UNICAST ROUTING

in
mobile ad hoc networks

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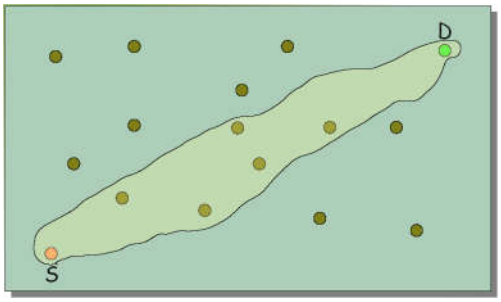
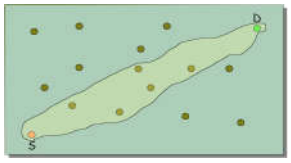
CSE 6811: Wireless Ad hoc Networks

Routing problem



Responsibility of a routing protocol

- Determining an "optimal" way to find "optimal" routes
- Determining a feasible path to a destination based on a certain criterion
- Discovering, storing, and exchanging routing information
- Gathering information about a path break and updating the information accordingly

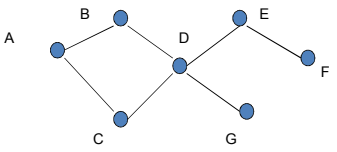


Why traditional routing is not suitable for Mobile Ad hoc Networks (MANETs)?

Why traditional routing is not suitable for MANET?

(1) Periodic updates in Wired Network is unnecessary in wireless ad hoc networks

Why traditional routing is not suitable for MANET?



Forwarding Table of A

Dest	Next Hop	Cost
B	B	1
C	C	1
D	B	2
G	C	3
E	B	3
F	B	4

- Periodic route advertisement as in DV may be unnecessary
- Could conserve battery power when little or no movement.
- Put in sleep mode whenever possible.

Why traditional routing is not suitable for MANET?

(2) Traditional network has small number of paths

Traditional network has few links

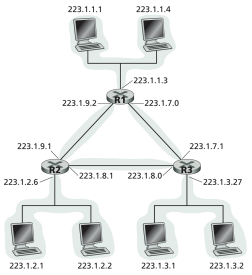
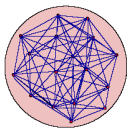


Figure 4.17 ♦ Three routers interconnecting six subnets

Why traditional routing is not suitable for MANET?

- Wireless channel is inherently broadcast
- Many links many path
- Most of the paths are redundant
- Redundant paths increase unnecessary routing updates



17 nodes

16 entries in the routing table of each node (although all are within 1 one hop)

Why traditional routing is not suitable for MANET?

(3) Mobile environment in Wireless ad hoc networks demands → new link characteristics

Why traditional routing is not suitable for MANET?

- Host mobility is a new phenomenon
  - Big challenge
  - link failure/repair due to mobility may have different characteristics than those due to other causes
  - In conventional routing—
    - Routers occasionally goes down and up
    - Cost may change due to congestion
    - But routers in wired network never move
  - rate of link failure/repair may be higher when nodes move fast

Why traditional routing is not suitable for MANET?

(4) In wired networks, usually there exists symmetric environment

Why traditional routing is not suitable for MANET?

- Fully Symmetric Environment
  - all nodes have identical capabilities and responsibilities
- Asymmetric Capabilities
  - transmission ranges and radios may differ
  - battery life at different nodes may differ
  - processing capacity may be different at different nodes

Why traditional routing is not suitable for MANET?

(5) New performance metrics for wireless ad hoc networks are needed

Why traditional routing is not suitable for MANET?

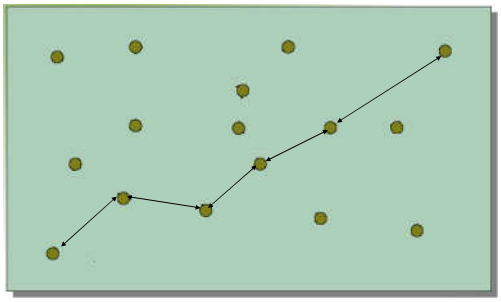
- New performance criteria may be needed
  - route stability despite mobility
  - energy consumption

Desirable characteristics of routing protocol in MANET

Desirable characteristics of routing protocol in MANET

- Minimum Control Overhead
  - Consumes BW, resources, power
- Minimal processing overhead
  - Heavy-weight protocols a big 'NO'
- Distributed protocol

Distributed vs Centralized algorithm



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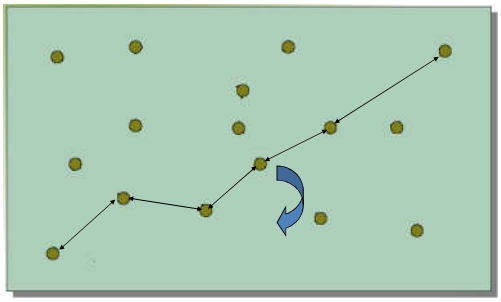
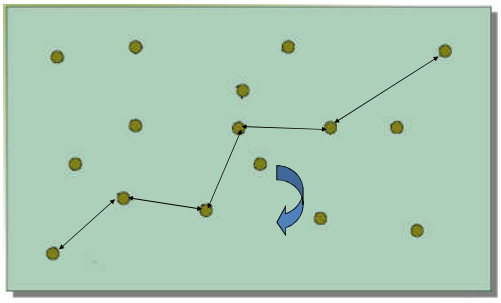
Fast Responsiveness to Topology changes



Fast Responsiveness to Topology changes



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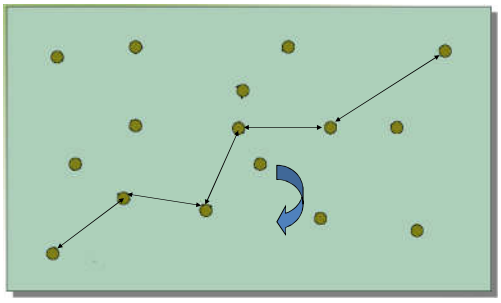
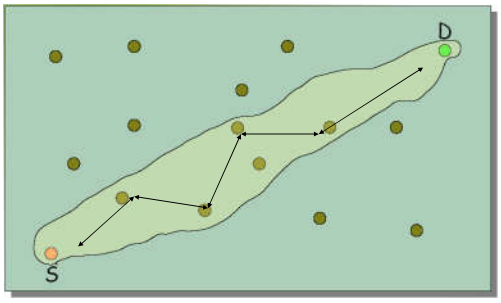
Localized reaction to topology changes



Localized reaction to topology changes



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- Fast responsiveness to topology changes
- Localized reaction to topology changes
- Loop avoidance

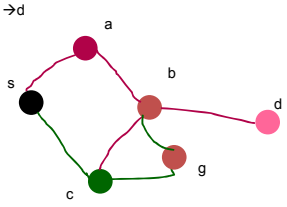
Loop formation in path

Path with loop:

s → a → b → c →g → b →d

Path without loop:

s → a → b → d



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- Localized reaction to topology changes
- Loop avoidance
- Scalability

Scalability

- Should be invariant with network size.
  - Flooding-based routing protocols→ non-scalable
  - Globalized reaction to topology changes →non-scalable
  - Header contains complete route info → non-scalable

Overview of Unicast Routing Protocols

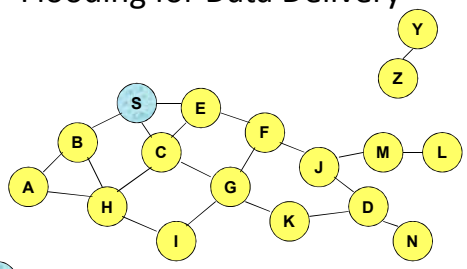
Possible approaches

- Flooding
- Swarm Intelligence
- Routing table based

Flooding for Data Delivery

- Sender S broadcasts data packet P to all its neighbors
- Each node receiving P forwards P to its neighbors
- Sequence numbers used to avoid the possibility of forwarding the same packet more than once
- Packet P reaches destination D provided that D is reachable from sender S
- Node D does not forward the packet

Flooding for Data Delivery

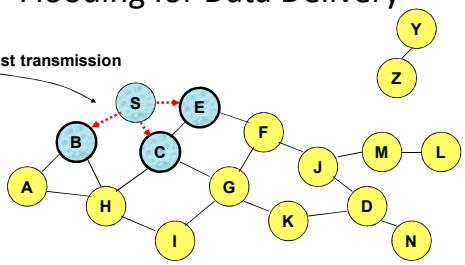


Represents a node that has received packet P

Represents that connected nodes are within each other's transmission range

Flooding for Data Delivery

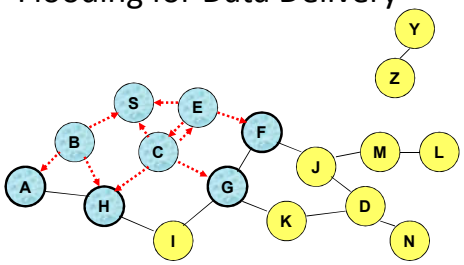
Broadcast transmission



Represents a node that receives packet P for the first time

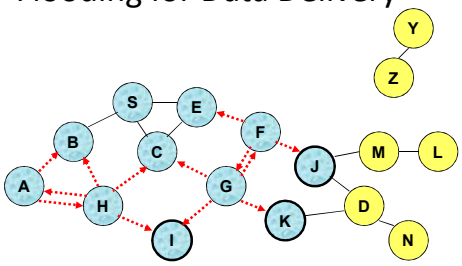
Represents transmission of packet P

Flooding for Data Delivery



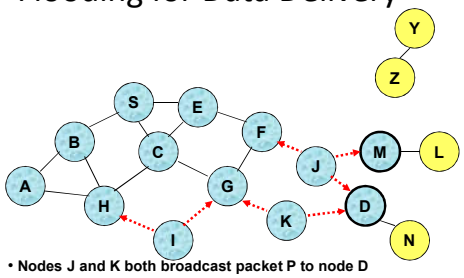
- Node H receives packet P from two neighbors: potential for collision

Flooding for Data Delivery



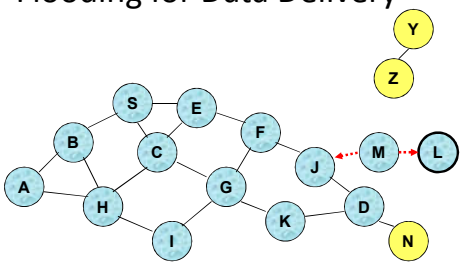
- Node C receives packet P from G and H, but does not forward it again, because node C has already forwarded packet P once

Flooding for Data Delivery



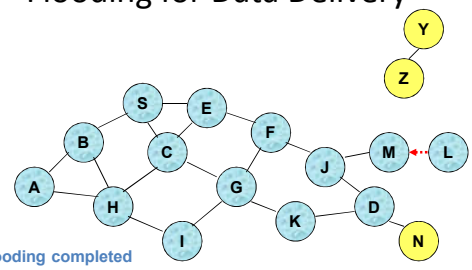
- Nodes J and K both broadcast packet P to node D
- Since nodes J and K are hidden from each other, their transmissions may collide
  - => Packet P may not be delivered to node D at all, despite the use of flooding

Flooding for Data Delivery



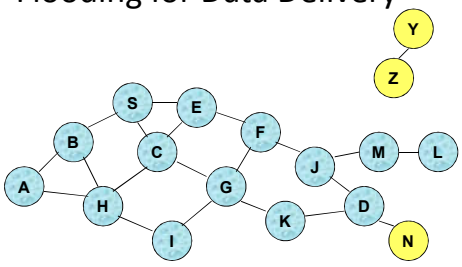
- **Node D does not forward packet P, because node D is the intended destination of packet P**

Flooding for Data Delivery



- **Flooding completed**
- **Nodes unreachable from S do not receive packet P (e.g., node Z)**
- **Nodes for which all paths from S go through the destination D also do not receive packet P (example: node N) (difference with flooding for broadcast and flooding unicast)**

Flooding for Data Delivery



- **Flooding may deliver packets to too many nodes (in the worst case, all nodes reachable from sender may receive the packet)**

Flooding for Data Delivery: Advantages

- Simplicity
- Almost memory-less
- Potentially higher possibility of data delivery
  - Because packets may be delivered to the destination on multiple paths

Flooding for Data Delivery: Advantages

- May be more efficient than other protocols when rate of information transmission is low enough that the overhead of explicit route discovery/maintenance incurred by other protocols is relatively higher
  - this scenario may occur, for instance, when nodes transmit small data packets relatively infrequently, and many topology changes occur between consecutive packet transmissions

Flooding for Data Delivery: Disadvantages

- Potentially, very high overhead
  - Data packets may be delivered to too many nodes who do not need to receive them
- Potentially lower reliability of data delivery
  - Flooding uses broadcasting -- hard to implement reliable broadcast delivery without significantly increasing overhead
    - Broadcasting in IEEE 802.11 MAC is unreliable

Flooding for Data Delivery: Disadvantages

– In our example, nodes J and K may transmit to node D simultaneously, resulting in loss of the packet
  – in this case, destination would not receive the packet at all

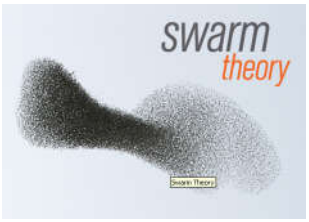
Flooding of Control Packets

- Many protocols perform (potentially *limited*) flooding of control packets, instead of data packets
- The control packets are used to discover routes
- Discovered routes are subsequently used to send data packet (s)
- Overhead of control packet flooding is amortized over data packets transmitted between consecutive control packet floods

Possible approaches

- Flooding
- Swarm Intelligence
- Routing table based

SWARM Intelligence



"The emergent collective intelligence of groups of simple agents"

Bonabeau et al. 1999

Swarming – The Definition

- aggregation of similar animals, generally cruising in the same direction

Swarming is Powerful

- Swarms can achieve things that an individual cannot

Swarming - Characteristics

- Simple rules for each individual
- No central control
  - Decentralized and hence robust
- Emergent
  - Performs complex functions

Swarming – The Definition

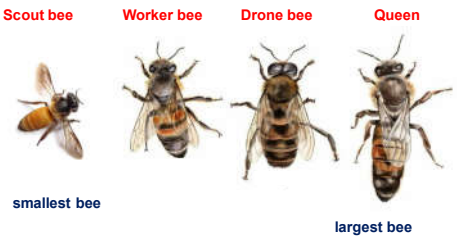
- Termites swarm to build colonies

Swarming – The Definition

- Bees swarm to collect honeys
- Honey Collection is a combined effort

Swarming – The Definition

- Different kinds of bees



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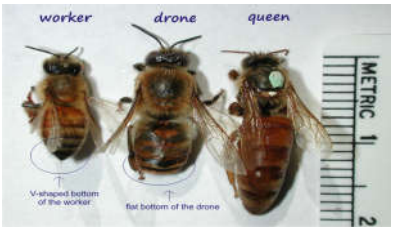
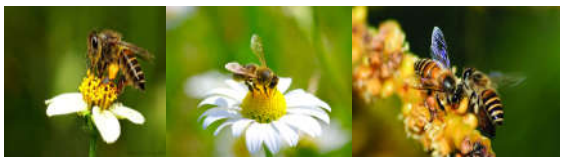


Steps in honey collection

- Scout bees search for nectar and pollen from flower to flower



- Scout bee comes back to the hive with the information of the flower containing best quality of nectar and pollen

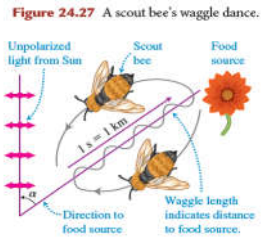
Steps in honey collection

- Scout bee inform the worker bees about the source of nectar and pollen through waggle dance

- A worker bee informs other worker bees about the source through waggle dance

Swarming – The Definition

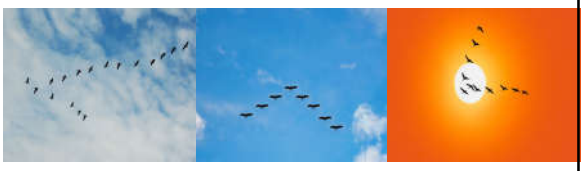
- Waggle dance carries direction and distance information?



Karl von Frisch, a professor of zoology earned the Nobel Prize in 1973 for his groundbreaking research on this dance language.

Swarming – The Definition

- Birds Flying in the sky show sign of intelligence



- Flies in a V-shape to conserve energy
- Each bird flies slightly above the bird in front of him, resulting in a reduction of wind resistance.
- In V-shape it is much easier to follow others

Swarming – The Definition

- Ants swarm to search food

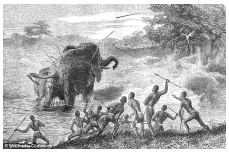
Ant colony based routing

Why are ants interesting?

- ants solve complex tasks by simple local means
- single ants are dumb ant colonies are intelligent
- ants are 'grand masters' in search and exploitation

Food search behavior

- Ants search for food by walking randomly
- Different from human approach
  - Human beings are more organized

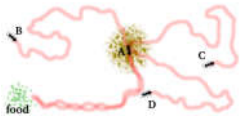


Food search behavior

- Although initially disorganized at some point they need to organize themselves
  - (self-organization)
- How can an ant, upon discovering food, find its way back to the nest?
- Even if an ant makes it back to the nest, how can it inform the other ants about the food's location?
  - Ants deposit pheromone along traveled path which is used by other ants to follow the trail

Ant colony in action

Ant colony in action



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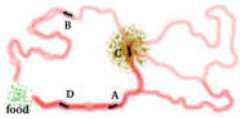

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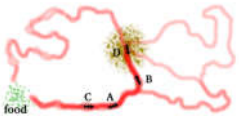


Powerful … but simple

All evidence suggests:

- No central control
- Only simple rules for each individual
- Emergent phenomena
- Self-organization

Harness this Power out of Simplicity

- Technical systems are getting larger and more complex
  - Global control hard to define and program
  - Larger systems lead to more errors
- Swarm intelligence systems are:
  - Robust
  - Relatively simple (How to program a swarm?)

Has been adopted for solving many computing science problems

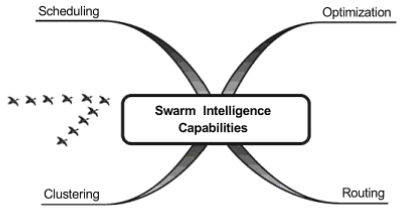
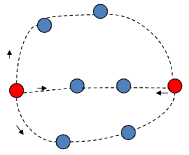


Fig. 6.11 Key capabilities of swarm intelligence

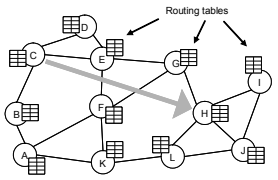
Rough Idea



Possible approaches

- Flooding
- Swarm Intelligence
- Routing table based

Routing table based Protocols



Routing table based Protocols

- Many protocols have been proposed
  - Some have been invented specifically for MANETs
  - Others are adapted from previously proposed protocols for wired networks
- No single protocol works well in all environments
  - some attempts have been made to develop adaptive protocols

Types of routing in MANET

- Flat Proactive Routing
  - Table driven: Destination-Sequenced Distance Vector (DSDV), WRP Routing
  - Link state Fish-Eye Routing, GSR, OLSR.
- On-Demand or Reactive Routing
  - Ad hoc On-demand Distance Vector (AODV) Routing
  - Dynamic Source Routing (DSR) Routing
- Hybrid Schemes
  - Zone Routing ZRP, SHARP (proactive near, reactive long distance)
  - Safari (reactive near, proactive long distance)
- Geographical Routing

Proactive routing in MANET

- Proactive: maintain routing information regardless of need for communication
- Update messages sent throughout the network periodically or when network topology changes.
- Low latency, suitable for real-time traffic
- Bandwidth might get wasted due to periodic updates
- They maintain O(N) state per node, N = #nodes

Reactive routing in MANET

- Reactive: discover route only when you need it
- Saves energy and bandwidth during inactivity
- Significant delay might occur as a result of route discovery
- Good for light loads, collapse in large loads

Trade-off

- Latency of route discovery
  - Proactive protocols may have lower latency since routes are maintained at all times
  - Reactive protocols may have higher latency because a route from X to Y will be found only when X attempts to send to Y
- Overhead of route discovery/maintenance
  - Reactive protocols may have lower overhead since routes are determined only if needed
  - Proactive protocols can (but not necessarily) result in higher overhead due to continuous route updating
- Which approach achieves a better trade-off depends on the traffic and mobility patterns