Multimedia Training Kit

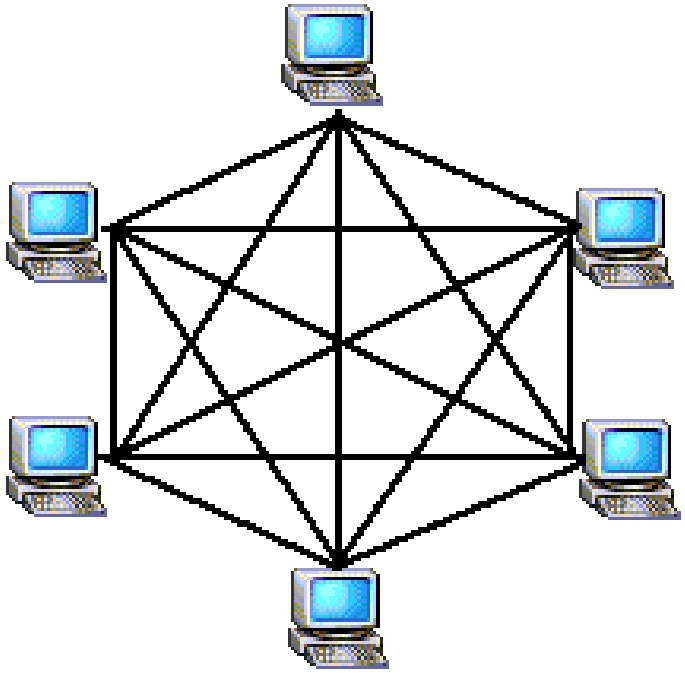
Mesh Networks

agenda

- Mesh topology
- Motivations & expectations
- Mesh routing protocols
- Mesh hardware
- Mesh oriented software, distros etc
- Some cases
- Issues in mesh networking

Mesh topology - definition

- Full Mesh Topology:



Mesh topology - definition

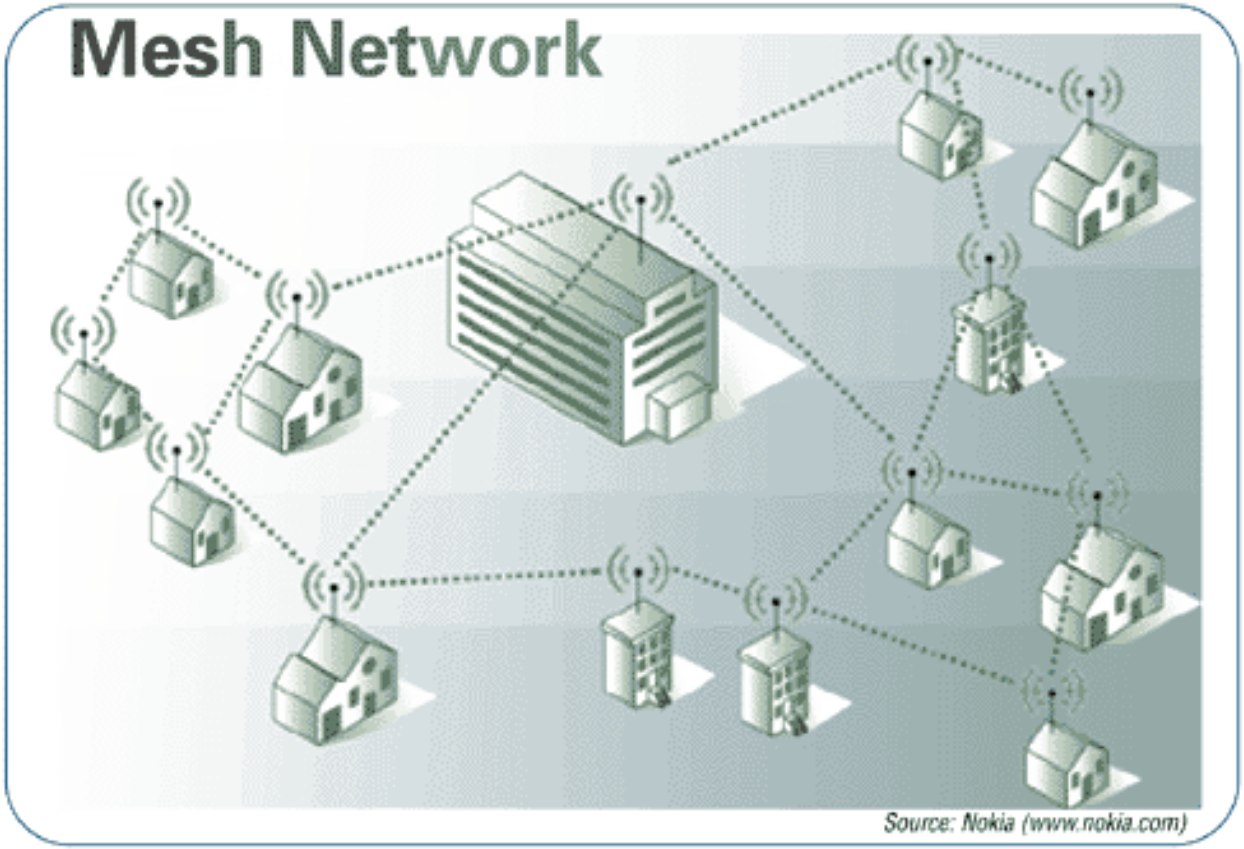
- A mesh network is a network that employs one of two connection arrangements, full mesh topology or partial mesh topology. In the **full mesh topology, each node is connected directly to each of the others**. In the **partial mesh topology**, nodes are **connected to only some**, not all, of the other nodes."

MANET – common definition

- MANET – a self-configuring network of mobile routers (and associated hosts) connected by wireless links—the union of which form an arbitrary topology.

* source: http://wikipedia.org

Mesh topology – a typical scenario



Why Mesh?

- Reality is not regular
- Low-cost (potentially)
- Distributed ownership models
- Gradual deployment of infrastructure
- Simple: Self-configuring
- Robust
- Low power requirements pr. unit

Why Mesh? Reality

- The Reality in which we build networks rarely conforms to a regular star, ring or bus topology
- A mesh topology gives us the flexibility to conform our network to the world

Why Mesh? Price

- Each node is both end-point and repeater in the wireless infrastructure
- No central nodes means that the maintenance of each node is less critical
- Wider dispersion of nodes means less need for towers and rooftop placement

Why Mesh? Business models

- Suitable for distributed/shared ownership of infrastructure
- Shared responsibility for maintenance
- Potential for gradual development of infrastructure
  - Critical if cost of capital is high

Why Mesh? Simplicity

- Self-configuring
- Self-healing

Why Mesh? Robustness

- Survives failure of single nodes
- Few critical infrastructure points
- Dynamically reconfigures with changing environments

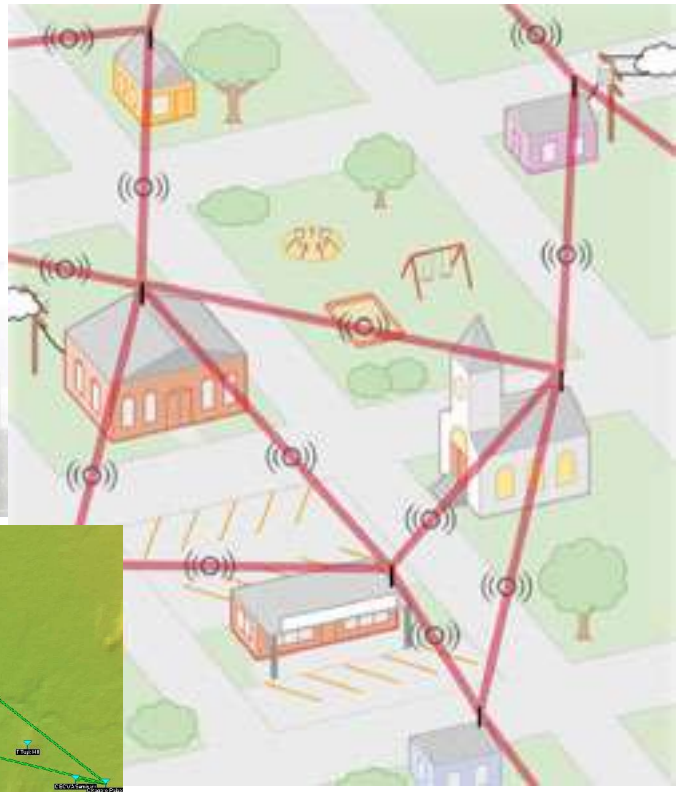
Why Mesh? Power Usage

- Wider distribution of nodes means shorter range requirements for a single node = Lower power pr. node
- Combined with self-healing =

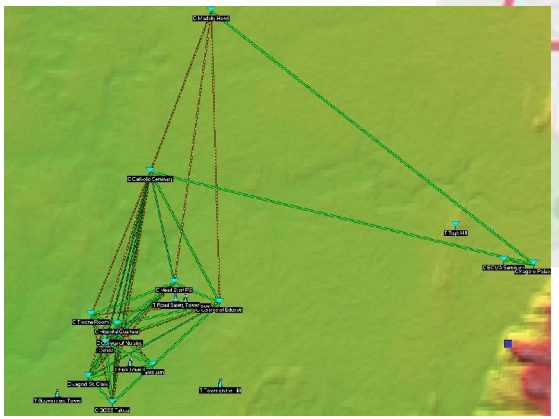
- Deployable with autonomous power sources

Mesh networks – motivations & expectations

- Until now, most often proposed for **Urban networks, Municipality networks**



Potential use in **rural and remote connectivity** scenarios



Mesh routing protocols: elements of mesh routing

- Node discovery
- Border discovery
- Link metrics
- Route calculation
- IP address management
- Uplink/backhaul management
- ... and more

Mesh routing protocols: Types

- **Pro-active (Table-driven)**
  Proactive checking of Link state and updating of routing tables – high complexity and CPU load, high performance
- **Reactive (On-demand)**
  Reacting on detection problems (non-working routes) – less demanding on CPU
- Lines between types not strict
- More types exist

Routing Protocols: Pro-active (Table-driven)

- OLSR (Optimized Link State Routing Protocol)OLSR-EXT, QOLSR
- TBRPF (Topology Broadcast based on Reverse-Path Forwarding routing protocol)
- HSLS (Hazy Sighted Link State routing protocol)
- MMRP (Mobile Mesh Routing Protocol), short: MobileMesh
- OSPF (Open Shortest Path First)

Routing Protocols: Reactive (On-demand)

- AODV

Mesh routing protocols: AODV

- The **Ad hoc On Demand Distance Vector (AODV) protocol** is a routing protocol designed for mobile ad hoc networks. ... enables dynamic, self-starting, multihop routing between computers.
- The protocol is in the process of being standardized at the IETF and currently is an experimental RFC
- The AODV@IETF project is made possible through the joint collaboration of the MOMENT and NMSL laboratories at UC Santa Barbara and Intel R&D.

Routing Protocols: MMRP

- Mobile Mesh protocol contains three separate protocols, each addressing a specific function
    1. Link Discovery – a Simple “Hello” Protocol
    2. Routing - Link State Packet Protocol
    3. Border Discovery - Enables external tunnels
- Developed by Mitre (with military interest involved)
- The Mobile Mesh software is covered by the GNU General Public License (Version 2)
- *Comment: Good starting point for ad hoc linux laptop fun .... a how-to is at:*
  http://www.oreillynet.com/pub/a/wireless/2004/01/22/wirelessmesh.html

Routing Protocols: OSPF

- Open Shortest Path First (OSPF) developed by the Interior Gateway Protocol (IGP) working group of the IETF , based on the SPF algorithm
- OSPF specification is in the public domain, published as RFC1247.
- Calls for the sending of link-state advertisements (LSAs) to all other routers within the same hierarchical area. Information on attached interfaces, metrics used, and other variables included in LSAs.
- OSPF routers accumulate link-state information, use the SPF algorithm to calculate shortest paths
- As a link-state routing protocol, OSPF contrasts (and competes) with RIP and IGRP, which are distance-vector routing protocols. Routers running the distance-vector algorithm send all or a portion of their routing tables in routing-update messages to their neighbors.

Routing Protocols: OLSR

- Optimized Link State Routing protocol. RFC3626.
- OLSR is a routing protocol for mobile ad-hoc networks. The protocol is pro-active, table driven and utilizes a technique called multipoint relaying (MPR) for message flooding. Currently the implementation compiles on GNU/Linux, Windows, OS X, FreeBSD and NetBSD systems.
- OLSRD is ment to be a well structured and well coded implementation that should be easy to maintain, expand and port to other platforms. The implementation is RFC3626 compliant with respect to both core and auxiliary functioning.
- One of the most promising and stable prorocols
- Used by a.o. the US navy in ship networks and behind-enemy-line drop-off autonomous units (verify!). Now that IS proof :)

Routing Metrics

- Metric calculation deals with the *cost* assigned to a certain route
- In principle, the routing protocol is independent from the metrics calculation – it just needs to know how 'good' the route is, not where that value comes from
- Yet sensible metrics are the core of wireless ad hoc networking

Routing Metrics

- Hop Count
- RTT: Round Trip Time
- PktPair: pe-hop Packet-pair Delay
- ETX: Expected Transmission Count

Metrics: Hop Count

- Very simple to implement
- Minimal protocol overhead
- Does not consider
  - transmit rate, reliability, load, interference
- Good performance on networks with many mobile clients, because it reacts very quickly to changes

Metrics: RTT

- Probe packet with timestamp sent to neighbours periodically and returned
- Node keeps exponentially weighted moving average of RTT samples
- Implicitly considers, load, interference and path loss
- Can cause self-interference
- High Overhead
- Measures bi-directional delay (includes queuing delay at remote end)

Metrics: PktPair

- 2 probe packets sent back-to-back (one small, one large). Neighbour calculates delay and reports back.
- Node keeps exponentially weighted moving average of RTT samples.
- Implicitly considers path loss, interference, transmit rate.
- Self-interference possible
- Very high overhead
- Measure is uni-directional

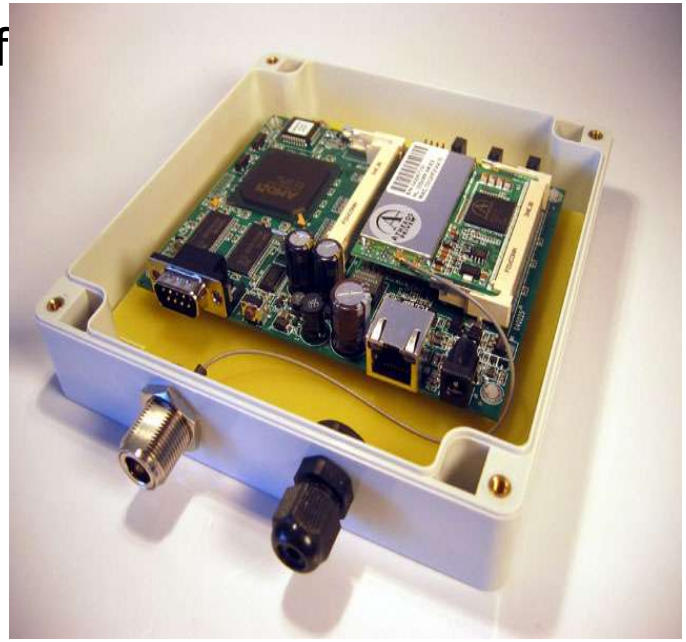
Metrics: ETX

- Estimates number of retransmissions needed for sending unicast package by measuring packet-loss of broadcast packets sent to each neighbour.
- Reasonable overhead because broadcast packets are used
- No self-interference because delay is not measured
- Does not measure under realistic conditions because broadcast packets are small, and are sent at low data rate.
- Favours high-capacity, reliable links.

Mesh hardware & software

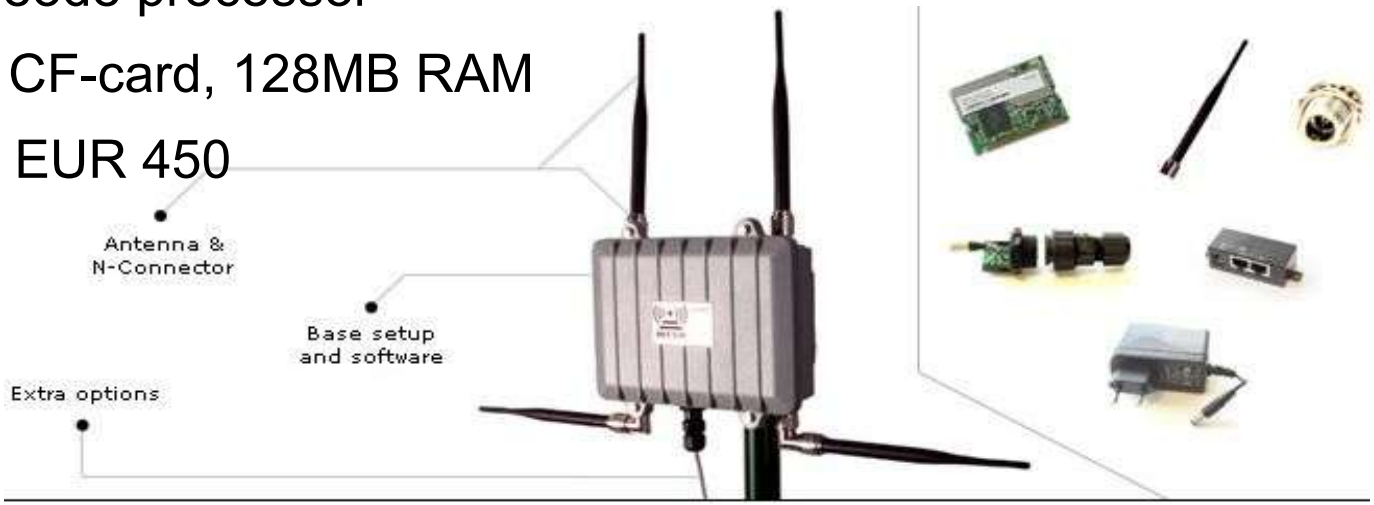
Mesh hardware: Metrix Mark I

- OLSR preinstalled
- low power consumption (ca. 10W)
- 100Mbps ethernet
- power over ethernet (802.3af standard)
- up to 2 (4,6) WLAN (802.11a/b/g) interf
- 133MHz AMD processor
- 64MB flash, 64MB RAM
- Circa USD 275



Mesh hardware: Meshnode

- OLSR preinstalled
- low power consumption (ca. 7W)
- power over ethernet (802.3af standard)
- Die-Cast Aluminum, protection class NEMA-67/IP-67
- up to 2 WLAN (802.11a/b/g) interfaces
- 266MHz Geode processor
- 64-256MB CF-card, 128MB RAM
- From circa EUR 450



Mesh hardware: Linksys WRT54G

- Not originally meant as a mesh device
- Due to low price and GPLed firmware, one of the most interesting and versatile low budget options
- Many firmware distros available: OpenWRT, EWRT, Batbox, Sveasoft (comment!), FreifunkFirmware, and many more
- Hardware specs: RAM / Flash / CPU speed

WRT54G v2	16	4	200 MHz
WRT54GS	32	8	200 MHz

  Processor: BCM4712KPB
- Price: circa EUR 60 (WRT54G) / 70 (WRT54GS)

Mesh hardware: Locustworld MeshAP

- 500mhz processor, 128mb ram, on board WiFi, 32mb compact flash drive.
- No moving parts!
- £250 each or £220 in orders of 10+

Mesh hardware: any old laptop

- Any old laptop or stationary PC can serve as a mesh node
- Targetted sw packages for this, e.g. Pebble Linux, MeshLinux, basically any Linux distro
- Many arguments pro/contra using refurbished hardware, incl power consumption

Mesh software packages

- Presenting a mix of distros, packages, software collections of different kinds
- All represent good starting points for mesh experiments/implementations
- Focus on Free Software

Mesh software packages: olsrd

- by Andreas Tønnesen
- Implementation of OLSR with ETX
- Runs on windows, Mac OSX, Linux and freeBSD

Mesh software packages: MeshLinux

- By Elektra, Berlin/Germany
- Based on slackware, circa 50 MB ISO
- Targetted at reuse of (older) laptops
- Mesh protocols included: MobileMesh, OLSR, BGP, OSPF, RIP, AODV

Mesh software packages: Zebra/Quagga

- By Kunihiro Ishiguro
- GNU Zebra is free software that manages TCP/IP based routing protocols. Part of the GNU Project, distributed under the GNU GPL
- Mesh protocols included: BGP-4 (RFC1771, A Border Gateway Protocol 4), RIPv1, RIPv2, OSPFv2, IPv6 ready.
- Fork: Quagga adds RIPv3, OSPFv3

Mesh software packages: CUWin

- By Champaign-Urbana community project, USA
- “The software the Champaign-Urbana Community Wireless Network (CUWiN) project releases is a complete operating system for wireless, meshing nodes. We start with a stock NetBSD distribution and add wireless drivers, routing code, and specialized systems which allow the nodes to work in harmony to route traffic for each other.”
- Uses HSLS, OSPF, ETX

Mesh software packages: Pebble

- By NYCWireless community
- Pebble Linux is a smallish (smaller than 64megs, larger than 8 megs) distro image designed for embedded style devices such as the Soekris boards, or a Stylistic 1000. It is based off of Debian GNU/Linux. It runs on many different types of systems, such as old 486 machines, mini-itx boards, etc
- Mesh protocols included: OSPF, (OLSR in Metrix version)

Mesh software packages: OpenWRT

- OpenWrt is a linux distribution for the Linksys WRT54G, a minimal firmware with support for add-on packages, custom tunable
- Two filesystems, a small readonly squashfs partition and a larger writable jffs2 partition.
- Readonly core provides: network initalization (ethernet and wireless), firewalling, dhcp client / server, caching dns server, telnet server and busybox environment
- ssh and web interfaces available via ipkg
- Many more packages, e.g. php,nocat spalsh, asterisk
- Mesh protocols: OLSR, AODV, ...

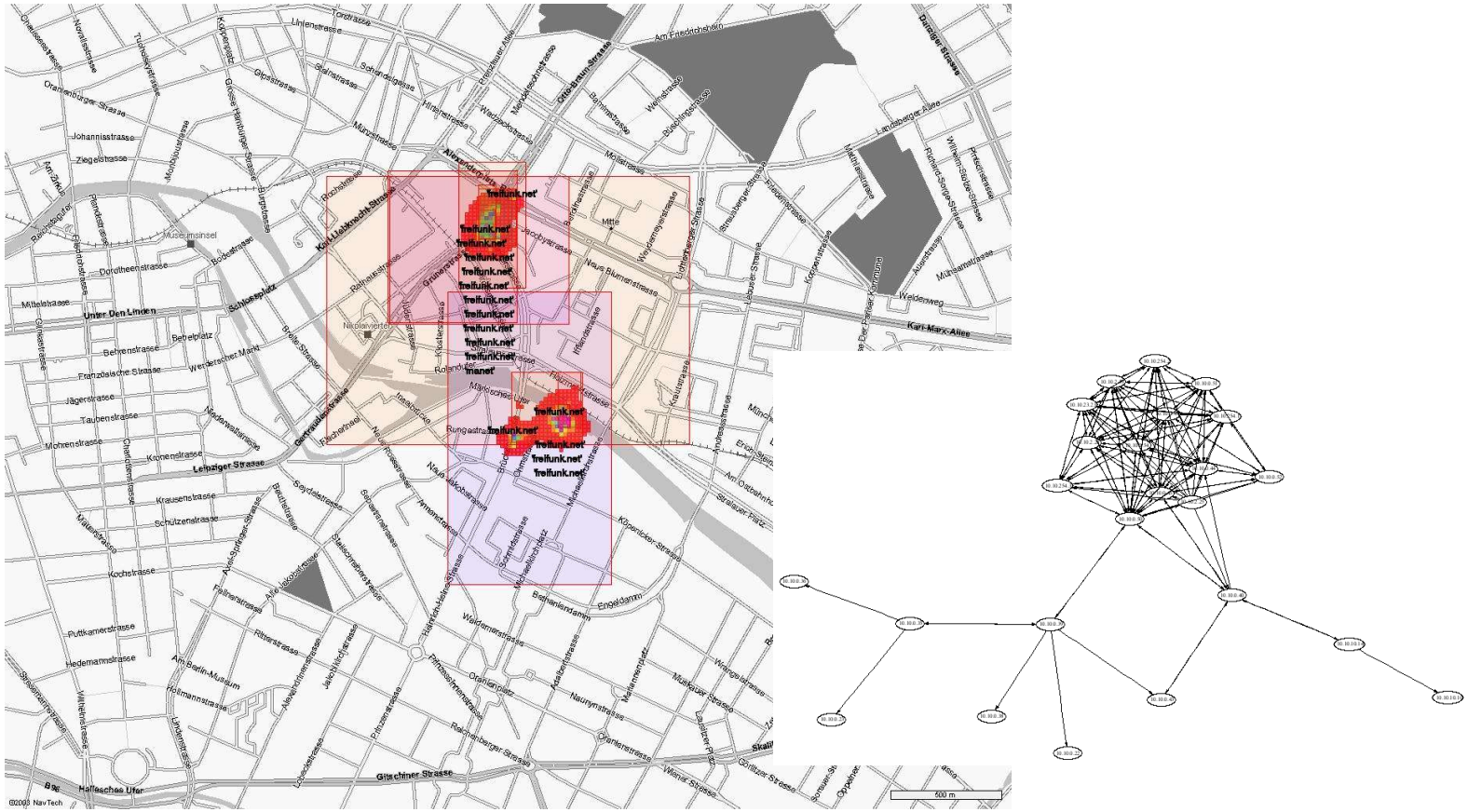
Mesh software packages: FreifunkFirmware

- By Freifunk group, Berlin/Germany
- Based off OpenWRT
- The Freifunk Firmware can be installed on either a Linksys WRT54g (version 1.0 to 2.2), a WRT54gs (version 1.0 and 1.1), a WAP54g (version 2.0 only) or a compatible device to set up a typical OLSR node quickly and easily.

Mesh cases

- Just a couple of examples (chosen almost at random)

Mesh cases: OLSRFreifunk,
Berlin, Germany



Mesh cases: MIT Rooftop

Mesh cases: Dharamsala

- Using Linksys WRT54G with OpenWRT firmware
- Using OLSR with ETX
- Connecting non-profit organizations
- Developed by Dharamsala Information Technology Group and David Ben-Yahel

Mesh cases: Dharamsala

The Indian EXPRESS
JOURNALISM OF COURAGE

Bring out white paper on KGB row: BJP to Govt

RSS first: Marching with Gandhi portraits

DTA, comprising IT professionals from India, Canada, Israel & Germany, has connected about 1,000 computers

Dharamsala gets wireless solution to its communication woes

SANGEETA J.
DHARAMSALA, OCTOBER 2

A SMALL group of IT professionals is all set to revolutionise communication in the little town and its outskirts by using wireless mesh networking. "The Wireless Mesh Network will enable connectivity to India's most remote regions," claim the excited promoters of Dharamsala Technology Association (DTA).

DTA, which comprises IT professionals from India, Canada, Israel and Germany, has connected about 1,000 computers, many of them in schools, through the network as part of an experiment in the last eight months.

Yahel Ben-David, the Chief Technical Officer of DTA, says they have used indigenous equipment to keep their costs down. "We see it as a non-

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commercial venture aimed only at providing alternative communication solutions in remote areas," explained Ben-David.

DTA, which is all set to launch the Dharamsala Community Wireless Mesh Network at a technical conference slated for Tuesday, will provide infrastructure to distribute broadband services for the entire region, and will enable fast, reliable, cost-efficient, and secure communication among member groups.

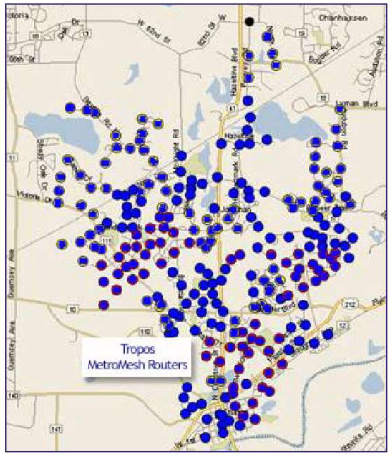
"Mesh network is a kind of decentralized networking infrastructure that is inexpensive, reliable and resilient, as each node need only transmit as far as the next node. Nodes act as repeaters to transmit data from nearby nodes to peers that are too far away to reach, resulting in a network that can span large distances, especially over rough or difficult terrain," explains Yahel Ben-David, the Chief Technical Officer of DTA.

DTA not only roped in Dharamsala Information Technology Group (DITG), an organisation chaired by the Tibetan Computer Resource

CONTINUED ON PAGE 2

Mesh cases: Tropos.com Chaska, Minnesota

- Quoting their website:
  .... delivering metro-scale Wi-Fi mesh network products and services, with more than 125 customers and 40 resellers in eight countries around the world at the end of 2004. .... fastest, lowest cost and simplest way to deliver true wireless broadband (>1 Mbps) over large geographic areas using low-cost standard Wi-Fi clients ..
- Proprietary MetroMeshTM routing software &
  Predictive Wireless Routing Protocol PWRP TM
- Chaska, Minnesota: Municipal network claims:
  circa 250 nodes
  covering 16 sqm
  with 36 backhaul points



The Tropos 5110 outdoor MetroMesh router.

Issues in mesh networking

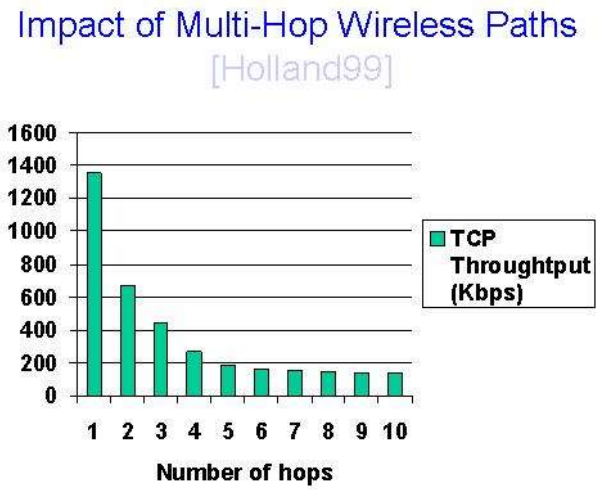
- Throughput
- Latency
- Scalability
- Security
- IP distribution

Issues in mesh networking

- Discussion is controversial and sometimes very biased, based on personal agenda
- Expectations and benchmark differ wildly ... *Enterprise level QoS* implies other challenges than *basic rural connectivity*
- Simply many things that haven't been tried yet (scale, stability, ...) and cannot be answered in lab.

Issues: Throughput

- Issue of throughput in all multi-hop networks
- Scales: with $1/n$ or $1/n^2$ or $1/n^{1/2}$?
- For 802.11 MAC, determined by half duplex quality of radios ... in that case: throughput ~ c/n^a with a = 1...2
- Mesh idea not tied to 802.11 MAC in principle



TCP Throughput using 2 Mbps 802.11 MAC

527

Issues: Latency

- Latency obviously has to grow with number of hops
- Effects of latency dependent on application
- Example VoIP: latency can be felt from 170ms on, but sometimes *walkie talkie* with 5 s delay is better than nothing

Issues: Scalability

- Mesh has not been tested in real life with more than a few dozen nodes:
  MIT roofnet: 40-50
  Berlin OLSR: circa 80?
- Commercial implementations (200 nodes? 10,000 nodes?) often do not share experiences .
- Lab is not real life!

Issues: Security

- Ad hoc networks per definition need to *talk to clients before they know them* --> inherent security challenge
- DoS issues

Issues: IP distribution

- IP distribution in mesh networks far from trivial
- DHCP in private IP ranges is fine, but what happens, when mesh1 meets mesh2?
- Possible Solution: Zeroconf/Bonjour
- Long-term solution: IPv6 and MobileIP

Mesh networks

Thank you for listening!

Questions?