Decentralized Synchronization for Zigbee wireless sensor networks in Multi-Hop Topology

I. Tinnirello[1], L. Giarrè[2], R. Pesenti[3]

[1] Università di Palermo, ilenia.tinnirello@tti.unipa.it

[2] Università di Palermo, giarre@unipa.it

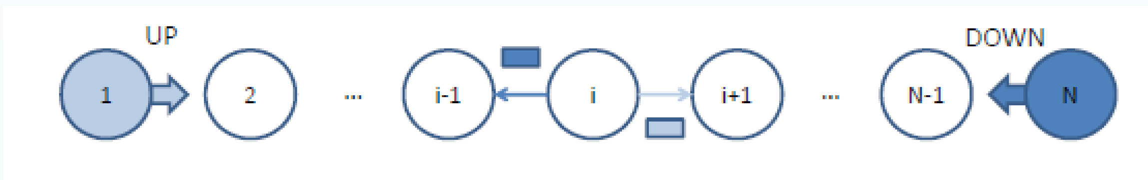
[3] Università Ca' Foscari di Venezia, pesenti@unive.it

• **Aim**: Scheduling beacon transmissions in a **Zigbee network** deployed in cluster-tree topologies.

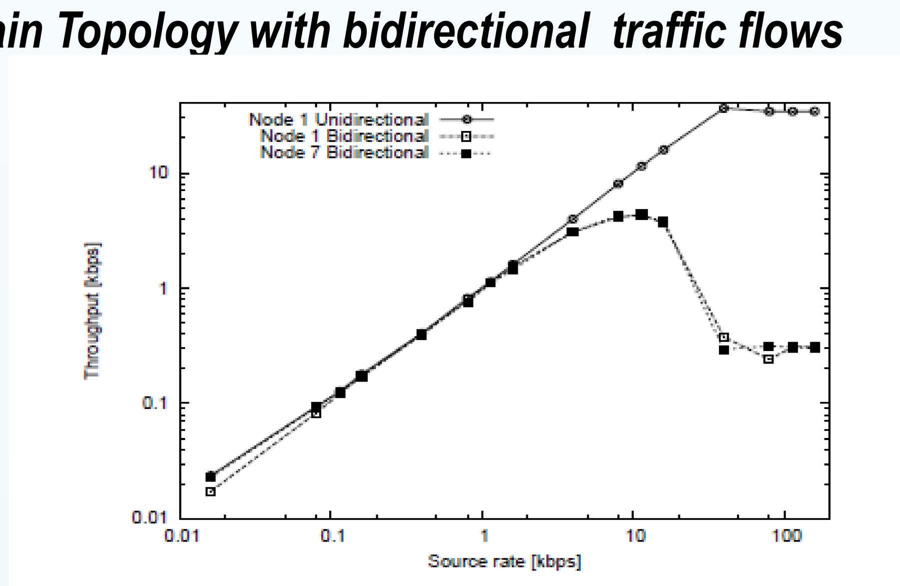
• **Main ideas:** 1) introducing regular time offsets between the **beacon transmissions** performed by coordinators in a parent-child relationship.
2) modeling the time offset tuning as a **graph coloring problem**, we define a distributed beacon scheduling policy improving the performance of the Zigbee MAC, avoiding **collisions** and enhancing the **energy saving**.

• **Solutions:** the current solution is based on homogeneous superframe durations for all the nodes, the next one will set heterogeneous activity intervals according to each cluster collision.

Zigbee Syncronization



Chain Topology with bidirectional traffic flows



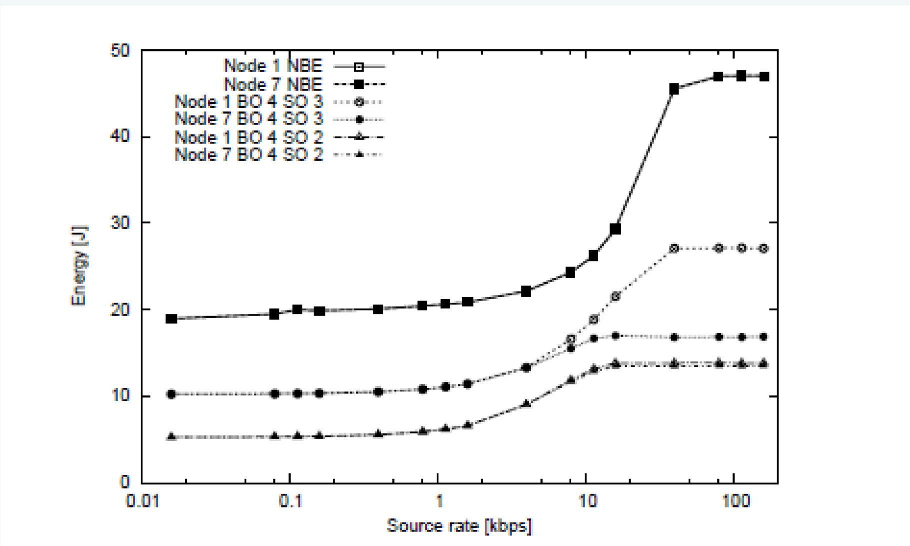
ZigBee Performance over a Chain Topology (no Beacon)

•**Problem:** During inactive periods nodes need to be synchronized in order to guarantee network connectivity.

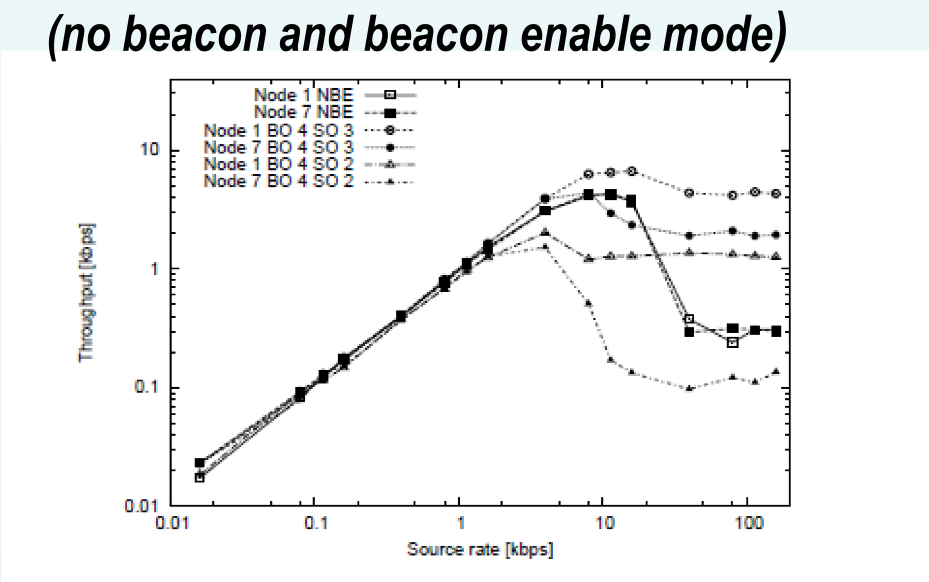
• **Possible solutions:** Star topologies - the network synchronization: all nodes are in the range of the PAN coordinator -> be synchronized to its beacon transmissions.
Multi-hop networks - several coordinators are necessary, in order to propagate a common temporal reference.

•**Our Solution**: a cluster-tree topology - each cluster is synchronized by a coordinator belonging to an higher-level cluster with an higher-level coordinator, up to the PAN coordinator).

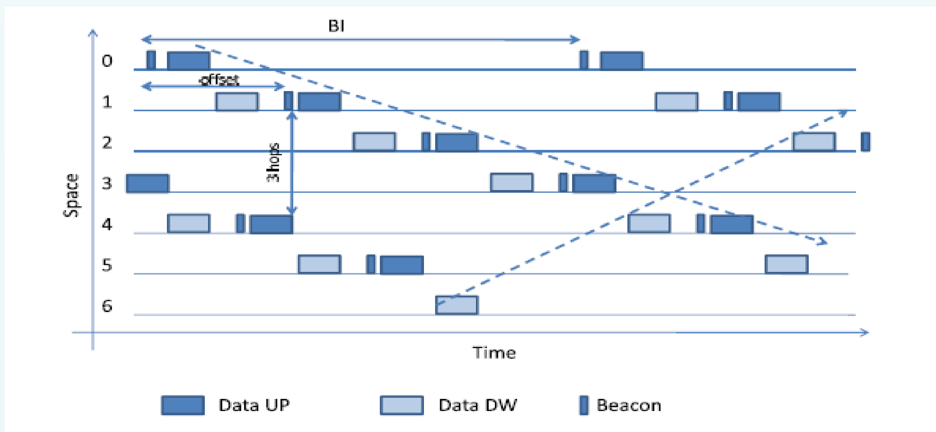
Opportunistic Syncronization in Cluster-tree Networks



Energy consumption (no beacon and beacon enable mode)



Throughput performance (no beacon and beacon enable mode)



Opportunistic beacon scheduling

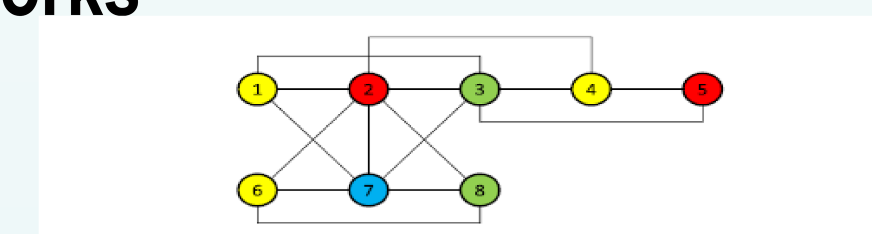
SCHEDULING BASIC IDEA

•Avoiding hidden node transmissions shifting the nodes activity periods along the chain

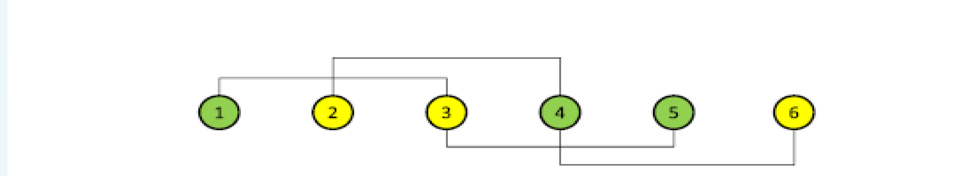
•If node i -1 is **active** during the sleeping interval of node i + 1, collisions due to hidden nodes do not occur.

•The shifting of the activity periods can be implemented in **Zigbee cluster-tree** networks.

• Enabling Zigbee routers to schedule beacon transmissions after an opportunistic temporal offset from the parent node.



Minimal coloring of the incompatibility graph (tree)



Minimal coloring of the incompatibility graph (chain)

MINIMUM GRAPH COLORING

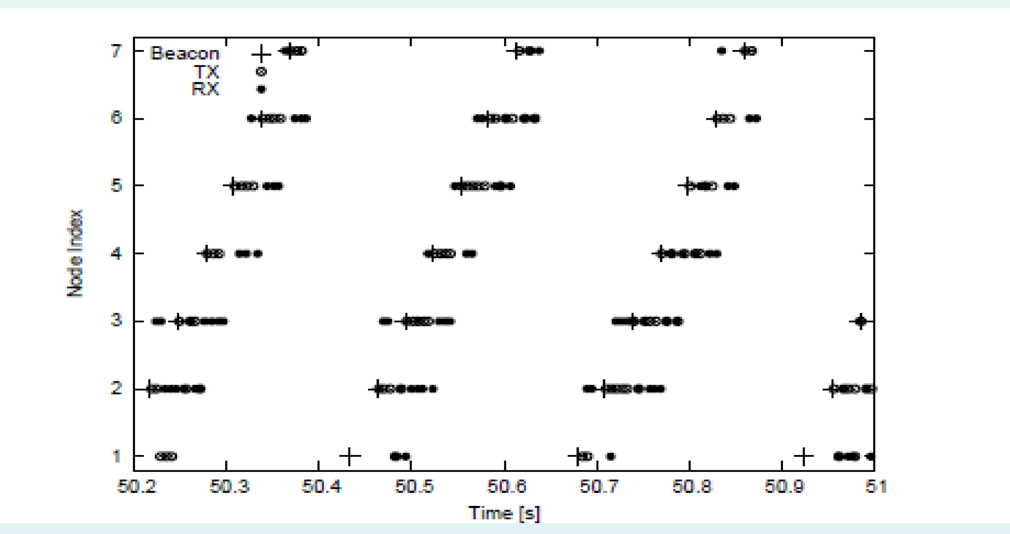
• Cyclically synchronize the node transmissions which do not interfere on a topology with a **Minimum Graph Coloring** (MGC) problem on an incompatibility graph G = (V,E)

•**V**: nodes i of the network, **E**: pairs of nodes (i, j) prevented from transmitting at the same time

• The MGC problem consists in determining the minimum cardinality of a coloring of G

• Same color node may transmit simultaneously without risking packet collisions

Performance Evaluation



Opportunistic frame transmission scheduling

Rate [kbps]	0.8	1.6	4	8	16
no offset [J]	0.371	0.677	1.689	2.960	4.781
offset [J]	0.334	0.540	1.183	2.178	3.334

Table 1. Energy in transmission at node 7.

Rate [kbps]	0.016	0.4	0.8	1.6	4
3 colors [J]	0.611	1.009	1.654	2.653	3.534
2 colors [J]	0.262	0.674	1.309	2.587	6.497

Table 2. Energy in reception at node 7.

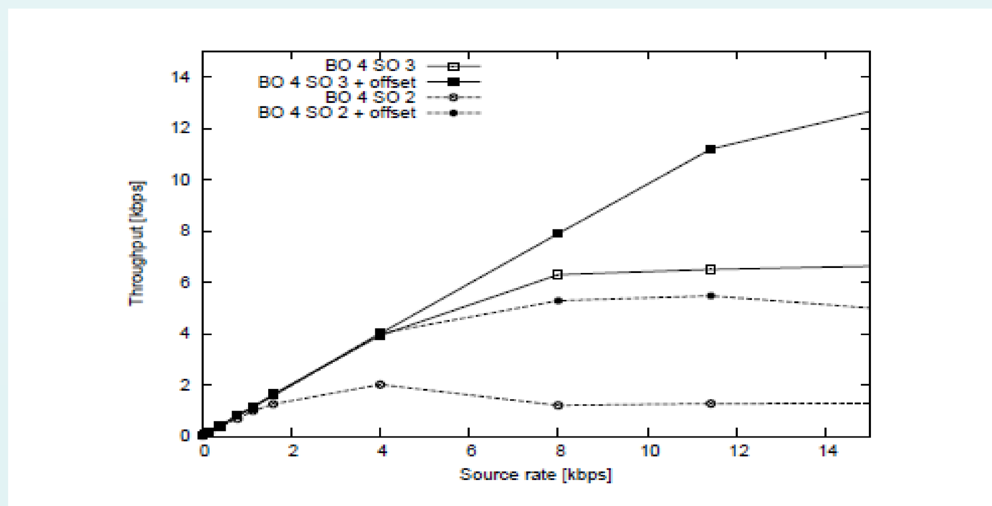
• The opportunistic beacon scheduling scheme is implemented in a NS2 simulator platform.

•A **simple chain topology** is simulated.

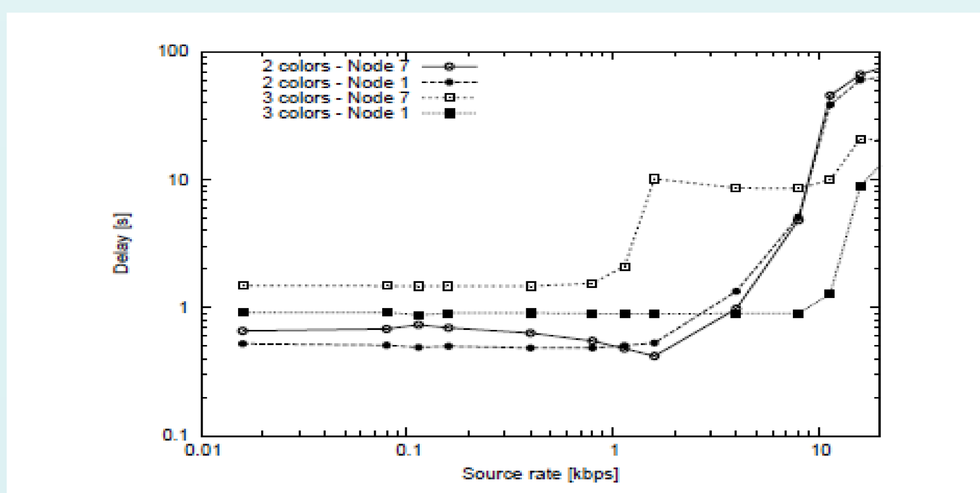
• The node coloring associated to the node index:
- all the node interferes (three colors)
- only the hidden interferes (two colors).

•**Distributed solutions** for finding the number of colors in general topologies can be done since several distributed **heuristics** for solving a graph coloring problem have been developed.

•Despite the higher throughput, the opportunistic offset scheme guarantees a **lower energy consumption** for transmissions.



Throughput performance with and without time offsets for beacon transmission



Delay Performance in a 3 colors or 2 colors beacon scheduling scheme