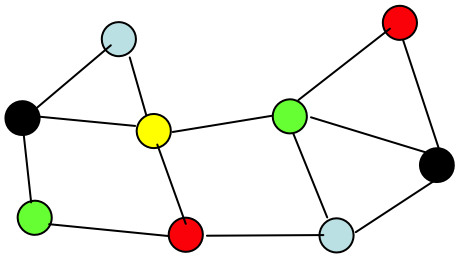
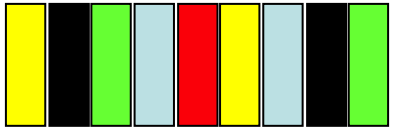
Node activity scheduling in wireless sensor networks

Saoucene Mahfoudh, Pascale Minet





RTNS 2009

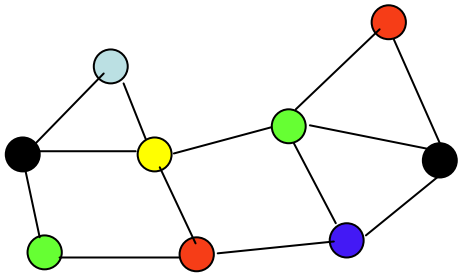
INSTITUT NATIONAL
DE RECHERCHE
EN INFORMATIQUE
ET EN AUTOMATIQUE

INRIA
ROCQUENCOURT

Outline

1. Introduction: Maximize network lifetime

2. The node coloring problem
   - Constraints
   - Complexity



3. Three-hop coloring in a tree
   - Principles and rules
   - Messages

4. Performance evaluation
   - Number of colors and messages
   - Data gathering delay
   - Adaptivity of the coloring algorithm

5. Conclusion: An efficient use of energy

Introduction

- Goal: to maximize network lifetime

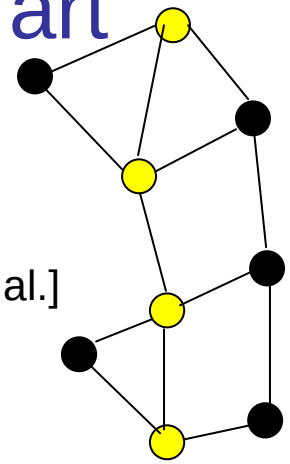


- Four classes of solutions

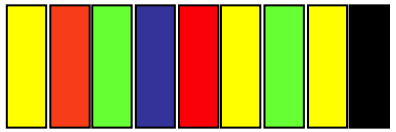
State	Power value (W)	
	802.11	802.15.4
Trans	1.3	0.1404
Recv	0.9	0.1404
Idle	0.74	0.0018
Sleep	0.047	0.000018

Topology Control	Reducing the Volume of info
Node Activity Scheduling	Energy Efficient Routing

Node activity scheduling: state of the art



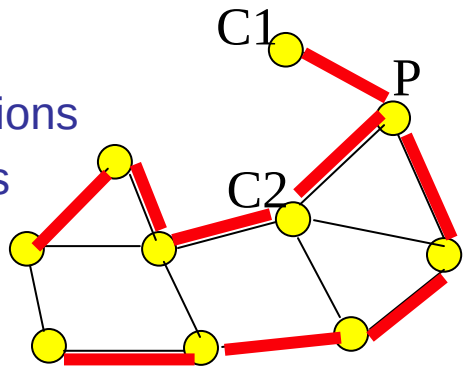
- Solutions building the connected set of active nodes
  - Centralized solutions with disjoint active sets or not [Cardei et al.]
  - Distributed solutions based on connected dominating sets [Simplot et al.]
- CSMA/CA based solutions
  - S-MAC with periodic listen & sleep
  - T-MAC with an adaptive length of the active state, D-MAC to reduce network latency
  - The use of RTS/CTS reduces protocol efficiency in case of short frames
- TDMA based solutions
  - TRAMA [Rajendran et al.] Neighborhood discovery + schedule exchange + adaptive election selecting the transmitter and receiver for each time slot => complex
  - FLAMA [Rajendran et al.] Designed for data gathering applications and based on a tree structure



- Hybrid
  - Z-MAC does not support the immediate acknowledgement of unicast transmissions

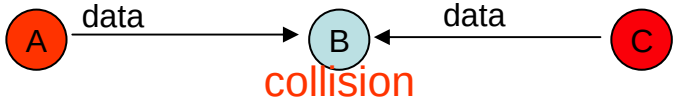
Node coloring: the problem

- Constraints
  - Supports both unicast and broadcast transmisions
  - Supports immediate acknowledgement of unicast transmisions
  - Minimizes the delay needed to collect data from all sensors

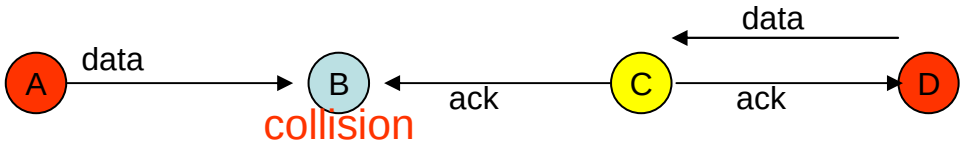


- Goal of k-hop coloring
  - To color each network node such that two nodes with the same color can transmit simultaneously without interfering and using the smallest number of colors
  - This a NP-complete problem [Garey79]
  - Heuristics based on node degree exhibit the best performances

- Three-hop coloring is required



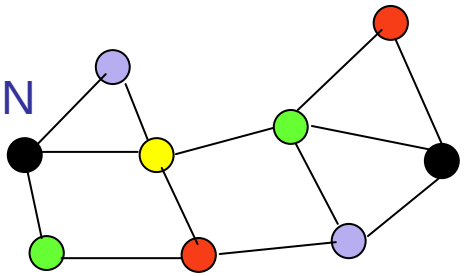
at least 2-hop coloring is needed



2-hop coloring is not sufficient

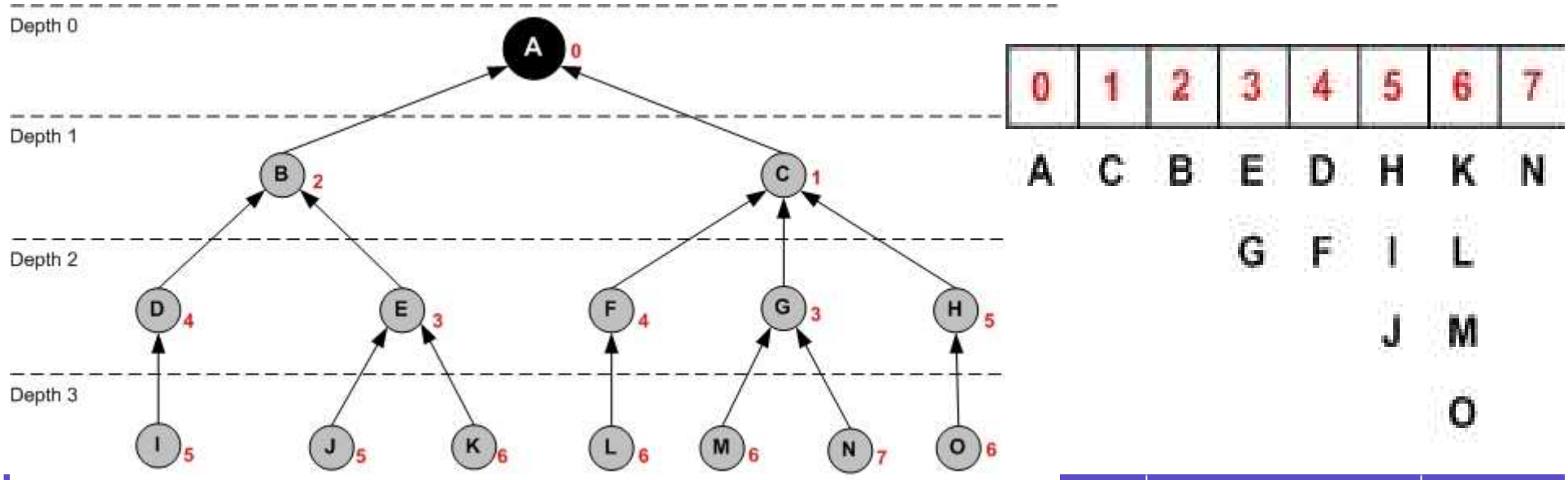
Three-hop coloring in a tree

- Neighbor^3(N) the neighborhood up to 3 hops from N
- Desc(N) the descendants of N in the tree
- *Priority(N)* = $|Desc(N)|$



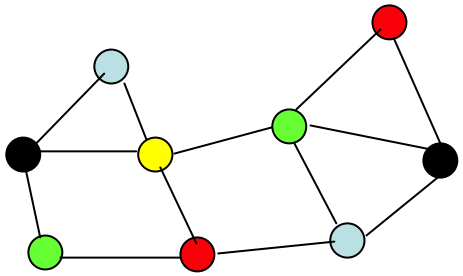
❑ Coloring rules

- Any node *N* colors itself iff all nodes in Neighbor^3(N) with a higher priority are already colored, the color taken is the smallest color unused in Neighbor^3(N) but higher than the color of its parent



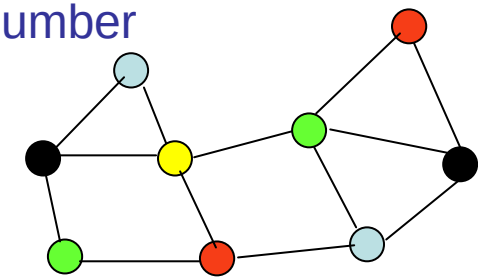
Three-hop coloring in a tree

- Principles
  - Any node must be awake
    - in its slot to transmit its messages
    - in the slots of its 1-hop neighbors to receive their messages
  - It sleeps the remaining time
  - Slots are assigned to nodes according to their color
  - A node transmits after its children in the tree

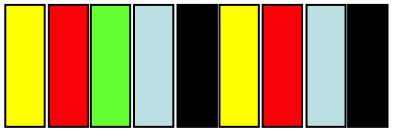


Three-hop coloring in a tree

- The Color message
  - a node N sends a message Color to its 1-hop neighbors containing
    - its identifier, priority, color and sequence number
    - for each of its 1-hop neighbor,
      - their identifier, priority, color and sequence number
    - and for each of its 2-hop neighbor
      - their identifier, priority and color

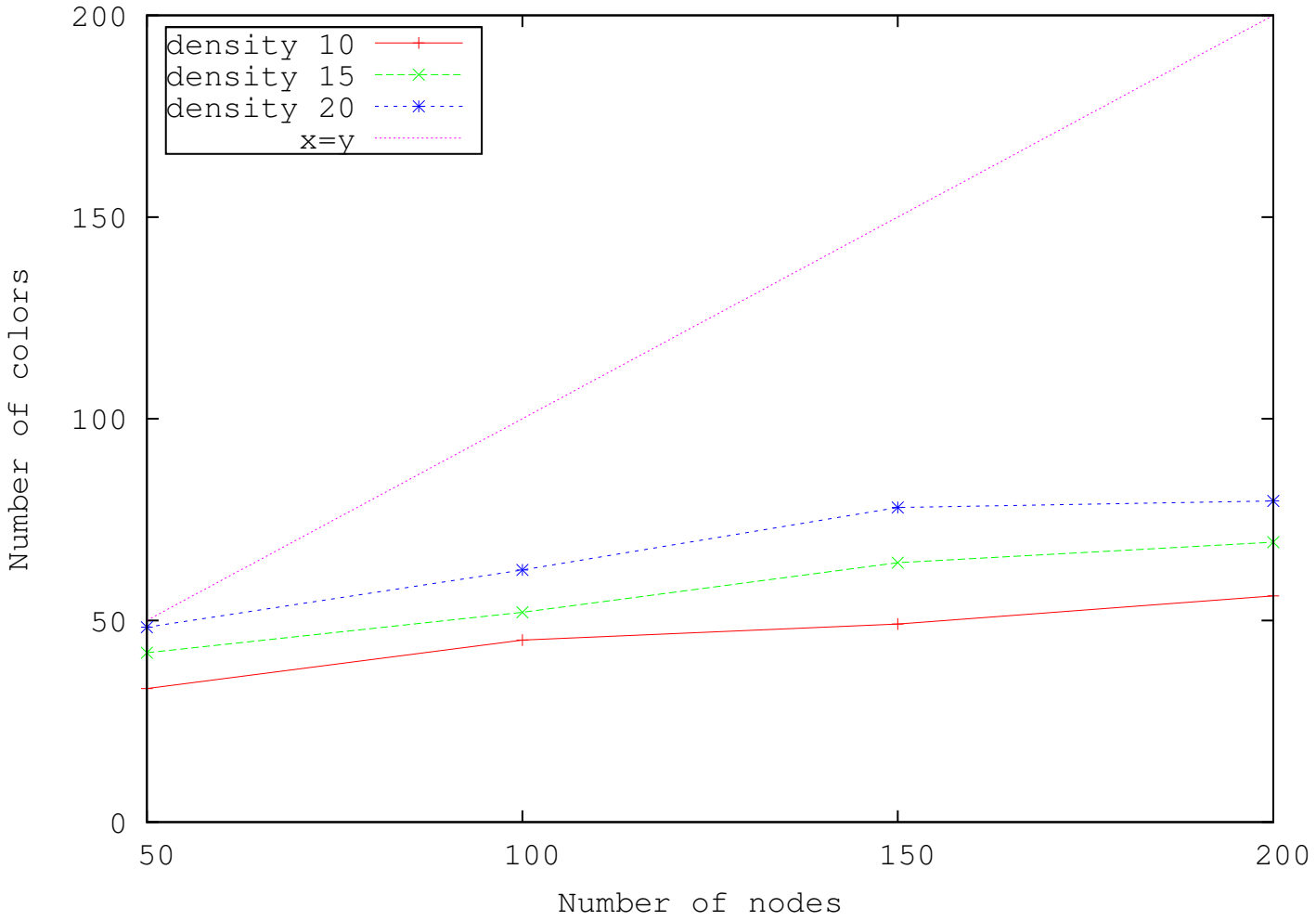


- The MaxColor message
  - a node N sends a message MaxColor to its parent in the tree containing
    - its identifier
    - a sequence number
    - the maximum color used by this node and its descendants



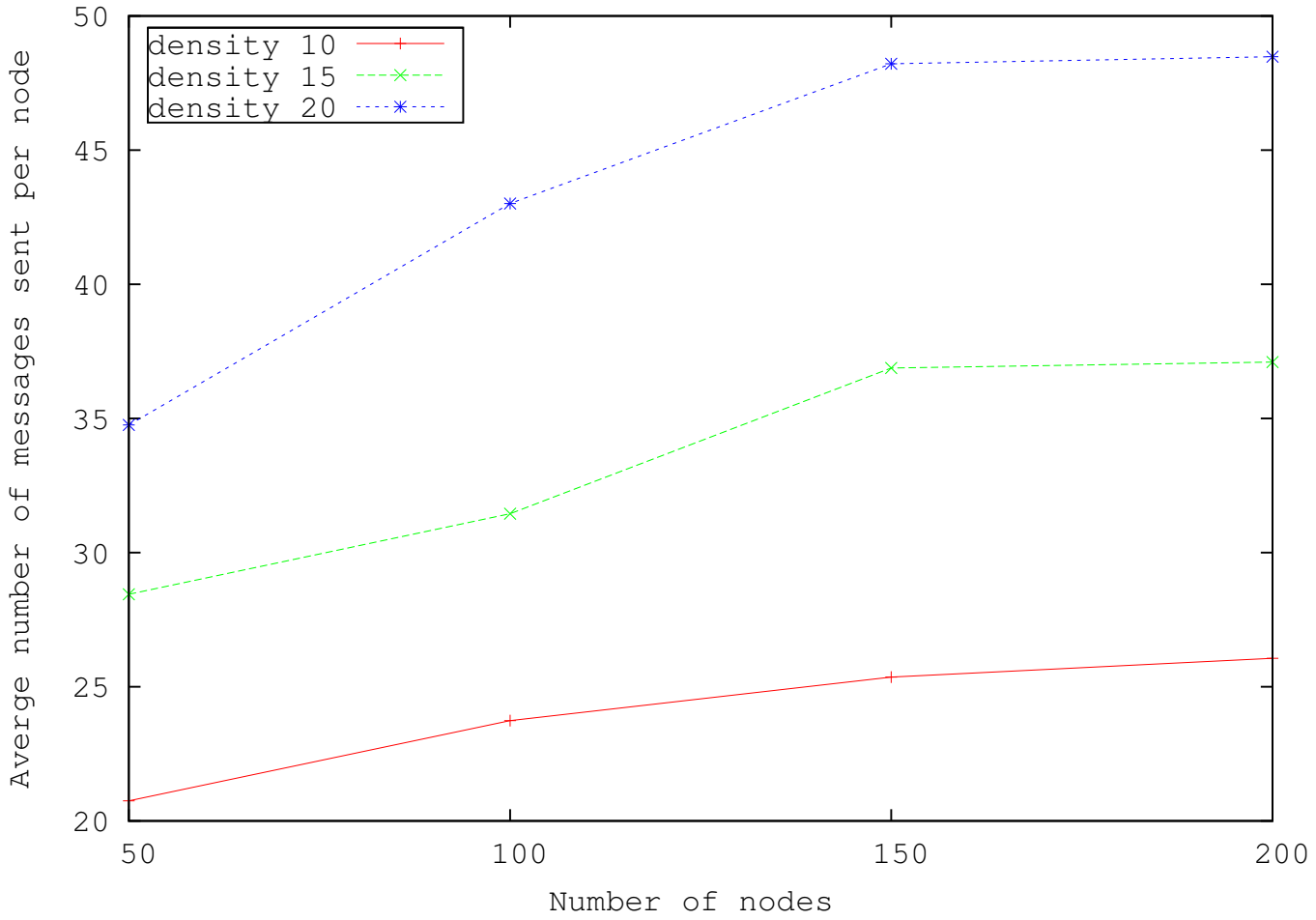
Performance evaluation of 3-hop coloring in a tree

- Number of colors used



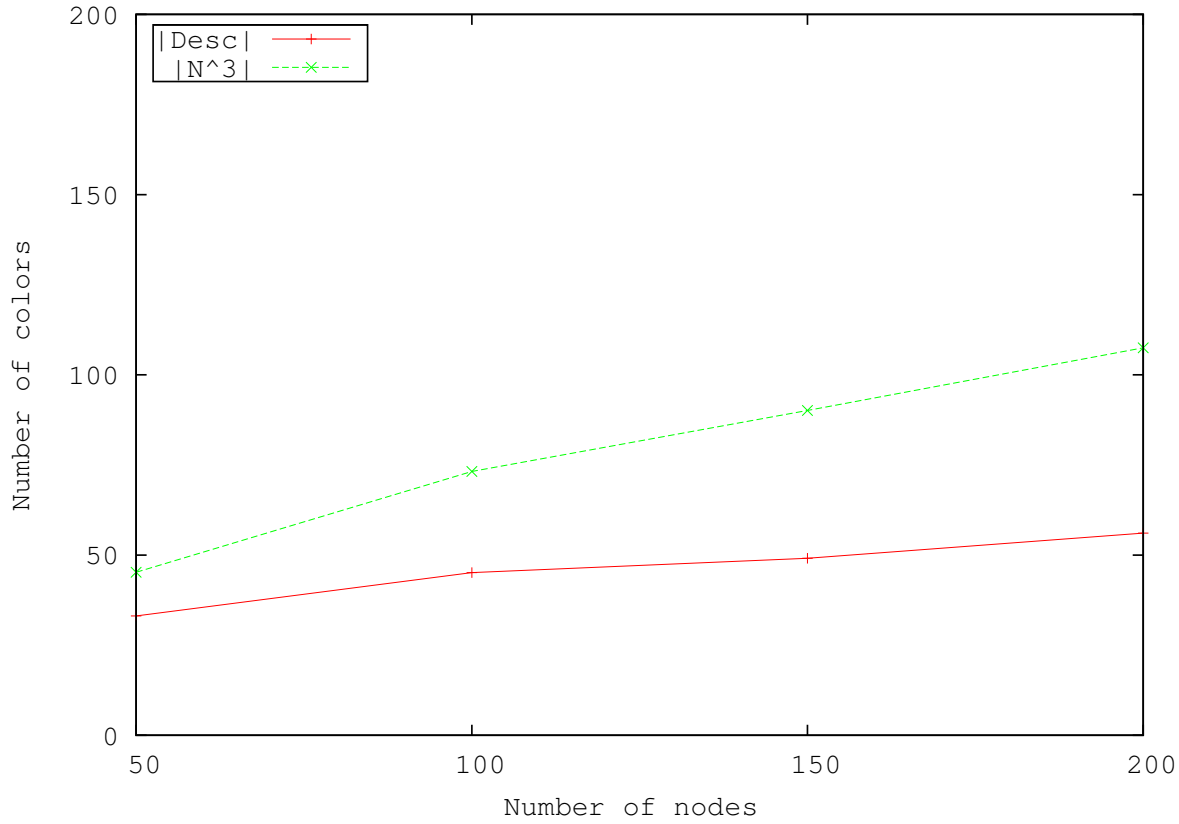
Performance evaluation of 3-hop coloring in a tree

- Average number of messages sent per node



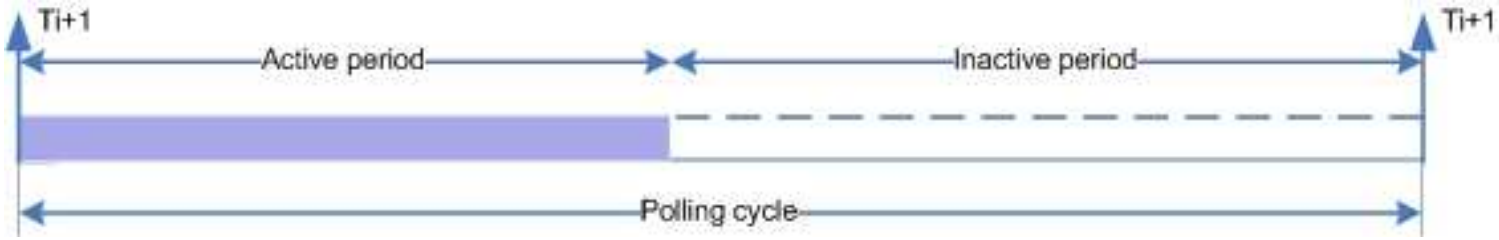
Performance evaluation of 3-hop coloring in a tree

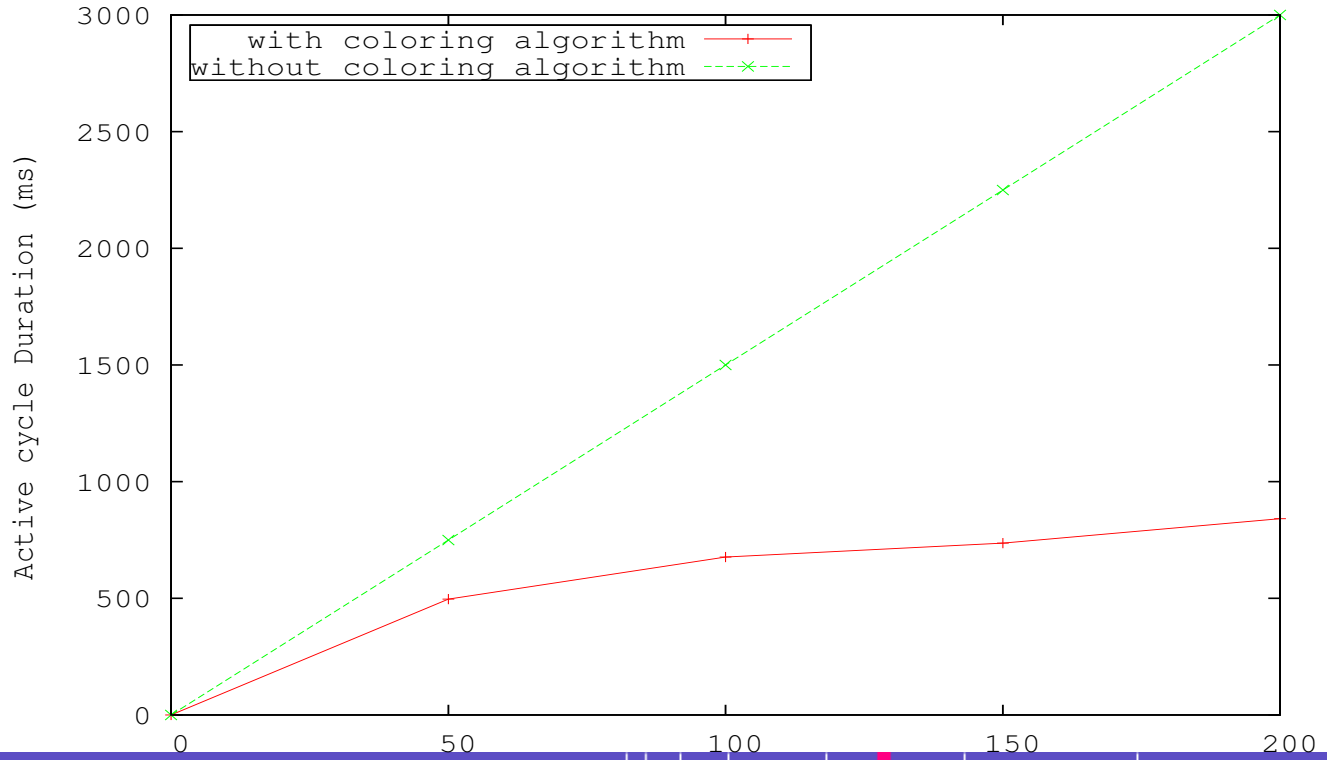
- A comparison with 3-hop coloring proceeding level by level



Performance evaluation of 3-hop coloring in a tree

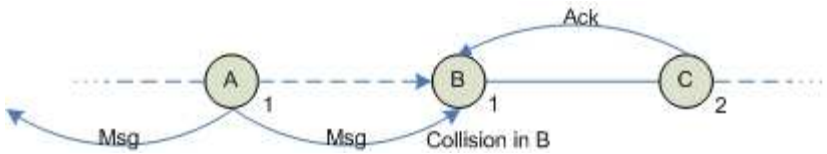
- A comparison with classical TDMA: Active period duration

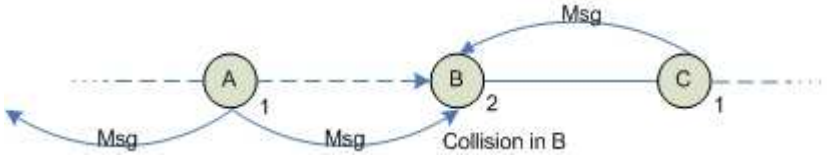




Adaptivity of the coloring algorithm

- Color conflicts
  - created by:
    - unidirectional links
    - changes in propagation conditions
    - late node arrivals
    - node mobility
  - cannot be avoided
  - are tolerated if the msg is received by its intended destination

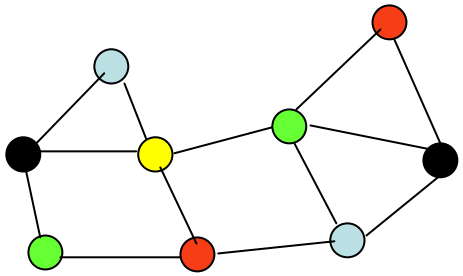




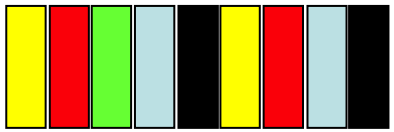
- Detection/resoltion of color conflicts
  - cross-layering approach with the MAC layer
    - joint work with the university of Clermont Ferrand (LIMOS)
    - MAC detects the conflict
    - MAC notifies SERENA of the conflict
    - SERENA solves the conflict

Conclusion

- We have proposed a distributed and localized solution for data gathering applications that
  - allows nodes to sleep while ensuring network connectivity
  - minimizes the data gathering delay and ensures time consistency of the collected data



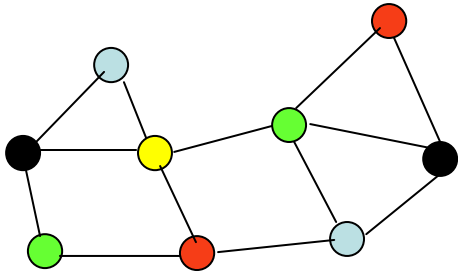
- This solution consists of
  - Three-hop coloring
  - Slot assignment based on node color



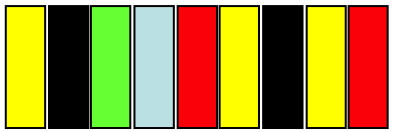
- A node
  - transmits during the slots assigned to its color
  - receives during the slots granted to its 1-hop neighbors
  - sleeps the remaining time

Conclusion

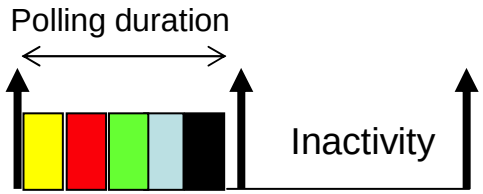
- Benefits brought by coloring



  - Bandwidth :
    - spatial reuse with colors
  - Energy:
    - a node is awake only when it transmits or is susceptible to receive



  - Delay:
    - the polling duration is shorter
    - data from all sensors are collected in a single cycle
    - collected data are fresher => a time consistent view of these data



Conclusion

- This solution contributes to a more efficient use of energy by decreasing the amount of energy lost in Idle and Interference states