# Extracting information from observed cascading data

Ian Dobson

IOWA STATE UNIVERSITY

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Cascading = initiating outages + propagating outages

Main questions for observed real cascades:

- How much do cascades propagate?
- How do cascades spread on the network?

Cascading failure is a complicated sequence of dependent outages of individual components that successively weakens the power system. The larger cascades cause blackouts.

# TADS data; how to extract cascades

- TADS = Transmission Availability Data System
  Standard outage data that is reported to NERC.
  Similar data is collected internationally.
- Data includes outage start time and which line outaged.
  For this talk we look at automatic (forced) outages
- Group outages into cascades according to
  **gaps** between starting times:
  new cascade when gap > 1 hour
- Group cascade outages into initial outages and generations of propagating outages:
  new generation when gap > 1 minute

# example of extracting cascades and generations

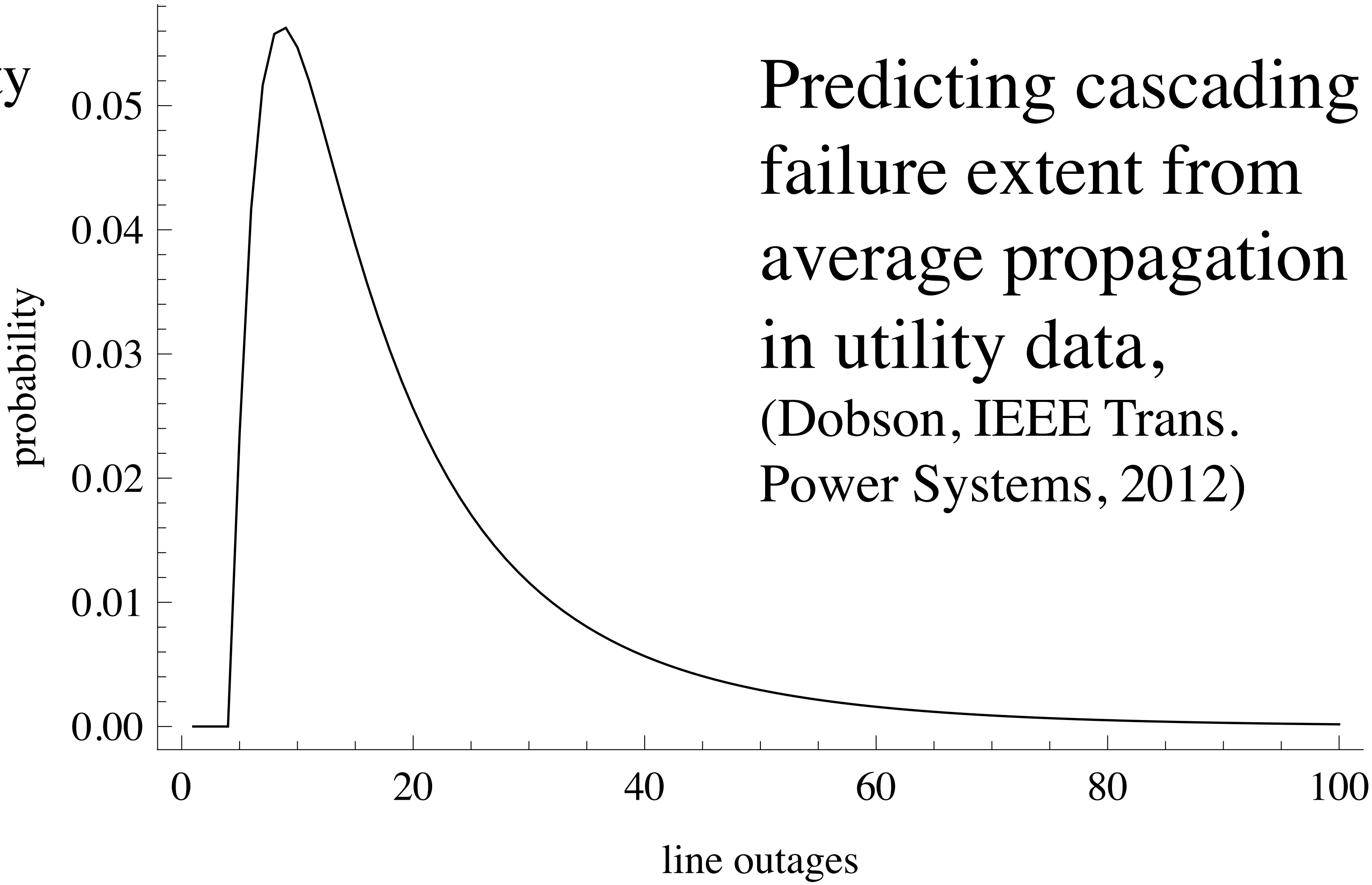
| transmission line | outage start time hour:minute | cascade | generation |
| --- | --- | --- | --- |
| LASSUS — PALESTRINA | 9:15 | 1 | 1 |
| | | - - - | |
| HOFHAIMER — ISAAC | 11:22 | 2 | 1 |
| LASSUS — VANEYCK | 11:22 | 2 | 1 |
| | | - - - | |
| JOSQUIN — ISAAC | 15:22 | 3 | 1 |
| GIBBONS — DOWLAND | 15:25 | 3 | 2 |
| ISAAC — OCKEGHEM | 15:27 | 3 | 3 |
| DOWLAND — BYRD | 15:37 | 3 | 4 |
| ANON — BYRD | 15:37 | 3 | 4 |
| OCKEGHEM — DUFAY No 1 | 15:49 | 3 | 5 |
| TYE — TALLIS | 15:57 | 3 | 6 |
| | | - - - | |
| LASSUS — PALESTRINA | 18:23 | 4 | 1 |

# Quantifying propagation from TADS data

- Cascade outages are grouped into initial outages (generation 0), generation 1, generation 2, etc.
- Estimate average propagation, which is the average number of "children outages" per "parent outage".
  For example, each line outage produces on average 0.25 line outages in next generation.
- Average propagation is a metric of resilience
- Can estimate average propagation annually in large utility
- Can use a validated branching process model to predict the total number of outages from the initial outages

Dobson, IEEE Trans power systems Nov 2012

Probability




Predicting cascading failure extent from average propagation in utility data,
(Dobson, IEEE Trans. Power Systems, 2012)

Number of line outages

Probability distribution of total number of line outages assuming 5 initial line outages

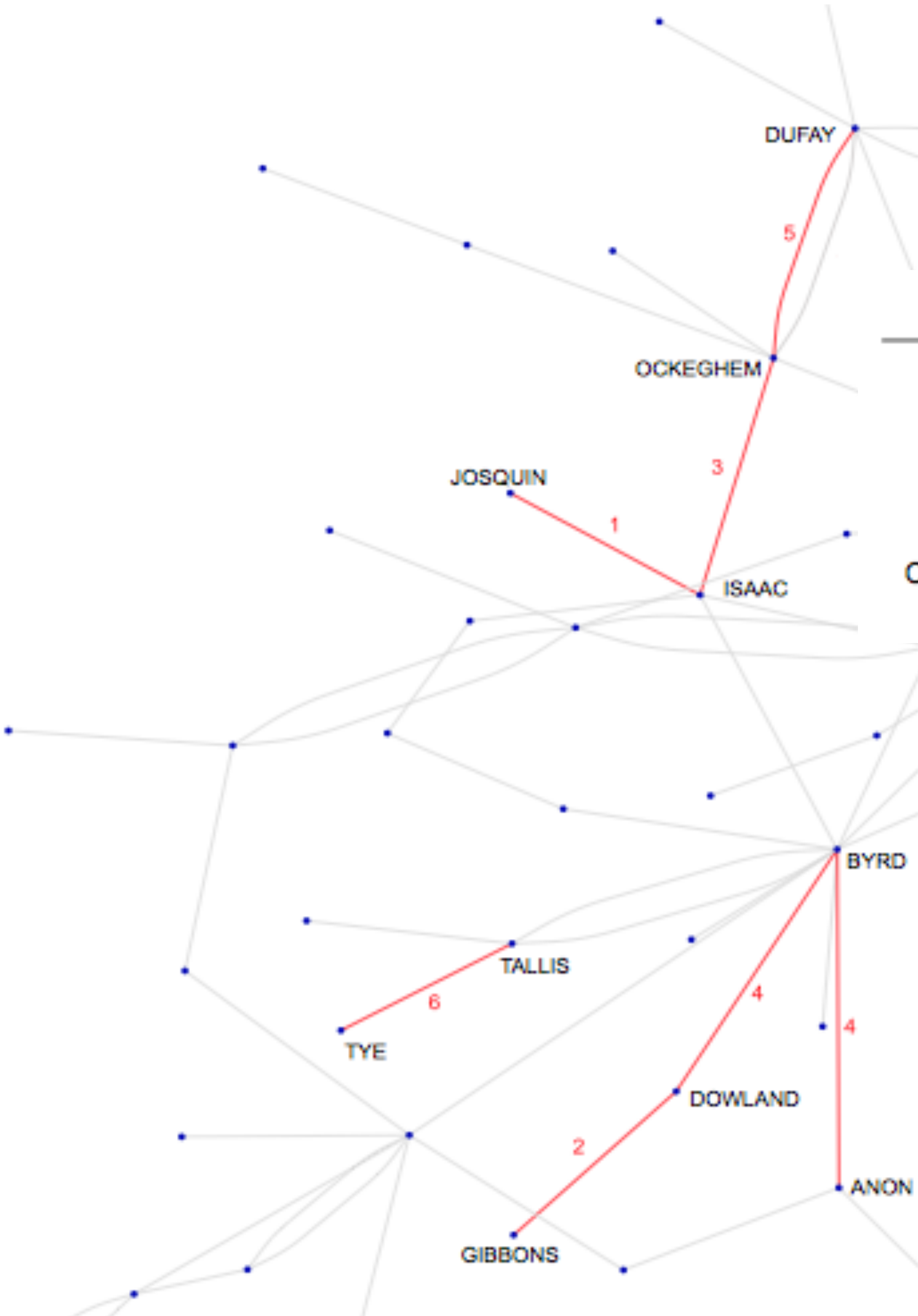
# Real data on cascading line outages spreading in power grids

- Also uses the standard utility TADS data
- Solved the problem of locating the outages on a grid consistent with the outages
- Now we can see cascades spreading and learn about their spatial statistical properties
  - get typical statistics, not just the worst cases!

Dobson 2015, arxiv.org/abs/1507.04277

Utility network that is consistent with TADS data

layout not geographic




| transmission line | outage start time hour:minute | generation |
|---|---|---|
| JOSQUIN – ISAAC | 15:22 | 1 |
| GIBBONS – DOWLAND | 15:25 | 2 |
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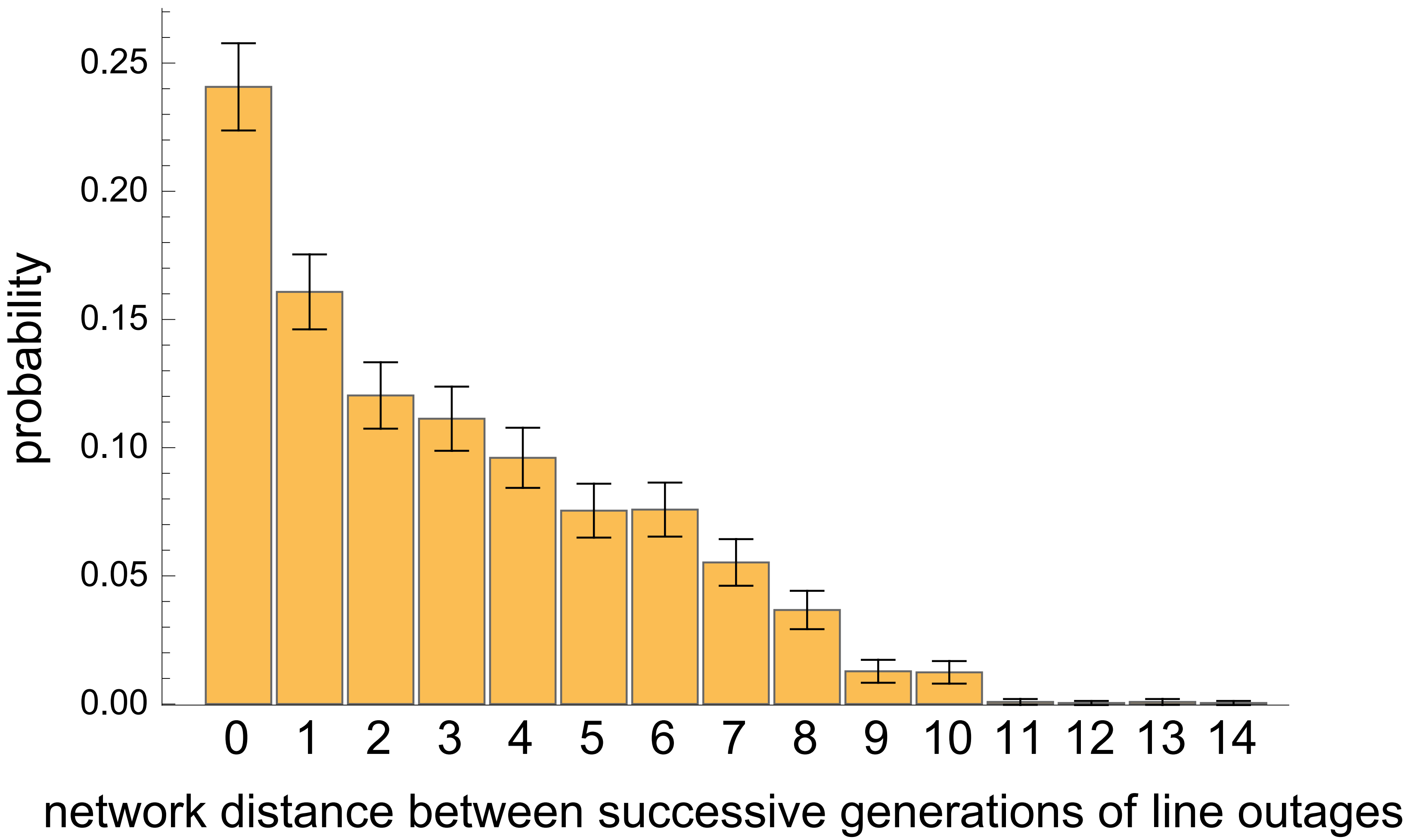
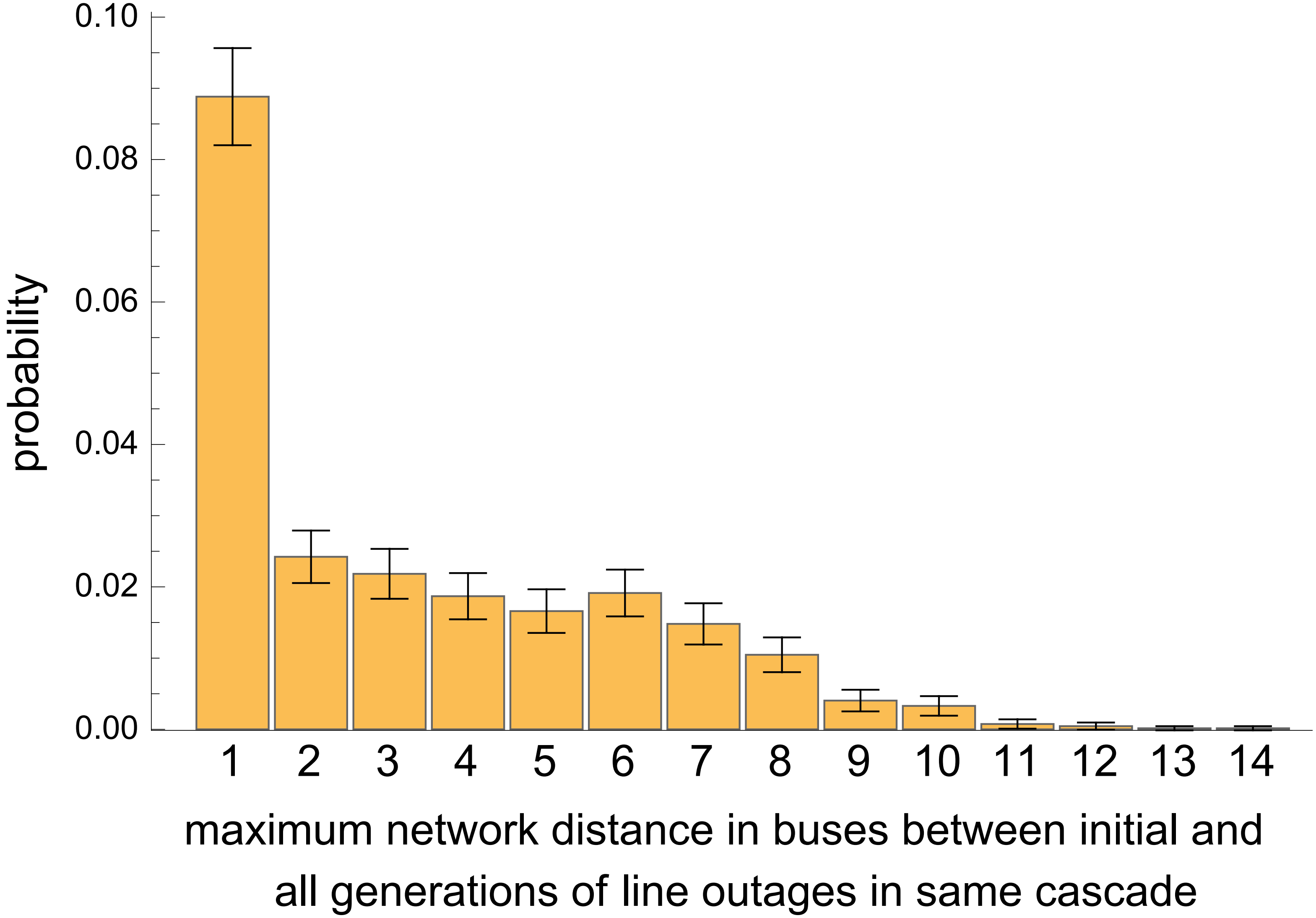
# Locating a cascade on the network

example of real cascade statistics:
network distance = number of buses between the lines
Distribution of distance between successive generations



# example of real cascade statistics: Distribution of maximum network distance from initial outages



# Traditional bottom-up approach to risk-based grid reliability for dependent events

- make model of one type of interaction mechanism (often steady state Markov Chain for up/down of components and elaborations thereof)
- seek data for model parameters

Advantage: understanding mechanism enables mitigation
Disadvantage: data sought but not often found

# Complementary top-down approach to grid reliability for cascading events

- Cascading is a complicated series of dependent events; many mechanisms
- Start from existing utility data; start by ignoring detailed mechanisms
- Develop high-level probability models that can be estimated from the data such as branching processes
- Model parameters such as average propagation are metrics of cascading and grid resilience
- Monitor average propagation and relate to risk
- Work out how to limit average propagation to improve resilience and mitigate risk

# Some directions opened up by data-driven cascading analysis

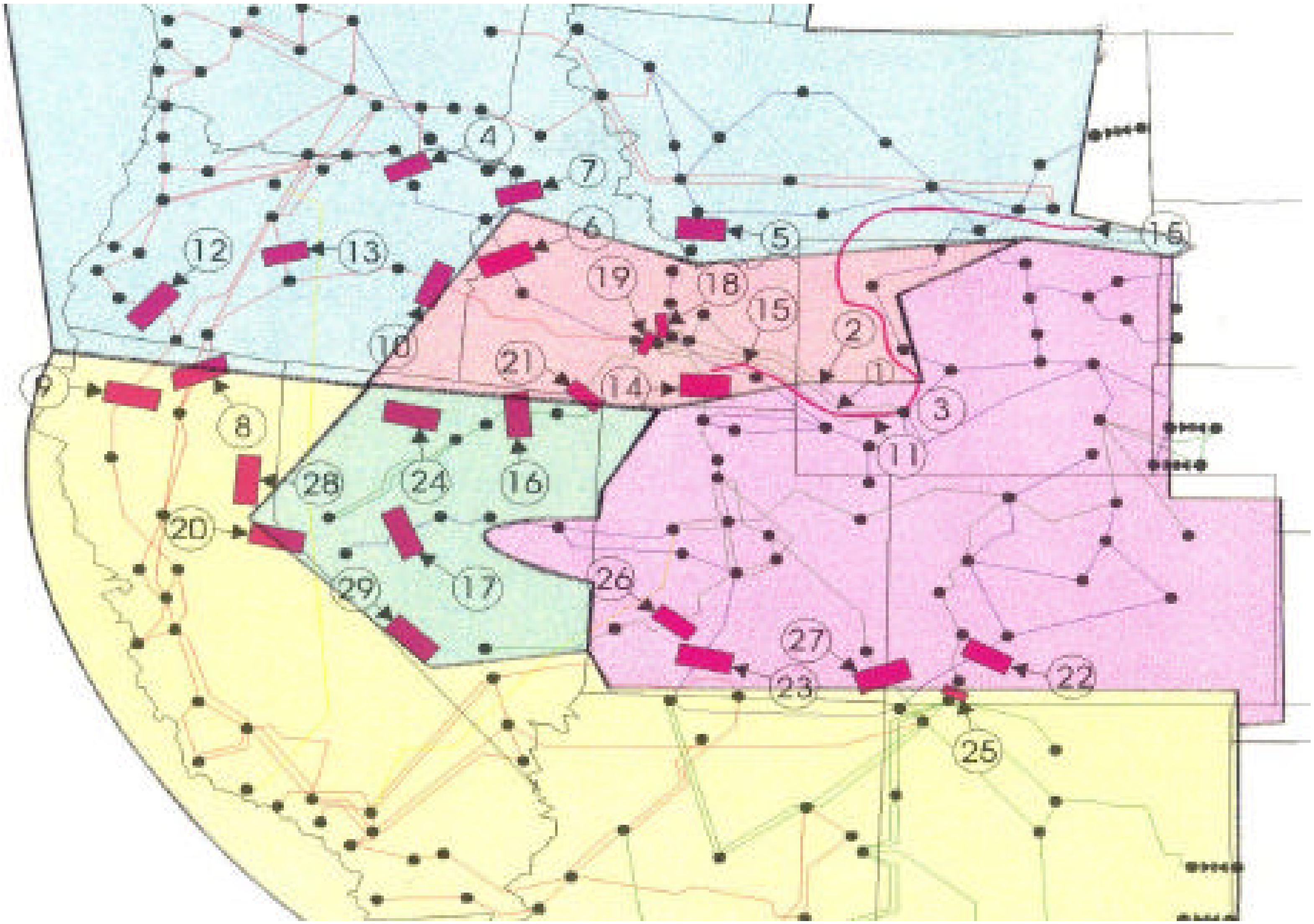
- Validate cascading models and simulations with the real bulk statistics of cascading
- Verify grid performance from observed outages:
  - monitor initial outages and annual average propagation (mean blackout size is too variable)
- Start disentangling how cascades spread top-down from the data – can we discriminate classes of mechanisms?
- Much potential in TADS data … here we only scratch the surface.

# QUESTIONS?

## References


1. I. Dobson, Estimating the propagation and extent of cascading line outages from utility data with a branching process, IEEE Trans. Power Systems, vol. 27, no. 4, November 2012, pp. 2146-2155.
2. I. Dobson, Obtaining statistics of cascading line outages spreading in an electric transmission network from standard utility data, ArXiv preprint July 2015, http://arxiv.org/abs/1507.04277

# Worst case cascading: for example, Sequence of outages in Western blackout, July 2 1996




from NERC 1996 blackout report