PINGIN' IN THE RAIN

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Weather causes residential link failures

Lightning destroys equipment and causes interference

Water seeps into unpressurized cables and equipment

Wind snaps tree limbs and stresses wires
Why measure weather-related failures?

To inform consumers about reliability
We rely on these links for Phone, T.V., and Internet

To inform providers about hidden problems
Weather is a routine mini-natural disaster
We need massive measurements

Are Fiber deployments more robust to wind than DSL?

Does rain (not t-storm) correlate with link failures?

Do extreme temps correlate with extreme failure rates?

Must observe many link types and locations
Every residential link deployment is unique
Weather events are natural experiments

Use ICMP pings to observe failures

Only ping links that may experience weather

Consider abnormal sequences of ping losses as failures
Weather alerts

- Ping links before, during, and after weather alerts
- Filter out broken vantage points
- Find and filter DOWN states
- Separate UP and HOSED states
- Remove power outage failures
- Correlate failures with weather
Aiming pings at weather

Monitor the alert feed from the U.S. National Weather Service

<title>Severe Weather Statement issued May 12 at 4:46PM CDT expiring May 12 at 5:15PM CDT by NWS GreenBay http://www.crh.noaa.gov/grb/</title>

<summary>...A SEVERE THUNDERSTORM WARNING REMAINS IN EFFECT FOR CENTRAL WAUPACA AND NORTHWESTERN OUTAGAMIE COUNTIES UNTIL 515 PM CDT...AT 443 PM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A SEVERE THUNDERSTORM CAPABLE OF PRODUCING QUARTER SIZE HAIL...AND DAMAGING WINDS IN EXCESS OF 60 MPH. THIS STORM WAS LOCATED 7 MILES NORTH OF NEW LONDON...OR 20 MILES NORTHEAST OF WAUPACA...MOVING</summary>

<cap:effective>2011-05-12T16:46:00-05:00</cap:effective>
<cap:expires>2011-05-12T17:15:00-05:00</cap:expires>
<cap:urgency>Immediate</cap:urgency>
<cap:severity>Severe</cap:severity>
<cap:certainty>Observed</cap:certainty>
<cap:geocode><valueName>FIPS6</valueName><value>055087 055135</value></cap:geocode>
Finding residential IPs to ping

71.96.2.1               L100.DLLSTX-DSL-08.verizon-gni.net.
71.96.2.2               pool-71-96-2-2.dfw.dsl-w.verizon.net.
71.96.2.253           pool-71-96-2-253.dfw.dsl-w.verizon.net.
71.96.2.254           pool-71-96-2-254.dfw.dsl-w.verizon.net.
216.27.175.1         vrrp-1-gw.216-27-175.atl1.speakeasy.net.
216.27.175.2         dns.atl1.speakeasy.net.
216.27.175.253     5.ge-0-2-0.cr2.atl1.speakeasy.net.
216.27.175.254     dsl027-175-254.atl1.dsl.speakeasy.net.

Found 100 Million U.S. residential IPs
Locating IPs covered by weather alerts

Locating 100 Million residential IPs
MaxMind database of IP to geolocation

Sampling IPs covered by a weather alert
Ping 100 IPs from each provider and link type

Finding the provider and link type of an IP
Reverse name (pool----.sangtx.dsl-w.verizon.net)
Pinging to observe failures

One vantage point is not enough
Ten PlanetLab-based vantage points

Ping infrequently
From each vantage point, ping once every 11 minutes

Omit needless pings
Only ping IPs that reply before the weather

One ping is not enough
Retry immediately when a ping indicates failure
4 Billion Pings
3.5 Million IPs
400 Days
Weather alerts

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- Correlate failures with weather
- Remove power outage failures
**Weather alerts**

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Pings | States | Failures
Reducing pings to responsiveness
Separating abnormal losses from normal losses

Links are not just UP or DOWN

There are sudden and temporary changes in loss

Need to find the time when the loss rate increased

The problem is similar to finding the edges in a noisy image

Ping interval (11 minutes)
Edge detection for separating UP and HOSED

σ = 6 thresh

Ping interval (11 minutes)

Blurred loss: f(x), σ = 6
Edge detect: abs(f'(x)), σ = 6

Ping reply
Ping timeout
UP
HOSED
Weather alerts

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U.S. airport weather stations monitor conditions.
### Weather Measurements

**5:13 PM**, 64.4, 55.4, 73, 30.26, 1.8, WSW, 10.4, 17.3, 0.03, Rain-Thunderstorm, **Heavy Thunderstorms and Rain**

**4:57 PM**, 64.9, 55.9, 73, 29.95, 10.0, West, 8.1, -0.13, Rain-Thunderstorm, **Light Thunderstorms and Rain**

**4:16 PM**, 64.4, 55.4, 73, 30.27, 5.0, North, 13.8, 17.3, 0.07, Rain-Thunderstorm, **Thunderstorms and Rain**

**3:57 PM**, 75.0, 45.0, 34, 29.93, 6.0, Variable, 3.5, -N/A, **Haze**

**2:57 PM**, 75.9, 48.0, 37, 29.92, 10.0, WNW, 6.9, -0.00, **Scattered Clouds**

**1:57 PM**, 81.0, 45.0, 28, 29.92, 10.0, SSW, 8.1, -N/A, **Clear**

**12:57 PM**, 80.1, 48.0, 32, 29.95, 10.0, Variable, 3.5, -N/A, **Clear**

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**METAR KFLG**

27/09 A3029 RMK AO2 SLP141 T02670089, 0, 2011-07-05 19:57:00

**051957Z VRB03KT 10SM CLR**

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**METAR KFLG**

052057Z 20007KT 170V240 10SM CLR 27/07 A3026 RMK AO2 SLP131 T02720072 58013, 200, 2011-07-05 20:57:00

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**METAR KFLG**

052157Z 29006KT 10SM SCT090 24/09 A3025 RMK AO2 RAB46E56 SLP130 P0000 T02440089, 290, 2011-07-05 21:57:00

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**METAR KFLG**

052257Z VRB03KT 6SM HZ BKN075 24/07 A3026 RMK AO2 SLP134 T02390072, 0, 2011-07-05 22:57:00

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**METAR KFLG**

052316Z 01012G15KT 5SM TSRA BKN041 BKN050 OVC075 18/13 A3027 RMK AO2 TSB10RAB2258 TS OVHD P0007, 10, 2011-07-05 23:16:00

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**METAR KFLG**

052357Z 27007KT 10SM -TSRA FEW031 BKN095 18/13 A3024 RMK AO2 TSB10RAB2258 SLP140 TS OVHD P0013 60013 T01830133 10294 20167 58007, 270, 2011-07-05 23:57:00

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**SPECI KFLG**

060013Z 24009G15KT 210V280 1 3/4SM +TSRA SCT027 BKN085 18/13 A3026 RMK AO2 P0003, 240, 2011-07-06 00:13:00
Results
Presence of weather

Daily probability of DOWN failure

- DSL
- CABLE
- WISP
- SAT
- FIBER
- DIALUP

Clear, Fog, Rain, F-Rain, Snow, Hail, T-Storm, Tornado

Fiber and Cable have the lowest probability of failure in clear conditions.

Satellite has the highest failure rate in rain compared to clear (1.7x).

Freezing rain hurts DSL (2.7x clear) and cable (3.5x clear).
Conclusion

Built a toolkit for observing residential link failures
Weather is just the beginning

There are interesting relationships between weather and failures
Non-linear relationships for wind and temperature
Linear for rain DOWN but not HOSED
Link type matters (even for wired)

Wired residential links experience HOSED
Outage studies need to take this into account
Adaptive Modulation (e.g., DOCSYS 3.1)
"Such an undertaking would cost approximately $41 billion, nearly six times the net book value of the utilities' current distribution assets, and would require approximately 25 years to complete," the report states. Customers' rates would have to more than double to pay for the project, the commission's staff found.

North Carolina State Utilities Commission, 2014