Outage Clustering: From Leaves to Trees

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joint work with Yuri Pradkin, Aqib Nisar
USC/ISI

CAIDA Active Internet Measurments (AIMS) / 15 March 2018

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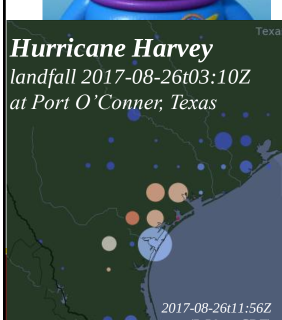
USC Viterbi School of Engineering · Information Sciences Institute

So Much Internet Outage Data…

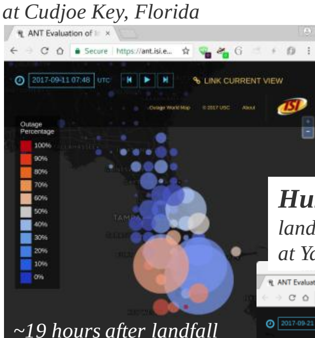
Trinocular
24x7 since Nov. 2013



Hurricane Harvey
landfall 2017-08-26t03:10Z
at Port O'Conner, Texas

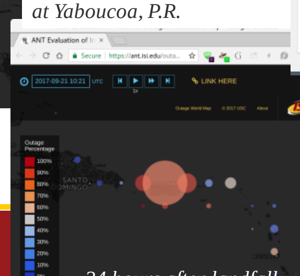
2017-08-26t11:56Z
(5:56am CDT)

Hurricane Irma
landfall 2017-09-10t13:10Z
at Cudjoe Key, Florida



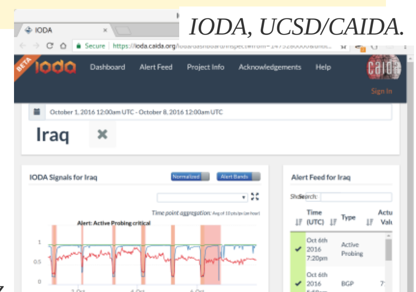
~19 hours after landfall

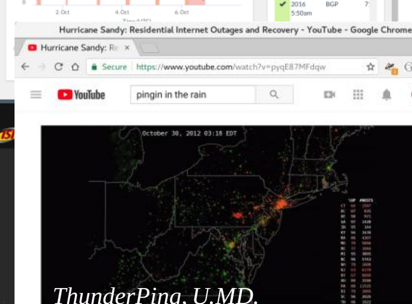
Hurricane Maria
landfall: 2017-09-20t10:15Z
at Yaboucoa, P.R.



~24 hours after landfall

IODA, UCSD/CAIDA.





ThunderPing, U.MD.

Too Much Long-Term Data?

- USC/ISI's Trinocular: outages, 24x7, since Nov. 2013
- about 40TB (!)
- about 20k observations x 4M blocks:
  80G datapoints (!!)

- how to make sense of it?
  - from leaves (edge networks)
  - to trees (events)
  - on the way to understanding the "forest" of Internet reliability

Making Sense of Too Much Data

- **geographic visualization**
  interactively explore the world

- **non-geographic visualization**
  begin to reveal patterns

with too much data
(40TB and
80G observations)

- **clustering by similarity**
  discover underlying dependencies

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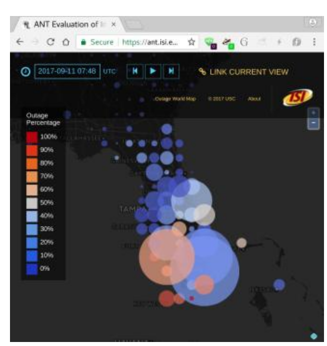
Geographic Visualization

- on the web: https://ant.isi.edu/outage/world/
- key features
  - circle size: *number* of blocks out
  - color: *percent* of blocks out
  - time selection
  - geographic zoom and pan
  - **geography: easy to relate to (what operators ask for!)**

Florida, ~19 hours after landfall of Hurricane Irma



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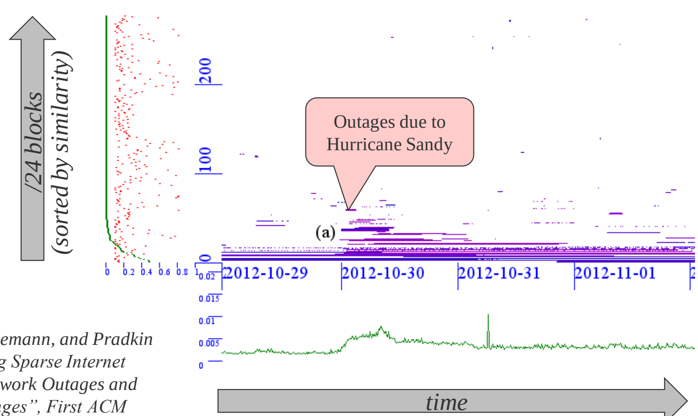
Non-Geographic Visualizations: the *Network* in Outages



Quan, Heidemann, and Pradkin "Visualizing Sparse Internet Events: Network Outages and Route Changes", First ACM Workshop on Internet Visualization, Nov. 2012

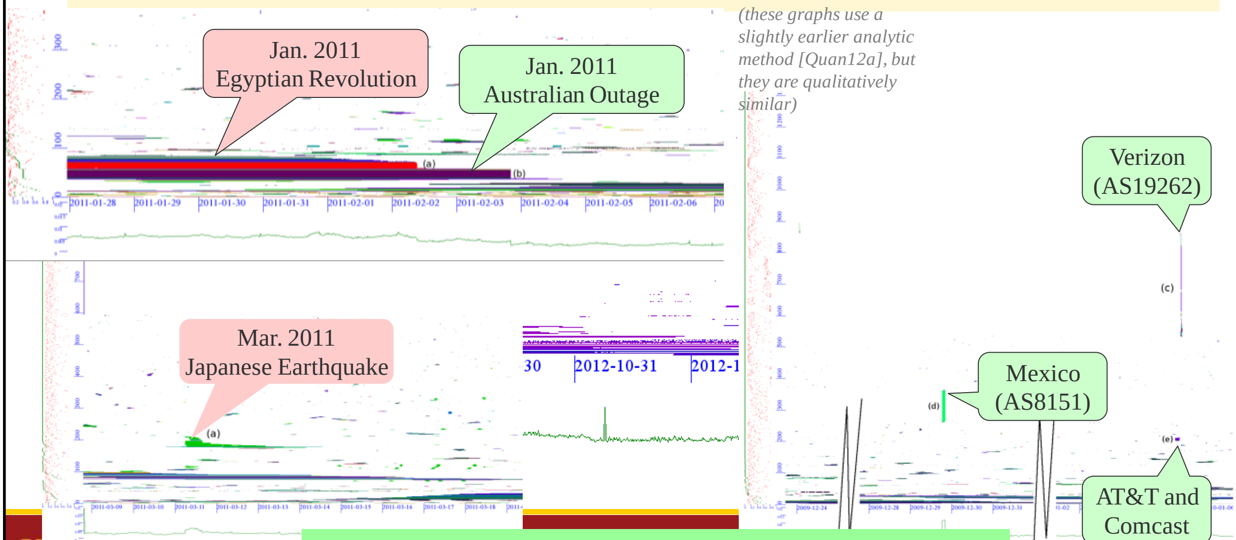
goal: reveal patterns

find dependencies among networks

(colored areas are outages, color shows location)

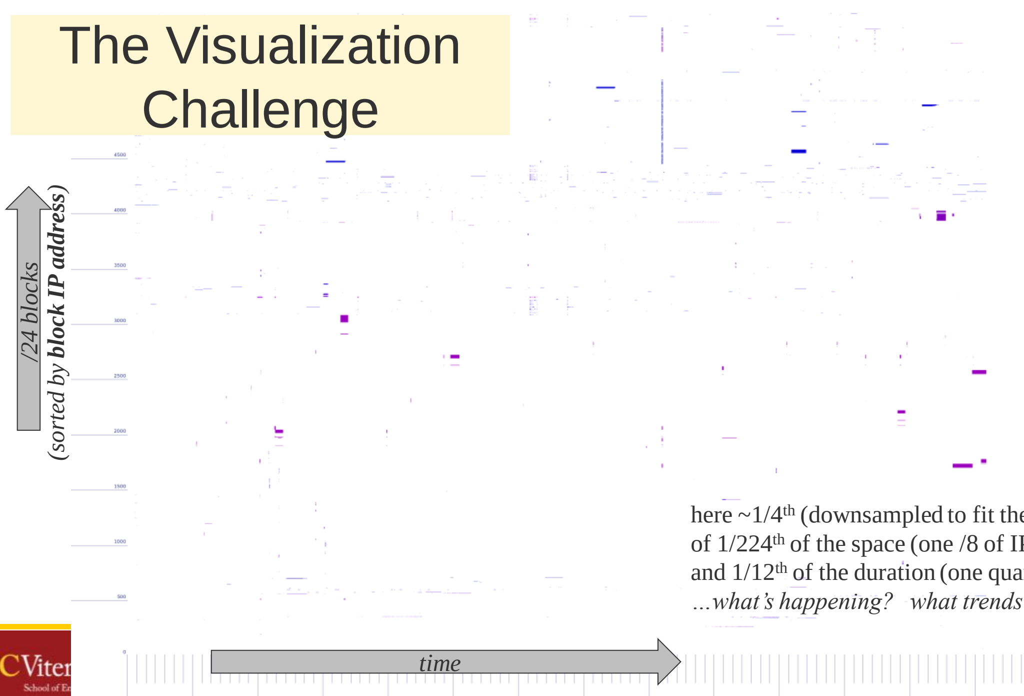
Global Network Outages: Prominent and *Unknown*

(these graphs use a slightly earlier analytic method [Quan12a], but they are qualitatively similar)



our goal: understand small *and* big

The Visualization Challenge



here ~1/4th (downsampled to fit the screen)
of 1/224th of the space (one /8 of IPv4)
and 1/12th of the duration (one quarter of ~3 years)
…what's happening? what trends? what's new?

Efficient Visualization

- **visualization with linear ordering algorithm**
  - runtime: O(n log n log m)
  - for n blocks and m duration timesteps
- approach:
  - map clustering to sorting: O(n log n) in time
  - sort on *multi-timescale bitmap:* O(log m) in space

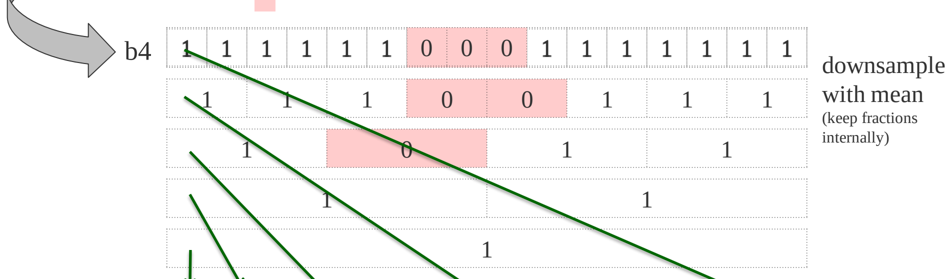
Presented at AIMS 2017 (last year!)

Details in "Back Out: End-to-end Inference of Common Points-of-Failure in the Internet (extended)". ISI-TR-724, Feb., 2018. *www.isi.edu/~johnh/PAPERS/Heidemann18b.pdf*

Multi-Timescale for Similarity

- input: outage timeseries from 5 /24 blocks
  - b1 1111 111**0** 1111 1111
  - b2 1111 1111 1111 111**0**
  - b3 1111 11**00** 1111 1111
  - b4 1111 11**00** **0**111 1111
  - b5 1111 111**0** 1111 1111

goal: cluster by "similarity"



concatenate: 1 - 11 - 1**0**11 - 111**0** **0**111 - 1111 11**00** **0**111 1111

Multi-Timescale Finds Similarity

- input: outage timeseries from 5 /24 blocks
  - b1 1111 111**0** 1111 1111
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  - b3 1111 11**00** 1111 1111
  - b4 1111 11**00** **0**111 1111
  - b5 1111 111**0** 1111 1111
- apply to all blocks…
  - b1 1 - 11 - 1111 - 111**0** 1111 - 1111 111**0** 1111 1111
  - b2 1 - 11 - 1111 - 1111 111**0** - 1111 1111 1111 111**0**
  - b3 1 - 11 - 1**0**11 - 111**0** 1111 - 1111 11**00** 1111 1111
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Multi-Timescale Finds Similarity

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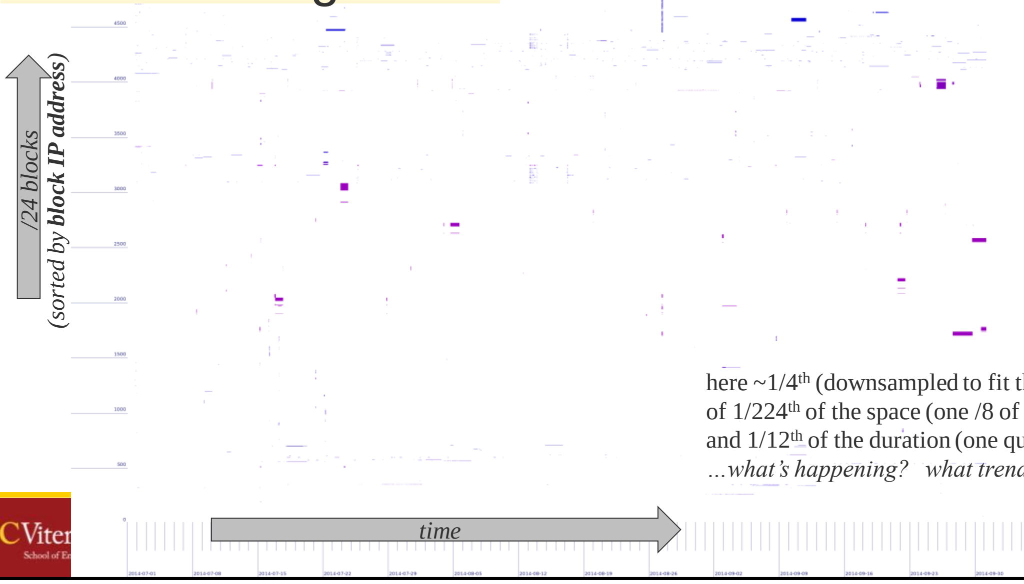
  - b4 1111 11**00** **0**111 1111
  - b5 1111 111**0** 1111 1111
- apply to all blocks and **sort**
  - b2 1 - 11 - 1111 - 1111 111**0** - 1111 1111 1111 111**0**
  - b1 1 - 11 - 1111 - 111**0** 1111 - 1111 111**0** 1111 1111
  - b5 1 - 11 - 1111 - 111**0** 1111 - 1111 111**0** 1111 1111
  - b3 1 - 11 - 1**0**11 - 111**0** 1111 - 1111 11**00** 1111 1111
  - b4 1 - 11 - 1**0**11 - 111**0** **0**111 - 1111 11**00** **0**111 1111

goal: cluster by "similarity"

define similar as adjacent in multi-timescale vectors

result: better clusters
(Hamming distance from 8 to 4)

The Visualization Challenge



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One Visualization Result

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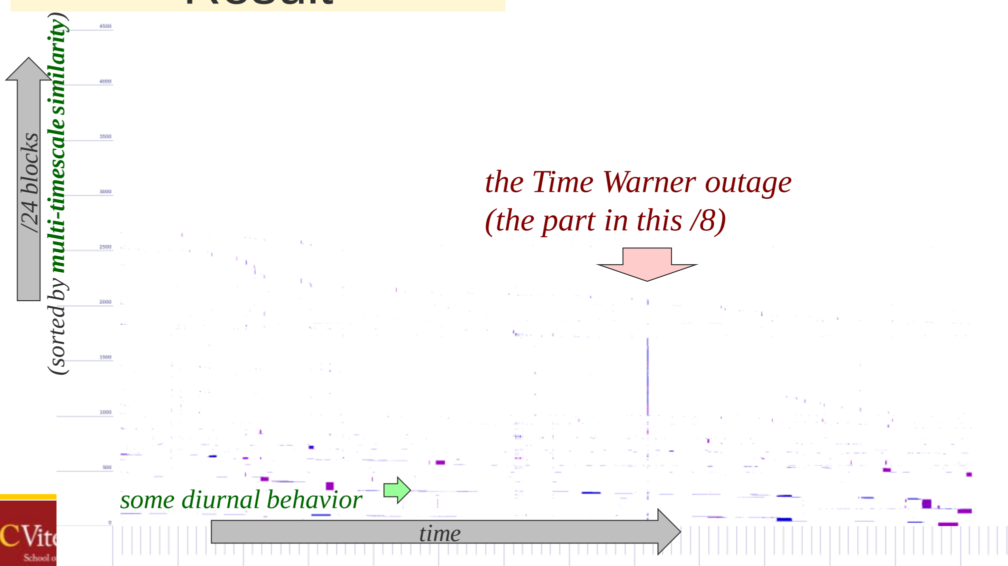

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Clustering to Discovery Dependencies

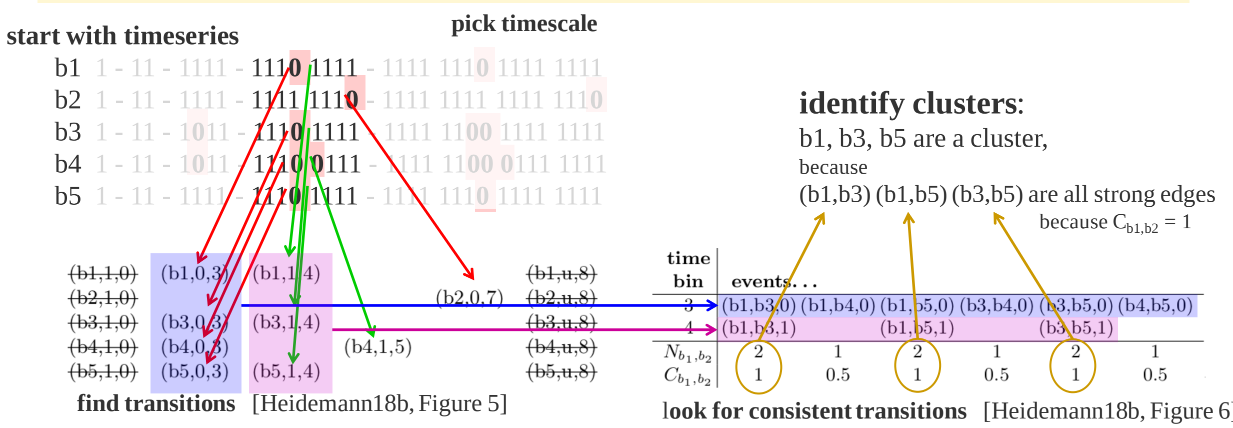
- visualization is nice, but humans can't look at everything
- new clustering algorithms can *discovery dependencies*
  – common failure patterns
  – implying common root causes
  – (unconstrained by 2-D visualization)

Clustering Insight

- things fail and recover together => possible dependency
- when *consistently, multiple times* => *probable* dependency

(Details: John Heidemann, Yuri Pradkin, and Aqib Nisar. Back Out: End-to-end Inference of Common Points-of-Failure in the Internet (extended). ISI-TR-724, February, 2018. https://www.isi.edu/%7ejohnh/PAPERS/Heidemann18b.html .)

Clustering Approach



One Clustering Result

1/224th of the space (one /8 of IPv4)
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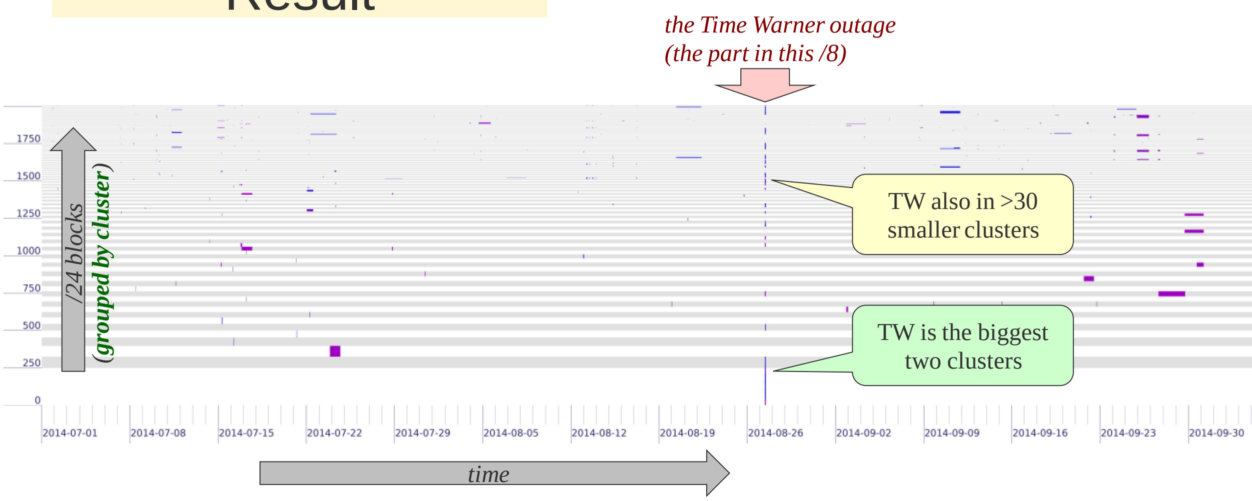


Iterative Clustering

1/224th of the space (one /8 of IPv4)
and 1/12th of the duration (one quarter of ~3 years)
now just **3 days** of time

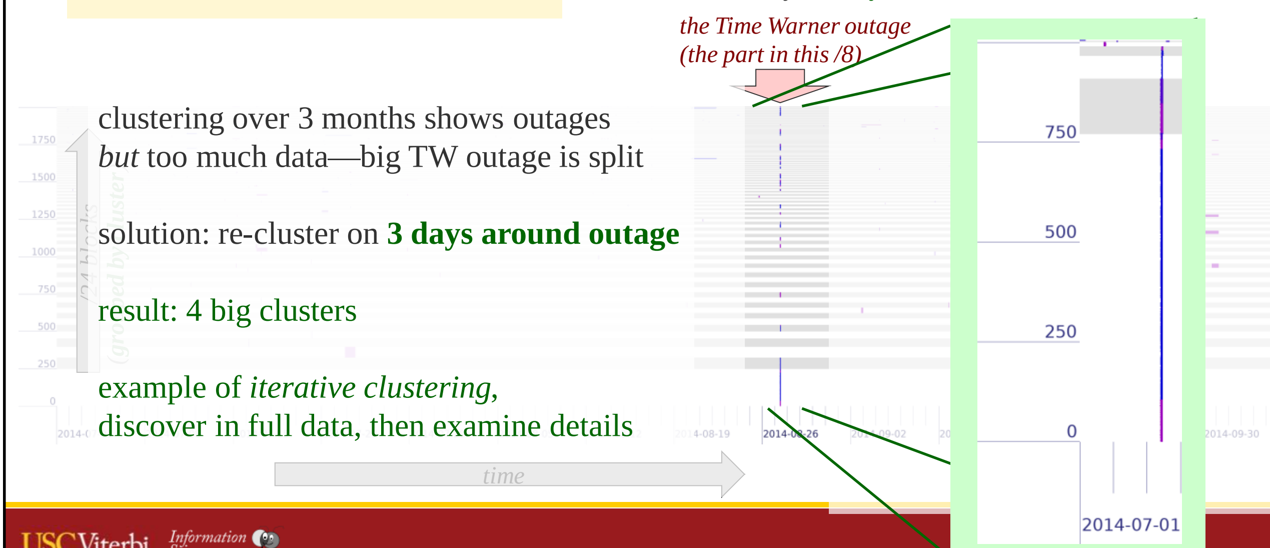
the Time Warner outage
(the part in this /8)

clustering over 3 months shows outages
but too much data—big TW outage is split

solution: re-cluster on **3 days around outage**

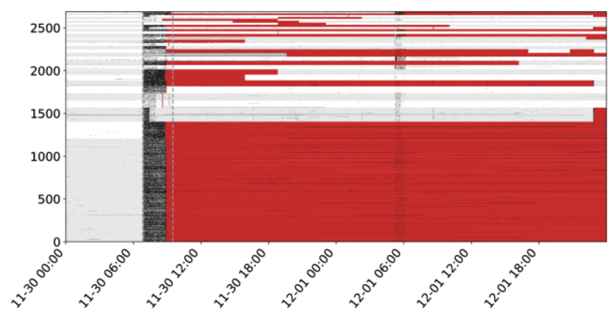
result: 4 big clusters

example of *iterative clustering*,
discover in full data, then examine details



Clustering Beyond Outages

- cluster generalizes:
  detects *temporal correlations*
  in *big timeseries*
- we've applied it to
  - outages
  - anycast catchments
  - routing updates
- for anycast:
  - map initial vs. new cluster to binary value
  - skip outages (from DDoS)

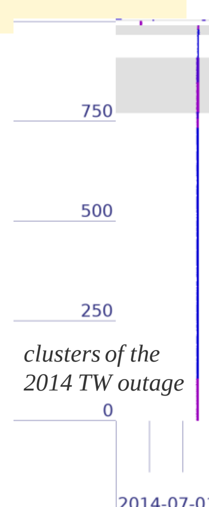


anycast catchments for J-Root around the 2015-11-30 DDoS attack

[Heidemann18b, Figure 9]

Outage Clustering from Here

- just released clustering technical report
- opens many new questions…
  - relating to other information? (like power outages)
  - what is "normal"?
  - can we evaluate policy <=> reliablity?
- datasets at https://ant.isi.edu/datasets/outage and https://imactcybertrust.org
- code available on request



clusters of the 2014 TW outage