

# INTRODUCTION TO WIRELESS SENSOR NETWORKS

## CHAPTER 5: MULTI-HOP COMMUNICATIONS

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# OVERVIEW

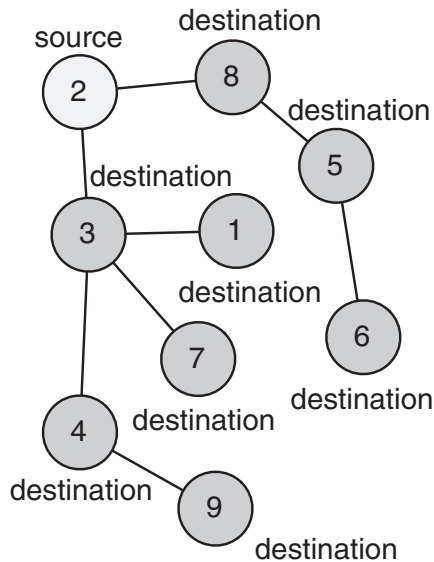
1. Routing Basics
2. Routing Metrics
3. Routing Protocols
  1. Full-network broadcast
  2. Location-based routing
  3. Directed Diffusion
  4. Collection Tree Protocol
  5. Zigbee

# Some Basic Definitions

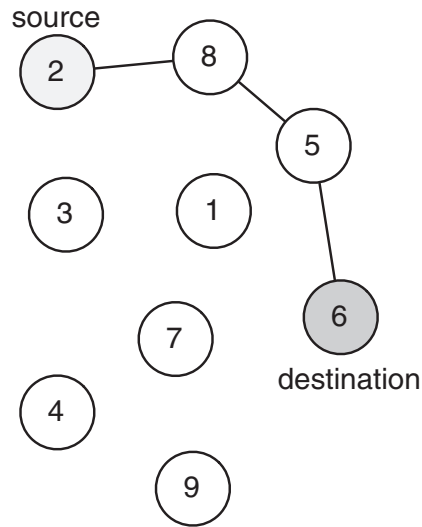
- **Data source.** *The node in the network, which produces the required data and is able to send it out to other nodes in the network.*
- **Data destination.** *The node in the network, which requires the*
  - *data and is able to receive it from other nodes in the network.*
- **Data forwarder.** *Any node in the network, which is not the source or the destination of the data, which is able to receive it from another node and to send it further in the network.*
- **Data sink.** *A dedicated node(s) in the network, which is the implicit destination of any data in this network.*

# Communication Scenarios

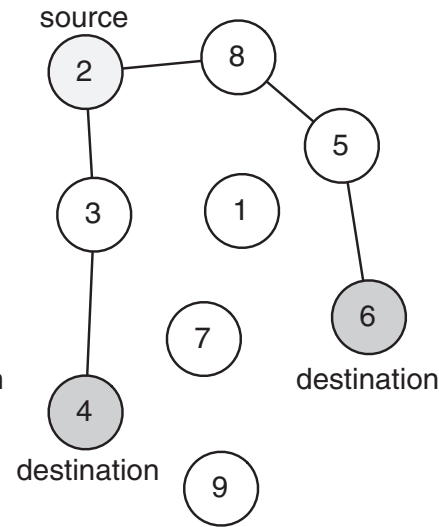
**FULL-NETWORK BROADCAST**



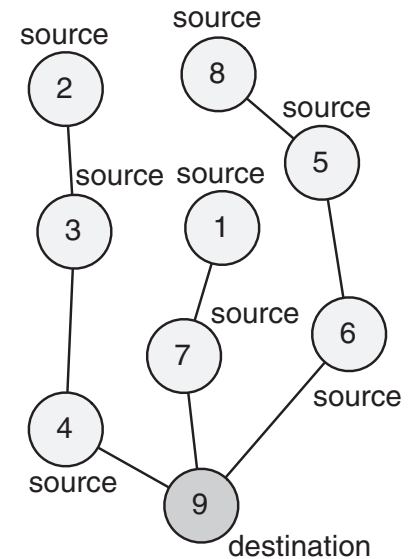
**UNICAST**



**MULTICAST**



**CONVERGECAST**

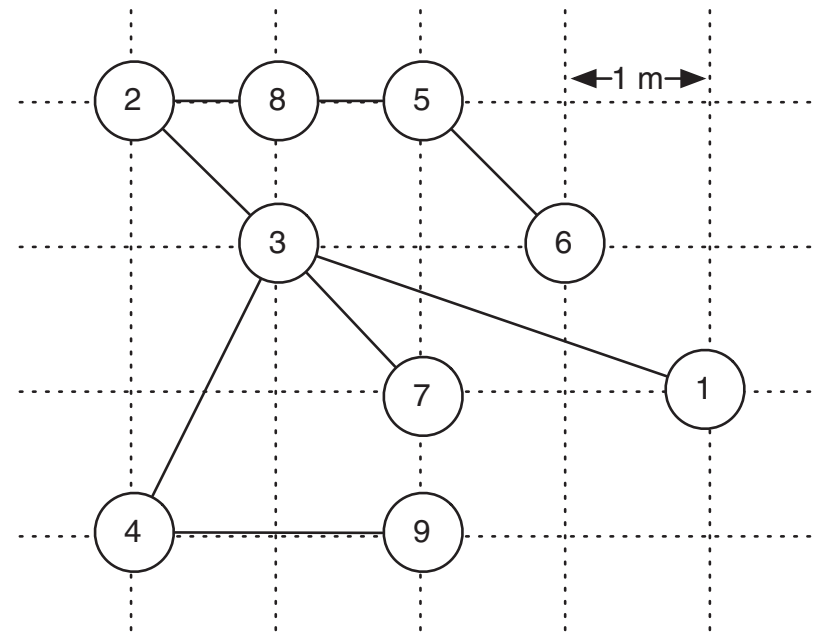


# Routing

- ***Routing*** is the process of selecting a sequence of nodes in the network, beginning from the data source(s) and ending at the data destination(s). This sequence of nodes is also called the ***routing path***.
- A valid ***routing path*** consists of a finite number of nodes and it does not contain loops.

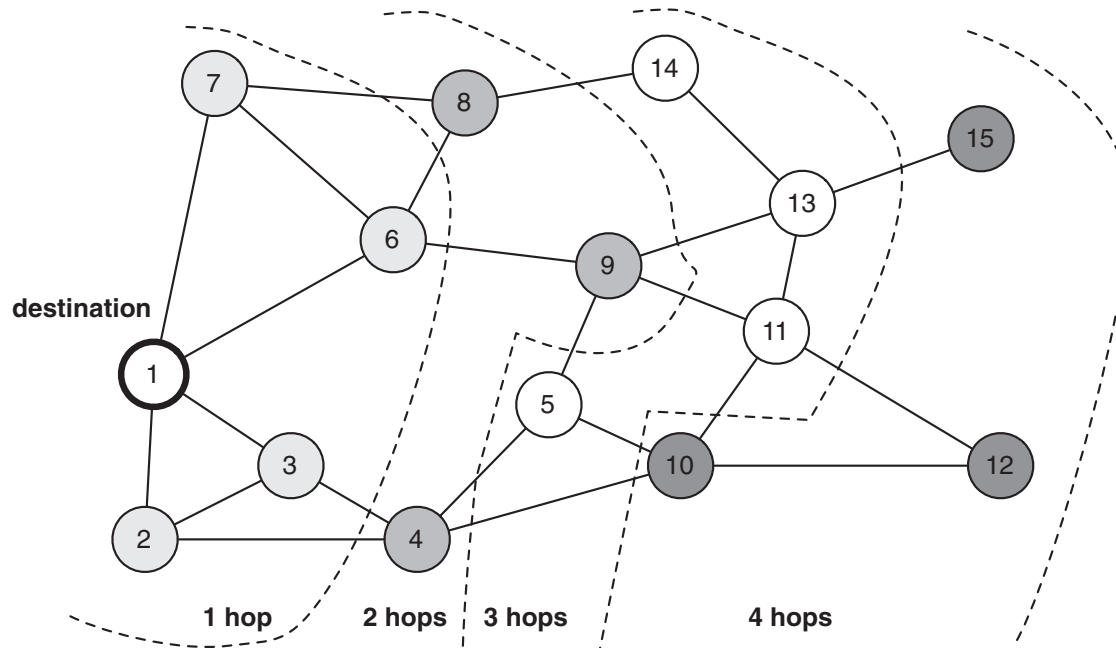
# Metric: Location and Distance

- Real geographic locations/distances
- Approximations like Manhattan distance
- Simple and clear
- Costly to obtain locations and to exchange information (see Chapter 8)



# Metric: Hops

- An approximation of distance in terms of communication
- Not trivial to obtain for all nodes in the network
- Reflects very well the topology of the network



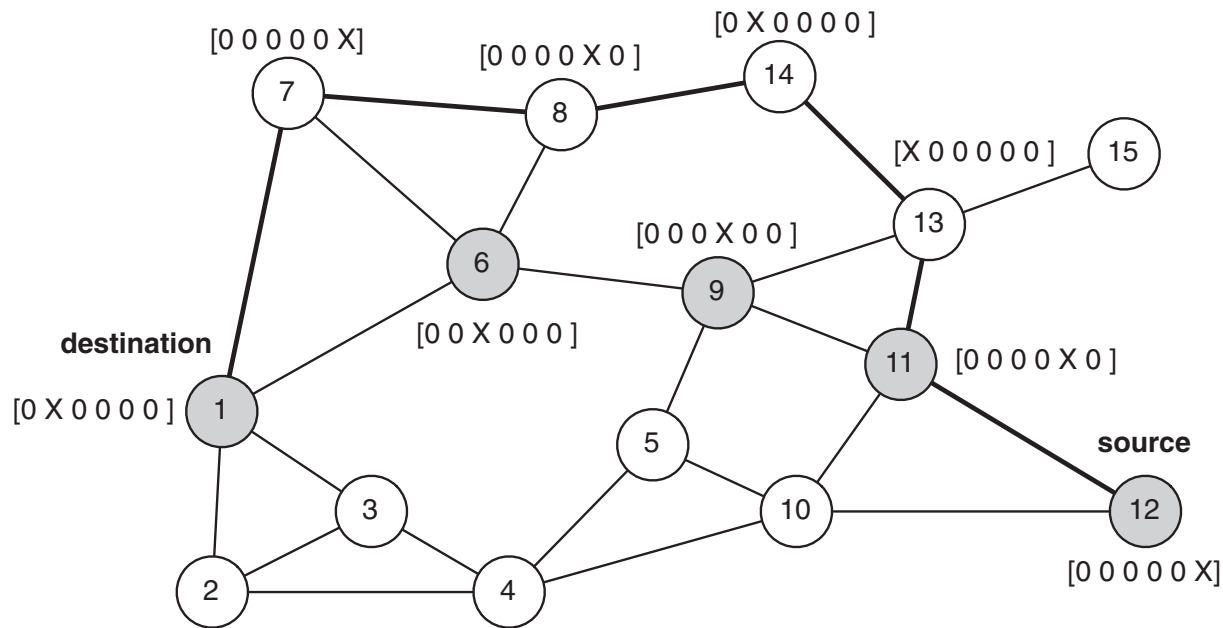
# Metric: Number of Retransmissions (ETX)

- An improvement of hops
- Takes into consideration also the needed retransmissions
- The number of retransmissions ETX over a route is always at least the number of hops over the same route.



# Metric: Delivery Delay

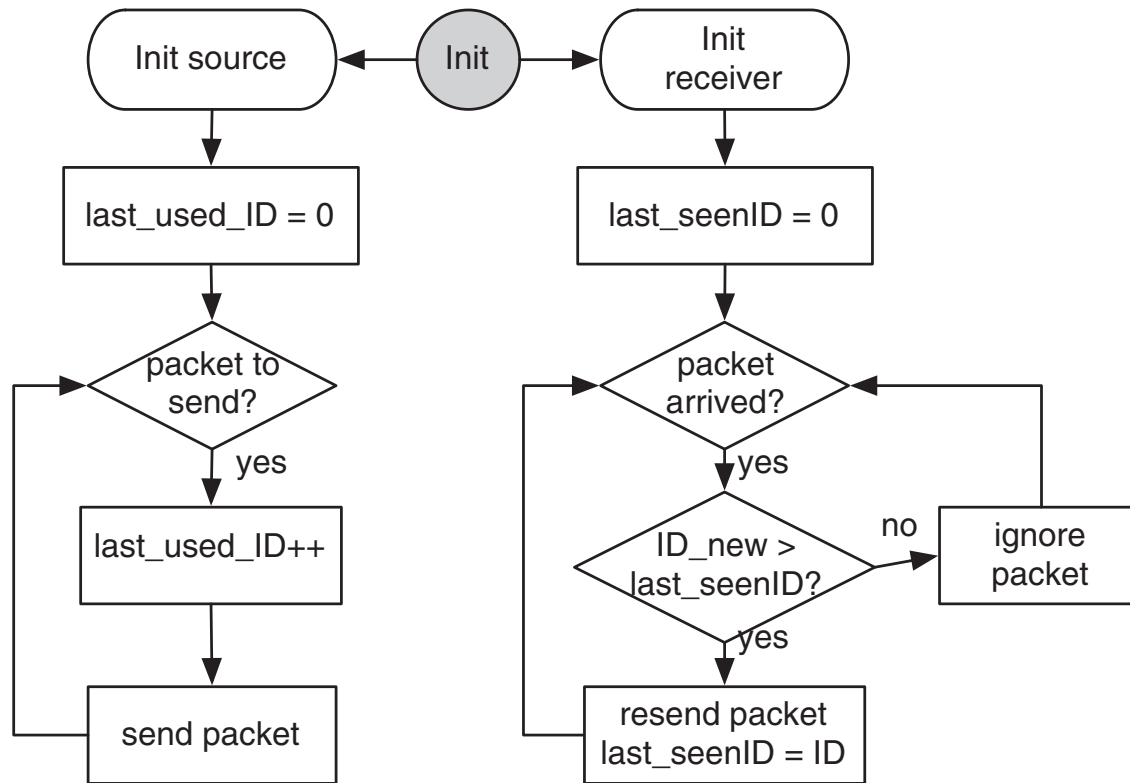
- Delivery delay is the time elapsed between sending a packet at the source and receiving it at the destination, irrespective of the delay reason.
- Reflects well the topology of the network and the interplay of different protocols and algorithms (e.g. TDMA schedules)



Anna Förster, Introduction to Wireless Sensor Networks, 2016

- [illegible]

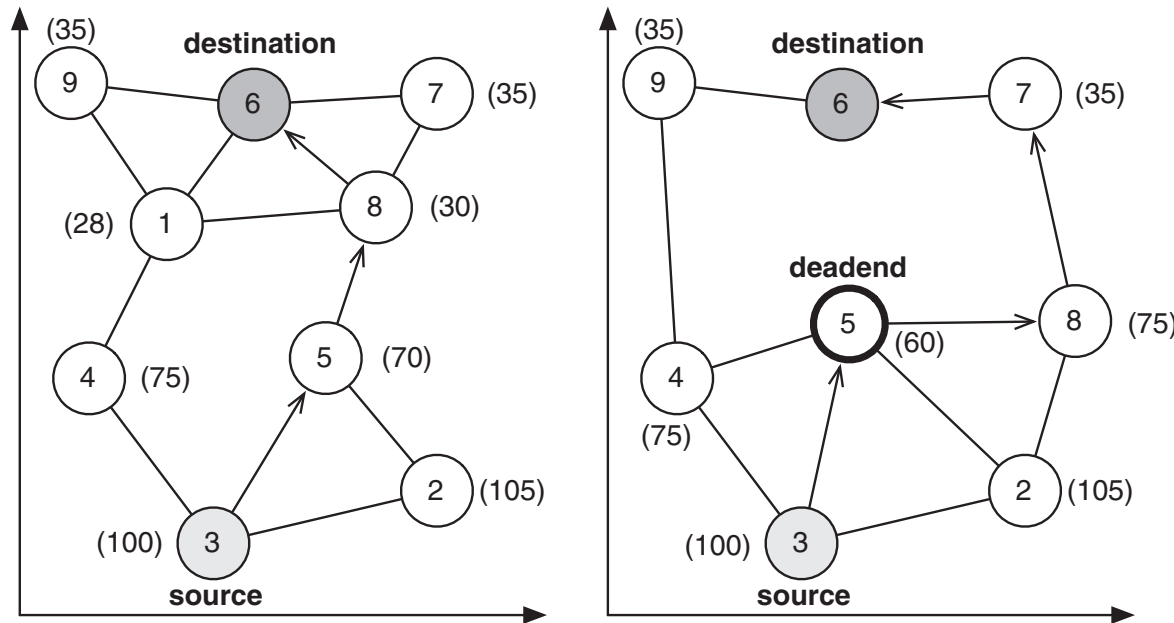
# Full Network Broadcast Algorithm



# Location-Based Routing

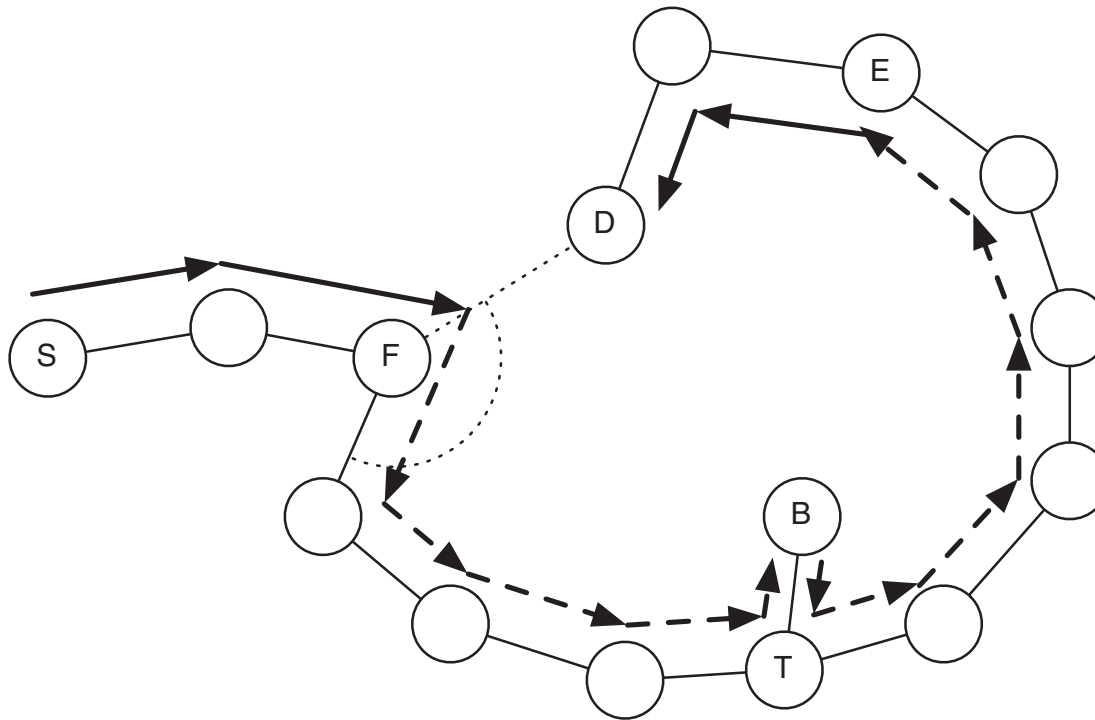
- Any data forwarder (beginning at the source) compares the coordinates of the destination with the coordinates of all its neighbors and selects one to forward the data.
- A neighbor is defined to have a **positive progress** towards some destination, when its own distance to the sink (independently from the routing metric used) is smaller than the distance to the sink of the current node.
- If a routing process is always able to find a neighbour with positive progress towards the destination, it is guaranteed that the data packet will reach the destination in finite number of hops.

# Location-Based Routing: Deadends



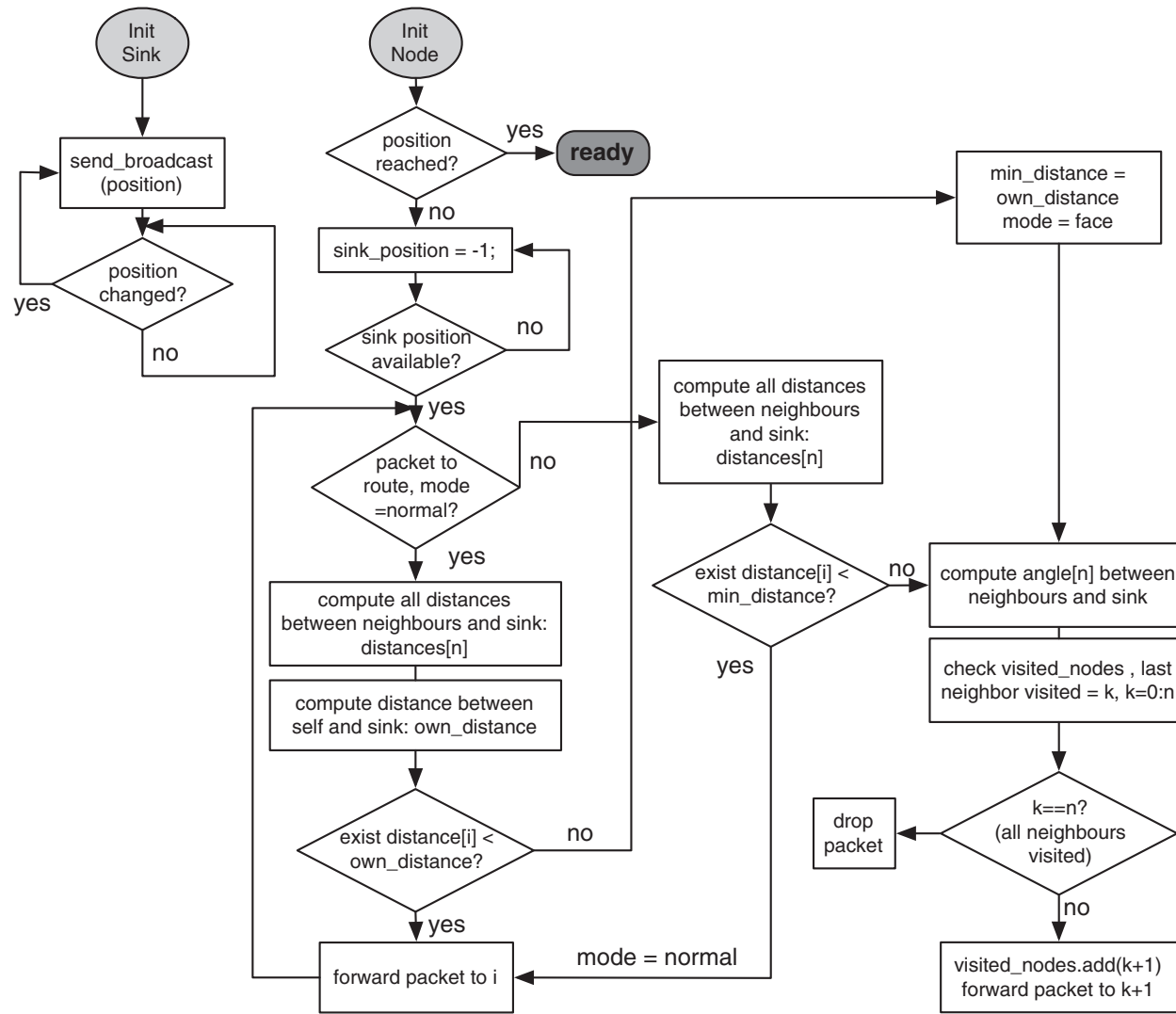
- In case of a deadend, follow “face routing” or the right-hand rule

# Location-Based Routing: Face Routing



- The right-hand rule, and also the left-hand rule, is used to escape from a simply connected maze whose walls are connected to each other. Next time you enter a maze, put your right hand on the wall next to you and follow it. You are guaranteed to find another exit, if there is one.

# Location-Based Routing: Algorithm



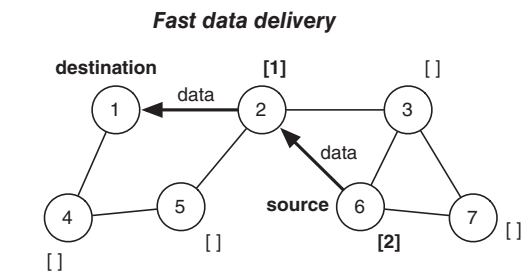
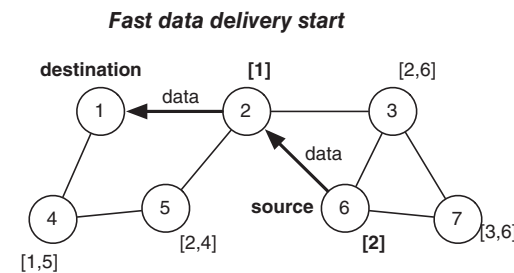
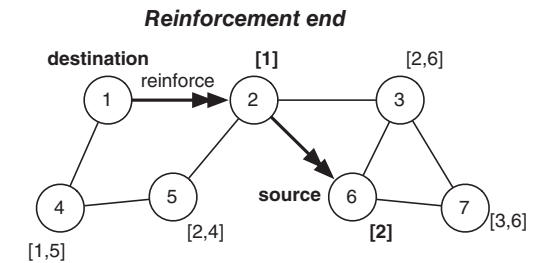
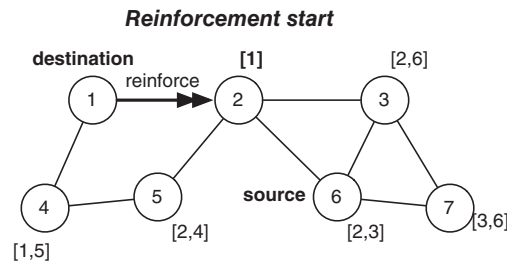
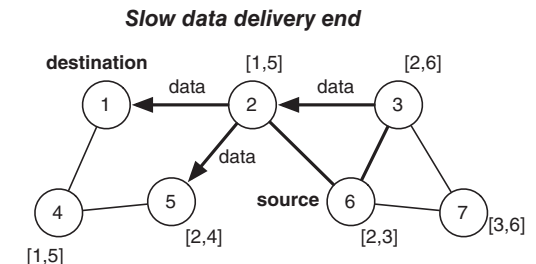
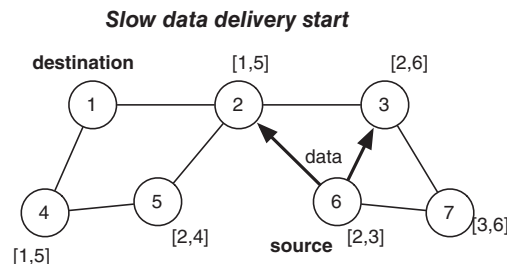
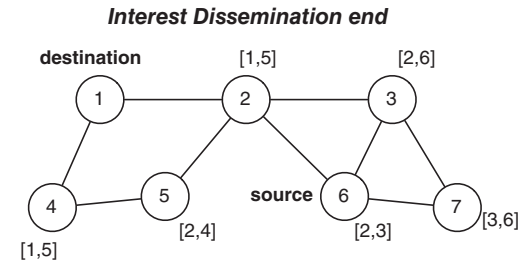
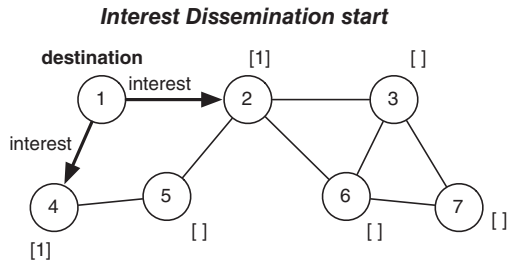
# Directed Diffusion (DD)

- A publish-subscribe algorithm
- Sinks register with “information interests” to sensors
- Sensors route data to all interested sinks
- Based on delivery delay, but checked in both directions



# DD: Main Algorithm

- Four phases
- Makes sure that communication works in both directions (recall: asymmetric links! TDMA schedules!)

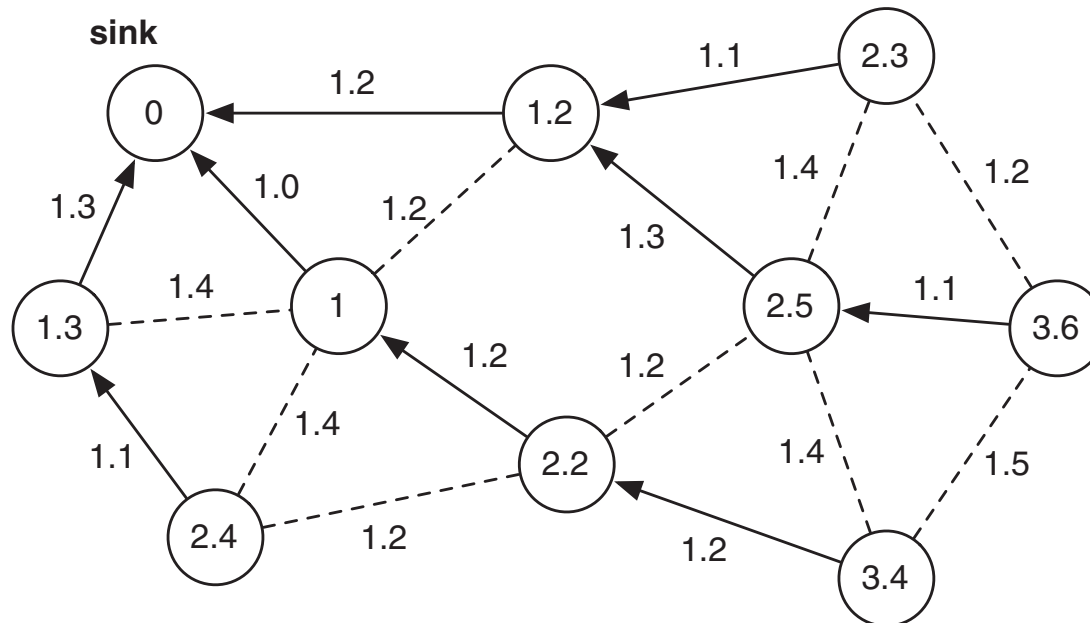


# DD: Variations

- **One Phase Pull:**  
only Interest Dissemination and Fast Data Delivery
- **Push:**  
Slow Delivery starts without Interest Dissemination

# Collection Tree Protocol (CTP)

- Consists of Link Management (already discussed in Chapter 4) and Routing
- Routing selects the neighbor with minimum ETX to sink:



# Zigbee

- Node Roles:
  - Coordinator
  - Router
  - End Device
- Beacon-Less Zigbee:
  - Routers use CSMA/CA, end devices sleep as much as they wish
- Beacon-based Zigbee:
  - Routers use TDMA to inform end devices when they are awake
  - Requires time synchronization
- Routing is based on AODV with full routing paths (Internet style vs. hop-by-hop in WSNs)

# Routing: Summary

- Routing is the process of forwarding a packet from the **source** to a **destination** via intermediate nodes called routers or forwarders.
- Routing in WSNs is performed always **hop-by-hop**.
- You use **routing metrics** to decide which next hop to take: **hops, delay, and ETX**.
- **Routing highly depends** on the MAC and link layer protocols at least.
- Routing is very **sensitive to link quality**—the more stable links are, the better the routing protocol works.
- Almost none of the currently existing protocols guarantee delivery of all packets. Instead, WSN routing is **best effort**.

# Routing: Summary of Protocols

- **Controlled full-network broadcast** sends a single packet from one source to all other nodes of the network. It is guaranteed that it will stop once all nodes receive the packet.
- **Location-based routing** selects next hops from a single source to a single destination by evaluating the geographic distance between the next hops and the final destination. Sometimes it enters a deadend, which needs to be solved via face routing.
- **Directed diffusion** explores an alternative routing approach, where there are no real destinations for the packets but interests. Data is routed towards these interests and eventually arrive at the interested destination(s).
- **CTP (Collection Tree Protocol)** is the most often protocol used in real-world applications. It builds a tree rooted at the sink and connects all nodes with the sink. The data gets collected from all nodes at the sink.
- **Zigbee** is a (industrial) standard protocol that is less flexible than CTP.