Sensor Networks

Wireless Sensor Networks

- Wireless sensor networks are a collection of hundreds or thousands of tiny disposable and low power sensor nodes communicating together to achieve an assigned task.
- A sensor node is a device that converts a sensed attribute into a data form that is comprehensible by the user. Each node includes a sensing module, a communication module, memory and a small battery.
- They are "data centric" networks, i.e., the interest is in "*what* is the data?" rather than "*where* is the data?". In wireless sensors, failure of one sensor does not affect the network operation as there are other nodes collecting similar data in the same area.

Wireless Sensor Networks - Queries

Query handling is another additional feature. Users using hand held devices should be able to request data from the network. User queries are of three types:

- **Historical queries**: Used for analysis of historical data stored at the BS, e.g "What was the temperature 2 hours back in the northwest quadrant?"
- **One time query**: Gives a snapshot of the network, e.g. "What is the current temperature in the northwest quadrant?".
- **Persistent query**: Used to monitor the network over a time interval with respect to some parameters, e.g. "Report the temperature for the next 2 hours".

Classification of Sensor Networks

- **Proactive Networks**

  The nodes in the network periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest.

- **Reactive Networks**

  In this scheme the nodes react immediately to sudden and drastic changes in the value of the sensed attribute.

Fundamentals of MAC Protocol for Wireless Sensor Networks

- Static Channel Allocation
  - In this category of protocols, if there are N nodes, the bandwidth is divided into N equal portions either in frequency (FDMA), in time (TDMA), in code (CDMA), in space (SDMA: Space Division Multiple Access) or OFDM (Orthogonal Frequency Division Multiplexing)
- Dynamic Channel Allocation
  - In this category of protocols, there is no fixed assignment of bandwidth.

Routing Issues in Sensor Networks

- In traditional wired networks each node is identified by a unique address, which is used for routing. Sensor networks, being data centric do not, in general, require routing between specific nodes.
- Adjacent nodes may have similar data. So it is desirable to aggregate this data and send it.
- The requirements of the network change with application, hence it is application specific.

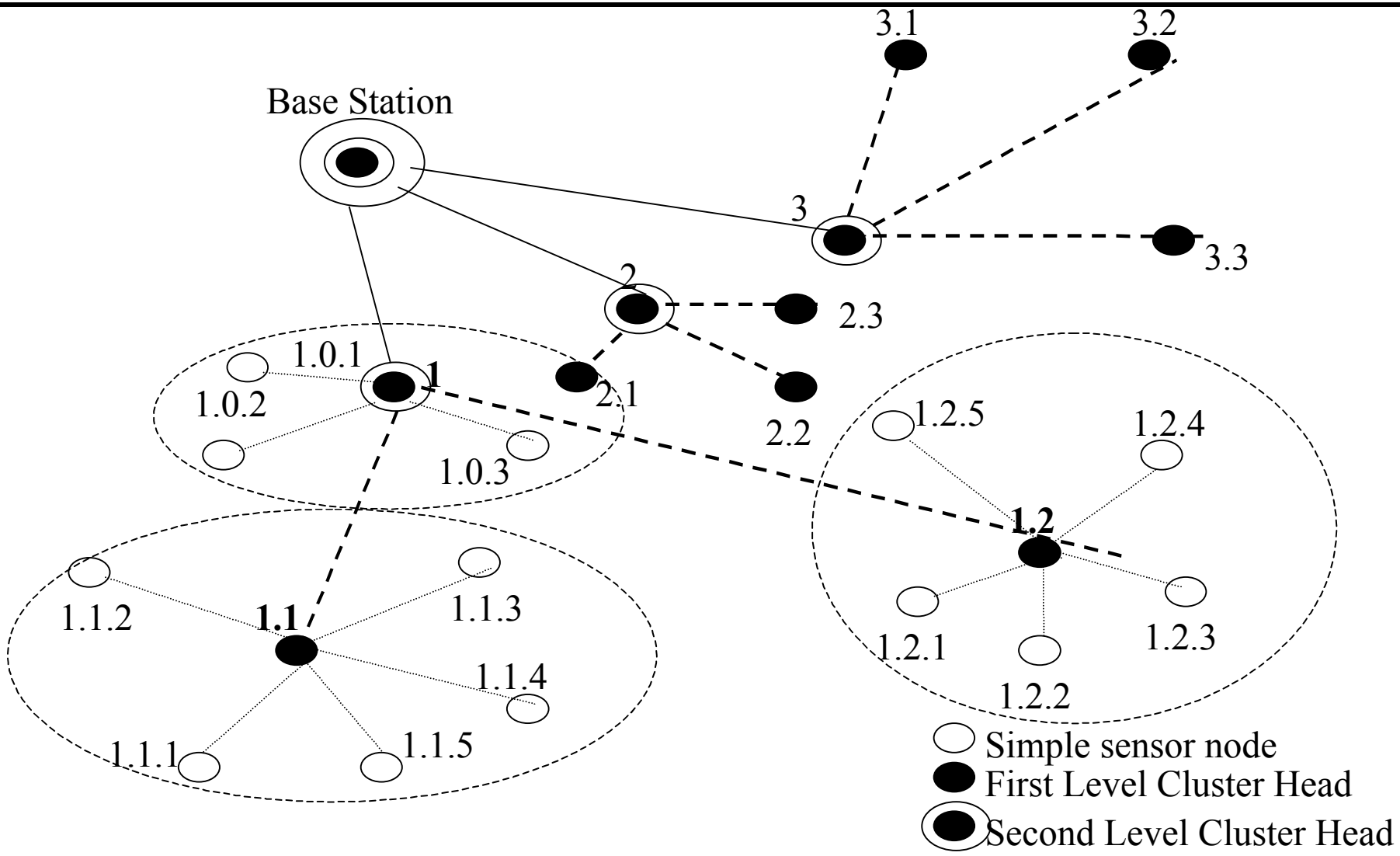
Routing in Sensor Networks – Flat Routing

- **Directed Diffusion**
  - The query is flooded throughout the network.
  - Events start from some specific points and move outwards to reach the requesting node
  - This type of data collection does not fully exploit the feature of sensor networks that adjacent nodes have similar data.
- **Sensor Protocols for Information via Negotiation** (SPIN)
  - Disseminates the information at each node to every node in the network.
- **Cougar**
  - This is a warehousing approach. The data is extracted in a pre-defined manner and stored in a central database (BS). Query processing takes place on the BS. Cougar is a unique model for query representation in sensor networks.

Hierarchical Routing in Sensor Networks

- Hierarchical clustering schemes are the most suitable for wireless sensor networks.
- The network consists of a Base Station (BS), away from the nodes, through which the end user can access data from the sensor network.
- BS can transmit with high power.
- Nodes cannot reply directly to the BS due to their low power constraints, resulting in asymmetric communication.

Hierarchical Routing (Cont'd)



Cluster Based Routing Protocol

Cluster Based Routing Protocol (CBRP)

- Here the cluster members just send the data to the cluster head (CH).
- The CH routes the data to the destination.
- Not suitable for a highly mobile environment, as a lot of HELLO messages are sent to maintain the cluster.

Low-Energy Adaptive Clustering Hierarchy (LEACH)

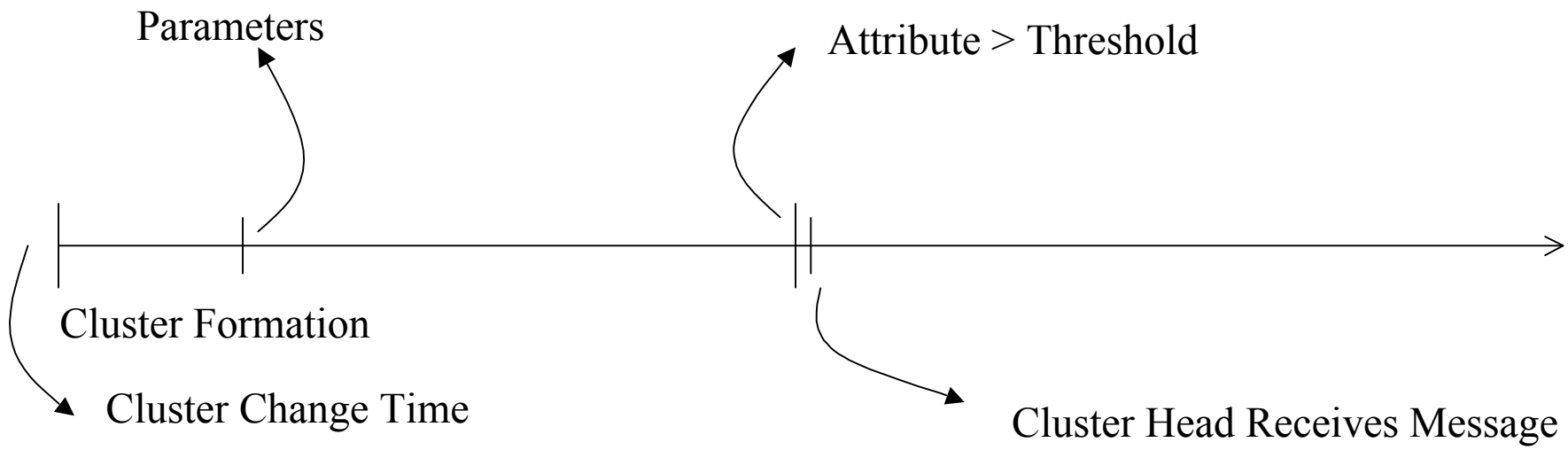
- LEACH is a family of protocols containing both distributed and centralized schemes and using proactive updates.
- It utilizes randomized rotation of local cluster heads (CHs) to evenly distribute the energy load among sensors.
- It makes use of a TDMA/CDMA MAC scheme to reduce inter and intra-cluster collisions.

Reactive Network Protocol:TEEN

TEEN (**T**hreshold-sensitive **E**nergy **E**fficient sensor **N**etwork protocol)

- It is targeted at reactive networks and is the first protocol developed for such networks.
- In this scheme at every cluster change time, the CH broadcasts the following to its members:
  - *Hard Threshold (HT):* This is a threshold value for the sensed attribute.
  - *Soft Threshold (ST):* This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit.

Reactive Network Protocol:TEEN



Time Line for TEEN

TEEN (Cont'd)

- The nodes sense their environment continuously.
- The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data.
- The sensed value is stored in an internal variable, called Sensed Value (SV).
- The nodes will transmit data in the current cluster period only when the following conditions are true:
  - The current value of the sensed attribute is greater than the hard threshold.
  - The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

TEEN

Important features:

- Suited for time critical sensing applications.
- Message transmission consumes more energy than data sensing. So the energy consumption in this scheme is less than the proactive networks.
- The soft threshold can be varied.
- At every cluster change time, the parameters are broadcast afresh and so, the user can change them as required.
- The main drawback is that if the thresholds are not reached, then the nodes will never communicate.

Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol (APTEEN)

Functioning:

The cluster heads broadcasts the following parameters:

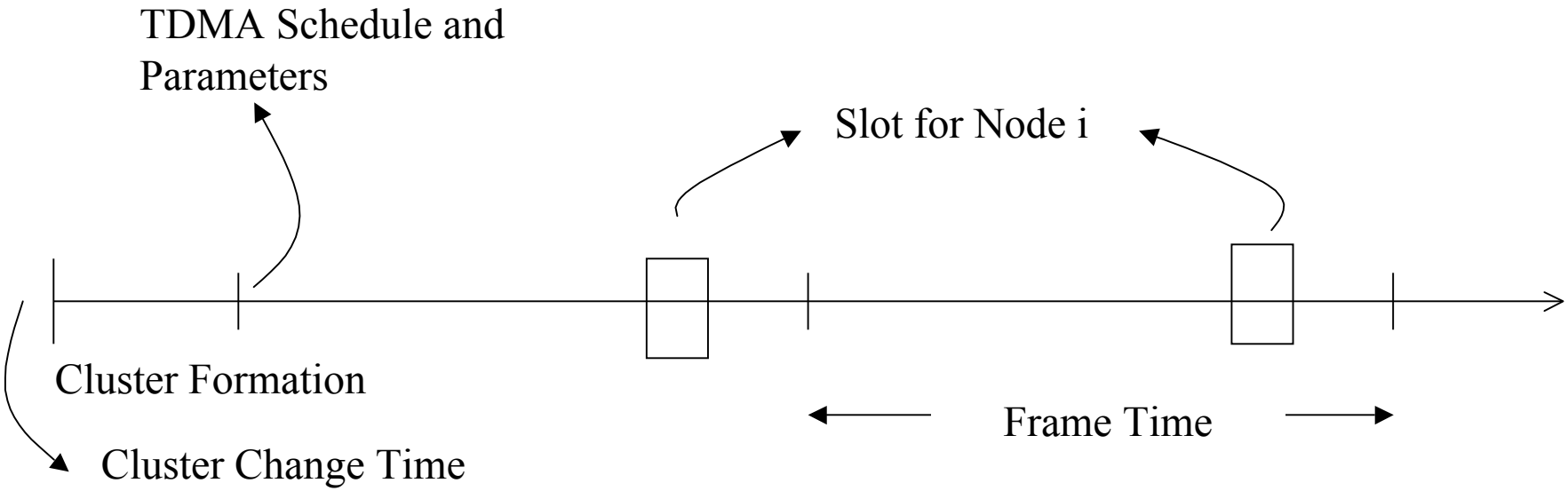
Attributes (A): This is a set of physical parameters which the user is interested in obtaining data about.

Thresholds: This parameter consists of a Hard Threshold (HT) and a Soft Threshold (ST).

Schedule: This is a TDMA schedule, assigning a slot to each node.

Count Time (CT): It is the maximum time period between two successive reports sent by a node.

Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol (APTEEN)



Time line for APTEEN

APTEEN (Cont'd)

- The node senses the environment continuously.
- Only those nodes which sense a data value at or beyond the hard threshold transmit.
- Once a node senses a value beyond HT, it next transmits data only when the value of that attribute changes by an amount equal to or greater than the ST.
- If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data.
- A TDMA schedule is used and each node in the cluster is assigned a transmission slot.

APTEEN (Cont'd)

Main features of the scheme:

- It combines both proactive and reactive policies.
- It offers a lot of flexibility by allowing the user to set the count-time interval (CT) and the threshold values for the attributes.
- Energy consumption can be controlled by changing the count time as well as the threshold values.
- The main drawback of the scheme is the additional complexity required to implement the threshold functions and the count time.

Hierarchical Vs Flat topologies

Hierarchical	Flat
Reservation-based scheduling	Contention-based scheduling
Collisions avoided	Collision overhead present
Reduced duty cycle due to periodic sleeping	Variable duty cycle by controlling sleep time of nodes
Data aggregation by cluster head	Node on multi-hop path aggregates incoming data from neighbors
Simple but non-optimal routing	Routing is complex but optimal
Requires global and local synchronization	Links formed on the fly, without synchronization
Overhead of cluster formation throughout the network	Routes formed only in regions that have data for transmission
Lower latency as multi-hop network formed by cluster-heads is always available	Latency in waking up intermediate nodes and setting up the multi-hop path
Energy dissipation is uniform	Energy dissipation depends on traffic patterns
Energy dissipation can not be controlled	Energy dissipation adapts to traffic pattern
Fair channel allocation	Fairness not guaranteed

Sensor Networks

Adapting to the Inherent Dynamic Nature of Wireless Sensor Networks

Certain objectives that need to be achieved are:

- Exploit spatial diversity and density of sensors.
- Build an adaptive node sleep schedule.
- Explore the tradeoff between data redundancy and bandwidth consumption.
- The nodes on deployment should create and assemble a network, adapt to device failure and degradation, manage mobility of sensor nodes and react to changes in task and sensor requirements.
- Adaptability to traffic changes. Certain nodes may detect an event that could trigger a number of updates and at other times very little traffic may be present.
- Allowing finer control over an algorithm rather than simply turning it on and off.