Architecture and Evaluation of an Unplanned 802.11b Mesh Network

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Contents

Motivation and advantages

What are we looking for in a network?

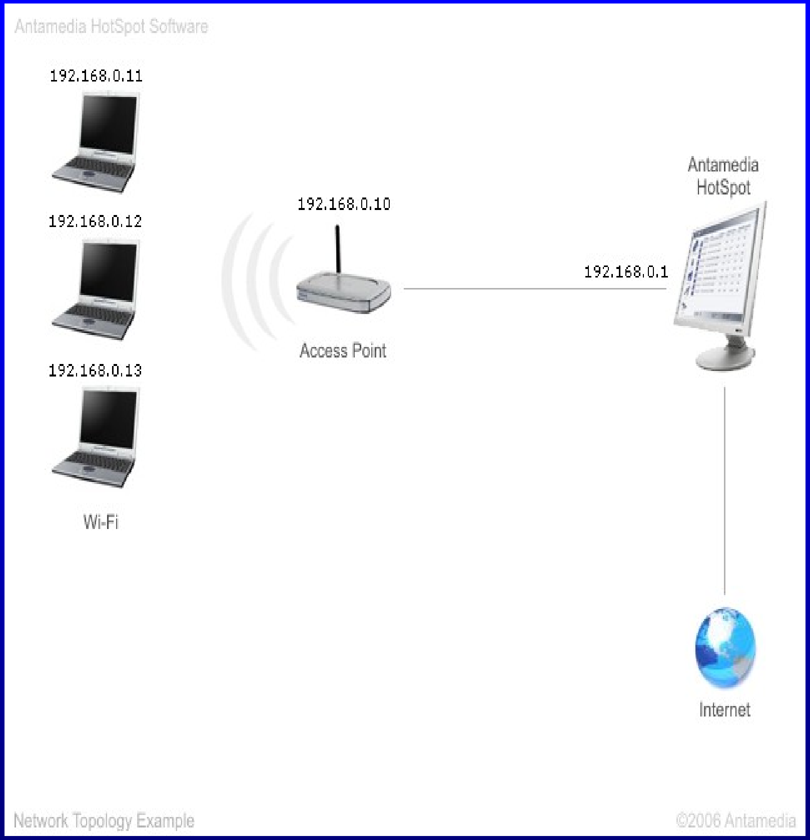
- Easy and quick to deploy
- Easy to manage for the users
- Good quality of service
- Robust
- Cheaper than other kinds of network

Wireless network architectures

1. Hot-spot network
2. Multihop network

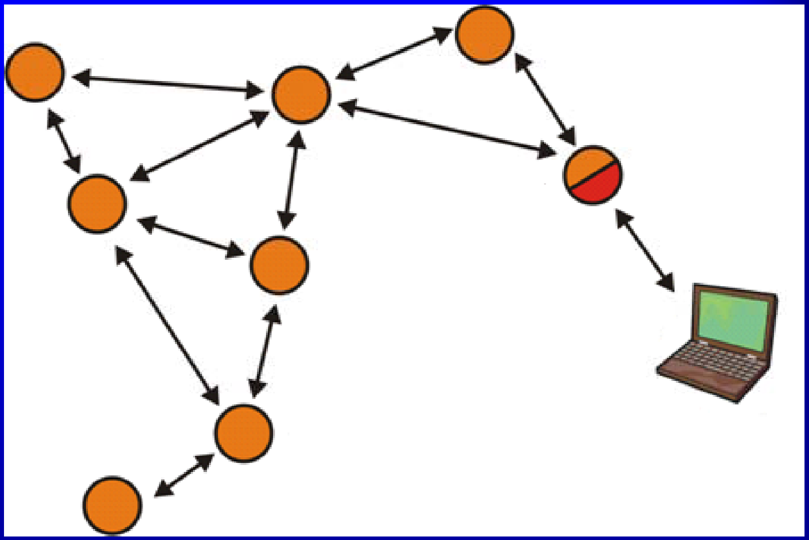
1. Hot-spot Network

- Omnidirectional antennas
- The hot-spots operate independently, they are not connected with each other
- Each hot-spot provides connection to the Internet
- Lower coverage per wired connection than multi-hop networks



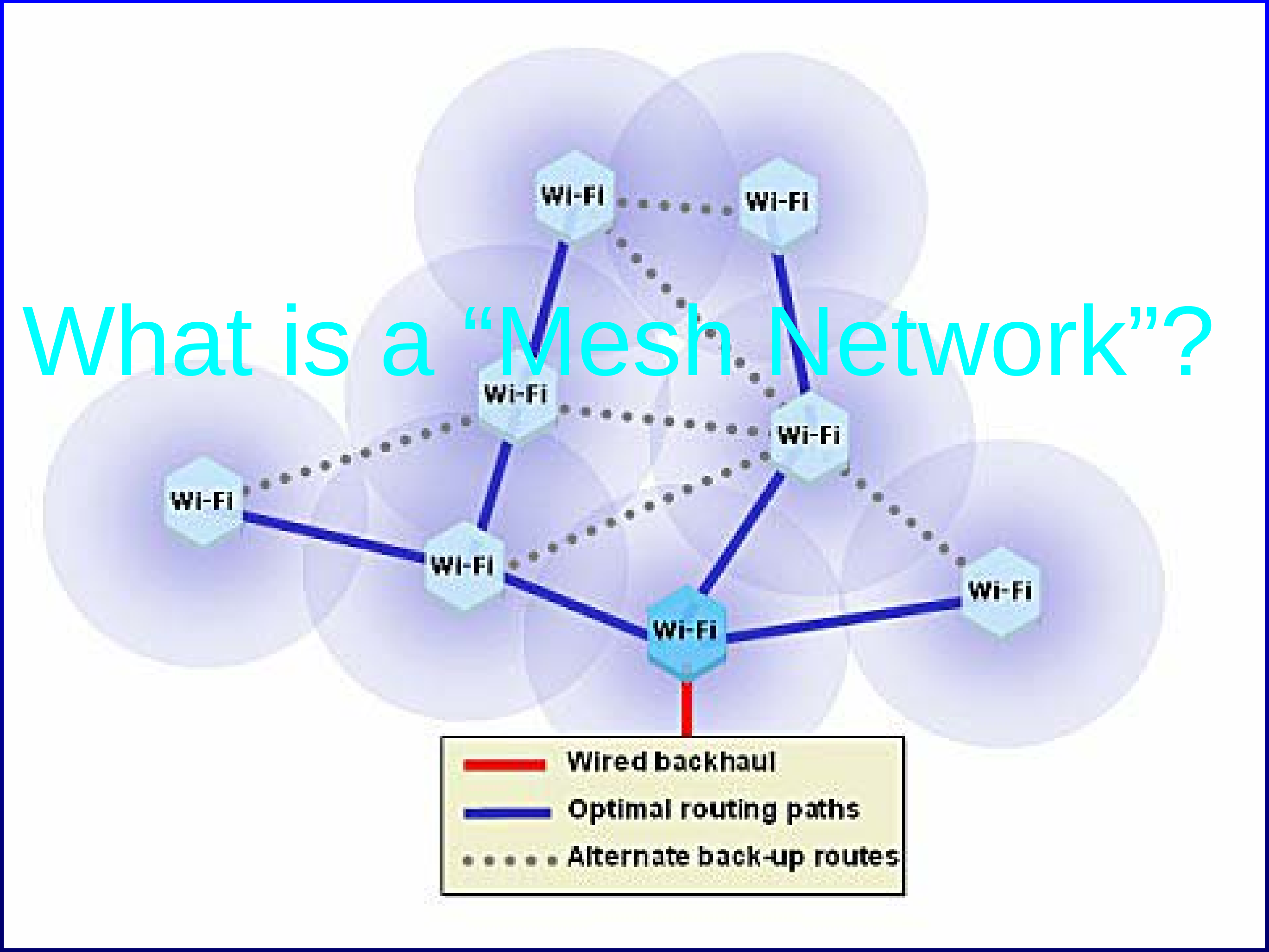
2. Multihop Network

- Typically, unidirectional antennas
- Typically, nodes placed by a technical expert group
- Good quality
- Not all the nodes must provide access to the Internet
- Several hops available to reach the destiny



Definition of "Mesh Network"

What is a "Mesh Network"?



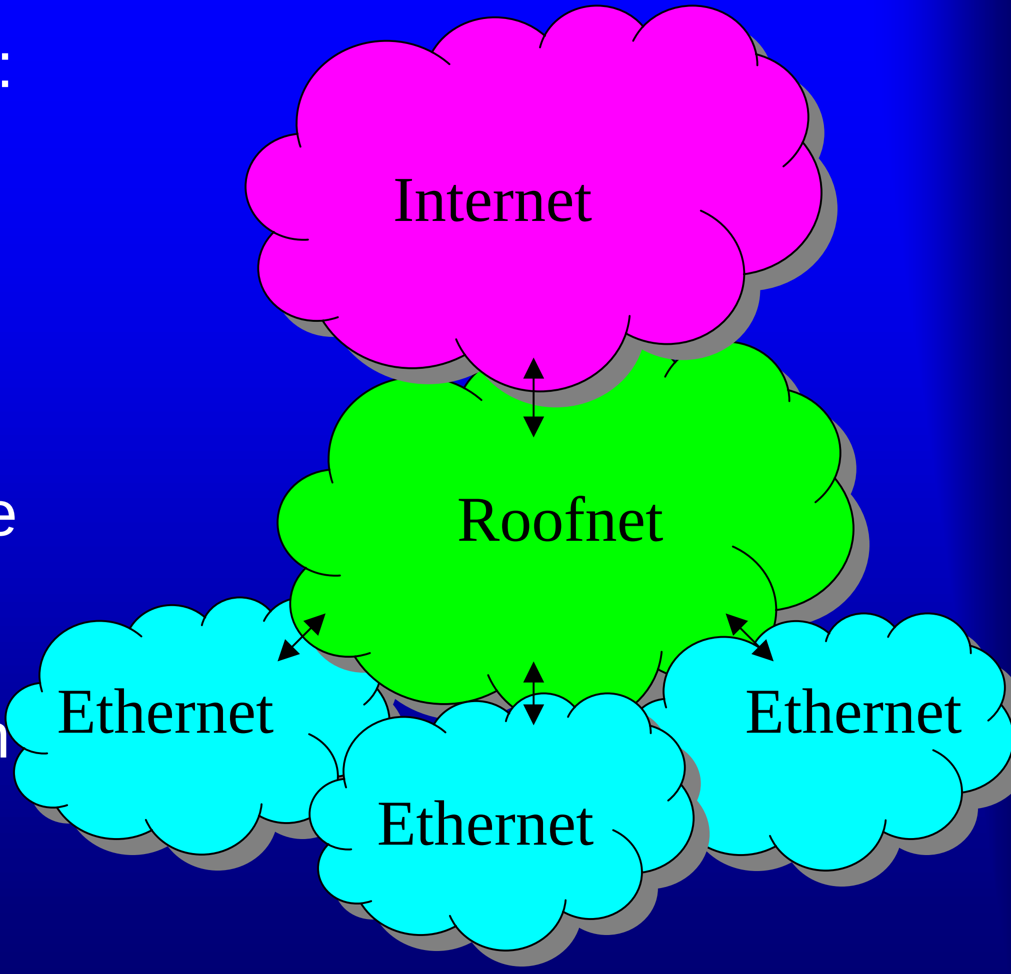
Characteristics of the Mesh Network under test

- General characteristics
- Network architecture

General characteristics

Network architecture

- 3 different networks involved:
  - Internet
  - Roofnet
  - Ethernet
- The nodes of the mesh network form the Roofnet
- Three of these nodes provide access to the Internet (Gateways)
- The users connected to each node form one separate Ethernet



Functioning

- Addressing
- Interconnecting networks
  - NAT (Network Address Translation)
- Routing
  - Routing metric
  - Routing protocol

Addressing

- The nodes have 2 addresses:
  - Private IP address: to manage IP applications between users of the Roofnet
  - Roofnet address: to route the packets through the Roofnet
- The gateways have in addition a public IP address
- The users have a private IP address obtained from their node (each node acts as DHCP for its users)

Interconnecting networks

- The packets of information sent by/to a user must travel through different networks
- The addressing system is different in each network
- The nodes run NAT (Network Address Translation) between their Ethernet and the Roofnet
- They encapsulate the IP packets into Roofnet packets in order to route them through the Roofnet
- The gateways run NAT between the Roofnet and the Internet

Routing

- The Roofnet must be able to find the best route for each connection and to change it, if it finds another route with better characteristics
- For that, the Roofnet “measures” every link and computes the best path
- The mesh network uses the routing metric to “measure” the links and the routing protocol to find the best route

Routing metric

- The routing metric used is called ETT (Estimated Transmission Time)
- ETT estimates the time spent to send a data packet through a link, taking into account the highest throughput of this link and the delivery probability at this bit-rate
- Three posible bit-rates (throughputs): 1, 2 and 5.5 megabits/second

Routing protocol

- Srcr is the Roofnet's routing protocol
- Srcr nodes maintain a database with some of the ETT metrics between links of the Roofnet
- They use Dijkstra's algorithm on that database to find the best route

Routing protocol

How do the nodes learn the ETT metrics of the links?

- Three ways:
  - When a node forwards a packet, it includes a metric of the current link on it, in order to inform the other nodes of the route
  - If a node has to send a packet to another one, but cannot find a route, it sends a query to all its neighbors and learns the metric of the links through the responses that it receives
  - Nodes can overhear queries and responses from other nodes and add the metric in those packets to their own databases

Routing protocol

- In addition to these methods, the gateways periodically flood (send to each node) a dummy query to allow all the nodes to find a route to them.

The route to/from a gateway

- The gateways learn the route to reach each node from the info that the packets sent by these nodes contain.

Evaluation

The evaluation is focused on the following characteristics:

- The effect of node density on connectivity and throughput.
- The characteristics of the links that the routing protocol elects to use.
- The usefulness of the highly connected mesh afforded by omnidirectional antennas for robustness and throughput.
- The potential performance of a single-hop network using the same nodes.

Evaluation

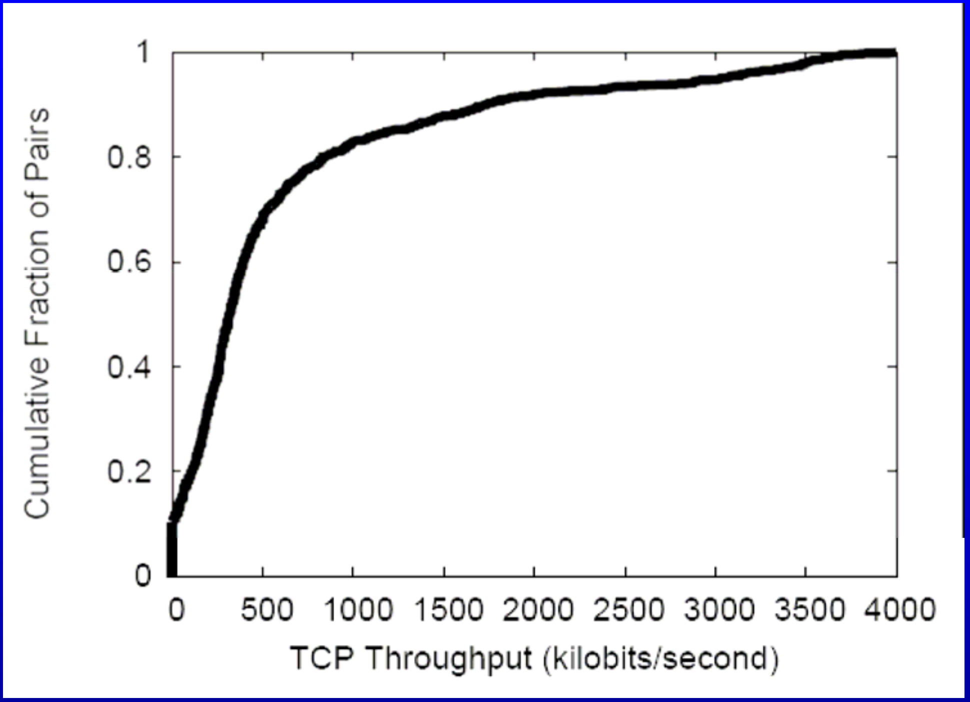
The measurements are obtained from the received information of the final application, in form of TCP throughputs.

The results are classified according to what is tested:

- Basic performance
- Link quality and distance
- Effect of density
- Mesh robustness
- Architectural alternatives
- Inter-hop interference

Basic performance

TCP Throughput



- Median throughput = 400 kbps
- Average throughput = 627 kbps

Basic performance

Hops	Number of Pairs	Throughput (kbits/sec)	Latency (ms)
1	158	2451	14
2	303	771	26
3	301	362	45
4	223	266	50
5	120	210	60
6	43	272	100
7	33	181	83
8	14	159	119
9	4	175	182
10	1	182	218
no route	132	0	–
Avg: 2.9	Total: 1332	Avg: 627	Avg: 39

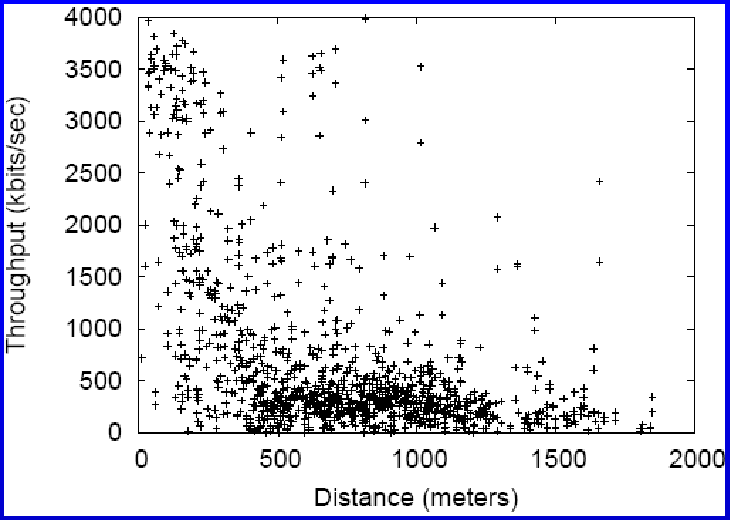
Hops needed between two nodes to establish each link

Hops	Number of nodes	Throughput (kbits/sec)	Latency (ms)
1	12	2752	9
2	8	940	19
3	5	552	27
4	7	379	43
5	1	89	37
Avg: 2.3	Total: 33	Avg: 1395	Avg: 22

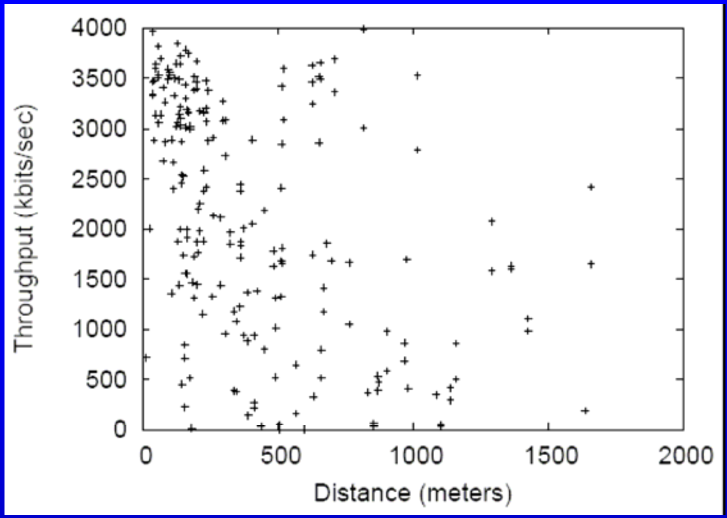
Hops needed to establish a link between each node and a gateway

- o Srcr protocol prefers multi-hops links to the larger-hops links
- o Most of the information travels by these links, in both cases, to connect nodes with each other or to connect nodes with a gateway

Link quality and distance



Throughput and distance of each link



Throughput and distance of each link chosen by Srcr protocol

- The links choosen are typically the shortest links with high throughput

Effect of density

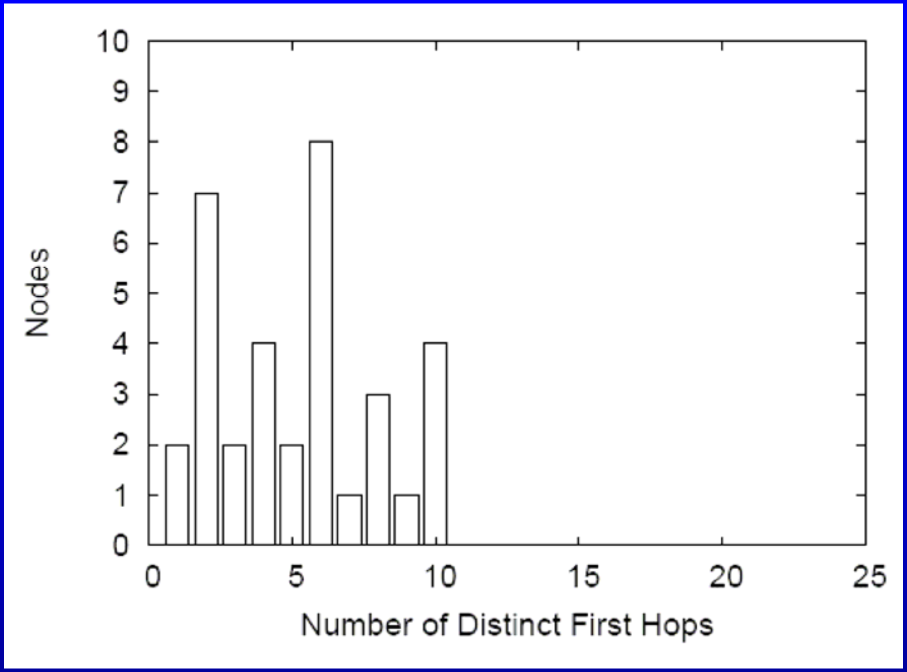
- For each number of nodes *n*, a random set of *n* nodes are selected.
- An estimated throughput between each pair of nodes is calculated.

  - The network starts to approach all the pairs’ connectivity characteristics when the number of nodes are 20 or more

Mesh robustness

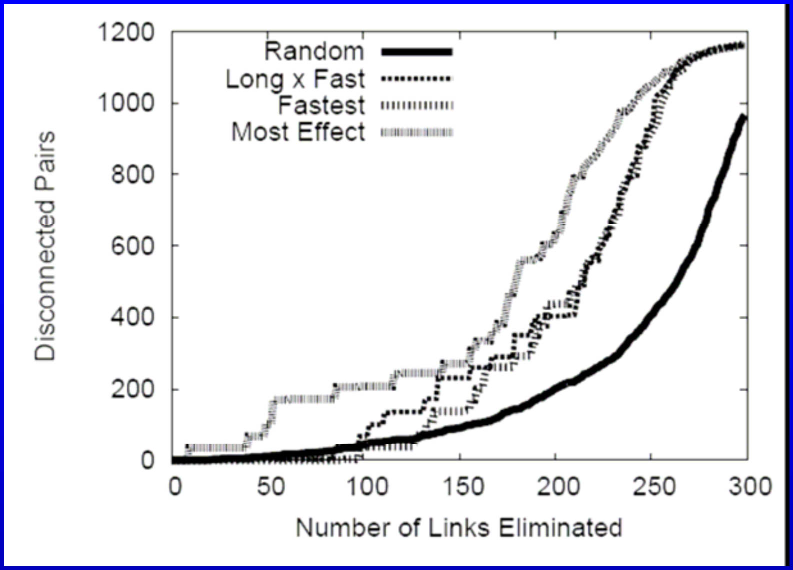
Number of nodes that use every number of distint

first hops

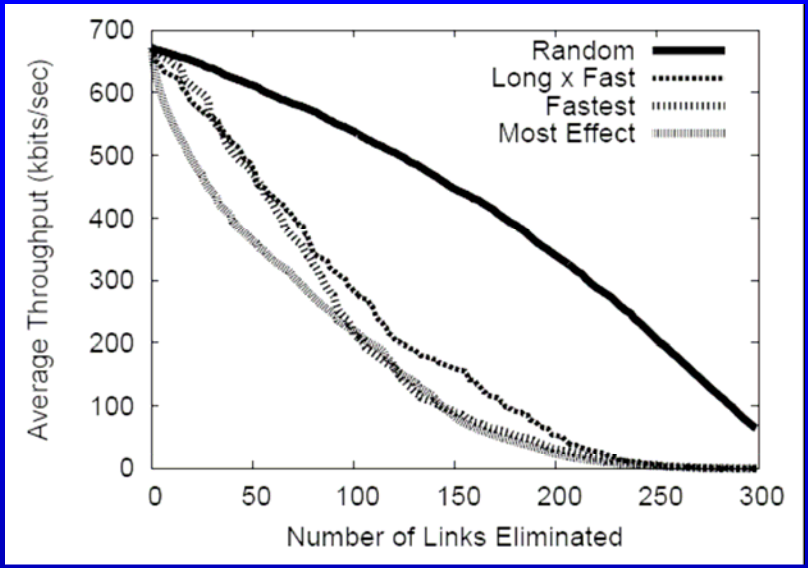


o Most of the nodes use many different neighbors as their first hop

Mesh robustness



Evolution of the number of disconnected pairs according to the number of links eliminated



Evolution of the average throughput according to the number of links eliminated

- The fastest links are more important than the long/fast links for throughput

Architectural alternatives

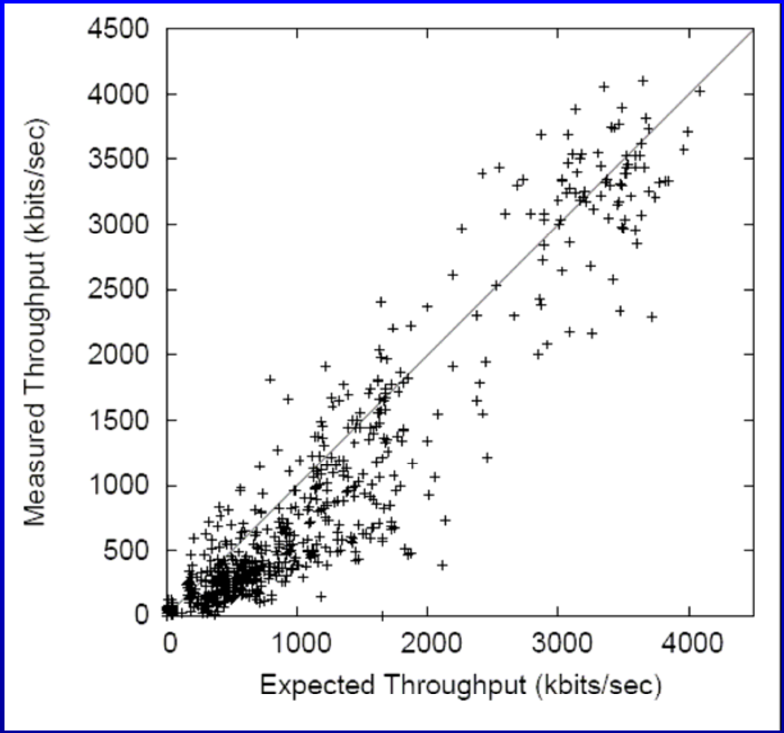
The mesh network is compared with a single-hop network with the same topology and direct radio links between each node and a gateway

- Optimal choice of the gateways' placements:
  - The single-hop network needs 5 gateways to cover all the nodes
  - The mesh network needs only 1 gateway
- Random choice of the gateways' placements:
  - The single-hop network needs 25 gateways to cover all the nodes
  - The mesh network needs only 8
- In both cases the multi-hop network increases throughput

Inter-hop interference

$$t = \frac{1}{\sum_i t_i}$$

Estimated throughput



Expected throughput vs measured throughput

o The inter-hop interference can be a limiting factor in the effective throughput of the mesh networks

Conclusions

The mesh network architecture:

- o provides reasonably good throughput and connectivity, with very robust behaviour
- o improves the results obtained with a single-hop network
- o easy to deploy and self-configurated
- o does not need many gateways to offer Internet connection

Thank you for your attention...

References

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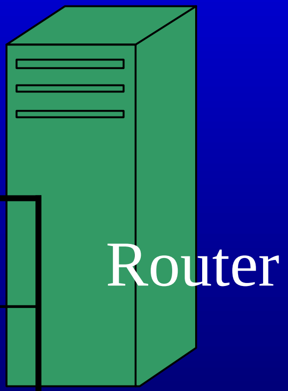
Questions?

NAT (Network Address Translation)

- Allows that several users of a network connect with another network using only one address of the later
- The entity which runs NAT stores the IP address and the port of the sender, and replaces these fields in the packet with its own IP address and port

Sender: IP_S / $Port_S$

Sender': IP_R / $Port_R$



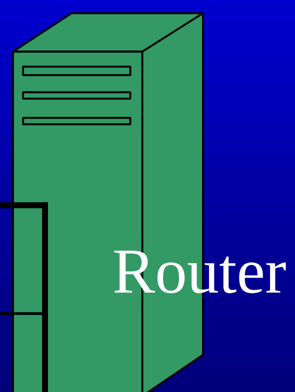
IP address and port of the sender	Port assigned
IP_S | $Port_S$	$Port_R$
...	...

NAT (Network Address Translation)

- The answer is sent to the router, which checks its table and resends the packet to the correct IP address and port

Receiver': IP_S / $Port_S$

Receiver: IP_R / $Port_R$



IP address and port of the sender	Port assigned
IP_S | $Port_S$ ←	$Port_R$
…	…