Redes de Sensores Sem Fio

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Outline

- Brief overview of wireless sensor networks
- Wireless networking considering energy
- Application design of networked sensor systems considering energy
- Conclusions

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Wireless Sensor Network

- Goal:
  - To get sensor devices to collaborate and monitor specific phenomena
- Challenge:
  - To aggregate sensor nodes into computational infrastructures that are able to produce globally meaningful information from raw local data obtained by individual sensor nodes

Basic Operation of Wireless Sensor Networks

Wireless Sensor Network

- Wireless Sensor Network (WSN) is an emerging technology that promises unprecedented ability to monitor, instrument, and eventually control the physical world

- In general, consists of a large number of inexpensive wireless devices (sensor nodes) densely distributed over the region of interest

Wireless Sensor Network

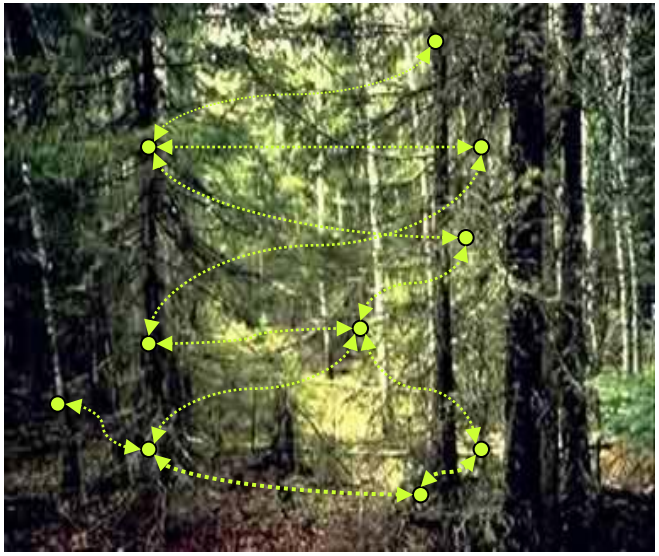
- WSN has the potential to be used in a variety of applications

- Examples
  - Monitor a forest to avoid fire
  - Monitor a river to detect pollution
  - Introduce a sensor network inside of a human body to drop some medicine when necessary

Potential WSN Applications
Environmental Monitoring

- Sensor nodes collecting different kinds of information
  - Flora and fauna (plants and animals)
  - Environment: fire risk, conditions at different heights

Potential WSN Applications
Environmental Monitoring



Areas of difficult access

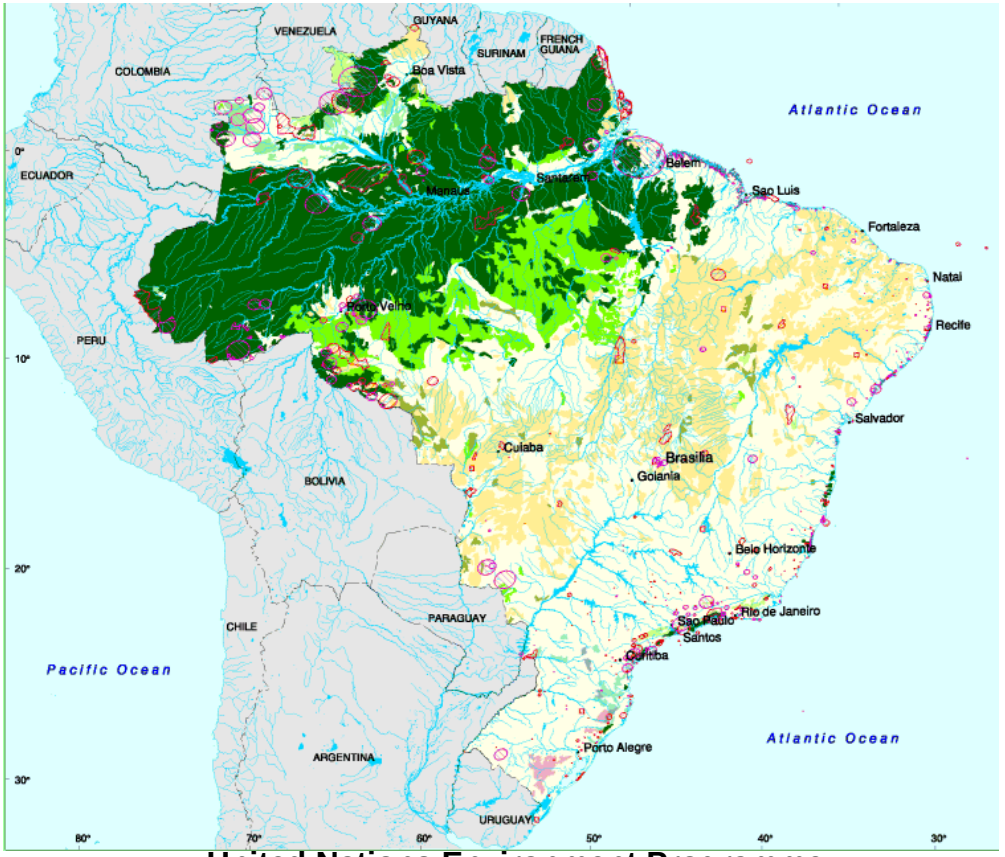
Potential WSN Applications
Environmental Monitoring

- Water quality, volume, throughput, etc
- Fire detection and prevention

Potential WSN Applications
Environmental Monitoring

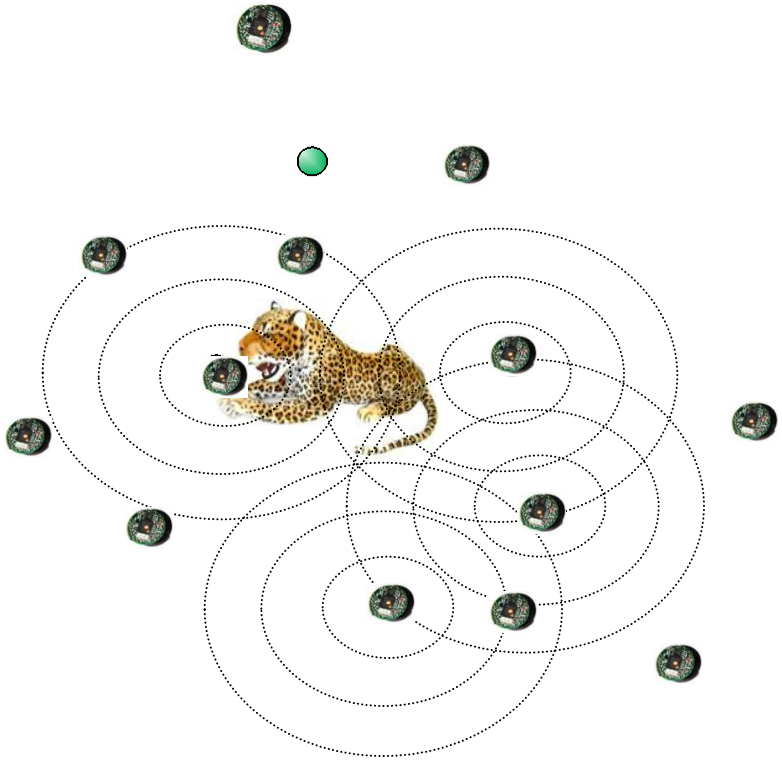
Brazilian Case:

- Has 10–20% of known species
- Is one of top 15 countries with a high degree of diversity
- Mammals, freshwater fish, and flowering plants of the world (1st place)
- Amphibians (2nd place)
- Birds (3rd place)
- Reptiles (5th place)
- Is one of top 5 countries with a high number of endemic species (present only in Brazil)

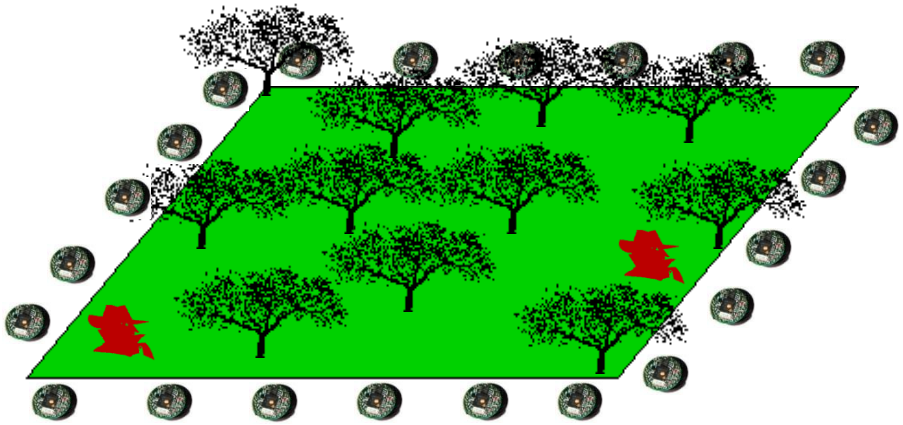


United Nations Environment Programme
World Conservation Monitoring Centre
http://www.unep-wcmc.org/

Potential WSN Applications
Environment/Security



Wireless Sensor Network
for helping biologists to better
understand the environment



Wireless Sensor Network
for monitoring intruders in a
given perimeter

Potential WSN Applications
Disaster Recovery

NASA and Sensors

http://sensorwebs.jpl.nasa.gov/

Jet Propulsion Laboratory
California Institute of Technology

VOLCANO SENSORWEB

Sensorweb

A networked set of instruments in which information from one or more sensors is automatically used to reconfigure the remainder of the sensors

Specifically, in our application, we use low resolution, high coverage sensors to trigger observations by high resolution instruments. Note that there are many other rationales to network sensors into a sensorweb. For example automated response might enable observation using complementary instruments such as imaging radar, infra-red, visible, etc. Or automated response might be used to apply more assets to increase the frequency of observation to improve the temporal resolution of available data.

Our sensorweb project is being used to monitor the Earth's 50 most active volcanos. We have also run sensorweb experiments to monitor flooding, wildfires, and cryospheric events (snowfall and melt, lake freezing and thawing, sea ice formation and breakup.)

Traditional Networks vs. WSNs

Traditional network	WSN
Are designed to accommodate a diversity of applications	Are typically designed for a specific application
Different network elements might execute different applications	Nodes often execute a common application in a cooperative way, i.e., there is clearly a common goal in the overall network
Network elements are often static and are deployed according to a given design, not a physical location	Sensor nodes are often static and are deployed according to a physical location, not a given design

Traditional Networks vs. WSNs

Traditional network	WSN
Maintenance of components or resources by technicians is a normal fact	Often, there is no physical maintenance of nodes
Network tends to follow a well-established planning of resources available	It might be difficult to define a priori how resources will be spent in the network
Initial configuration reflects a design specification and is followed	Initial configuration can be quite different from what was supposed to be in case of throwing the nodes in an ocean, forest and other remote regions

Traditional Networks vs. WSNs

Traditional network	WSN
Faults should not be a common fact	Faults are a common fact
Software developed for a network element may have restrictions such as performance and response time	Software developed for a sensor node must consider its hardware limitations
It is not common to have network elements with physical restrictions	Main physical restriction is energy available since batteries are often not recharged and all activities performed by the node must take into account the energy consumption

Wireless Sensor Network

- Sensor nodes are battery driven and hence operate on an energy budget
- Sensor nodes must have a lifetime on the order of months to years
- Battery replacement is not an option for networks with thousands of physically embedded nodes

Energy consumption is the most important factor that determines the network lifetime

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How Are Protocols Dealing with Energy Restriction?

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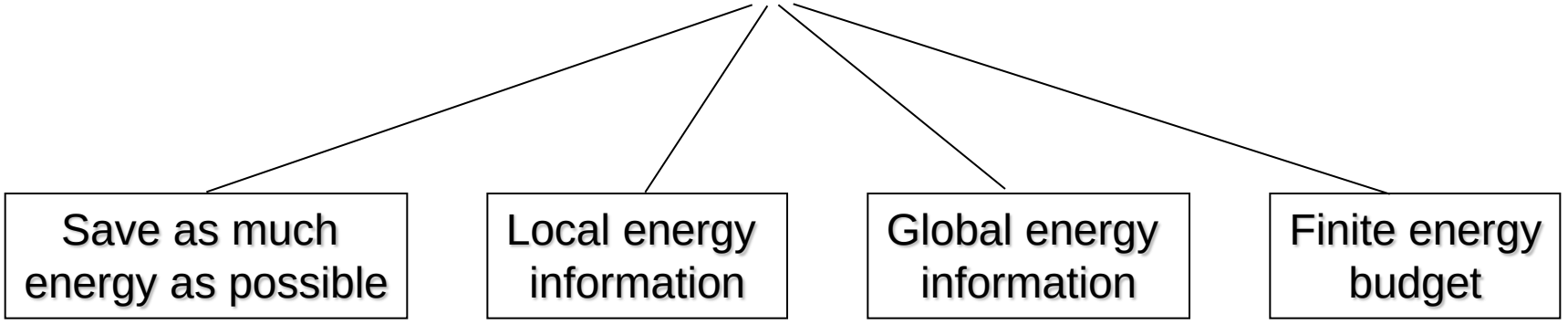
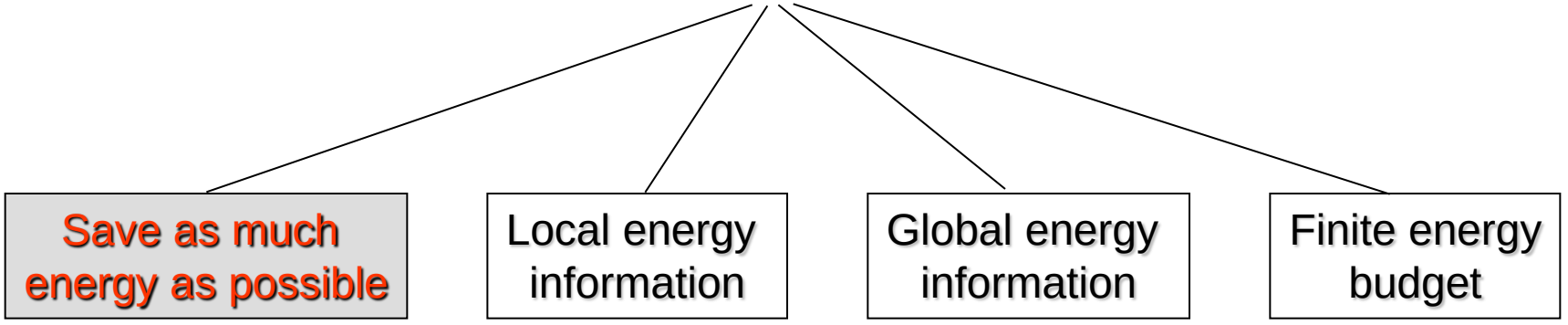


Most of the protocols use more than one of these techniques

How Are Protocols Dealing with Energy Restriction?

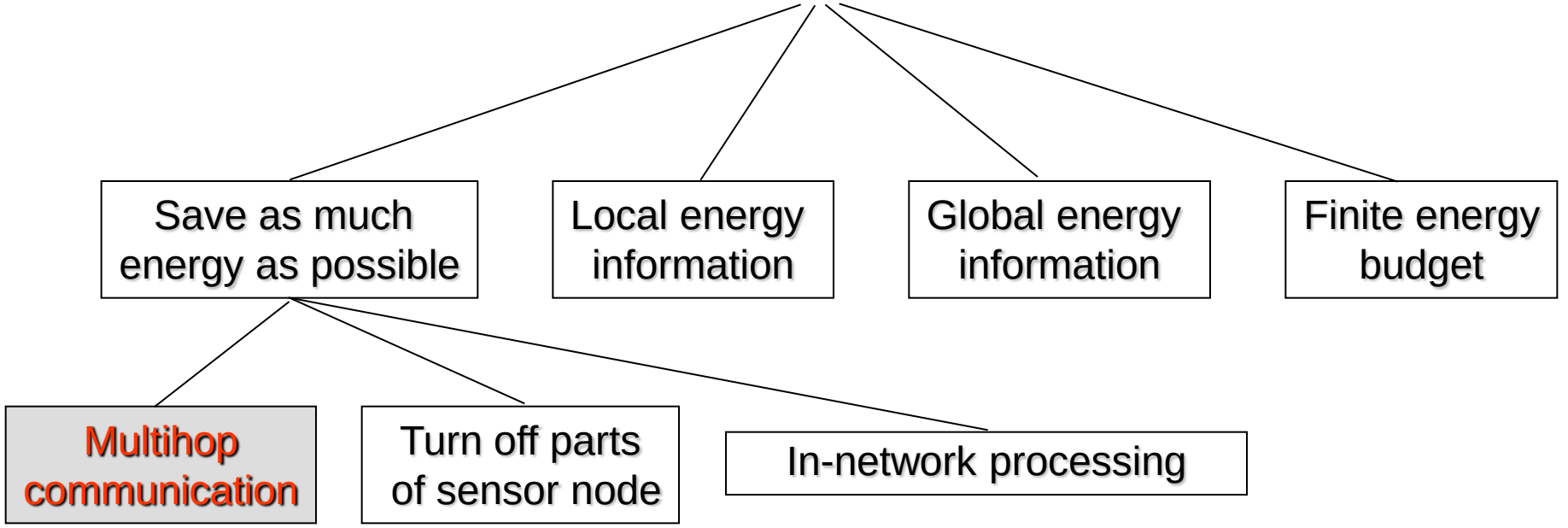


Protocols try to reduce the energy consumption in order to be suitable for this new kind of network

Save as Much Energy as Possible

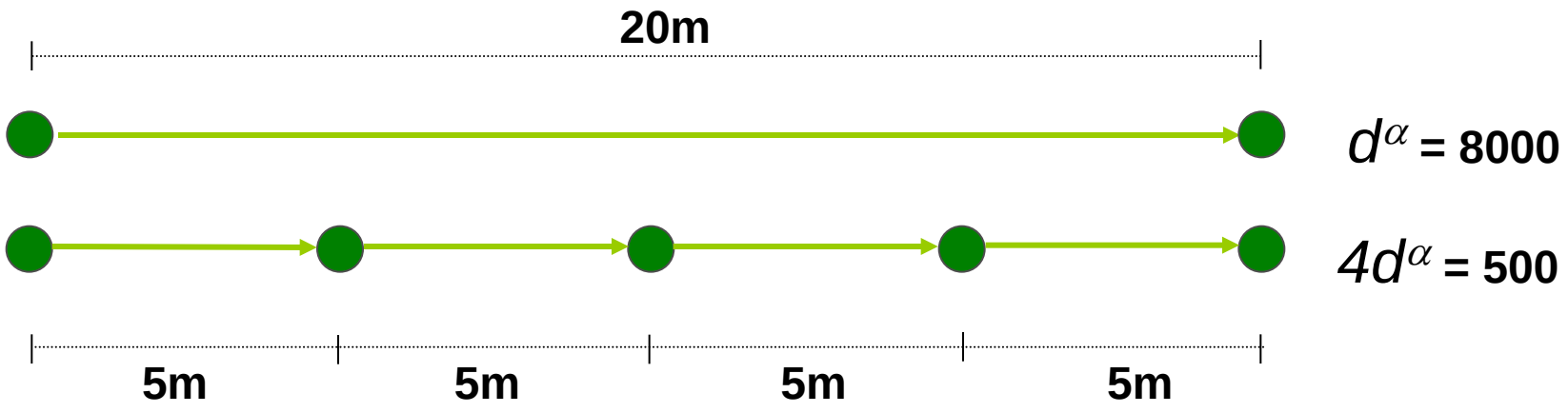
- Some techniques are used to save as much energy as possible
  - Multihop communication
  - Turn off parts of sensor node
  - In-network processing

How Are Protocols Dealing with Energy Restriction?



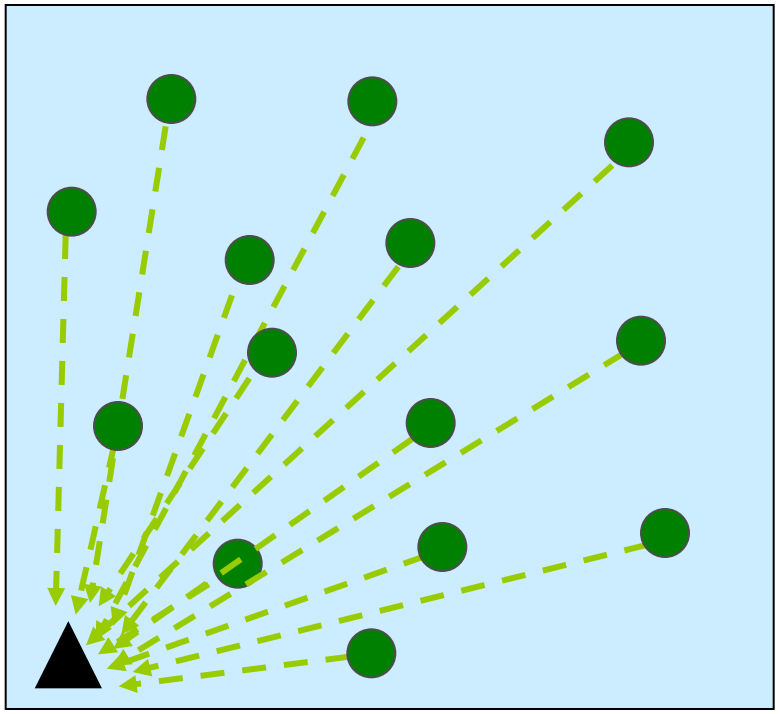
Wireless Communication

- Long distance wireless communication is expensive in terms of energy consumption
- Minimum output power required to transmit a signal is d^{α}, where d is the transmission distance and α the path loss exponent ($2 \leq \alpha < 4$)
- Example ($\alpha = 3$):



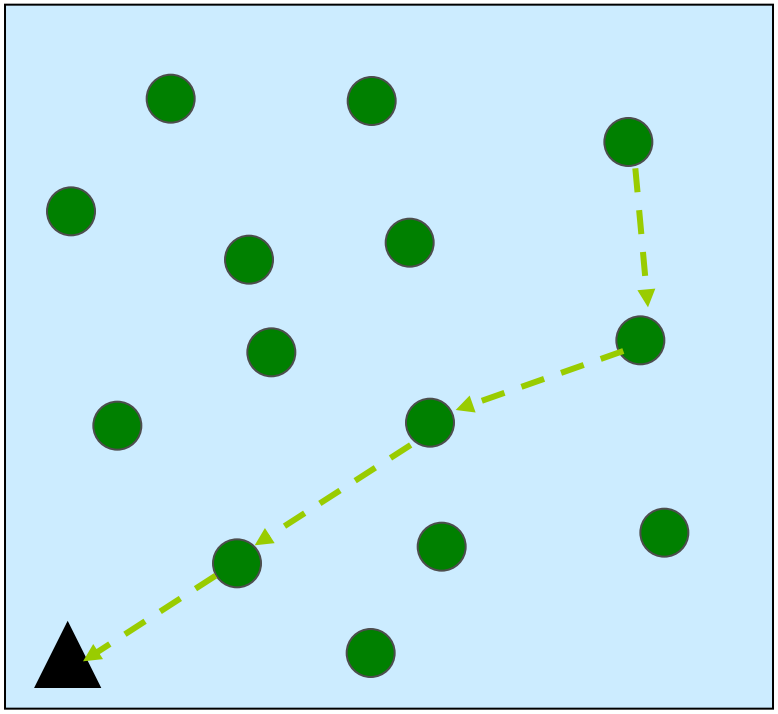
Single-hop Communication

- All nodes communicate directly with the monitoring station
- Communication load would quickly drain the network power resources



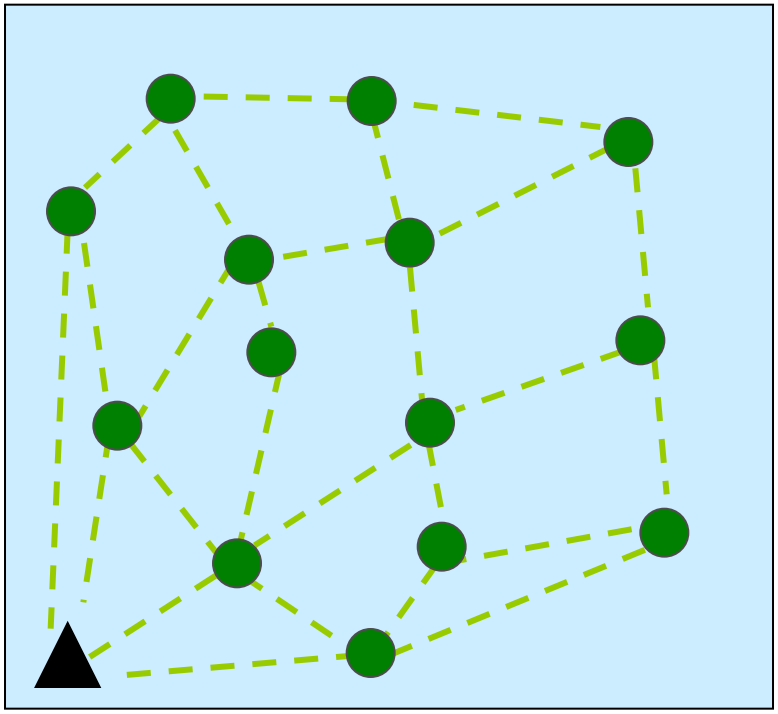
Multihop Communication

- Nodes use neighboring node to send information to the monitoring node



Multihop Communication

- Nodes form an ad-hoc network



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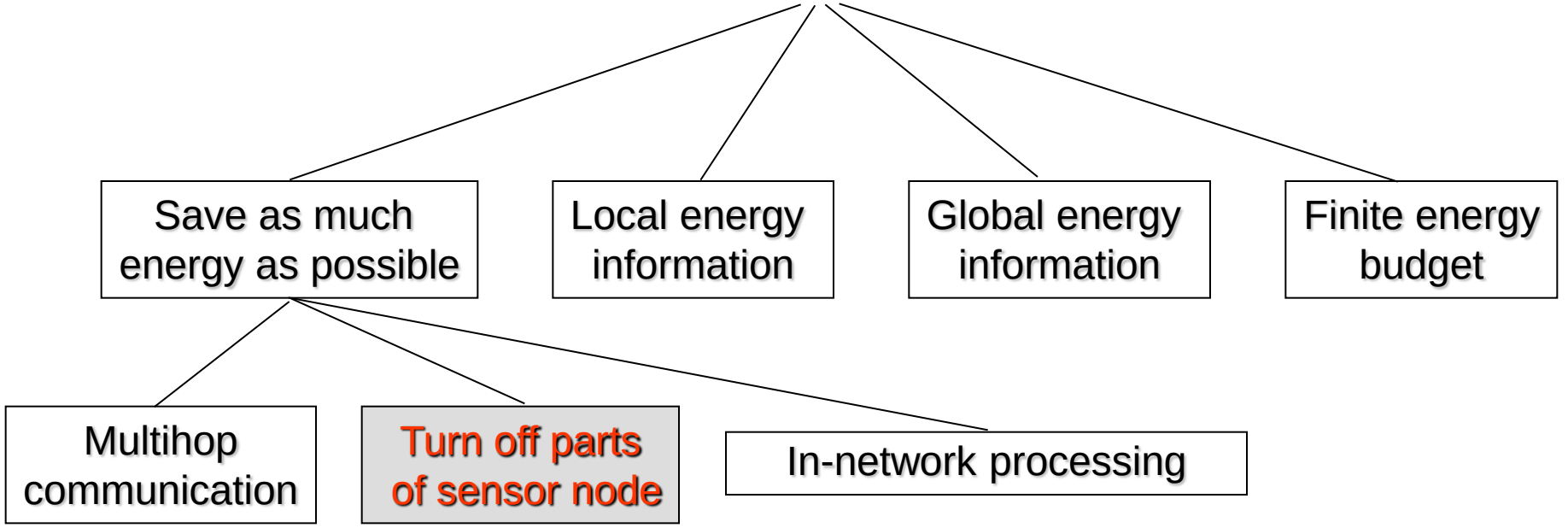
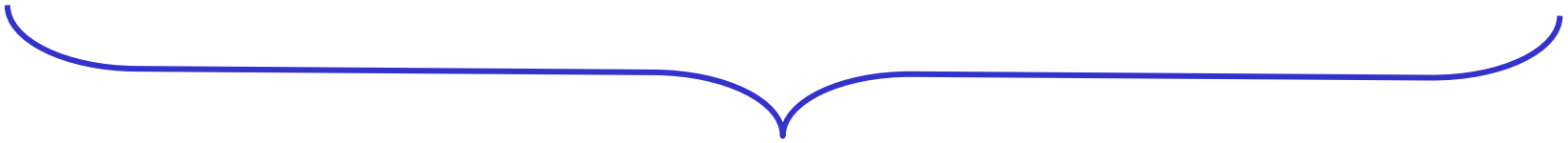


Turn off Parts of Sensor Node

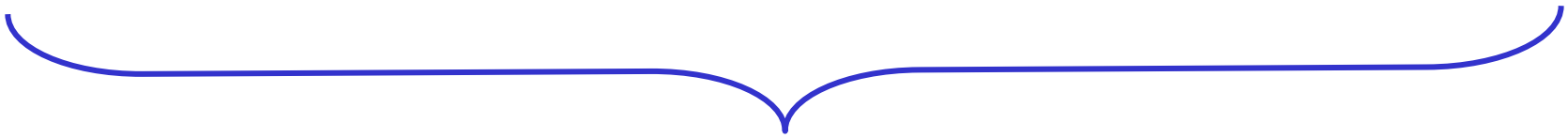
- The best way to save energy is to make unused components inactive whenever possible
- Nodes or parts of nodes that are not in use should be turned off to save energy
- During periods of low activity, the network may enter a dormant state in which nodes go to sleep to save energy



MAC Protocols

Turn off Parts of Sensor Node

- SMAC (Sensor-MAC)
  - In many sensor network applications, nodes are in idle for a long time if no sensing event happens
  - If no sensing event happens, nodes listen to receive possible traffic that will not be sent



Idle listening

  - Idle listening is the major sources of energy consumption
  - It is possible to save energy if nodes periodically sleep

Turn off Parts of Sensor Node: SMAC

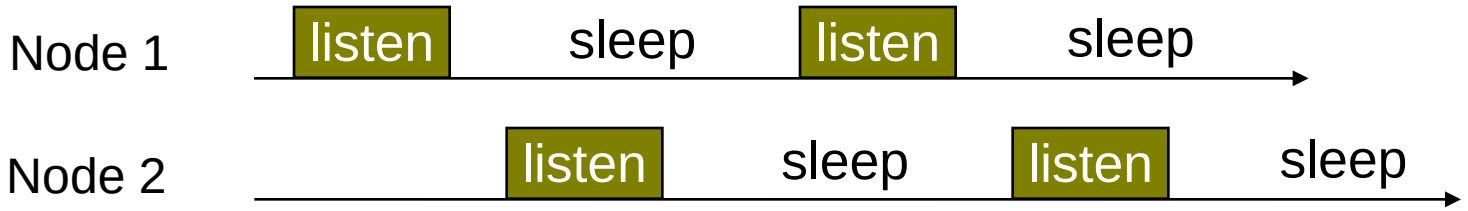
- **Problem**: Idle listening consumes significant energy
- **Solution**: Periodic listen and sleep

- Turn off radio when sleeping
- Reduce duty cycle

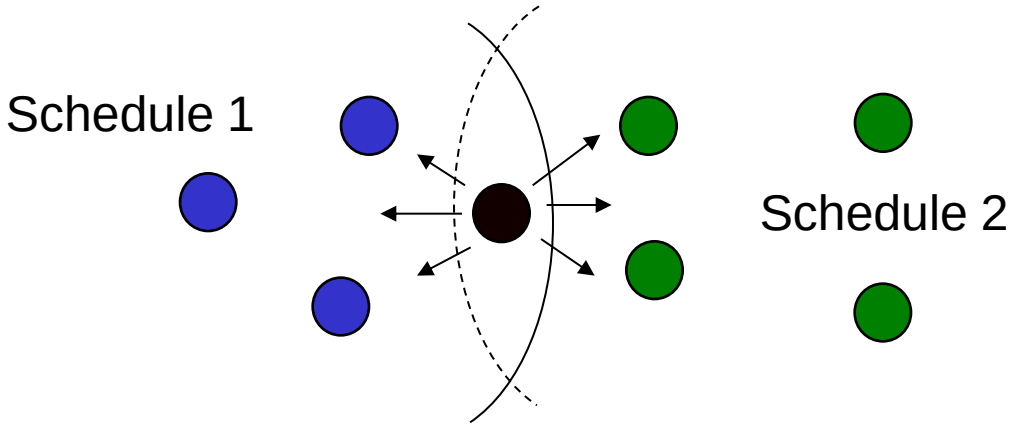
Increase Latency → **Save Energy**

Turn off Parts of Sensor Node: SMAC

- Schedules can differ



- Prefer neighboring nodes have same schedule – easy broadcast & low control overhead



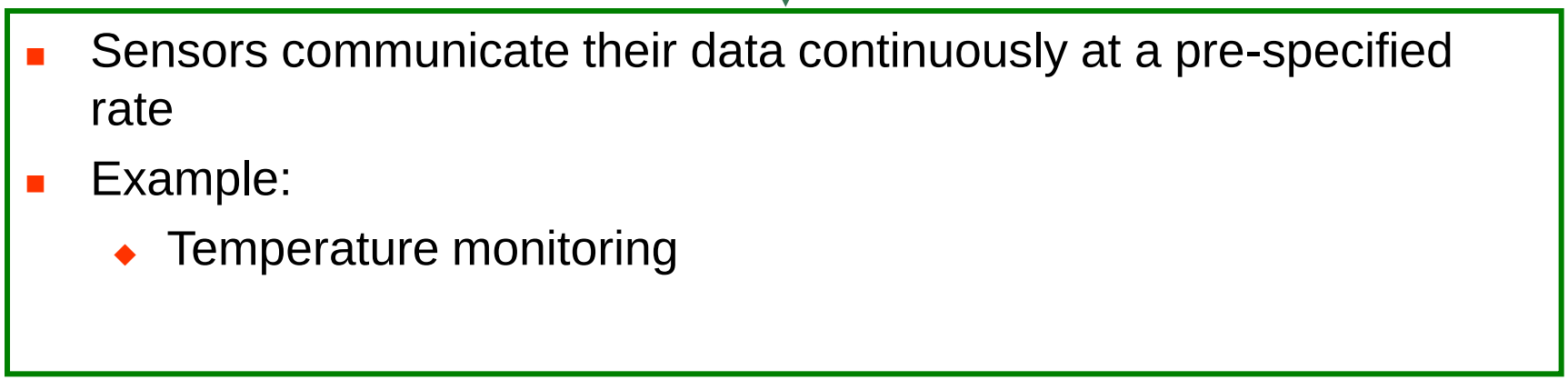
Border nodes: two schedules broadcast twice

Turn off Parts of Sensor Node

- Characteristic of the application can help MAC protocols to turn off parts of sensor node

Turn off Parts of Sensor Node

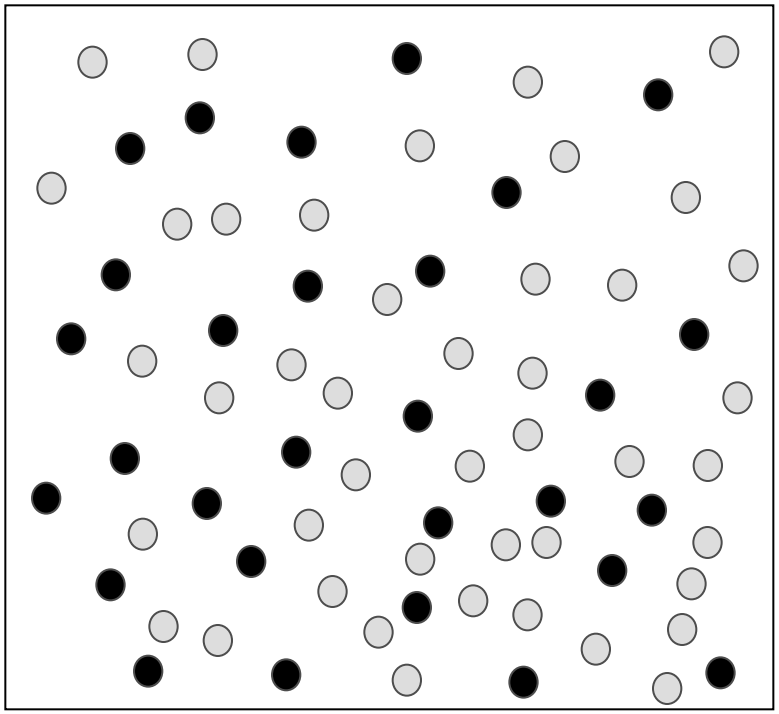
- Data Delivery Models:
  - Continuous
  - Event-driven
  - Demand-driven



Turn off Parts of Sensor Node

- Continuous network
  - Create a round robin schedule

Round 1



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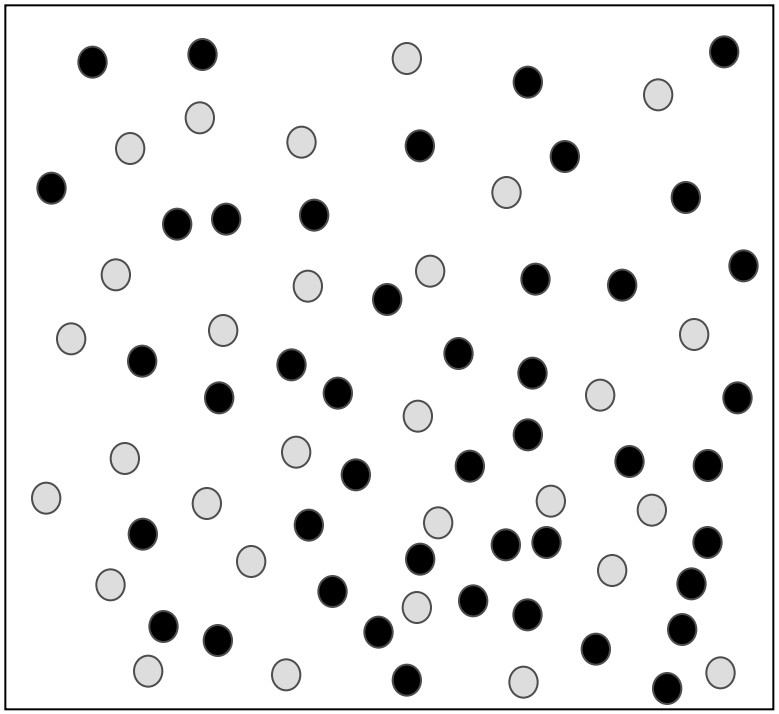
Round 2



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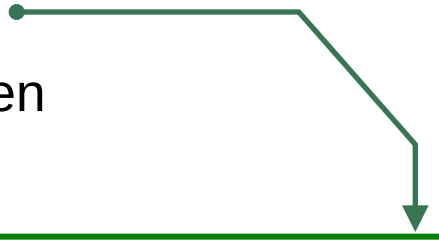
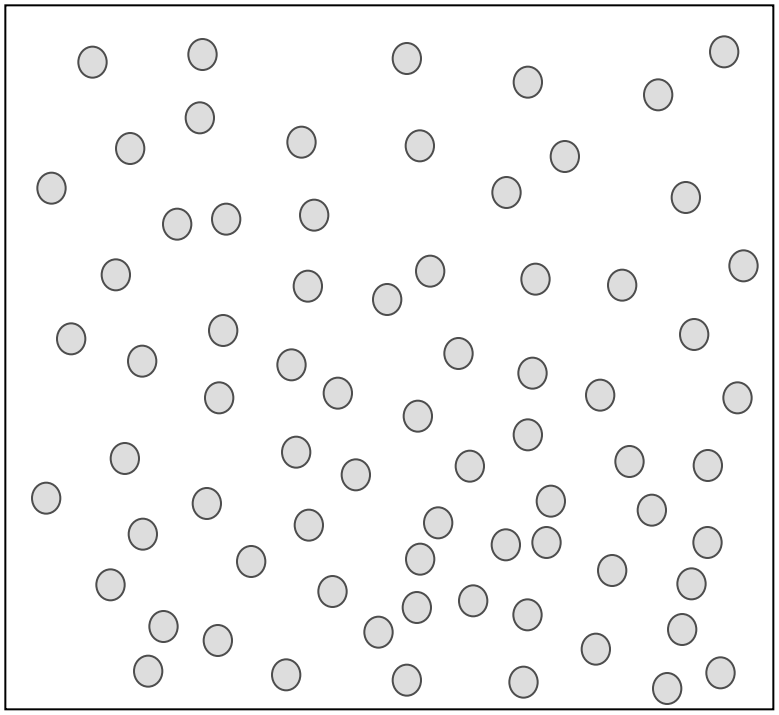


- Sensors report information only if an event of interest occurs
- Example:
  - Sensor network is deployed for forest-fire detection

Turn off Parts of Sensor Node

- Event-driven network
  - Only nodes near the event are turned on



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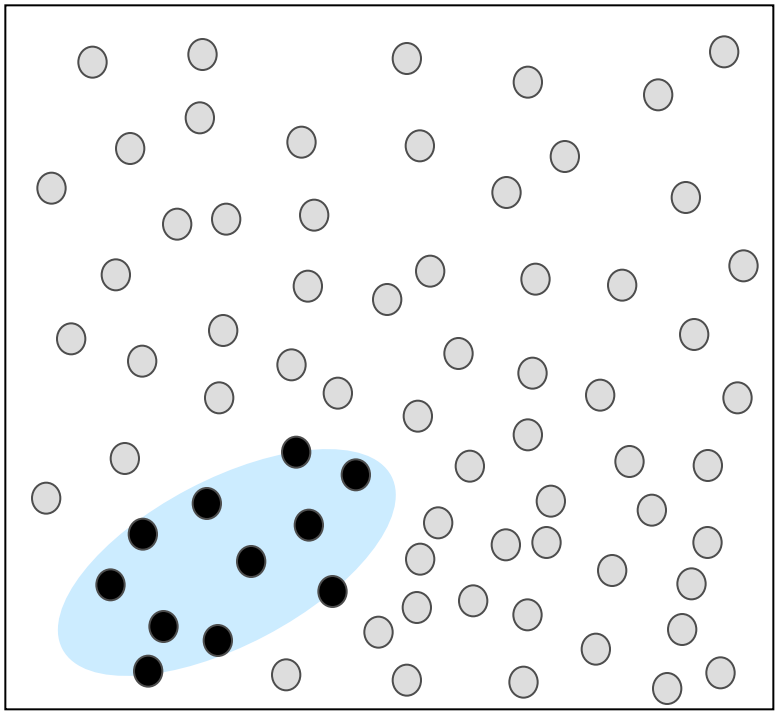

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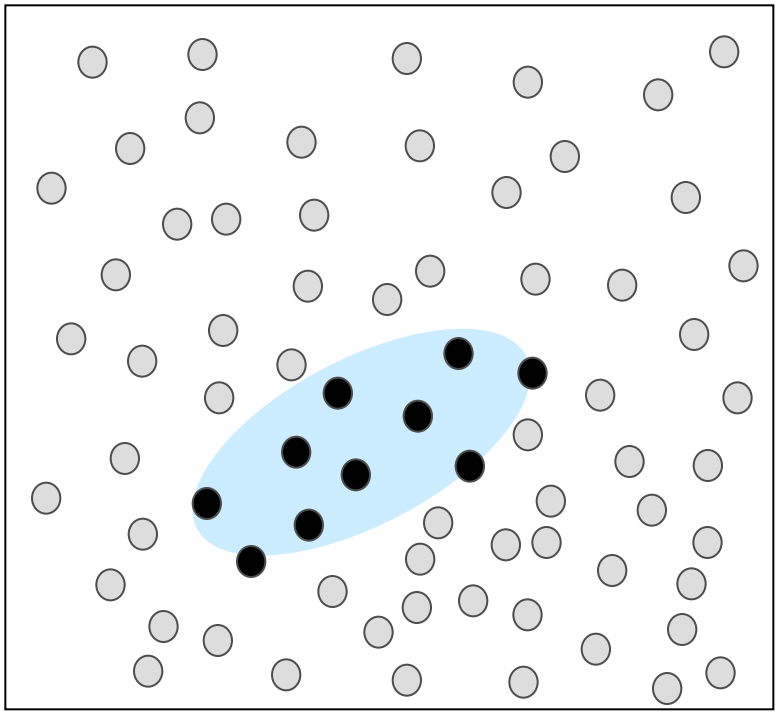

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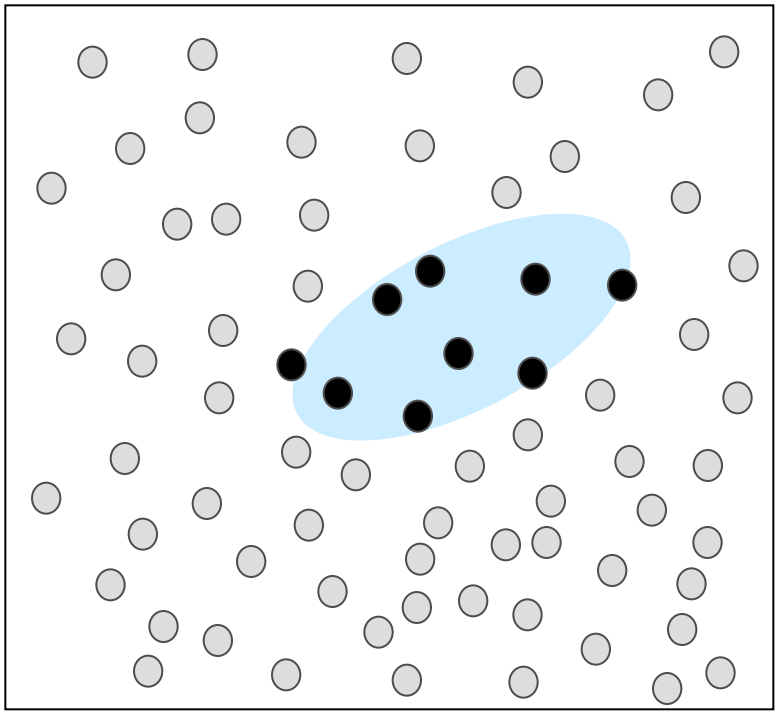

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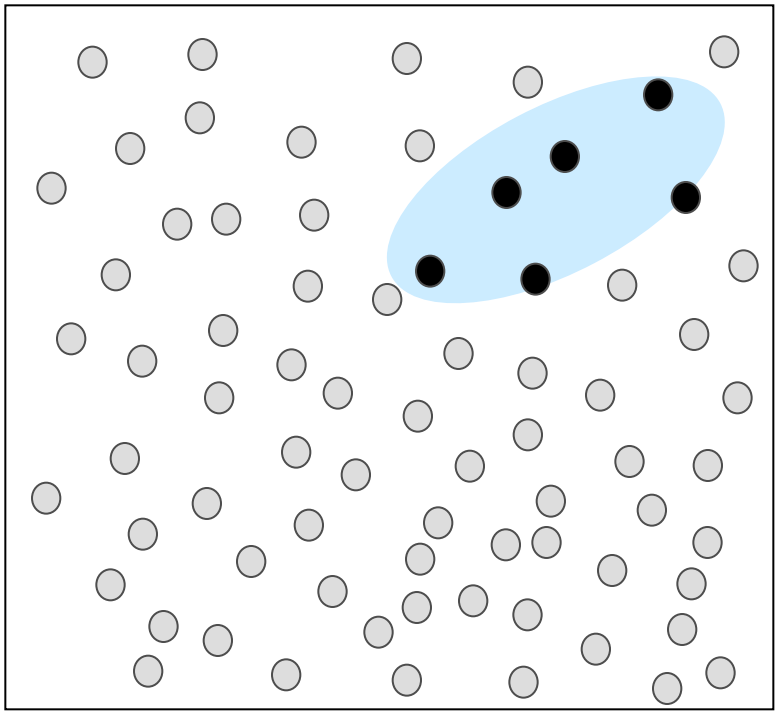


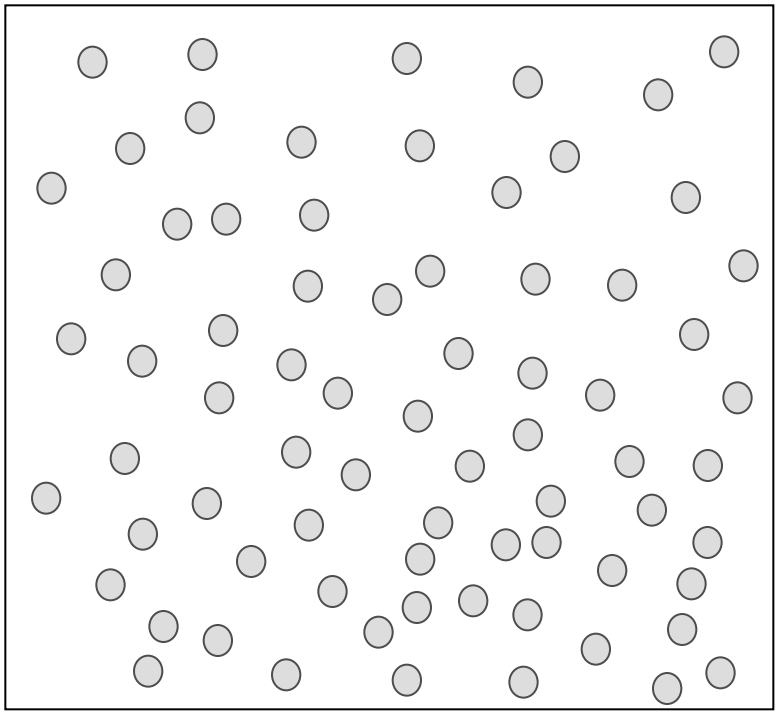
Turn off Parts of Sensor Node

- Data Delivery Models:
  - Continuous
  - Event-driven
  - Demand-driven

- Sensors remain silent until they receive a request from the monitoring station
- Example:
  - Observer wants to know how many animals there are in a specific area

Turn off Parts of Sensor Node

- Demand-driven network
  - Only nodes near in the specific area are turned on



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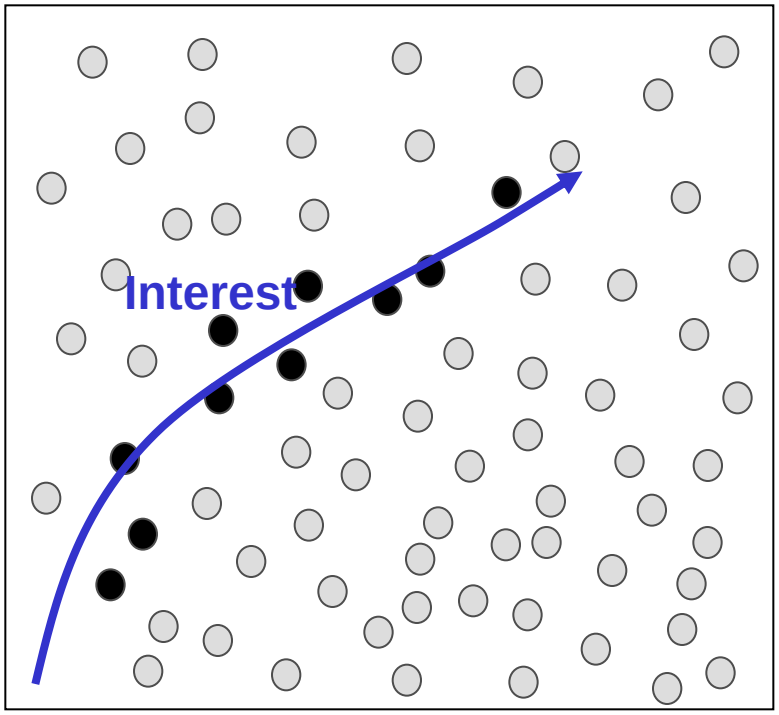

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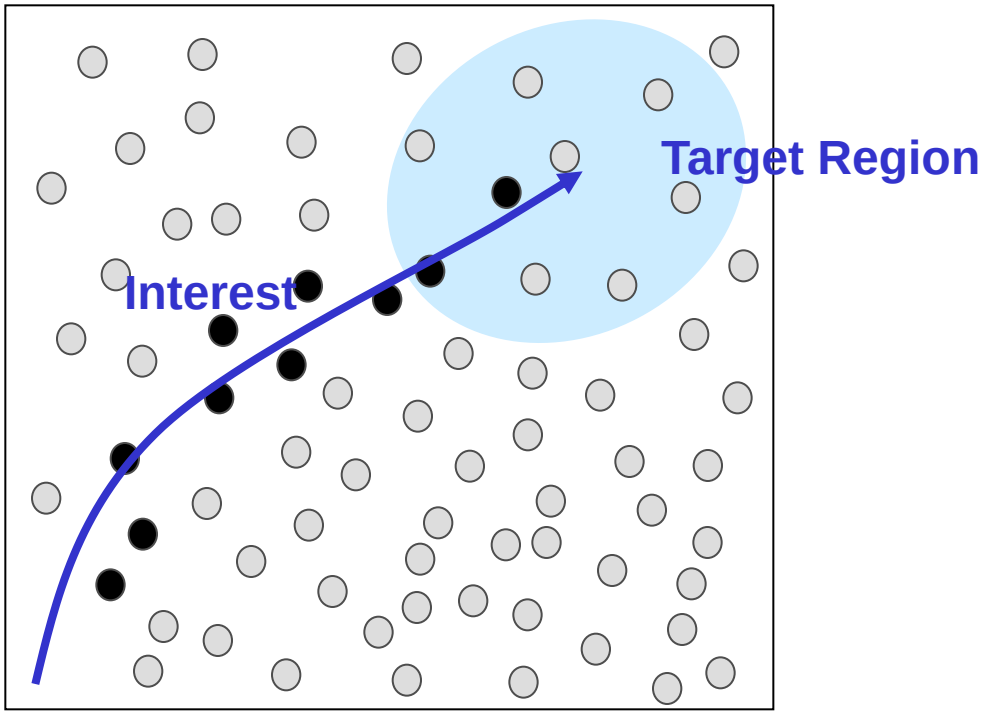

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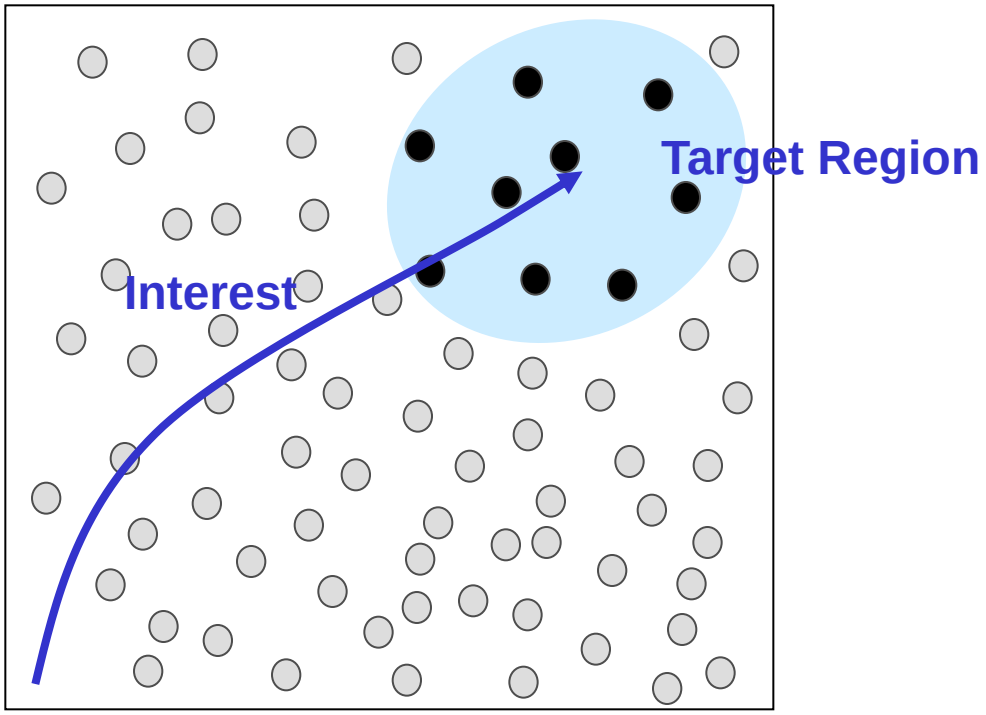
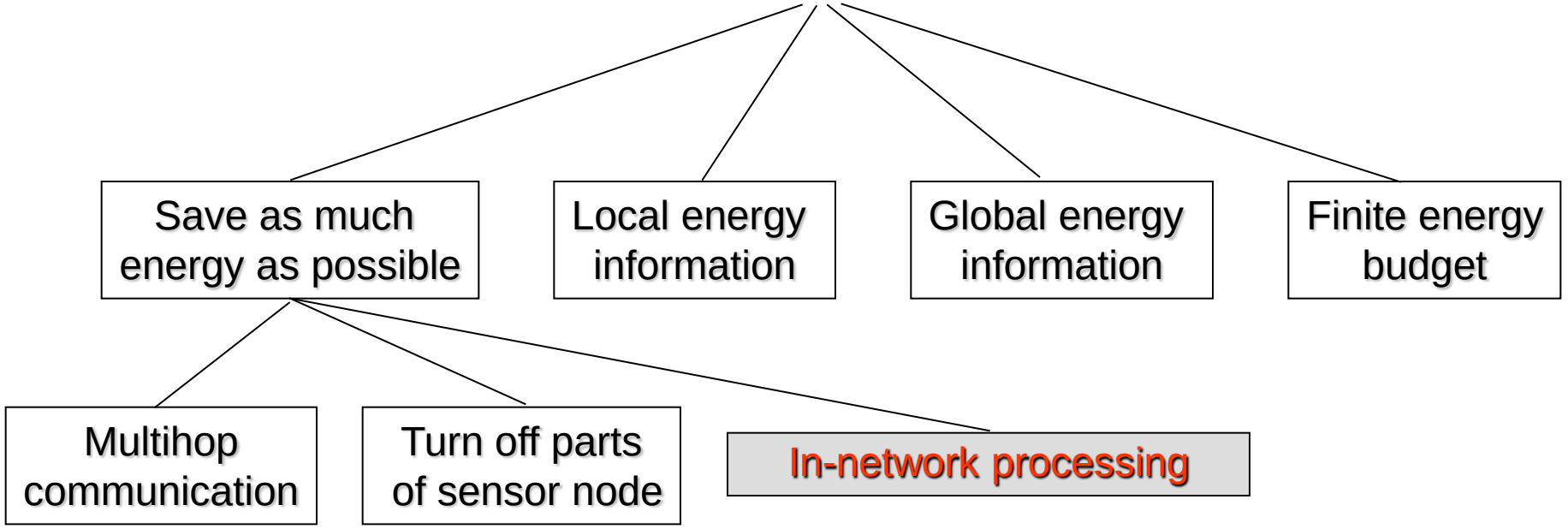


Turn off Parts of Sensor Node

- Instead of two modes of operation (listen and sleep), some protocols consider that nodes have various modes of operation
- Each mode of operation has different rates of energy consumption
- As an example, considering the energy consumption of Mica Imote2:
  - Mode 1 (sleep mode): 1.9 mW
  - Mode 2 (13MHz, radio off): 155 mW
  - Mode 3 (13MHz, radio Tx/Rx): 220 mW
  - Mode 4 (104MHz, radio Tx/Rx): 330 mW

How Are Protocols Dealing with Energy Restriction?

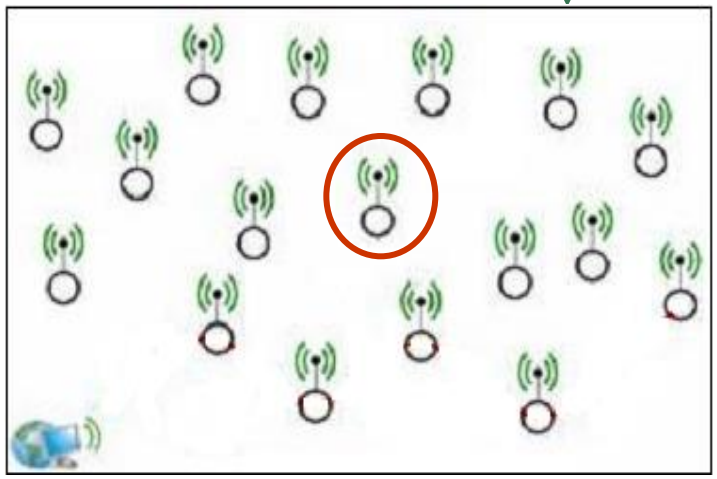


In-network Processing

- Wireless sensor network is a computer network
  - Collection of autonomous computing devices interconnected by a single technology
  - Interconnected: sensors are able to exchange information
  - Autonomous: sensors are able to perform some kind of computation
- In-network processing defines a set of techniques employed when sensor nodes use their processing abilities to diminish the amount of information sent to the monitoring node
- In-network processing techniques can help to save the scarce energy resources

In-network Processing

- In-network processing techniques:
  - Local Processing
  - Localized Processing (cooperation, negotiation)
  - Data Fusion (aggregation)



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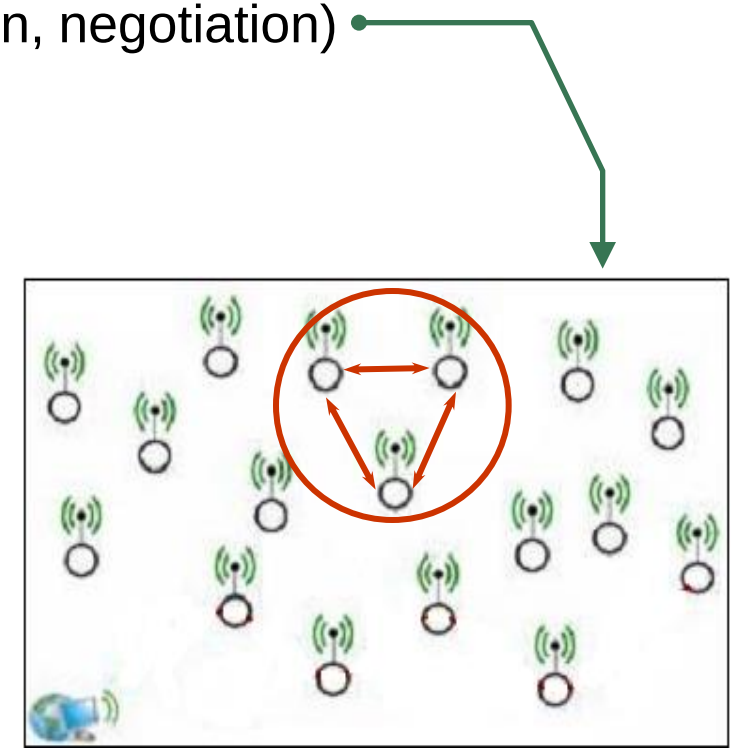

In-network Processing

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  - Local Processing
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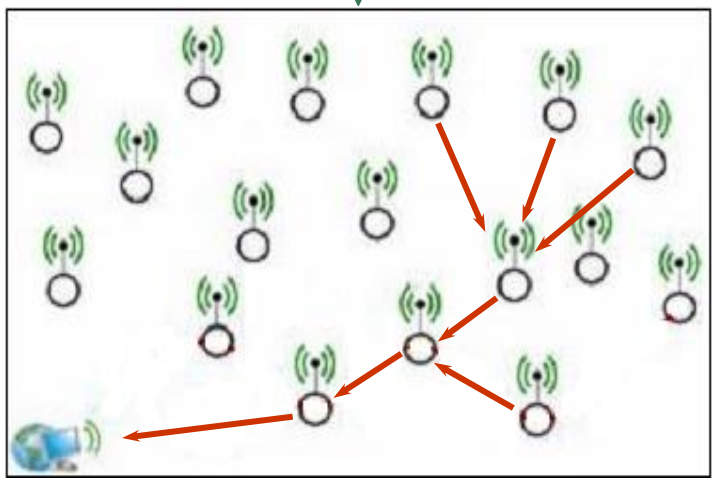
Some protocols use more than one of these techniques



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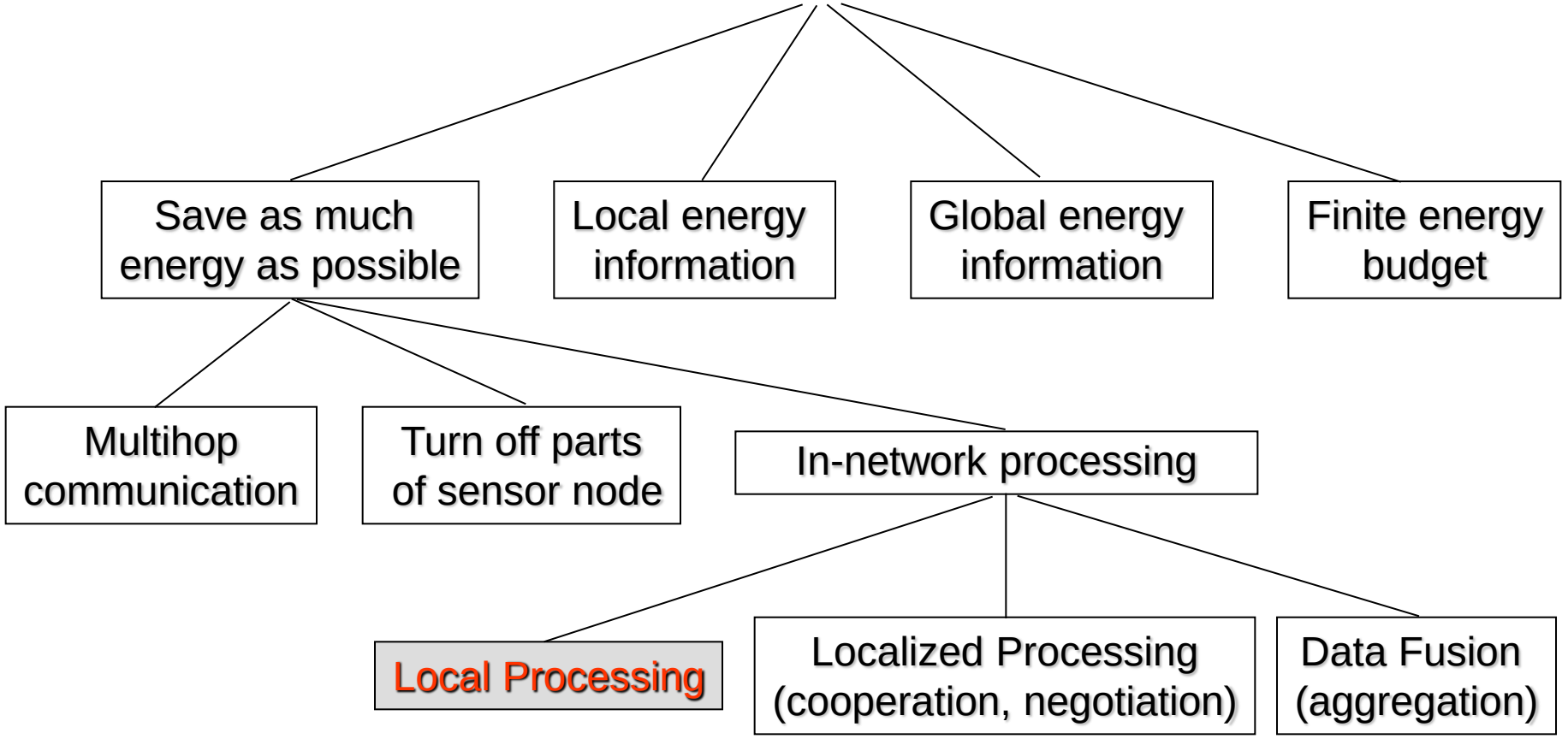
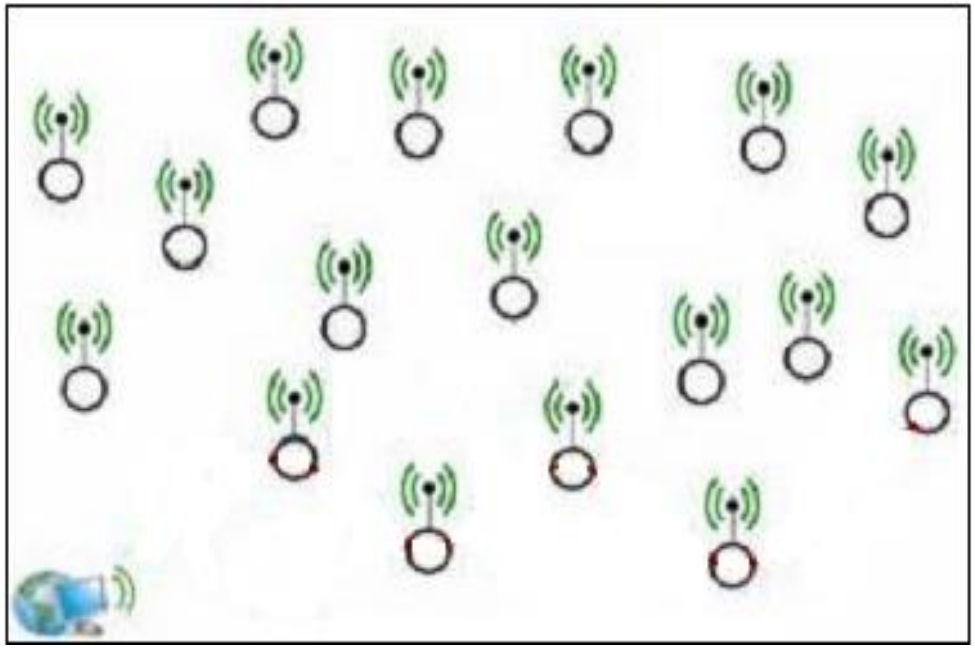


In-network Processing: Local Processing

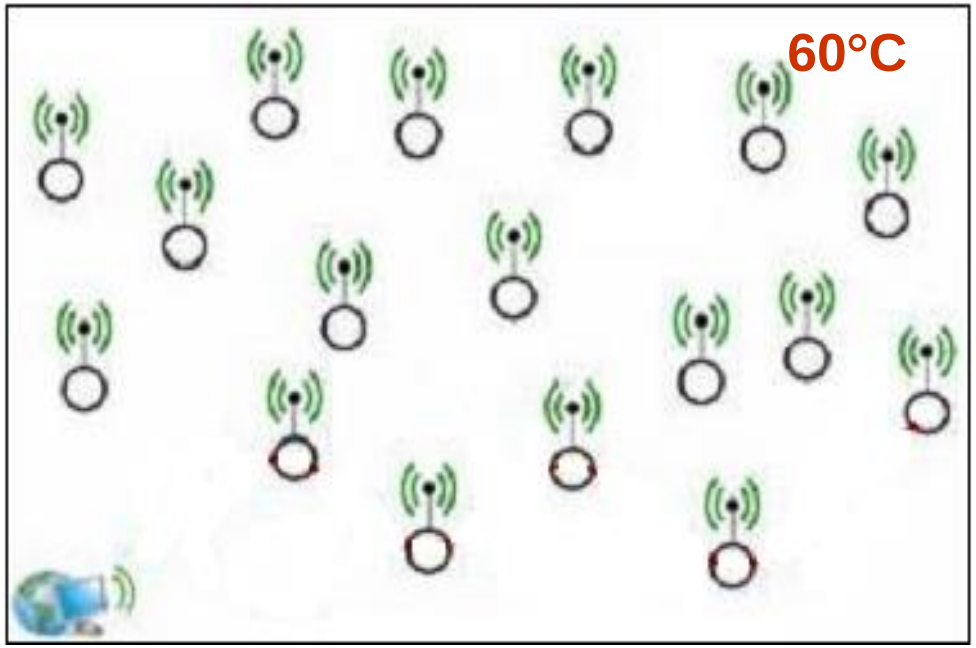
- Locally carry out simple computations and transmit only the required and partially processed data



Fire detection application

In-network Processing: Local Processing

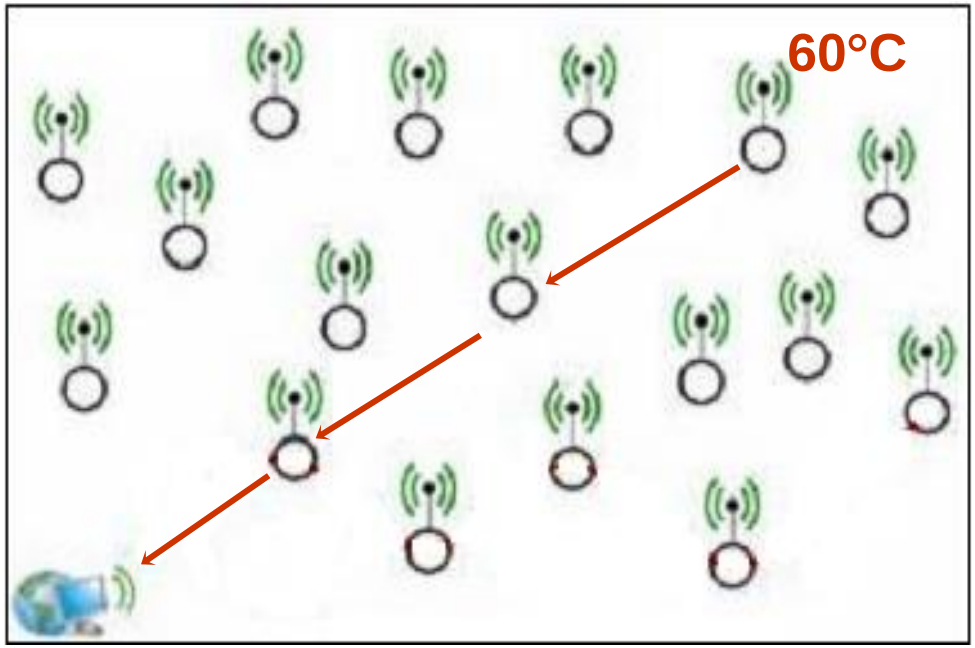
- Abnormal event is detected



Fire detection application

In-network Processing: Local Processing

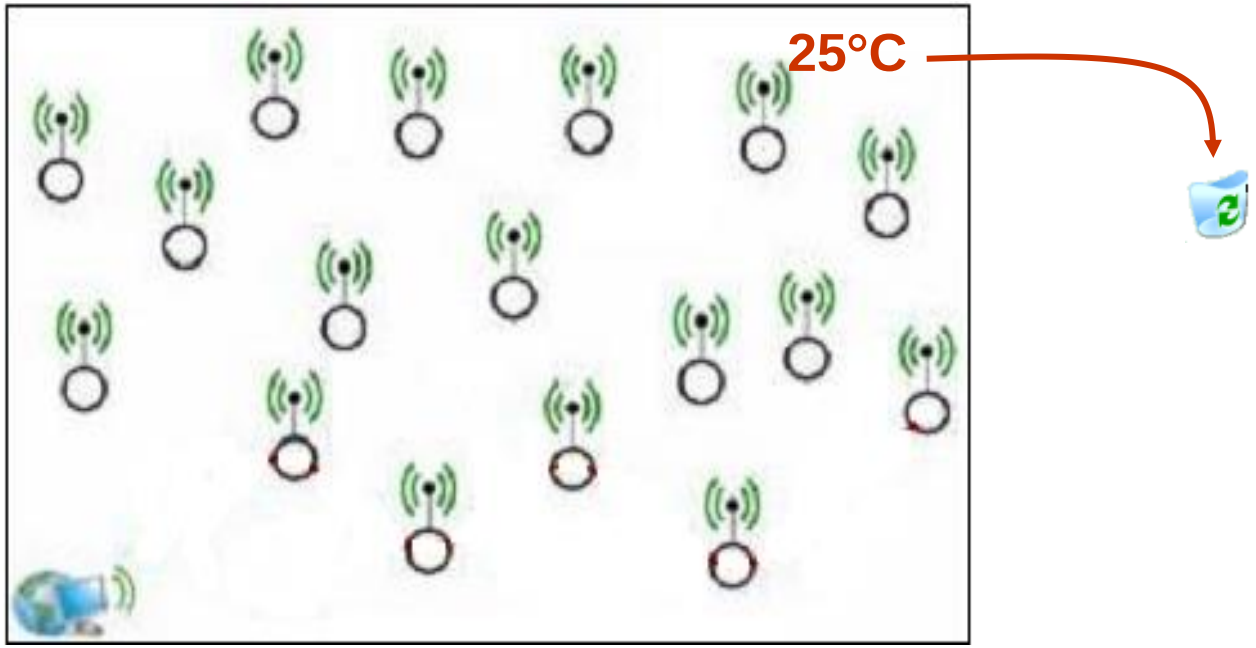
- After performing some computation, sensor node decides to send the information to the monitoring node



Fire detection application

In-network Processing: Local Processing

- If a normal event is detected, no information is sent



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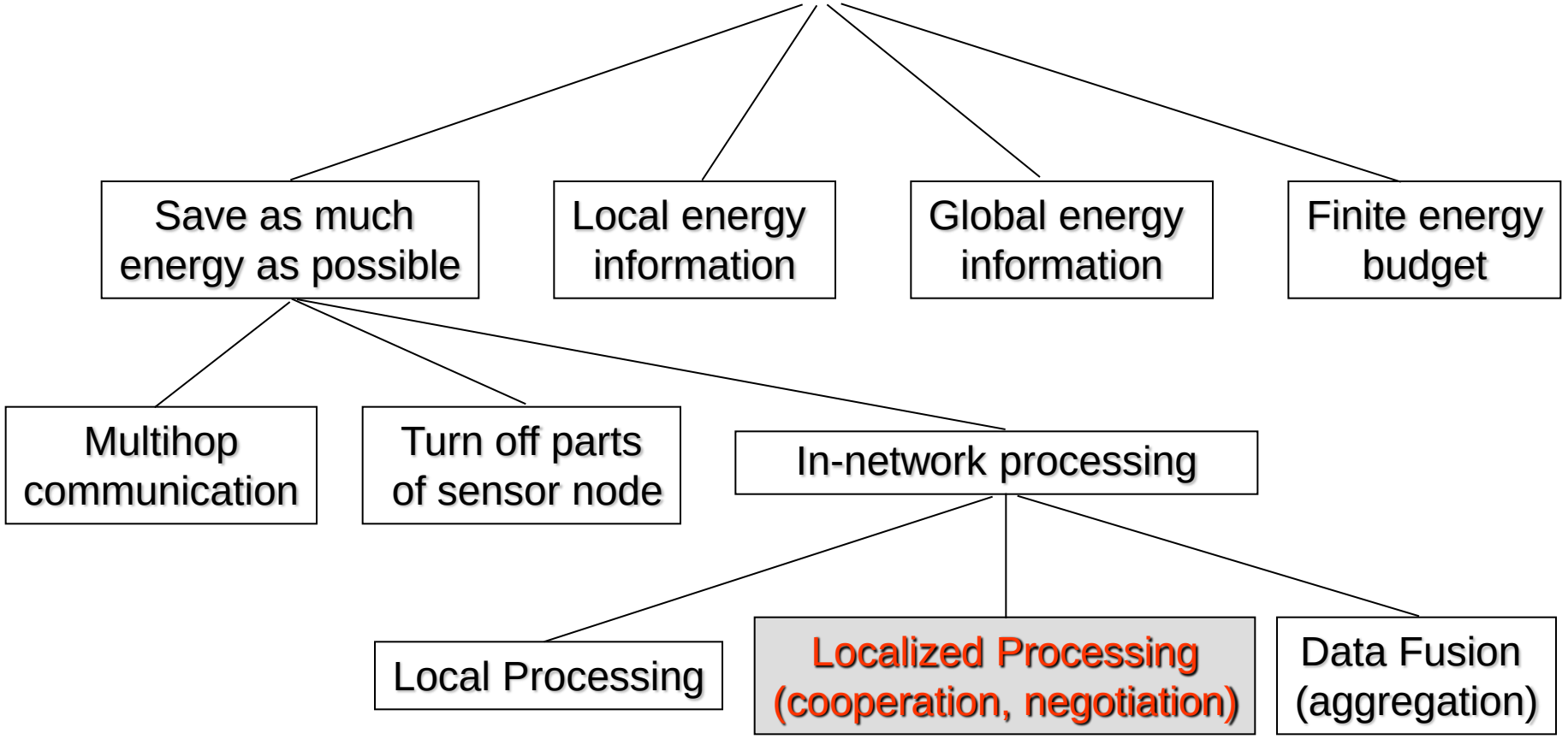
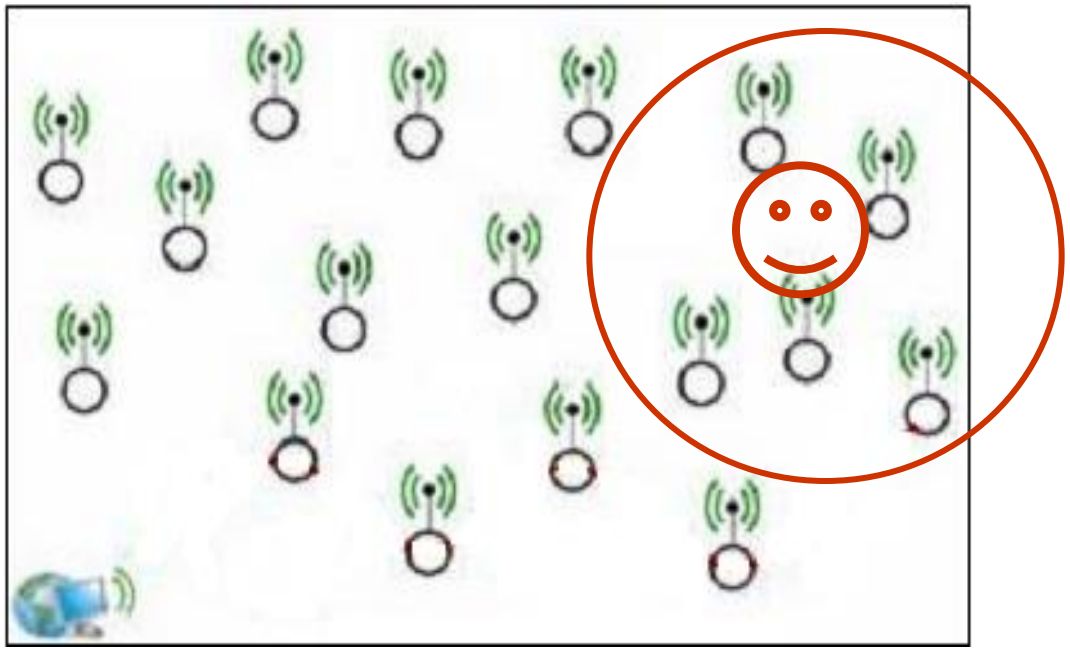


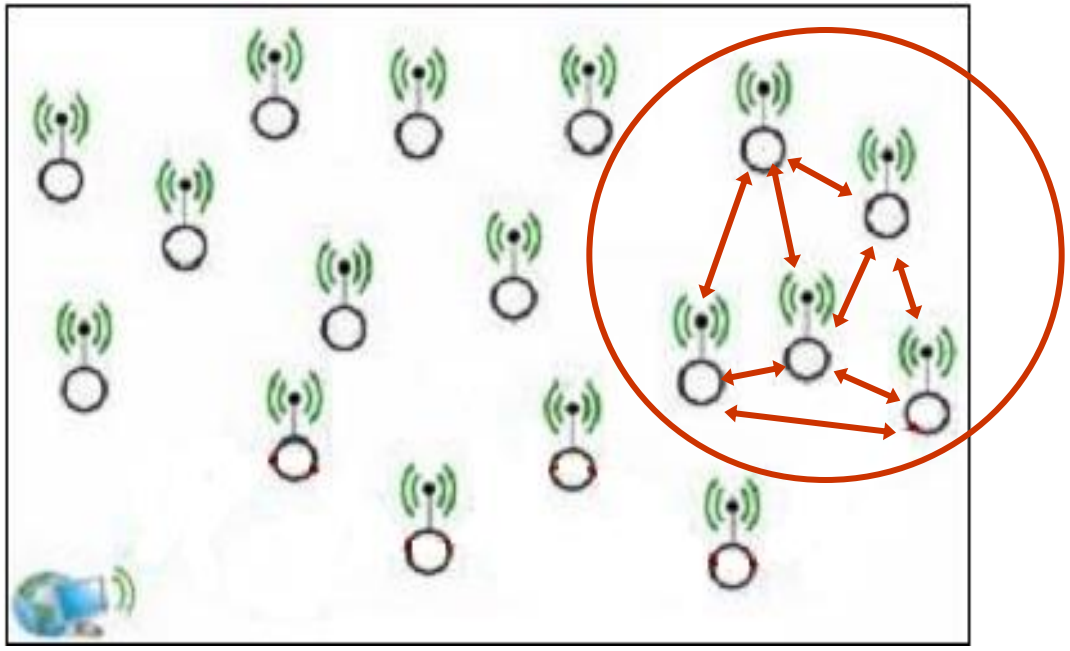
In-network Processing: Localized Processing

- Various sensor nodes often detect the same phenomenon
- There is likely to be some redundancy in the data nodes sense



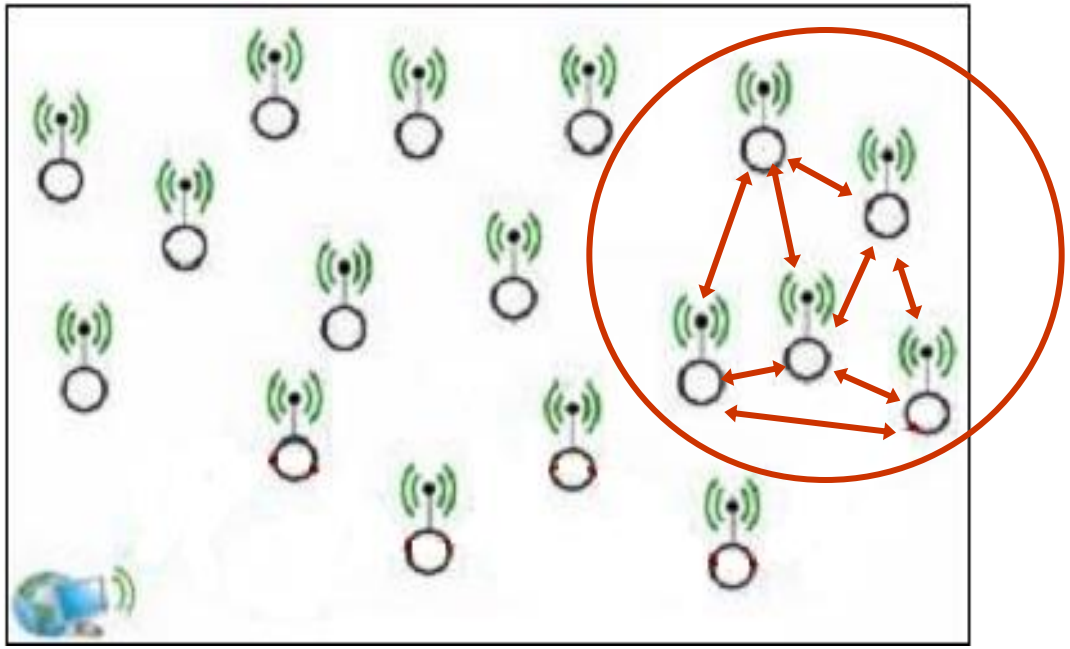
In-network Processing: Localized Processing

- Neighboring nodes exchange messages in order to ensure that only useful information will be transferred (cooperation, negotiation)



In-network Processing: Localized Processing

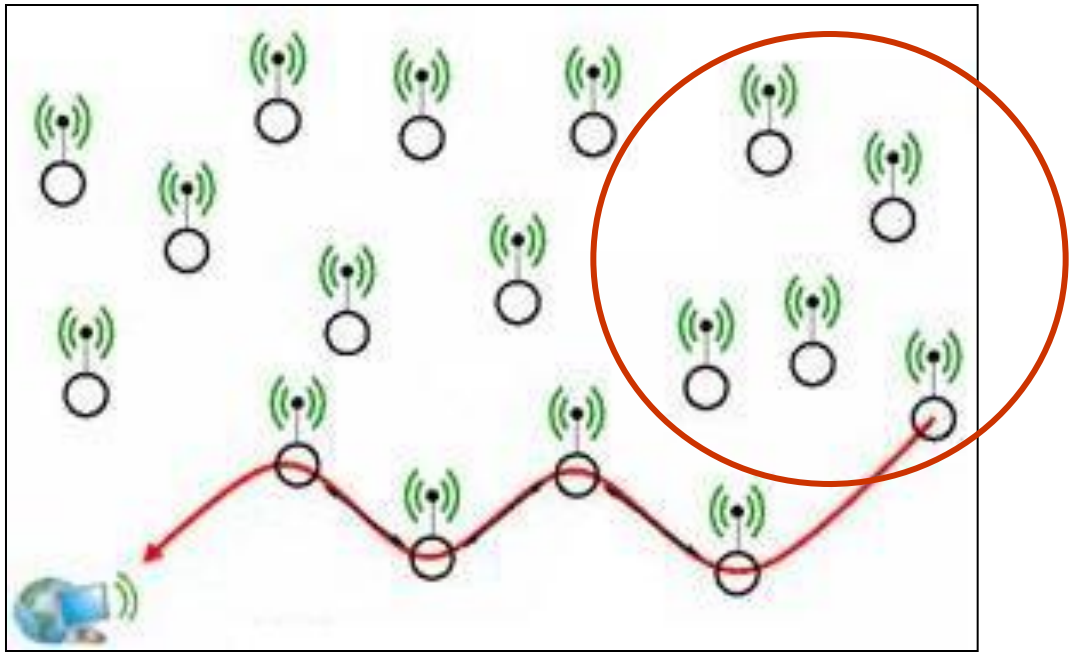
- To cooperate successfully, nodes must be able to describe or name data they observe ➡ **Data-centric**



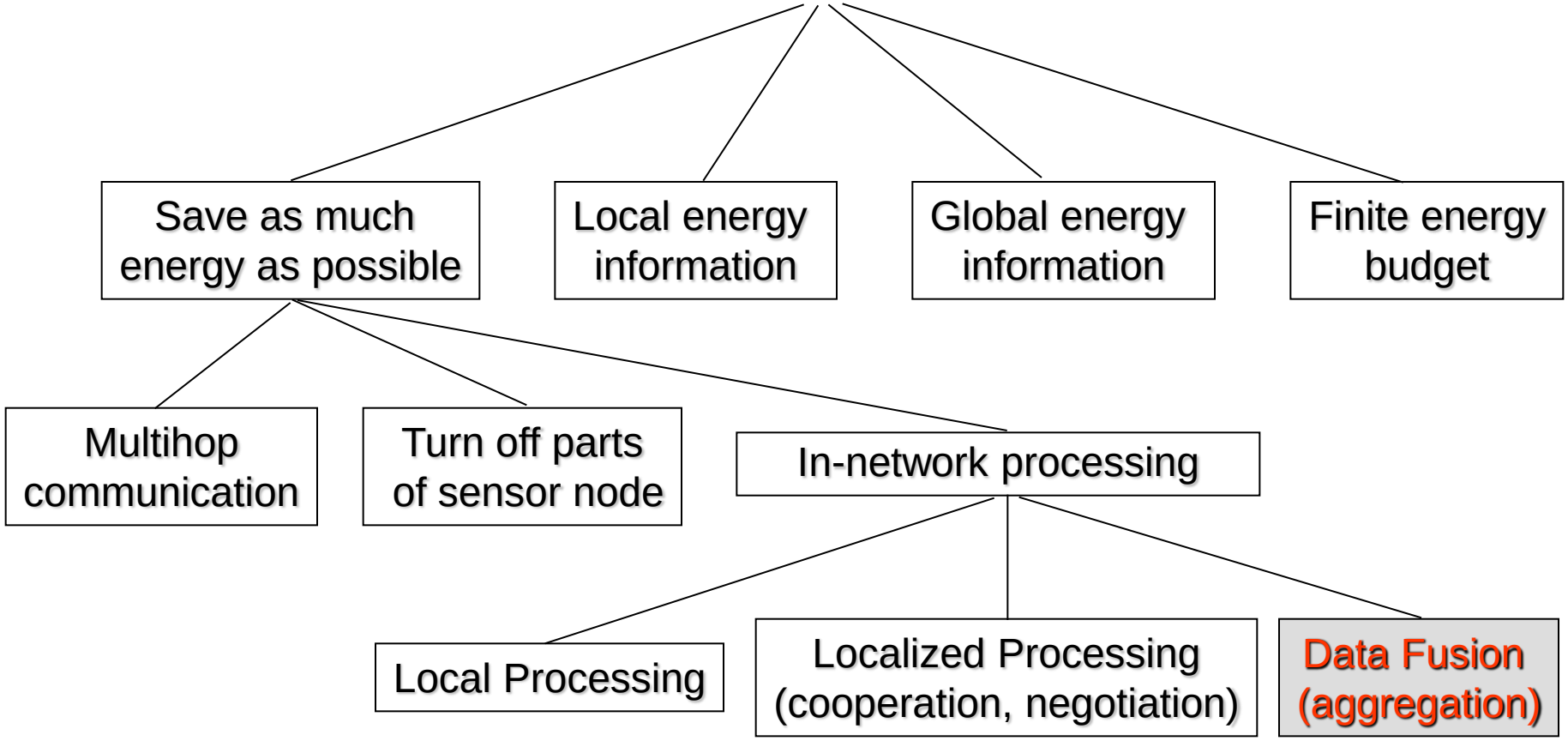
- Used by Directed Diffusion and SPIN

In-network Processing: Localized Processing

- Only one (or a few) node sends the information to the monitoring node
- Save the scarce energy resources



How Are Protocols Dealing with Energy Restriction?

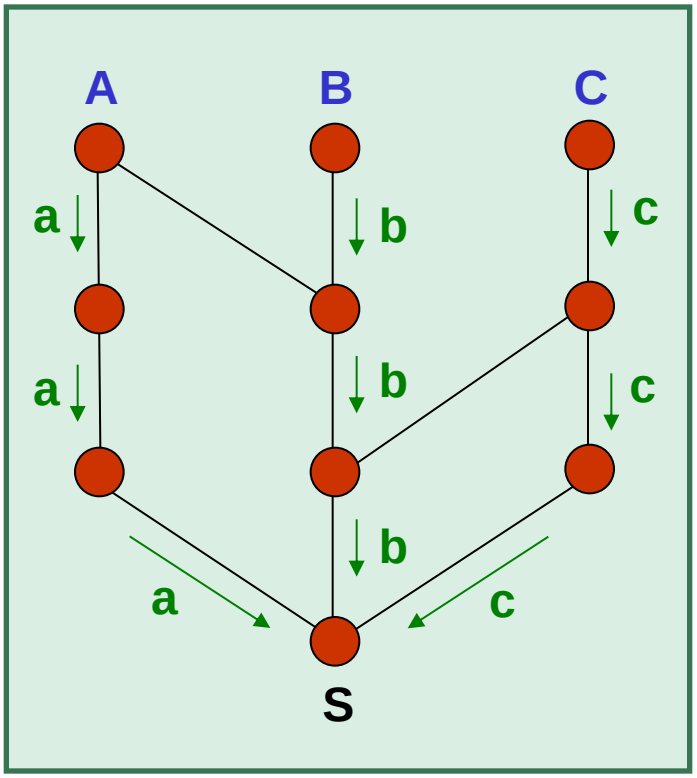


In-network Processing: Data Fusion

- Combine the data coming from different sources in order to:
  - Eliminate redundancy
  - Minimize the number of transmissions
  - Minimize the number of collisions
  - Save energy
- Intermediate nodes may aggregate several events into a single event to reduce transmissions and the amount of data size for system resource savings
- Data fusion requires store-and-forward processing of message

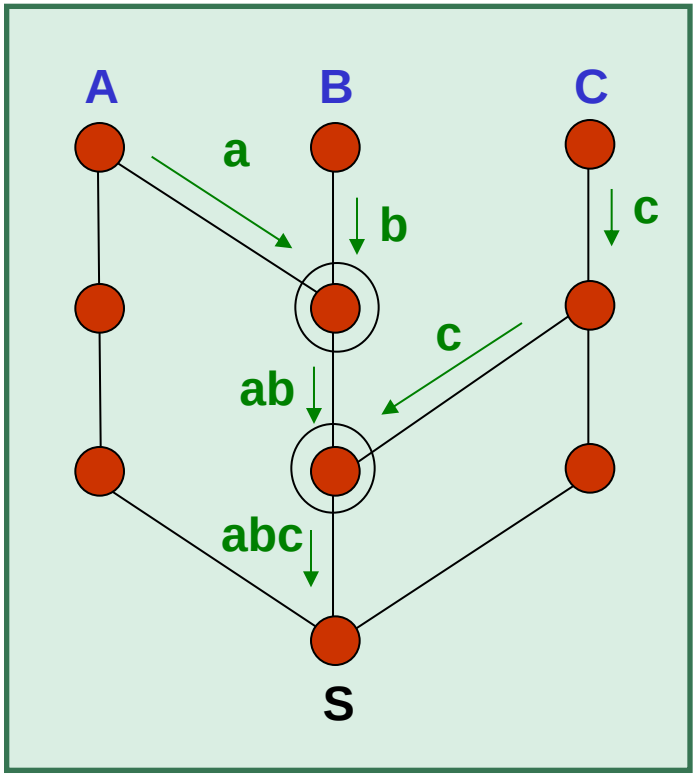
In-network Processing: Data Fusion

Without Data Fusion



9 messages

With Data Fusion



6 messages

In-network Processing: Data Fusion

- Main goal
  - Reduce the amount of information that must be transmitted to the base station
- Advantage
  - Decrease the number of transmissions
- Disadvantage
  - Increase the latency

Tarefa 8 – postar no Canvas até 18/04/2021

1. Por que os nós sensores realizam processamento dentro da rede? Não seria mais fácil espalhar sensores que transmitissem todas as informações sensoriadas para uma central de processamento fora da rede?

2. O que significa data-centric? Qual é a importância desta técnica para as redes de sensores.

3. Apresente um desafio de projeto que aparece quando desligamos partes de um nó sensor.