Mobile Communications Chapter 8: Routing Protocols

- Ad-hoc networks
- Routing protocols

Mobile ad hoc networks

Standard Mobile IP needs an infrastructure

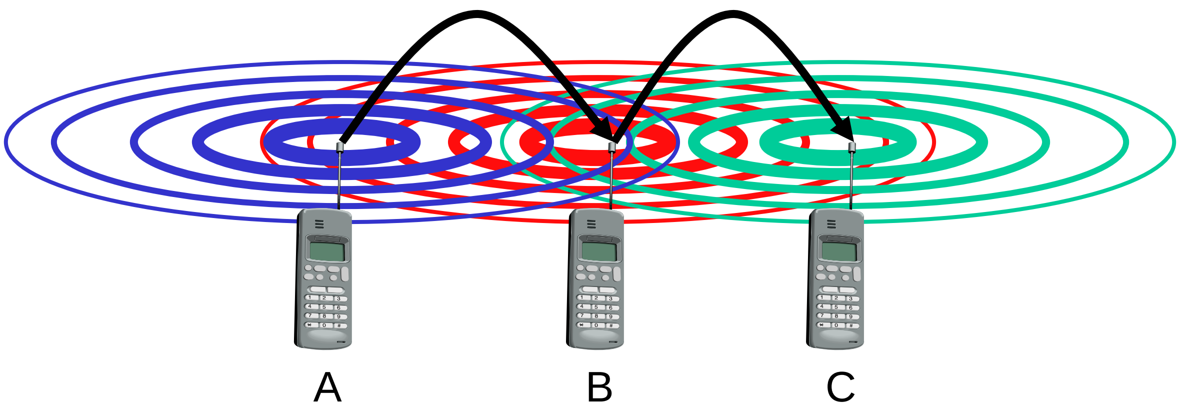
- Home Agent/Foreign Agent in the fixed network
- DNS, routing etc. are not designed for mobility

Sometimes there is no infrastructure!

- remote areas, ad-hoc meetings, disaster areas
- cost can also be an argument against an infrastructure!

Main topic: routing

- no default router available
- every node should be able to forward

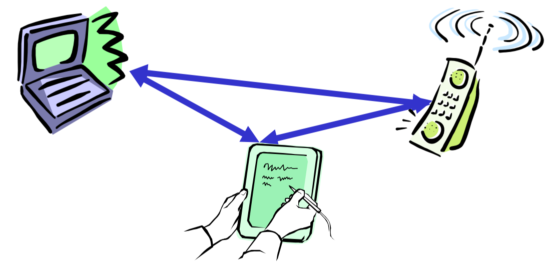


Network without infrastructure

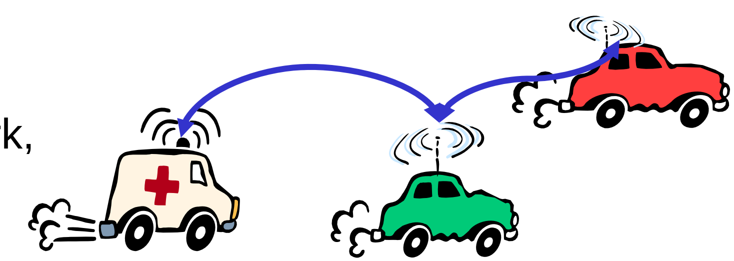
- Use components of participants for networking

Examples

- Single-hop: All partners max. one hop apart
  - Bluetooth piconet, PDAs in a room, gaming devices…

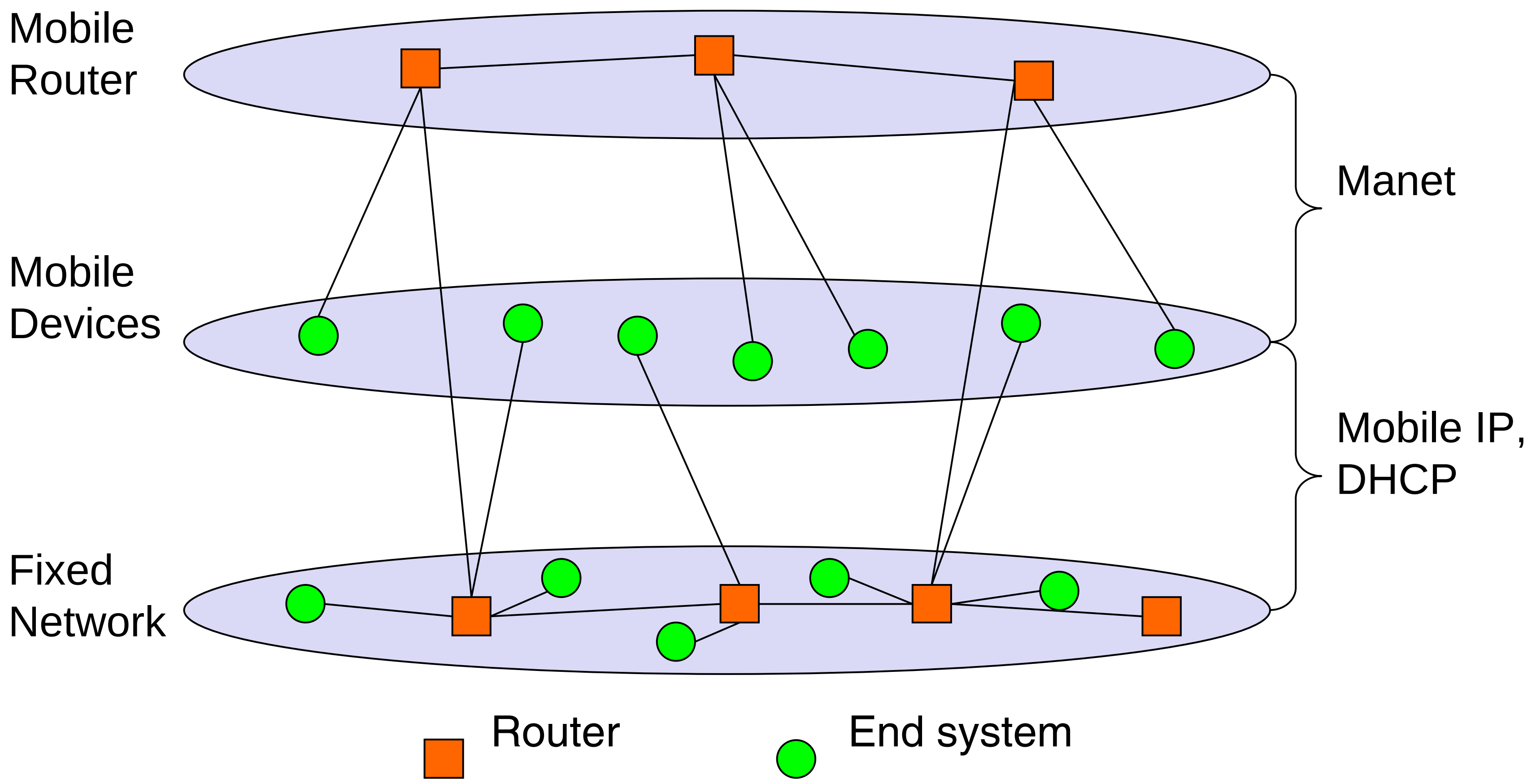


- Multi-hop: Cover larger distances, circumvent obstacles
  - Bluetooth scatternet, TETRA police network, car-to-car networks…



Internet: MANET (Mobile Ad-hoc Networking) group

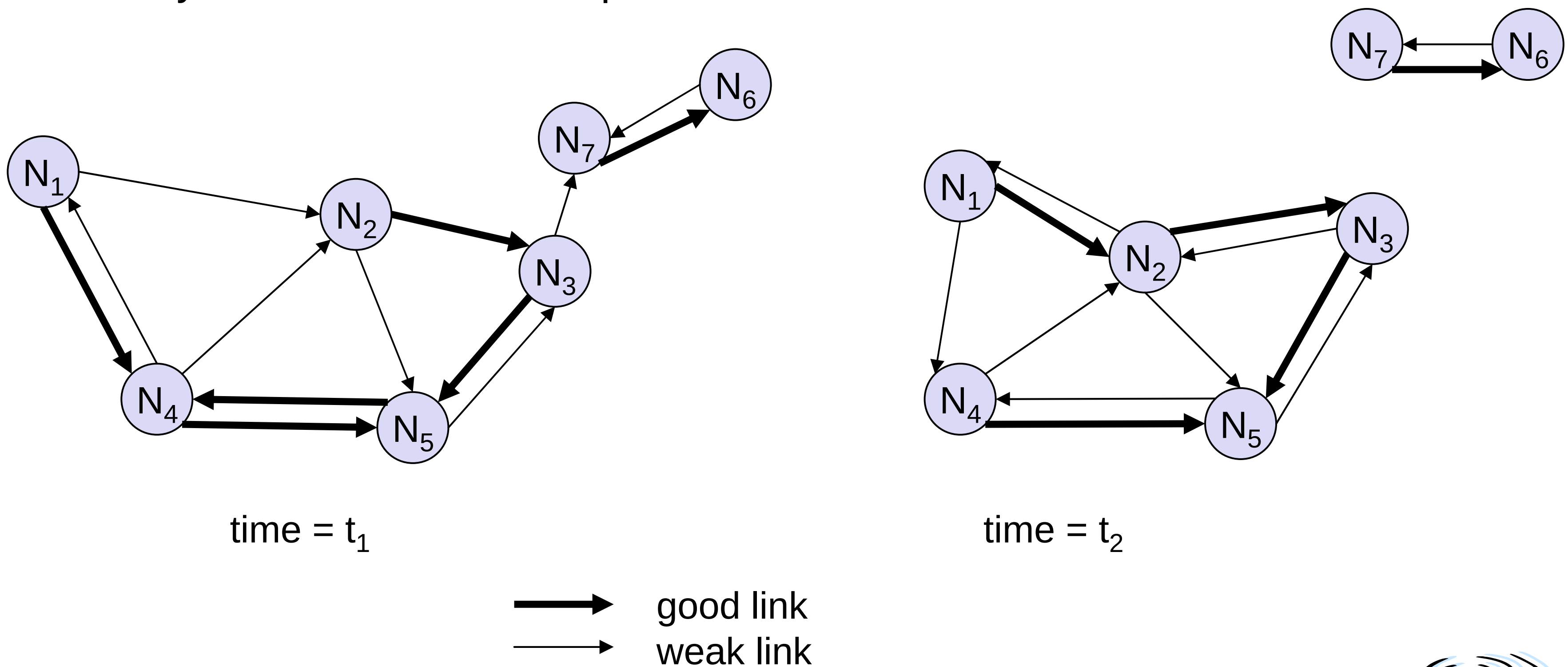
Manet: Mobile Ad-hoc Networking



Problem No. 1: Routing

Highly dynamic network topology

- Device mobility plus varying channel quality
- Separation and merging of networks possible
- Asymmetric connections possible



Traditional routing algorithms

Distance Vector

- periodic exchange of messages with all physical neighbors that contain information about who can be reached at what distance
- selection of the shortest path if several paths available

Link State

- periodic notification of all routers about the current state of all physical links
- router get a complete picture of the network

Example

- ARPA packet radio network (1973), DV-Routing
- every 7.5s exchange of routing tables including link quality
- updating of tables also by reception of packets
- routing problems solved with limited flooding

Routing in ad-hoc networks

THE big topic in many research projects

- Far more than 50 different proposals exist
- The most simplest one: Flooding!

Reasons

- Classical approaches from fixed networks fail
  - Very slow convergence, large overhead
- High dynamicity, low bandwidth, low computing power

Metrics for routing

- Minimal
  - Number of nodes, loss rate, delay, congestion, interference …
- Maximal
  - Stability of the logical network, battery run-time, time of connectivity …

Problems of traditional routing algorithms

Dynamic of the topology

- frequent changes of connections, connection quality, participants

Limited performance of mobile systems

- periodic updates of routing tables need energy without contributing to the transmission of user data, sleep modes difficult to realize
- limited bandwidth of the system is reduced even more due to the exchange of routing information
- links can be asymmetric, i.e., they can have a direction dependent transmission quality

DSDV (Destination Sequenced Distance Vector)

Early work

- on demand version: AODV

Expansion of distance vector routing

Sequence numbers for all routing updates

- assures in-order execution of all updates
- avoids loops and inconsistencies

Decrease of update frequency

- store time between first and best announcement of a path
- inhibit update if it seems to be unstable (based on the stored time values)

Dynamic source routing I

Split routing into discovering a path and maintaining a path

Discover a path

- only if a path for sending packets to a certain destination is needed and no path is currently available

Maintaining a path

- only while the path is in use one has to make sure that it can be used continuously

No periodic updates needed!

Dynamic source routing II

Path discovery

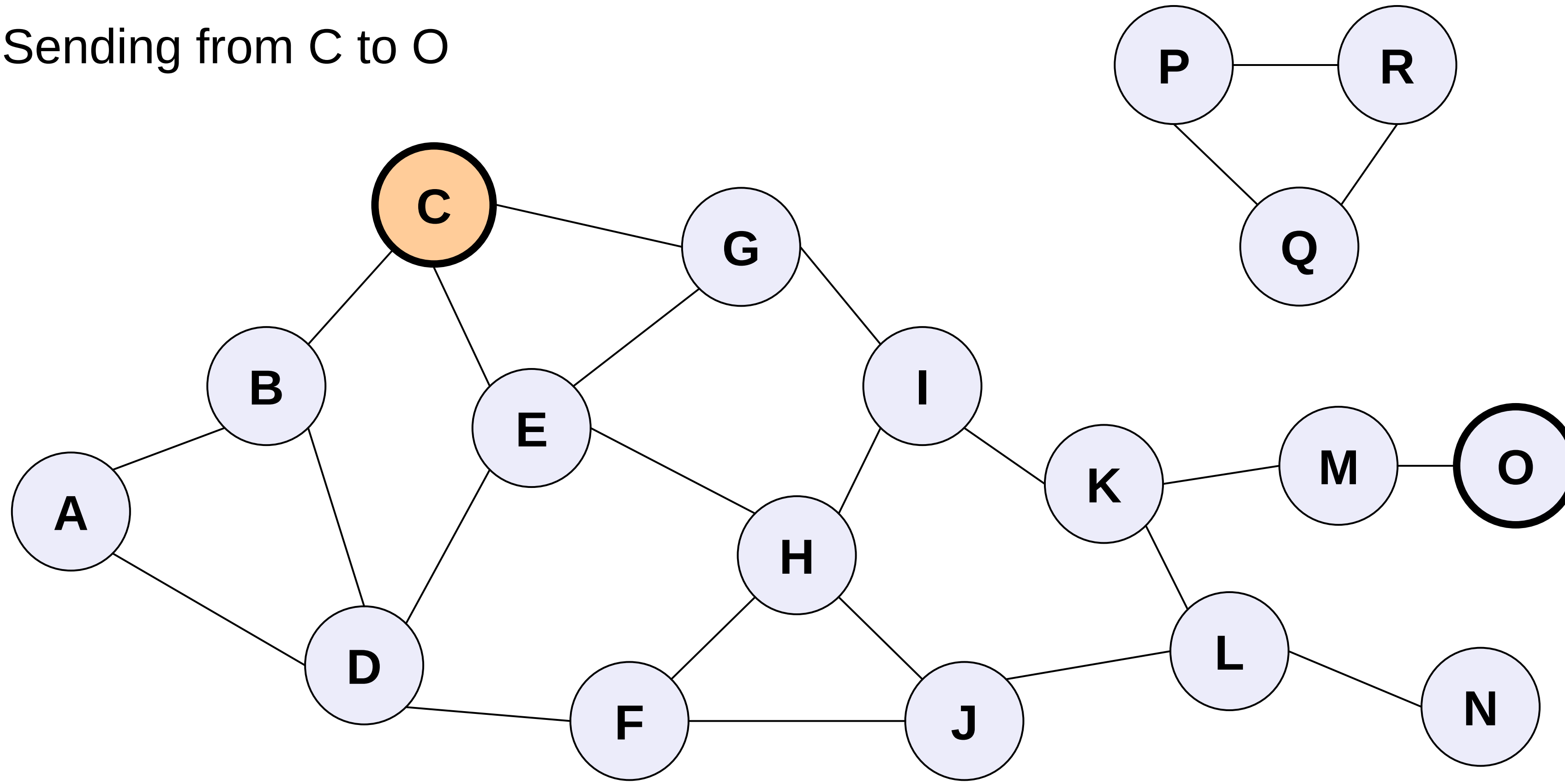
- broadcast a packet with destination address and unique ID
- if a station receives a broadcast packet
  - if the station is the receiver (i.e., has the correct destination address) then return the packet to the sender (path was collected in the packet)
  - if the packet has already been received earlier (identified via ID) then discard the packet
  - otherwise, append own address and broadcast packet
- sender receives packet with the current path (address list)

Optimizations

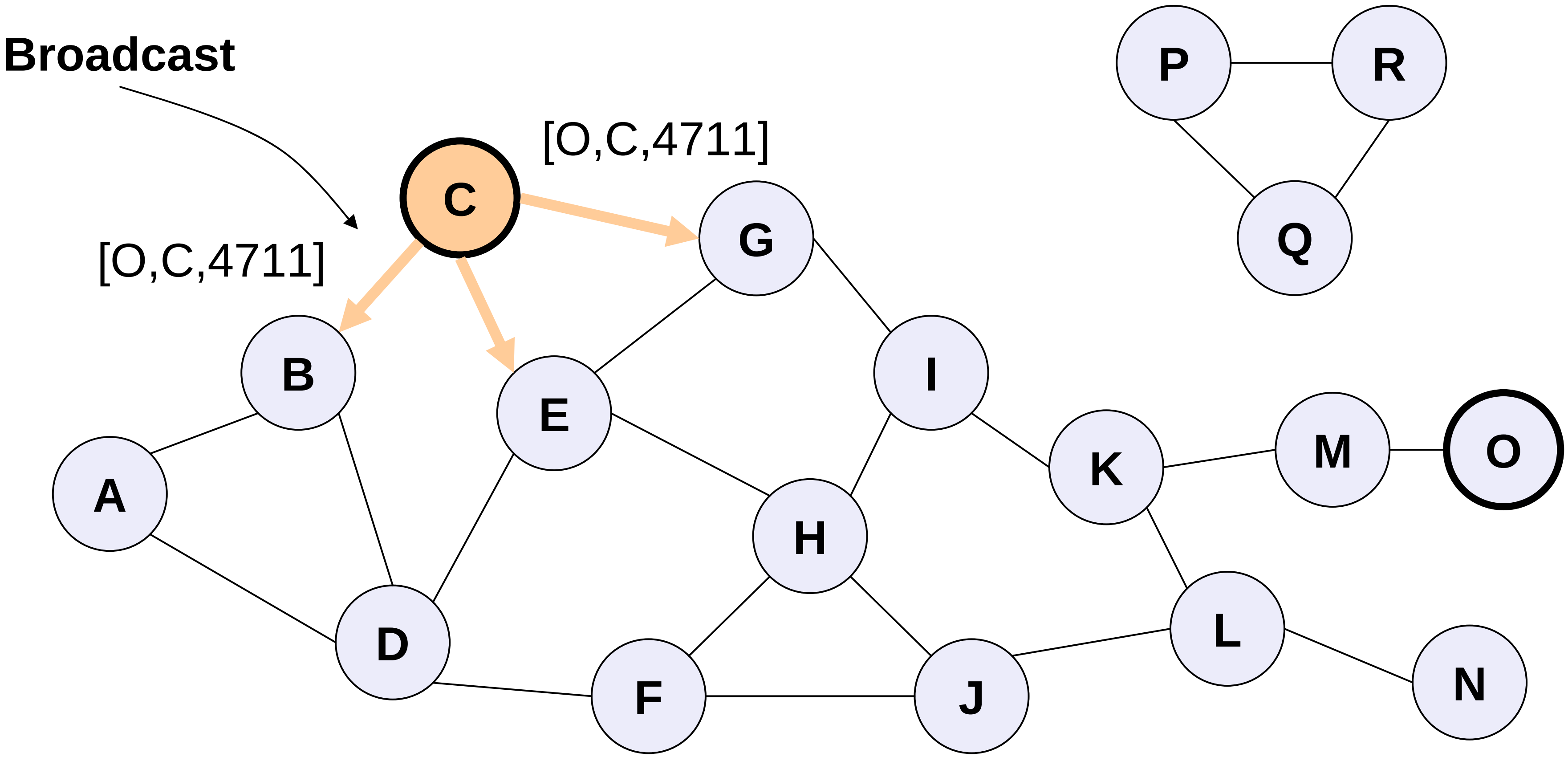
- limit broadcasting if maximum diameter of the network is known
- caching of address lists (i.e. paths) with help of passing packets
  - stations can use the cached information for path discovery (own paths or paths for other hosts)

DSR: Route Discovery

Sending from C to O



DSR: Route Discovery



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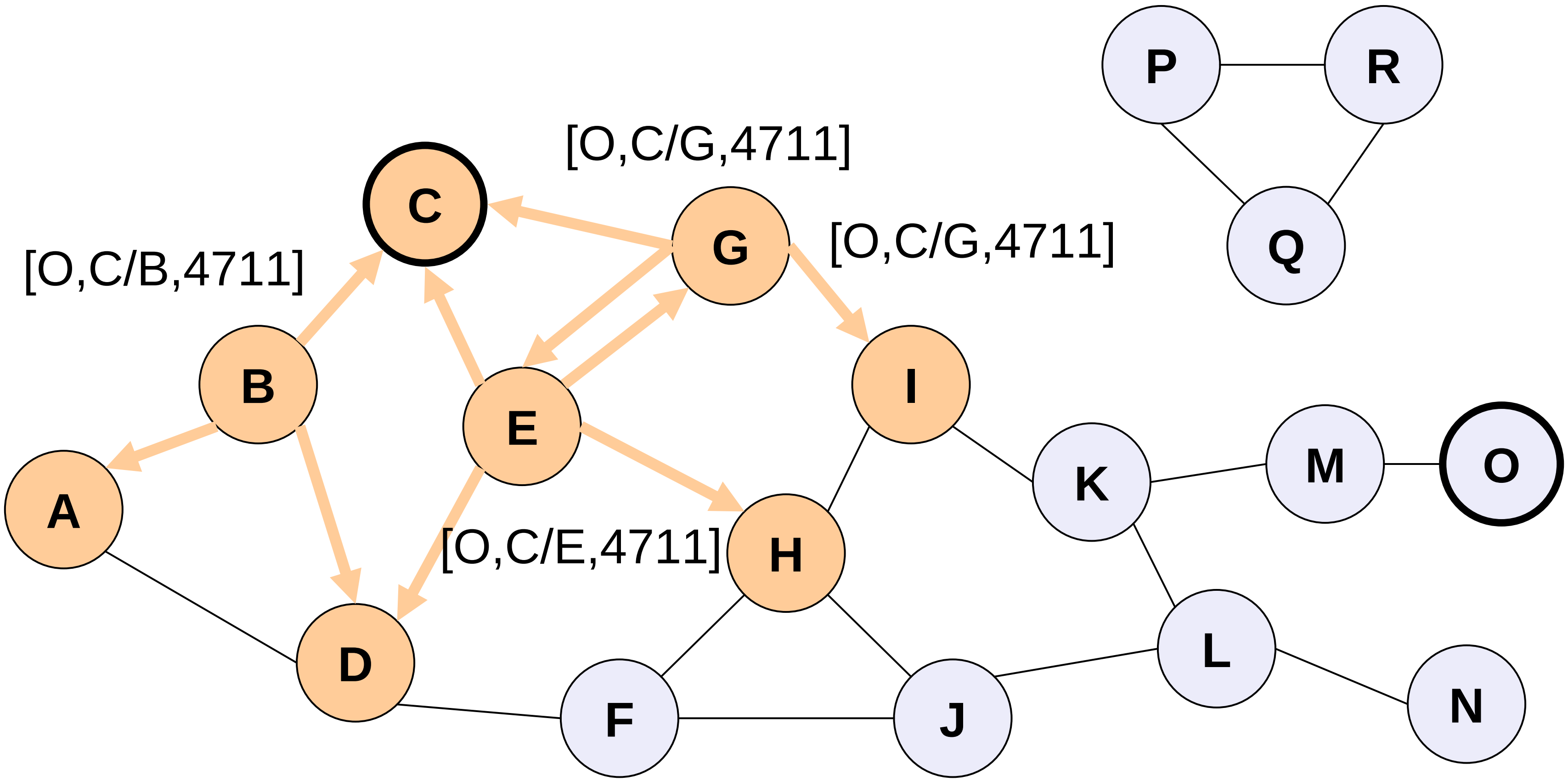

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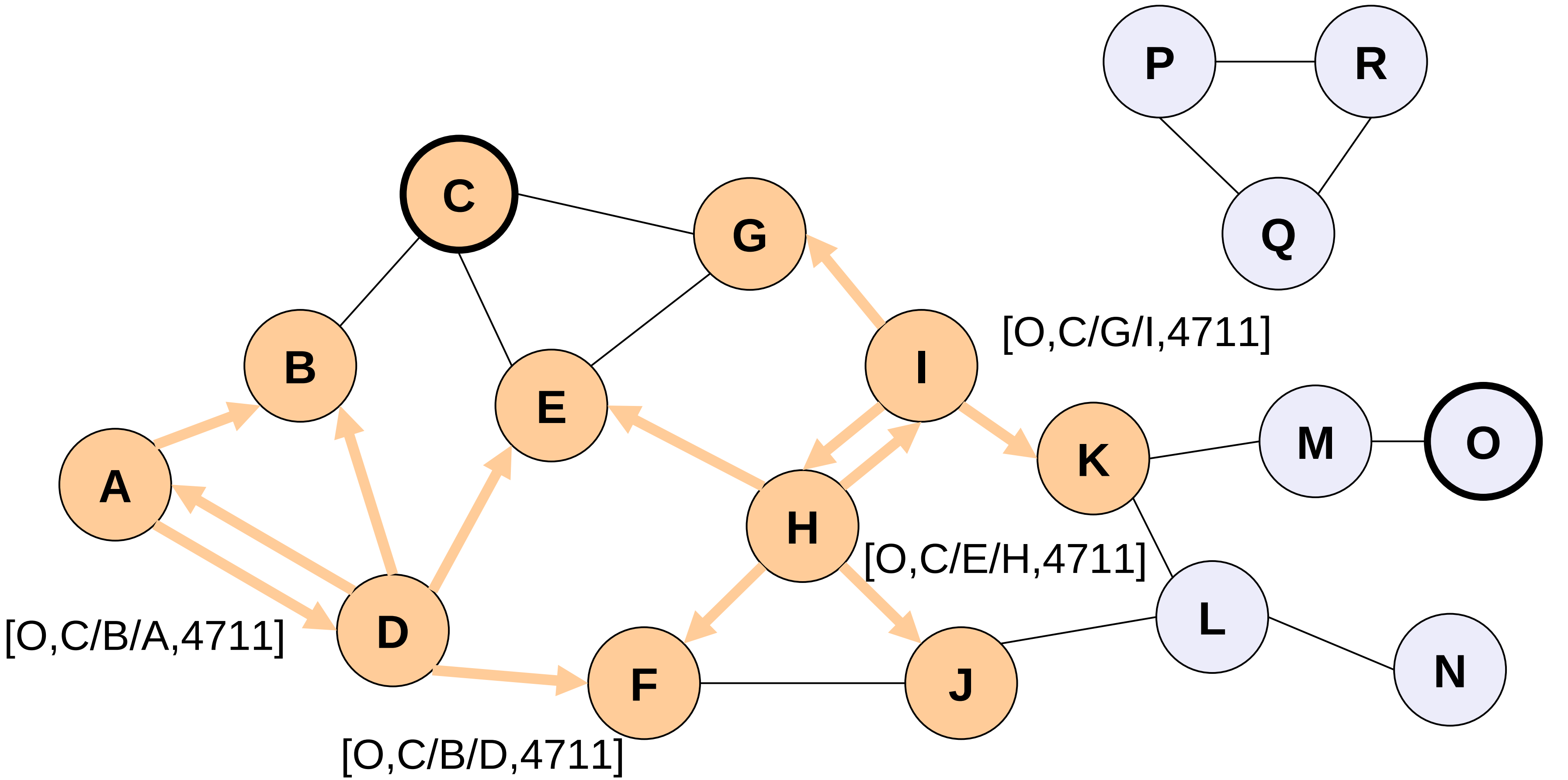
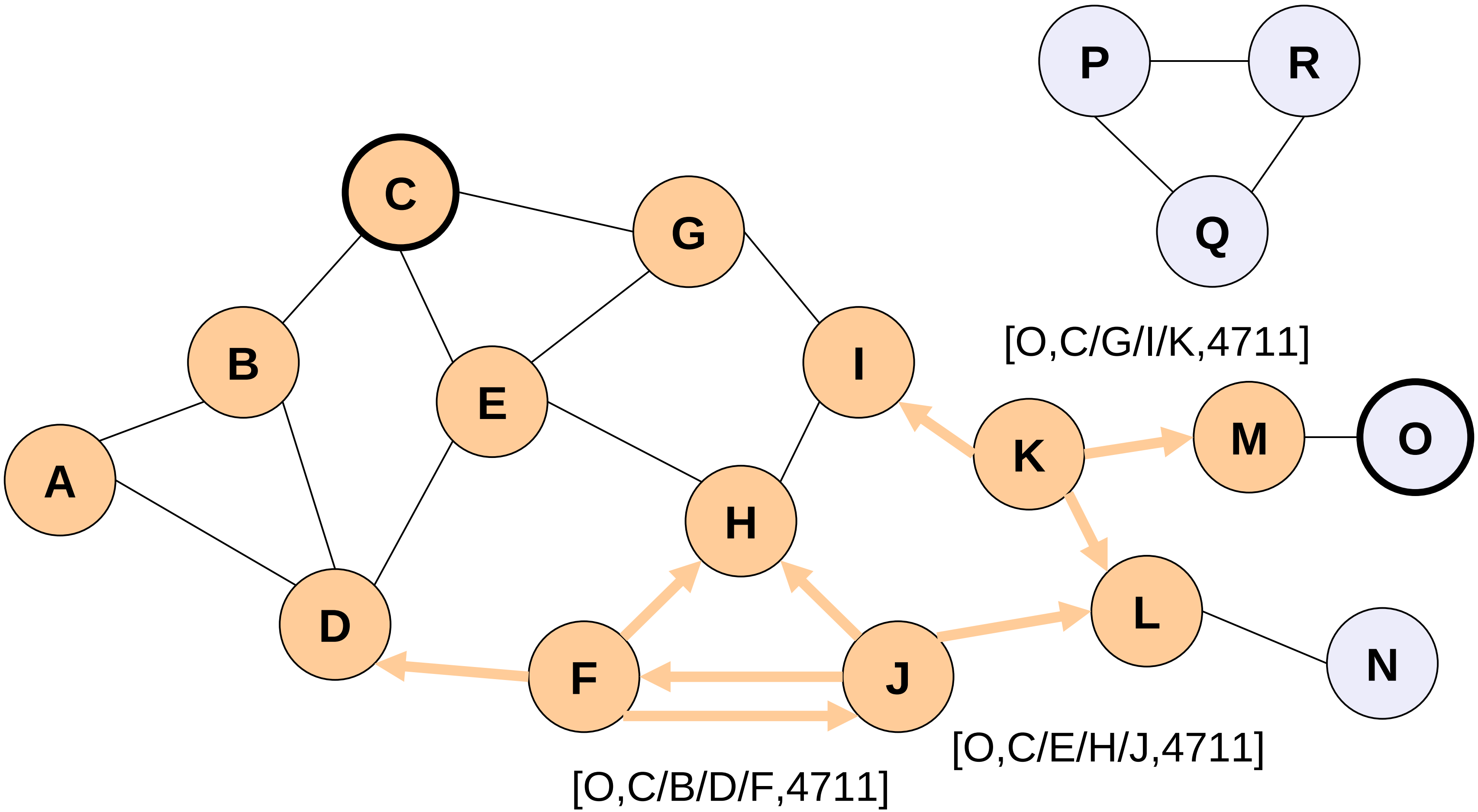


(alternatively: [O,C/E/D,4711])

DSR: Route Discovery



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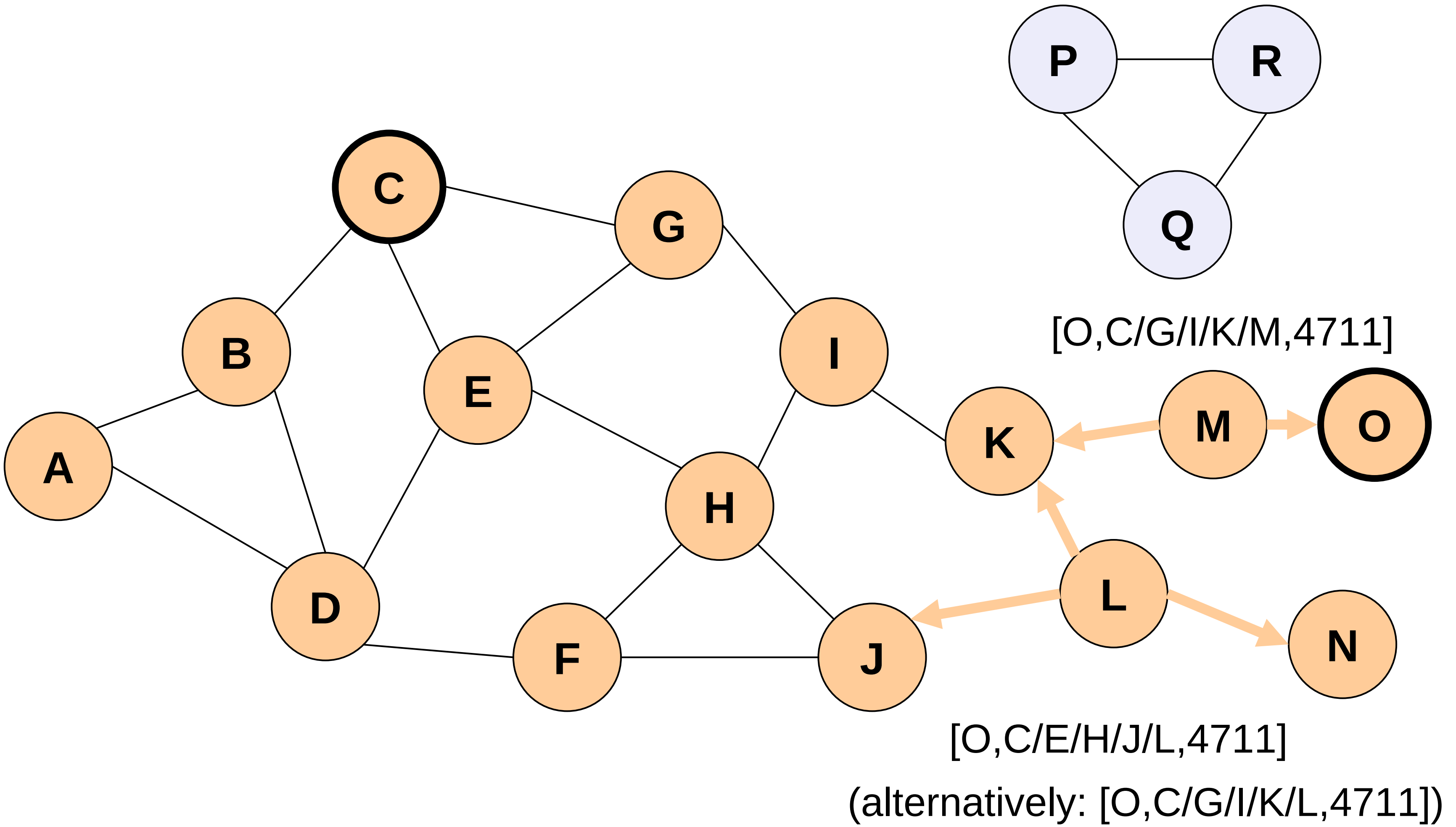

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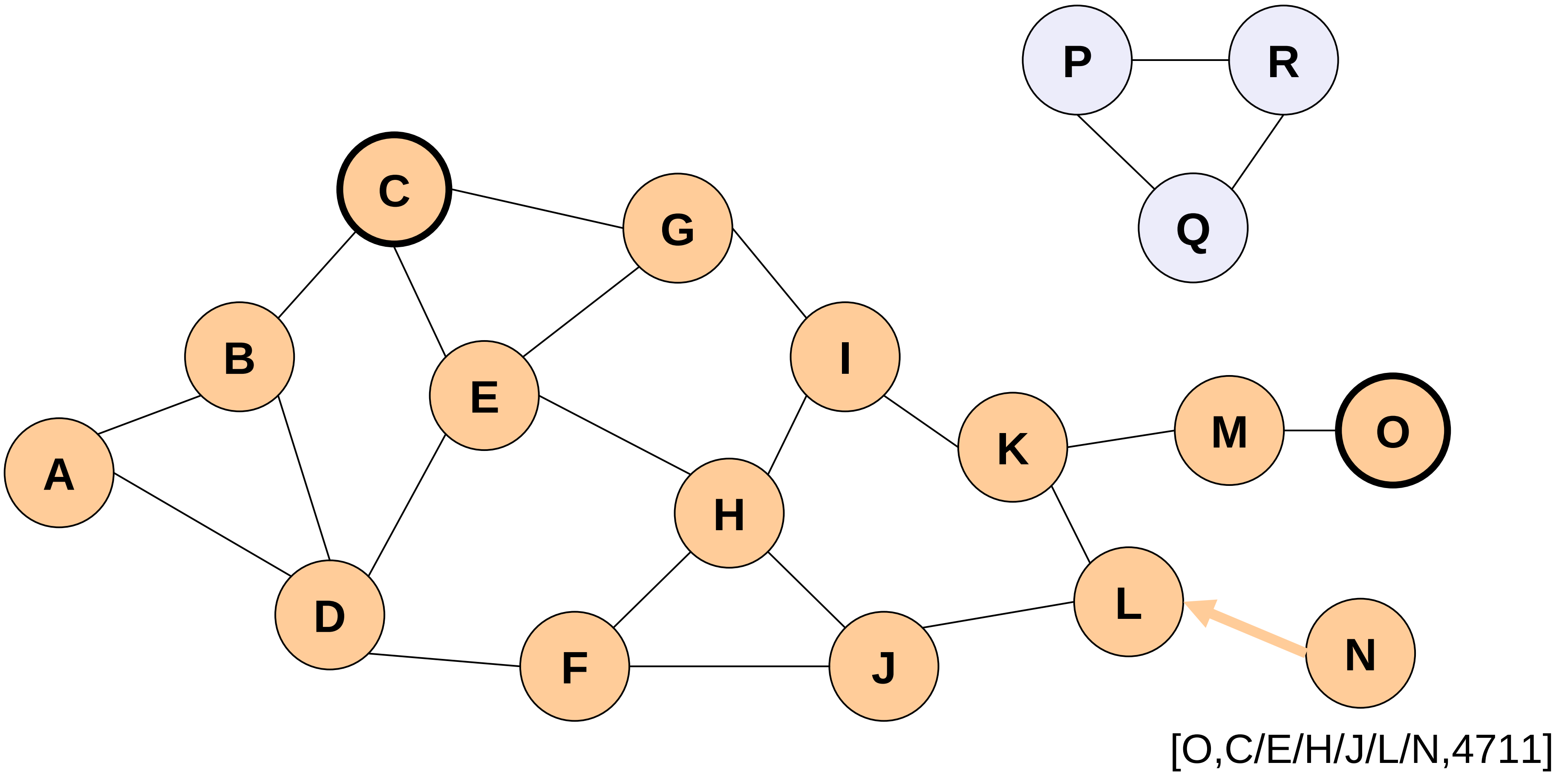

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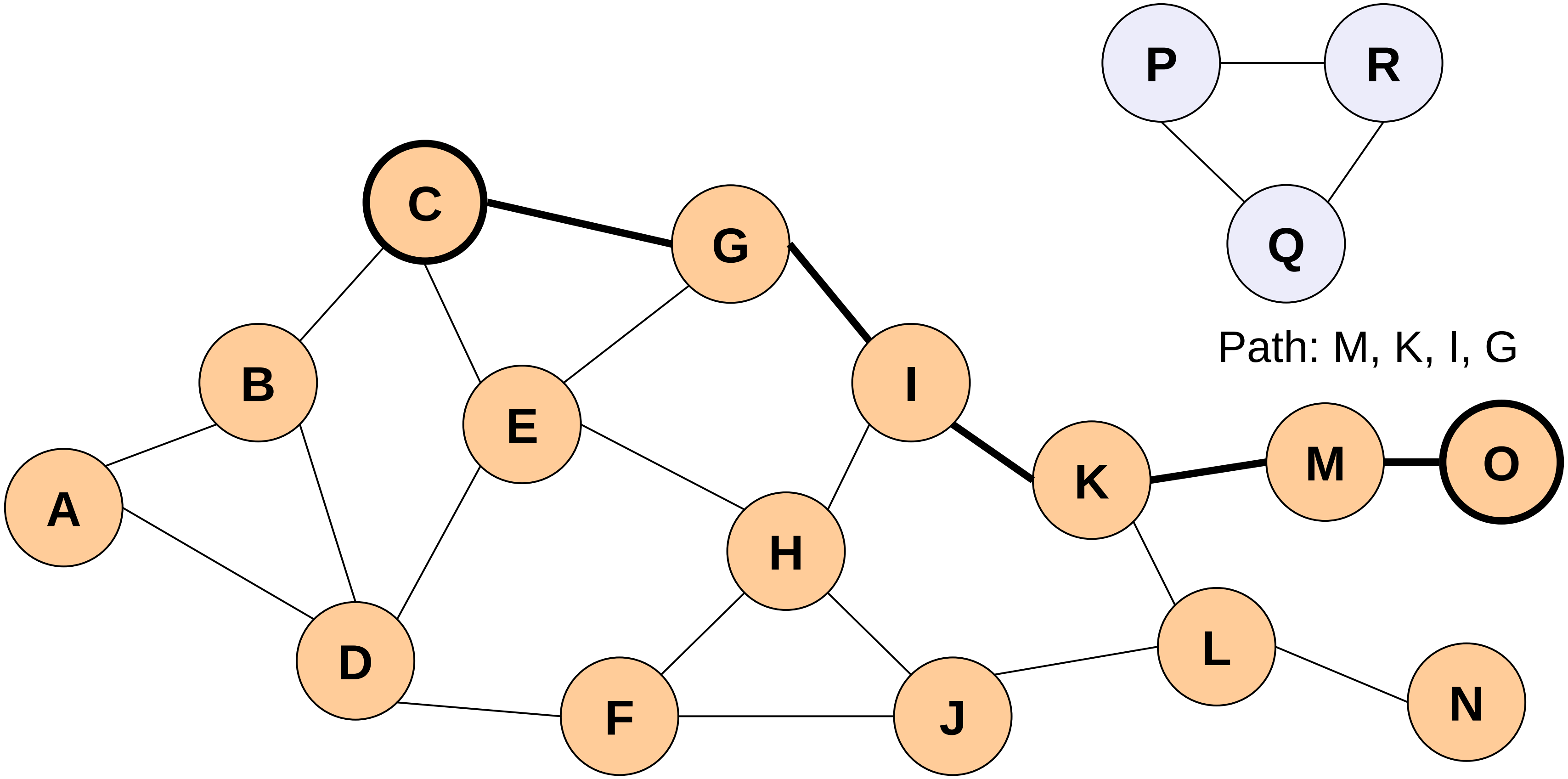


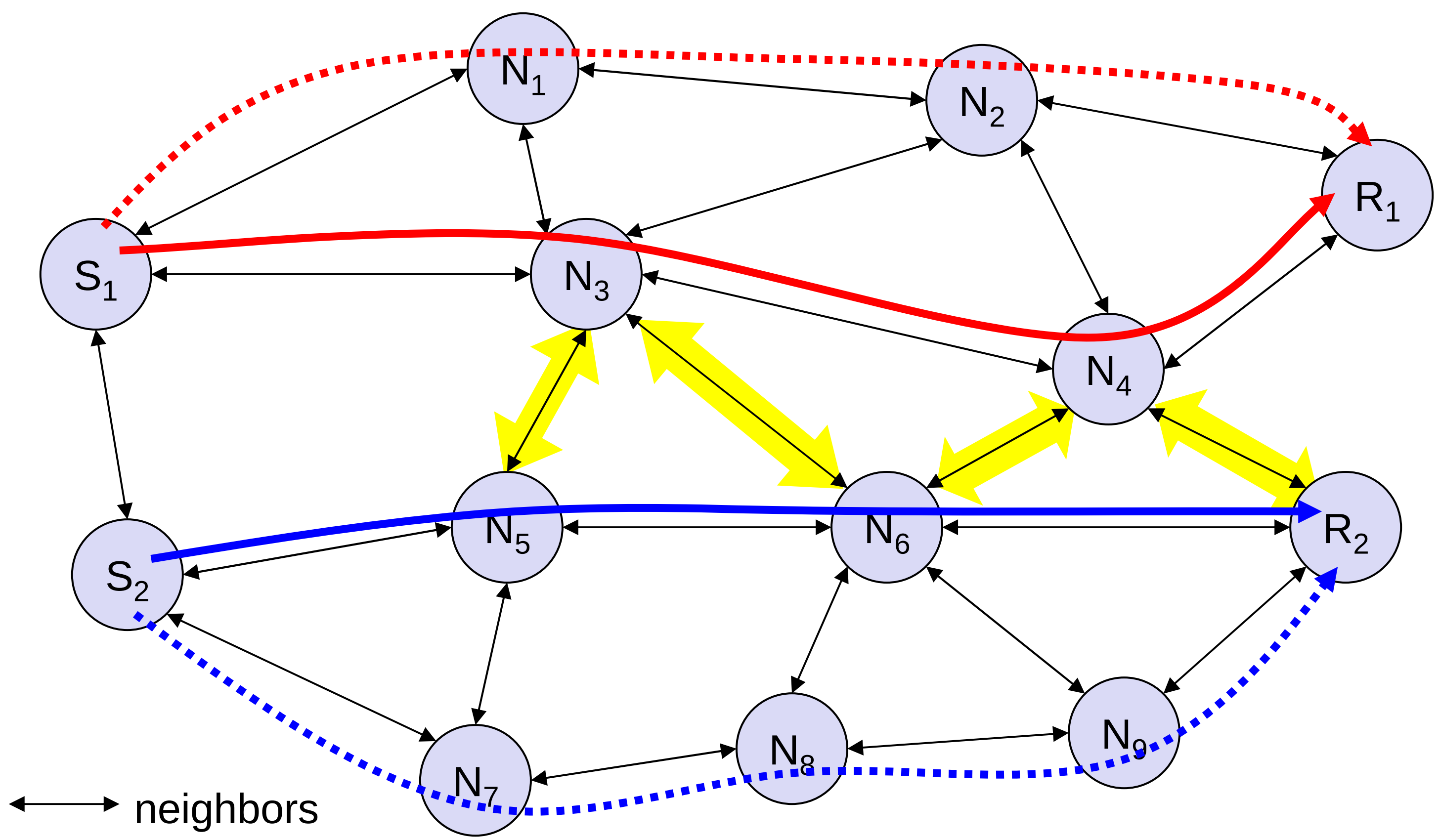
Dynamic Source Routing III

Maintaining paths

- after sending a packet
  - wait for a layer 2 acknowledgement (if applicable)
  - listen into the medium to detect if other stations forward the packet (if possible)
  - request an explicit acknowledgement
- if a station encounters problems it can inform the sender of a packet or look-up a new path locally

Interference-based routing

Routing based on assumptions about interference between signals



Examples for interference based routing

Least Interference Routing (LIR)

- calculate the cost of a path based on the number of stations that can receive a transmission

Max-Min Residual Capacity Routing (MMRCR)

- calculate the cost of a path based on a probability function of successful transmissions and interference

Least Resistance Routing (LRR)

- calculate the cost of a path based on interference, jamming and other transmissions

LIR is very simple to implement, only information from direct neighbors is necessary

A plethora of ad hoc routing protocols

Flat

- proactive
  - FSLS – Fuzzy Sighted Link State
  - FSR – Fisheye State Routing
  - OLSR – Optimised Link State Routing Protocol
  - TBRPF – Topology Broadcast Based on Reverse Path Forwarding
- reactive
  - **AODV** – Ad hoc On demand Distance Vector
  - DSR – Dynamic Source Routing

Hierarchical

- CGSR – Clusterhead-Gateway Switch Routing
- HSR – Hierarchical State Routing
- LANMAR – Landmark Ad Hoc Routing
- ZRP – Zone Routing Protocol

Geographic position assisted

- DREAM – Distance Routing Effect Algorithm for Mobility
- GeoCast – Geographic Addressing and Routing
- GPSR – Greedy Perimeter Stateless Routing
- LAR – Location-Aided Routing

Further difficulties and research areas

Auto-Configuration

- Assignment of addresses, function, profile, program, …

Service discovery

- Discovery of services and service providers

Multicast

- Transmission to a selected group of receivers

Quality-of-Service

- Maintenance of a certain transmission quality

Power control

- Minimizing interference, energy conservation mechanisms

Security

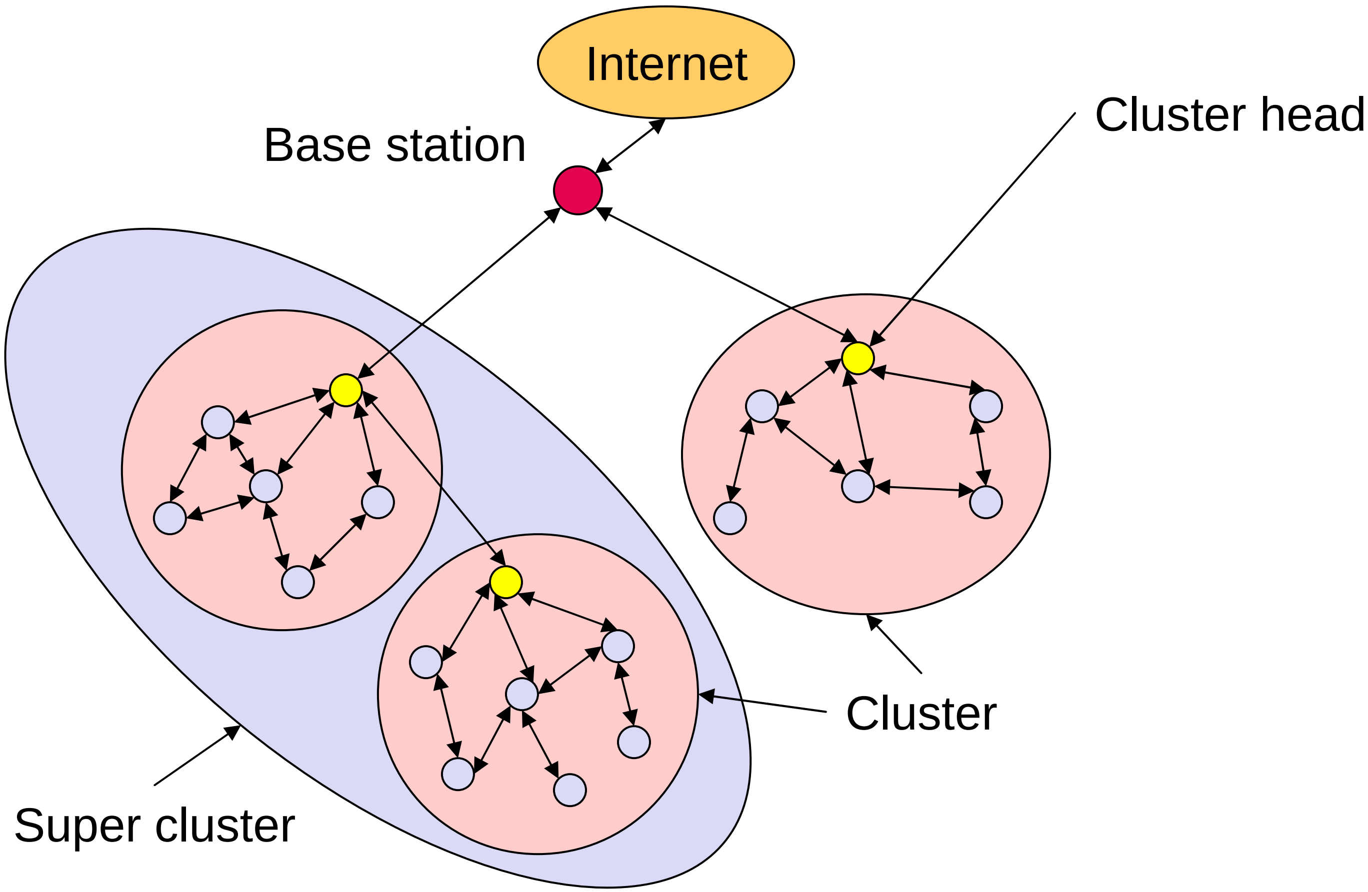
- Data integrity, protection from attacks (e.g. Denial of Service)

Scalability

- 10 nodes? 100 nodes? 1000 nodes? 10000 nodes?

Integration with fixed networks

Clustering of ad-hoc networks



The next step: Wireless Sensor Networks (WSN)

Example:
www.scatterweb.net

Commonalities with MANETs

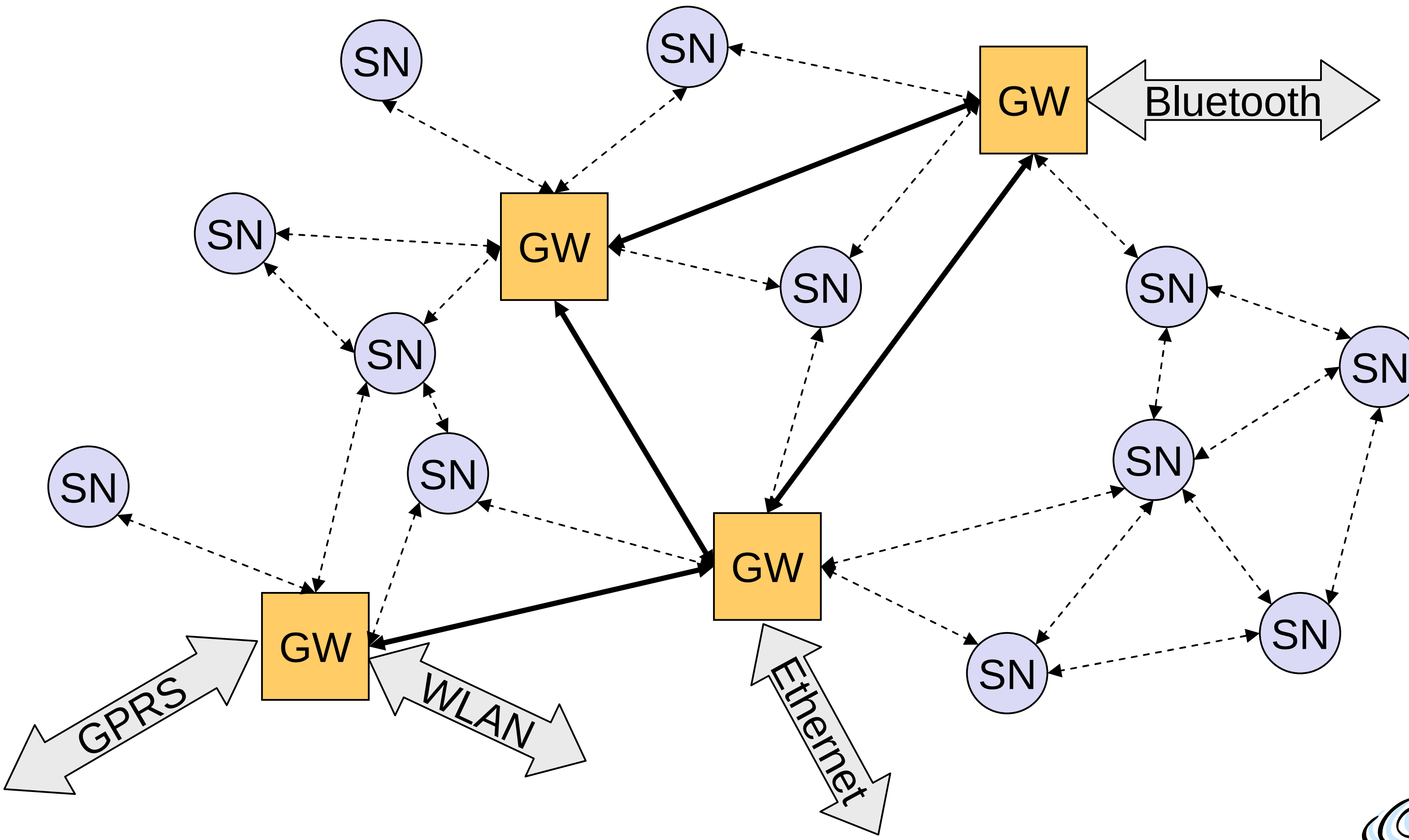
- Self-organization, multi-hop
- Typically wireless, should be energy efficient

Differences to MANETs

- *Applications:* MANET more powerful, more general
  ↔ WSN more specific
- *Devices:* MANET more powerful, higher data rates, more resources
  ↔ WSN rather limited, embedded, interacting with environment
- *Scale:* MANET rather small (some dozen devices)
  ↔ WSN can be large (thousands)
- *Basic paradigms:* MANET individual node important, ID centric
  ↔ WSN network important, individual node may be dispensable, data centric
- Mobility patterns, Quality-of Service, Energy, **Cost per node** …

A typical WSN

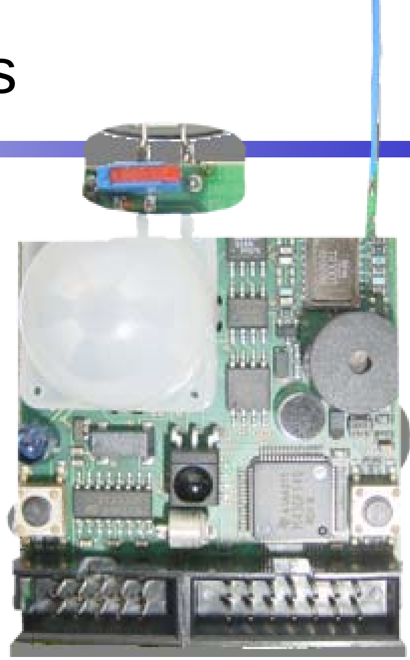
Integration of Sensor Nodes (SN) and Gateways (GW)



Example: ScatterWeb Sensor Nodes

Embedded Sensor Board

- Sensors
  - Luminosity, noise detection, gas, vibration, PIR movement detection, pressure…
- Microphone/speaker, camera, display, IR sender/receiver, precise timing
- Communication using 868 MHz radio transceiver
  - Range up to 2 km LOS, 500 m indoor
- Software
  - Simple programming (C interface)
  - Optional: operating systems TinyOS, Contiki …
  - Optional: TCP/IP, web server …
  - Routing, management, flashing …



Embedded Sensor Board

Modular Sensor Node

Further information:
www.scatterweb.net

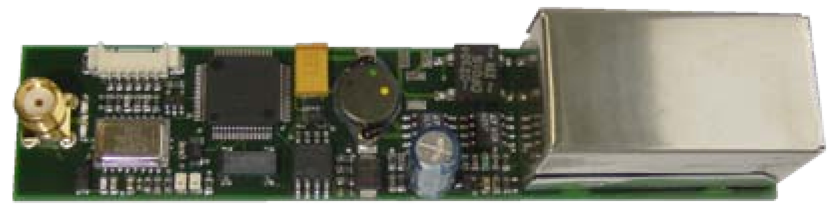
Example: ScatterWeb Gateways

USB

- Simple Integration PC world
- Enables over-the-air programming either point-to-point or broadcast including reliable multi-hop

Ethernet

- RJ45 Adapter for 10/100 Mbit/s
- Power-over-Ethernet (802.3af)
- Standard Internet protocols (IP, TCP, HTTP, HTTPS, ARP, DHCP)
- Integrated Web server providing applets for sensor net control
- Secure access of ScatterWeb from any browser on the net



All-in-one

- WLAN, Ethernet, Bluetooth, GPS, GSM/GPRS, USB, serial…

Sensor Networks: Challenges and Research Areas

Long-lived, autonomous networks

- Use environmental energy sources
- Embed and forget
- Self-healing

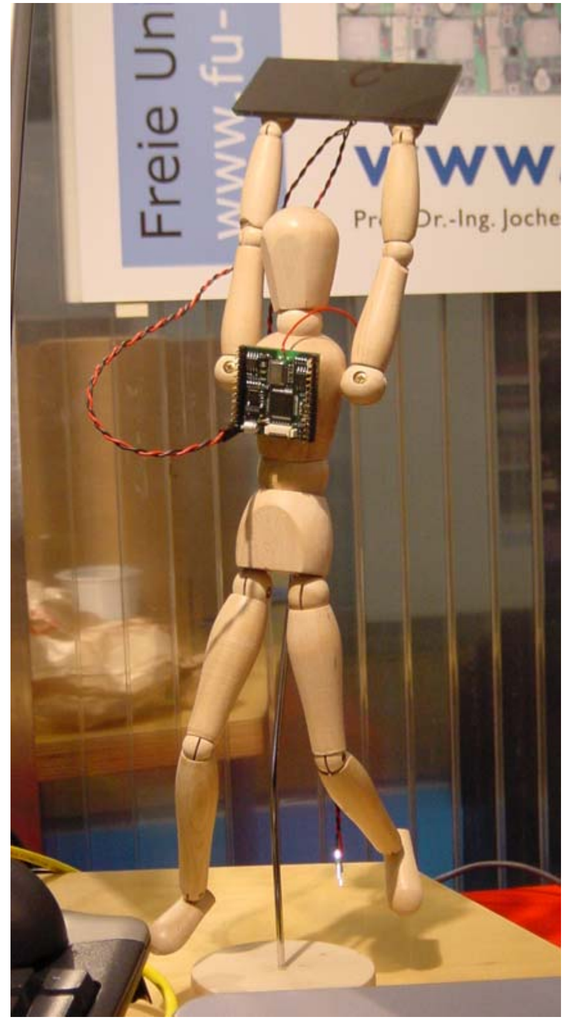
Self-configuring networks

- Routing
- Data aggregation
- Localization

Managing wireless sensor networks

- Tools for access and programming
- Update distribution

Scalability, Quality of Service…

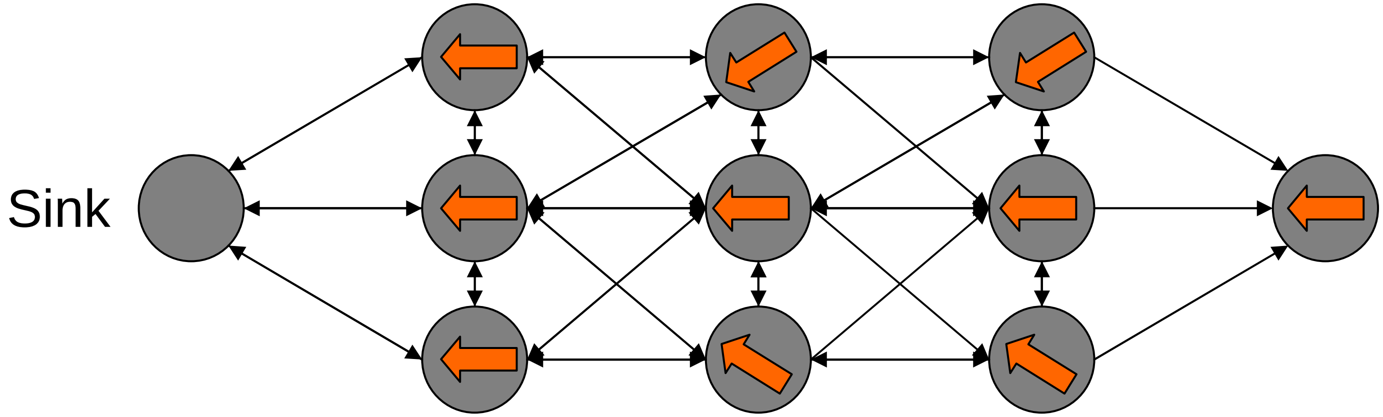


Routing in WSNs is different

No IP addressing, but simple, locally valid IDs

Example: directed diffusion

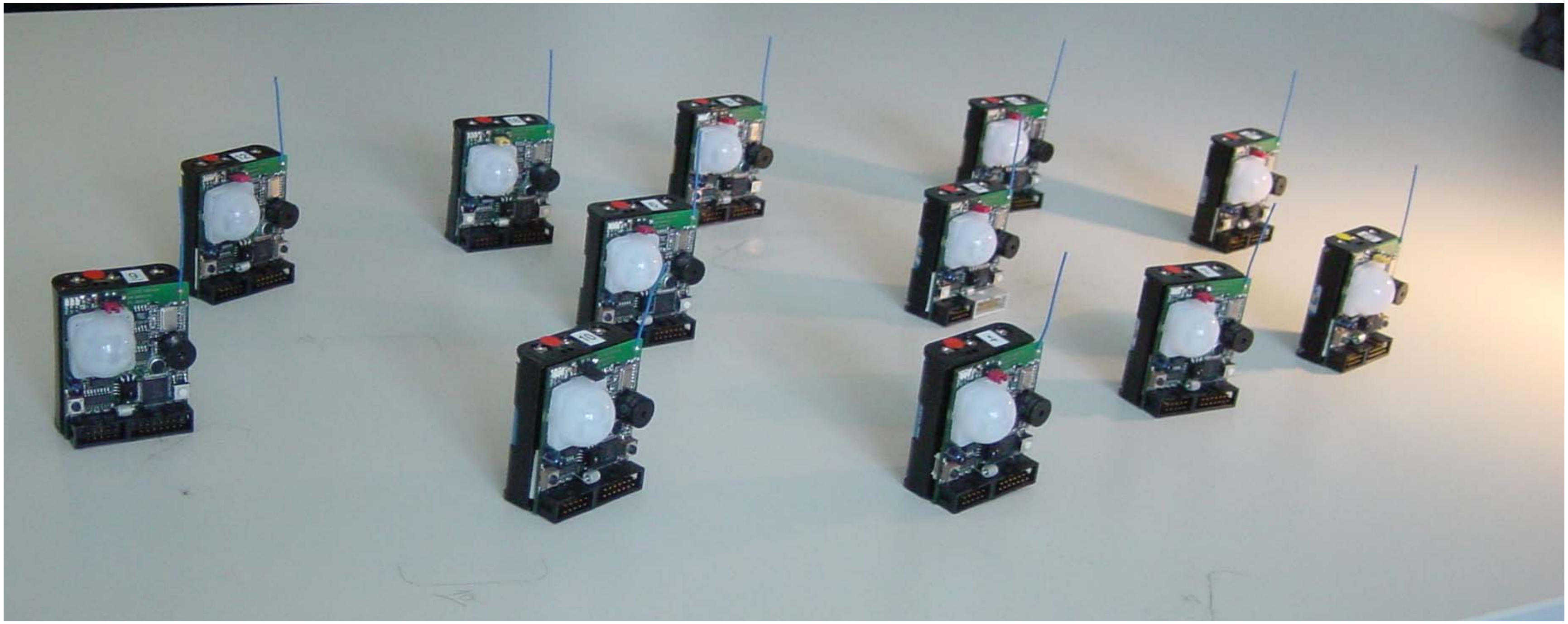
- Interest Messages
  - Interest in sensor data: Attribute/Value pair
  - Gradient: remember direction of interested node
- Data Messages
  - Send back data using gradients
  - Hop count guarantees shortest path



Energy-aware routing

Only sensors with sufficient energy forward data for other nodes

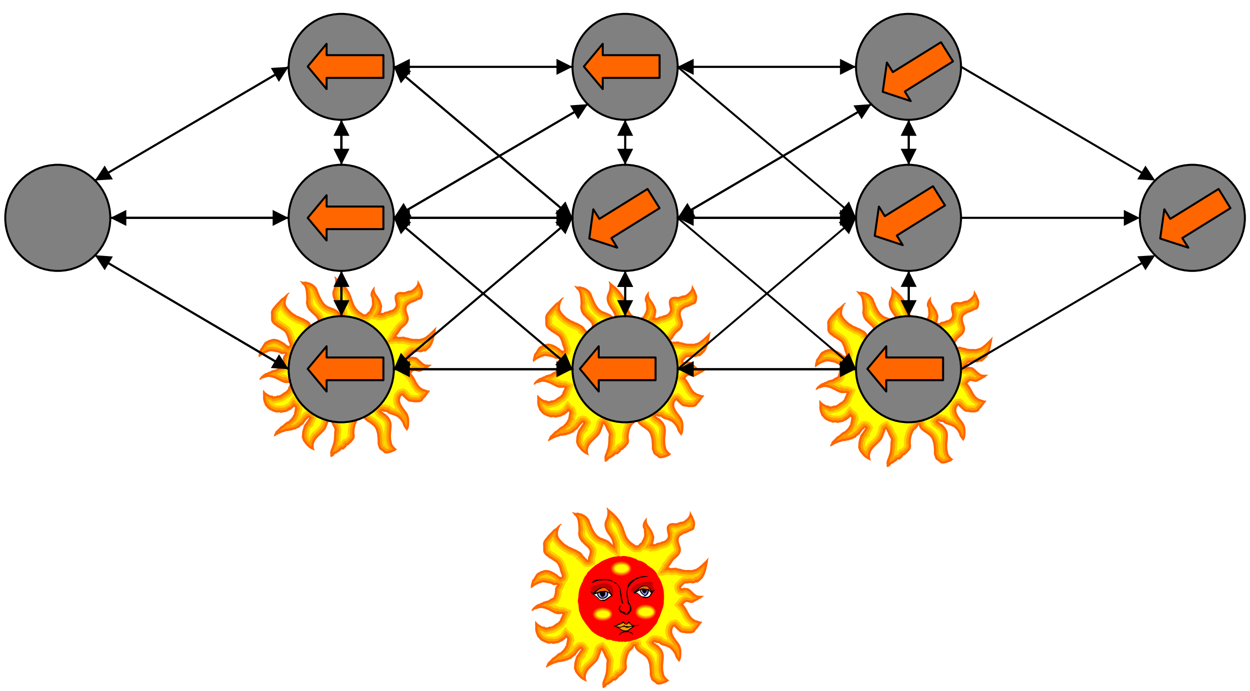
Example: Routing via nodes with enough solar power is considered “for free”



Solar-aware routing

Solar-powered node

- Send status updates to neighbors
  - Either proactive or when sniffing ongoing traffic
- Have neighbor nodes rero[illegible]e traffic



Example: Software for controlling a sensor network

Today's WSNs

First generation of WSNs is available

- Diverse sensor nodes, several gateways
- Even with special sensors: cameras, body temperature…
- Basic software
  - Routing, energy conservation, management

Several prototypes for different applications

- Environmental monitoring, industrial automation, wildlife monitoring …

Many see new possibilities for monitoring, surveillance, protection

- Sensor networks as a cheap and flexible new means for surveillance
- Monitoring and protection of goods
  - Chemicals, food, vehicles, machines, containers, …
- Large application area besides military
  - Law enforcement, disaster recovery, industry, private homes, …