LifeNet Evaluation & Deployment

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The Flexible Routing Protocol

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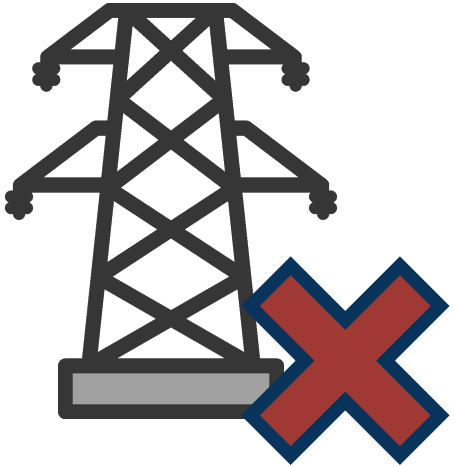
Reliable packet delivery under transience

- Lack of a **routing metric that accurately captures** transience
- Lack of a routing protocol that **naturally enables fault-tolerant communication** under varying degrees of transience



Minimum use of infrastructure

Most popular wireless communication solutions are **infrastructure-based** and **not applicable**

For example: a remote rural village in a developing country, establishment of a GSM base station is infeasible

No functional hierarchy

Multipath routing

Why Multipath routing?

High availability

Fault-tolerance

Proactive routing

Trade-Off:
Throughput vs. Reliability

Design

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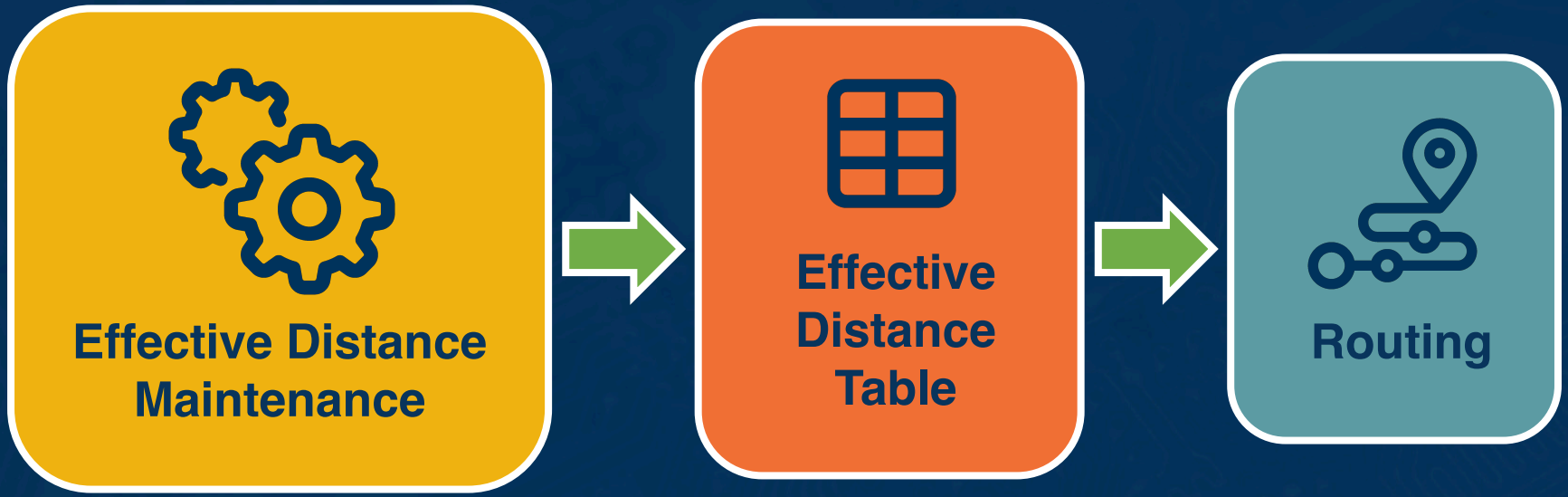
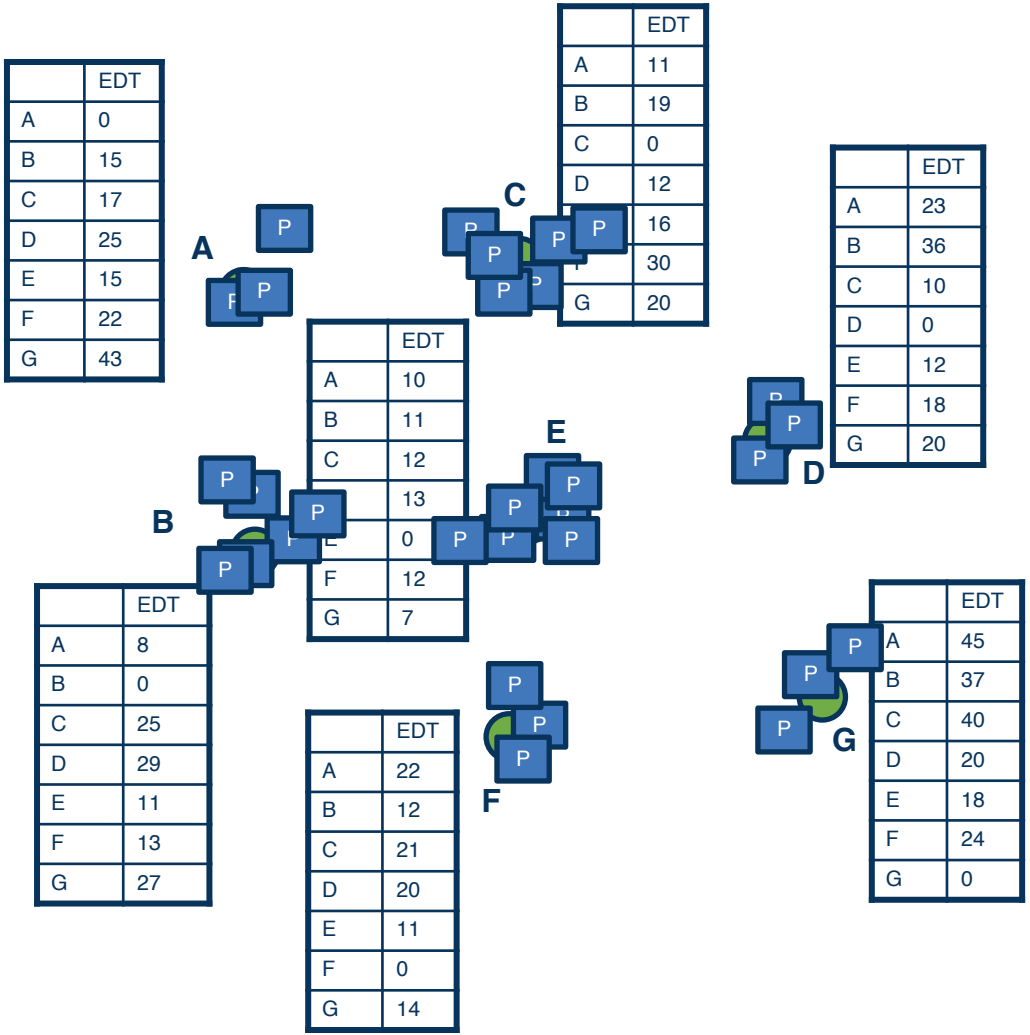
Functional Block Diagram





	EDT
A	0
B	15
C	17
D	25
E	15
F	22
G	43

	EDT
A	11
B	19
C	0
D	12
E	16
F	30
G	20

	EDT
A	23
B	36
C	10
D	0
E	12
F	18
G	20

	EDT
A	10
B	11
C	12
D	13
E	0
F	12
G	7

	EDT
A	8
B	0
C	25
D	29
E	11
F	13
G	27

	EDT
A	22
B	12
C	21
D	20
E	11
F	0
G	14

	EDT
A	45
B	37
C	40
D	20
E	18
F	24
G	0

Effective Distance Maintenance

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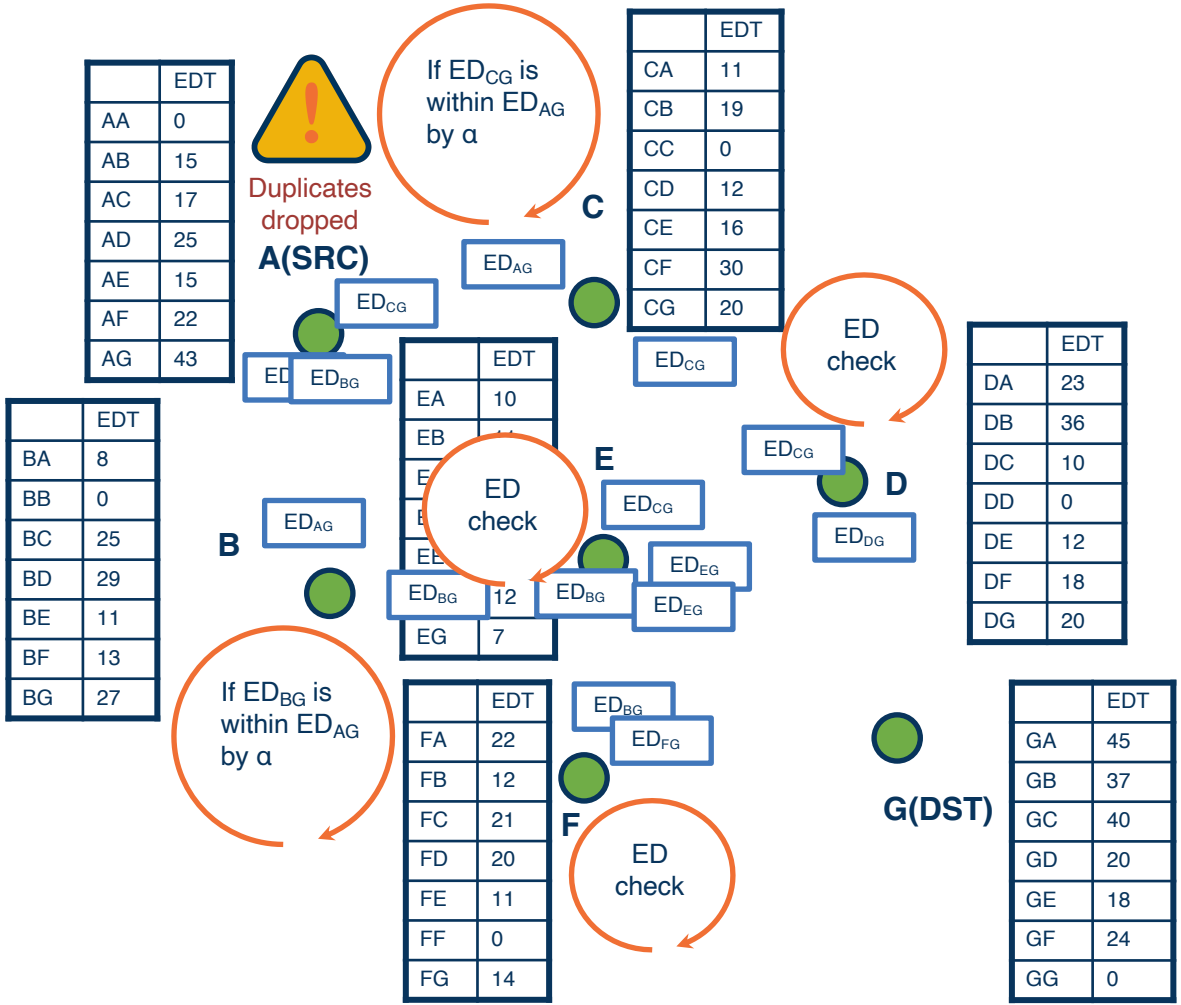

	EDT
AA	0
AB	15
AC	17
AD	25
AE	15
AF	22
AG	43

	EDT
BA	8
BB	0
BC	25
BD	29
BE	11
BF	13
BG	27

	EDT
CA	11
CB	19
CC	0
CD	12
CE	16
CF	30
CG	20

	EDT
EA	10
EB	
EC	
ED	
EE	
EF	12
EG	7

	EDT
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DB	36
DC	10
DD	0
DE	12
DF	18
DG	20

	EDT
FA	22
FB	12
FC	21
FD	20
FE	11
FF	0
FG	14

	EDT
GA	45
GB	37
GC	40
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GE	18
GF	24
GG	0

Routing

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Implementation Challenges

Transport Layer
TCP not suitable for lossy networks

Network Layer
Autoconfiguration of IP Addresses

MAC Layer
- Problems like hidden node and exposed node
- Limited support for ad hoc networking
- Buggy device driver implementations

Physical Layer
- Multipath fading
- Shadowing
- Interference
- Loss due to distance attenuation

Transport Layer
TCP not suitable for lossy networks

Network Layer
Autoconfiguration of IP Addresses

Flexible Routing Layer
Kernel Module

MAC Layer
- Problems like hidden node and exposed node
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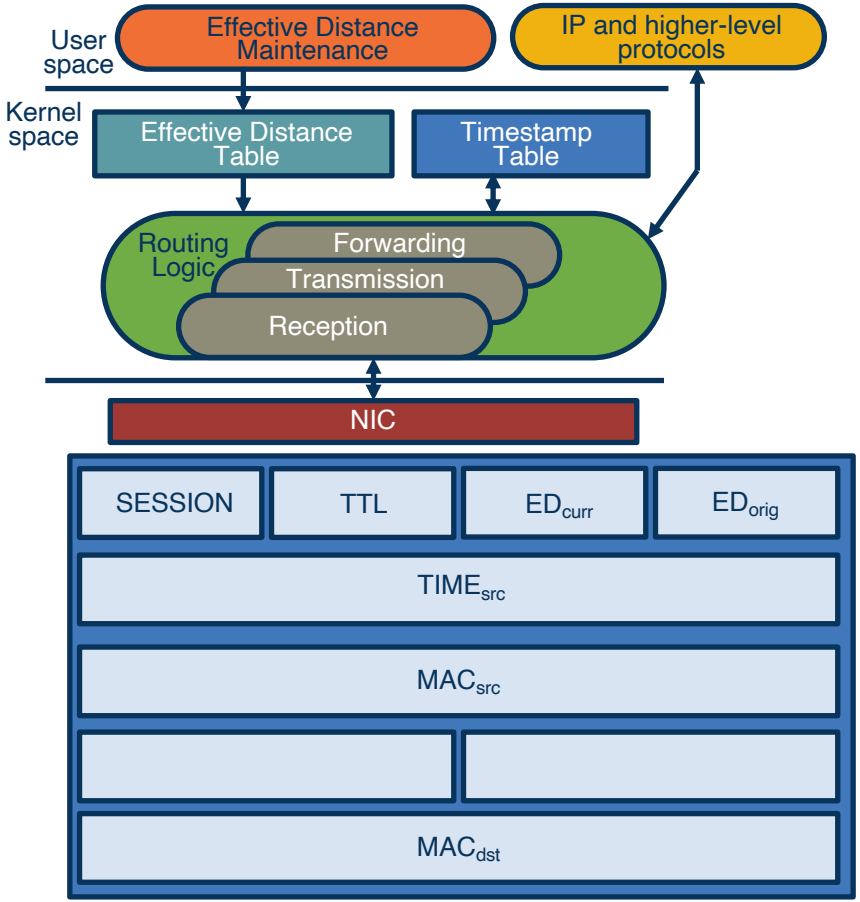

Implementation

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Layer 2.5 Advantages

- **Faster forwarding** due to implementation in kernel
- Transparency to the higher and lower layers allowing **compatibility with existing network and transport protocols**
- MAC-based routing considerably **reduces configuration overhead**
- Commodity MAC remains untouched, which makes the routing protocol more **generic and MAC and hardware independent**

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Evaluation

Scalability

- Reachability captures the phenomenon that connectivity of the network increases as the network scales
- Reachability captures the effect of physical obstructions
- Flexible Routing improves end-to-end flow capacity and packet loss as the network scales

Node-failures

- Reachability captures the effect of node failures
- Flexible Routing successfully handles node failures
- Flexible Routing ensures that a flow remains unaffected by removal of nodes that are not a part of it

Mobility

- Reachability captures the effect of mobility
- Flexible Routing successfully handles mobility

Redundancy-control

- Excessive Redundancy can be controlled in Flexible Routing

Hypothesis

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Connectivity
(Number of strongly connected pairs) / (Total number of pairs)

Flow capacity
Min SRC-DST cut of the flow graph when edge-weights are reachability values

Reliability
Standard definition (fraction of node pairs that remain connected when each node fails independently with some probability)

Evaluation Metrics

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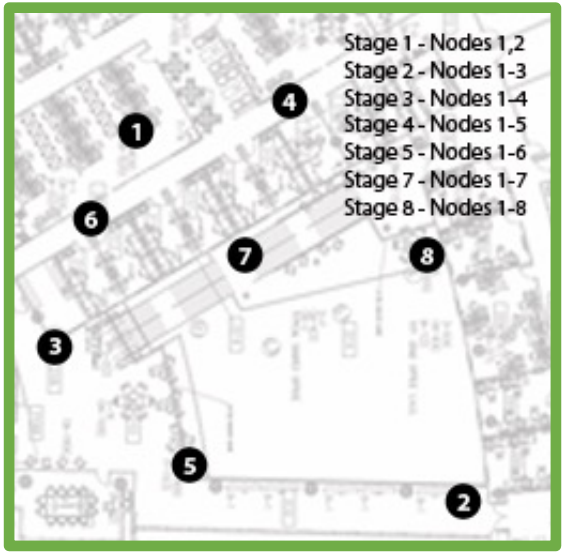
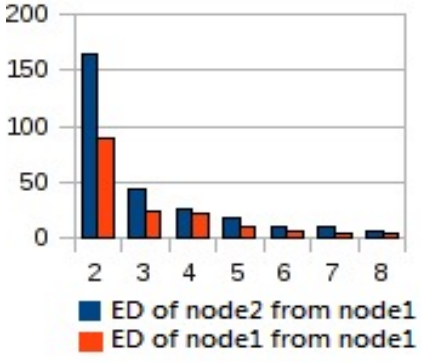
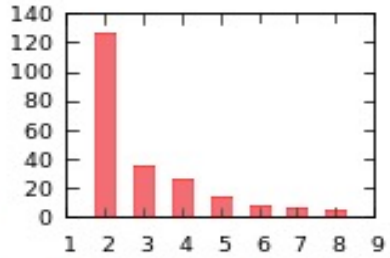
- **Reachability:** the phenomenon that network connectivity increases as the network scales
- **Reachability** captures the **effect of physical obstructions**
- **Flexible Routing** improves packet loss and flow capacity as the network scales



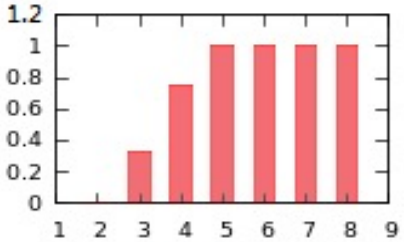
Experiment 1



EDs of Stage 1 nodes vs. Num of active nodes
(a)



Average ED per node vs. Number of active nodes
(b)



Connectivity vs. Number of nodes
(c)

Scaling the Network

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- **Reachability:** the phenomenon that network connectivity increases as the network scales
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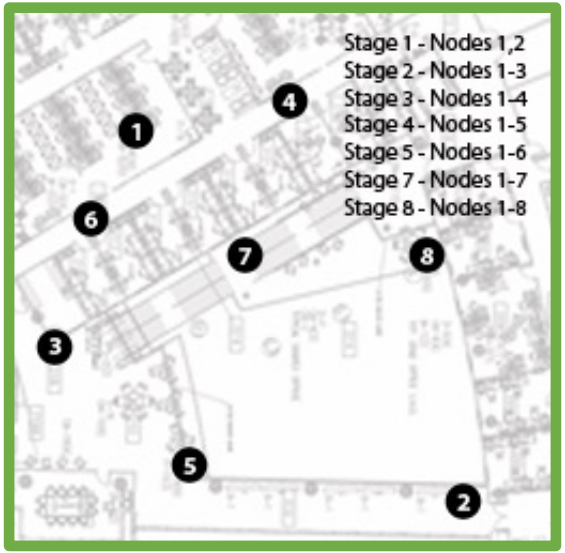
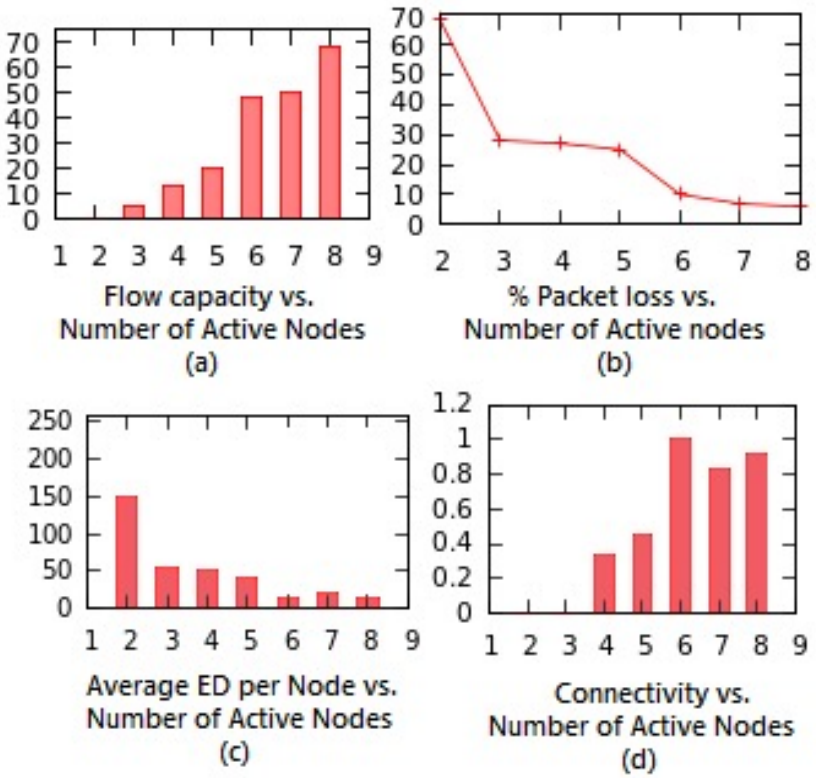
- **Flexible Routing** improves packet loss and flow capacity as the network scales



Experiment 2



Scaling the Network

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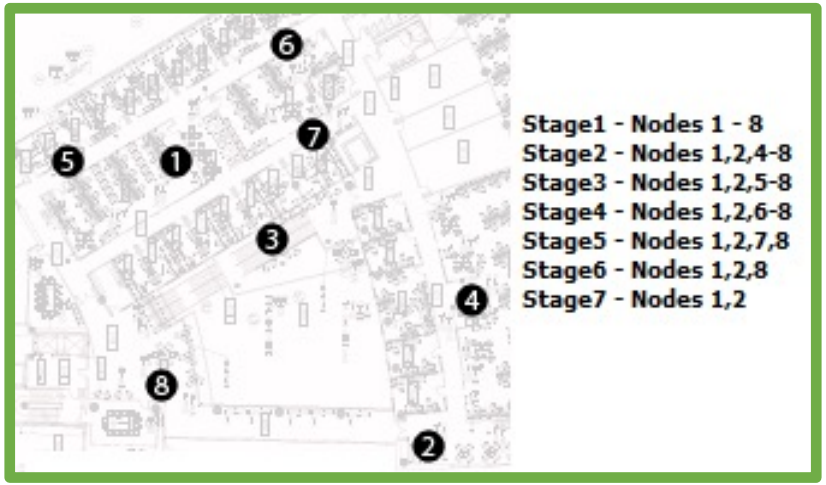
- Reachability captures the **effect of node failures**
- **Flexible Routing** successfully handles node failures
- **Flexible Routing** ensures that a flow remains **unaffected by removal of nodes** that are not a part of it



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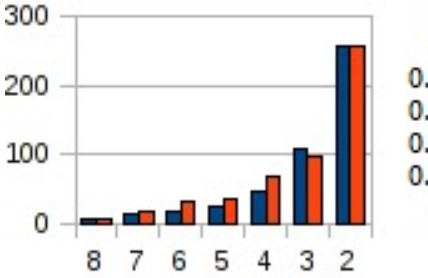
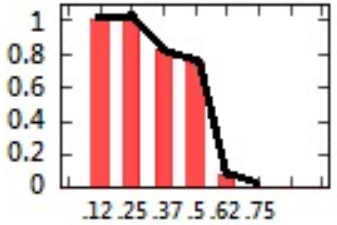
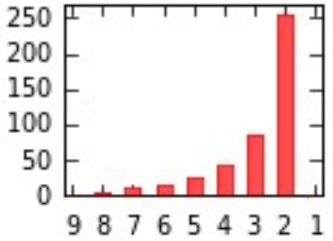


ED vs. Number of Active Nodes
(a)



(b)



ED Averaged over all node pairs vs.
Number of nodes
(c)

Node Failures

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- Reachability captures the **effect of node failures**
- **Flexible Routing** successfully handles node failures
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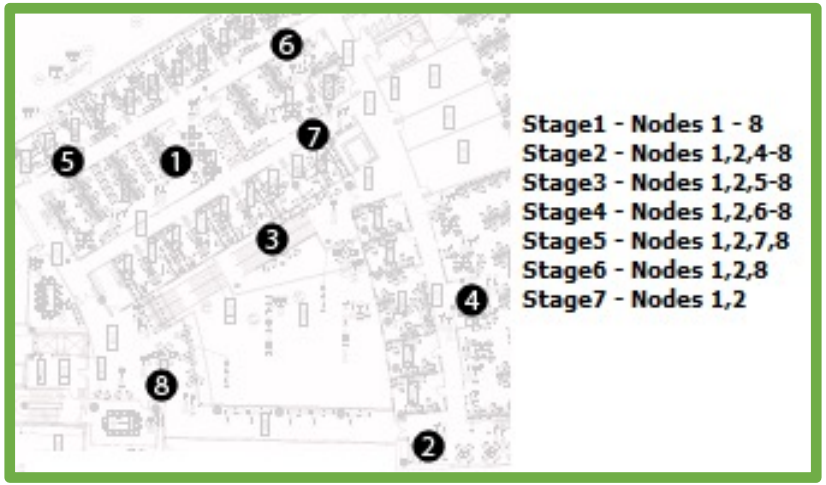
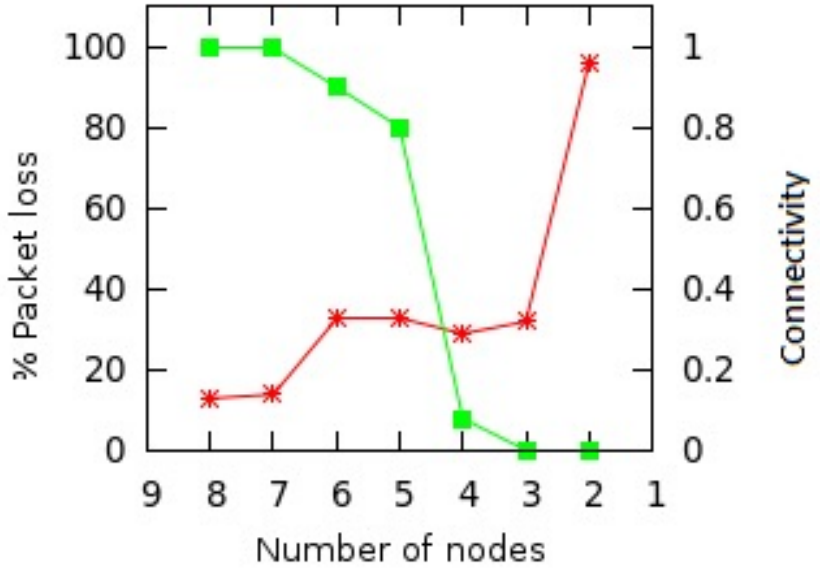
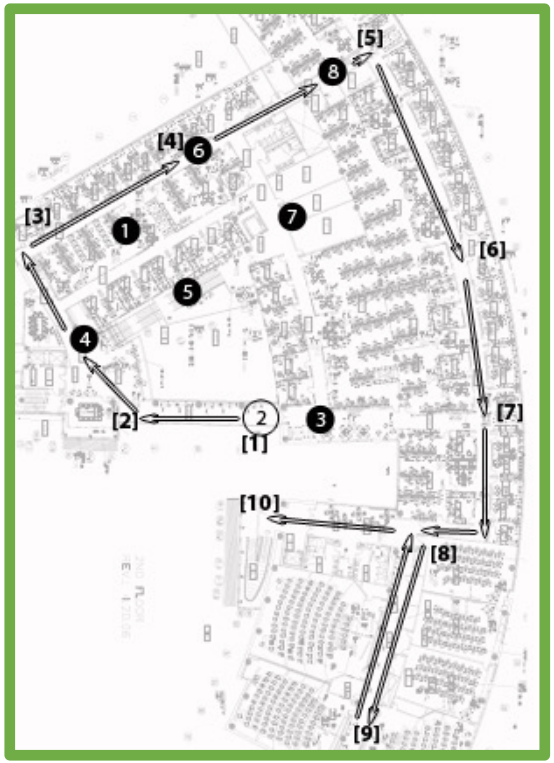


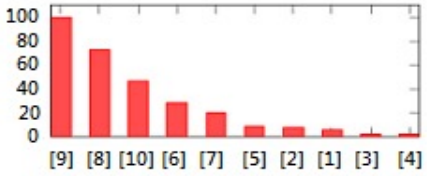
Experiment 2



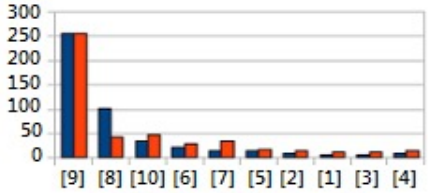
Node Failures

- **Reachability** captures the effect of mobility
- **Flexible Routing** successfully handles mobility

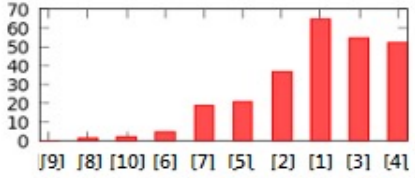




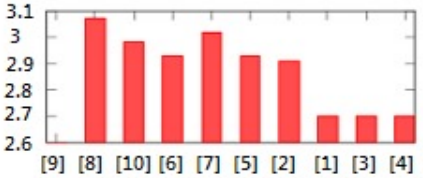
Packet loss vs. Node Positions
(a)



ED vs. Node Positions
(b)



Flow Capacity vs. Node Positions
(c)



Weighted Avg. Number of Hops
vs. Node Positions
(d)

Mobility

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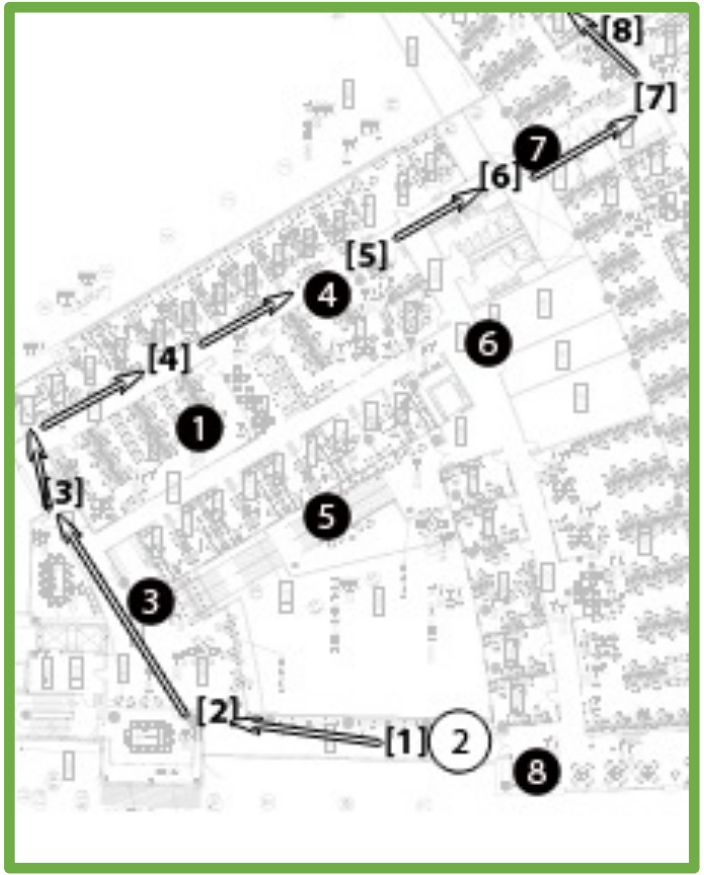

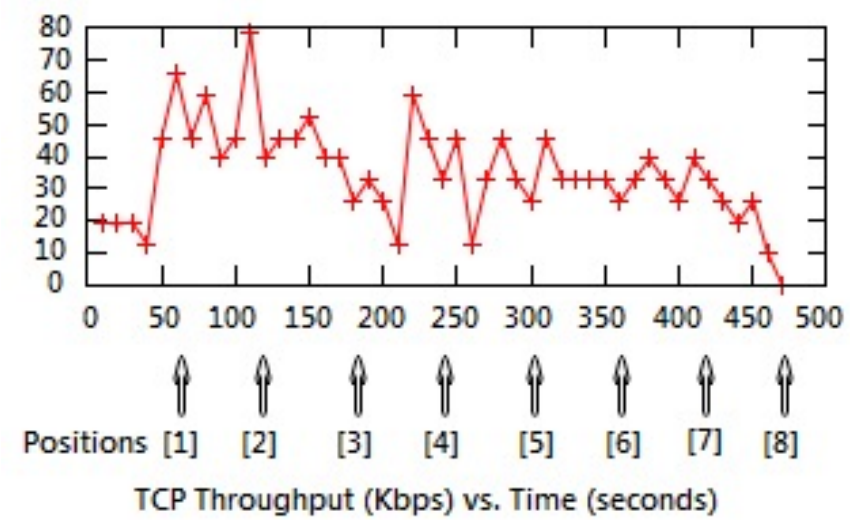

Throughput

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Deployment & Improvements

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Early Feedback

December 2009

January 2010

February 2010

March 2010

Dec. ‘09
First outdoor field test with FAA

Jan. – Mar. ‘10
NCIIA grant and workshop

Jan. – Mar. ‘10
Collaboration with TISS

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Field Trips

September 2010

Sept. ‘10
Talk at TISS, Team finalized

October 2010

Oct. ‘10
Meeting with government officials (Maharashtra State, India)

November 2010

December 2010

Dec. ‘10
Deployment Location Shortlisted

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2010

Porting on OpenWRT

2011

Porting on Android

POC for Microsoft Windows

Presented demo at SIGCOM

https://conferences.sigcomm.org/sigcomm/2011/papers/sigcomm/p446.pdf

Field tests

2012

Hrushi created MeGo Technologies

Improvements

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MeGo Technologies

- LifeNet by itself was **not ready for commercial sustainability**
- **Hrushi started company** with a broader set of internet solutions
- **Successful and active** 10 years later
- Develops **innovative networking solutions**

https://www.megotechnologies.com/

mego

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Lessons Learned & Thanks

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Minimum use of infrastructure is important

Give **authority to local residents**

Minimal power consumption

Locally available & maintainable communication equipment

Make the solution a **part of users' daily lives**

Lessons Learned

Georgia Tech

Hrushikesh Mehendale

- Lead architect of LifeNet, C4G MS student, MS research award

Ashwin Paranjpe

- Co-designer of routing protocol and implementation, C4G MS student

Dr. Janki Andheria

- Dean of School of Disaster Studies, Tata Institute of Social Sciences

Dr. Shibu Mani

- Professor, TISS

TISS Students:

- Soma Sinha, Amit Prakash, Santosh Kumar

Thanks

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