Integrating traffic, geographic and economic aspects in Internet modeling

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Autonomous Systems

- Internet is divided into different subnetworks—Autonomous Systems (AS)
- An IP network (or collection of IP networks) with the same routing policy.
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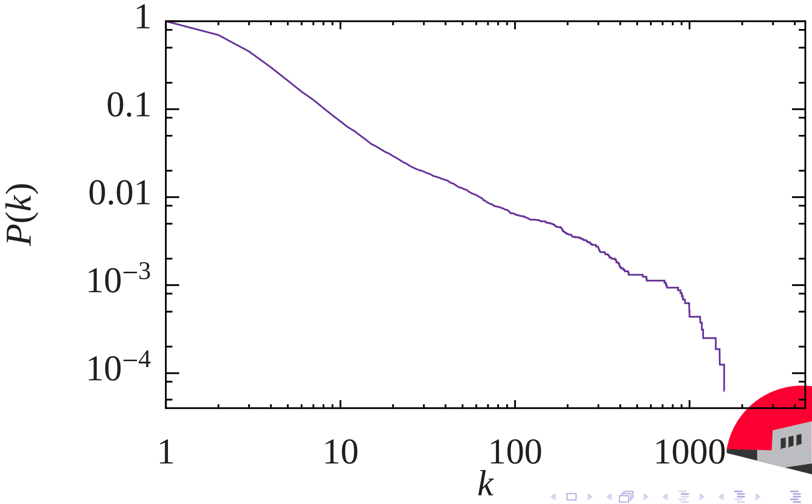
Degree distribution

Broad degree-distribution (possibly power-law, or log-normal).



Models

- Typically focus on network topology.
- . . . possibly with a geometry.
- . . . or traffic.
- No geograficaly explicit ASes.

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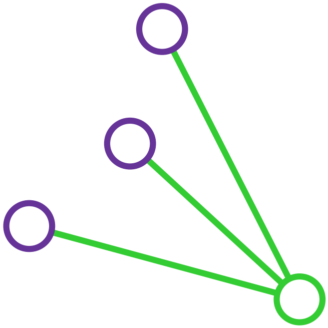

probability of attachment: $\propto k_i$

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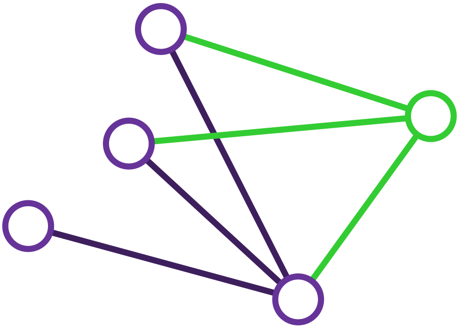

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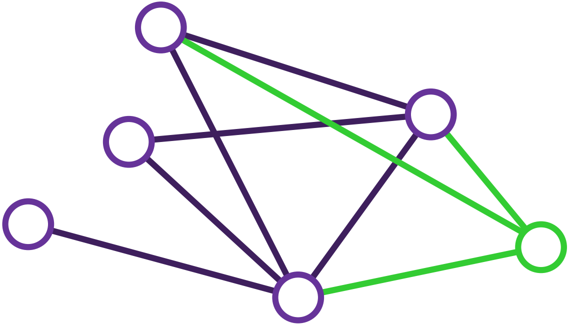

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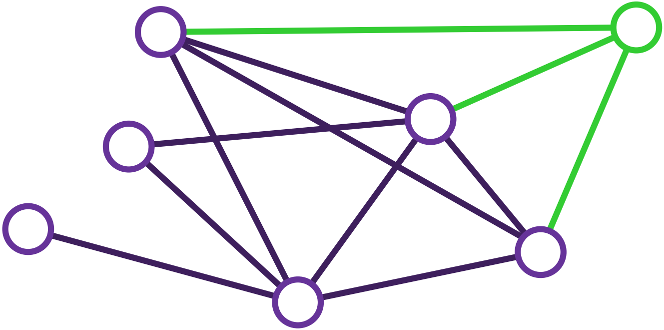

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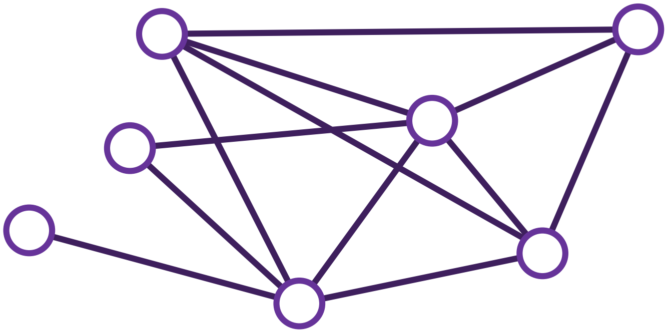

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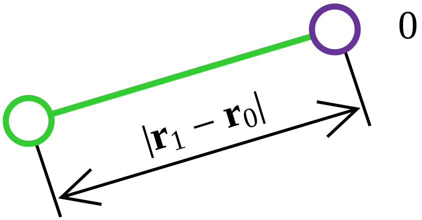
FKP model

attach i to vertex j minimizing:

$$|\mathbf{r}_i - \mathbf{r}_j| + \alpha d(j, 0)$$

FKP model



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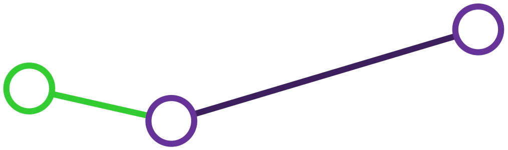

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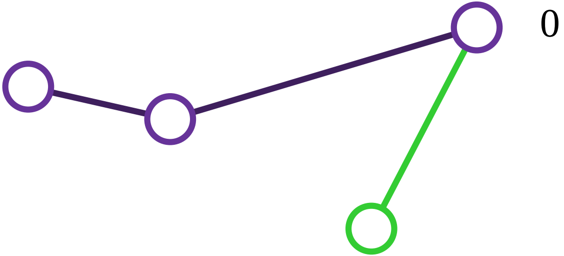

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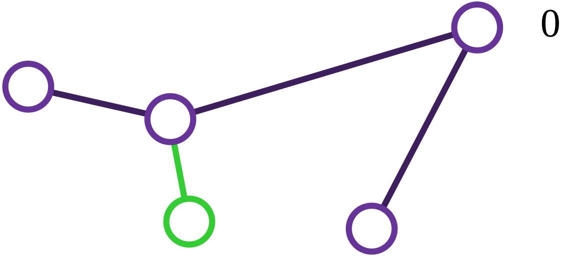

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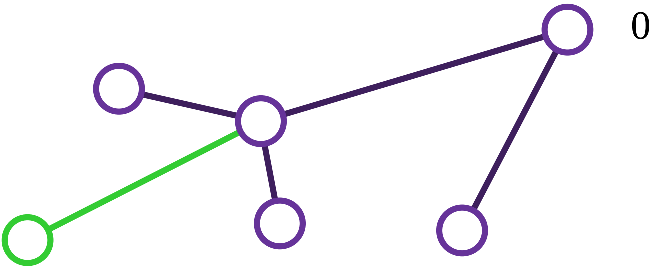

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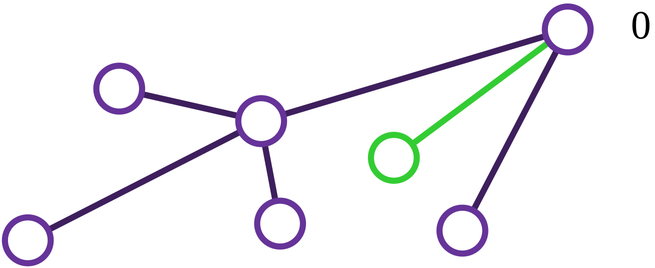

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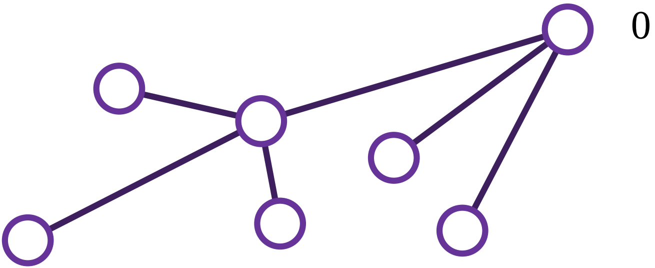

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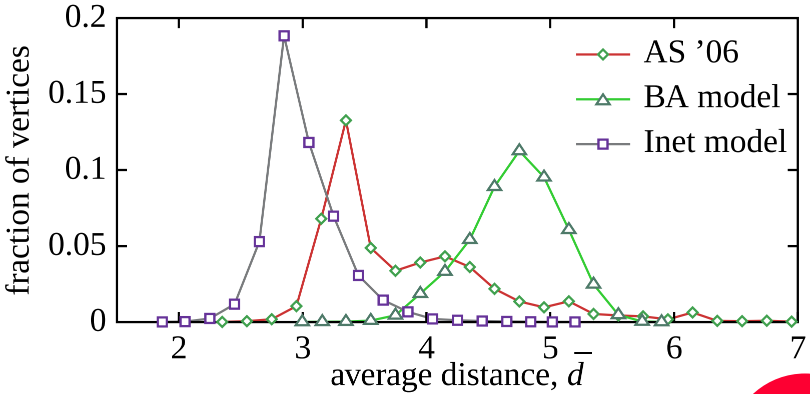
Radial structure

Plot quantities as function of the average distance to the rest of the AS graph.

P. Holme, J. Karlin and S. Forrest, Proc. R. Soc. A **463**, 1231–1246 (2007).

Radial structure



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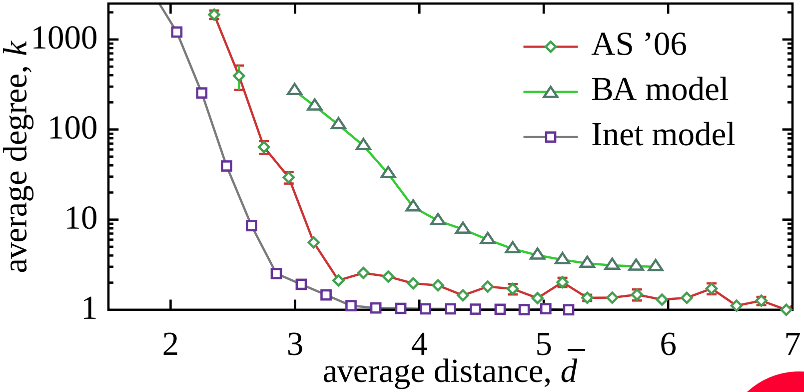

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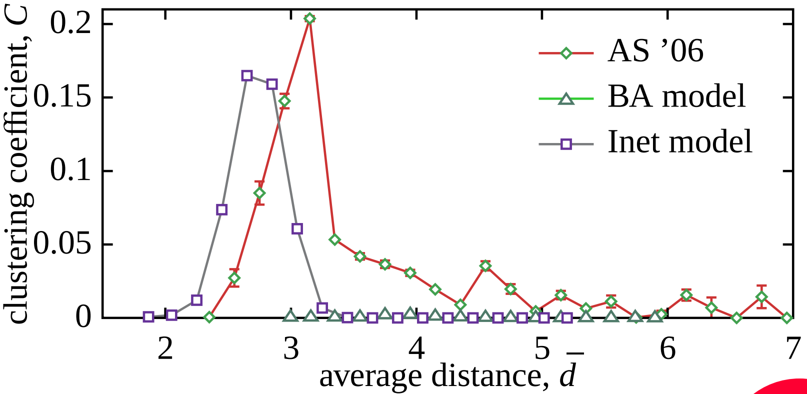

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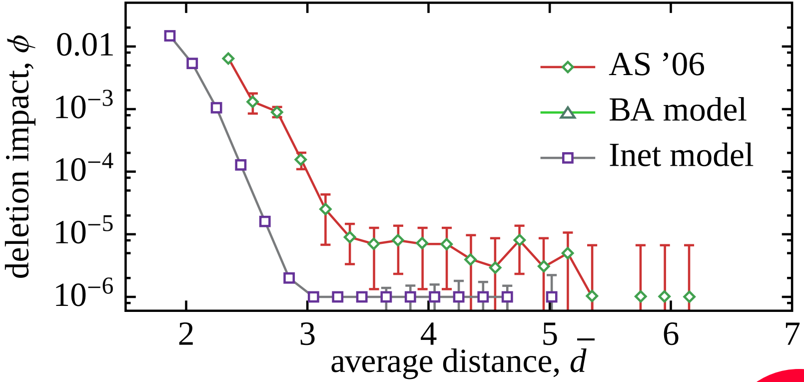

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that the AS can invest in geographical growth

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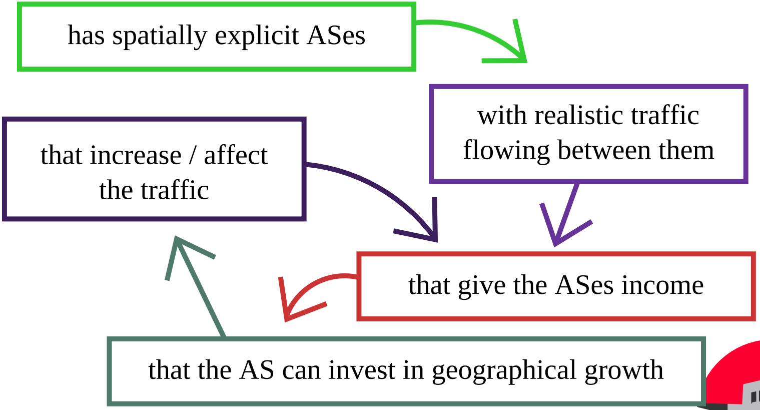

Overall structure

The model begins with one agent located at the pixel with the highest population density. The model then iterates over the following steps:

1. *Network growth.* The number of agents is increased. The agents are expanded geometrically, and their capacities are adjusted.
2. *Network traffic.* Messages are created, migrated toward their targets, and delivered. This process is repeated N_{traffic} times before the next network-growth step.

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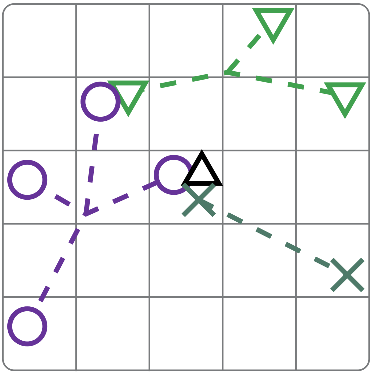
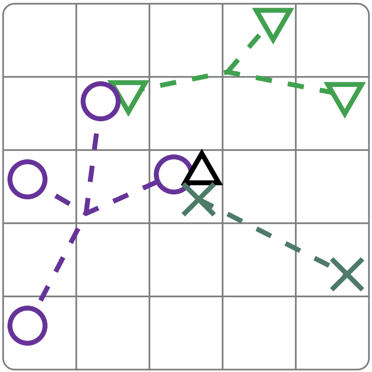


geography represented as sq. grid

Network Growth



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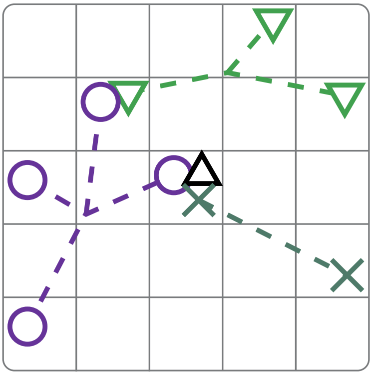

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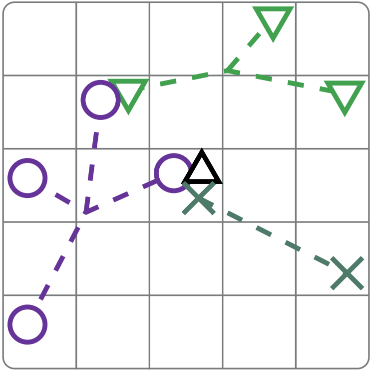

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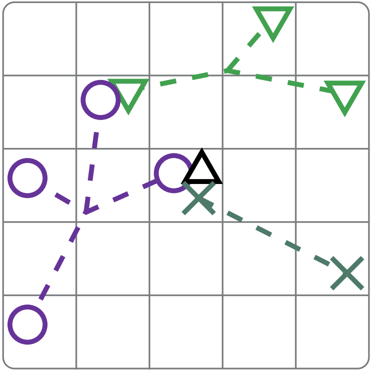

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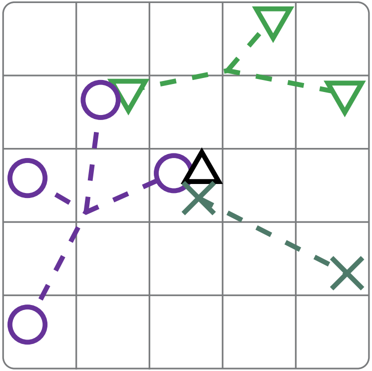

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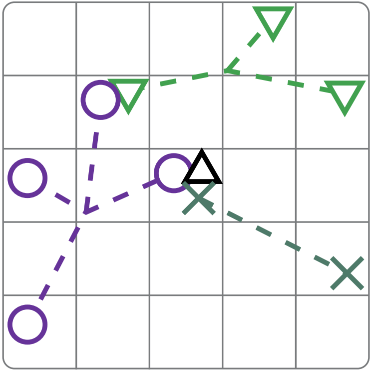

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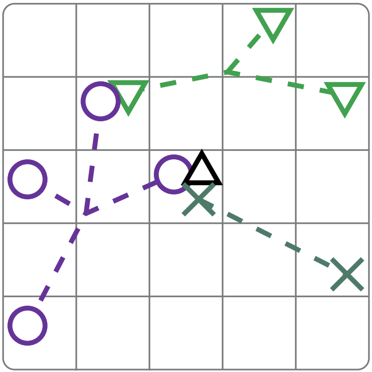

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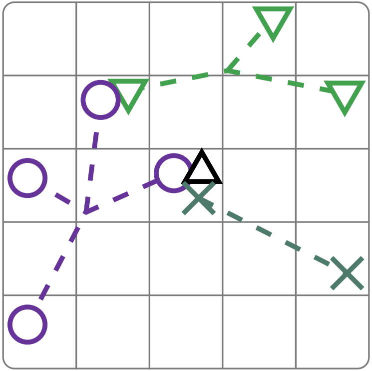

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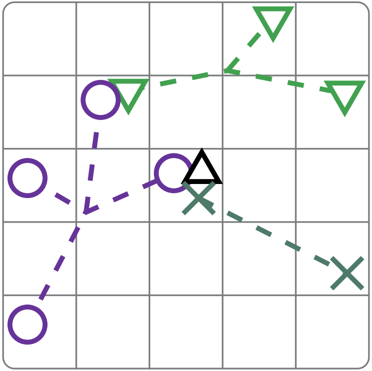
costs for: increasing capacity
connecting to other, adding loc.

Network Growth



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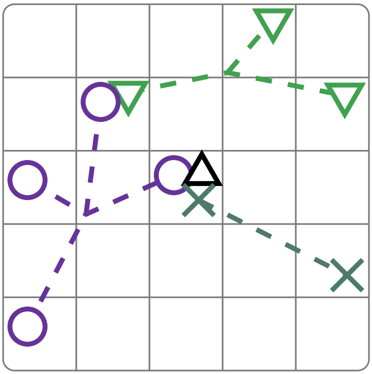
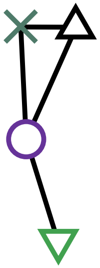
income prop. to traffic

Network Growth





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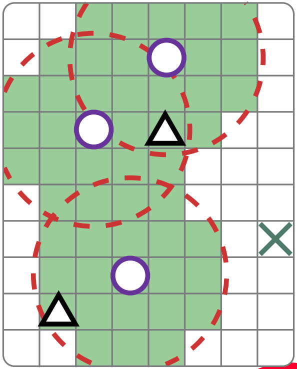

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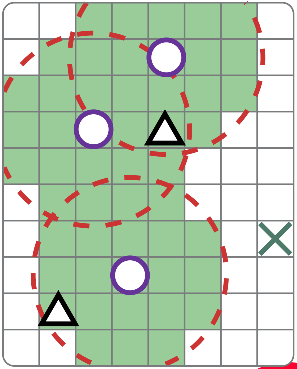

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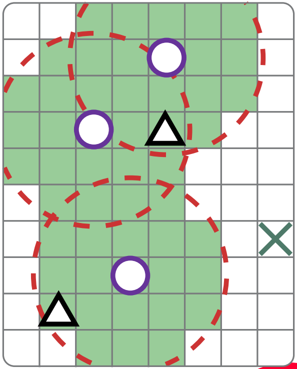
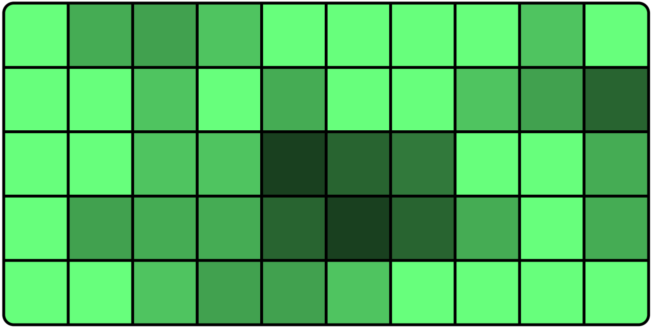
   ASes spend their budget on new loc

   choose affordable pixel w highest pop



Traffic dynamics



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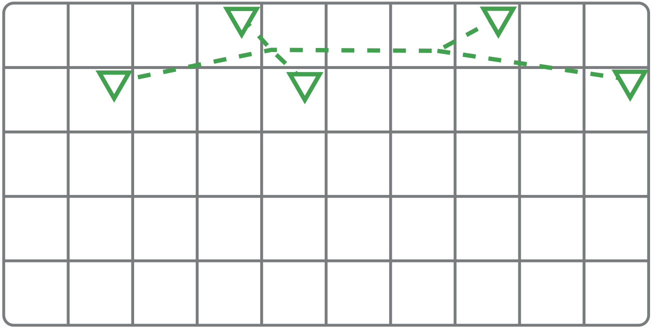

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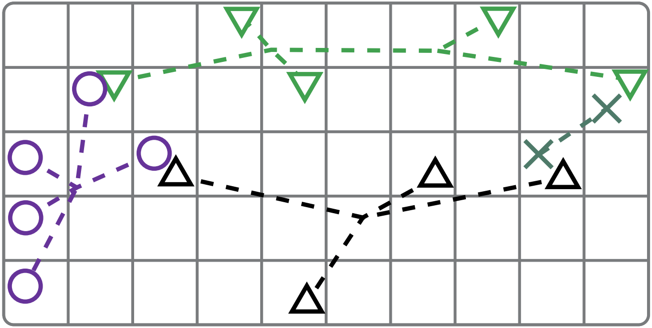

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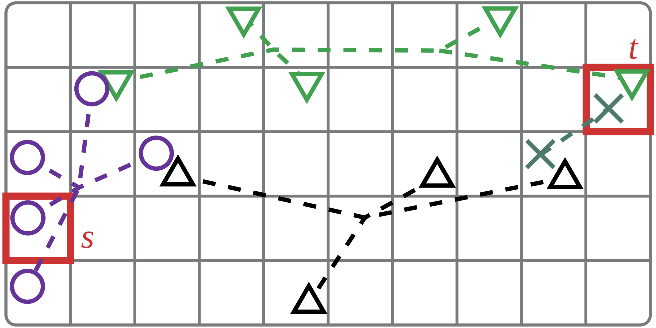

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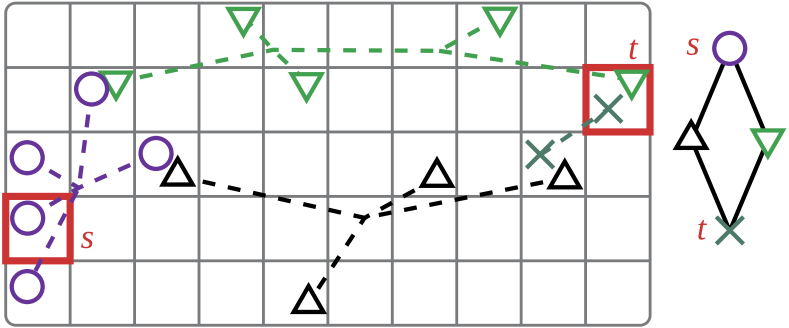

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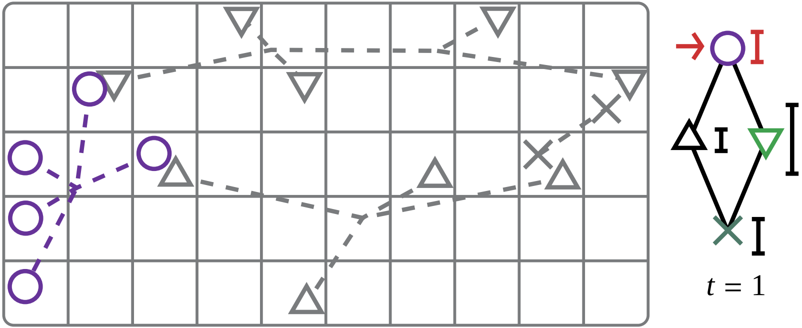

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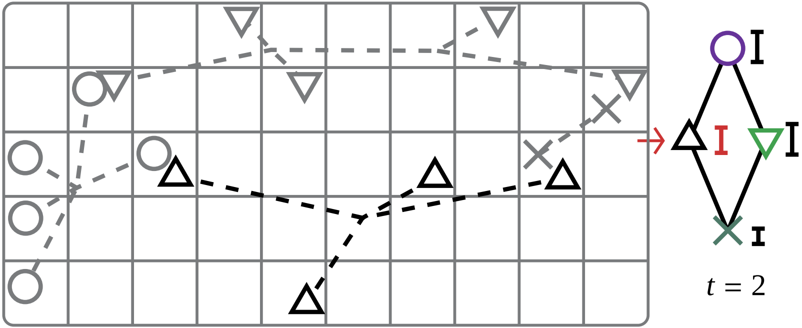

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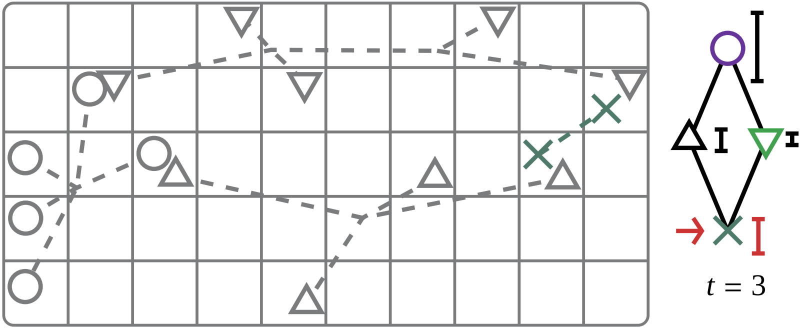
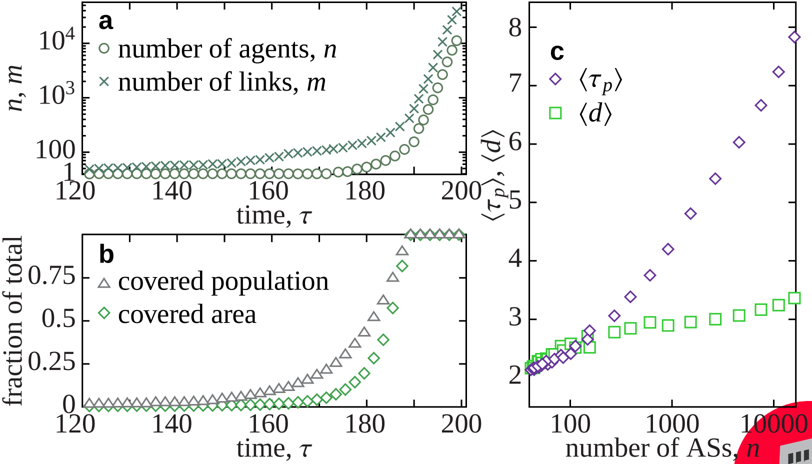
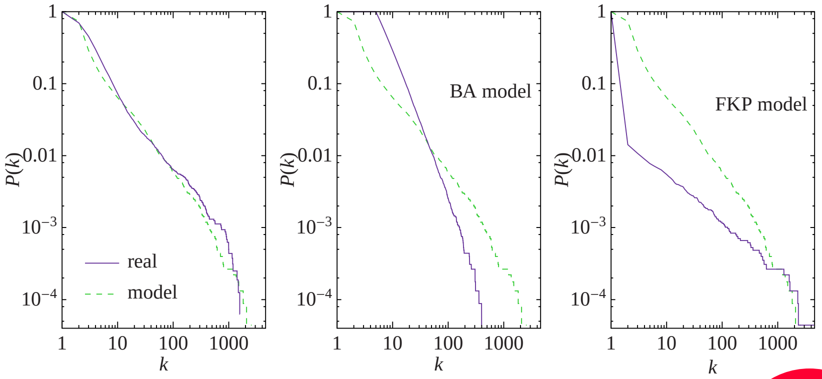


Time evolution



Degree distribution



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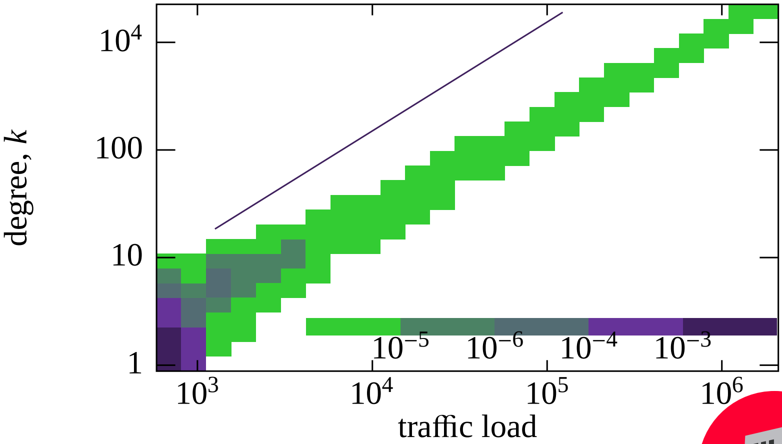
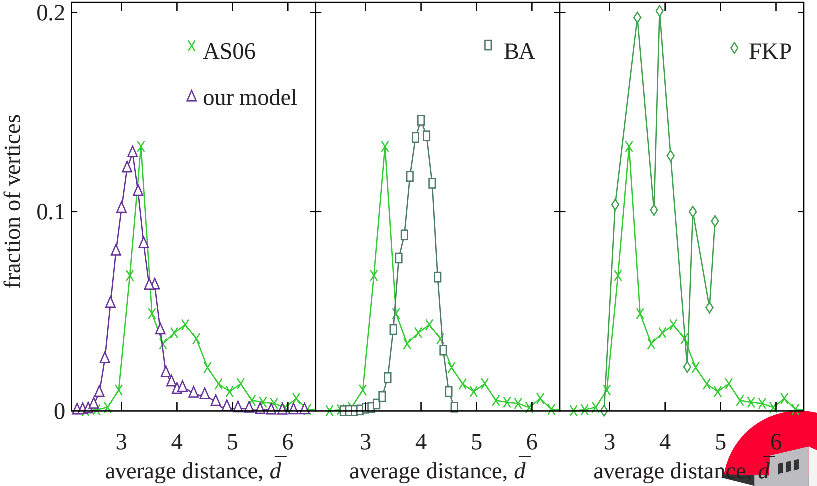


Radial statistics



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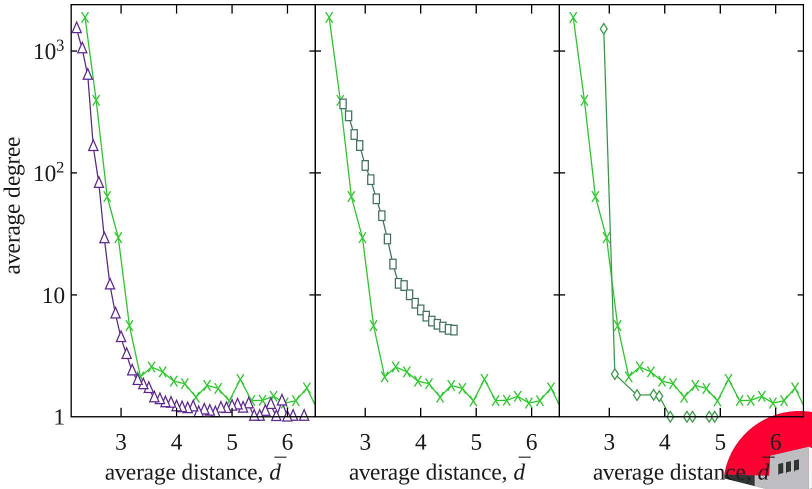
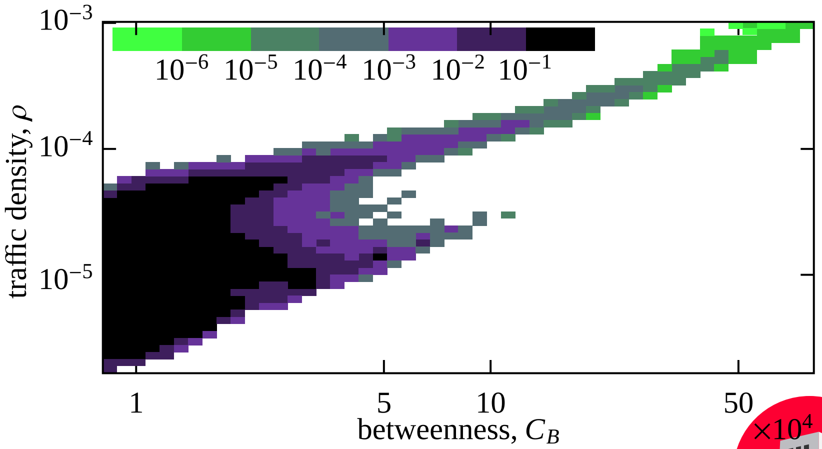
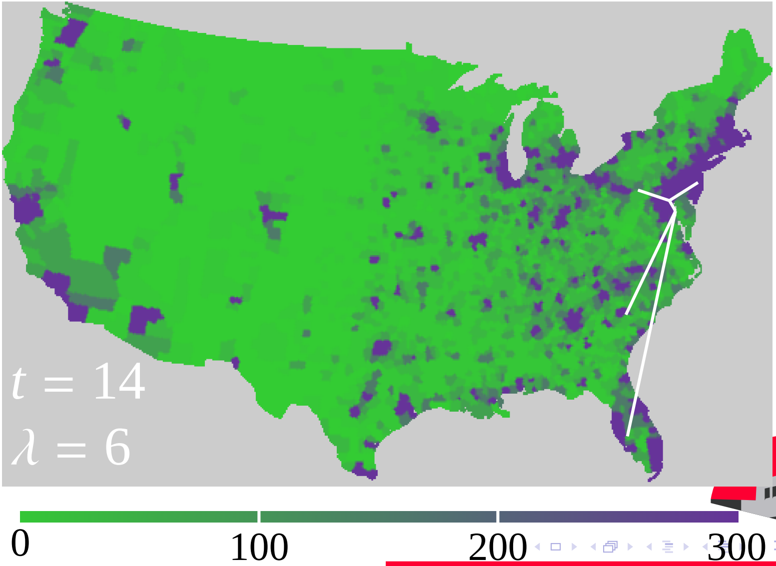


Traffic vs centrality



Geography



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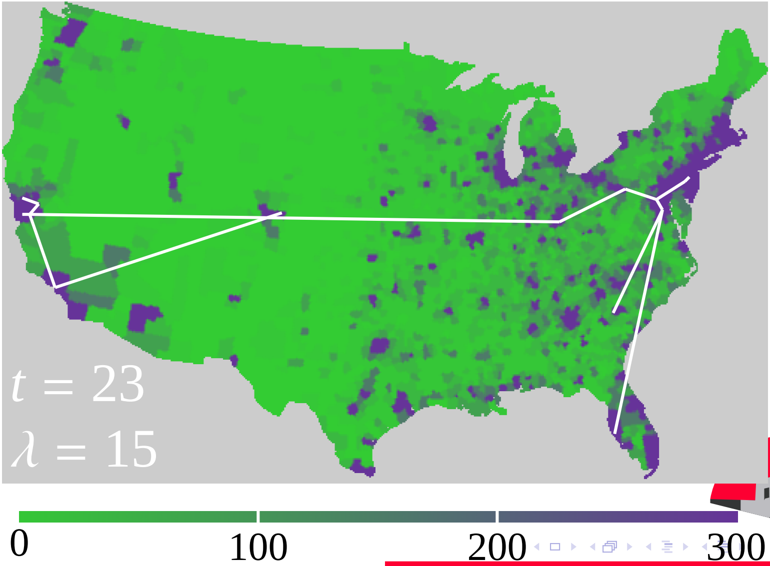

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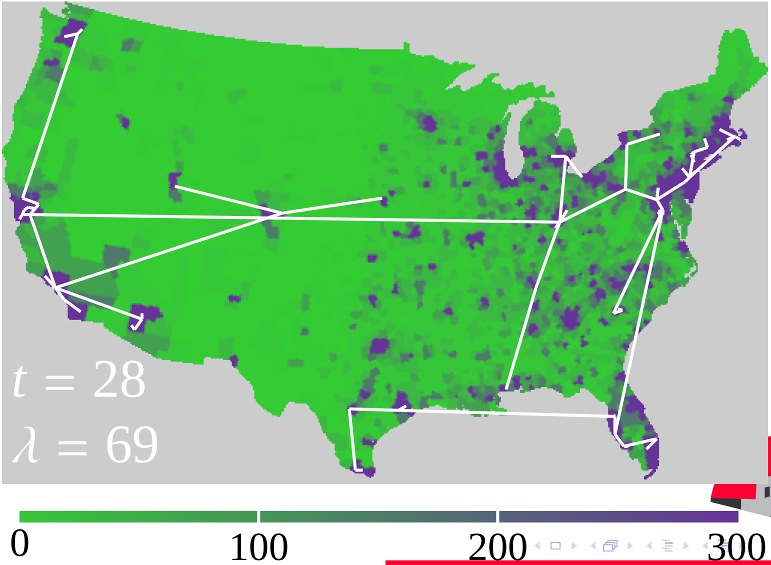

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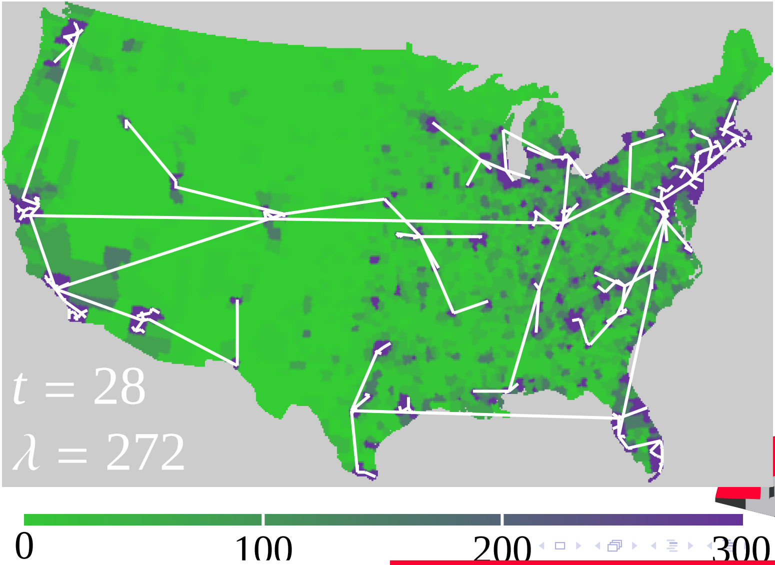
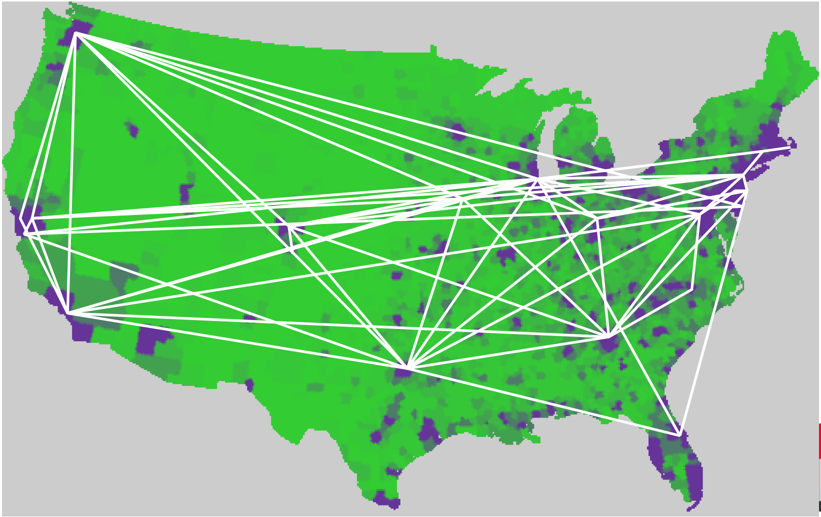
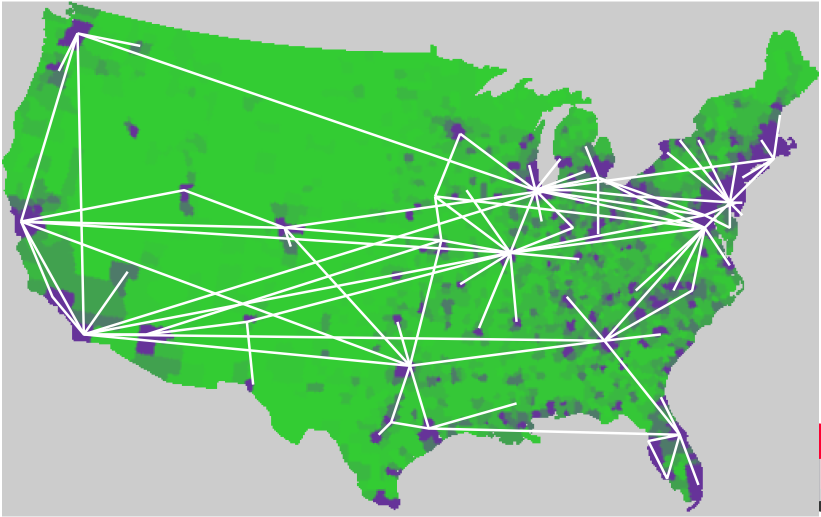


Geography



Geography



Summary

- Mechanistic growth model of AS-level Internet
- Degree distribution matches
- Periphery not as complex as reality
- Traffic fluctuations affect low- and medium-sized ASes
- Spatial distribution not completely crazy

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