Ad Hoc, manet, AODV, and ng

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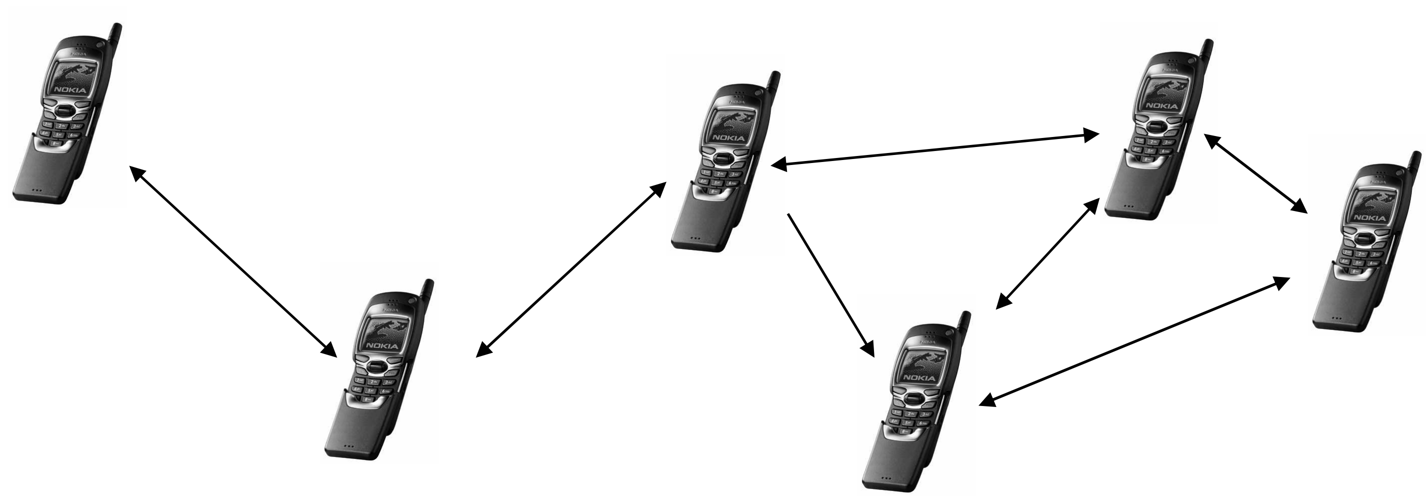
Outline of Presentation

- Ad Hoc Networks in general
- Recent results from manet
- AODV in particular
- Internet Gateways for ad hoc networks
- Address autoconfiguration
- Flooding – a current frontier!
- Some harebrained ideas
- AODVng 2002 workshop report

Ad Hoc Network characteristics



- peer-to-peer
- multihop
- dynamic
- low power
- autonomous
- autoconfigured/zero-administration

But, most these have exceptions!

Commercial Opportunities

- Conferencing
- Home networking
- Cellular Range extension
- Emergency services
  - Ambulance
  - Police
- Hospitals
- Embedded computing applications
  - Ubiquitous computers with short-range interactions
  - Automotive/Automotive/PAN interaction
- Enable network computing where subnets do not exist
- *Stuff should just work!*

Technical/Market/Political hurdles

- Scalability (memory search time, bandwidth, processing): *no aggregation*
- Power budget vs. latency
- Protocol deployment, incompatible standards
- Why should one node *"waste power"* to help a neighbor *?*
- Wireless data rates, low protocol efficiency
- Obsoletes the client/server model... → breaks a *lot* of protocols
- Antenna inconvenience
- Higher bit-error-rate (BER)
- Additional security exposure
- Perceived dependence upon heavy, short-lived batteries
- Non-ubiquitous coverage
- People don't demand it – but they might if it was better known (e.g., NYT)

Various Ad Hoc Routing Projects

- DSR (Dave Johnson, CMU)
- WINGs (JJ Garcia/UCSC)
- ODMRP (Gerla et.al/UCLA)
- TRAVLR (Kleinrock/UCLA)
- Tora/IMEP (Park, Corson/UMD)
- SSA(link quality) (Rohit Dube/UMD)
- LAR (Ko/Texas A&M)
- TBRPF (Ogier,Templin/SRI)
- OLSR (Inria: Clausen./Jacquet)
- DSDV (Dest. Sequence #'s)
- DREAM(Basagni/UT Dallas)
- CEDAR (Urbana-Champaign)
- AODV (refinement of DSDV)
- AOMDV (Multipath – Das/Marina)
- Hierarchical (Akyildiz/Georgia Tech)
- GPSR (Karp/Harvard)
- CBRP (Jian,Tay/Singapore)
- Terminodes (Hubaux/EPFL)
- MMWN (Steenstrup/BBN)
- ABR (C.K. Toh)
- STAR (JJ Garcia/UCSC)
- ZRP (Zygmunt Haas/Cornell)
- Fisheye/Hierarchical (UCLA)
- SLURP (OSU)

On-Demand Routing Protocols

- Eliminate route table updates for routes that are not used
- Fewer control packets:
  - → Better scalability
  - → Reduced congestion
  - → More robust protocol action
- Less frequent control packets → reduced processing requirement
- Can be made to work for link-state
- Even more localization for topology changes if distance vector
- Downsides:
  - Latency
  - Route Discovery broadcasts (congestion at “wrong time”)
  - ICMP Unreachable only after Route Discovery attempt (kernel API)

IETF Mobile Ad Hoc Networking (manet)

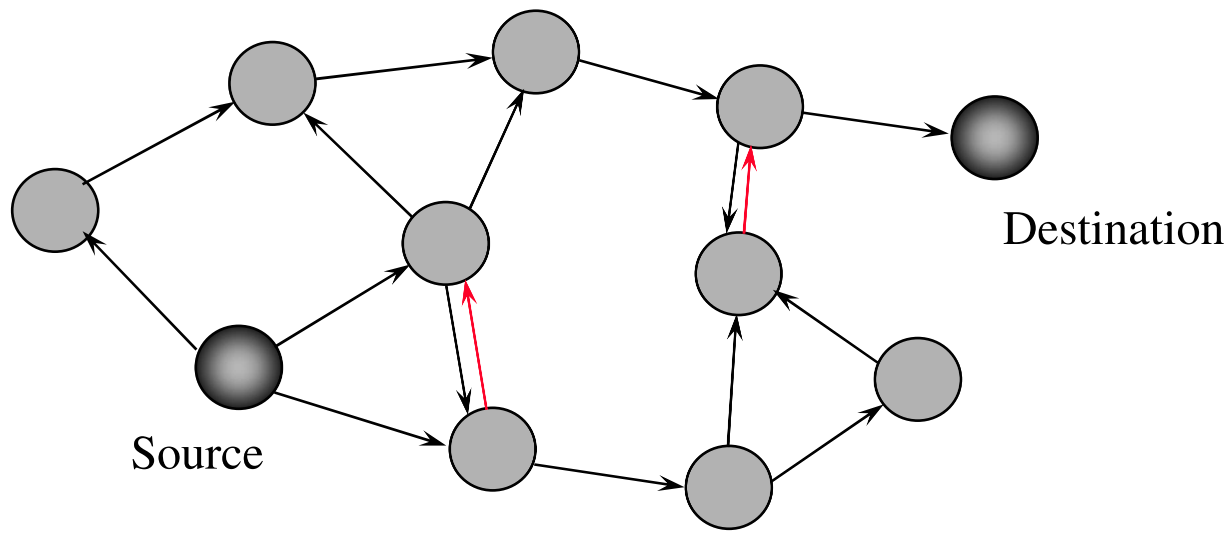
- IETF working group has been in process for several years
- Four main protocols under consideration
  - AODV: **A**d hoc, **O**n-demand **D**istance-**V**ector
  - DSR: **D**ynamic **S**ource **R**outing
  - OLSR: **O**ptimized **L**ink-**S**tate **R**outing
  - TBRPF: **T**opology-**B**ased **R**everse **P**ath **F**orwarding
- First two are "on-demand", last two are "table-driven/proactive"
- All four may soon be published as "Experimental" RFCs
- Proposed Standard seems elusive, given rate of protocol changes
- Current emphasis is almost entirely on IPv4
  - But, AODV for IPv6 is specified, built, and works
- Unidirectional, Multicast, QoS, Power mgmt, Service Discovery not currently chartered

Overview of AODV

- Reactive routing protocol
- Route discovery cycle for route finding
  - Flooded RREQ, unicast RREP along reverse path of RREQ
- Loop freedom achieved through sequence numbers
  - also solves *"counting to infinity"* problem
- Proved “correct”
- No overhead on data packets
- Interoperability testing, and Experimental RFC status
- Scalability shown to 10,000 nodes
  - performance suffers

AODV Unicast Route Discovery Initiation

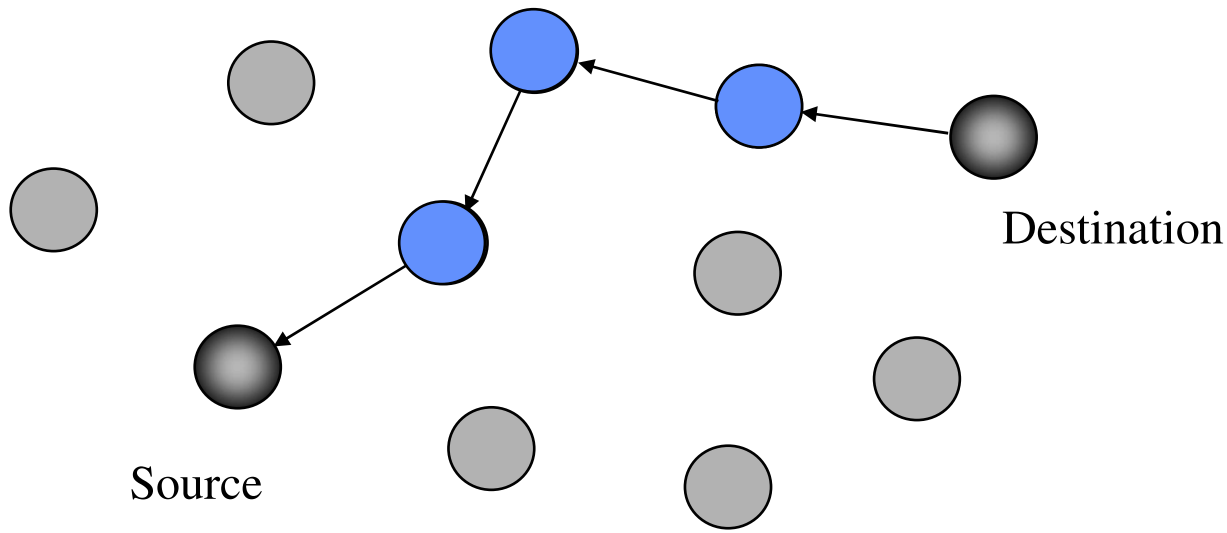
Route Request (RREQ) broadcast flood



Note: a RREQ must never be broadcast more than once by any node

AODV Unicast Route Discovery Completion

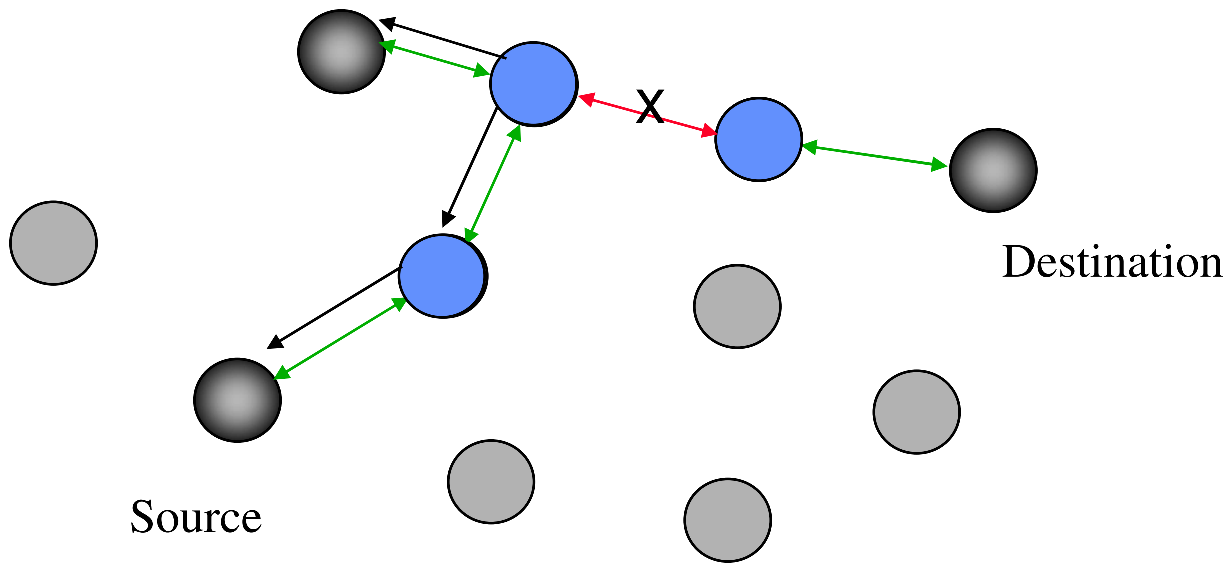
Route Reply (RREP) propagation



Note: Same Flooding Query Technique can be used for Service Discovery, or QoS

AODV Route Error (RERR) dissemination

Suppose the red link breaks



Note: Each node maintains a list of *precursors* for each destination

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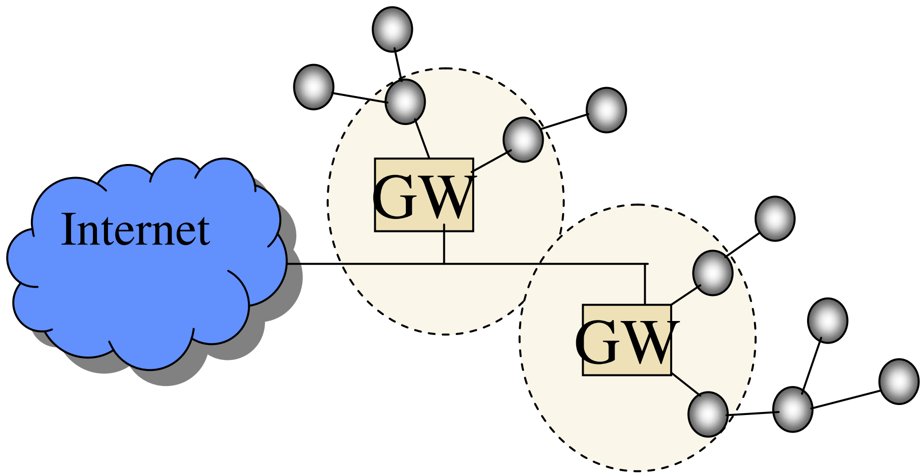
Other features

- Local Repair (eliminates costly broadcasts in many cases)
- Expanding-ring search
- Unidirectional link black hole avoidance for RREP
  - RREP-ACK and blacklisting
- Use of Hello message, vs. layer-2 acknowledgement
- Maintenance of active routes & Route cache management
  - Route repairs and TTL restrictions reduce network-wide flooding
  - Route caching & timeout offers improvement over others
- Service Discovery draft
- Integrated multicast protocol (MAODV) specified
  - multiple next hops
  - *group leader* maintains sequence #
- QoS

Internet Gateways for Ad Hoc Networks



- Our model: do not inject per-host routes into Internet
- Good start: ad hoc nodes use gateway as default router
  - but it could be multiple hops away
  - plus, the ad hoc nodes need to know its IP address
  - Router solicitation & advertisement “work”, with changes
- Gateway should be “protocol-agnostic” (for any *manet* protocol)
- Gateway needs a host route for each *manet* node

Address Autoconfiguration

- Must discover appropriate prefix from Internet Gateway if available
- Otherwise, use canonical site-local address
- Required: some variety of Duplicate Address Detection (DAD)
- For connected networks, RREQ/RREP does the job
  - tricky part: what is the source address?
  - Have specified AREQ and AREP for “general” case (should work with protocols other than AODV)
- The hard part: dealing with network merge or healing

Flooding is needed for on-demand discovery

- Application flooding vs. IP-level flooding
  - TTL = 1   vs.   TTL = network-diameter
- Multicast vs. Broadcast vs. ???
  - No multicast tree needed
  - 255.255.255.255 isn't right
  - No subnet broadcast
- Wanted: *manet-local* flooding
- Goal: reduce number of packet retransmissions
- Unique identification for flooded packets
- Also reduce number of nodes doing the retransmissions
  - E.g., by picking a set of multipoint relays

Multi-point Relay (MPR) selection

- Identify the one-hop symmetric neighborhood
- Identify the two-hop symmetric neighborhood
- Pick out the neighbors that cover the whole two-hop neighborhood
- Try to make it a “minimal set”
- Try to make it “source-independent”
- Make it robust
  - simulations show that double-coverage *improves* performance
- Make it work for all four manet protocols

Four steps

- Receive advertisement messages
  - Use for neighbor sensing if needed
- Construct internal representation for neighborhoods
  - Symmetric one-hop and symmetric two-hop
- Select multi-point relays that cover the two-hop neighborhood
- Multicast advertisement message
  - # + list of symmetric one-hops
  - # + list of other one-hops
  - # + list of MPRs
  - Sequence number
  - Incremental vs. complete?
    - # + list of *lost neighbors*
  - Willingness?

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Issues for flooding

- Use of *all-manet-nodes* multicast address
- Flooding for multiple simultaneous messages?
- MPR dependence on last hop?
- ICMP vs. UDP vs. IP vs. ??
- Redundant coverage (at least 2 seems advisable)

Mathematical Endeavors

- “Capacity” results
  - Can increase with mobility!
  - Trade-off against latency
- Time-varying topology
- Meaning of connectedness, and “holes”
- Synchronization issues
- Characterizing traffic models
  - Random-waypoint considered harmful
  - Random direction better
  - Also, should get flatter distribution

AODVng2002 Workshop

- Preceding, but not organizationally affiliated with, MobiHoc 2002
  - MobiHoc success shows viability of ad hoc network research field
  - MobiHoc 2003 in Annapolis, MobiHoc 2004 in Asia
- What's wrong/missing from AODV today
- What's hard to implement/interoperability considerations
- Performance and algorithmic improvements
- Avoidance of duplicated effort
- Community of implementers and designers
- Presentations about experiences, not refereed papers
- Short reports are coming in the next MC2R (SIGMOBILE quarterly)
- Diversity of viewpoints!

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Summary and Conclusions

- Ad Hoc Networking is well-established as a viable research area
- Infrastructureless operation has commercial and military applications
- On-demand protocols offer significant advantages
- AODV makes use of advantages from both Distance-Vector and On-demand
- AODV has good chances for standardization
- Ad hoc networks can be glued to the Internet and then provide wireless extension domains
- Address autoconfiguration techniques have been adapted