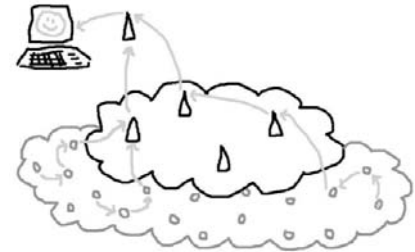


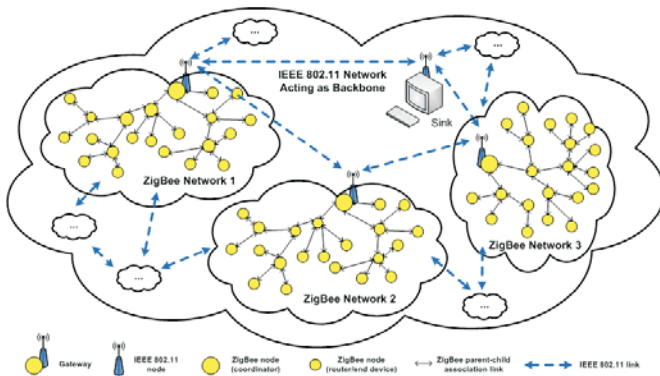
Fault-Tolerance Mechanisms for ZigBee Cluster-Tree Wireless Sensor Networks

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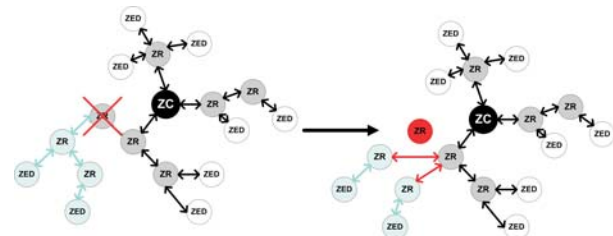


Fault-tolerance is a rising issue in Wireless Sensor Networks (WSNs) namely in critical applications which impose stringent Reliability and Timeliness requirements. In this work we proposed fault-tolerance mechanisms for overcoming ZigBee Router failures in ZigBee cluster-tree topologies. These proposals improve on the default ZigBee orphan realignment mechanism by reducing or even eliminating network inaccessibility times and guaranteeing the parent-to-child link quality above a certain threshold, increasing overall reliability.

ART-WiSe Network Structure



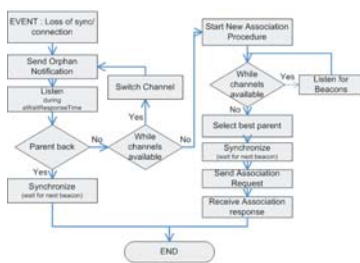
Fault Situations



ZigBee cluster-tree topology

- each device (child) is associated to another device (parent) in order to communicate with the rest of the network;
- if a parent device fails all its child devices become orphans
- the devices within the clusters depending on the failing parent are isolated from the network and are unable to communicate data.

Standard Fault-Tolerance Mechanism

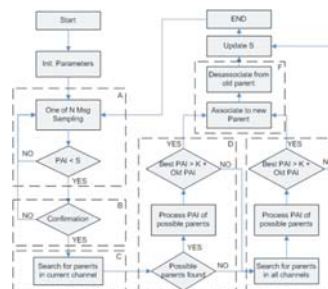


-The standard orphan realignment procedure needs two channel scans in order to connect to a new parent if the current parent fails.

-Orphan Notifications can cause collisions with beacons or with GTS transmissions

-This operation is inefficient because it is time and energy consuming.

Proactive Re-association Mechanism



-Based on a regular assessment of the parent-to-child link quality, avoiding link loss (orphaning) when there are alternative parents in the vicinity.

-If the quality goes down a certain threshold, the child device anticipates the link degradation and chooses another parent device.

-A certain link quality hysteresis between the old and the new parent must be defined in order to avoid the "ping-pong" effect.

Improvements

- The proposed mechanisms are backward compatible with the ZigBee standard; no impact on legacy nodes;
- Can be implemented as a NWK layer module with minor modifications to the IEEE 802.15.4 MAC sublayer;
- New parents are chosen more accurately using the PAI indicator;
- The proactive mechanism eliminates network inaccessibility times and improves the reliability in ZigBee cluster-tree networks;
- The proactive mechanism offers interesting potentiality for supporting mobility.

The Parent Assessment Indicator (PAI) is a weighted quality indicator used to evaluate the parent-to-child link

$$PAI = LQI \cdot (a \cdot Ei) \cdot \left(\frac{b}{Dp} \right) \cdot \left(\frac{c}{Tf} \right)$$

where:
 a, b, c - weighting factors
 LQI - Link Quality Indicator
 Ei - parent's energy indicator
 Dp - parent's depth in the cluster-tree
 Tf - parent's transmit failure rate

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