Toward an Atlas of the Physical Internet

Summer 2014

Paul Barford
Computer Sciences
University of Wisconsin

Motivation

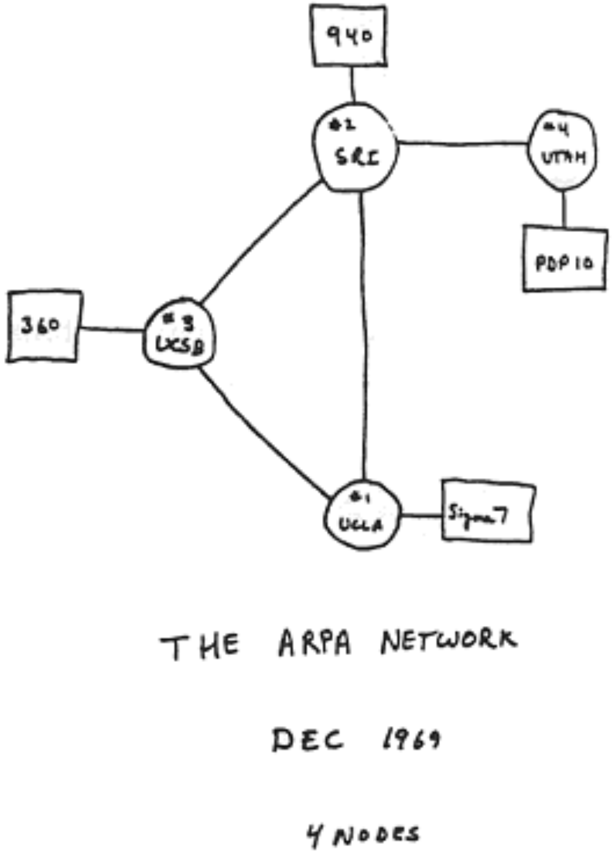
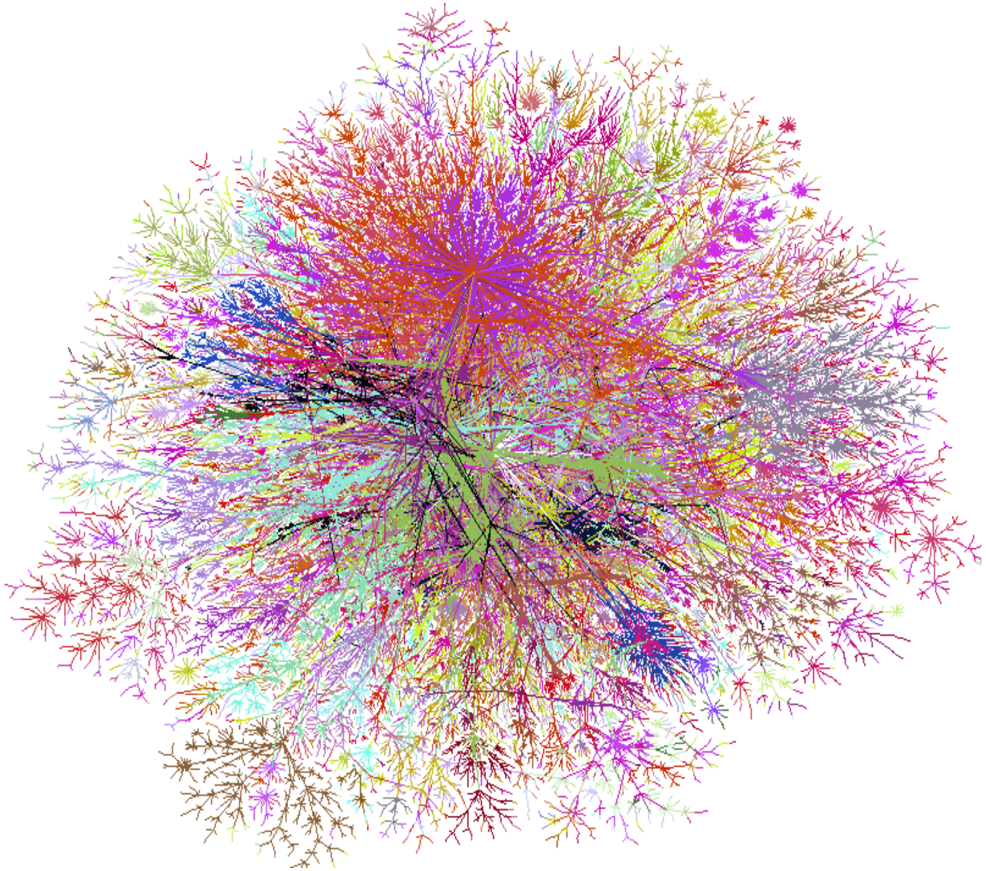


FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)



Objectives of our work

- Create and maintain a comprehensive catalog of the *physical Internet*
  - Geographic locations of nodes (buildings that house PoPs, IXPs etc.) and links (fiber conduits)
- Extend with relevant related data
  - Active probes, BGP updates, weather, etc.
- Maintain portal for visualization and analysis
- Apply maps to problems of interest
  - Robustness, performance, security

pb@cs.wisc.edu

Related work

- Many prior Internet mapping efforts
  - S. Gorman studies from early 2000’s
  - CAIDA
  - DIMES
  - iPlane
- Commercial activities
  - TeleGeography
  - Renesys/Dyn
  - Lumeta
- Internet Topology Zoo

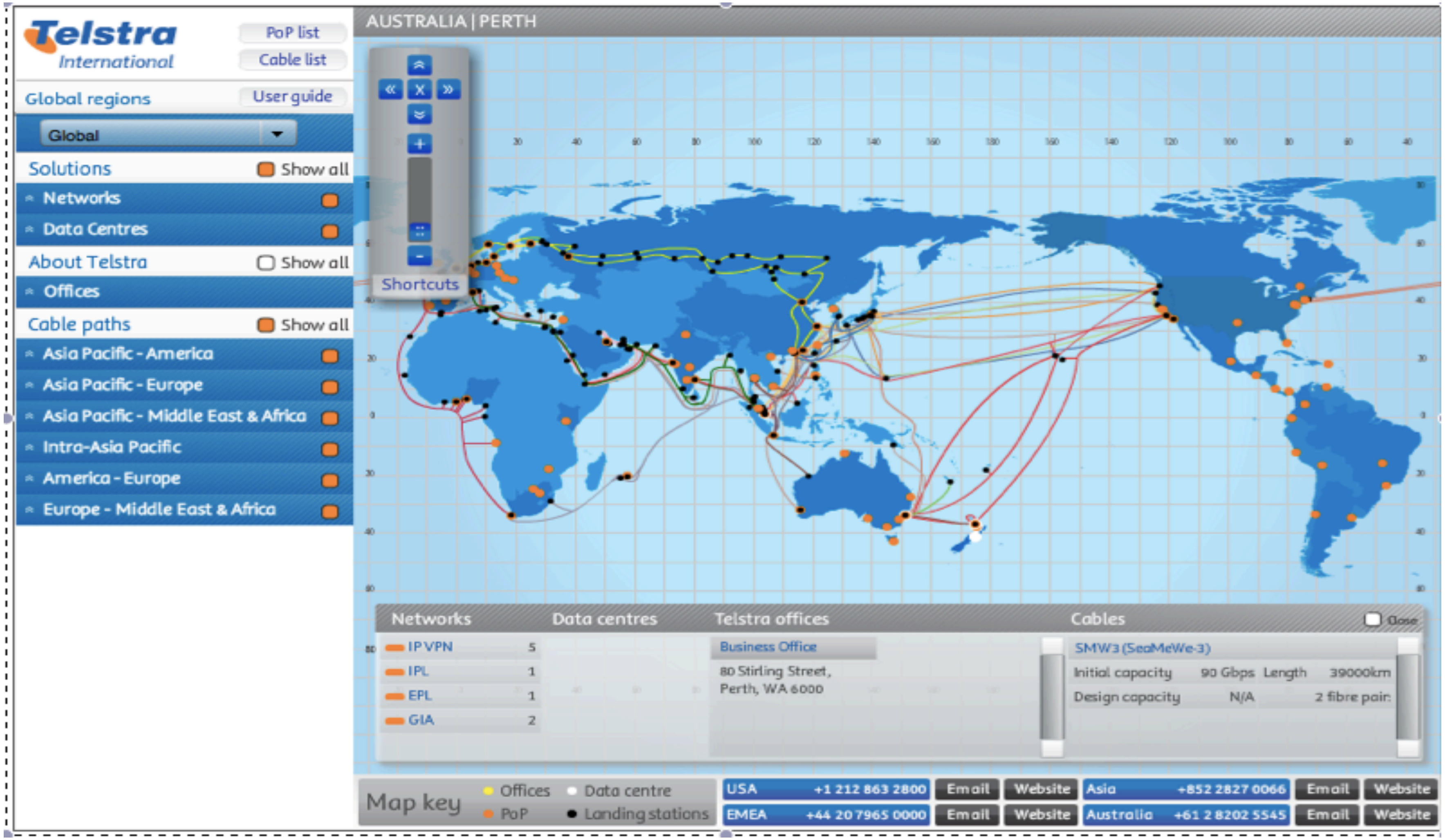
pb@cs.wisc.edu

Compiling a physical repository

- Step #1: Identification
  - Utilize *search* to find maps of physical locations
- Step #2: Transcription
  - Multiple methods to automate data entry
- Step #3: Verification
  - Ensure that data reflects latest network maps
- Our hypothesis is that physical sites are limited in number and fixed in location
  - But the raw number is still large!

pb@cs.wisc.edu

Example: Telstra world wide



Networks	
IP VPN	5
IPL	1
EPL	1
GIA	2

Business Office

80 Stirling Street,
Perth, WA 6000

SMW3 (SeaMeWe-3)

Initial capacity	90 Gbps	Length	39000km
Design capacity	N/A		2 fibre pair

USA +1 212 863 2800

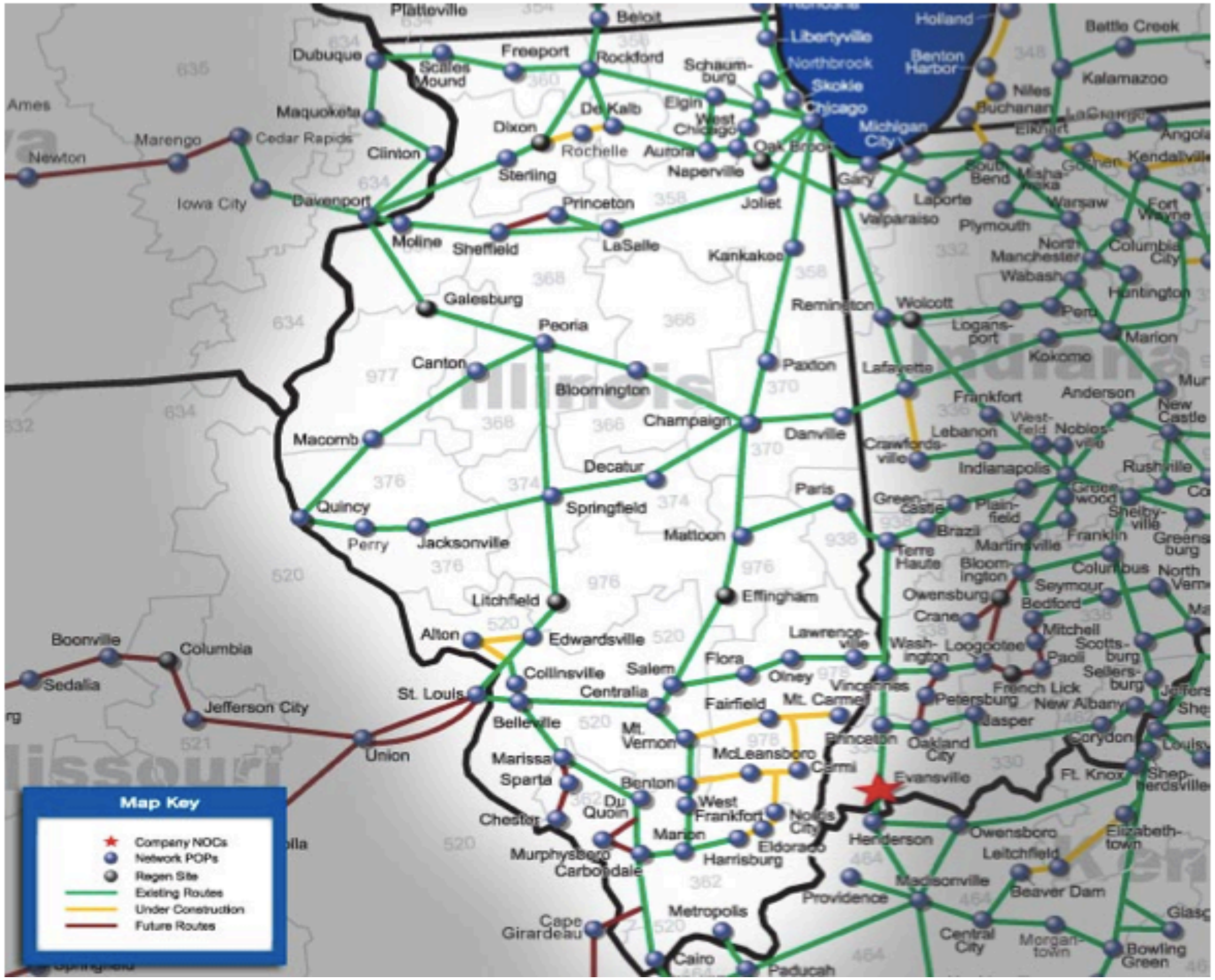
EMEA +44 20 7965 0000

Asia +852 2827 0066

Australia +61 2 8202 5545

Example: Sprint IP network (US)

Example: Regional fiber



Illinois POP List

ALTON

Address: 1805 Washington Ave Zip: 62002
Type: CO Status: FUTURE
CLLI: ALTNILAK

BELLEVILLE

Address: 211 Kretschmer Ave Zip: 62220
Type: CO Status: ACTIVE
CLLI: BLVLILAD

BLOOMINGTON

Address: 110 E Monroe St Zip: 61701
Type: CO Status: ACTIVE
CLLI: BLTNILXD

Address: 110 E Monroe St Zip: 61701
Type: CO Status: DOUBLE
CLLI: BLTNILXD

CAIRO

Address: 221 15th St Zip: 62914
Type: CO Status: ACTIVE
CLLI: CAIRILCF

CANTON

Address: 75 W Pine St Zip: 61520
Type: CO Status: ACTIVE
CLLI: CNTNILCN

CARBONDALE

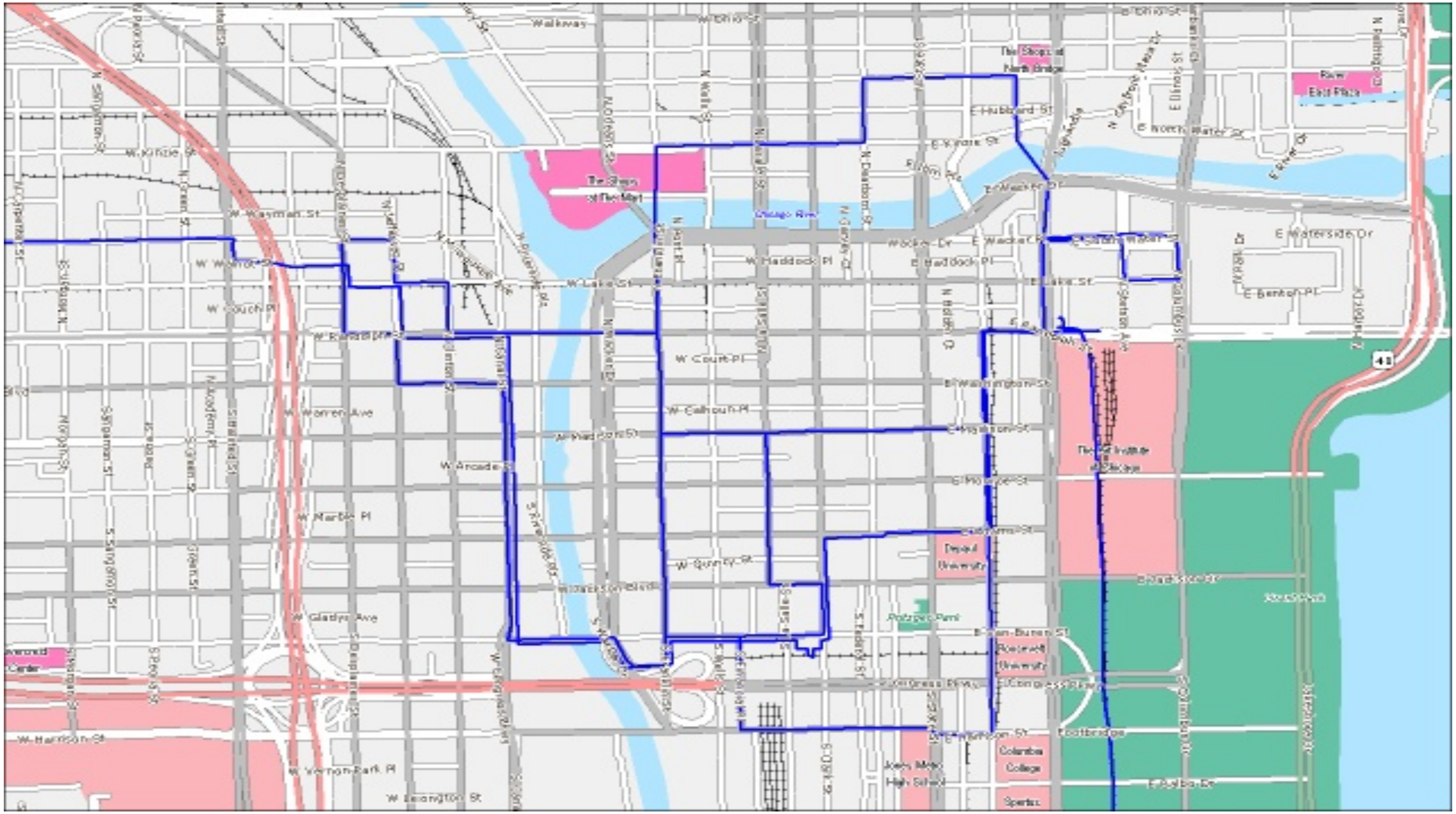
Address: 208 W Monroe St Zip: 62901
Type: CO Status: ACTIVE
CLLI: CRDLILXE

CARMI

Address: 200 W Cherry St Zip: 62821

pb@cs.wisc.edu

Example: Metro fiber maps



Internet Atlas @ UW

- Effort began in September ’11
  - Capture everything from maps discovered by search
  - Use all relevant data sources (ISP maps, colocation, data centers, NTP, traceroute, etc.)
- Data extraction and verification tools
- Comprehensive database
- Interactive web portal
  - Includes ArcGIS for visualization and analysis
- Paper in ACM SIGCOMM HotPlanet WS ‘13

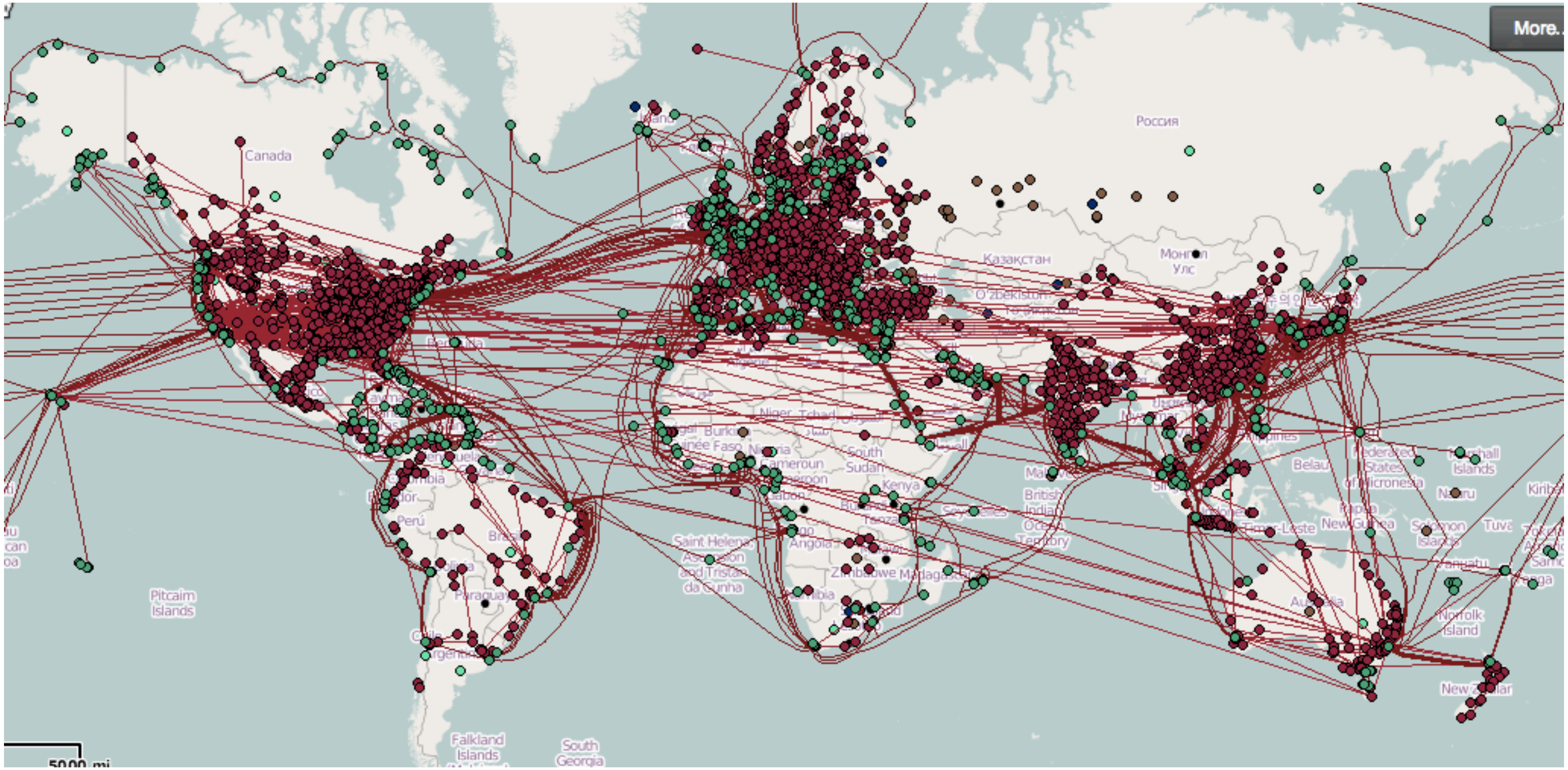
pb@cs.wisc.edu

Current DB

- **Number of networks: 389**
- **Number of tier 1 networks: 10**
- **Number of data centers: 2,232**
- **Number of NTP servers: 744**
- **Number of traceroute servers: 221**
- **Number and type of other nodes: IXP (358), DNS root (282)**
- **Total number of nodes: 14,827**
- **Number of unique locations of nodes: 7,988**
- **Maximum overlap at any one node: 92**
- **Total number of links: 13,861**
- **Peering DB facility locations: 1058**
- **WiGLE Wireless SSID locations: 5202**
- **Antenna locations from FCC: 5786**

pb@cs.wisc.edu

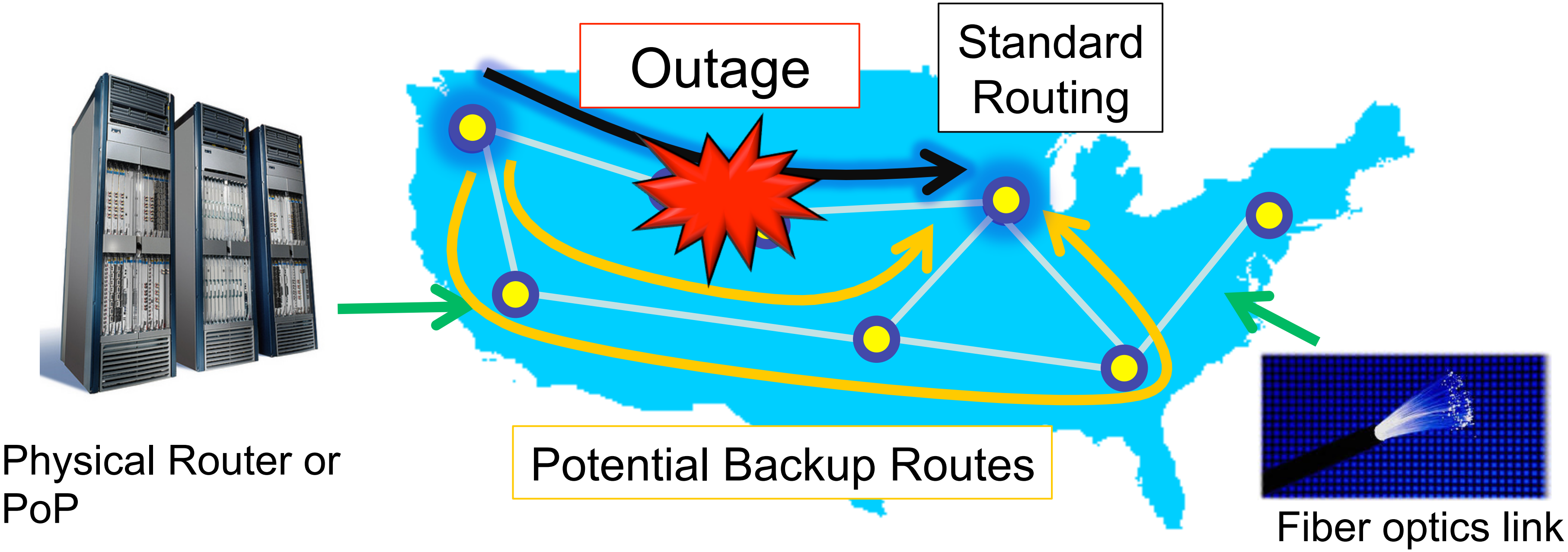
Internet Atlas – Full View



pb@cs.wisc.edu

Case study: RiskRoute

Consider Internet physical infrastructure:



Outage

Standard Routing

Physical Router or PoP

Potential Backup Routes

Fiber optics link

- **Can we automatically adjust routes to avoid outages before they happen?**
- **Can we identify the best backup routes?**

pb@cs.wisc.edu

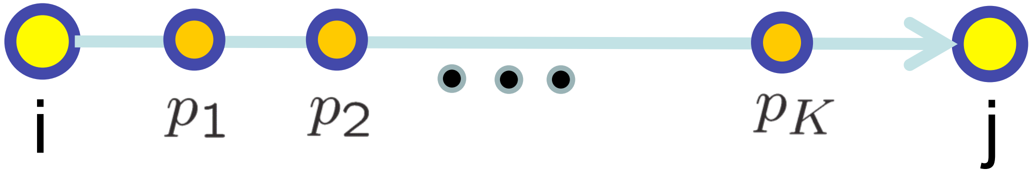
Bit-risk miles metric

- **The idea of bit-miles motivates the introduction of *bit-risk miles***

# of Bits Sent + **Distance** + **Outage Risk** = **Bit-Risk Miles**

  - **Consider a network path:**

$$\mathbf{p} = \{p_1, p_2, \ldots, p_K\}$$



  - **The bit-risk miles of the routing path is defined as:**

$$r_{i,j}(\mathbf{p}) = \Sigma_{x=1}^{K} \left(d_{p_x,p_{x+1}} + \gamma_{i,j}\left(\lambda_h o_h(p_x) + \lambda_f o_f(p_x)\right)\right)$$

Bit miles

Outage risk

pb@cs.wisc.edu

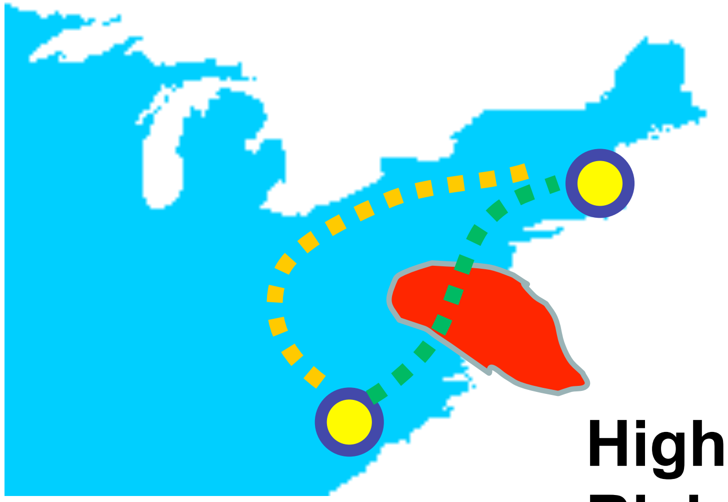
Utility of bit-risk miles

- **Quantifies the trade-offs between:**

Short geographic routing paths with **high** outage risk

vs.

Long geographic routing paths with **low** outage risk



High Risk Area

Defining terms

- **Gamma: what is the <u>cost of an outage</u> between the source and destination?**
  - **To approximate this, we use the fraction of population affected clustered to nearest PoP**
- **Lambda$_h$: what is <u>historical outage probability</u> at a PoP location?**
  - **We use corpus of events from 1970 to 2010 (29,865 FEMA emergency declarations and over 145,000 NOAA severe weather events**
- **Lambda$_f$: what is <u>forecasted outage probability</u> at a PoP location?**
  - **Based on reported information from NWS, NHC, etc.**

RiskRoute methodology

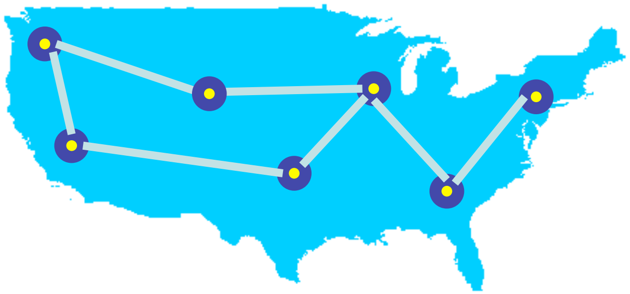
How do we choose which backup path has the smallest bit-risk miles?

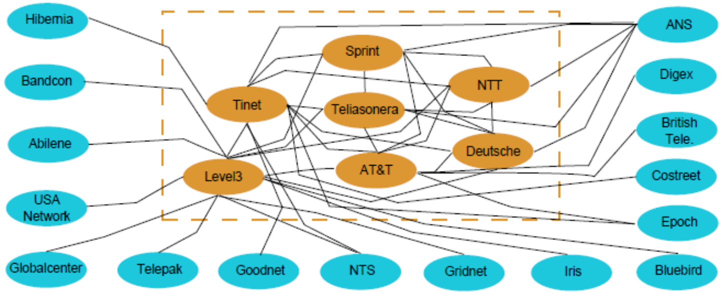
- **Current techniques: Storing only one backup path (*e.g.,* Fast Reroute) is fragile to large-scale outages**
- **Storing all the backup paths is combinatorial**
- **<u>RiskRoute Framework</u>: Using shortest path techniques, continuously recalculate all paths with the smallest bit-risk miles**

pb@cs.wisc.edu

Analysis

- **Real-World Network**
  - **7 Tier-1 ISPs, 16 regional networks**
- **Intra-domain Routing**
  - **Routing inside a specified network**
- **Inter-domain Routing**
  - **Routing between networks**
- **Performance Metrics:**





① **Risk Ratio** – The average reduction in bit-risk miles using RiskRoute compared with shortest path routing

$$r_r = 1 - \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}\frac{r\left(\mathbf{p}_{i,j}^{rr}\right)}{r\left(\mathbf{p}_{i,j}^{shortest}\right)}$$

② **Distance Ratio** – The average increase in bit-miles using RiskRoute compared with shortest path routing

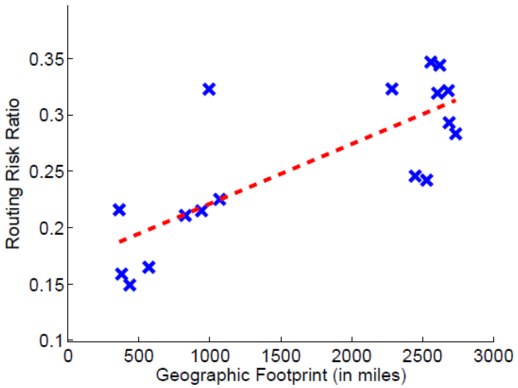
$$d_r = \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}\frac{d\left(\mathbf{p}_{i,j}^{rr}\right)}{d\left(\mathbf{p}_{i,j}^{shortest}\right)} - 1$$

pb@cs.wisc.edu

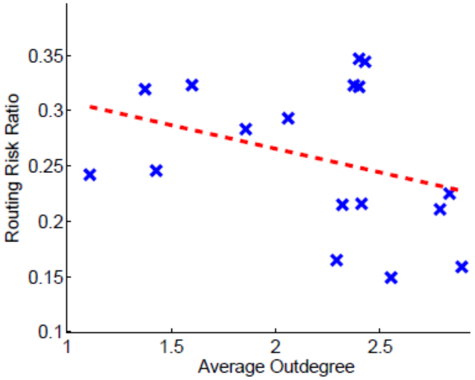
Intradomain results

- **Why is RiskRoute more advantageous to some networks?**

Reduction in Bit-Risk Miles (Risk Ratio)

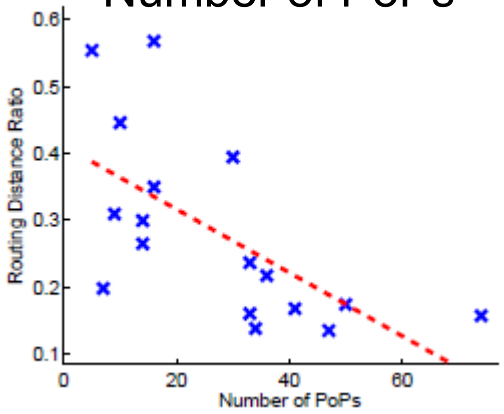


Geographic footprint

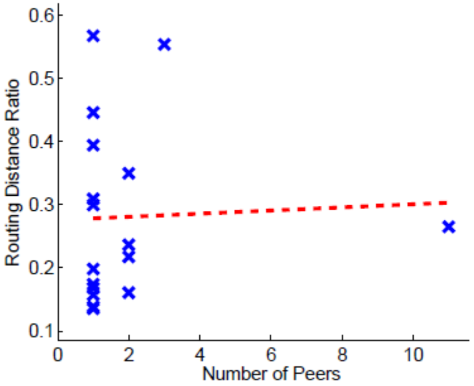


Avg. router outdegree

Increase in Bit-Miles (Distance Ratio)



Number of PoPs

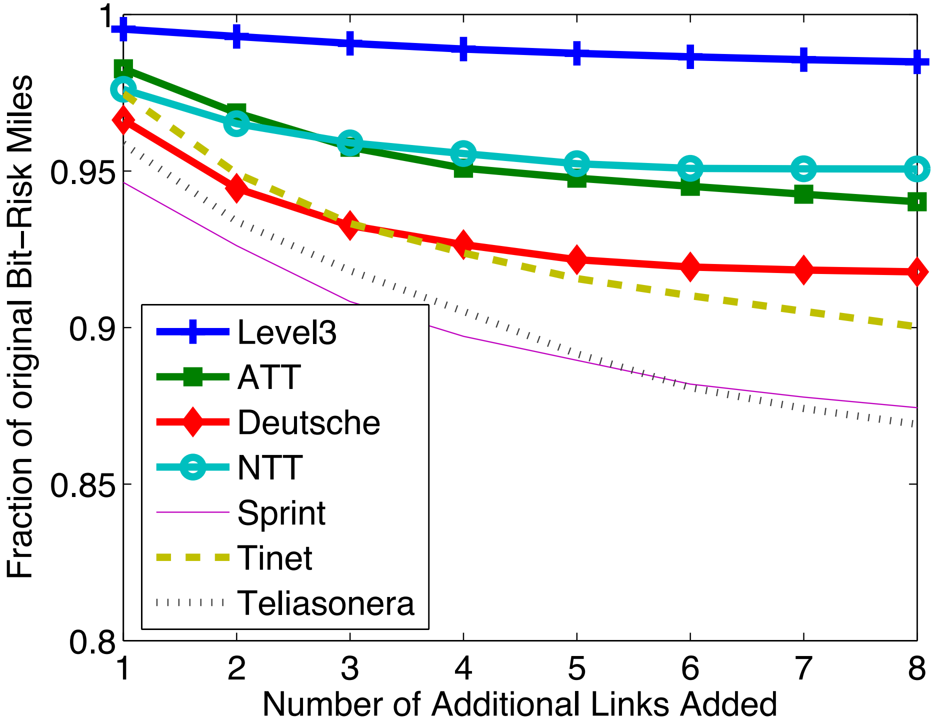


Number of peers

pb@cs.wisc.edu

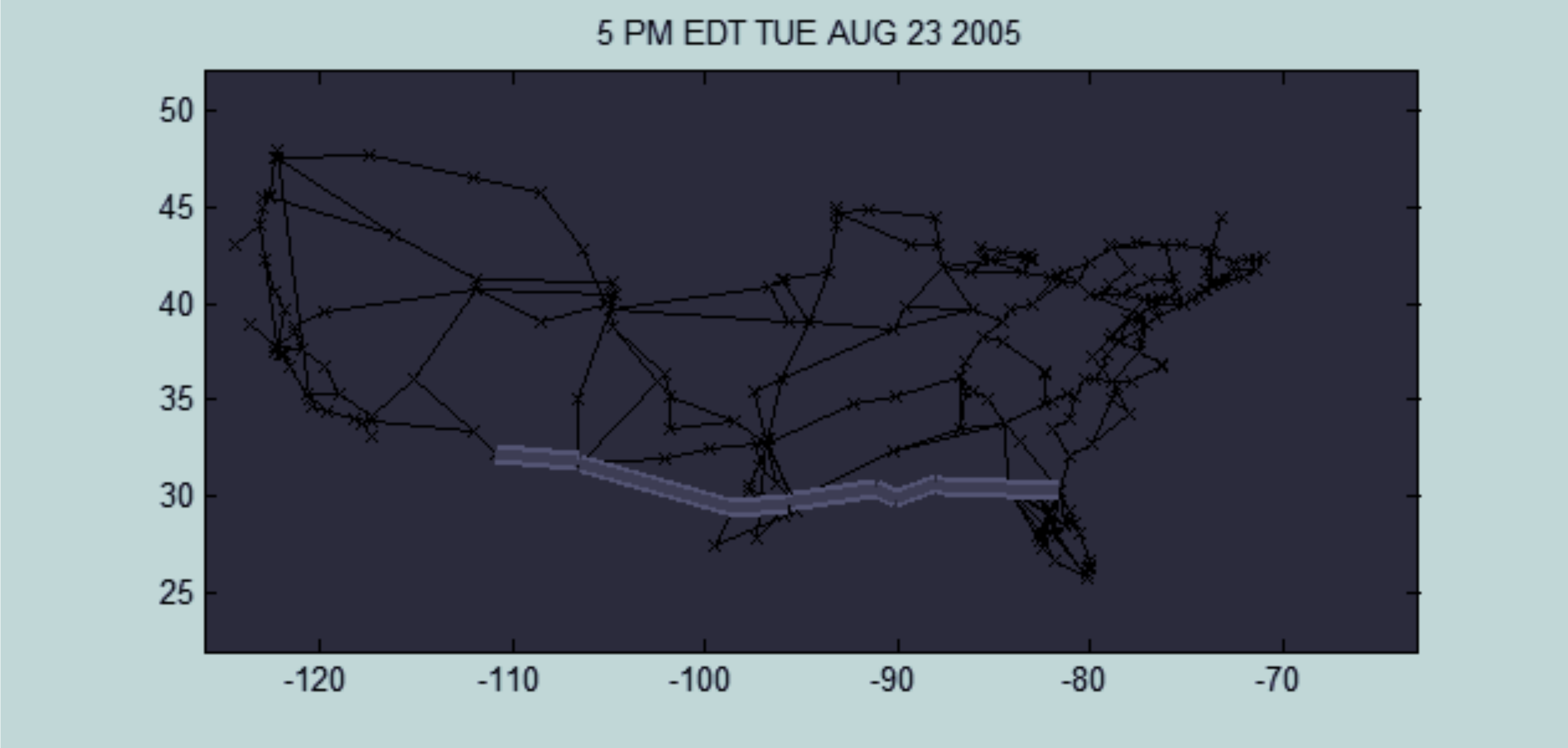
Robustness results

- **Can all networks decrease risk via the new link infrastructure?**



pb@cs.wisc.edu

Hurricane Katrina and Level3



Next steps

- Continue to populate DB
  - Goal = 500 networks by December, ‘14
- Continue to enhance web portal
  - Expanded analytic capability
- Add related data for physical sites
  - PoPs, routers, IP addresses, peering, etc.
- Expanded active probing capability
  - IP geolocation is the key
- Expand focus for target applications
  - Shared infrastructure risk

pb@cs.wisc.edu

Thank you!

- Ram Durairajan
- Brian Eriksson
- Xin Tang
- Subhadip Ghosh

Portal

http://internetatlas.org