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Extracting Benefit from Harm: Using Malware Pollution to Analyze the Impact of Political and Geophysical Events on the Internet

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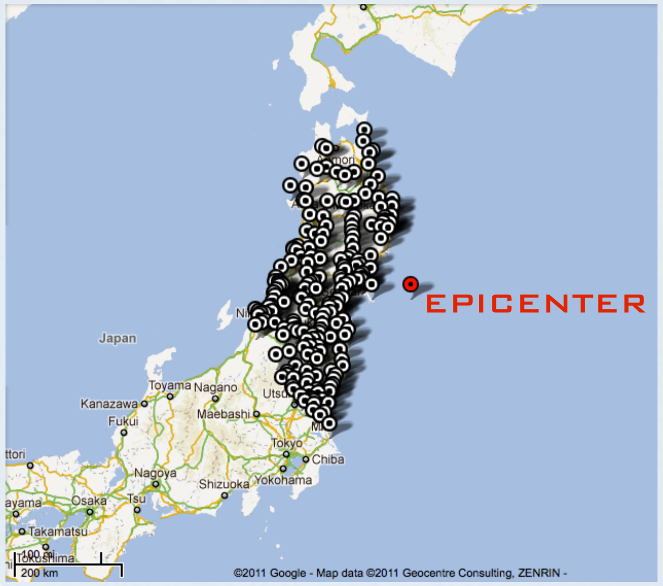
CONTEXT

Analysis of large-scale Internet Outages

- Country-level Internet Blackouts *(BGP withdrawals, packet-filtering, satellite-signal jamming, ...)*

EGYPT, JAN 2011
GOVERNMENT ORDERS TO SHUT DOWN THE INTERNET

- Natural disasters affecting the infrastructure/population

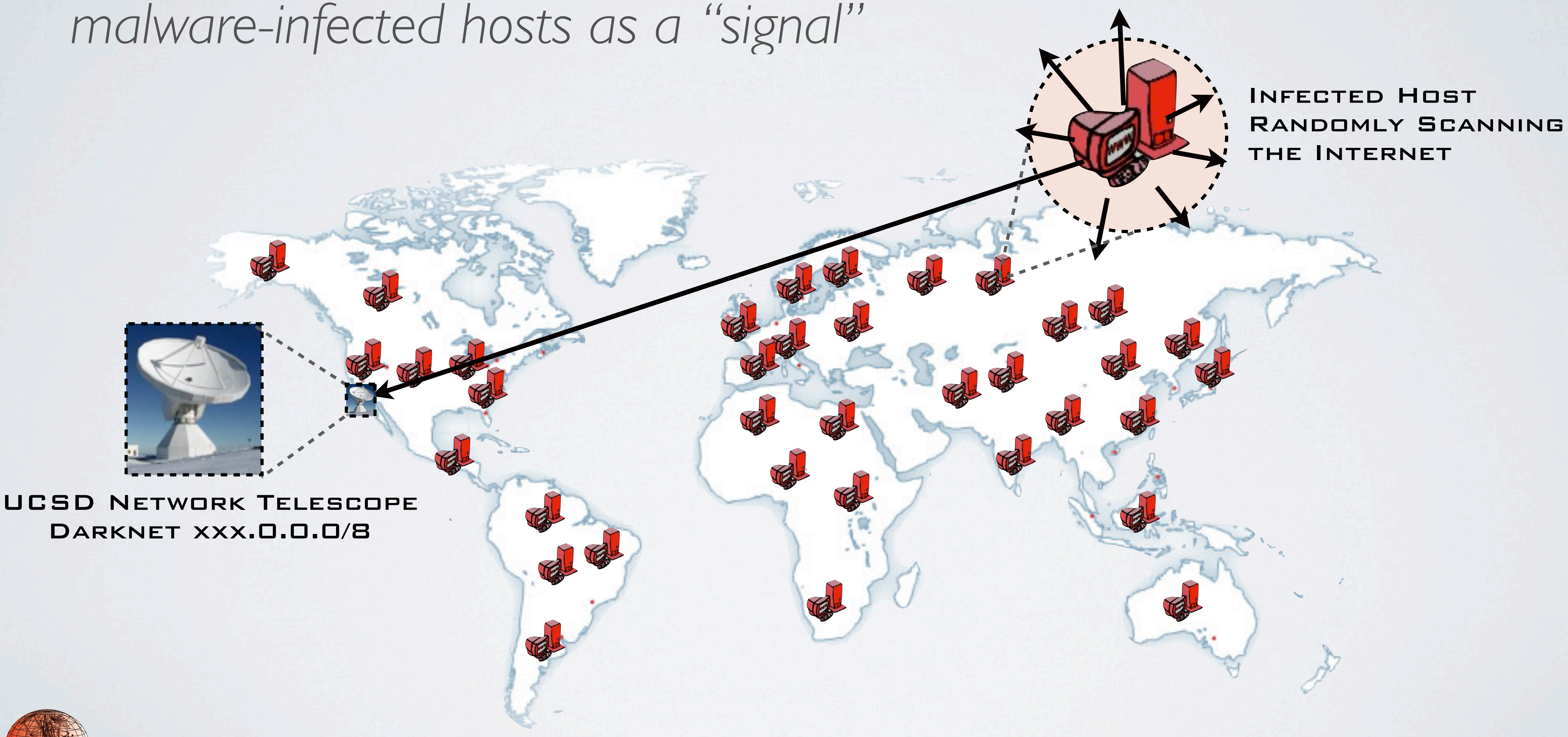


JAPAN, MAR 2011
EARTHQUAKE OF MAGNITUDE 9.0

IDEA

"Extracting benefit from harm.."

- Use *Internet Background Radiation (IBR) generated by malware-infected hosts as a "signal"*



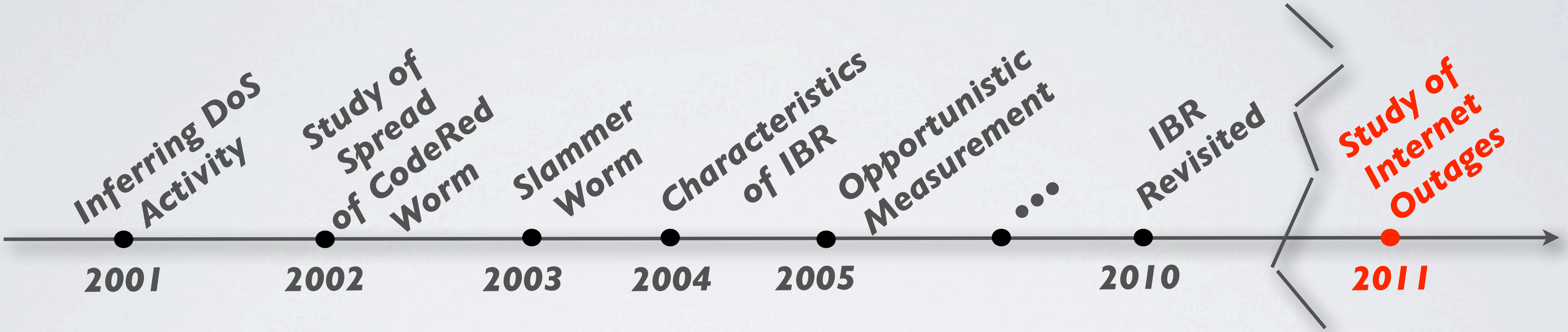
Infected Host Randomly Scanning the Internet

UCSD Network Telescope
Darknet xxx.0.0.0/8

NOVELTY

Using IBR to study Internet Outages

- Revival of Network Telescopes



Inferring DoS Activity

2001

Study of Spread of CodeRed Worm

2002

Slammer Worm

2003

Characteristics of IBR

2004

Opportunistic Measurement

2005

...

IBR Revisited

2010

Study of Internet Outages

2011

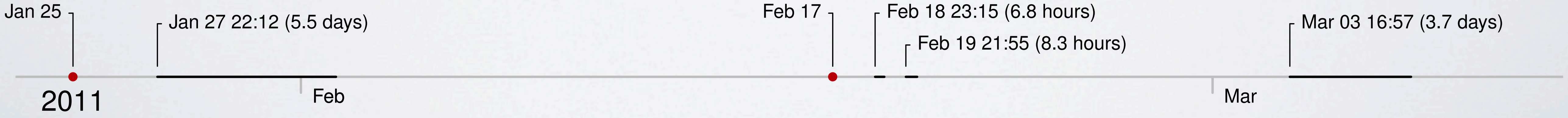
- Alternative/Complementary measurement approaches to study outages
  - *BGP* **[13][28]**
  - *Active Probing* **[20][42]**
  - *Passive Traffic* **[22][24]**
  - *Google services* **[13][14]**
  - *Peer-to-Peer traffic* **[5][6]**

THE EVENTS (1/2)

Internet Disruptions in North Africa

- Egypt
  - *January 25th, 2011*: protests start in the country
  - The government orders service providers to "shut down" the Internet
  - ***January 27th, around 22:34 UTC***: several sources report the withdrawal in the Internet's global routing table of almost all routes to Egyptian networks
  - The disruption lasts ***5.5 days***

- Libya
  - *February 17th, 2011*: protests start in the country
  - The government controls most of the country's communication infrastructure
  - ***February 18th (6.8 hrs), 19th (8.3 hrs), March 3rd (3.7 days):*** three different connectivity disruptions:



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NETWORK INFO

Prefixes, ASes, Filtering

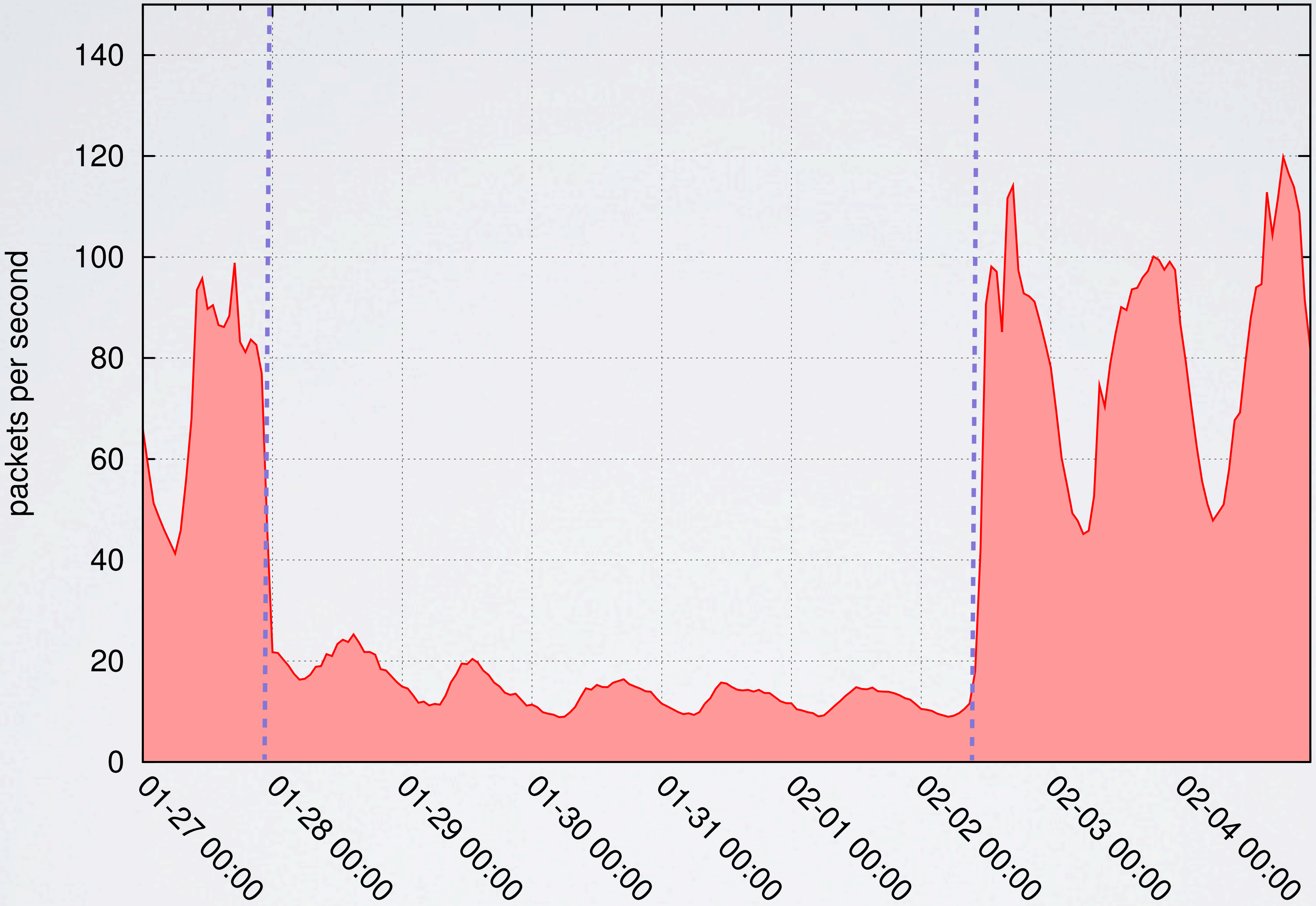
- Egypt
  - 3165 *IPv4* and 6 *IPv6* prefixes are delegated to Egypt by AfriNIC
  - They are managed by 51 Autonomous Systems
  - Filtering type: BGP only

- Libya
  - 13 *IPv4* prefixes, no *IPv6* prefixes
  - 3 Autonomous Systems operate in the country
  - Filtering type: mix of BGP, packet filtering, satellite signal jamming

A. Dainotti, C. Squarcella, E. Aben, K. C. Claffy, M. Chiesa, M. Russo, A. Pescapè,
"Analysis of Country-wide Internet Outages Caused by Censorship"
ACM SIGCOMM Internet Measurement Conference 2011

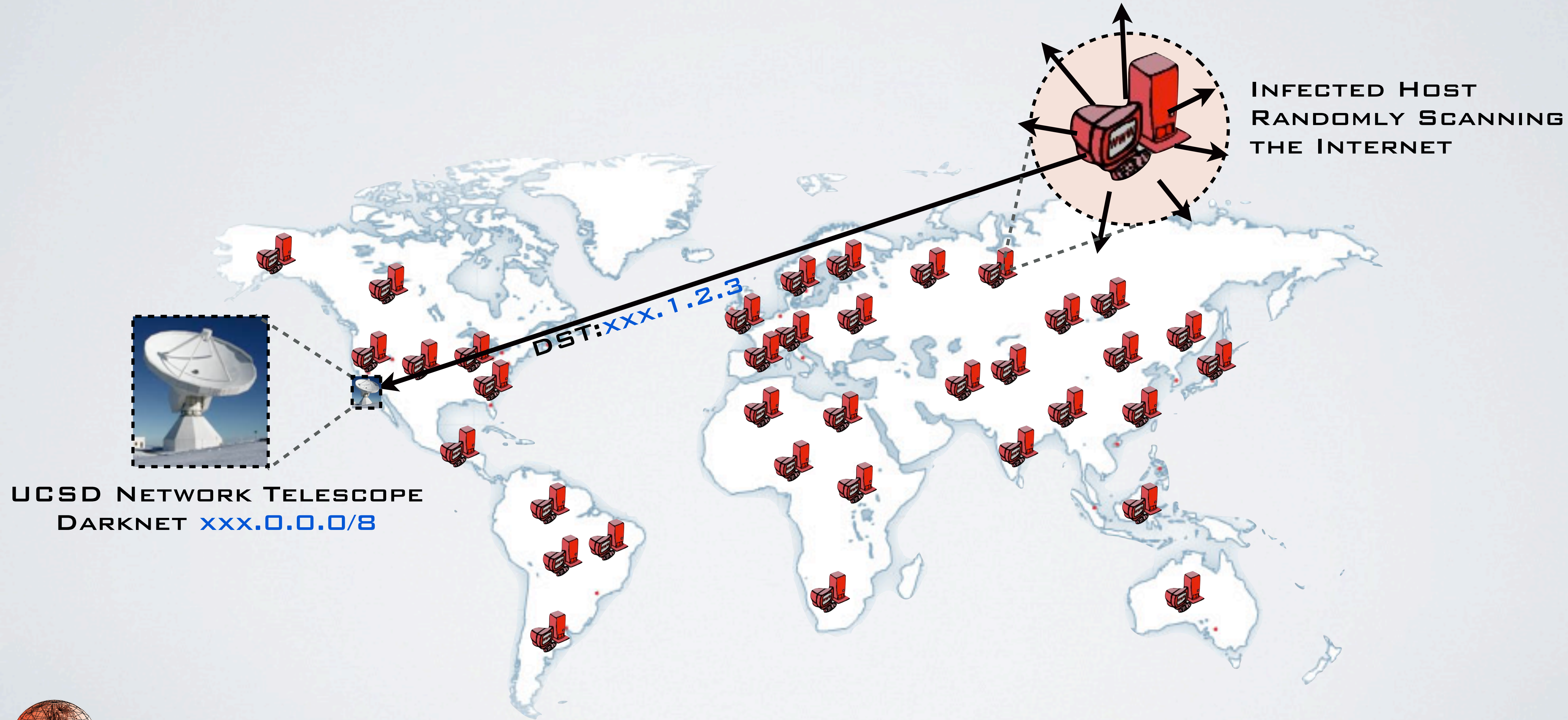
EGYPT

IBR: packet rate



RANDOM PROBING

E.g., Conficker



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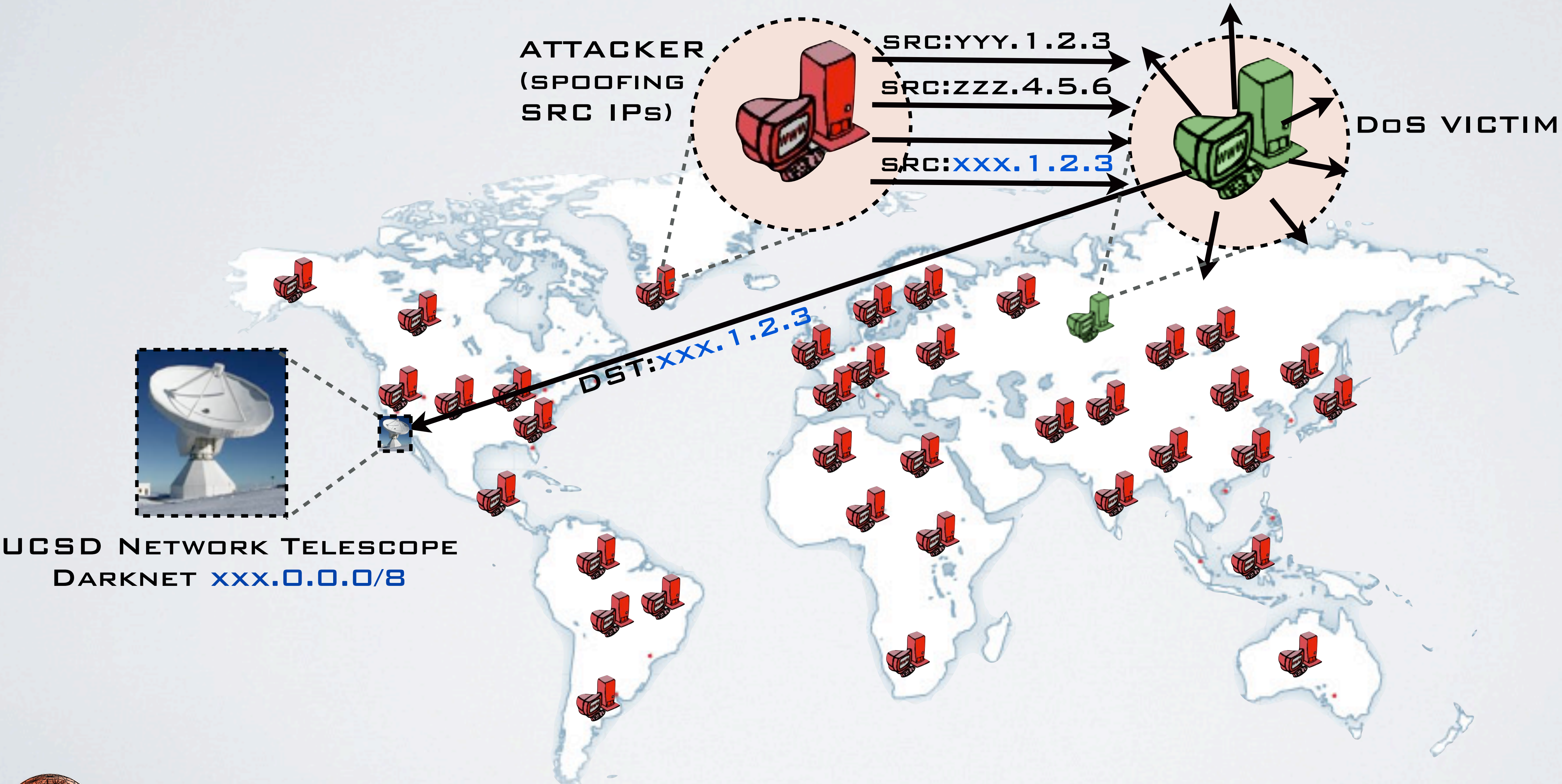
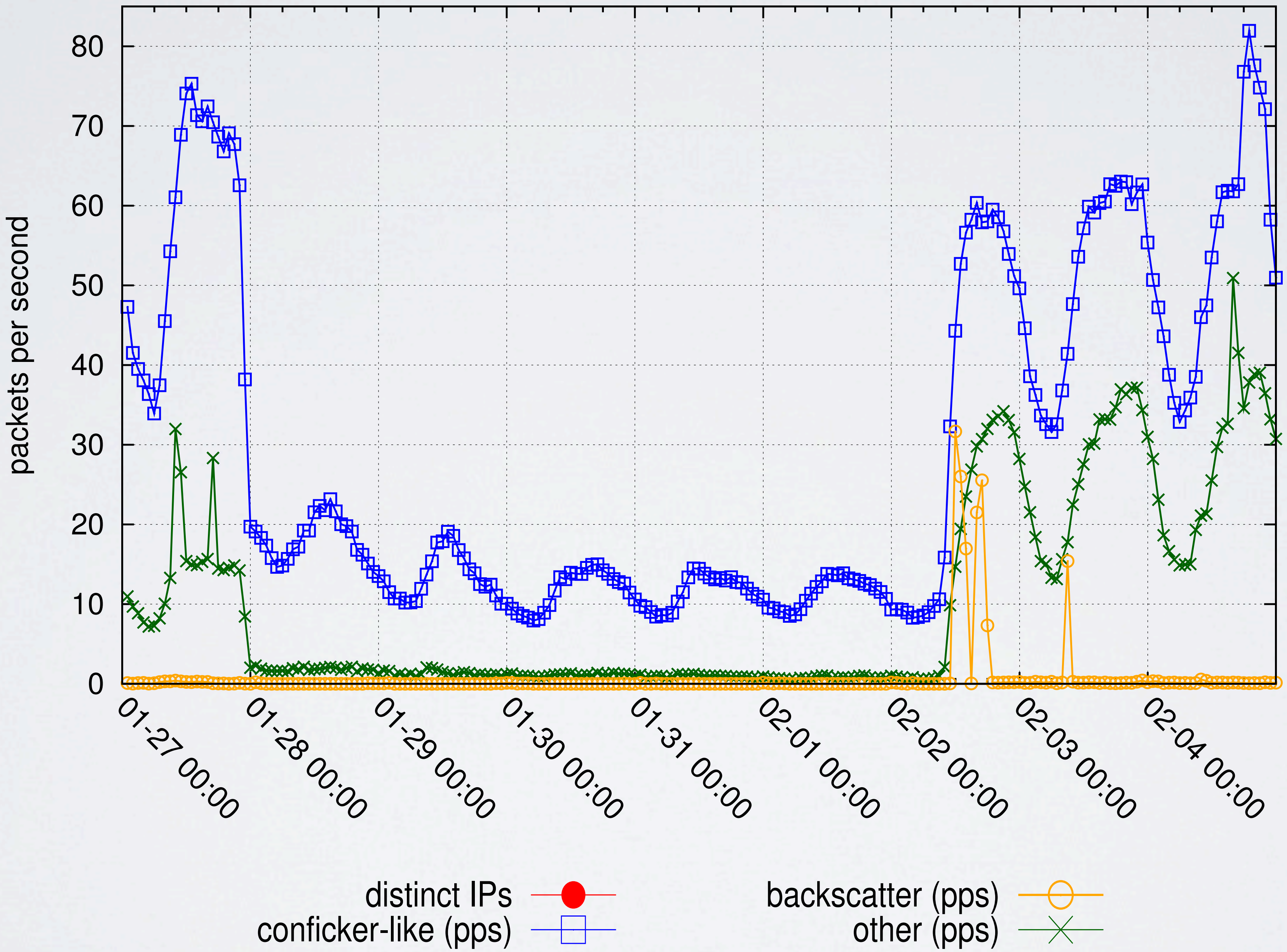
BACKSCATTER

e.g., SYN+ACK replies to spoofed SYNs



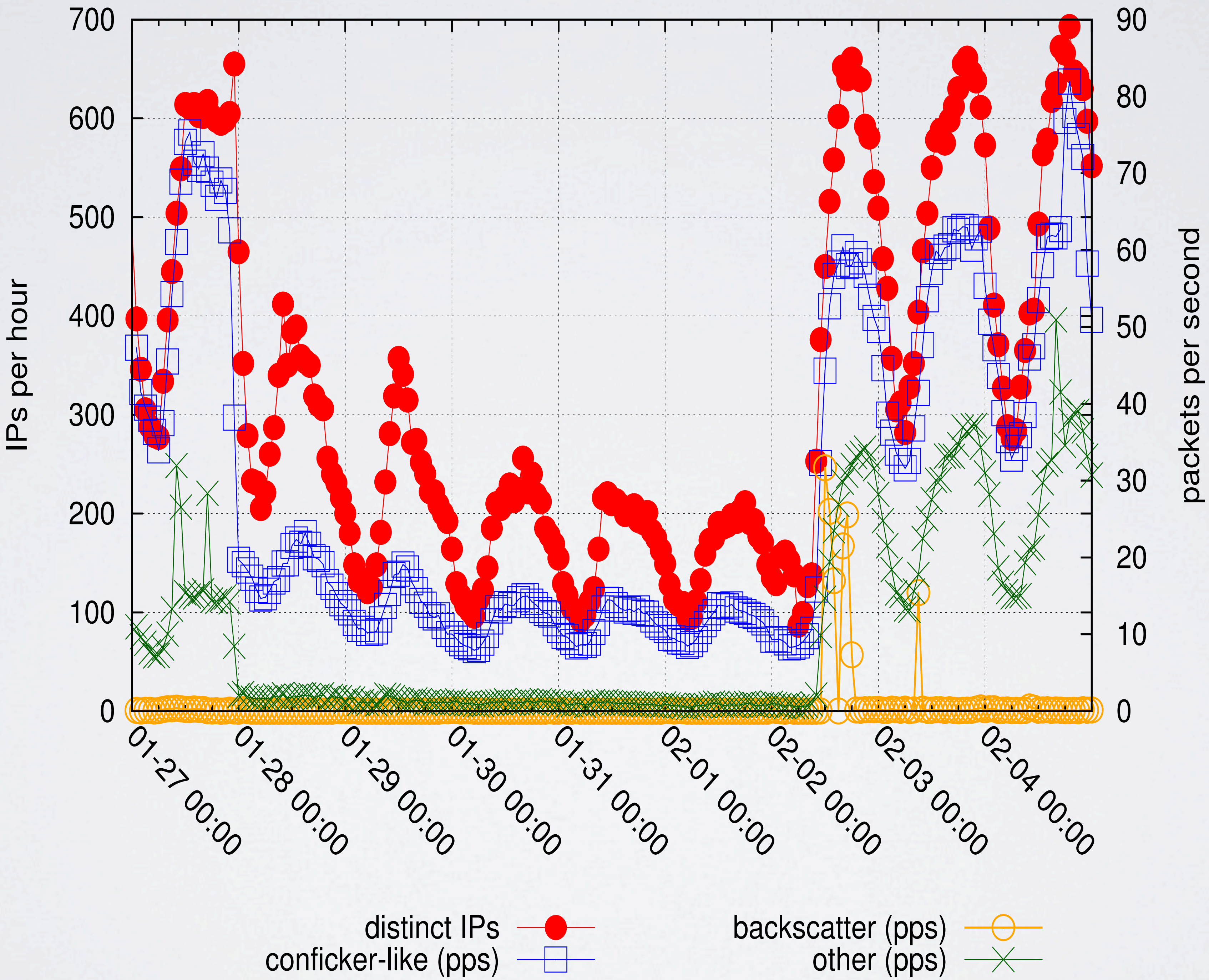
EGYPT

IBR: dissecting it



EGYPT

IBR: rate of distinct src IPs vs packet rate



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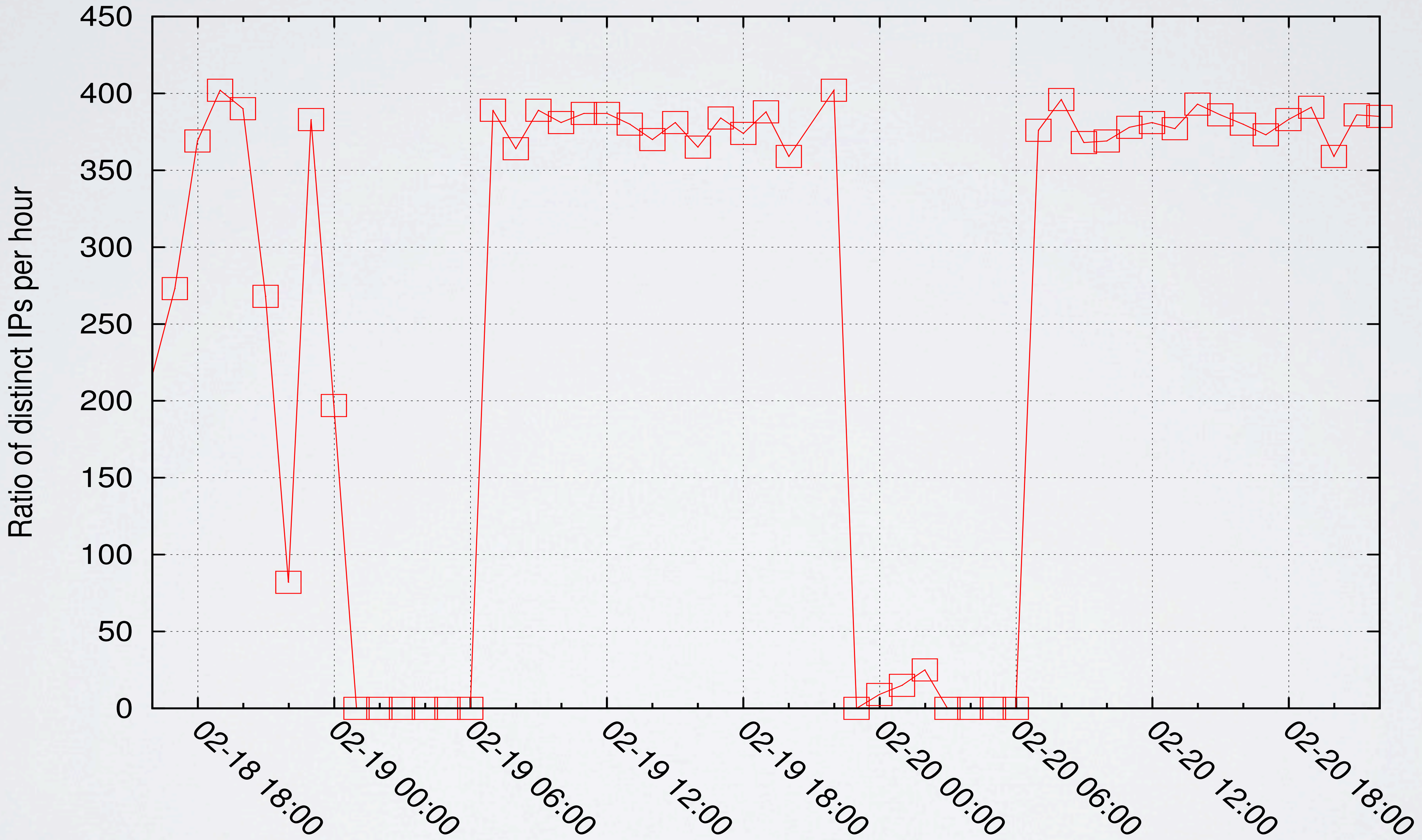
LIBYA

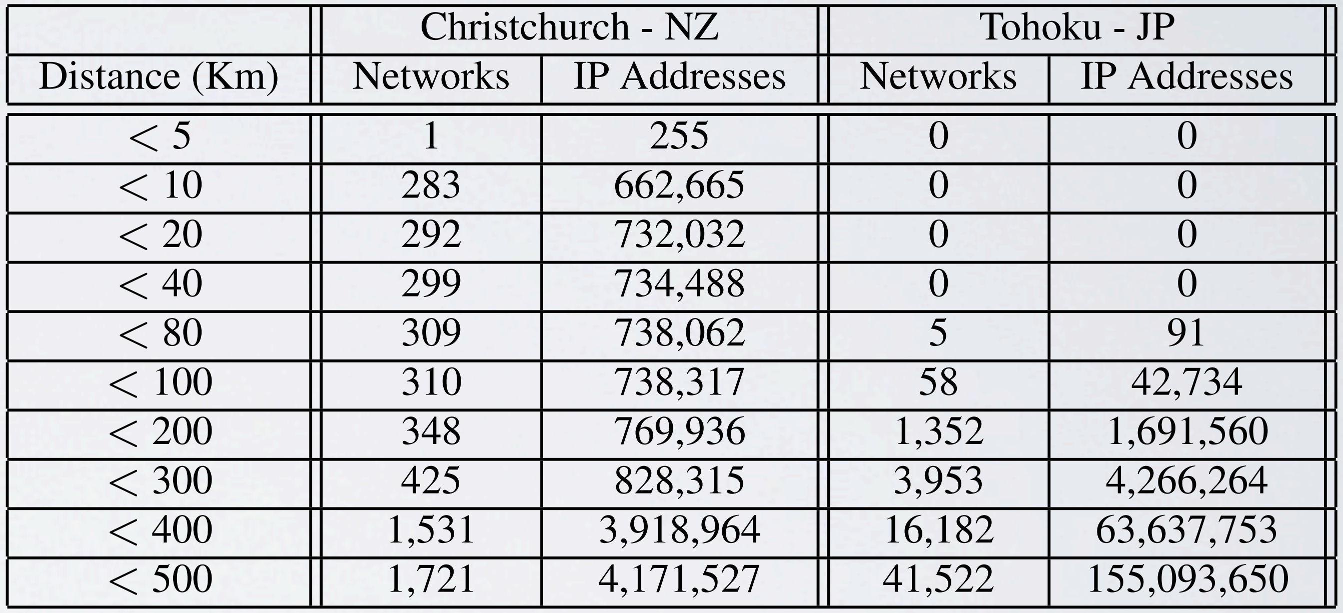
the first two outages



THE EVENTS (2/2)

Earthquakes

- Christchurch - NZ
  - *February 21st, 2011* 23:51:42 UTC
  - Local time 22nd, 12:51:42 PM
  - Magnitude: 6.1
- Tohoku - JP
  - *March 11th, 2011* 05:46:23 UTC
  - Local time 02:46:23 PM
  - Magnitude: 9.0



	Christchurch - NZ		Tohoku - JP	
Distance (Km)	Networks	IP Addresses	Networks	IP Addresses
< 5	1	255	0	0
< 10	283	662,665	0	0
< 20	292	732,032	0	0
< 40	299	734,488	0	0
< 80	309	738,062	5	91
< 100	310	738,317	58	42,734
< 200	348	769,936	1,352	1,691,560
< 300	425	828,315	3,953	4,266,264
< 400	1,531	3,918,964	16,182	63,637,753
< 500	1,721	4,171,527	41,522	155,093,650

We use MaxMind GeoLite City DB to compute distance from a given network to the epicenters

A SIMPLE METRIC

to evaluate impact and extension

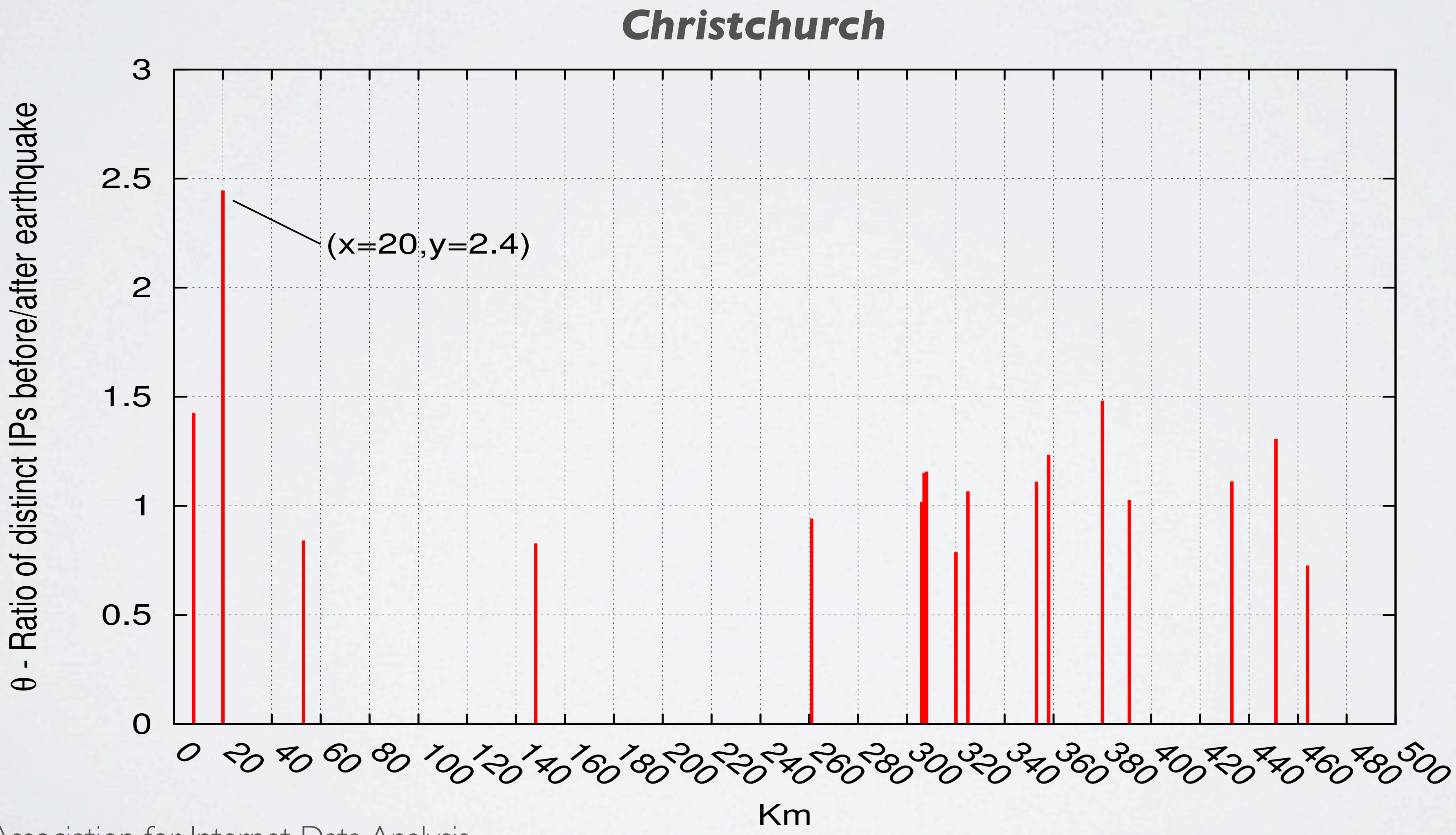
- $I_{\Delta t_i}$ number of distinct source IP addresses seen by the telescope over the interval **Δ**ti,
- $\Delta t_1, ..., \Delta t_n$ 1-hour time slots ***following*** the event
- $\Delta t_{-1}, ..., \Delta t_{-n}$ 1-hour time slots ***preceding*** the event

$$\theta = \frac{\sum_{i=-1}^{-24} I_{\Delta t_i}}{\sum_{j=1}^{24} I_{\Delta t_j}}$$

RADIUS OF IMPACT

rough estimate based on θ

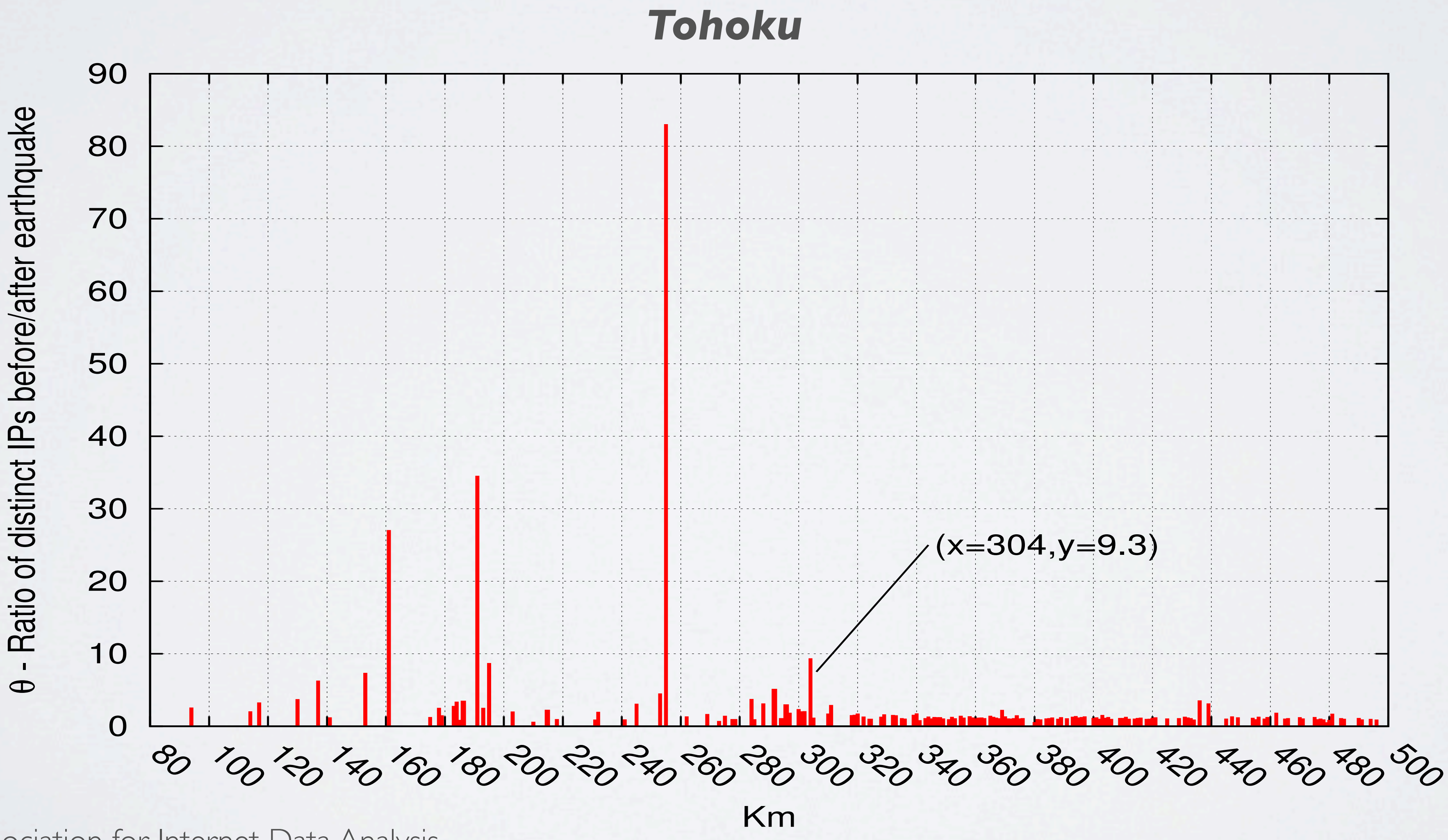
- We compute θ for address ranges geolocated at different distances from the epicenter of the earthquake *(0 to 500km in bins of 1km each)*
- θ around 1 indicates no substantial change in the number of unique IP addresses observed in IBR before and after the event.



RADIUS OF IMPACT

rough estimate based on θ

We call ρ_{max} the maximum distance at which we observe a value of θ significantly > 1



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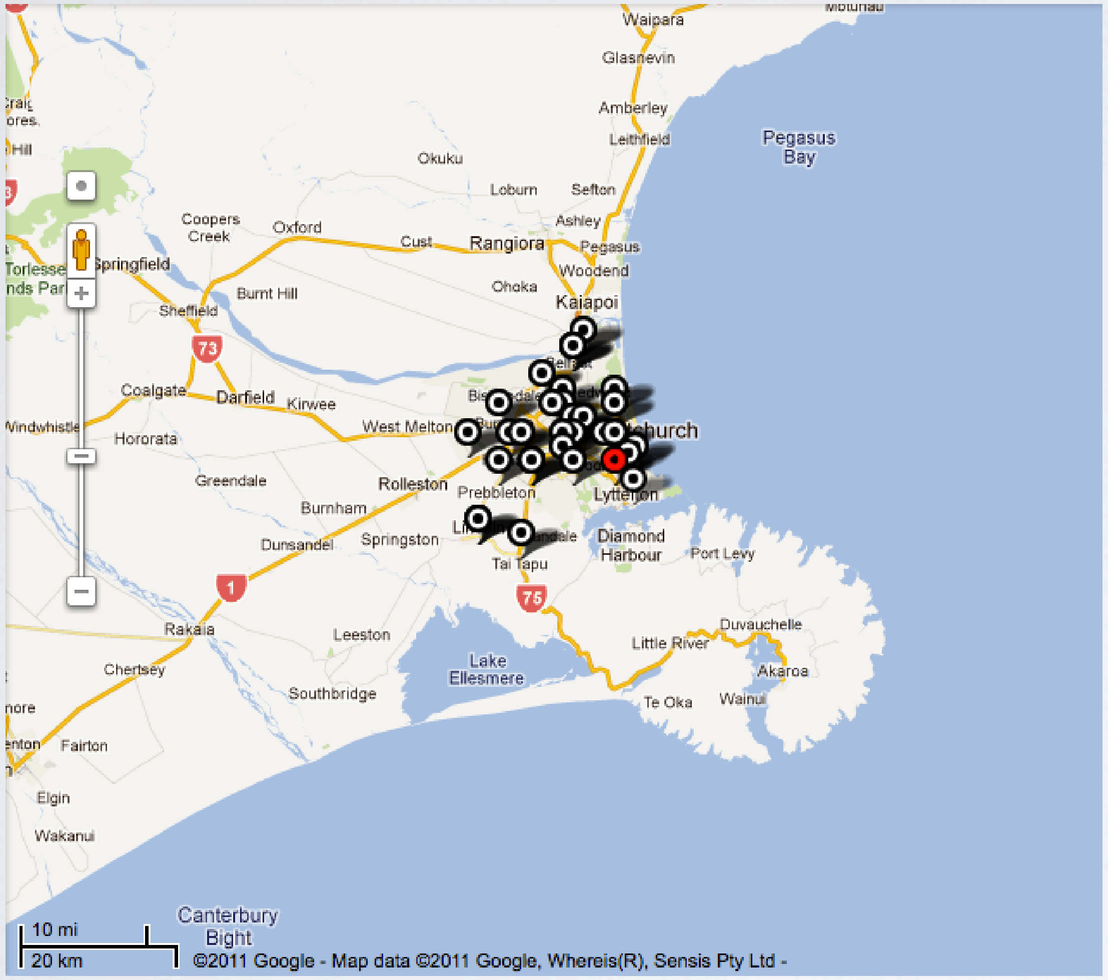
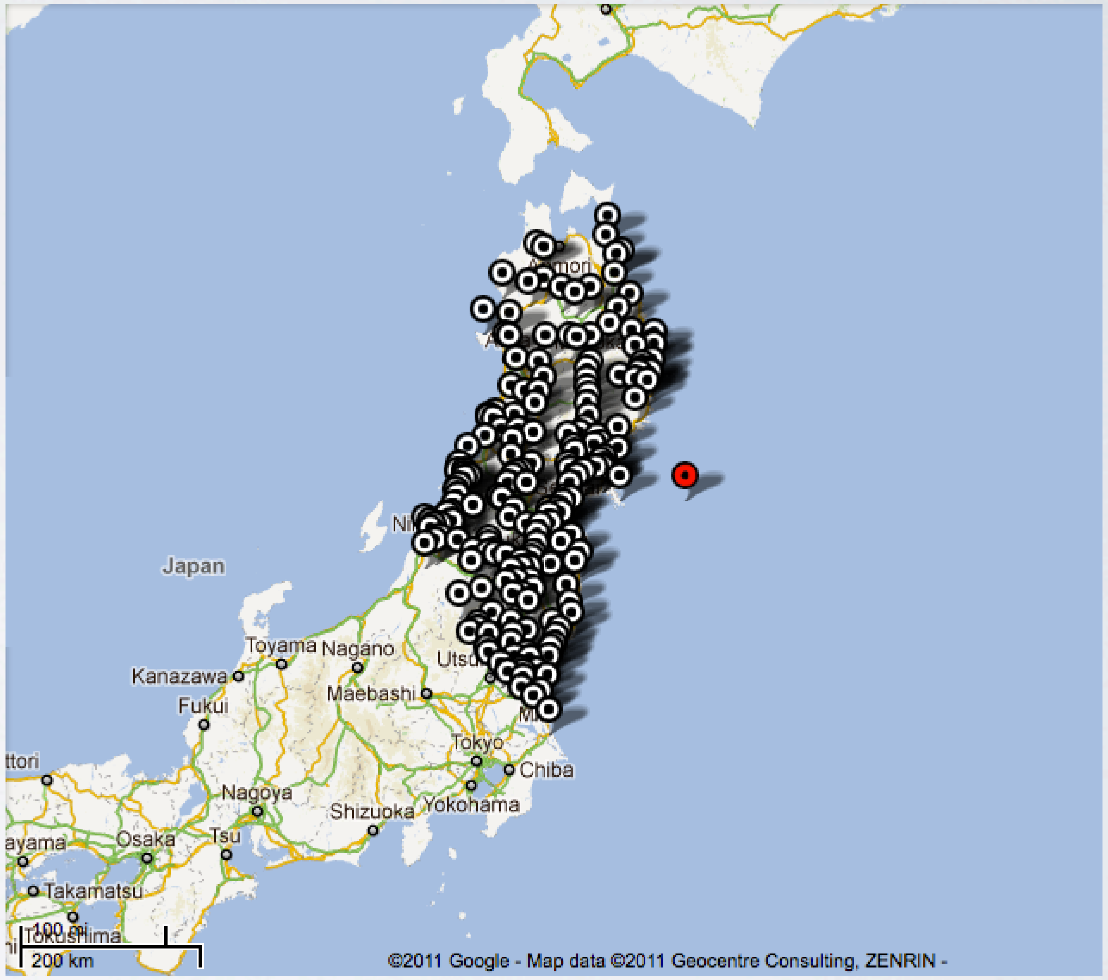
EXTENSION OF IMPACT

geo coordinates of most affected networks

Networks within each respective ρ_{max}



(a) Christchurch

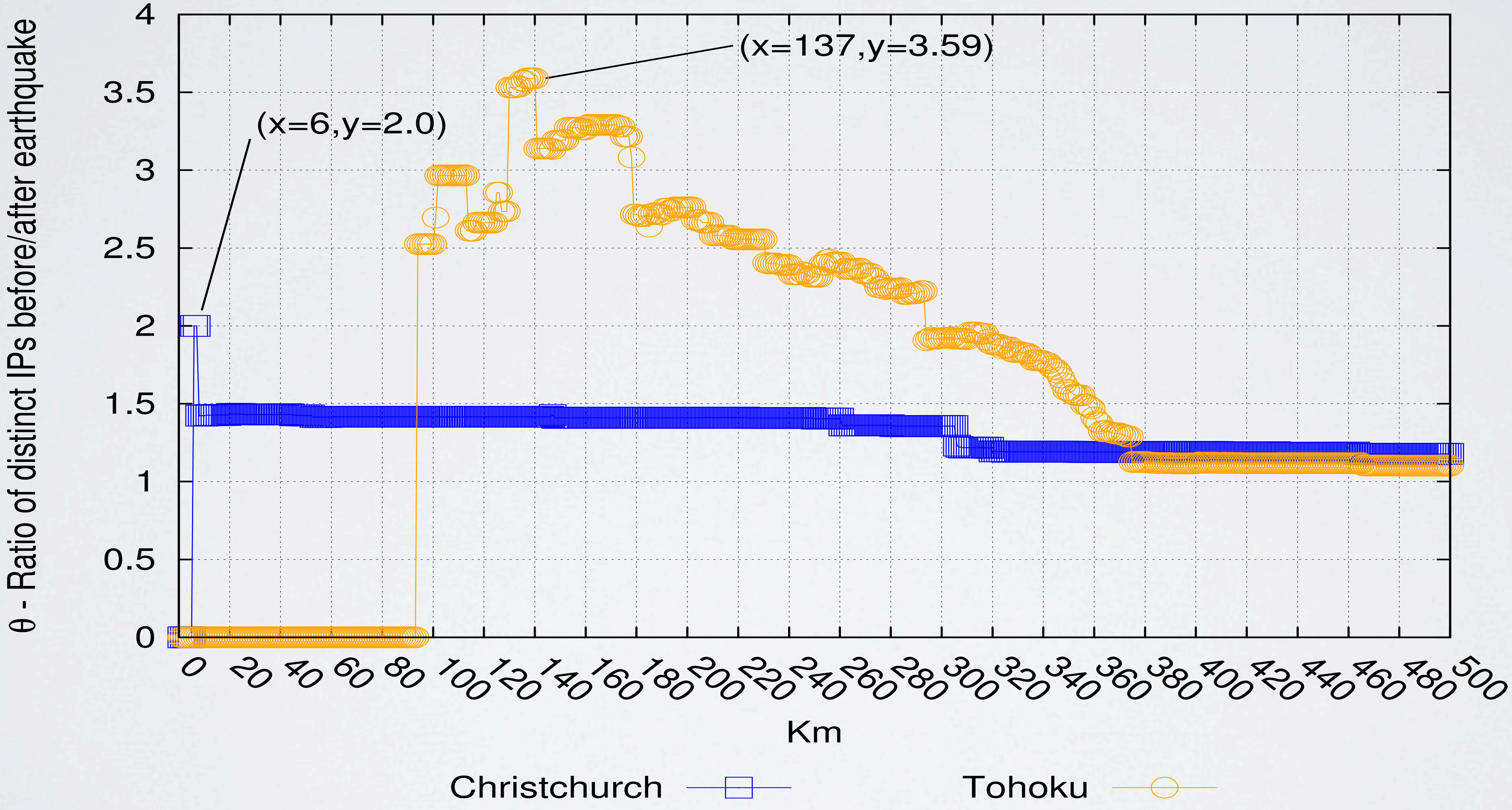


(b) Tohoku

“MAGNITUDE”

A measure of impact

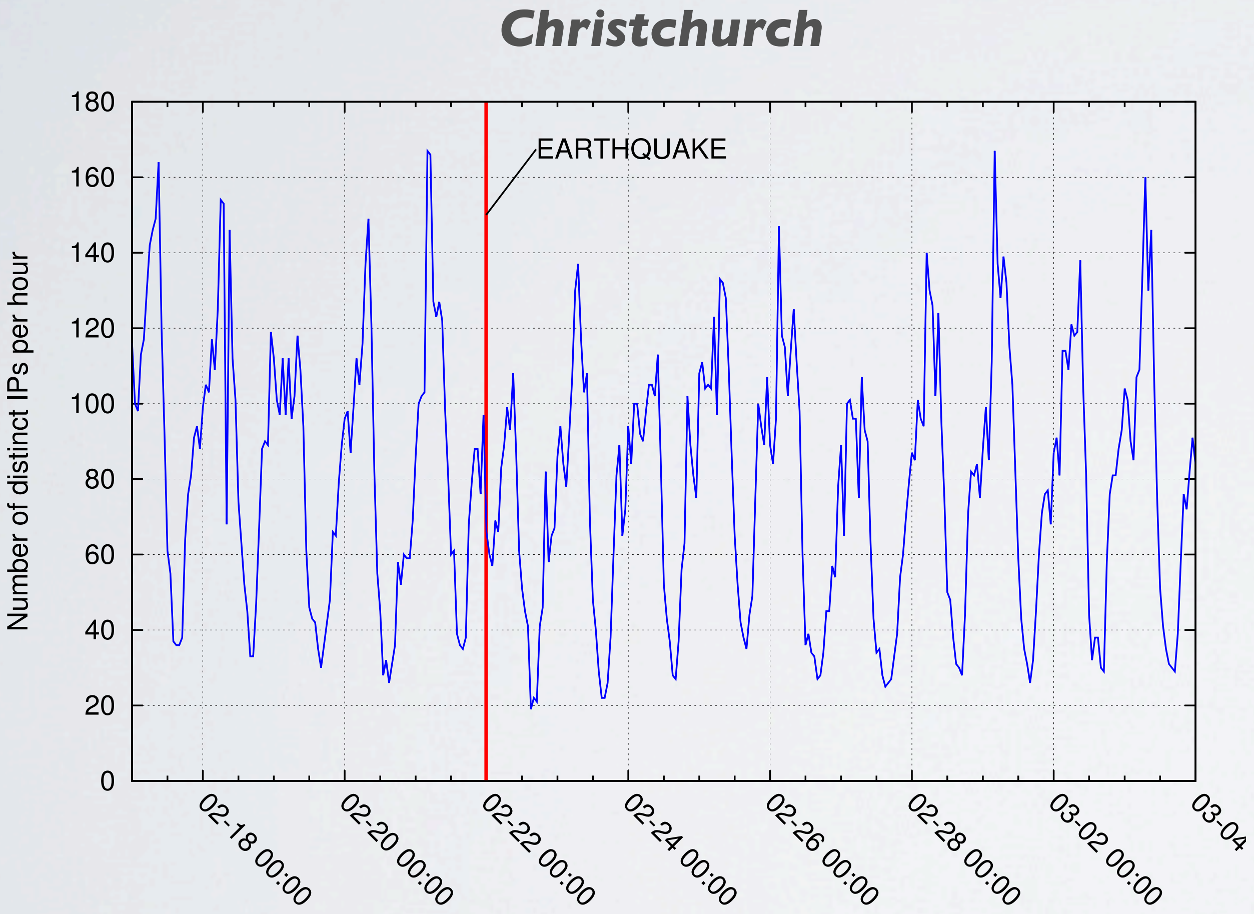
- Varying the radius, we pick the highest value of θ calculated for *the whole set of* networks within the corresponding circle

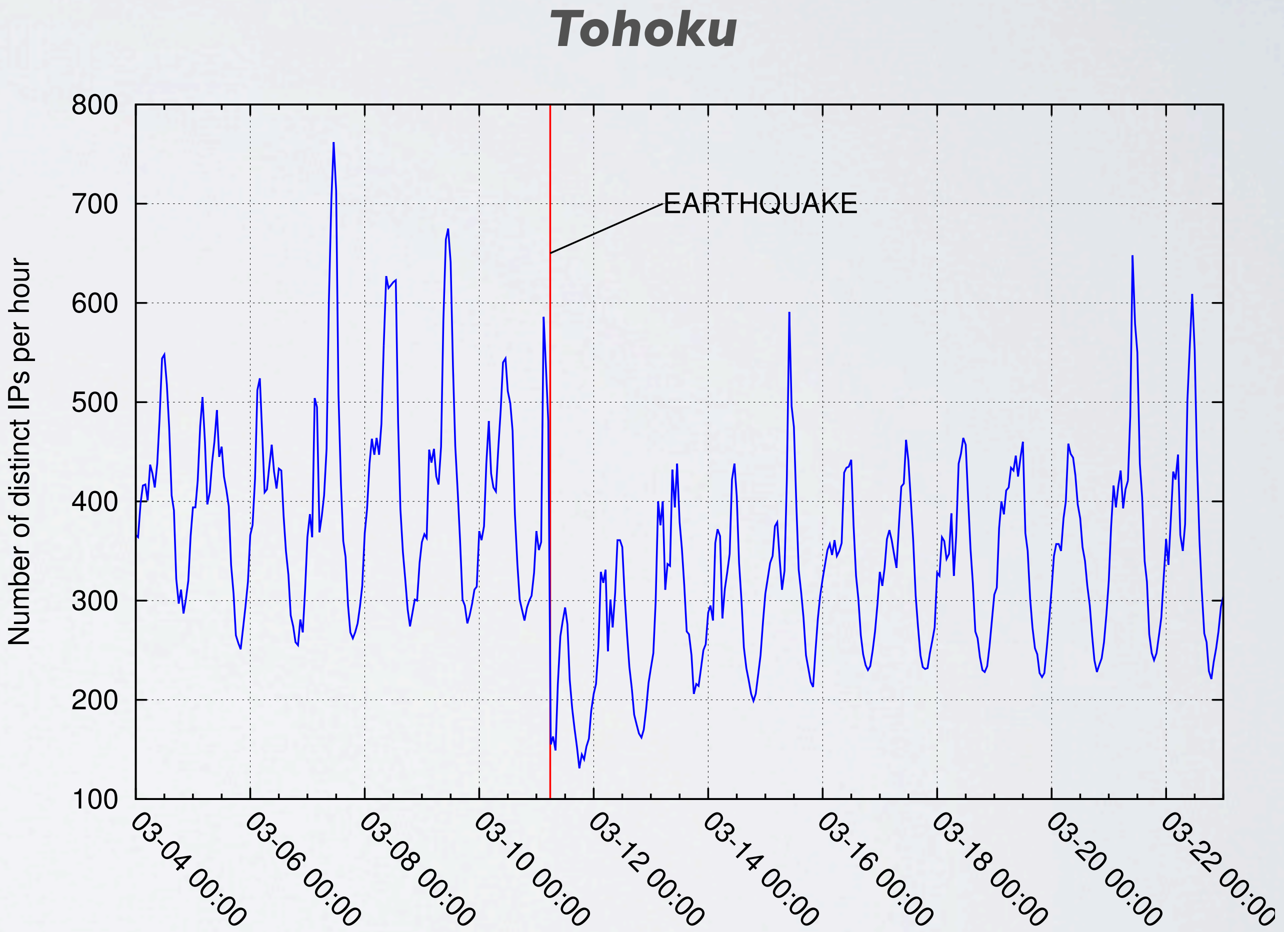


	Christchurch	Tohoku
Magnitude (θ_{max})	2 at $6km$	3.59 at $137km$
Radius (ρ_{max})	$20km$	$304km$

IP RATE IN TIME

reflects the dynamics of the event

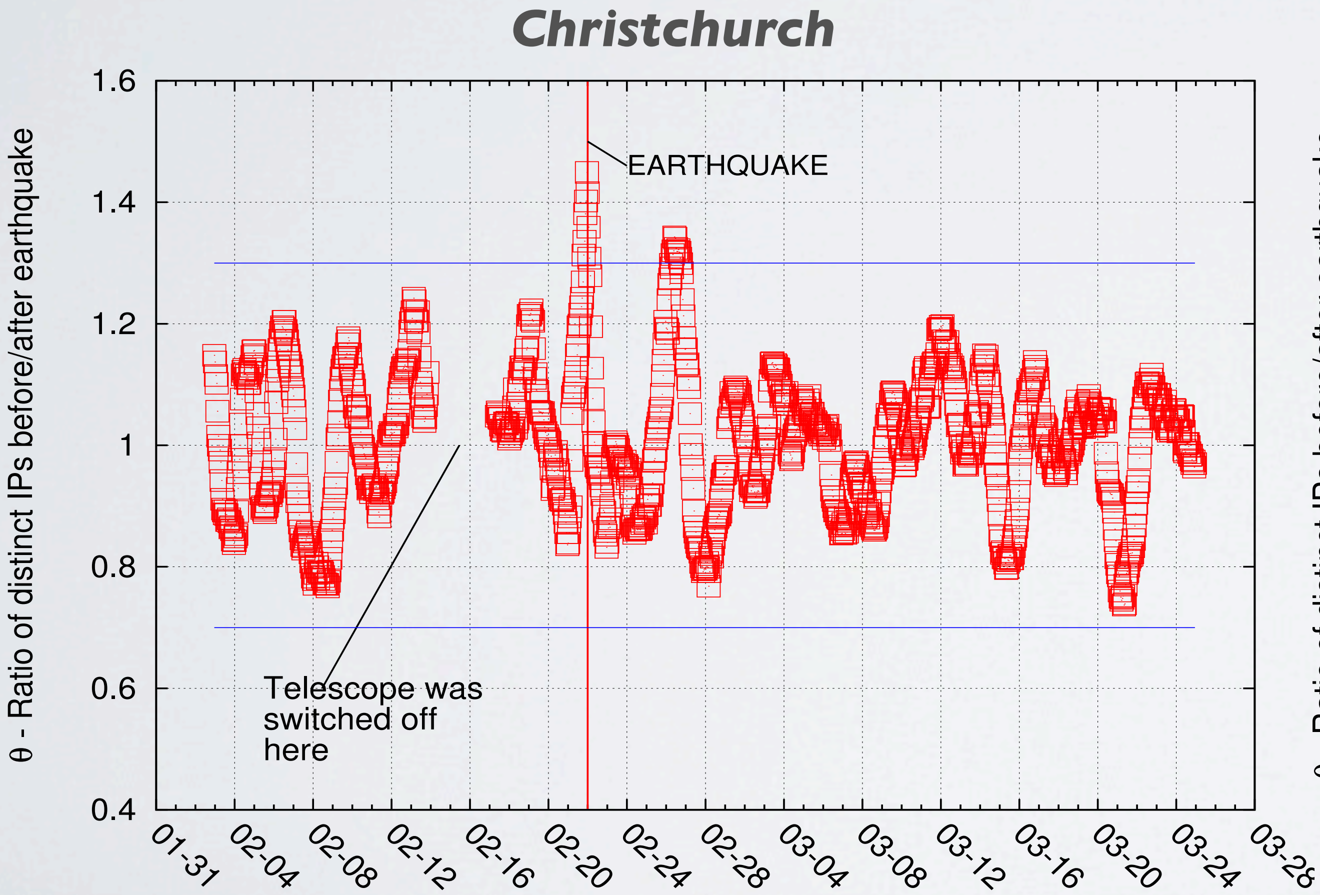


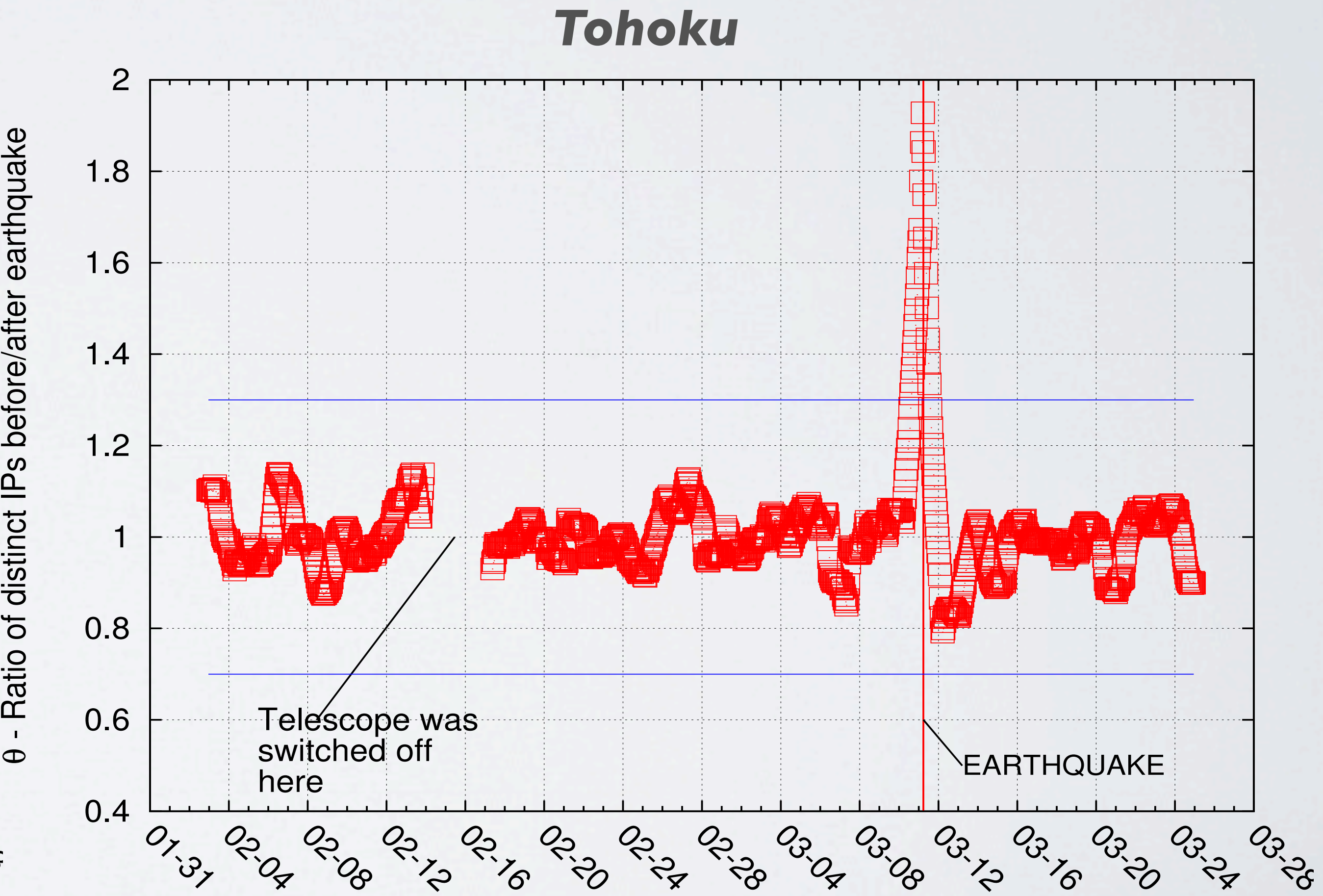


EVALUATING Θ

variations over a long time period

- 2 months period of observation
- θ normally stays within [0.7 - 1.3]





CONCLUSION

ongoing work

- IBR is an effective source of data for the analysis of network outages caused by events of different type

- Future work

  - Integrate and combine analysis of multiple data sources (BGP, IBR, active measurement, ...)
  - Analysis of AS/Link-level topology
  - Automated detection + triggered active measurements

THANKS