1.Energy Efficient Routing

- In most sensor network scenarios, these devices acquire data from the environment, and send it to other nodes for further processing and analysis.
- When such destinations are not within the radio range of the source node, intermediate sensor nodes are used as relays.
- Routing protocols for wireless sensor networks are used to transmit messages from sources to destinations. They can be classified as
  - Unicast
  - Broadcast
  - Multicast
- **Unicast routing,** is used to send a message generated by a sensor node to a single destination or sink.
- **Broadcasting**, is used to send a message from a sensor node to every other node in the network.
- **Multicasting**, is used to deliver messages from a single source to a set of destinations. Multicasting protocols try to minimize the consumption of network resources. For instance, sending one copy of the data to each destination using unicast is not considered as multicast routing.

1.1Energy-Efficient unicast

- Energy-efficient unicast routing appears to be a simple problem: take the network graph, assign to each link a cost value that reflects the energy consumption across this link, and pick any algorithm that computes least-cost paths in a graph.
- The Dijkstra's shortest path algorithm is used to obtain routes with minimal total transmission power. In fact, there are various aspects how energy or power efficiency can be conceived of in a routing context. Figure 3.20 shows an example scenario for a communication between nodes A and H including link energy costs and available battery capacity per node.

Minimize energy per packet

- The most straightforward formulation is to look at the total energy required to transport a packet over a multi-hop path from source to destination. The goal is then to minimize, for each packet, this total amount of energy by selecting a good route.
- Minimizing the hop count will typically not achieve this goal as routes with few hops might include hops with large transmission power to cover large distances – but be aware of distance-independent, constant offsets in the energy-consumption model. Nonetheless, this cost metric can be easily included in standard routing algorithms. It can lead to widely differing energy consumption on different nodes.

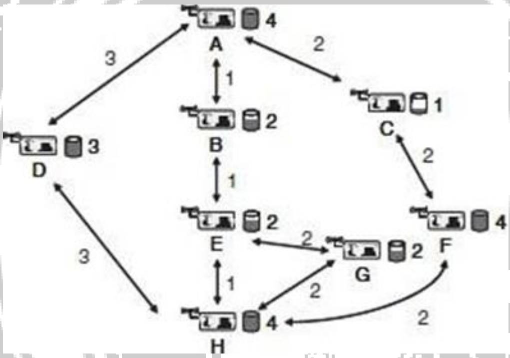

Figure 3.20 various example routes for communication between nodes A and H, showing energy costs per packet for each link and available battery capacity for each node

- In the example of Figure 3.20, the minimum energy route is A-B-E-H, requiring 3 units of energy. The minimum hop count route would be A-D- H, requiring 6 units of energy.

Maximize the Network Life Time

- Energy-efficient transmission is at best a means to an end and the actual end should be the optimization goal: the network should be able to fulfill its duty for as long as possible. Network lifetime which is defined as the time until the first sensor's energy runs out is an important performance metric in WSNs

Routing considering available battery energy

- Maximizing the network lifetime is clearly a useful goal, As the finite energy supply in nodes' batteries is the limiting factor to network lifetime, it stands to reason to use information about battery status in routing decisions. Some of the possibilities are:

  - **Maximum Total Available Battery Capacity** : Choose that route where the sum of the available battery capacity is maximized, without taking needless detours. Looking only at the intermediate nodes in Figure 3.20, route A-B-E-G-H has a total available capacity of 6 units, but that is only because of the extra node G that is not really needed – such detours can of course arbitrarily increase this metric. Hence, A-B-E-G-H should be discarded as it contains A-B-E- H as a proper subset.

  - **Minimum Battery Cost Routing (MBCR)** : Instead of looking directly at the sum of available battery capacities along a given path, MBCR instead looks at the "reluctance" of a node to route traffic. This reluctance increases as its battery is drained; for example, reluctance or routing cost can be measured as the reciprocal of the battery capacity.

    - Then, the cost of a path is the sum of this reciprocals and the rule is to pick that path with the smallest cost. Since the reciprocal function assigns high costs to nodes with low battery capacity, this will automatically shift traffic away from routes with nodes about to run out of energy.

    - In the example of Figure 3.20, route A-C-F- H is assigned a cost of 1/1 + 1/4 = 1.25, but route A-D- H only has cost 1/3. Consequently, this route is chosen, protecting node C from needless effort.

  - **Min–Max Battery Cost Routing (MMBCR)** : This scheme follows a similar intention, to protect nodes with low energy battery resources. Instead of using the sum of reciprocal battery levels, simply the largest reciprocal level of all nodes along a path is used as the cost for this path. Then, again the path with the smallest cost is used.

- In this sense, the optimal path is chosen by minimizing over a maximum. The same effect is achieved by using the smallest battery level along a path and then maximizing over these path values. This is then a maximum/minimum formulation of the problem. In the example of Figure 3.20, route A-D- H will be selected.

Conditional Max–Min Battery Capacity Routing (CMMBCR) : This scheme work as conditionalize upon the actual battery power levels available. If there are routes along which all nodes have a battery level exceeding a given threshold, then select the route that requires the lowest energy per bit. If there is no such route, then pick that route which maximizes the minimum battery level.

- **Minimize variance in power levels** : To ensure a long network lifetime, one strategy is to use up all the batteries uniformly to avoid some nodes prematurely running out of energy and disrupting the network. Hence, routes should be chosen such that the variance in battery levels between different routes is reduced.