Remote Measurement of Last-mile Internet Reliability During Severe Weather

Ramakrishna Padmanabhan[1], Ramakrishnan Sundara Raman[2], Reethika Ramesh[2], Aaron Schulman[3], Dave Levin[1], Neil Spring[1]

[1] University of Maryland, [2] Microsoft, India, [3] University of California, San Diego

How does severe weather affect last-mile Internet reliability?

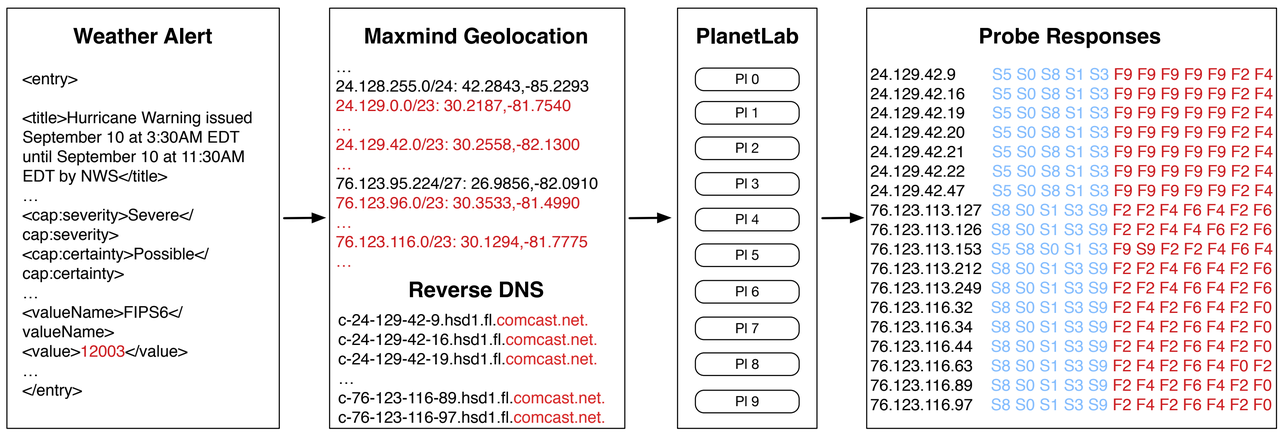
ThunderPing shows that severe weather is correlated with higher likelihood of last-mile Internet outages in the U.S. [1].

However, interpreting detected outages presents challenges:

1. Confounding factors such as frequent dynamic addressing, high RTT, rate-limiting can lead to false outage inferences.
2. Outages can be due to network or power failure, but can also be due to users powering down their home Internet equipment.
3. When measuring ISP-level reliability, must find the subset of detected outages that solely affected that ISP.

Goal: Categorize detected outages by likely cause to reason about last-mile Internet reliability across ISPs and geographical areas.

ThunderPing detects outages during times of severe weather



Parse weather alerts and identify locations to ping

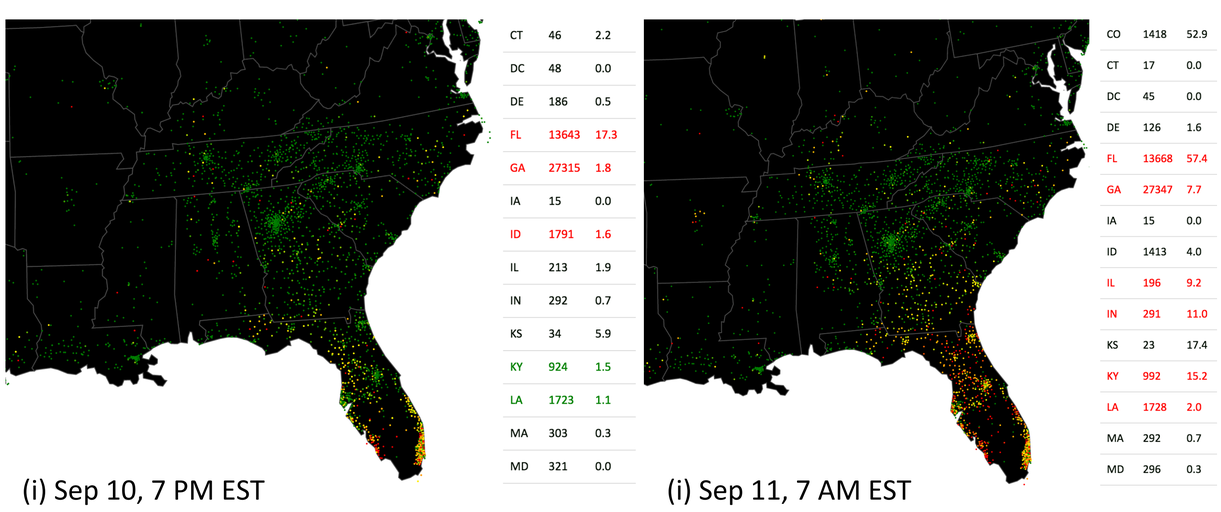
Choose addresses to ping in residential ISPs in those locations

Ping from distributed vantage points

If a previously responsive address stops responding, infer outage

Live visualization shows detected outages in real time

http://bluepill.cs.umd.edu:3000/map/countymap
http://bluepill.cs.umd.edu:3000/map/statemap



(i) Sep 10, 7 PM EST

(i) Sep 11, 7 AM EST

Fig 1: Screenshots of the live visualization tool during Hurricane Irma

Identify and mitigate confounding factors that can lead to false outage inferences

1. Responses can arrive after timeouts but mostly in cellular ISPs [2].

2. Addresses can be dynamically reassigned but dynamic reassignment is infrequent in the U.S. [3].

3. ISPs can rate-limit probes to their addresses:
   - If probes to an address are rate-limited, we would expect some successful responses followed by losses
   - We detect rate-limiting by identifying addresses which consistently responded to less than half of the probes sent to them after a successful response

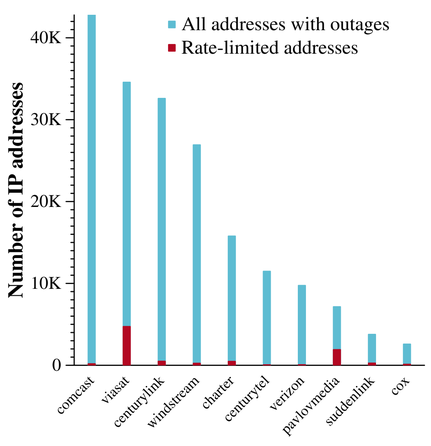


Fig 2: Among the 10 ISPs with most addresses that had outages detected by ThunderPing between Jun 1 through Sep 30 2017, 8 did not appear to rate-limit probes and 2 only appeared to rate-limit probes sent to some addresses

Categorize outages by analyzing correlated failures

Correlated failures suggest cause:

1. A power outage in an area would cause multiple addresses belonging to multiple ISPs to fail simultaneously.
2. A network outage would cause multiple addresses belonging to a single ISP to fail simultaneously.
3. Home users powering down their Internet equipment will typically cause only a single address to fail at a time.

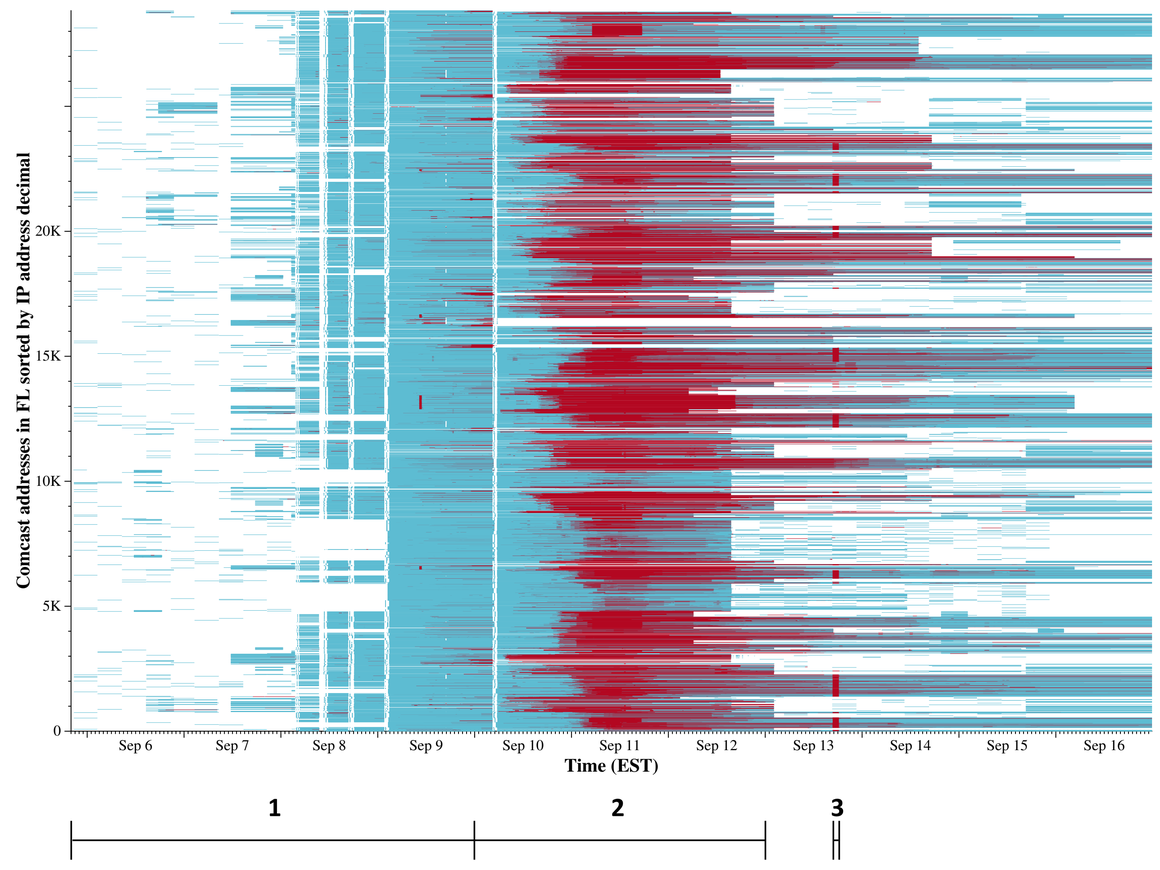


Fig 3: Failure and recovery of Comcast IP addresses in Florida before and after Hurricane Irma.

1. Most pinged IP addresses are responsive until Sep 10.
2. 82% of addresses experienced at least one outage between Sep 10 and Sep 12.
3. On Sep 13, 813 Comcast IP addresses in FL failed at 16:40 and recovered at 18:15. Correlated failures affecting addresses in a single ISP suggests a network failure. We found evidence of this failure in the outages mailing list.

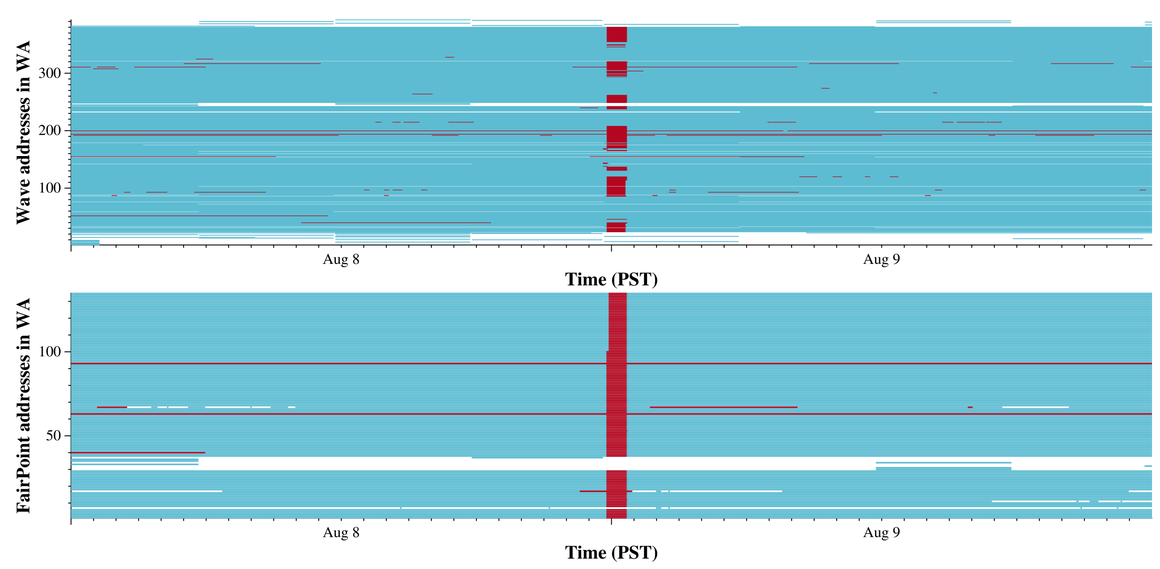


Fig 4: At local time 23:50 on Aug 8 2017, 163 addresses from Wave Broadband and 88 addresses from FairPoint Communications failed. All these addresses recovered at 00:42 on Aug 9 2017.
Correlated failures from multiple ISPs suggests a power outage

Ongoing Work

1. Probe addresses outside the U.S. as well.
   - Even in ISPs with frequent dynamic addressing, correlated periods where previously responsive addresses cease to respond are likely outages.
2. Probe addresses in other scenarios where outages are likely.
   - Use recent history of BGP routing churn events, censorship prone addresses, unusual drop in IP address activity (From darknet, CDN logs etc.).
3. Probe addresses to increase the likelihood of detecting simultaneous failures when they occur.
   - Find **related addresses** that share features, such as ISP, geography, network topology [4], common dynamic addressing pools [3].

REFERENCES:

1. Aaron Schulman and Neil Spring. Pingin' in the Rain. In *IMC* Berlin, November 2011.
2. Ramakrishna Padmanabhan, Patrick Owen, Aaron Schulman, and Neil Spring. "Timeouts: Beware Surprisingly High Delay". In *IMC* Tokyo, November 2015.
3. Ramakrishna Padmanabhan, Amogh Dhamdhere, Emile Aben, kc claffy, and Neil Spring. "Reasons Dynamic Addresses Change". In *IMC* Los Angeles, November 2016.
4. Youndo Lee and Neil Spring. Identifying and Aggregating Homogeneous IPv4 /24 Blocks with Hobbit. In *IMC* Los Angeles, November 2016.