| Title | Dynamic reassignment of aggregation point for network load balancing |
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| Publication date | 2008-01-30 |
| Publication information | Ruzzelli, Antonio G., Raja Jurdak, and G. M. P. (Greg M. P.) O'Hare. "Dynamic Reassignment of Aggregation Point for Network Load Balancing," 2008. |
| Conference details | The 5th European conference on Wireless Sensor Networks (EWSN 2008), Bologna, Italy, January 30th-31st and February 1st, 2008 |
| Item record/more information | http://hdl.handle.net/10197/4544 |

# Poster Abstract: Dynamic Reassignment of Aggregation Point for Network Load Balancing

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***Abstract*—Some wireless sensor network applications forward data to a central aggregation point (AP) that is responsible for processing, aggregating, and relaying information to the base station. For example one node in a body sensor network is responsible for aggregating data and then forwarding only useful information to an external ambient network. This procedure leads to asymmetry in the AP node energy consumption due to (1) higher forwarding activity for nodes in the vicinity of the AP and (2) higher AP activity relative to nodes. Existing approaches of load and energy consumption balancing employ either suboptimal periodical route changes or random AP rotations. In contrast, we propose a novel technique[1] to enable a dynamic reassignment of the sensor AP according to a novel cost function that is based on relevant node energy metrics. We show that the technique lead to a network lifetime extension up to 50% for applications, such as medical, that require power-intensive tasks at the AP and for high traffic applications.**

## I. Introduction

Most sensor network applications are based on the forwarding of data to a resourceful node, namely aggregation point (**AP**), that collects, processes and relays relevant information. Typically, an AP performs power intensive tasks such as in-network processing and longer range transmissions for reaching other clusters, external ambient networks or a base station. A common assumption considers the AP having great energy resources. In reality, the AP is also a battery operated device and can be a common sensor node whose depletion would cause a premature network disconnection.

By way of example, sensor-based medical systems consist of (1) some body-sensor nodes located on patients, and (2) ambient-sensor nodes deployed in the environment. In order to collect data from the patient, the body-sensor nodes form a small tree-based network and nominate a node as AP to serve as a gateway and to communicate to the ambient-sensors. The AP performs data aggregation to relay only useful information to the user or other nodes in the vicinity of the patient that forward the data to the doctor for analysis. The node activity and energy consumption, which is greatest at the AP, is somehow proportional to the number of node's children. This results in its earlier battery depletion for the AP and some nodes in the networks.

in order to balance the energy consumption and to extend the operative network lifetime, we describe a novel technique of REassigning the Central AP (**RECAP**) in sensor networks. RECAP is a reactive mechanism that operates either when the AP or when another sensor node experiences a significant energy depletion. The decision is made by means of a cost function that combines energy state parameters polled from the network. Although the design of RECAP is independent of any particular communication protocol, our performance evaluation utilises the IEEE 802.15.4 [2] MAC/Phy layer and the TICOSS [1] forwarding technique that provides coordinated sleeping and routing support.

[1]The technique is patented by University College Dublin

## II. Related Work

To date, there have been limited attempts to balance network energy consumption and prolong network lifetime through an opportunistic reassignment of the AP. Cluster Based Routing Protocol (CBRP) [6] exemplifies a class of protocols which initially selects APs according to lowest ID or highest connectivity. Subsequent changes in APs are only triggered for highly mobile situations where two APs move within range of each other or when node mobility causes certain nodes to wander out of the coverage areas of all APs.

Another class of protocols, typified by LEACH [5] and PEGASIS [7] attempt to balance energy consumption among a homogeneous set of sensor nodes through a random or geographic rotation of the AP. The recent work in [4] also adopts a periodic random rotation policy of the AP for a hierarchical sensor network that includes ground-based sensor nodes and some AP nodes that communicate with unmanned aerial vehicles (UAV). While RECAP targets similar network topologies, the use of node energy metrics in RECAP ensures that the choice of the next AP is the most appropriate to prolong network lifetime.

## III. The RECAP technique

RECAP builds on TICOSS and IEEE 802.15.4 to provide a dynamic AP reassignment. TICOSS provides coordinated sleeping to streamline the flow of packets to and from the AP. The 802.15.4 initialization starts with the network association of the AP represented by the 802.15.4 PAN coordinator. In turn, each node performs network association. Concurrently, the TICOSS routing assigns short IDs to nodes and divides the network in timezones which identify the number of hops to the AP [1].

Should the AP determine a significant energy depletion, it sets a timer and broadcasts a **State_Request** to all the nodes that reply with a **State_Indication**, which contains their node state figure **F**, as detailed in section III-A. In RECAP, nodes filter state indications by forwarding only an higher energy figure than the previous **F** forwarded. When the timer fires, the AP sends a **Handover_Request** message to the designate AP that in turn will broadcast a **Handover_Time_Confirm** message. This will ensure that all nodes will re-synchronise simultaneously to the new AP. RECAP relies on a global time synchronization procedure, such as The Flooding Time Synchronization Protocol [3]. Following the reassignment, the packets traveling across the network are seamlessly routed to the new destination. The technique also provides an override function that enables nodes with high-energy consumption to notify the AP of their state that will trigger the reassignment. Regarding robustness, RECAP provides a reassignment sequence number in each control packet to allow the detection of stale packets. Should a communication failure happen a node can still re-synchronise to the new AP by requesting any **RECAP_Update** packet from the neighbouring nodes.

### A. The Cost Function

A node's energy consumption is primarily due to the transceiver communication activity ($E_c$), the processing activity ($E_p$) and the sensing activity ($E_s$). In general, $E_p$ is negligible relative to $E_c$ and $E_s$. Furthermore, $E_c$ at a node consists of the energy for transmitting the node's own generated data, $E_t$, and the energy consumed in forwarding other nodes' data, $E_f$. For the AP, $E_f$ is substituted with $E_{ext}$ that represents the energy consumed to transmit to an external network (e.g. wifi) which involves a higher transmission power. *The cost figure F is based on a weighted sum of (1) the total battery level B(t) at time t normalized to the initial battery level B; (2) The forwarding energy $E_f$ or the external energy ($E_{ext}$), (3) the sensing energy $E_s$ and transmitting energy $E_t$ normalized to $B_r(i)$* as follows:

$$F(t) = \alpha[B(t)/B] + \beta[E_f(t)/B_r(i)] + \gamma[(E_s + E_t)/B_r(i)] + \delta[E_{ext}/B_r(i)]$$

Where $E_{ext} \neq 0$ and $E_f = 0$ for the AP and $\alpha + \beta + \gamma = 1, \gamma = \delta$. Such weights can be tuned in accordance with application requirements, network topology and user's choice of either privileging node balancing or single node lifetime (e.g. a larger $\alpha$ corresponds to a more energy greedy node).

### B. Simulation Results

An initial assessment of RECAP with the OmNet++ simulator considers the *network lifetime* as *the time when the first node in the network is depleted*. The setup consists of a series multihop networks of 30 nodes randomly located. Figure 1 shows the network lifetime achieved by varying the average node data rate. Figure 2 shows the network longevity benefits of RECAP relative to the single AP and random AP assignments with respect to the ratio of AP external transmitting power Pext and node transmitting power Ptx. Recalling that the transmitting power ($Pt$) is affected exponentially by the distance, i.e. $Pt \sim D^{\alpha}$, $2 \leq \alpha \leq 4$ in air, the range of ratios corresponds to an external transmitting distance of AP that is between about 3.3 and 6.2 times the sensor transmitting distance. Such a range reflects real application scenarios such as the medical sensor networking described in section I. The results clearly show an extension of the operative network lifetime from 20% to about 50% with respect to a single AP and in between 12% and 40% with respect to random reassignment. As the average node data rate increases, the AP is exposed to a higher load. Therefore reassigning the AP has a greater impact on the network lifetime. The results show an improvement of the operative network lifetime that is more effective in case of large external transmitting power ratio.

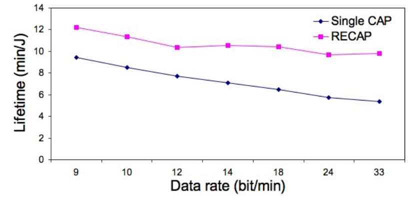


Fig. 1. Network lifetime for different node data rate

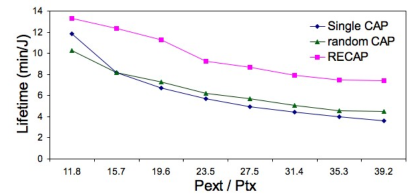


Fig. 2. The network lifetime with respect to different values of extra AP transmission power

## IV. Conclusion

This paper has presented RECAP, a novel technique for energy/load balancing of wireless sensor networks. RECAP enables a dynamic reassignment of the central aggregation point according to a node cost function. RECAP is a flexible technique that provides several tunable parameters, such as significant energy depletion $E_d$, aggregation factor $A_g$, network size and network topology, for tailoring network behavior according to application requirements. Investigating the impact of two such parameters, the simulation results have shown that network lifetime, over both the static and random AP cases, increases greatly with respect to both the data rate and the external transmission power ratio.

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