Ad-hoc Networks

Wishfull thinking? We want . . .

- the wireless, self-configuring, self-optimizing data network
- trillions of nodes, global interconnectivity, quality of service
- all Internet applications, and voice, and video
- seamless operations from laptops, mainframes, to headsets
- . . . and it shouldn't cost too much.

This is the vision.

What is Ad-hoc?

From Latin: "for this (only)"

- **Webster:** "*ad-hoc* – for the particular end or case at hand without consideration of wider application"
- Ad-hoc committee, ad-hoc report, ad-hoc protest

In the case of computer networks:

- Ad-hoc network = wireless network without infrastructure.
- Related terms: spontaneous networks – the network automatically "emerges" when nodes gather together.

Why Ad-hoc?

Ad-hoc networking is often justfied by scenarios where you do not want or where you cannot deploy & manage an infrastructure.

- Spontaneous meetings (at work, airport):
  exchange files, play games
- Special circumstances:
  disaster relief
- Or simply cabeling costs, management overhead:
  old building, "wearable LAN", wireless headset

Why is Ad-hoc so Hard?

- **Routing, routing, routing!**
  already hard to solve in fixed networks,
  now a constantly changing set of nodes
- Security:
  new vulnerabilities, nasty neighbors
- Small devices:
  running with batteries, little computing power

Ad-hoc Network = **multi-hop** Network

- No default router available
- Potentially every node becomes a router:
  must be able to forward traffic on behalf of others
- Higher fan-out, multiple routes:
  a wireless network has potentially more route alternatives,
  how to find out the “best” path in a communication mesh?

Pro-active and Re-active Routing

Routing means: making forwarding decisions based on **routing state**. Routing protocol’s role: gather routing state.

When should routing state be collected?

- **Pro-active Routing Protocols:**
  learn the network’s topology before a forwarding
  request comes in
- **Re-active Routing Protcol:**
  be lazy – become active only when needed.

Pro-active Routing

Current Internet routing protocols are pro-active.

- Also called *table-driven* routing protocols
- Imagine that each node knows the full topology
  $\rightarrow$ connectivity matrix
- Simplification: each node maintains a vector
  – indexed by potential destination names
  – entry contains forwarding information for this dest.
- RIP (routing information protocol), distance-vector
  OSPF (open shortest path first), link-state

Pro-active Ad-hoc Routing Protocols

Among the first proposals for ad-hoc routing, still investigated.

- DSDV 1994 – Destination Sequenced Distance-Vector
- WRP 1996 – Wireless Routing Protocol
- GSR 1998 – Global State Routing
- Fisheye 1999 – Fisheye State Routing

Pro-active Routing: e.g., based on Distance Vector

Also called Bellman-Ford routing algorithm: periodic exchange of the routing tables.

Problems of Distance Vector (in Ad-hoc)

- Topology changes are slowly propagated
- Count-to-infinity problem ($\rightarrow$ poisened reverse)
- Moving nodes create confusion:
  they carry connectivity data which, at the new place, are wrong!
  $\rightarrow$ fatal routing loops
- Table exchange eats bandwidth.

Pro-active Routing Example: DSDV (I)

DSDV is based on Distance Vector. How DSDV addresses the problems:

- Tagging of distance information:
  – the destination issues increasing sequence numbers
  – other nodes can discard old/duplicate updates
- Changes are not immediately propagated:
  – wait some “settling” time
- Incremental updates instead of full table exchange.

DSDV (II)

Destination D adds a sequence number n
– assume msg n is delayed over D$\rightarrow$G$\rightarrow$F$\rightarrow$A
– and $n+1$ reaches A via C before msg n
A can discard the late message n

Re-active Ad-hoc Routing

Also called “on-demand” routing protocols.

- The source has to *discover* a route to the destination.
- The source (and intermediate nodes) have to *maintain* a route as long as it is used.
- Routes have to be *repaired* in case of topology changes.

On-Demand Routing

Also several proposals:

- DSR – Dynamic Source Routing
- AODV – Ad hoc On-demand Distance Vector
- TORA – Temporally Ordered Routing Algorithm
- ABR – Associativity Based Routing

On-Demand Routing: Discovery

- Discovery is based on broadcasting **route_request** msgs (flooding)
- Each node re-broadcasts the **route_request**, and adds its own address to a “path history”
- Eventually the destination hears the request:
  $\rightarrow$ **route_reply**
  travels along the revers path history

On-Demand Routing: AODV Example

On-Demand Routing: Optimization

- Intermediate nodes remember successful paths
  $\rightarrow$ they answer on behalf of the destination
- Intermediate nodes discover broken links and automatically repair the link (instead of letting the source find out)

Scaling Problems

Common assumption of current ad-hoc research:
small networks with less than 100 nodes.

How to scale this to 1000 and more nodes? $\rightarrow$ routing hierarchy

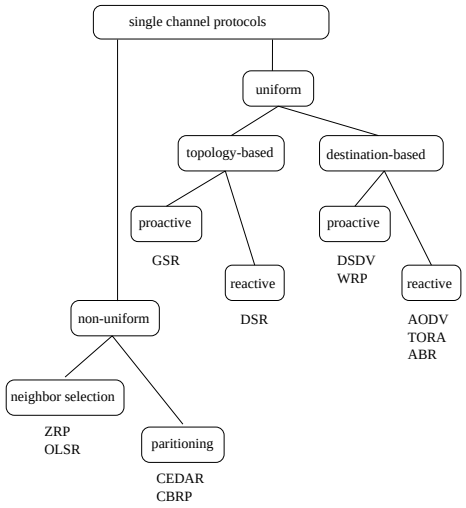
- Create logical cells (partitioning into clusters)
  – use one of AODV, DSDV etc inside a cell
  – designate a “cluster-head” or gateway
- Two-level routing:
  – direct routing inside a cluster
  – inter-cluster routing via cluster-heads
  – add more levels if needed

Clustering Example

Some Names of Clustering Routing Protocols

- ZRP – Zone Routing Protocol
- OLSR – Optimized Link State Routing
- CEDAR – Core Extraction Distributed Ad hoc Routing
- CBRP – Cluster Based Routing Protocol

Routing Protocol Classification (L.M.Feeney, SICS)



Naming and Addressing in Ad-hoc Networks

IP-Number is a mix of network name and host name:
– routing is based on network part
– does not work for ad-hoc networking
networks are created/destroyed on-the-fly

- “Network” becomes a virtual & transient concept
- Ad-hoc nodes have “unique identifiers” (names)
  e.g., based on WaveLAN card number

Associating IP-Subnet with Ad-hoc Network

How to include ad-hoc networks into IP?

- Install a gateway with wireless interface,
  – gateway participates in ad-hoc routing
  – can forward data to the Internet
- Assign an IP network number to this ad-hoc network.
- Each ad-hoc node has its IP host number inside this subnet.

IP-Subnet with Ad-hoc Network (contd)

What we do: We fool IP! $\rightarrow$ routing at level 2.5

A problem is:

- Two gateways, and two overlapping ad-hoc networks:
  – to which IP-subnet does a node belong?
  – can it switch?
  – how far may an IP-subnet be extended?

More Problem Areas for Ad-hoc Networks

- Security:
  – trust your neighbors?
  – how to create “secure (overlay) networks”?
  – also opportunities: we could hide traffic patterns.

- Advanced network services:
  – Quality of Service (merging voice and data)
  – Multicasting

→ Ad-hoc will remain a research area for many years to come.

Other Routing Ideas I

Geographic routing: use the destination’s location!

- The mobile destination measures its position (GPS)
- It informs from time to time a registry
- A sender does routing “towards” this location
- In the supposed vicinity of the destination we use discovery à la reactive ad-hoc routing.

Other Routing Ideas II

High-density wireless networks and multipath routing

- Presume many nodes in a metropolitan aera
  e.g. cellular phones
- Simulations show:
  above a critical density, you can satisfy all point-to-point bandwidth requests by multipath-multihop forwarding
- This can become a telephony network without network operator!

Military usage: create communication infrastructure by “sprinkling” thousands of nodes with planes or balistic guns over enemy area.

Linking Routing with Resource Control

- Why should a node forward traffic from others?
  – only drains our precious battery
  – limits what we can send
- Create an incentive to forward packets:
  – collect fees from passing packets
  – use the electronic coins for later purchase of bandwidth

Ideally, routing would “automatically” avoid expensive regions.

Denail-of-Service attacks would be *very* expensive.

Resource Control

Another link of a Packet Forwarding Economy to wireless communications:
spectrum is like real estate - buy, lease, sell it etc.

- Several countries have started to **auction** some frequency ranges.
- Currently, a frequency range is allocated for (10) years.
- Move towards real-time allocation:
  – during the day: use spectrum for mobile nodes
  – during the evening: for TV broadcasting
  – during the night: bulk data transfer

Summary

- Ad hoc networks: mainly routing, security problems
- Existing routing algorithms not suited for wireless networks
- Pro-active vs. re-active routing strategies
- Examples: DSDV and AODV
- The future (?):
  – ubiquitious high density wireless networks
  – computational (communicational) economies