Sensor Networks

- Tiny sensor nodes, typically wireless capable of data sensing, processing and communications.
- Deployment in inaccessible terrains or disaster relief operations.
- Many nodes – very large in number.
- Co-operation among sensors needed.
- Since the deployment is typically in inaccessible terrain – battery life critical for the functioning and longevity of the network.
Information flows from Sensor Network to User

Figure 1. Sensor nodes scattered in a sensor field.

Figure from Akyldiz et. al, IEEE Comm. Mag, Aug 2002 [1]
Block Representation of a Sensor

Figure from Reference [1].
• Some sensors may have solar power extraction capabilities.

• Typically, the sensor sub-units need to fit into the size of a matchbox.

• Main task of a sensor node is to detect events, perform quick data processing and then transmit the data – possibly route it to the sink.
Differences between sensor and ad hoc networks.

- Sensors are typically much more in number.
- More prone to failure - changes in topology due to failures, sensors going to sleep, etc.
- Data transport has a specific pattern.
- Sensors are very limited in terms of power, computational capabilities and memory.
• Notice that we have a power management plane – in general there are management planes.

• We need power efficiency at all layers of the protocol stack.

Figure 3. The sensor networks protocol stack.
Physical Layer

• Thus far, 915 Mhz ISM band.

• Shorter ranges
  • Higher transmission needed for reaching longer distances – power drops off as $d^n$, where $d$ is the distance at which the signal power is measured.

• Good modulation schemes – we won’t worry about this in this course.
MAC Layer

- Bluetooth
  - Master Slave configuration – probably not suitable for Sensor Networks.


- MANET – Mobile Ad Hoc Networks – typically use 802.11 – not power efficient – requires constant monitoring of the channel.
MAC Layer (continued)

- CSMA Based -
  - Contention based random access.
  - There have been schemes that try to take into account correlated data traffic transfers.
  - In one of the papers, there is an attempt to take into account the rates of “local” originating traffic at a sensor and the route-thru traffic to ensure MAC fairness.
  - Important to manage the listening mechanism and back-off times.
Self-Organizing Medium Access Control (SMACS)

- By Dr. Greg Pottie’s group at UCLA (refer [1]).

- SMACS provides network startup and link-organization.

- Frequency hopping allowed – sensors discover their neighbors and establish transmission/reception schedules.

- Each link consists of a pair of time-slots that operate on fixed frequencies.

- Random wake up schedule during connection phase and nodes sleep during idle time slots.

- No need for network wide synchronization.
The Eavesdrop and Register (EAR) protocol

- Mobile nodes take responsibility for registering static nodes.
- Each static node is affiliated with a mobile node and sensed data is ultimately relayed to the mobile node.
- Possibility of fragmented subnets.
Routing -- I

- Various metrics possible
  - Total power available (PA) along a path.
  - Minimum Energy Route
  - Maximum (minimum PA) on a path.
Routing -- II

- $\alpha_i$ is the cost of link $i$.
- PA $\rightarrow$ total available power at the particular node.
- Node T is the source (a single sensor).
- Data is to be sent to sink.

Figure from Reference [1].
In-Network Data Aggregation

- Data aggregation useful when it does not hinder collaborative effort of sensor nodes.
- Attributes specify the kind of data being sensed – whether aggregation is possible etc.
- Combining data from a plurality of sensor nodes into a set of meaningful information.
- Also referred to as Data Fusion.
- E.g. If three sensors in a particular area report a temperature > 70 degrees, then a single report saying so will suffice.
A Reverse Multicast Tree

B fuses data from C and D

C performs data fusion - the data received from nodes E and F is fused.
Interests and Attributes

• How do the sensors know when to send data?
• Attribute based
  • One possibility is that the sink may broadcast the interest.
  • Sensors may broadcast an advertisement for the available data.
• Typically application dependent.
Flooding and Broadcasting

- Of interest not only in sensor nets but also ad hoc nets.
- In flooding each node repeats the broadcast from the source - expensive.
- Duplications, overlap → wasteful.
- Gossiping - node does not broadcast but picks a randomly selected neighbor to send the packet - this neighbor does the same thing and so on.
- Delays, and could lead to wastage as well.
- Intelligent power efficient broadcast needed.
Clustering and LEACH

- Clustering helps in organized access etc. - reduction in wasteful collisions.
- Low-Energy Adaptive Clustering Hierarchy (LEACH) is a clustering based protocol that helps reduce energy dissipation.
- At set up, each node computes a random number and decides whether to become a clusterhead.
- This random number takes into account whether the node was a clusterhead in the recent past.
LEACH

• Once the clusterheads are selected they announce their presence.
• Nodes join clusterheads.
• Clusterheads assign time on which sensors can send data – TDMA based approach.
• This is steady phase.
• Network remains in steady phase for a while and then reverts to set up phase – new clusterheads are selected.
Directed Diffusion

• By Intanonwiwat et al (Dr. Estrin’s group UCLA).
• Sink sends out an interest or task description.
• Attribute value pairs describe a task.
• Each sensor node stores interest-entry in cache.
• Interest Entry contains a time-stamp and several gradient fields – back towards the sink.
• As the interest is propagated the gradients from each source to the sink are set up.
• When there is data for the interest, source sends data along the interest’s gradient path.
Pictorial Example of Directed Diffusion

Figure from Reference [1].
Transport Layer

- TCP and UDP are not appropriate - not geared towards sensor networks.
- There needs to be an attribute based transport layer.
- Reliability or the “credibility” of an event as opposed to the reliability of an individual byte of importance.
- OPEN AREA of Research.
- There is a paper by Aykildiz et al in MOBIHOC 2003 - ETSI -- possible paper for presentation.
Other topics

- Effects of density – how can we exploit?
- When do we turn sensor nodes on and off?
- Time Synchronization – needed for arbitration of access – else collisions can waste channel capacity and energy.
- Moving sensors – how do we move?
- Sink trajectory control
- Internetworking sink nodes
- Anycasting to any of the sink nodes.
Important Resources

- ACM MOBICOM
- ACM MOBIHOC
- IEEE INFOCOM
- Workshop on Sensors and Applications (WSNA)
- Journals.
- The survey paper has a set of websites that you may want to visit.