End-to-end Routing Behavior in the Internet:

A Re-Appraisal from Access Networks

Introduction

- Large scale behavior of end-to-end routing
  - Collect traceroutes and other network performance metrics
  - BISmark routers all over the world
  - A unique view from home networks - users' POV
- Impact of current ISP policies on end-users

About the data

- MLAB servers and devices
- Approximately every 70 mins for each device
- 'UP' followed by 'DW' in 10 mins
- More than one year of traceroute data available
- 230+ devices, 59 servers

Questions we strive to answer:

- One or many
- Preferred path
- Periods of activity
- 'Intra-ISP' or 'inter-ISP'
- Effect on end user
  - Hops to destination, RTT
  - Associated changes in packet loss, bitrate, jitter ...
  - New path on 'busy' and/or 'expensive' route

Evaluation criteria

Paxson's areas of interest:

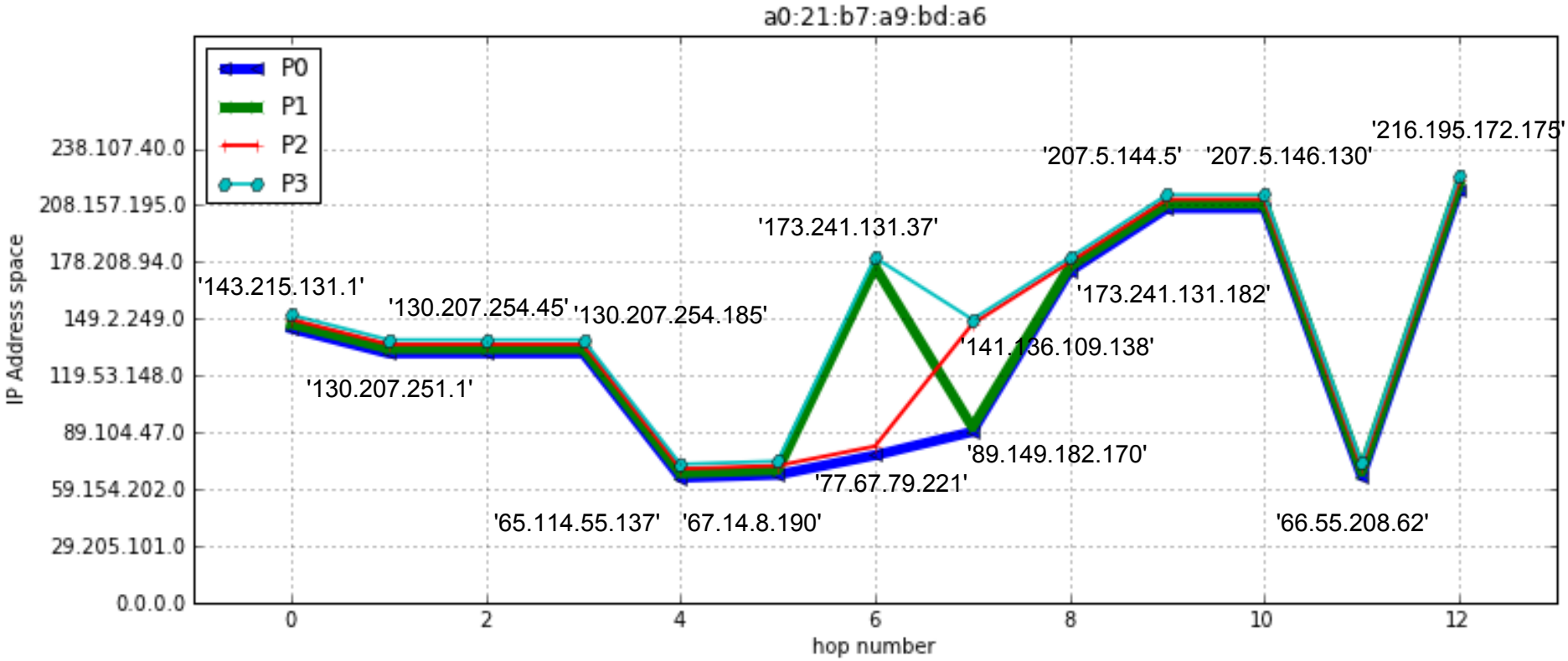
- Prevalence
- Persistence
- Symmetry
- Pathologies

Routing weirdness

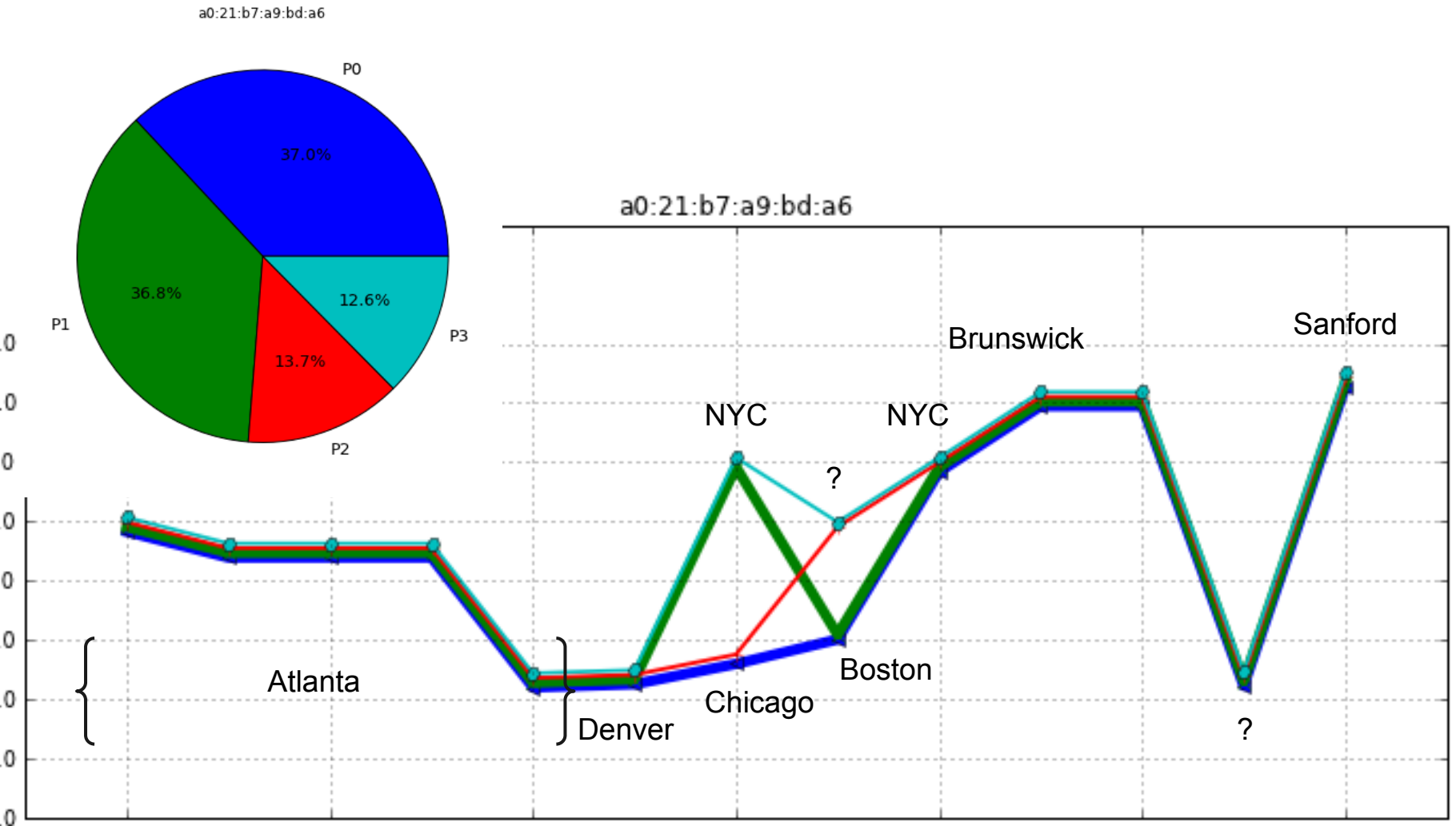
- Dealing with traceroutes:
  - Private addresses
  - Repetitions
  - Loops
  - Missing hops

- Errors? Loops? Pathologies? - Unknown
- Counting distinct paths

Example


a0:21:b7:a9:bd:a6
P0
P1
P2
P3
IP Address space
238.107.40.0
208.157.195.0
178.208.94.0
149.2.249.0
119.53.148.0
89.104.47.0
59.154.202.0
29.205.101.0
0.0.0.0
hop number
0
2
4
6
8
10
12
'143.215.131.1'
'130.207.254.45'
'130.207.254.185'
'173.241.131.37'
'207.5.144.5'
'207.5.146.130'
'216.195.172.175'
'173.241.131.182'
'141.136.109.138'
'130.207.251.1'
'89.149.182.170'
'77.67.79.221'
'65.114.55.137'
'67.14.8.190'
'66.55.208.62'

Example


a0:21:b7:a9:bd:a6
P0
37.0%
P1
36.8%
P2
13.7%
P3
12.6%
a0:21:b7:a9:bd:a6
Atlanta
Denver
NYC
?
Chicago
NYC
Brunswick
Boston
?
Sanford

A quick comparison

Prevalence

- At IP granularity, half of the source-destination pairs had 2 or more prevalent paths
- At AS granularity, single path dominates (overall mean was 0.92**)

Persistence

- Fast variations (every next measurement)
- Constant for almost a week

Future Work

- Relationship between path fluctuations and other performance metrics
- Time-of-the-day patterns, evidence of traffic engineering
- Pathologies
- Changes near last mile v/s core Internet

Why am I here then?

- Share the data - MLAB (coming)
- Get suggestions from the Internet measurement community
- Ideas on what to do next - other tools - as a lot more BISmark users are getting added
- FCC v/s ISPs - what would you like to look at from access networks POV

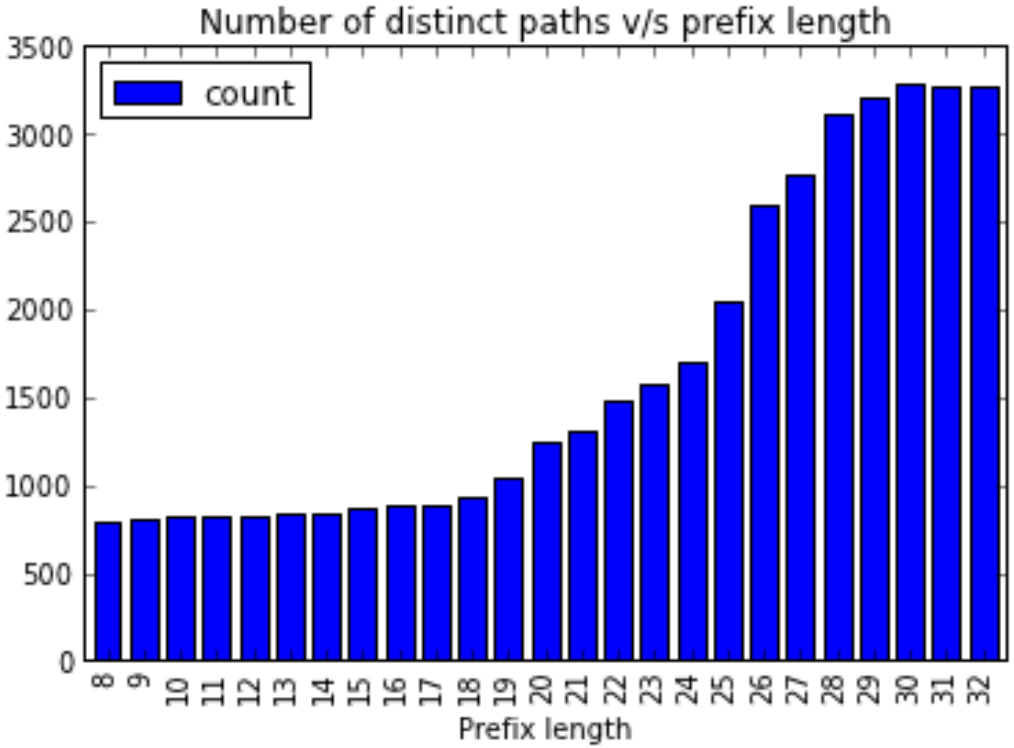
Thanks!

Extra

Current work

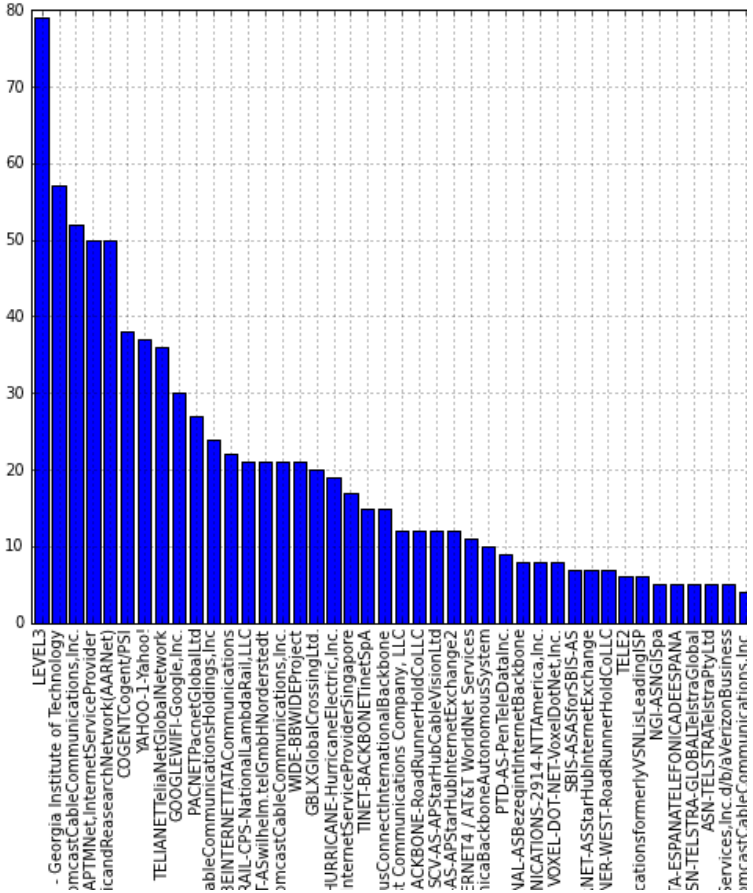
- A work in progress
- Glimpse at ~ 44,000 measurements over 10 days
- source-destination pairs in only UP direction: 171
- source-destination pairs in only DW direction: 131
- source-destination pairs with bidirectional data: 123

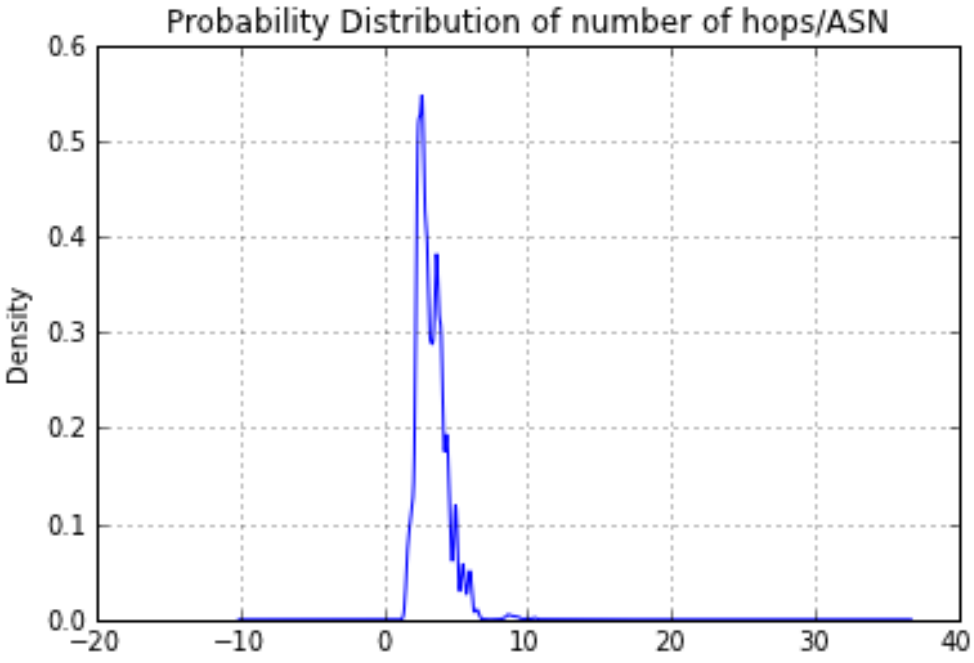
Number of distinct paths



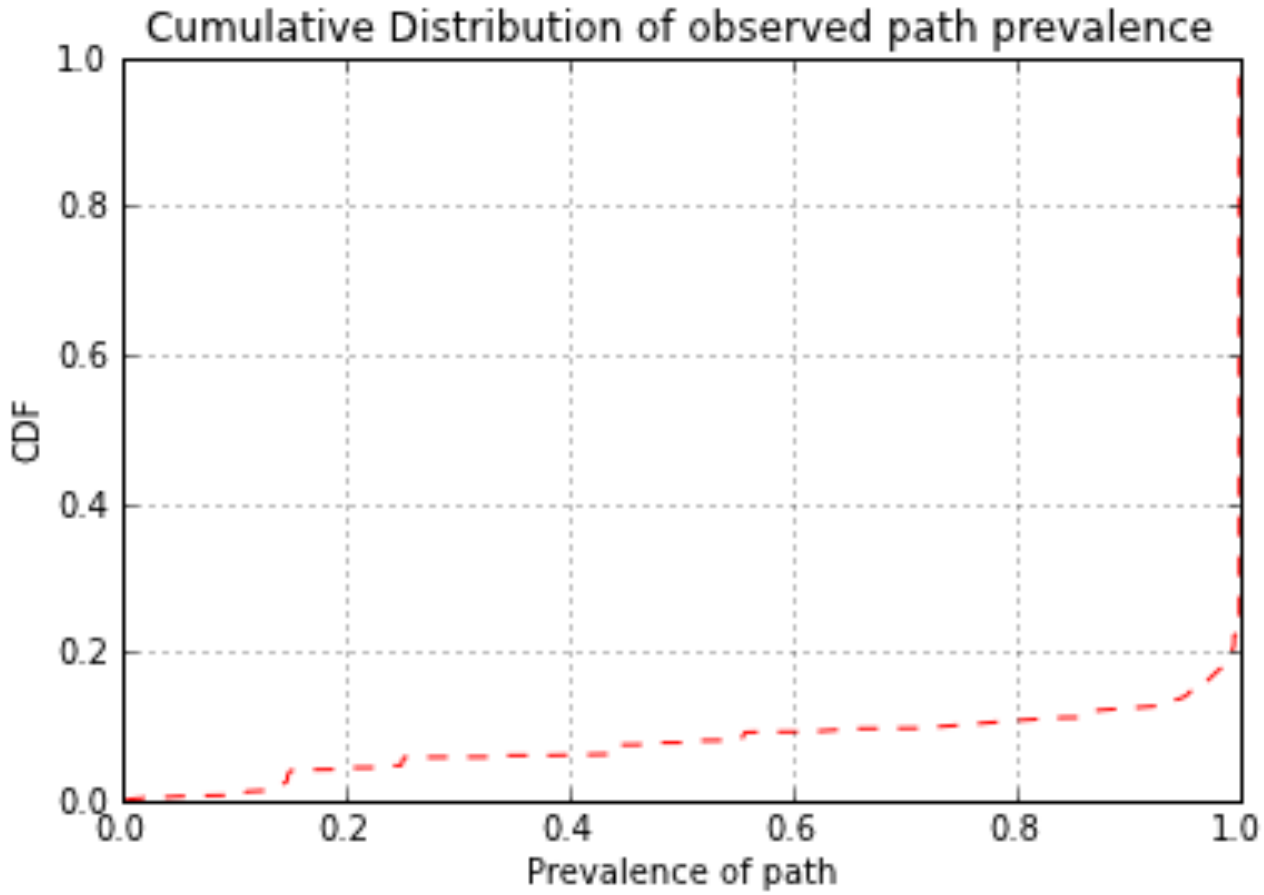
Of 249 source-destination pairs, only 119 with a single prevalent path at prefix 16.

AS level

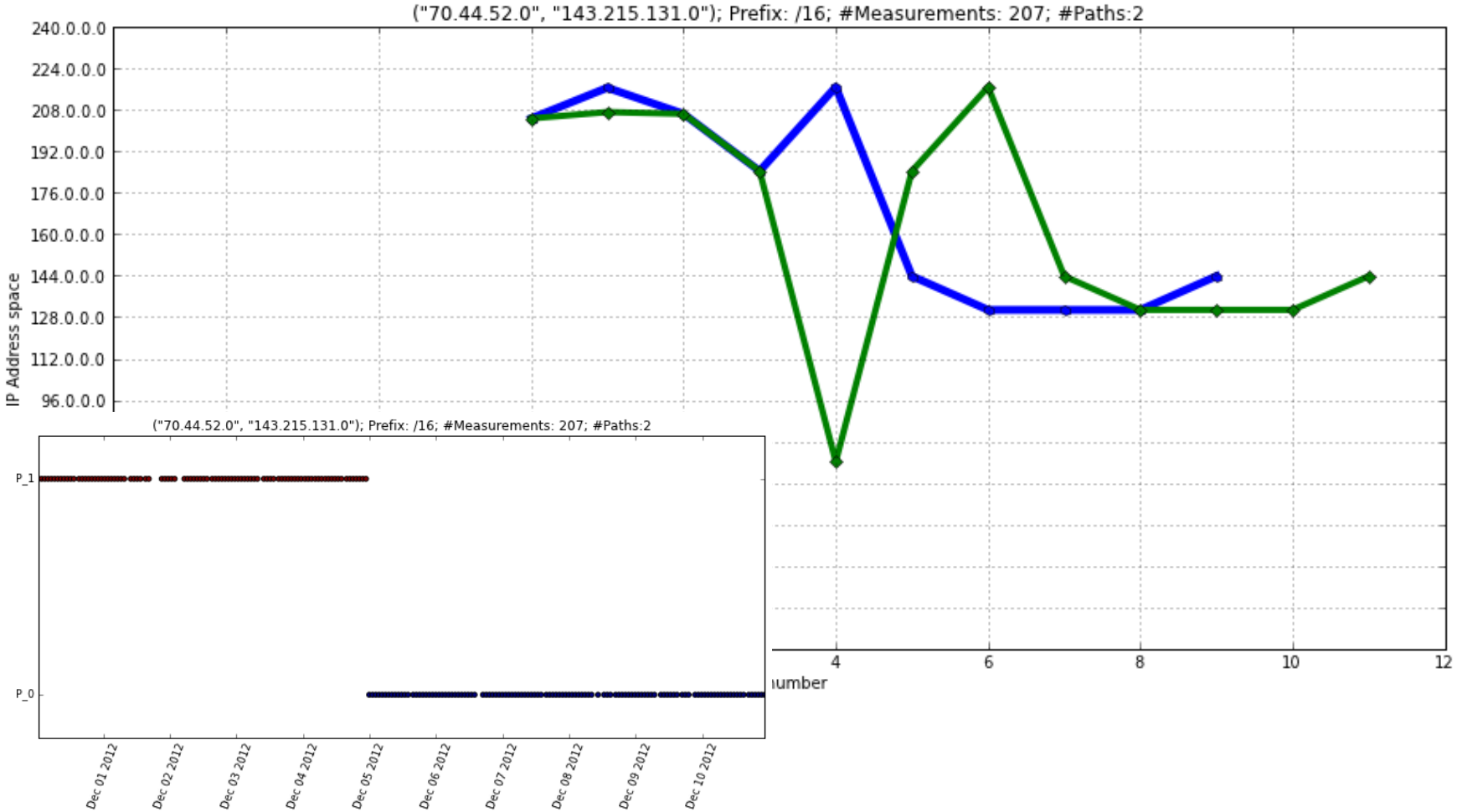

80
70
60
50
40
30
20
10
0
LEVEL3
- Georgia Institute of Technology
omcastCableCommunications,Inc.
APTMNet,InternetServiceProvider
icandReasearchNetwork(AARNet)
COGENTCogent/PSI
YAHOO-1-Yahoo!
TELIANETTeliaNetGlobalNetwork
GOOGLEWiFi-Google,Inc.
PACNETPacnetGlobalLtd
ableCommunicationsHoldings,Inc
EINTERNETTATACommunications
RAIL-CPS-NationalLambdaRail,LLC
T-ASwilhelm.telGmbHNorderstedt
omcastCableCommunications,Inc.
WIDE-BBWIDEProject
GBLXGlobalCrossingLtd.
HURRICANE-HurricaneElectric,Inc.
nternetServiceProviderSingapore
TINET-BACKBONETinetSpA
usConnectInternationalBackbone
t Communications Company, LLC
ACKBONE-RoadRunnerHoldCoLLC
SCV-AS-APStarHubCableVisionLtd
AS-APStarHubInternetExchange2
ERNET4 / AT&T WorldNet Services
icaBackboneAutonomousSystem
PTD-AS-PenTeleDataInc.
VAL-ASBezeqintInternetBackbone
NICATIONS-2914-NTTAmerica,Inc.
VOXEL-DOT-NET-VoxelDotNet,Inc.
SBIS-ASASforSBIS-AS
NET-ASStarHubInternetExchange
VER-WEST-RoadRunnerHoldCoLLC
TELE2
cationsformerlyVSNLisLeadingISP
NGI-ASNGISpa
A-ESPANATELEFONICADEESPANA
SN-TELSTRA-GLOBALTelstraGlobal
ASN-TELSTRATelstraPtyLtd
ervices,Inc.d/b/aVerizonBusiness
omcastCableCommunications,Inc


Probability Distribution of number of hops/ASN
Density
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−20
−10
0
10
20
30
40

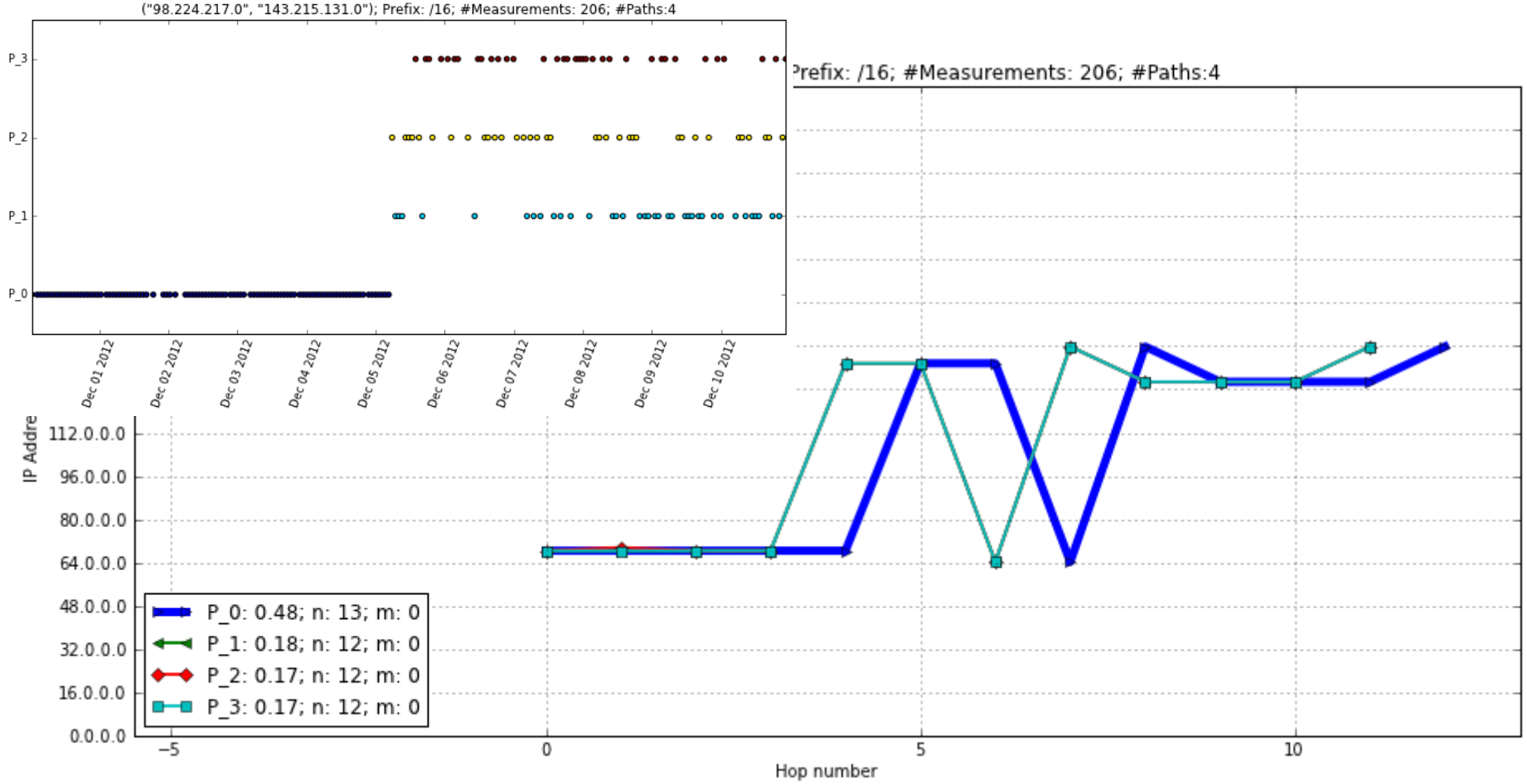
AS level


Cumulative Distribution of observed path prevalence
CDF
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Prevalence of path

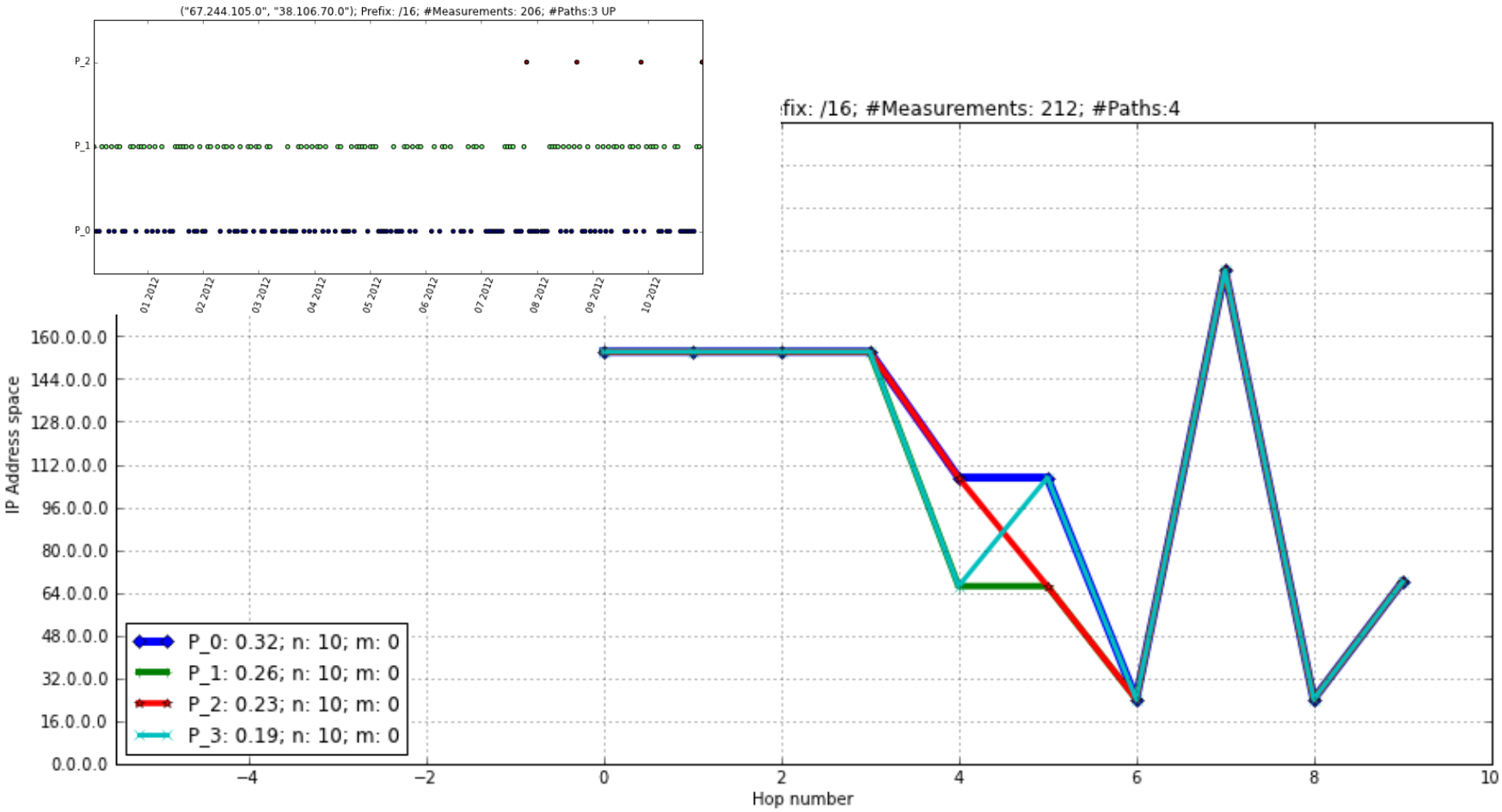
Example 1


("70.44.52.0", "143.215.131.0"); Prefix: /16; #Measurements: 207; #Paths:2
240.0.0.0
224.0.0.0
208.0.0.0
192.0.0.0
176.0.0.0
160.0.0.0
144.0.0.0
128.0.0.0
112.0.0.0
96.0.0.0
IP Address space
4
6
8
10
12
("70.44.52.0", "143.215.131.0"); Prefix: /16; #Measurements: 207; #Paths:2
P_1
P_0
Dec 01 2012
Dec 02 2012
Dec 03 2012
Dec 04 2012
Dec 05 2012
Dec 06 2012
Dec 07 2012
Dec 08 2012
Dec 09 2012
Dec 10 2012

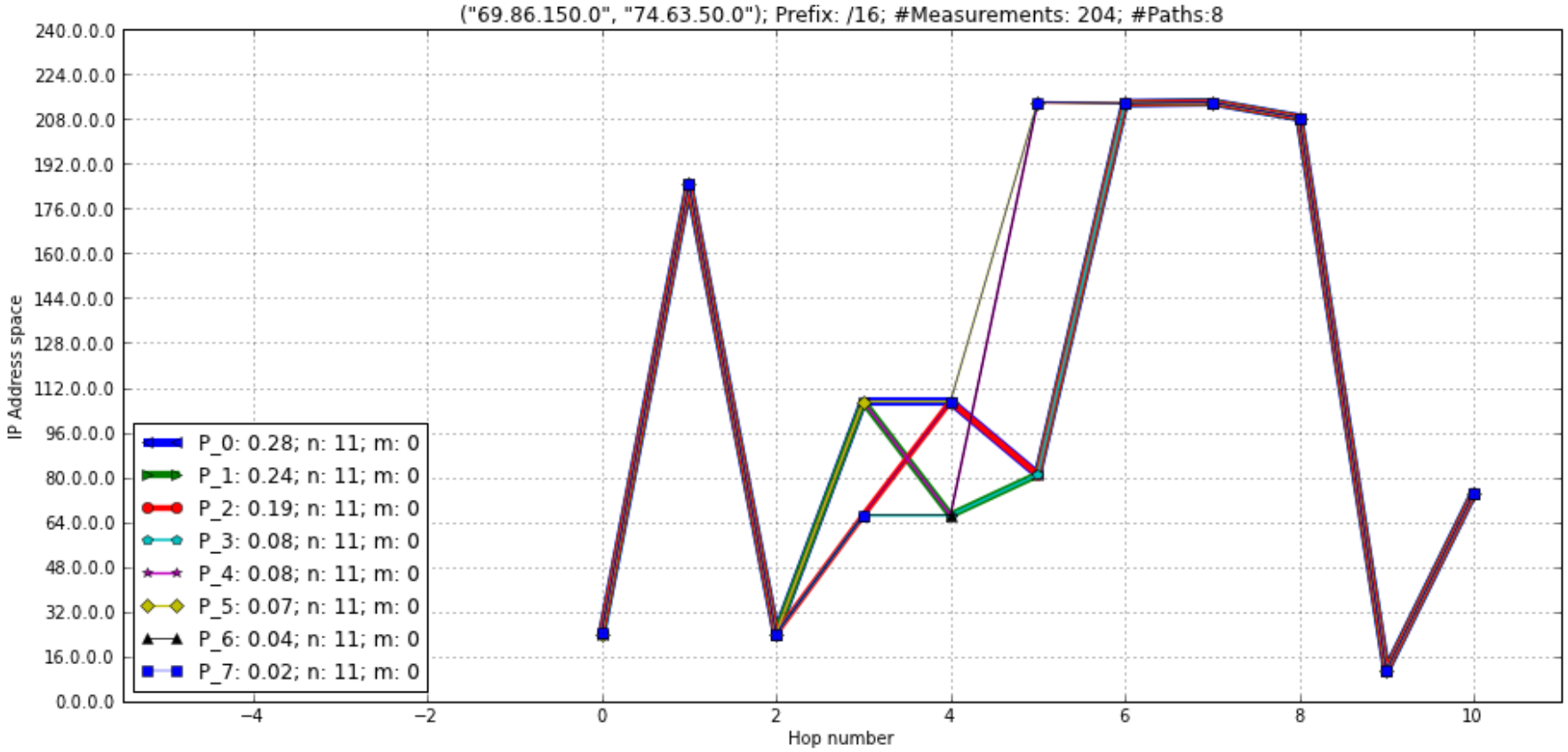
Example 1


("98.224.217.0", "143.215.131.0"); Prefix: /16; #Measurements: 206; #Paths:4
P_3
P_2
P_1
P_0
Dec 01 2012
Dec 02 2012
Dec 03 2012
Dec 04 2012
Dec 05 2012
Dec 06 2012
Dec 07 2012
Dec 08 2012
Dec 09 2012
Dec 10 2012
Prefix: /16; #Measurements: 206; #Paths:4
IP Addre
112.0.0.0
96.0.0.0
80.0.0.0
64.0.0.0
48.0.0.0
32.0.0.0
16.0.0.0
0.0.0.0
P_0: 0.48; n: 13; m: 0
P_1: 0.18; n: 12; m: 0
P_2: 0.17; n: 12; m: 0
P_3: 0.17; n: 12; m: 0
−5
0
5
10
Hop number

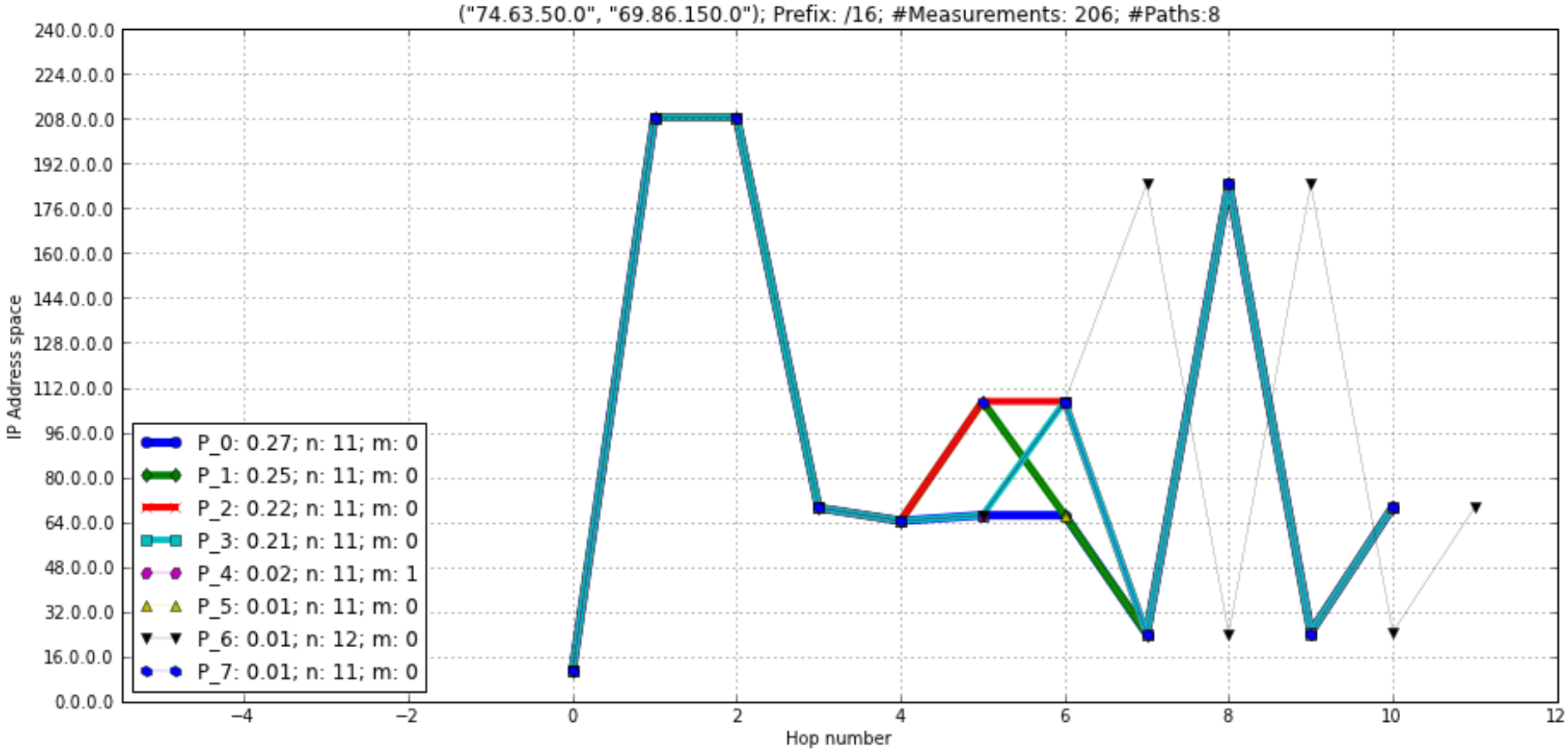
Example 2


("67.244.105.0", "38.106.70.0"); Prefix: /16; #Measurements: 206; #Paths:3 UP
P_2
P_1
P_0
01 2012
02 2012
03 2012
04 2012
05 2012
06 2012
07 2012
08 2012
09 2012
10 2012
fix: /16; #Measurements: 212; #Paths:4
IP Address space
160.0.0.0
144.0.0.0
128.0.0.0
112.0.0.0
96.0.0.0
80.0.0.0
64.0.0.0
48.0.0.0
32.0.0.0
16.0.0.0
0.0.0.0
−4
−2
0
2
4
6
8
10
Hop number
P_0: 0.32; n: 10; m: 0
P_1: 0.26; n: 10; m: 0
P_2: 0.23; n: 10; m: 0
P_3: 0.19; n: 10; m: 0

Example 3


("69.86.150.0", "74.63.50.0"); Prefix: /16; #Measurements: 204; #Paths:8
IP Address space
240.0.0.0
224.0.0.0
208.0.0.0
192.0.0.0
176.0.0.0
160.0.0.0
144.0.0.0
128.0.0.0
112.0.0.0
96.0.0.0
80.0.0.0
64.0.0.0
48.0.0.0
32.0.0.0
16.0.0.0
0.0.0.0
−4
−2
0
2
4
6
8
10
Hop number
P_0: 0.28; n: 11; m: 0
P_1: 0.24; n: 11; m: 0
P_2: 0.19; n: 11; m: 0
P_3: 0.08; n: 11; m: 0
P_4: 0.08; n: 11; m: 0
P_5: 0.07; n: 11; m: 0
P_6: 0.04; n: 11; m: 0
P_7: 0.02; n: 11; m: 0

Example 3


("74.63.50.0", "69.86.150.0"); Prefix: /16; #Measurements: 206; #Paths:8
IP Address space
240.0.0.0
224.0.0.0
208.0.0.0
192.0.0.0
176.0.0.0
160.0.0.0
144.0.0.0
128.0.0.0
112.0.0.0
96.0.0.0
80.0.0.0
64.0.0.0
48.0.0.0
32.0.0.0
16.0.0.0
0.0.0.0
−4
−2
0
2
4
6
8
10
12
Hop number
P_0: 0.27; n: 11; m: 0
P_1: 0.25; n: 11; m: 0
P_2: 0.22; n: 11; m: 0
P_3: 0.21; n: 11; m: 0
P_4: 0.02; n: 11; m: 1
P_5: 0.01; n: 11; m: 0
P_6: 0.01; n: 12; m: 0
P_7: 0.01; n: 11; m: 0