# A Testbed-based Performance Investigation of an Energy-efficient, Load-Balancing Protocol for Geo-forwarding in Wireless Sensor Networks

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This demonstration concerns Geographic Forwarding (GF) as an effective solution for data dissemination (from sensors to a *sink*) in wireless sensor networks (WSNs). With the sole knowledge of a node's own location information as well as that of its one-hop neighbors, GF has been shown to be scalable and energy effective.

The GF protocol we consider here, termed ALBA–R [1], meets the desirable requirements of 1) imposing low overhead; 2) delivering packets to the sink even when the network topology in not a unit disk graph (UDG), 3) being capable of performing reliable data delivery in presence of significant localization errors, and 4) being capable of delivering packets to the sink also for those nodes that have no neighbors in the geographical direction of the sink (*dead ends*).

The aim of this demonstration is that of showing the ALBA–R capabilities of finding routes to the sink dynamically, in presence of nodal faults, and of re-routing packets that are stuck in a dead-end, thus making efficient and practical the use of Geographic Forwarding (GF) in real WSNs. At the same time, we show how ALBA–R is resilient to localization errors and it is able to route all packets to the sink even when the estimated location of a node is considerably distant from it actual position.

**Demonstration Settings**. A number of EYES sensor nodes [2] (see also http://www.eyes.eu.org) are deployed in order to form a multi-hop wireless networks. For the sake of considering localization errors, each node is assigned *physical coordinates* (its real position) and *estimated coordinates* (its position as estimated by the node by means of some localization protocol). Also, each node follows an asynchronous awake/asleep schedule. (A blinking led shows when a node is awake.)

A special node, called the *inspector*, directly connected to a laptop, is used for three important operations: *Node programming*, *network configuration* and *network monitoring*. In particular, protocol code is transferred (wirelessly) from the laptop to each node through the inspector. Furthermore, a specific network topology (including the section of the sink) can be manually or randomly generated using the laptop, and communicated to the nodes. Network monitoring allows us to visualize on the laptop the state of each node in the network as well as the path followed by data packets in real-time, thus being able to control route formation and the protocol adaptiveness to changes in the topology. In this case the inspector acts like a "sniffer." Thanks to the inspector no node involved in the demonstration is directly connected to the laptop.

We developed a **software tool**, running on the laptop, to aid in the programming of the sensor nodes and to collect real-time information about the network status (which nodes are asleep or awake, which node has a packet, packets progress toward the sink, etc.). More specifically, our software tool: 1) performs functions of network configuration, 2) shows the topology of the network indicating the current forwarder nodes and relevant nodal parameters, and 3) shows charts and curves related to the collected metrics.

We demonstrate three fundamental characteristics of ALBA–R. 1) *Fault-tolerance*. ALBA–R finds paths to the sink in an on-line fashion, even when some nodes are (manually) disconnected from the network. If a path to the sink exists ALBA–R is always able to find it. 2) *Resilience to connectivity holes*. ALBA–R can find paths to the sink for those nodes that are dead ends or on a branch to a dead end. 3) *Resilience to localization errors*. A localization error is introduced (i.e., the physical and estimated coordinated are different) and we show that ALBA–R is capable of finding paths to the sink for every node in the network even in this (realistically common) case.

Our software tools makes our demonstration interactive. Those attending the demo can participate in network configuration (deciding a specific topology, selecting the sink, etc.) as well as in removing some of the network nodes (for topology changes) and in selecting localization errors.

Besides a table for the demo and support for the accompanying poster, we also require power outlets for a couple of laptops.

## References

[1] P. Casari, M. Nati, C. Petrioli, and M. Zorzi, "Efficient Non Planar Routing around Dead Ends in Sparse Topologies using Random Forwarding," in *Proc. of the IEEE International Conference on Communications, ICC 2007*, Scotland, UK, 2007.

[2] P. J. M. Havinga, , S. Etalle, H. Karl, C. Petrioli, M. Zorzi, H. Kip, and T. Lentsch, "EYES—energY Efficient Sensor networks," in *Proceedings of the 4th IFIP TC6/WG6.8 International Conference on Personal Wireless Communications (PWC) LNCS 2775, M. Conti, S. Giordano, E. Gregori and S. Olariu (eds.)*, Venezia, Italy, September 23–25 2003, pp. 198–201.