ALBA: An Adaptive Load-Balanced Algorithm for Geographic Forwarding in Wireless Sensor Networks

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Geographic Forwarding

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- No need for complex topology information
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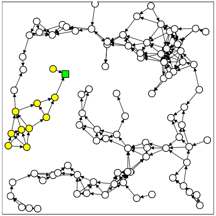
Cons of GF

- Presence of dead-ends, due to connectivity holes
  - Previous solutions (e.g., GEDIR, GPSR, MACRO) require high overhead for bypassing holes

Yellow nodes are the only nodes that can delivery their packets to the sink using GF (through the "yellow brick route")



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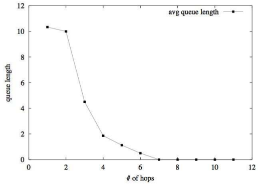

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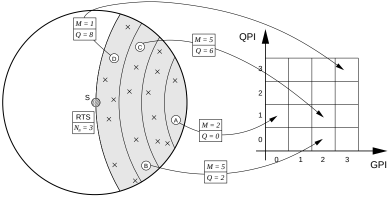
ALBA-R solves these problems

Features of ALBA-R

ALBA-R (**A**daptive-**L**oad **B**alanced **A**lgorithm–**R**ainbow) achieves the followings goals:

- Defines a node awake/asleep schedule
- Minimizes the number of hops required to reach the sink through a greedy relay selection scheme
- Distributes traffic evenly in the network, favoring low congested nodes and avoiding overloaded regions
- Optimizes channel access efficiency through an adaptive transmission of "*batches of packets*"
- Re–routes packet when connectivity holes occur

Regular ALBA-R Operations



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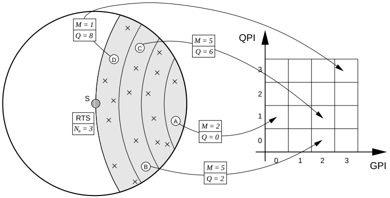

- ALBA-R assigns to relay nodes a Queue-based Priority Index and a Geographic Priority Index (QPI and GPI)
- The QPI measures the goodness of a node for forwarding a packet

$$QPI = \lceil (Q + N_B)/M \rceil - 1$$

1. Packets are sent in bursts
2. $Q \rightarrow$ Queue occupancy
3. $N_B \rightarrow$ Number of expected packets (in a burst)
4. $M \rightarrow$ Average length of a burst that can be sent by the relay node

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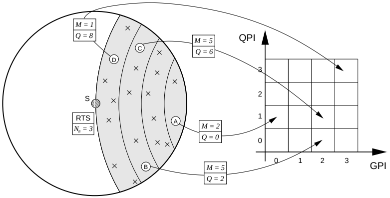

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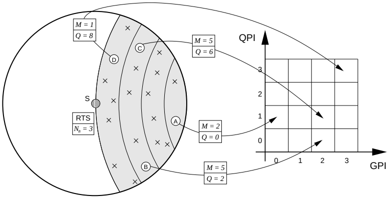

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- The relay is selected based on QPI
  - in case of multiple relays with the same QPI, the GPI breaks the tie
- Example: Node A is nearer to the sink ($GPI = 1$) but has a low QPI ($M = 2$); node B, is farther but has greater reliability (M) and comparable queue occupancy (Q); B has a greater QPI than A

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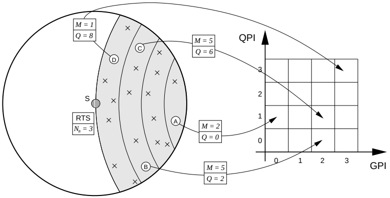

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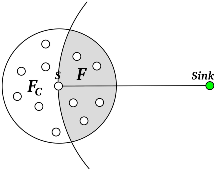
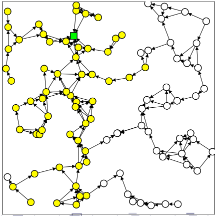
ALBA-R improves scalability & decreases congestion

Re–routing
Basic Concepts

- Re–route packets stuck in a dead-end in order to increase the percentage of delivered packets
- Nodes have colors and try to reach the **“yellow brick route”**

- Initially all nodes are yellow → they look for relays in F





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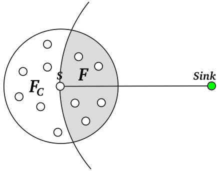
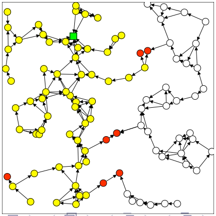
- No relays in F → the node changes to red and it looks for (yellow, red) relays in F_C





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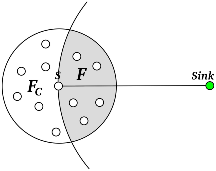
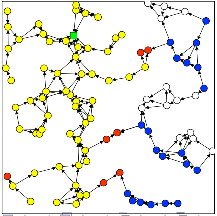
- No relays in F_C → the node changes to blue and it looks for (red, blue) relays in F





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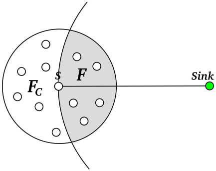
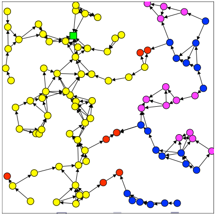
- No relays in F → the node changes to purple and it looks for (blue, purple) relays in F_C





Re–routing

Provable Results

Theorem (Rainbow is loop–free)

The Rainbow extension to ALBA always finds loop–free routes to the sink.

Theorem

Under the hypothesis that nodes are aware of existing relays in F or F_C, all nodes exhibiting no less than h alternations on route toward the sink assume the color h in a finite time.

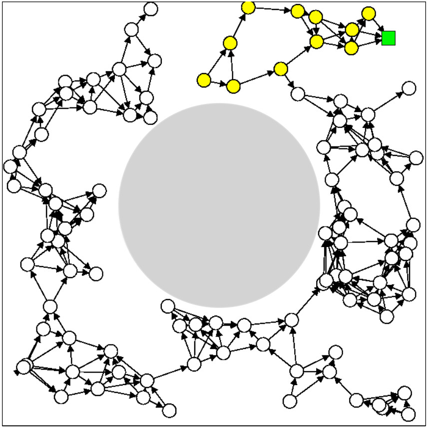
For finding the “yellow brick route” (a route to the sink)

- No additional overhead is required
- The process is very fast

Simulation Results (NS-2)

Scenarios

- **Nodes:** 100 to 600, deployed in a square of side 240m
  1. Randomly and uniformly
  2. With a hole of radius 80m, placed at the center



Simulation Results (NS-2)
Scenarios

- **Nodes:** 100 to 600, deployed in a square of side 240m
  1. Randomly and uniformly
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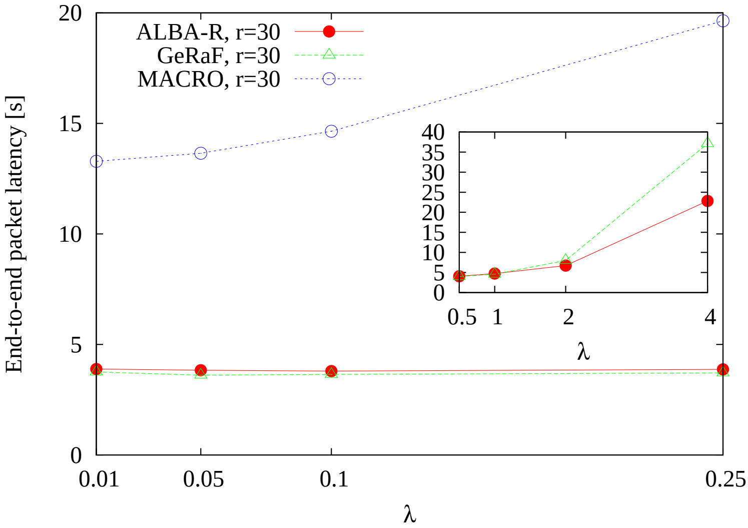
- **Sink:** randomly positioned
- r = 30m. Duty-cycle 0.1
- *First Order Energy Model*
- *Poisson Traffic Arrival* ($\lambda = \{0.01, ..., 4.0\}$); sources randomly selected
- Comparison with GeRaF and MACRO
- Metrics:
  1. End-to-end packet latency
  2. Packet delivery ratio
  3. Node energy consumption

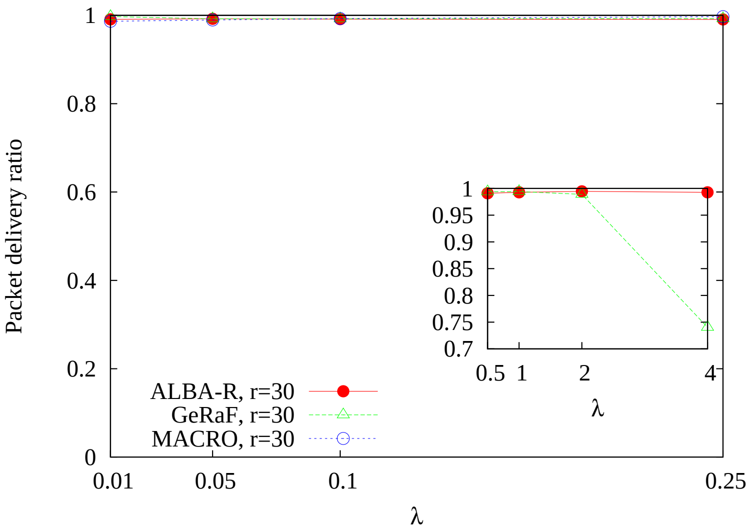
ALBA-R vs. GeRaF and MACRO 1/3

End-to-end packet latency ($n = 600$)



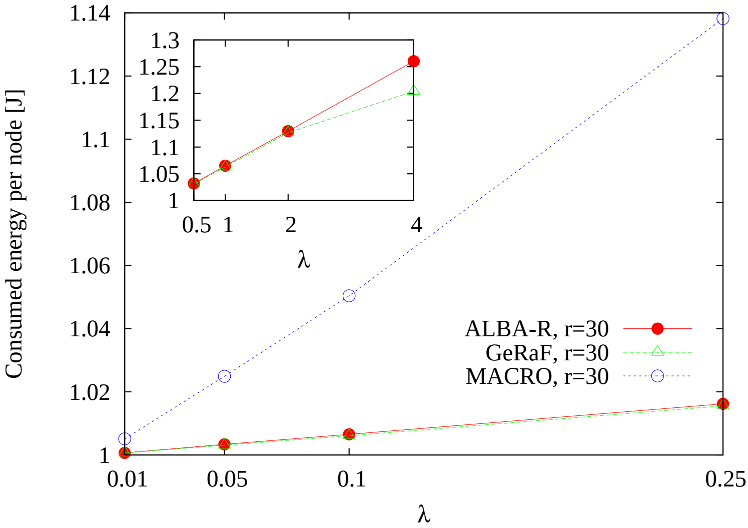
ALBA-R vs. GeRaF and MACRO 2/3

Packet delivery ratio ($n = 600$)



ALBA-R vs. GeRaF and MACRO 3/3

Node energy consumption ($n = 600$)



ALBA-R: Sparse Scenarios

- High packet delivery ratio!!!

Avg. degree	*ALBA-R*			
	h=1	**h=2**	**h=3**	**h=4**
$d = 4.9$ $(n = 100)$	43%	74%	88%	**93%**
$d = 9.8$ $(n = 200)$	82%	**100%**	−−	−−

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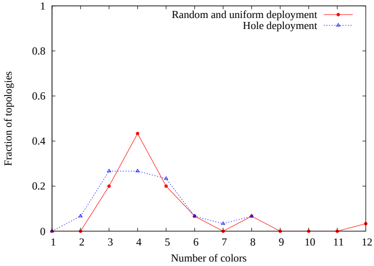
- Needed number of colors depends on nodal degree



Conclusions

- Due to load-balancing and effective packet delivery, as traffic load grows, ALBA-R continues to work properly in terms of all relevant metrics
- ALBA-R is a promising and very simple approach to dealing with dead-ends in sparse sensor networks scenarios

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- ALBA-R is a promising and very simple approach to dealing with dead-ends in sparse sensor networks scenarios
- The algorithm is simple, thus suitable to implement on nodes with limited computational capabilities
- A test-bed using TinyOS on Tmote Sky and Eyes platforms is currently under development