Active Probing of Edge Networks: Hurricane Sandy and Beyond

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joint work with Lin Quan and Yuri Pradkin

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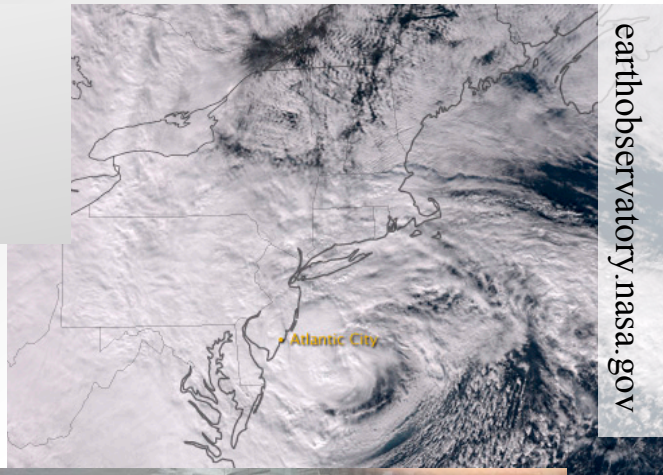
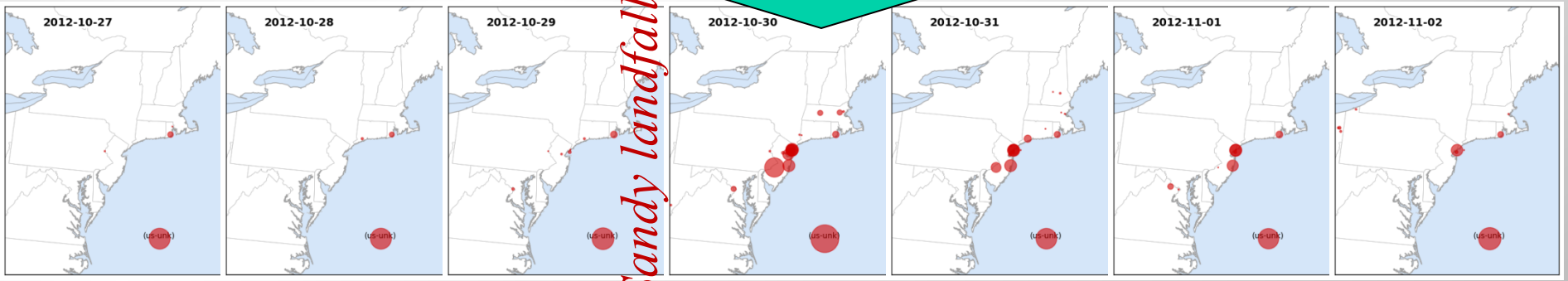
Can Pings Measure Hurricane Damage?

```
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_req=1 ttl=251 time=89.6 ms
64 bytes from 8.8.8.8: icmp_req=2 ttl=251 time=83.6 ms
64 bytes from 8.8.8.8: icmp_req=3 ttl=251 time=86.6
^C
--- 8.8.8.8 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2001ms
rtt min/avg/max/mdev = 83.602/86.627/89.641/2.465 ms
```



earthobservatory.nasa.gov

abcnews.com



Broader Goal: Tracking Outages in Edge Networks

- quickly know the impact of **natural disasters**
  - Hurricane Sandy, Tōhoku Earthquake 2011, etc.
  - and human ones :-(like Egypt 2011, etc.

- learn about **outage shapes**
  - *wide outages:* many people
  - *long outages:* long time
  - and both

- in ***edge networks*** *(/24* address *blocks,* like 1.2.3.*)
  - most outages are small, *inside* ISPs, *not* from routing
    - e.g.: [Bush et al, IMC 2007]; us: ~70% smaller than routable prefixes
  - want to characterize what people see at home

Background: Active Probing with Pings

pings (ICMP echo request)
draw **positive replies** when an IP address is in use

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--- 8.8.8.8 ping statistics ---
6 packets transmitted, 3 received, 50% packet loss, time 6001ms
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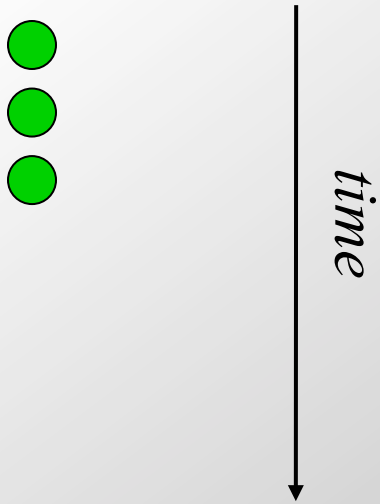

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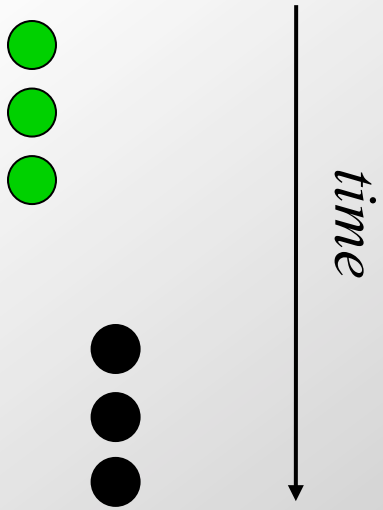

or get **negative (non-)replies**

no reply from 8.8.8.8: icmp_req=4
no reply from 8.8.8.8: icmp_req=5
no reply from 8.8.8.8: icmp_req=6
^C
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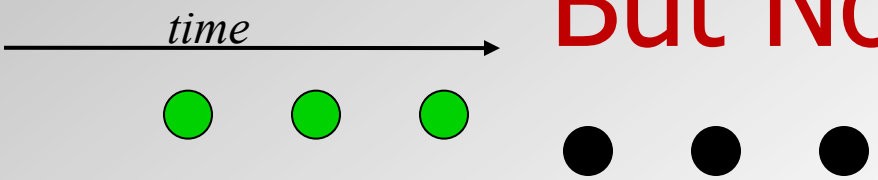
Pings Tell You Something But Not Everything

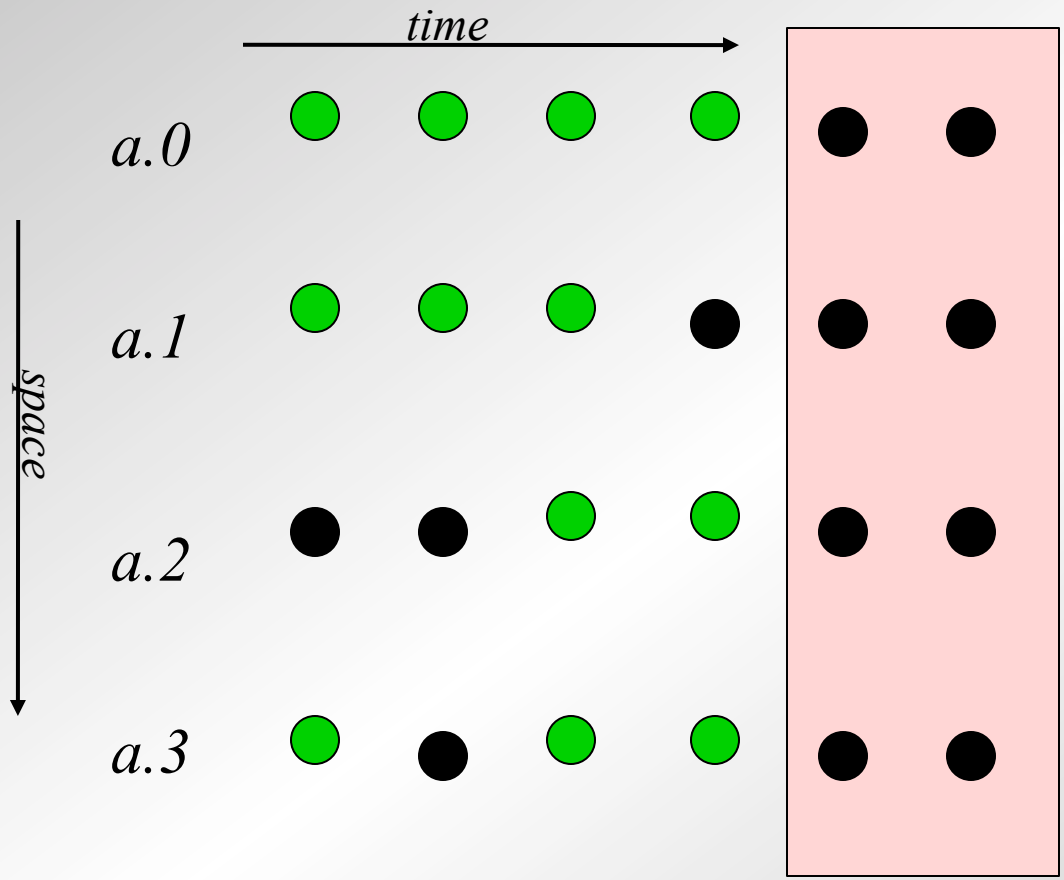


positive:
block is up

negative:
block is down
or
computer crashed
laptop suspended
computer address reassigned
probe or reply lost
firewall enabled

negative replies are ambiguious

So We Probe *Multiple* Addresses

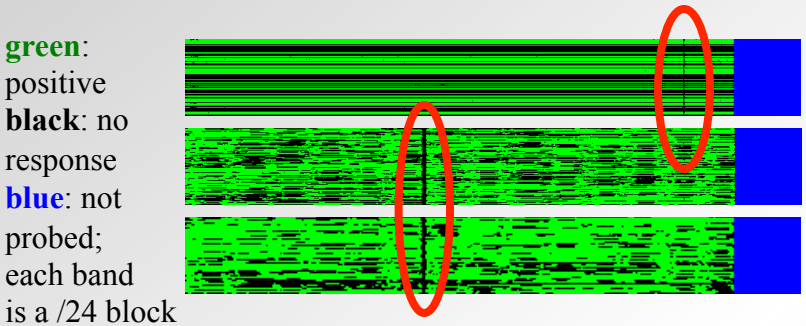


all negative together disambiguates:

network is ***really*** *down*

Approach: Detect Changes in Ping Response

1. probe multiple addresses in each block frequently



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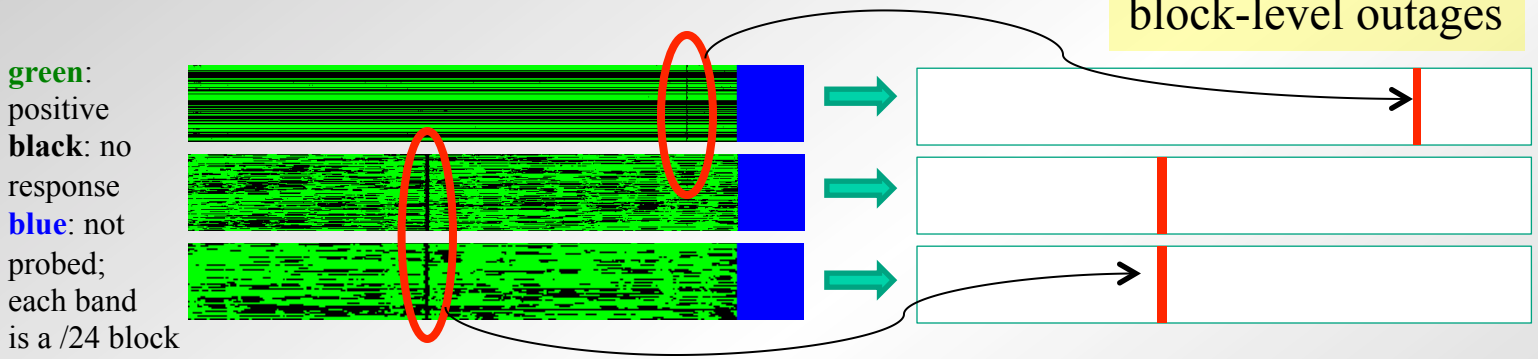

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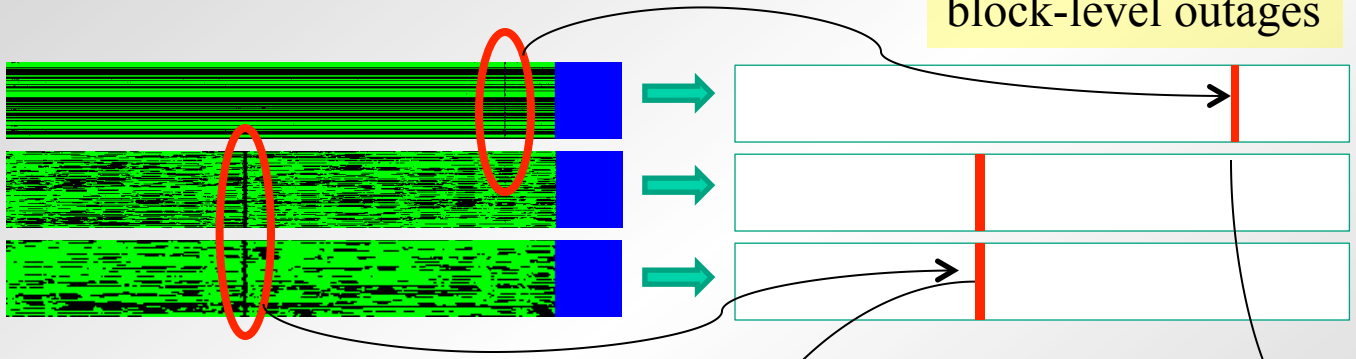

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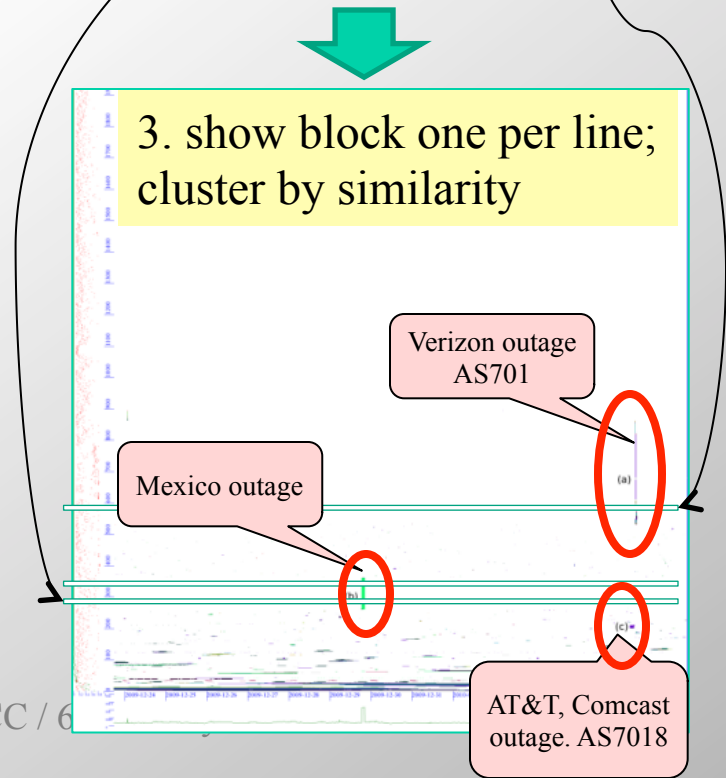

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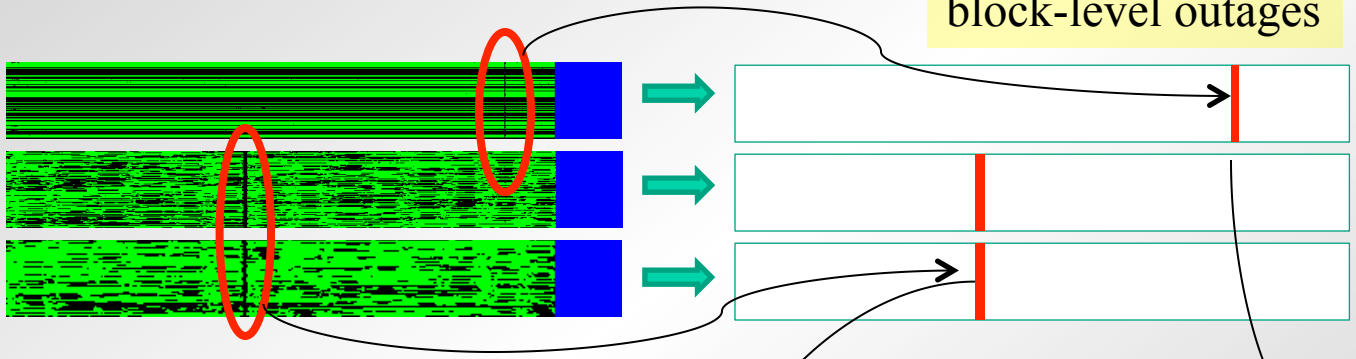

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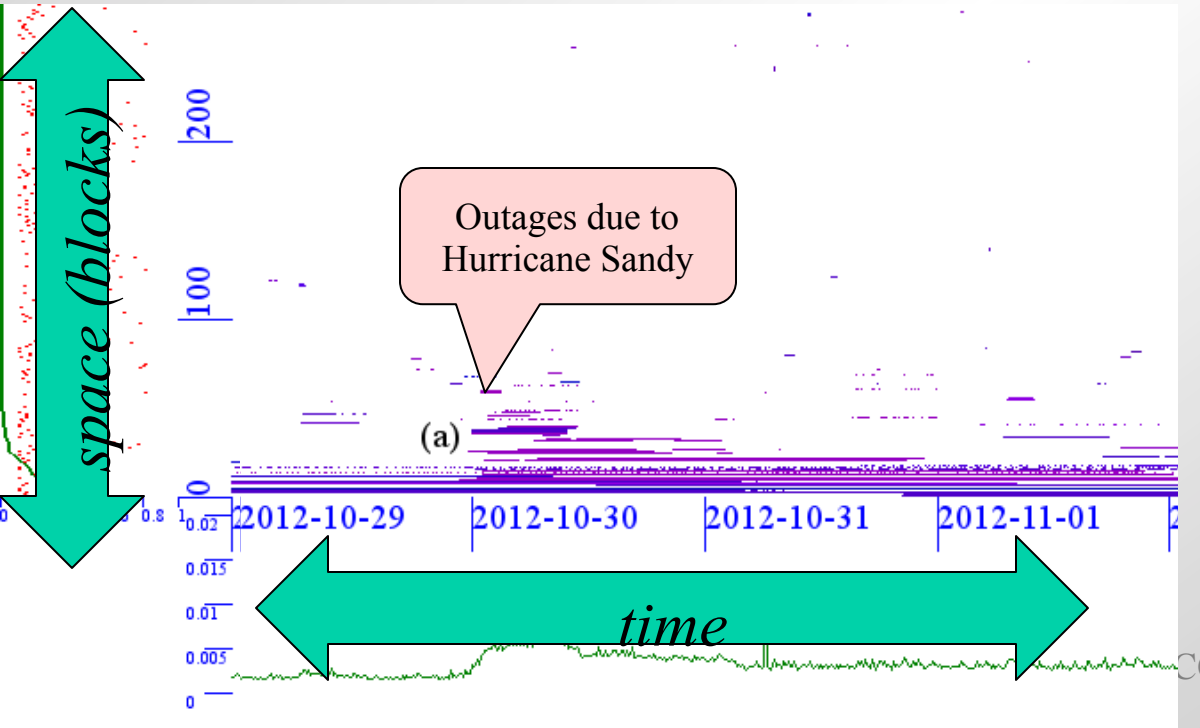
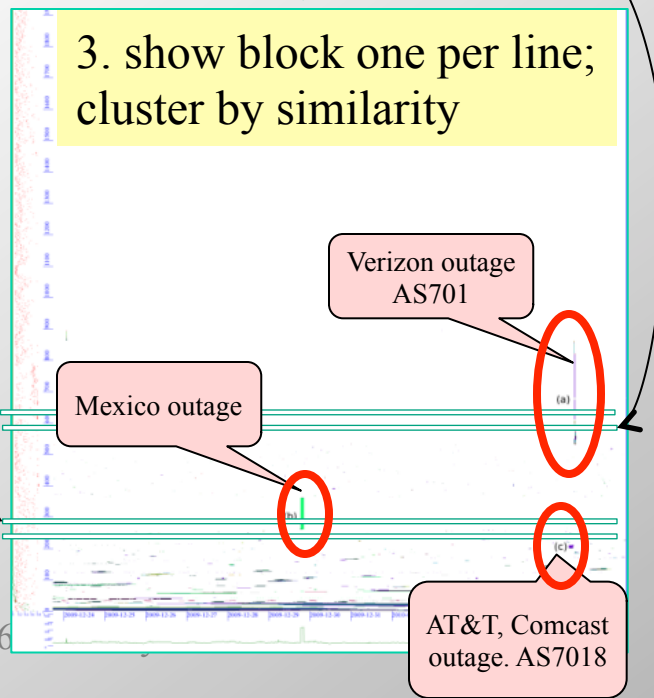


3. show block one per line; cluster by similarity



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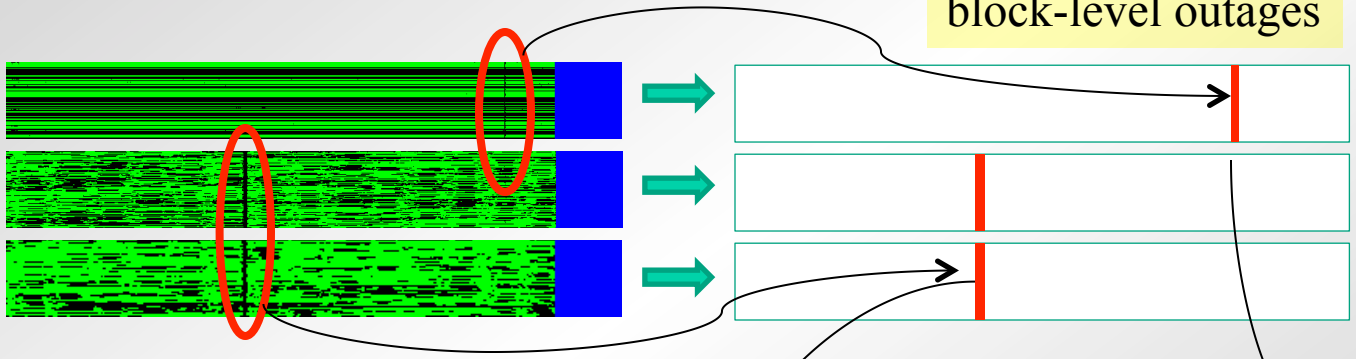

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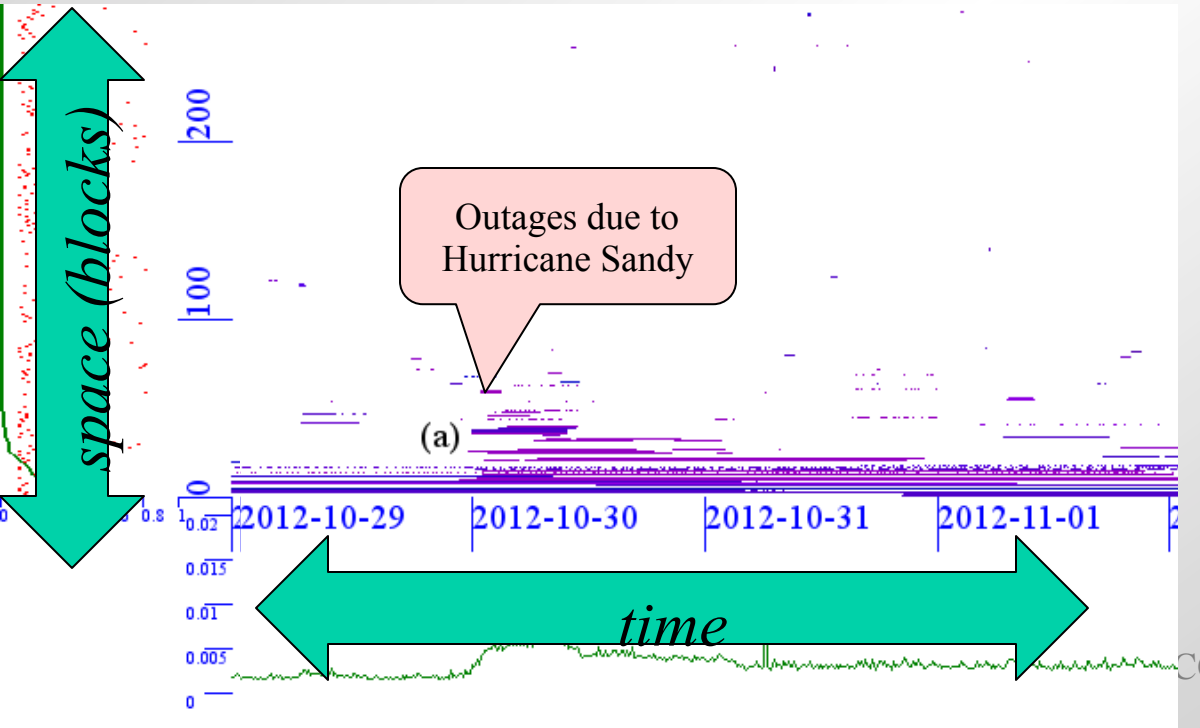

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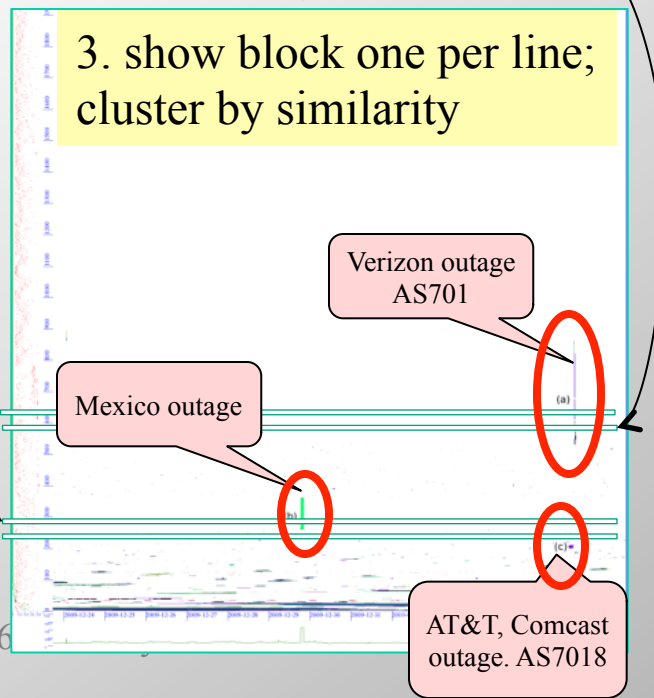


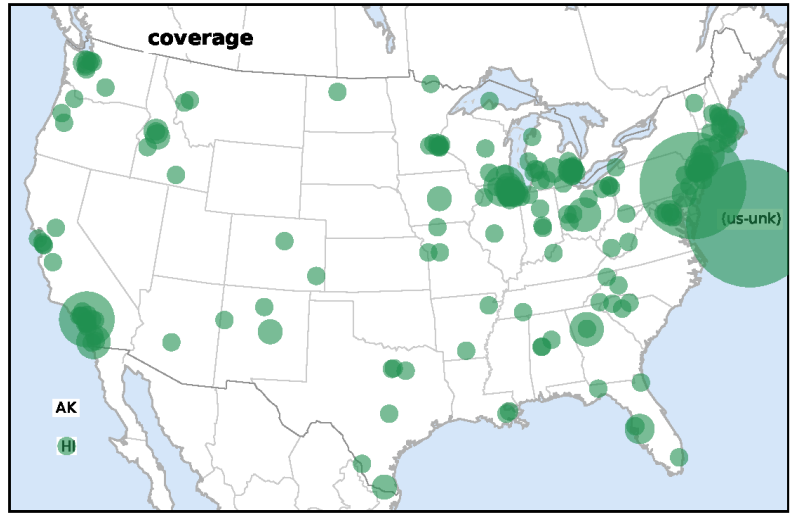
Details: Sandy Analysis

- for Sandy, we re-analyze existing data
- Internet Surveys
  - sample: 41k blocks (~2% of active address space)
  - probe for 2 weeks
  - every 11 minutes
  - we have been taking surveys since 2006

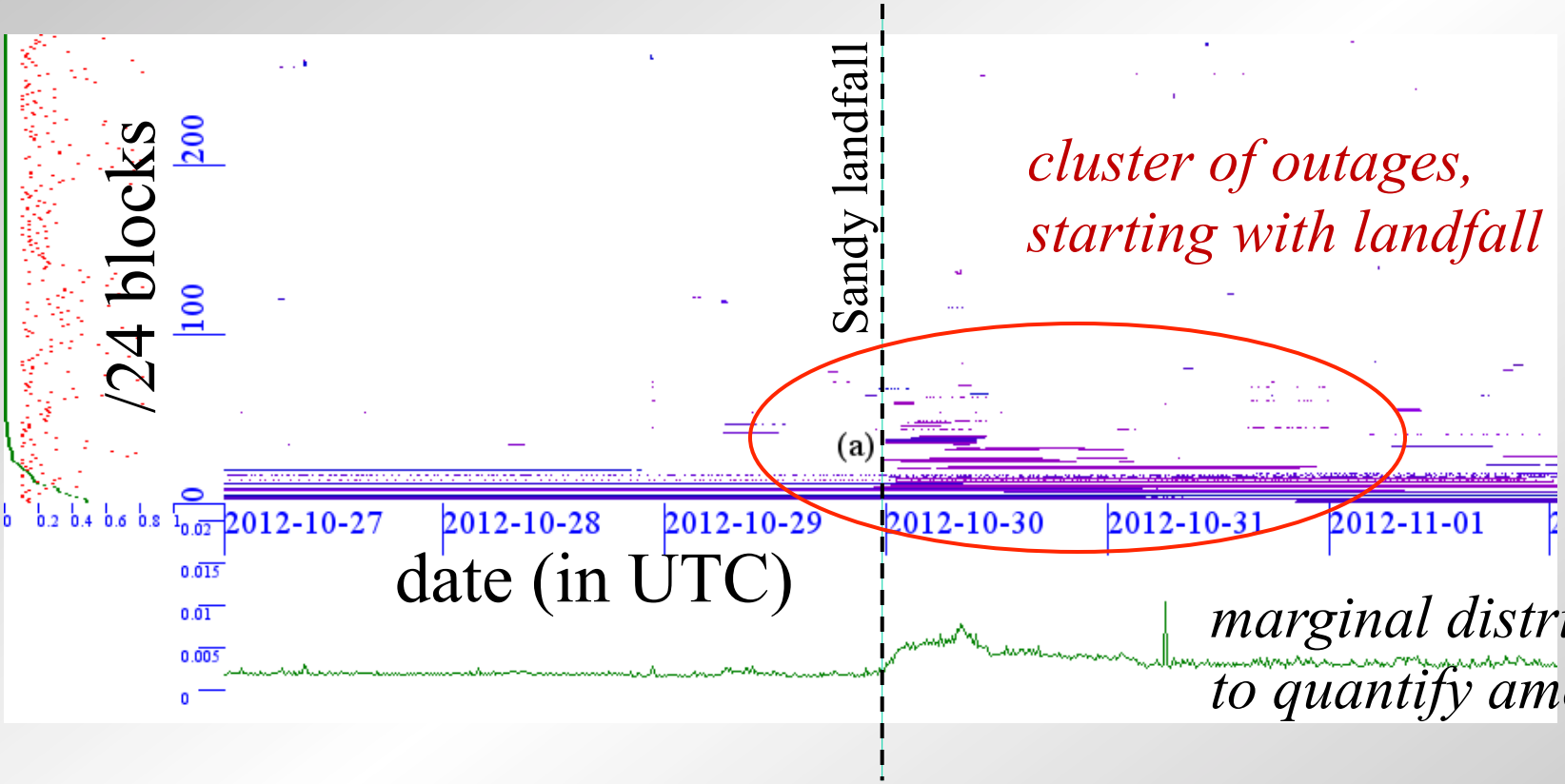
- details and data are available
  - ISI-TR-678b: http://www.isi.edu/~johnh/PAPERS/Quan12a.html
  - data: http://www.isi.edu/ant/traces/

Data About Sandy

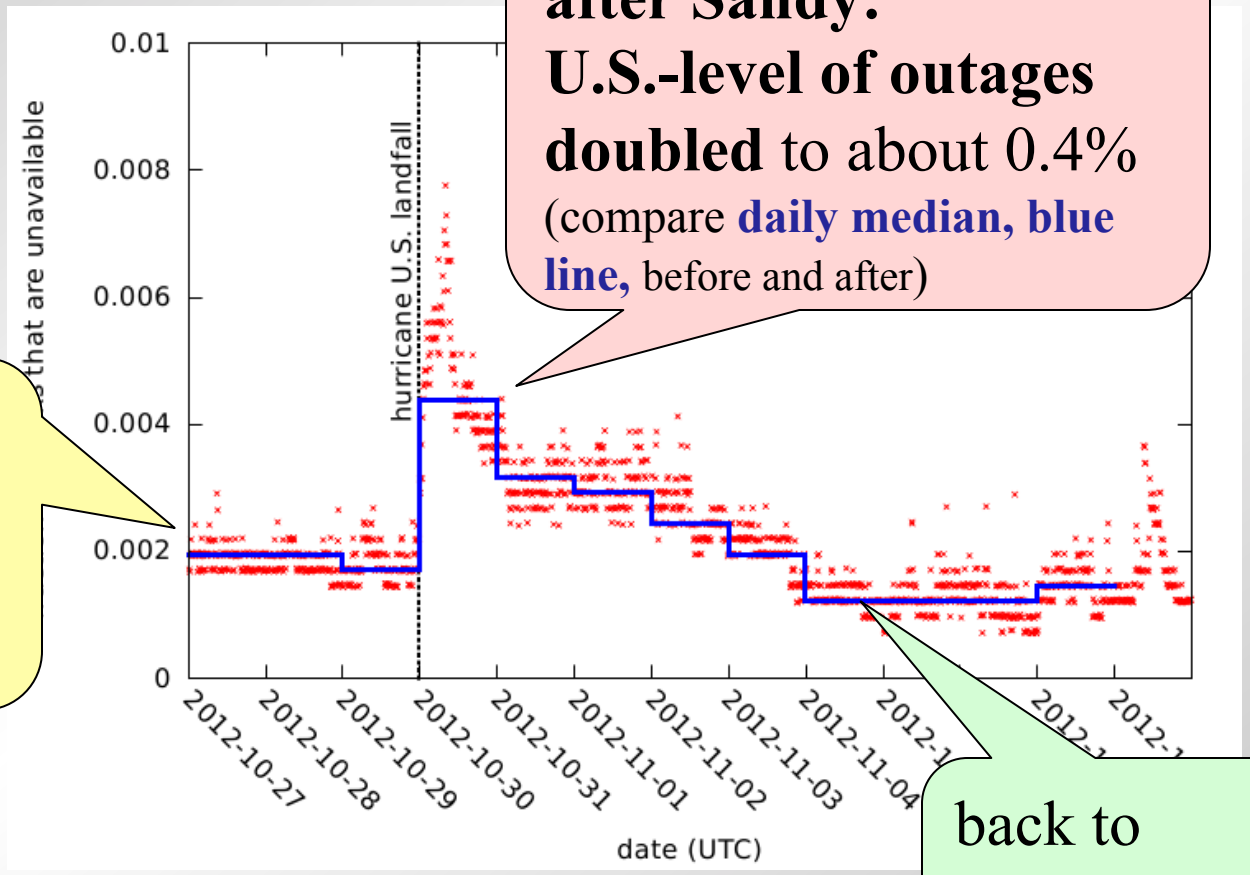
- look at one dataset: internet_address_reprobing_it50j-20121027
- 41,582 /24 blocks
- 11,900 geolocate to US
- 4,117 have enough reponse to analyze
  - 60 of these don't have states



Outages at Sandy Landfall



Measuring the Impact



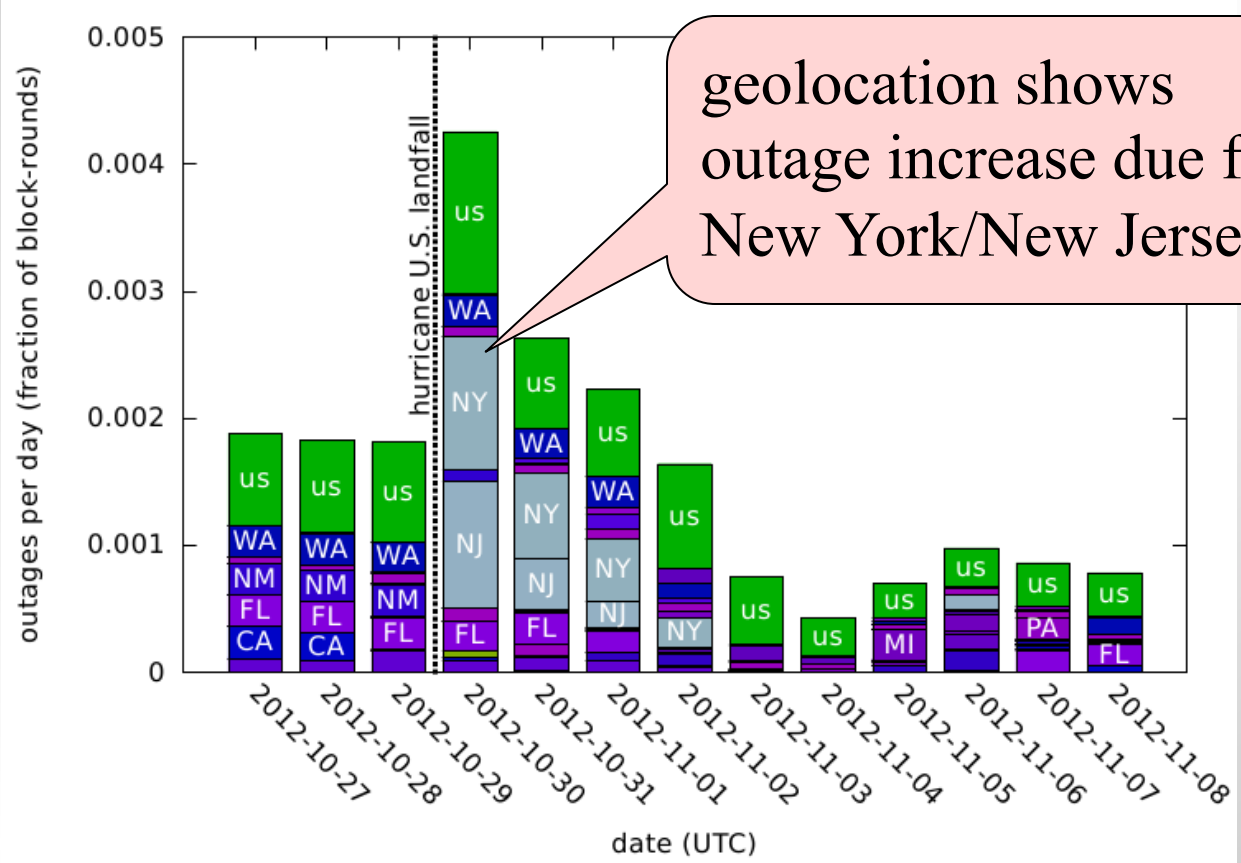
after Sandy:
U.S.-level of outages doubled to about 0.4%
(compare **daily median, blue line,** before and after)

always *some outages* in US:
about 0.2%

(each red X is amount of U.S. outage for 11 minutes)

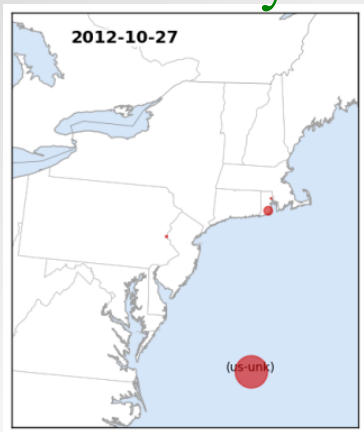
back to baseline after about 4 days

Where Are Outages? NY/NJ



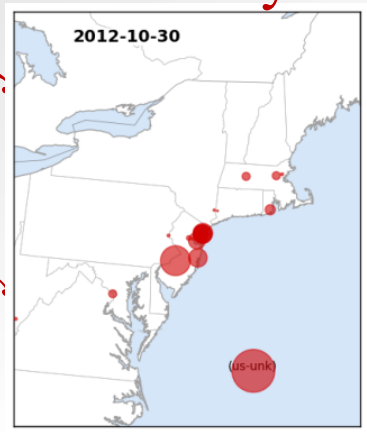
The Northeast, by Day

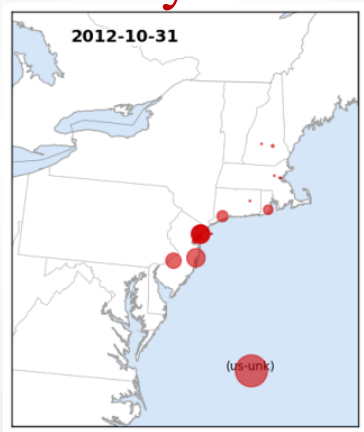
3 days before Sandy landfall



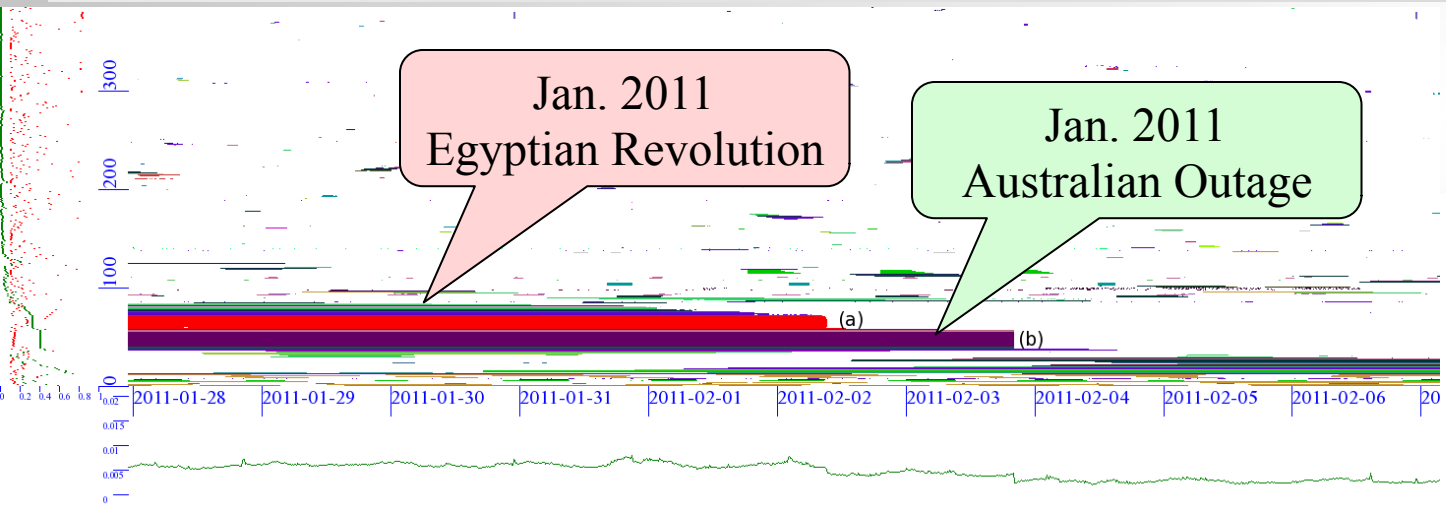
Sandy landfall

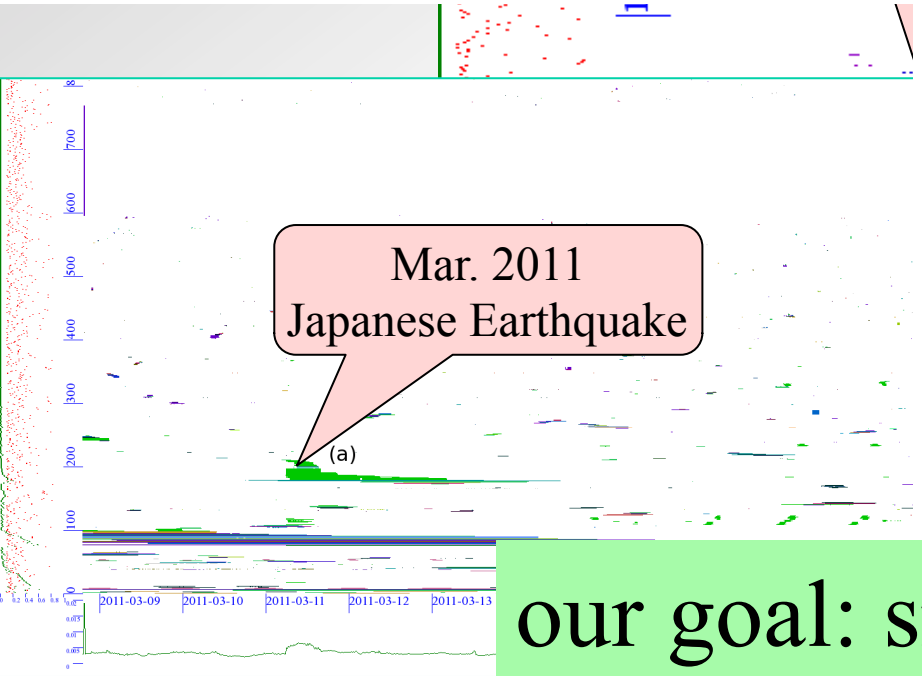
4 days after Sandy landfall

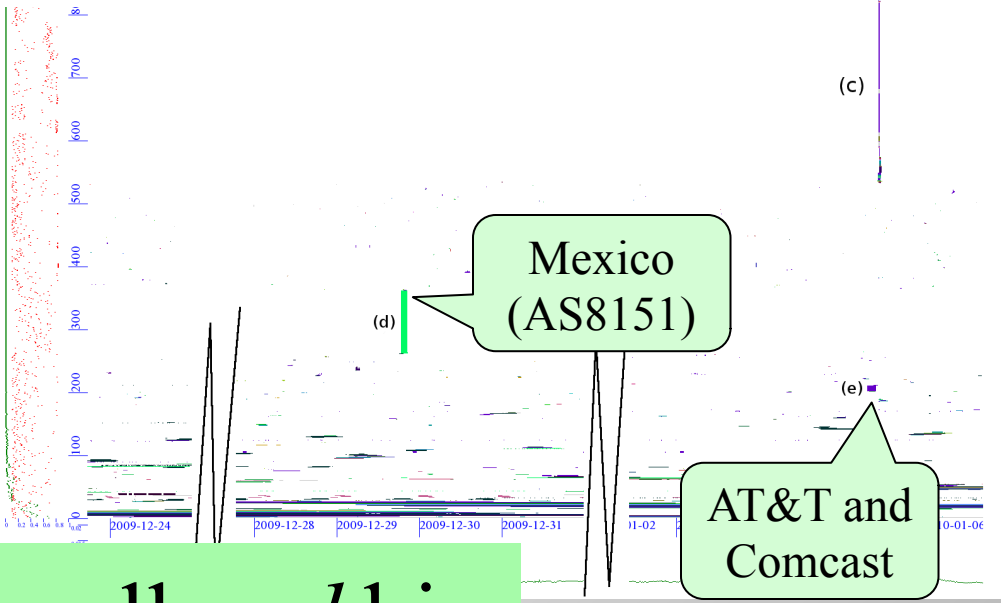




Outages: Prominent and *Unknown*







our goal: small *and* big

Outages Everywhere?

- what would it take to track *all* IPv4?
  - about 3.4M blocks are analyzable
- current surveys: too much traffic
  - 1 probe / 3 seconds (1400 probes/hour) per block
- work in progress: *intelligent probing*
  - detecting outages at < 20 probes/hour per block
  - a *single machine* can watch the whole Internet

What Next?

- pings *can* detect edge-network outages
- Internet-wide detection: work-in-progress

- tech report about Sandy: http://www.isi.edu/~johnh/PAPERS/Heidemann12d.html
- datasets: http://www.isi.edu/ant/traces

- feedback or interest? let me know