realistic static load measures (taking load balancing into account).
- Load from dynamical simulations of network flow.
- Analytical studies (tough since the network structure changes during a breakdown avalanche).



based on:

Petter Holme and Beom Jun Kim *Vertex overload breakdown in evolving networks*, to be published in Phys. Rev E., e-print cond-mat/0204120.

Petter Holme *Edge overload breakdown in evolving networks*, submitted to Phys. Rev. E.

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