Roofnet

Free Wireless Internet in Cambridge

ESD 342

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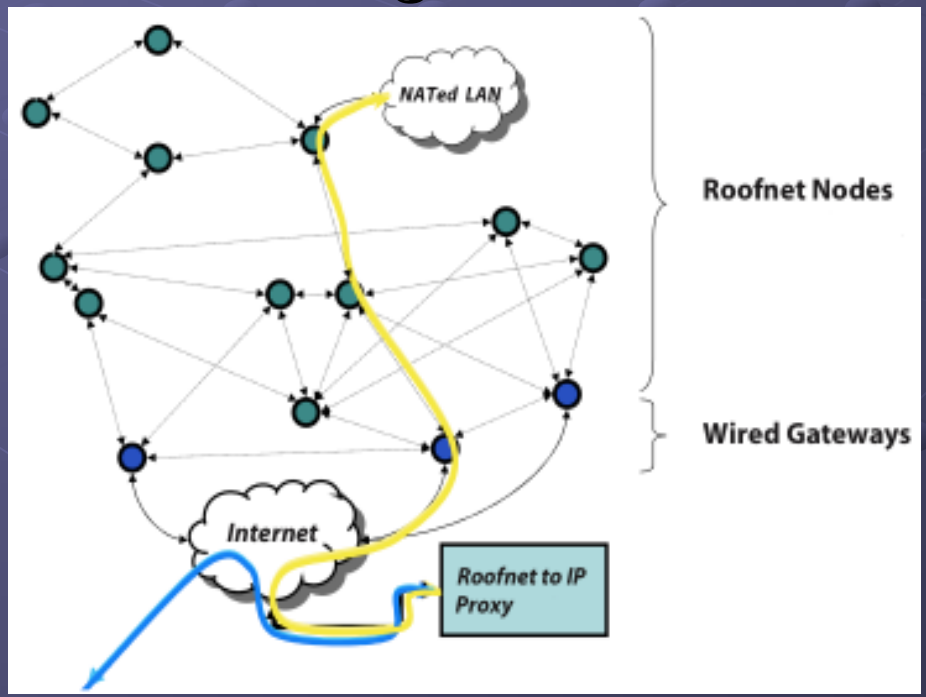
Roofnet Revisited

- The goal of Roofnet project is to provide broadband wireless Internet access to users in Cambridge
- Network engineered to study



Roofnet Background

- One of the first networks to measure and route based on delivery probability
- Novel routing algorithms
- Found that links varied greatly even over a single day
- Doesn't require a technician to set up like other systems
- Self-configures
- Moving away from rooftop deployment and toward “small and many” similar to sensor network

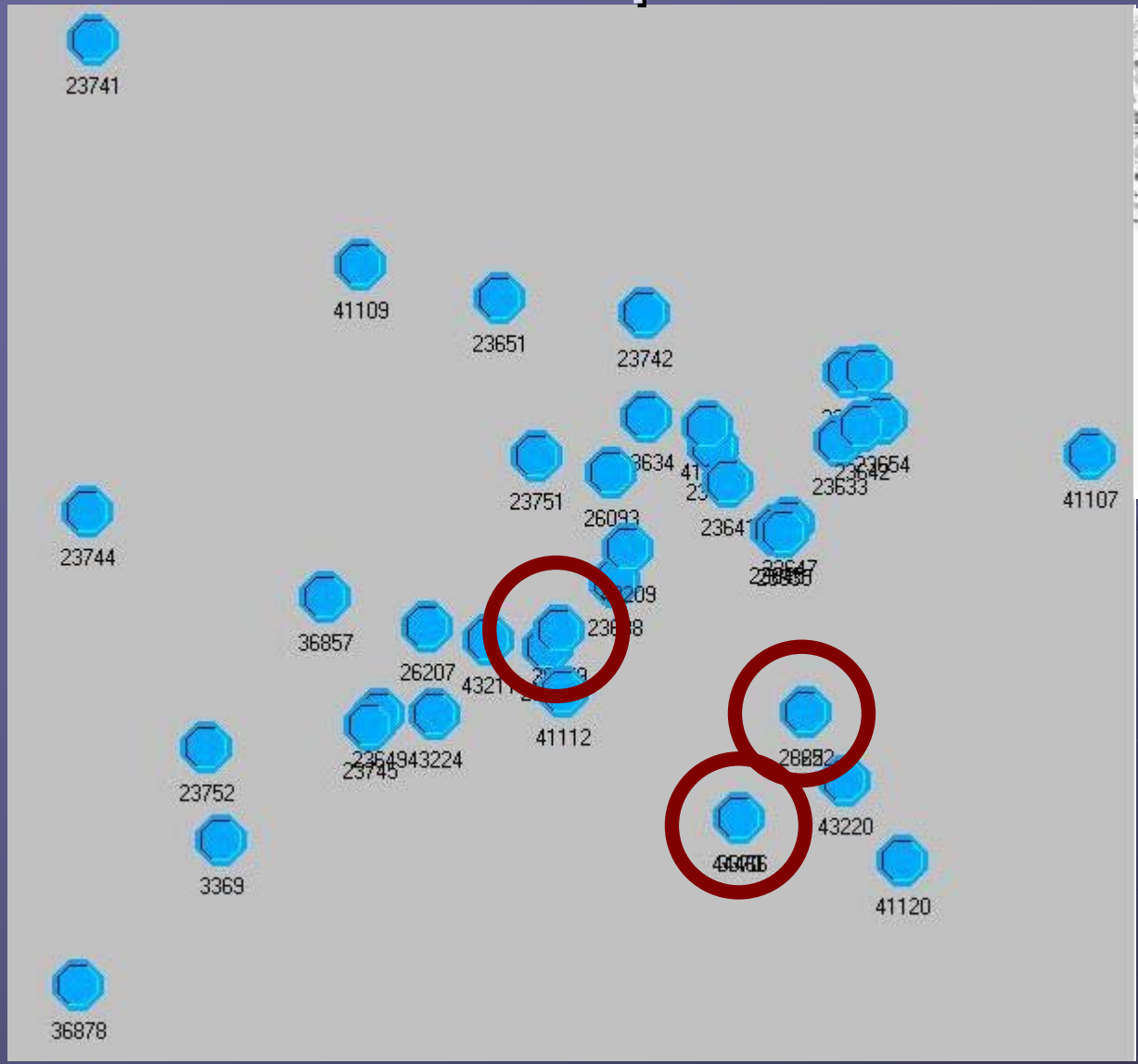
Agenda

- Data resolution
- Analysis of network topological properties and variation in connectivity strengths as attempted data rate increases
- Analysis and benchmarking of network topological properties for aggregate data
- Analysis of robustness
- Analysis of periphery nodes performance
  - Indicated as problem by Roofnet group
- Political situation
- Conclusions

Data Resolution

- Coordinate data in the SIGCOMM2004 paper supplementary information:
  - Inconsistencies resolved with Roofnet team
- Gateway nodes
  - Building NE43: 26222 and 23652
  - Building 36: 44466/3370
  - Cherry St.: 26206
- Traffic data arranged by “experiment”
  - Attempted bit rates: 1, 2, 5.5, and 11 Mbps
  - One node sends while others listen and record

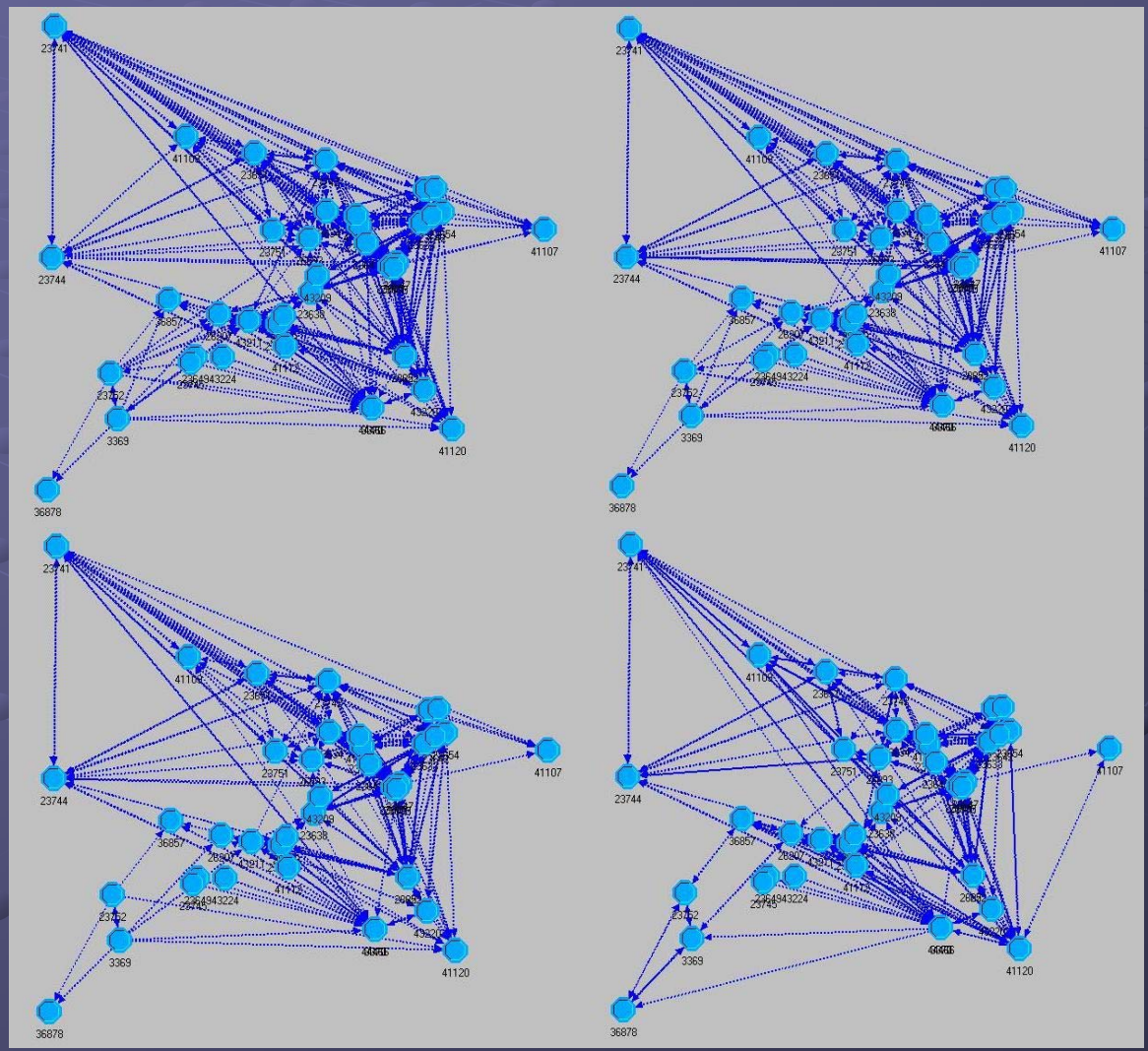
Roofnet Map w/ Gateways Circled



Network Analysis across Experiments

1 Mbps

2 Mbps



5.5 Mbps

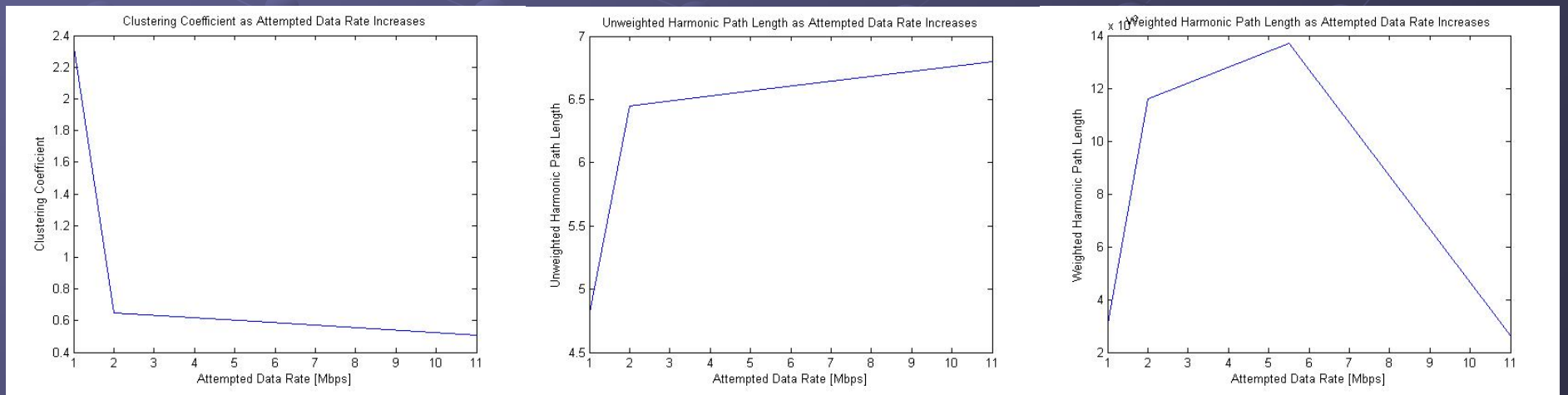
11 Mbps

Network Analysis across Experiments

- Asymmetric topology

Attempted Data Rate	Degree Centrality out-degree [%]	Degree Centrality in-degree [%]	Network Centralization Index [%]
Aggregate	34.06	31.5	9.19
1	20.18	29.46	7.86
2	20.4	24.05	8.69
5.5	20.04	18.76	10.27
11	14.3	14.39	10.7

Attempted Data Rate	Nodes	Edges	Avg Degree	Maximal out-degree	Maximal in-degree	Degree Correlation	Clustering Coefficient	Unweighted harmonic path length	Weighted harmonic path length
Aggregate	41	562	27.4	27	26	0.10450	0.56250	5.59620	-
1	38	530	27.9	26	24	0.08660	2.34210	4.79870	0.00300
2	38	462	24.3	23	24	-0.00097	0.64614	6.44820	0.01160
5.5	38	409	21.5	21	21	0.02930	0.59485	6.58540	0.01370
11	38	336	17.7	18	19	0.04210	0.50873	6.79820	0.00260



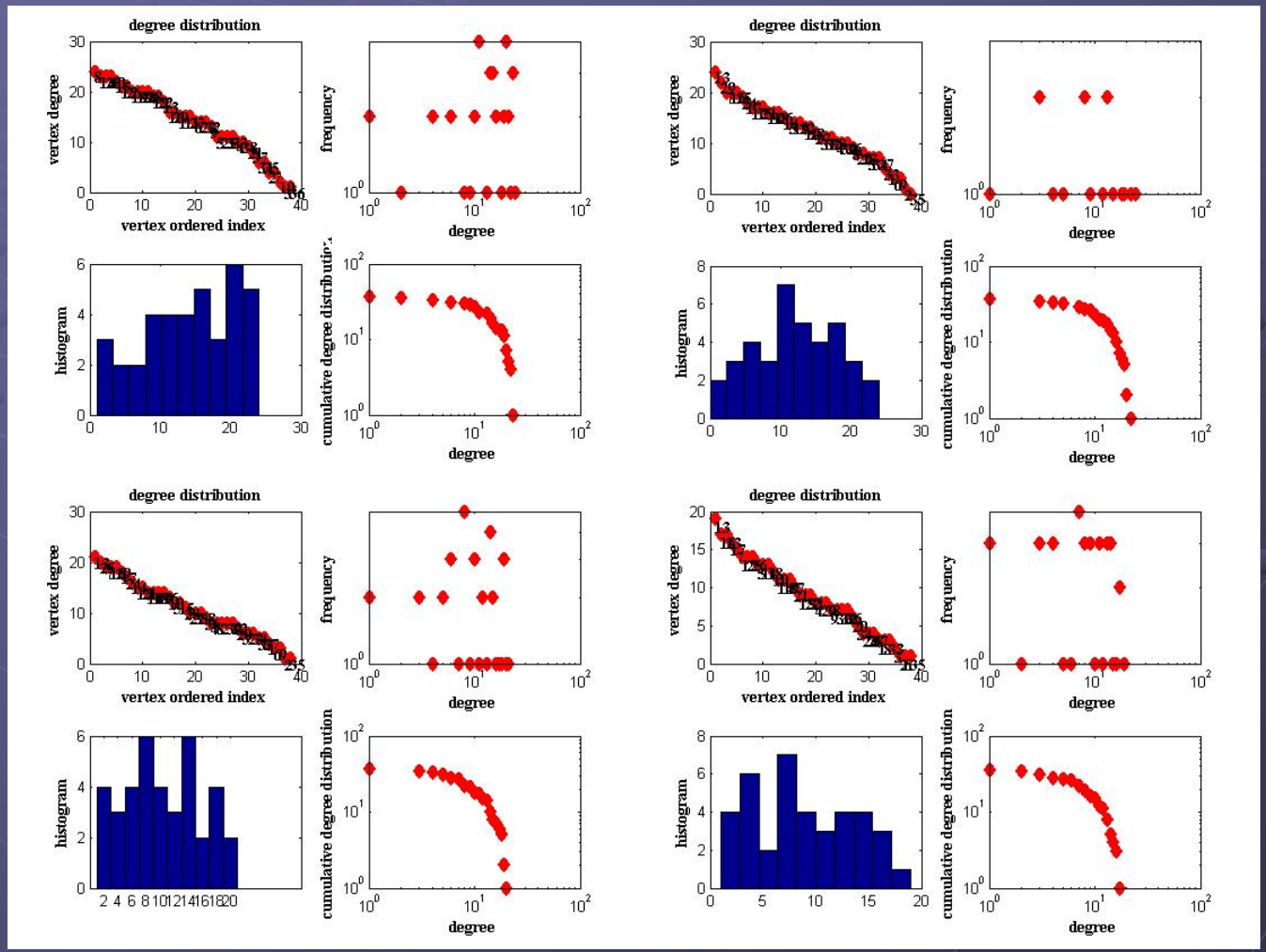
Degree Distributions as Attempted Data Rates Increase

1 Mbps

2 Mbps

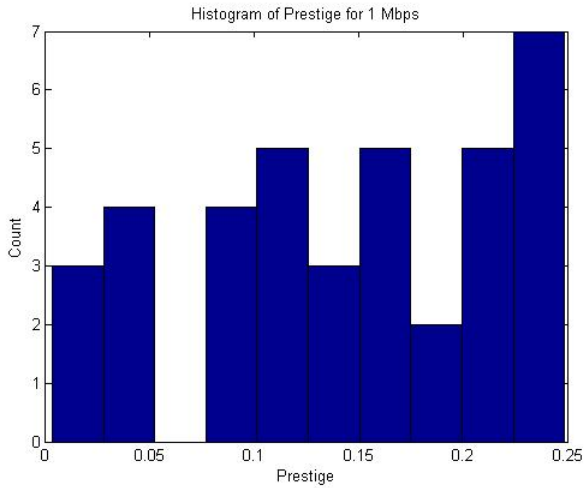
5.5 Mbps

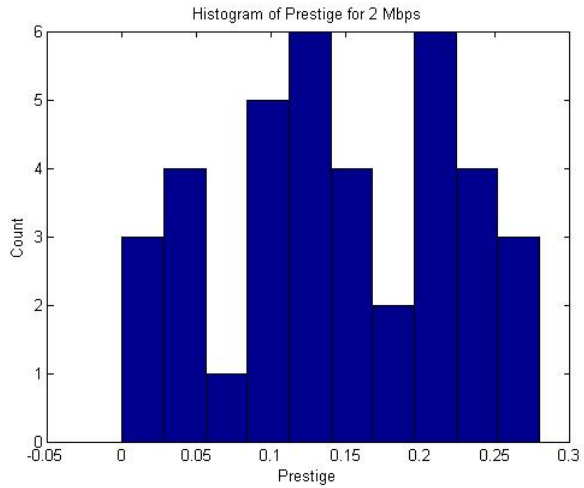
11 Mbps



Prestige as Attempted Data Rates Increase

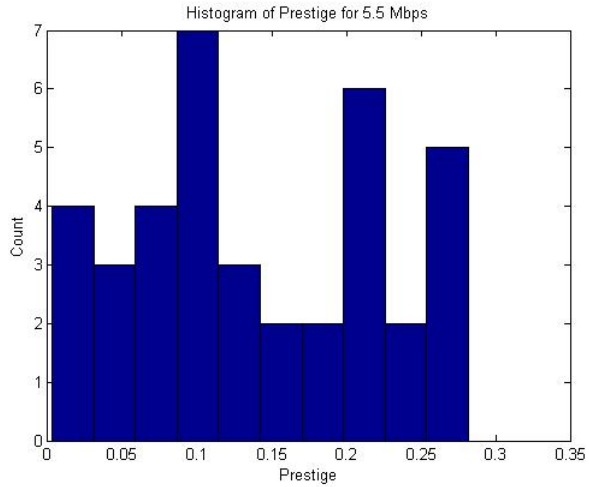
1 Mbps

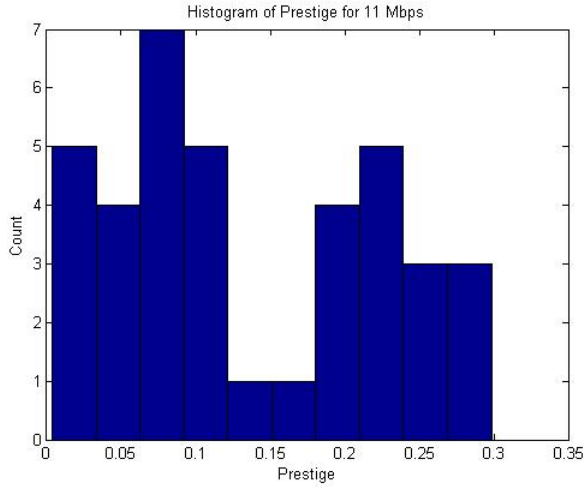




2 Mbps

5.5 Mbps

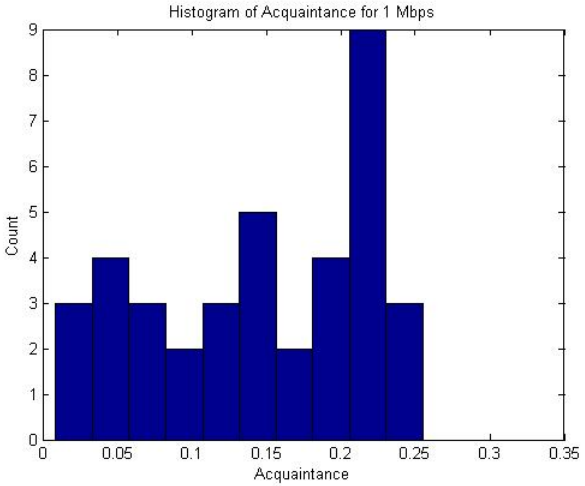




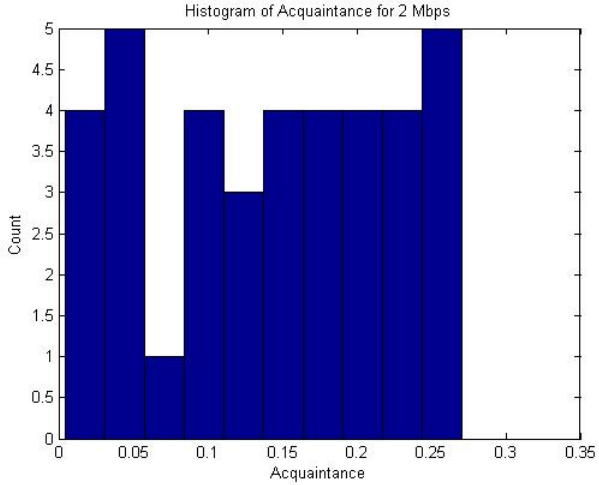
11 Mbps

Acquaintance as Attempted Data Rate Increases

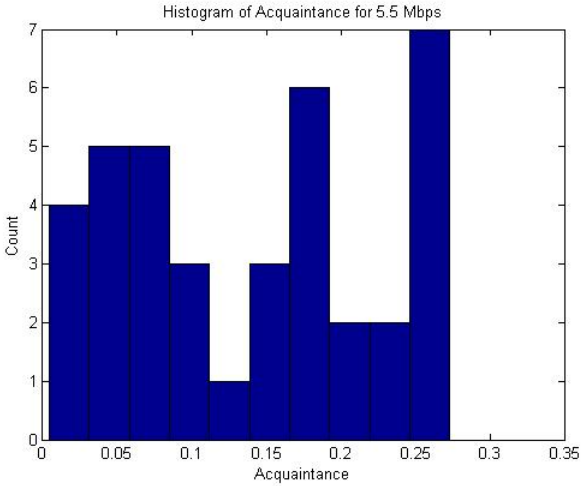
1 Mbps



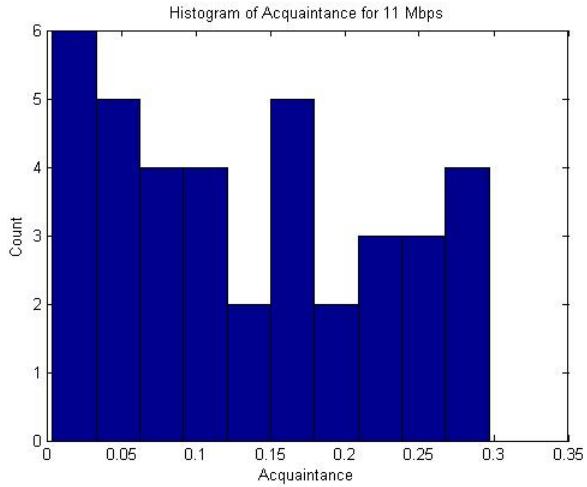
2 Mbps



5.5 Mbps



11 Mbps

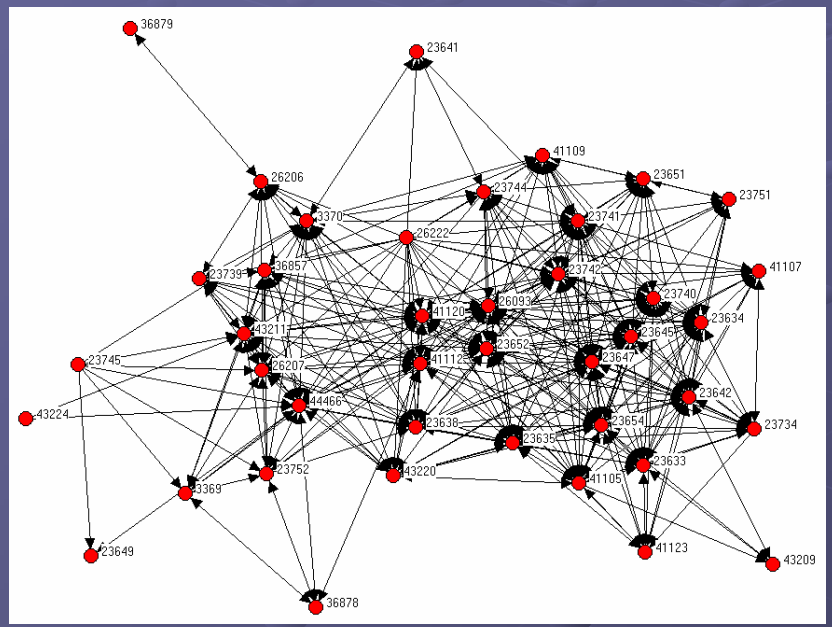


Network Analysis of Aggregate Data

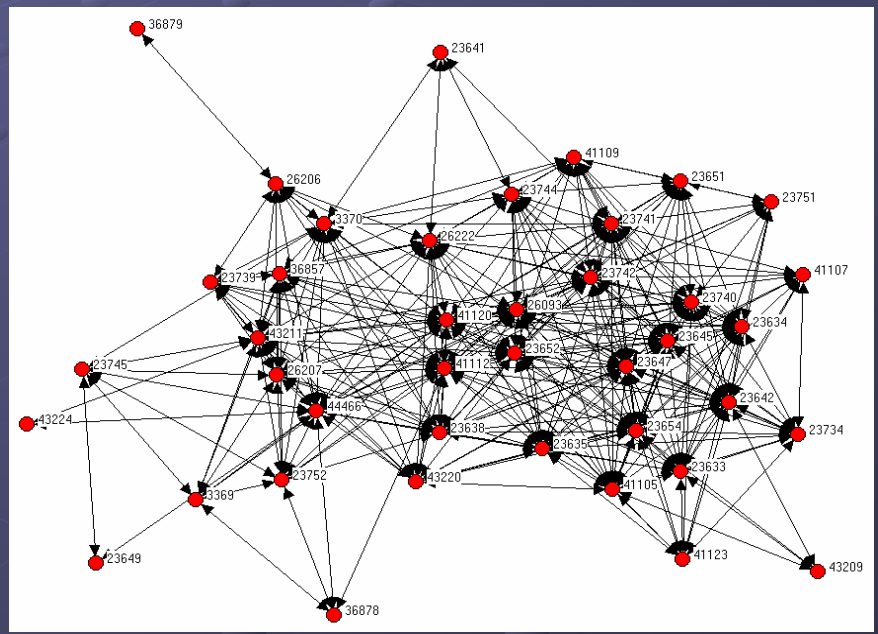
- This is done by comparing different network architectures:
  - Real Roofnet network
  - Model1: LAN
  - Model2: WAN

Roofnet network

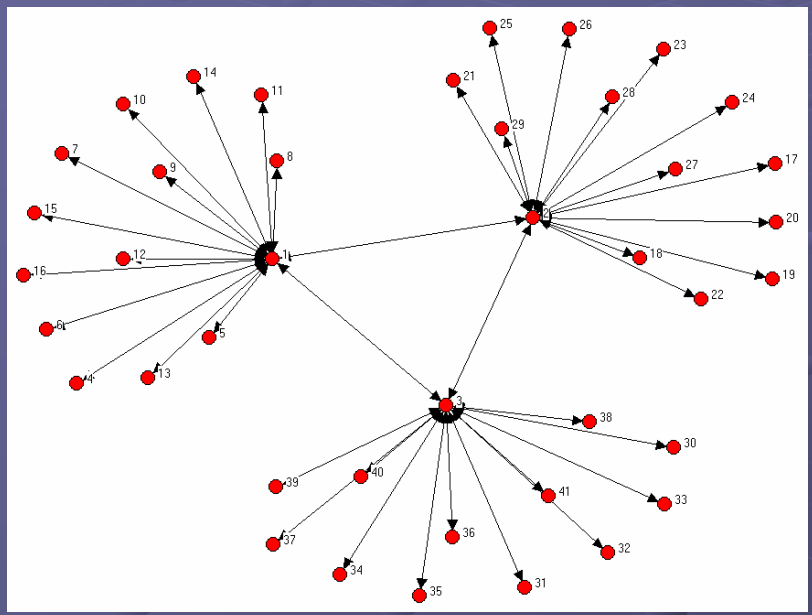
Asymmetric



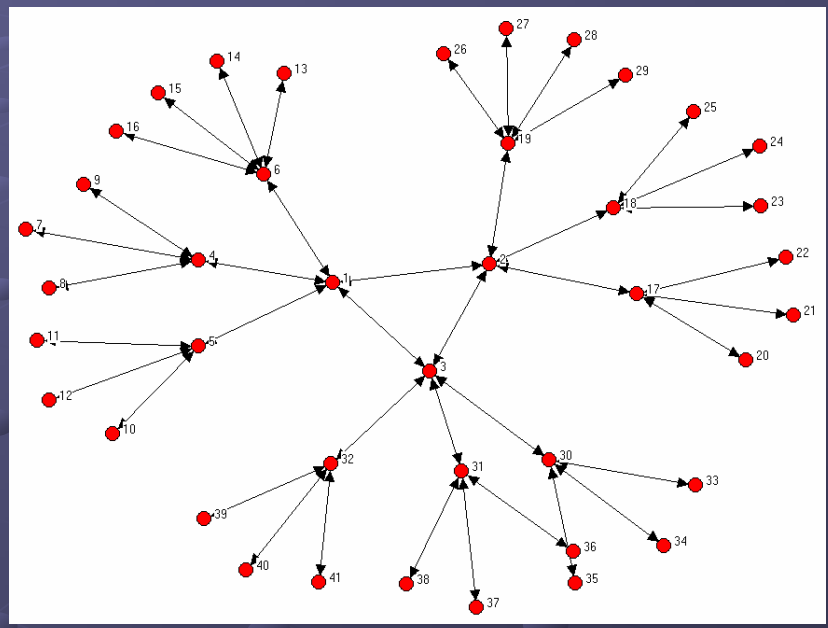
Symmetric



Model 1(LAN)



Model 2 (WAN)



Metrics Calculation

	n	m	k	C	l_1	l_2	r	C_b	C_d
LAN (Model 1)	41	82	2	0.1	0.6039	9.8306	-0.8623	52.34%	34.17%
WAN (Model 2)	41	82	2	0.025	0.9048	13.4575	-0.355	46.13%	7.88%
Roofnet (sym)	41	638	15.6	0.716	0.4123	6.2269	0.0117	10.15%	32.69%
Roofnet (asym)	41	562	13.7	0.5625	0.367	5.5962	0.0633	9.19%	32.69%

L1: average path length

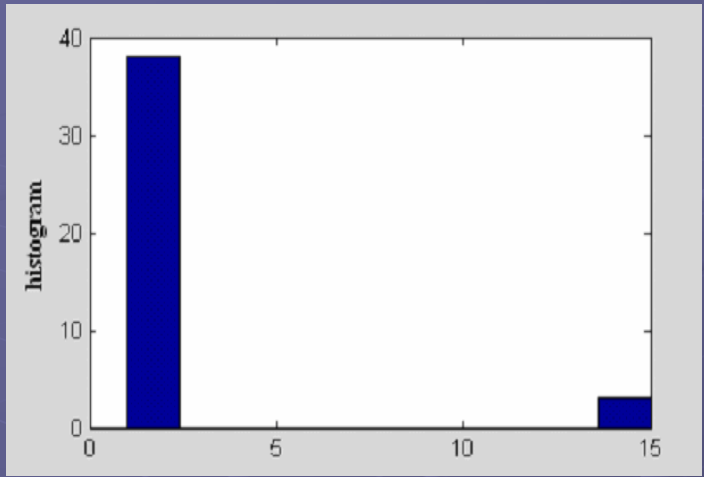
L2: Harmonic path length

r: degree correlation

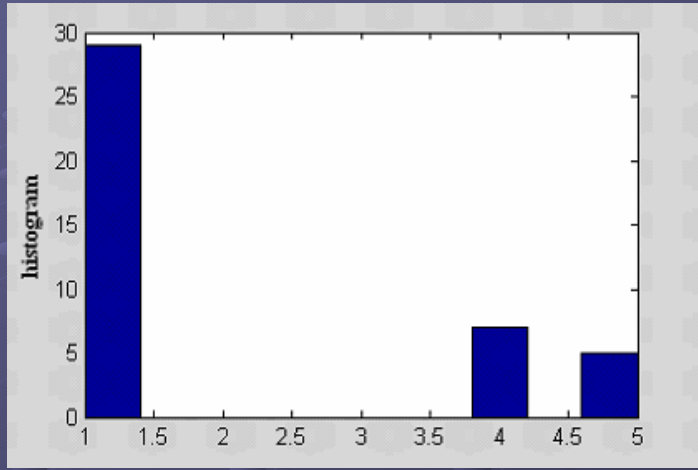
Cb: Betweenness Centrality (Network Centrality Index)

Cd: Degree Centrality

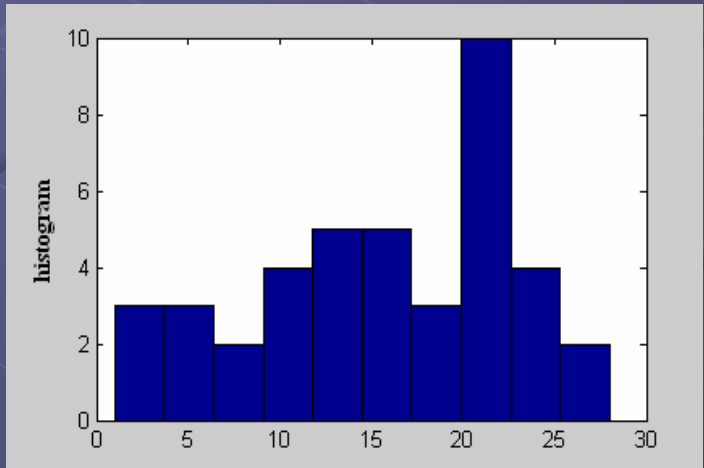
Degree Distribution



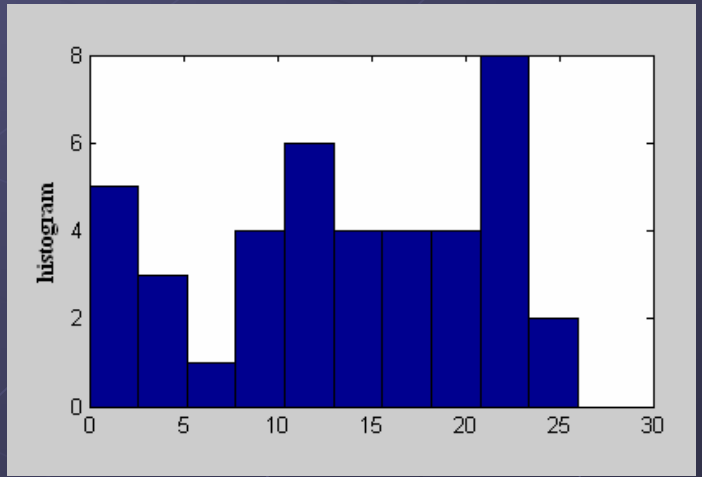
Model 1



Model 2

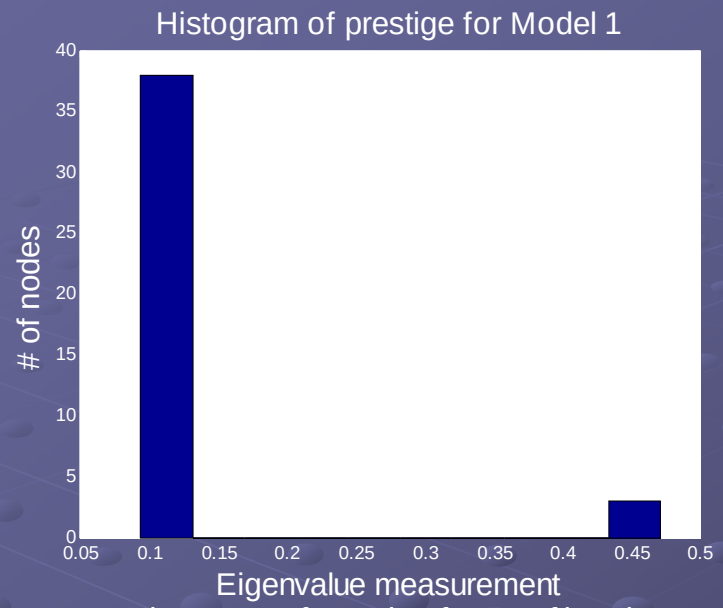


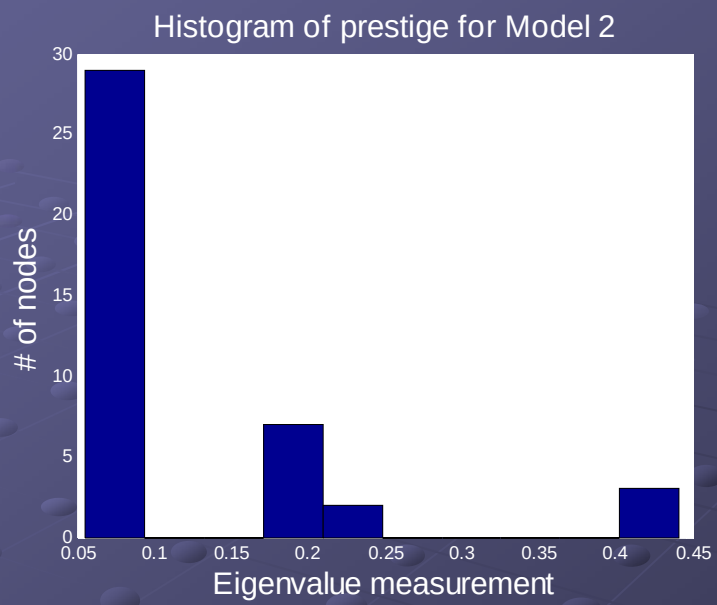
Roofnet (sym)

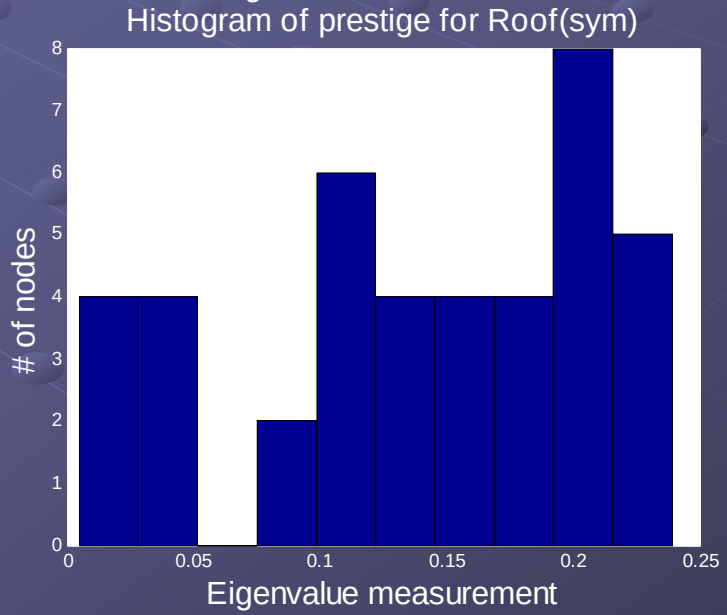


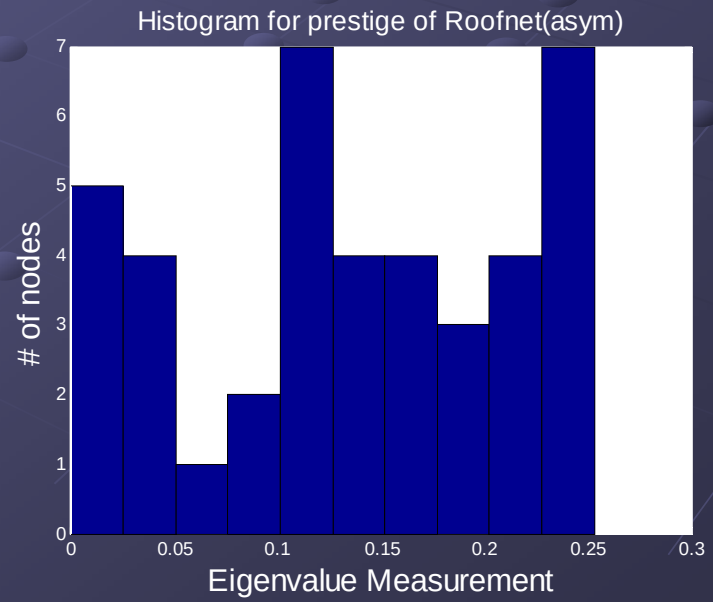
Roofnet (asym)

Prestige

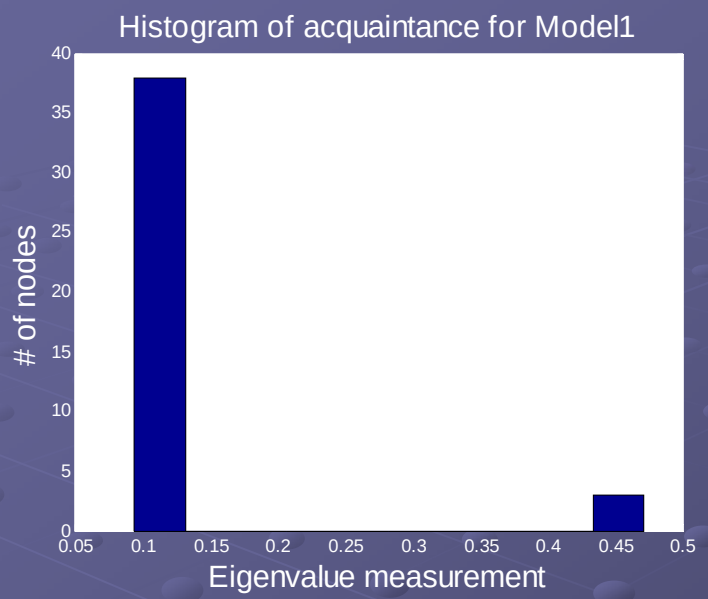

Histogram of prestige for Model 1
# of nodes
Eigenvalue measurement

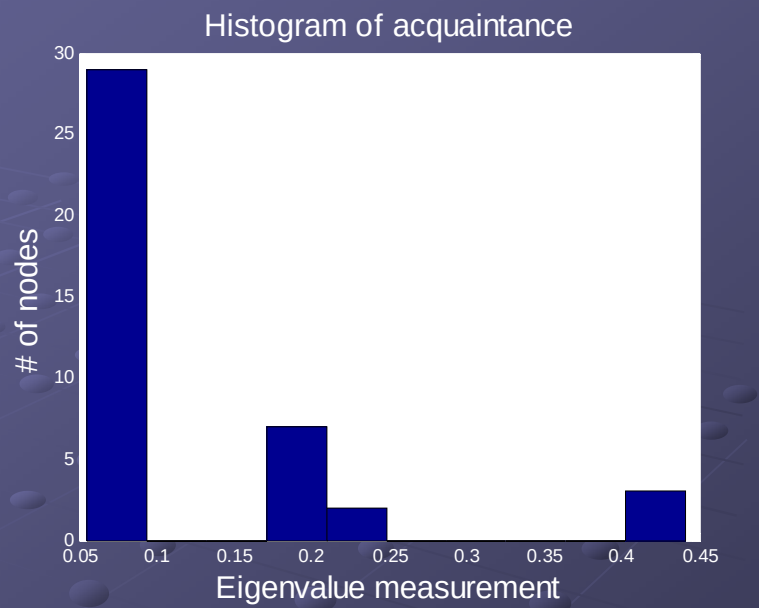

Histogram of prestige for Model 2
# of nodes
Eigenvalue measurement

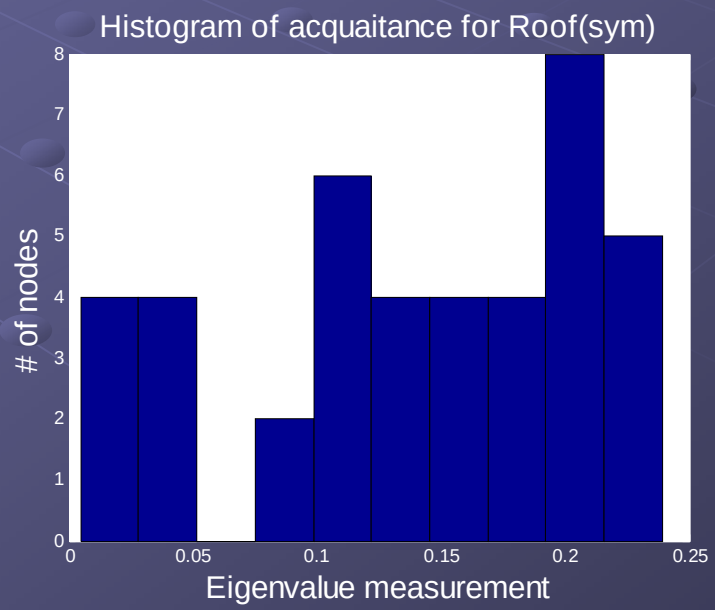

Histogram of prestige for Roof(sym)
# of nodes
Eigenvalue measurement

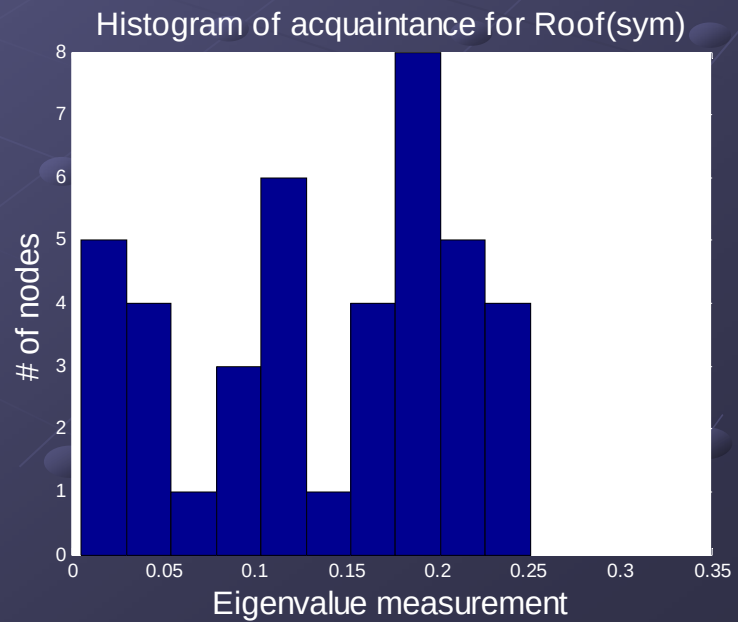

Histogram for prestige of Roofnet(asym)
# of nodes
Eigenvalue Measurement

Acquaintance

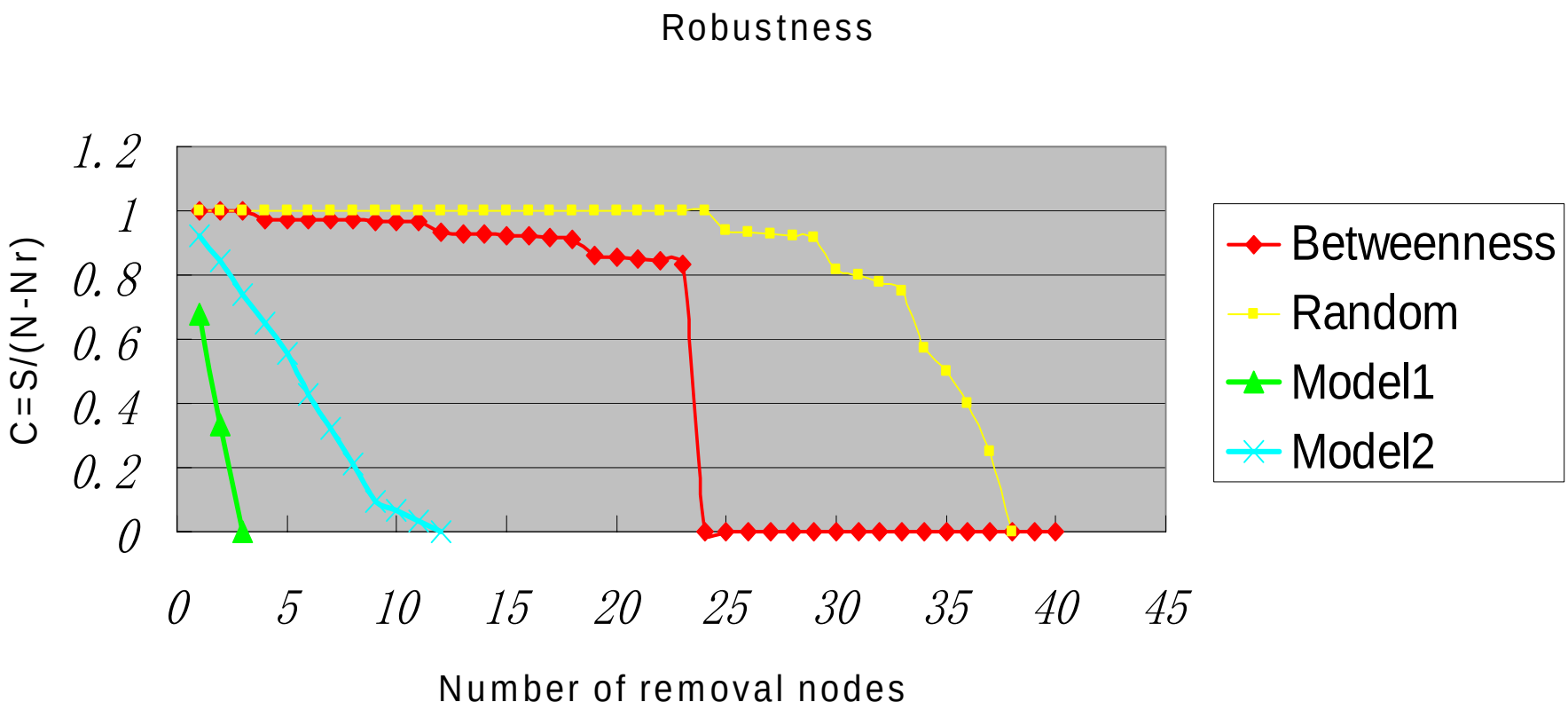






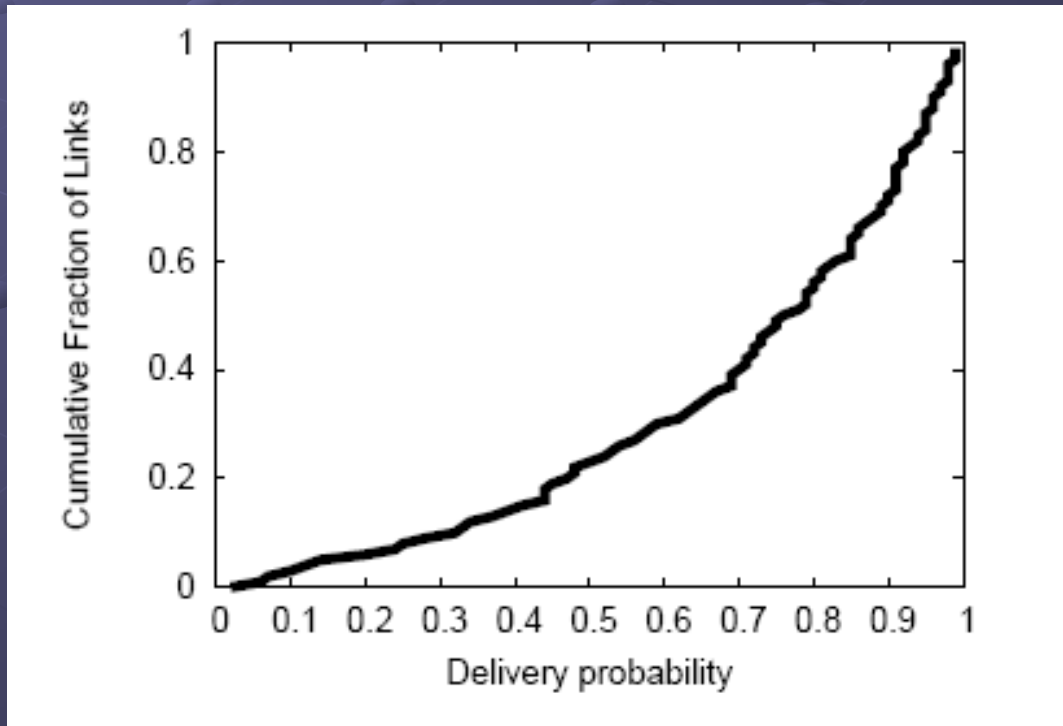


Robustness Analysis



Periphery: where's the edge?

- Roofnet definition of periphery:
  - Nodes with neighbors with low packet delivery probabilities, or too many hops
  - Asymmetrical



ExOR: Opportunistic Routing

- Traditional routing: sender decides on route, midpoints try to execute
- ExOR: try multiple paths, hope for luck
- Every link has a probability of failure
- How to pick the right one?
- Don't: send to "all", see who gets it
  - "All" = 10 "best" midpoints
- Closest midpoint that received takes over
  - Tells others to forget about that packet
- ExOR doubles throughput

Wireless in Cambridge: Actors

- Roofnet Research Group @ MIT
  - Develop routing protocols
  - Not involved in deployment
- MuniMesh
  - Kurt Keville and Bob Keyes (“wifi activists”)
  - Kurt happens to be an MIT employee
  - Bob is writing a book on municipal mesh wifi
- Cambridge Public Internet
  - City: Mary Hart and Linda Turner
  - Other: Housing Authority, Museum of Science, Health Alliance, Harvard

Past and Future

- Early 2005
  - Cambridge decides to offer free wireless
- Mid 2005
  - MuniMesh approaches city
- November 2005
  - Committee formed
- Summer 2006
  - Beta deployment
  - Triangle covering parts of Area 4
  - Main gateways: MIT, Lombardi building beside city hall, one other city building
- City Manager is holding the financial reins

Practical Problems

- Getting signal inside buildings
  - Tropos: more external light-pole repeaters
  - RoofNet: run cable to roof
  - MuniMesh: radio to roof
- Roof issues
  - No power, no ethernet, unhappy landlords
  - MuniMesh: solar powered roof repeaters
- Cost of equipment
  - Roofnet: $700 per node
  - MuniMesh: $100 per node
    - Separate home radio from rooftop repeater
    - Reprogram COT NetGear router for in home
    - Repeater will still be expensive

Conclusions

- Unexpected result: Increasing attempted data rate changes the effective architecture
- Roofnet architecture is noticeably different from the representative baseline LAN/WAN internet models
- Roofnet architecture is robust and not fragile (as the designers intended)

Back-up Slides