45 minutes

Purpose of this lesson

- Introduce students to the concept of sensor networks

Materials

Copy of the lesson
Computers with internet access

Background and discussion

Sensor Networks
Sensors are changing the way scientific and engineering research is conducted. With sensors continuously streaming data, even in, and especially during inclement weather or in hostile environments, we are filling in the gaps of knowledge and forming a better at understanding of the environment. Sensor networks are being installed in the ocean, in rivers, in watersheds, in the atmosphere, in the soil, in trees, on animals, in buildings, cars, bridges, crop fields, and the list goes on.

Sensors are pivotal for understanding and predicting many systems.

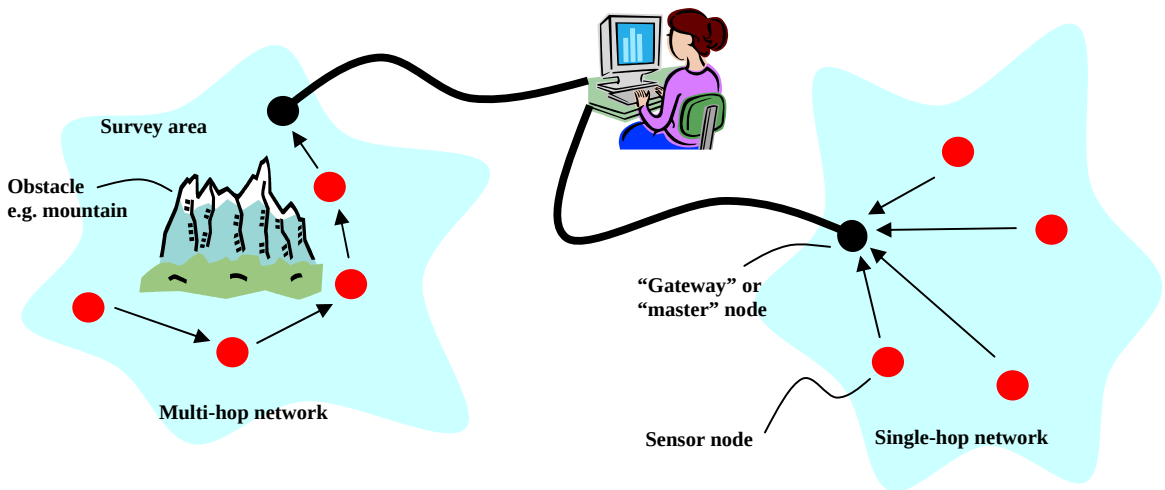

Figure 1. In a "single hop" network (right), each sensor node transmits its data directly back to a gateway node, from which it can be delivered to the scientist's computer for analysis. If the data has to be transmitted over very large distances, or around an obstacle, then it may be necessary to use a "multi hop" network (left) in which data is relayed from one node to the next along a chain of communicating way-stations.

A *wireless sensor network* (WSN) consists of a group of sensor "nodes" which are scattered over a region of interest. Together, this group of sensors is used cooperatively to measure and monitor the region. In environmental applications, water temperature or pollutants might be measured by the sensors at many nodes in different locations across the region, to build up a map of how these quantities vary over the region. This is sometimes known as "area monitoring". In military applications, sensors might be scattered across a battlefield to detect and monitor the movements of enemy vehicles. In industrial applications, sensors might be positioned in many different places across a large factory, to ensure that the factory processes are all running correctly.

Such sensors could communicate their information through cables or wires. However, laying cables is expensive and time consuming and this expense and difficulty increases as the distances between sensors increase - a few inches of wire is cheap, but a few miles of wire is very expensive indeed! For this reason, it is useful to build sensor networks without any wires connecting the sensors – i.e. "wireless" sensor networks. Wireless Sensor Networks (WSNs) use radio transmitters to send their information back to a scientist at a central monitoring location. This means that sensors can be installed without fixed wires, and so it is easy to add additional sensors to the network, or to move an old sensor to a new location, without changing the underlying infrastructure of the system.

Each sensor node will typically include the following important elements:

- One or more sensors of various kinds (e.g. temperature, salinity and turbidity for water quality measurements).
- A power source (e.g. batteries, solar panels, wind turbines).
- A radio transmitter to report the data measured by the sensors.
- A small computer to collect data from the sensors and create data files for transmission by the radio transmitter.

Considerations when designing a network
Energy source: how long must the sensor be deployed for without human intervention or servicing? How much power do the sensors, and transmitters require? How long would a battery last? Do we need an extra source of power like solar panels or a windmill, to top up the batteries so that they do not need to be regularly replaced. Sending an engineer to visit a sensor to replace its battery costs time and money. What are the tradeoffs between this and buying longer lasting (more costly) batteries, or building expensive solar panel systems to recharge the batteries?

Transmitter: how far does each sensor node need to transmit its data? Should you use a large expensive transmitter to cover this distance in a single "hop" (see figure 1)? Or could each node user a smaller and cheaper transmitter to send data over a shorter distance to the next node, and thereby send the data back to the scientist in a series of hops ("multi hop" network). How much energy do these transmitters require? Do your sensor nodes have enough battery power to power the long range transmitters, or would using a series of short range transmitters allow the sensors to last longer without having their batteries replaced?

Sensor locations: where should we position our sensors, in order to build a meaningful and representative map of what is going on in our region of interest? Should we concentrate our sensors in the most variable or interesting parts of the region – if so, do we risk missing an event that happens elsewhere? How many sensors do we need, and how densely should we space them? If water salinity varies a lot over small distances then we must place our salinity

sensors close together if we want to observe this variation-otherwise we cannot measure it. Should we use a small number of accurate (and expensive sensors) or a large number of cheap (and less accurate) sensors?

Assessment

1. Select one of the following Sensor Network ideas:
    - Tracking monarch butterfly migration
    - Misting plants and temperature control in a greenhouse
    - Real time snow removal

2. Consider the requirements to install the sensor network. Address the following:
    - What types of sensors (which parameters) would be required? (e.g. temperature, salinity and turbidity for water quality measurements).
    - A power source (e.g. batteries, solar panels, wind turbines, power cables to land).
    - A radio transmitter to report the data measured by the sensors (what distance is required by the network).

Note: there are not necessarily any right or wrong answers to these questions. In each particular sensor problem, the engineer will have to weigh up the pros and cons of different approaches and arrive at the best compromise design – this may also be known as a problem of “design trade-offs”. Different problems in different contexts will require different solutions.

3. Prepare a short presentation on the sensor network design to address the sensor network requirements.