Contention-based protocols

- In a given transmit opportunity toward a receiver node can in principle be taken by any of its neighbors.
- If only one neighbor tries its luck, the packet goes through the channel.
- If two or more neighbors try their luck, these have to compete with each other and in unlucky cases due to hidden-terminal situations, a collision might occur, wasting energy for both transmitter and receiver.

PAMAS

- The PAMAS protocol (Power Aware Multiaccess with Signaling) originally designed for ad hoc networks.
- It provides a detailed overhearing avoidance mechanism while it does not consider the idle listening problem.
- The protocol combines the busy-tone solution and RTS/CTS handshake similar to the MACA protocol

Features of PAMAS:

- It uses two channels: a data channel and a control channel.
- All the signaling packets (RTS, CTS, busy tones) are transmitted on the control channel, while the data channel is reserved for data packets.

Protocol operation of PAMAS:

- Let us consider an idle node x to which a new packet destined to a neighboring node y arrives.
- First, x sends an RTS packet on the control channel without doing any carrier sensing. This packet carries both x's and y's MAC addresses.
- If y receives this packet, it answers with a CTS packet if y does not know of any ongoing transmission in its vicinity.
- Upon receiving the CTS, x starts to transmit the packet to y on the data channel. When y starts to receive the data, it sends out a busy-tone packet on the control channel.
- If x fails to receive a CTS packet within some time window, it enters the backoff mode, where a binary exponential backoff scheme is used.
- The backoff time is uniformly chosen from a time interval that is doubled after each failure to receive a CTS.

- Now, let us look at the nodes receiving x's RTS packet on the control channel. There is the intended receiver y and there are other nodes; let z be one of them.
- If z is currently receiving a packet, it reacts by sending a busy-tone packet, which overlaps with y's CTS at node x and effectively destroys the CTS.
- Therefore, x cannot start transmission and z's packet reception is not disturbed. Since the busy-tone packet is longer than the CTS, we can be sure that the CTS is really destroyed. Next, we consider the intended receiver y. If y knows about an ongoing transmission in its vicinity, it suppresses its CTS, causing x to back off.
- Node y can obtain this knowledge by either sensing the data channel or by checking whether there was some noise on the control channel immediately after receiving the RTS.
- This noise can be an RTS or CTS of another node colliding at y.
- In the other case, y answers with a CTS packet and starts to send out a busy-tone packet as soon as x's transmission has started.
- Furthermore, y sends out busy-tone packets each time it receives some noise or a valid packet on the control channel, to prevent its neighborhood from any activities.

Schedule-based protocols

- Schedule-based protocols that do not explicitly address idle listening avoidance but do so implicitly, for example, by employing TDMA schemes, which explicitly assign transmission and reception opportunities to nodes and let them sleep at all other times.
- In schedule-based protocols is that transmission schedules can be computed such that no collisions occur at receivers and hence no special mechanisms are needed to avoid hidden-terminal situations.

Disadvantages:

- First, the setup and maintenance of schedules involves signaling traffic, especially when faced to variable topologies.
- Second, if a TDMA variant is employed, time is divided into comparably small slots, and both transmitter and receiver have to agree to slot boundaries to actually meet each other and to avoid overlaps with other slots, which would lead to collisions.
- However, maintaining time synchronization involves some extra signaling traffic.

- Third drawback is that such schedules are not easily adapted to different load situations on small timescales. Specifically, in TDMA, it is difficult for a node to give up unused time slots to its neighbors.

- Fourth drawback is that the schedule of a node may require a significant amount of memory, which is a scarce resource in several sensor node designs.

- Finally, distributed assignment of conflict-free TDMA schedules is a difficult problem in itself.

LEACH

The LEACH protocol (Low-energy Adaptive Clustering Hierarchy) assumes a dense sensor network of homogeneous, energy-constrained nodes, which shall report their data to a sink node.

- In LEACH, a TDMA based MAC protocol is integrated with clustering and a simple “routing” protocol.
- LEACH partitions the nodes into **clusters** and in each cluster a dedicated node, the **clusterhead**, is responsible for creating and maintaining a TDMA schedule; all the other nodes of a cluster are **member nodes**.
- To all member nodes, TDMA slots are assigned, which can be used to exchange data between the member and the clusterhead; there is no peer-to-peer communication. With the exception of their time slots, the members can spend their time in sleep state.
- The clusterhead aggregates the data of its members and transmits it to the sink node or to other nodes for further relaying.
- Since the sink is often far away, the clusterhead must spend significant energy for this transmission.
- For a member, it is typically much cheaper to reach the clusterhead than to transmit directly to the sink.
- The clusterheads role is energy consuming since it is always switched on and is responsible for the long-range transmissions.
- If a fixed node has this role, it would burn its energy quickly, and after it died, all its members would be “headless” and therefore useless.
- Therefore, this burden is rotated among the nodes. Specifically, each node decides independent of other nodes whether it becomes a clusterhead, and therefore there is no signaling traffic related to clusterhead election.

- This decision takes into account when the node served as clusterhead the last time, such that a node that has not been a clusterhead for a long time is more likely to elect itself than a node serving just recently.
- The protocol is round based, that is, all nodes make their decisions whether to become a clusterhead at the same time and the nonclusterhead nodes have to associate to a clusterhead subsequently.
- The nonclusterheads choose their clusterhead based on received signal strengths.
- The network partitioning into clusters is time variable and the protocol assumes global time synchronization.
- After the clusters have been formed, each clusterhead picks a random CDMA code for its cluster, which it broadcasts and which its member nodes have to use subsequently.
- This avoids a situation where a border node belonging to clusterhead *A* distorts transmissions directed to clusterhead *B*.

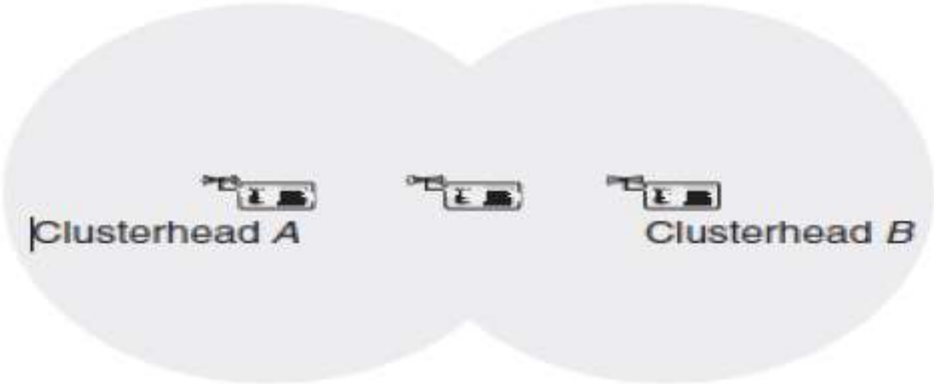

Fig 2.3.1 Intercluster Interferences

Stages of LEACH protocol:

- The protocol is organized in **rounds** and each round is subdivided into a setup phase and a steady-state phase.

Setup Phase:

- ✓ The **setup phase** starts with the self-election of nodes to clusterheads.
- ✓ In the following **advertisement phase**, the clusterheads inform their neighborhood with an advertisement packet.
- ✓ The clusterheads contend for the medium using a CSMA protocol with no further provision against the hidden-terminal problem.

- ✓ The nonclusterhead nodes pick the advertisement packet with the strongest received signal strength.
- ✓ In the following cluster-setup phase, the members inform their clusterhead (“join”), again using a CSMA protocol.
- ✓ After the cluster setup-phase, the clusterhead knows the number of members and their identifiers.
- ✓ It constructs a TDMA schedule, picks a CDMA code randomly, and broadcasts this information in the broadcast schedule subphase.

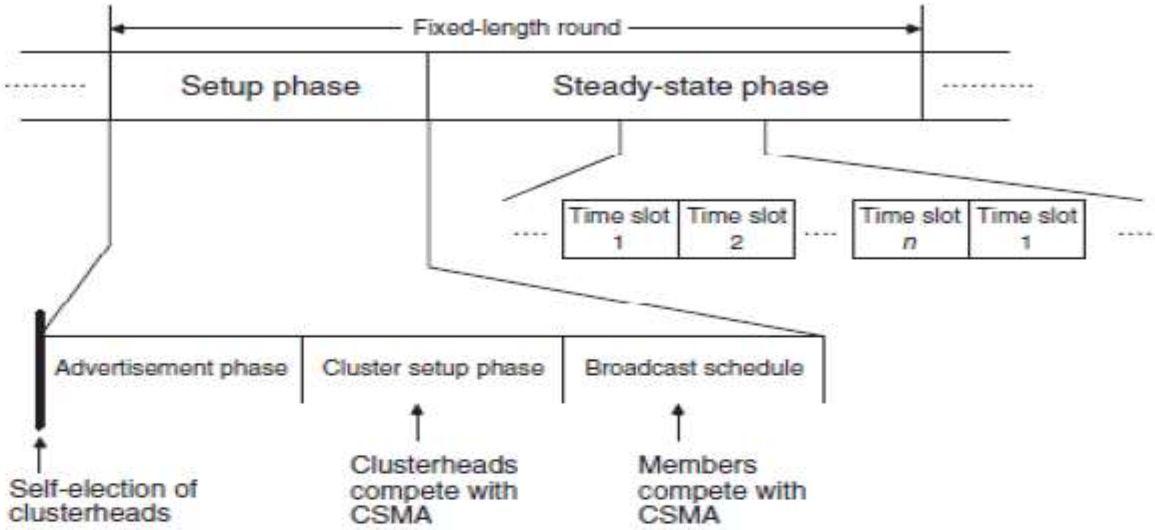

Fig 2.3.2 Organization of Leach round

Steady state phase:

- ❖ After this, the TDMA steady-state phase begins. Because of collisions of advertisement or join packets, the protocol cannot guarantee that each non clusterhead node belongs to a cluster.
- ❖ However, it can guarantee that nodes belong to at most one cluster.
- ❖ The clusterhead is switched on during the whole round and the member nodes have to be switched on during the setup phase and occasionally in the steady-state phase, according to their position in the cluster’s TDMA schedule.

Drawback:

- ➢ unable to cover large geographical areas because a clusterhead two miles away from the sink likely does not have enough energy to reach the sink at all, not to mention achieving a low BER.

Solution:

- ➢ If it can be arranged that a clusterhead can use other clusterheads for forwarding, this limitation can be mitigated.