The Challenge of Partial Reachability in Active Measurement

John Heidemann, Guillermo Baltra, Tarang Saluja, Yuri Pradkin

Abstract

A number of systems study Internet outages, looking to detect when people drop off the network. We suggest that *partial reachability* is a problem affecting even more people than outages–when Internet users in some locations cannot reach other parts of the Internet because of persistent network unreachability. We infer partial reachability by reanalyzing data from Trinocular outage detection and RIPE Atlas. We show that partial reachability is at least as common as outages in Trinocular, that it accounts for more than half of the problems seen in RIPE's DNSmon, and we suggest that it is at root of corner cases in other Internet-wide measurement platforms.

Venue

This invited talk was given at the CAIDA AIMS (Active Internet Measurement) Workshop on 2026-02-24.

This talk is based on the paper "Understanding Partial Reachability in the Internet Core" to appear at ACM NINeS in March 2026; https://ant.isi.edu/%7ejohnh/PAPERS/Baltra26a.pdf

Acknowledgments

This work was supported in part by NSF EIEIO/CNS-2007106, MINCEQ/2028279, BRIPOD/2530698, and DARPA contract AQUARIUS/HR001124C0403. Prior work was supported by NSF and DHS HSAPRRPA Cyber Security Division. The views herein are those of the authors and do not necessarily represent those of DHS or the U.S. Gov't.

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at CAIDA AIMS

2026-02-24

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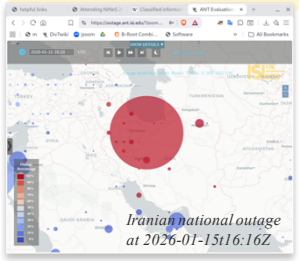
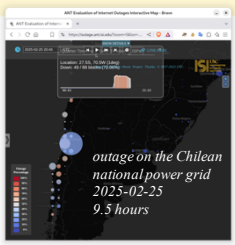
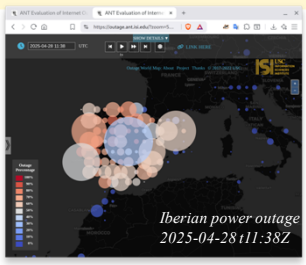
Internet Outages are a Big Deal



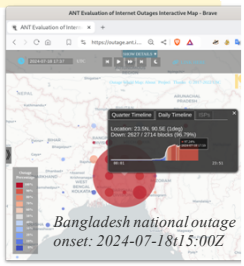
Iranian national outage at 2026-01-15t16:16Z



outage on the Chilean national power grid 2025-02-25 9.5 hours



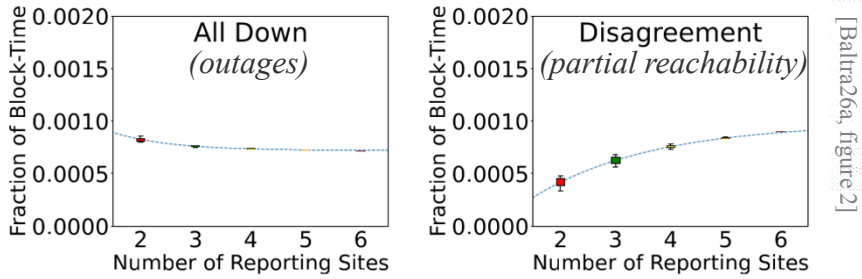
Iberian power outage 2025-04-28 t11:38Z



Bangladesh national outage onset: 2024-07-18t15:00Z

- we measure them today
  - we built Trinocular in 2013 and have run it since
  - others built Thunderping, IODA, and commercial versions
- about 0.075% of the Internet is down at any moment

Partial Reachability is at least as big!



[Baltra26a, figure 2]

- about 0.075% of the Internet is down at any moment (left)
- about 0.080% of the Internet is partially reachable (right)

Today's Contributions

- defining the problem: partial reachability
- an algorithm to detect it: Taitao
- some initial results

- for context and more details: "Understanding Partial Reachability in the Internet Core" at ACM NINeS, Feb. 2026, https://dx.doi.org/10.4230/OASIcs.NINeS.2026.4

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Outage Detection (Un)Certainty

- **Trinocular** observes from 6 sites
  - LA, Denver, Washington/DC, Tokyo, Netherlands, Greece
- tested against several other systems
- and tested against *itself*… we compare the 6 sites
  - we vote to get **a single** answer
- but is it *correct*?

  …**but what about when our six sites *don't* agree?**
  - **measurement error? bugs?**
  - **or something else?**

We Need Better Theory to Explain Partial Outages

- outage detection has struggled with partial outages for years…
  - ThunderPing (2011) *hosed* state—some pings work and some don't‘
  - Trinocular (2013): precision improvement small diffs are timing
  - CDN (Richter, 2018): maybe it's outages in *part* of the /24?
  - Trinocular (2019): majority voting for long disagreements
  - other systems ignore conflicting data
- common problem:
  no theory explaining disagreement in reachability observations

Premise 1: **Partial Reachability is Real**

- agreements are typical
- *some* disagreement is measurement error
  - ex: timing variation between sites (transient disagreement)

time	truth	A	B	belief
1:00	up	+		up
1:01	down			up (*wrong!)
1:02	down		-	conflicting
1:11	down	-		down (aggreeing)
1:13	down		-	down
1:22	down	-		down
1:24	down		-	down

Premise 1: **Partial Reachability is Real**

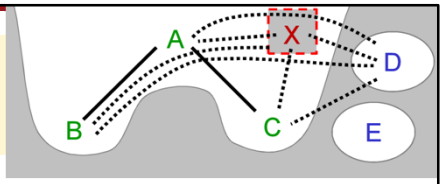
- agreements are typical
- *some* disagreement is measurement error
  - ex: timing variation between sites (transient disagreement)
- but **persistent disagreement is real:**
  => partial reachability in the Internet

time	truth	A	B	belief
1:00	up	+		up
1:01	partial			true partial reach.
1:02	partial		+	
1:11	partial	-		**confirmed partial**
1:13	partial		+	
1:22	partial	-		
1:24	partial		+	

Outages Given Partial Reachaility

- **true outages** are disconnected from the Internet (or off)
- **partial rechability is also real**
  - disagreements observing reachability happen!
  - don't try to rationalize them away

Partial Reachability is a **Peninsula**



- two locations (ASes) cannot reach each other, but *can* reach others (B-C)

- routing transients make many short-lived peninsulas
  - see "Internet Optometry" by Bush et al, ACM IMC 2009
- sometimes persistent
  - peering disputes: like Cogent/HE peering dispute around IPv6
  - routing misconfiguration
  - firewalls

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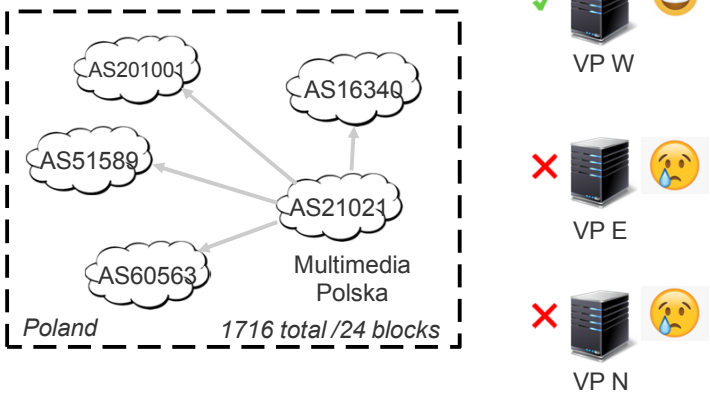
A Peninsula in Poland

On 2017-10-23,
for 3 hours from 22:02Z

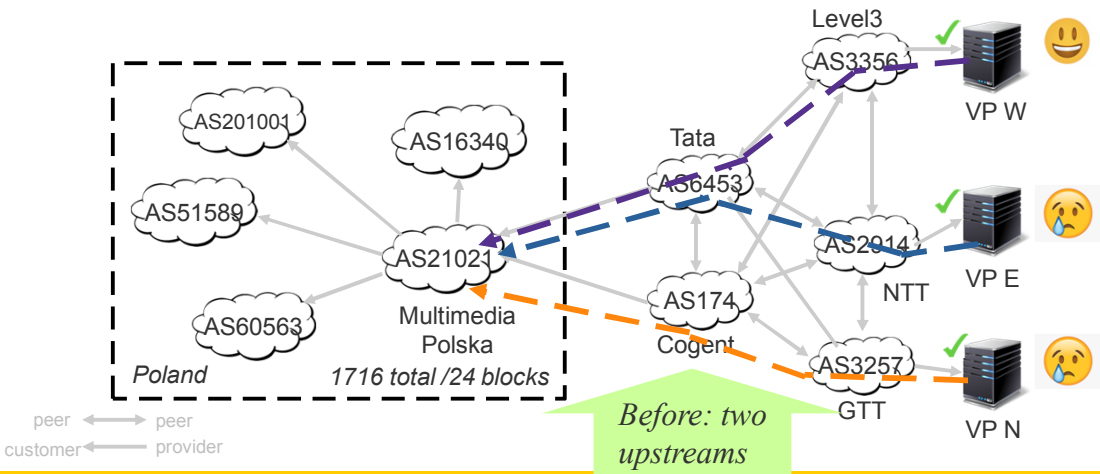
one VP (W)
could reach 5 Polish ISPs

but 5 others could not.

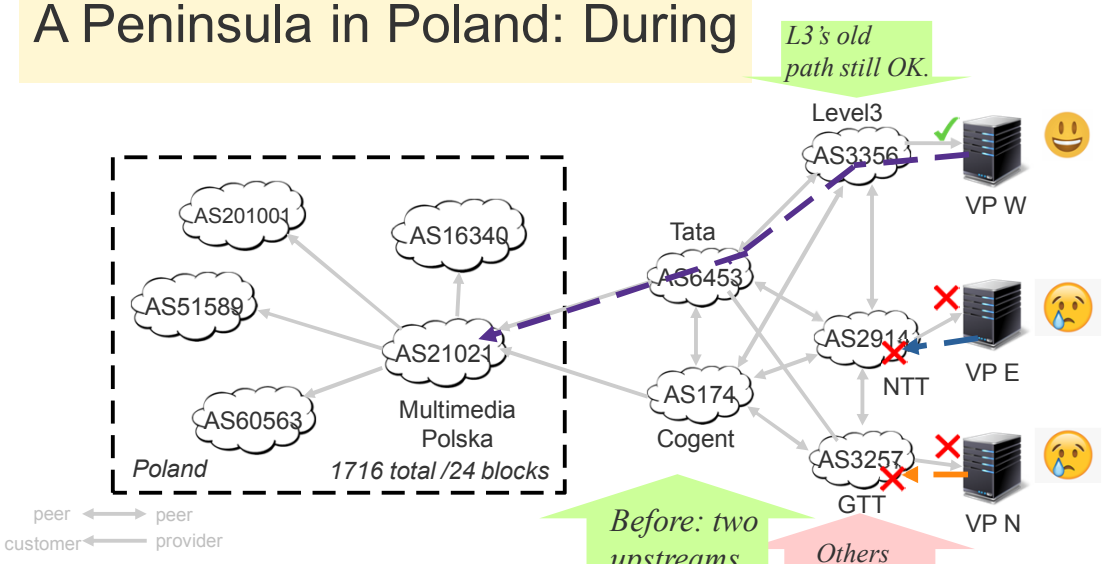
=> A peninsula! *Why?*



A Peninsula in Poland: Before

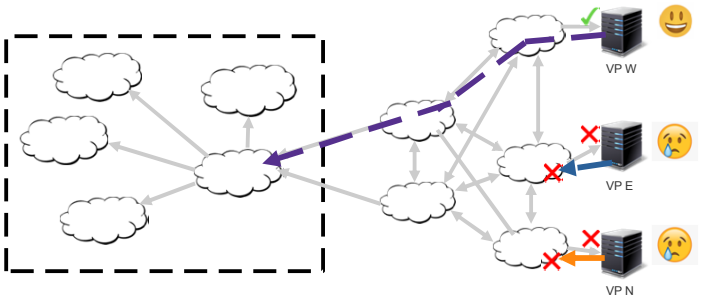


A Peninsula in Poland: During



Taitao: An Algorithm to Detect Peninsulas

- idea: probe a target network from several independent VPs
- if they disagree (some reach and others don't) => peninsula



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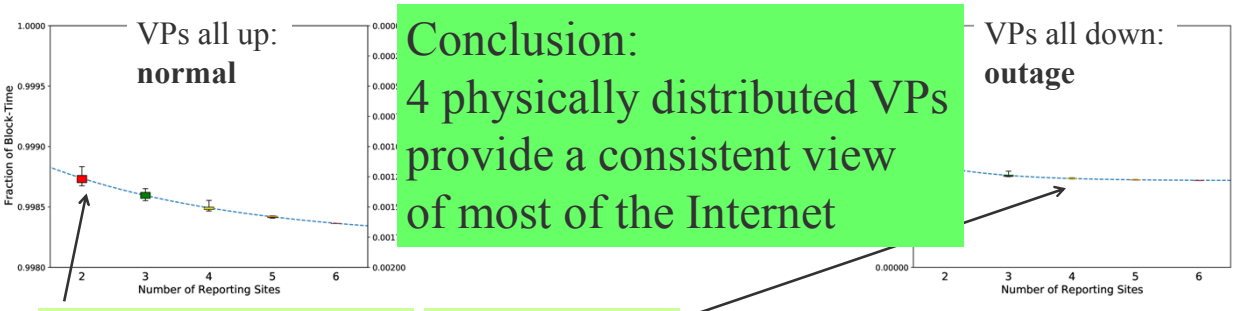
Outages from *N* Vantage Points

Compare: Taitao for 40 days (start 2017-10-06), compare all combinations of 2 to 6 VPs.



Conclusion:
4 physically distributed VPs provide a consistent view of most of the Internet

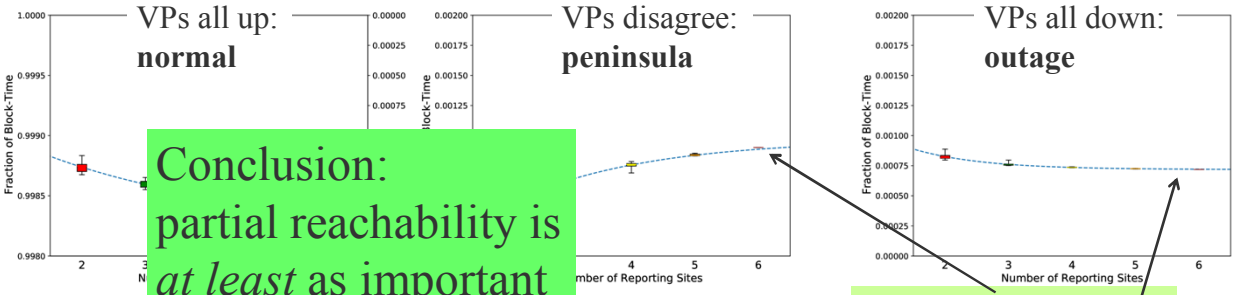
variance is small:
⇒VPs are *independent*
(any 2 give the same result)

values converge
(4 VPs ≈ 6 VPs)
⇒VPs are *enough*

How Common Are Peninsulas?

(disagreement in reachability)

Compare: Taitao for 40 days (start 2017-10-06), compare all combinations of 2 to 6 VPs.



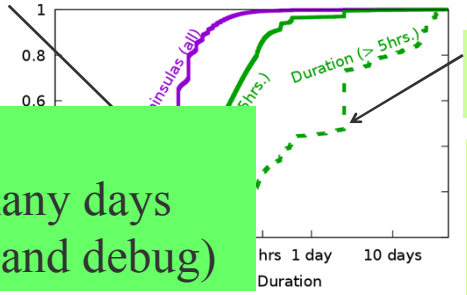
Conclusion:
partial reachability is *at least* as important as outages!

as many peninsulas as outages
(each ~0.075% of time)
⇒peninsulas matter!

How Long Do Peninsulas Last?

Methodology:
Taitao for 2017q4
(90 days)

Most peninsula events are short-lived (33% less than 60 minutes) => routing transients



some last 2+ days => policy disagreement

Conclusion:
some peninsulas last many days (enough time to detect and debug)

Users that see peninsulas see long-lasting ones (60% are ~2+ days).

Conclusions

- partial outages are a real problem
- we are just beginning to study them
- can this perspective help clarify *your* active measurements?

- more info?
  - data: https://ant.isi.edu/datasets/
  - details: “Understanding Partial Reachability in the Internet Core” at ACM NINeS, Feb. 2026, https://dx.doi.org/10.4230/OASIcs.NINeS.2026.4 and https://ant.isi.edu/~johnh/PAPERS/Baltra26a
  - or talk to me Tue. or Wed. this week