# Chapter 11
# MAC and Routing Integration in Wireless Sensor Networks

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## ABSTRACT

*Wireless Sensor Networks are a promising way to interconnect smart objects sensing and acting on the environment, enabling the Internet of Things. However, this kind of network is particularly constrained: nodes have limited energy reserve, their CPU and memory resources are limited, and the radio bandwidth is very low. After exposing the main approaches for the routing and MAC layers, the authors explain why they must be jointly optimized. They explain why a metric reflecting the radio link quality is necessary and how it should integrate different criteria in layers 2 and 3. The authors also introduce a new architecture based on IEEE 802.15.4 and RPL so that both protocols work in symbiosis. Finally, they conclude detailing some open problems in this research area.*

## INTRODUCTION

Wireless Sensor Networks (WSN) have attracted much interest in the last few years. The IETF Routing Over Low-Power lossy Networks (ROLL) working group has already targeted several key applications:

- Industrial environments to monitor assembly lines or machines;
- Building automation to control the HVAC, lighting to detect fire, etc.
- Healthcare so that the patient can safely stay at home while being connected with the medical staff;
- Urban Sensor Networks to control urban lighting, noise and air pollution, monitor the containers filling.

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Since the Machine2Machine market is expected to quickly grow in the next years, it is essential to design efficient protocols for this kind of environment. Unfortunately, existing solutions designed for wired networks cannot be applied as is in WSN, since we face to specific constraints that must be tackled in the networking stack:

1. Energy optimization: each node is battery-powered and has to save energy to prolong the network lifetime;
2. Scalability: a WSN may comprise hundreds of nodes. The topology is not hierarchized unlike wired networks;
3. Limited constraints: a node has very limited resources (CPU, memory), and protocols must maintain a very limited number of states;
4. Low-cost: for some applications (e.g. home automation), smart object have to be cheap to be integrated everywhere;
5. Fault-tolerance: a node may fail suddenly (e.g. cheap and faulty hardware, energy depletion). The network must react in an autonomous way;

A Wireless Sensor Network comprises several smart objects (also called sensors and/or actuators or PAN). One sink may collect the data, or as this is more and more frequent, a collection of gateways interconnects the WSN area to the Internet. Since the network may be deployed to cover a large area, transmissions may be multihop, i.e. smart objects have to forward packets after having constructed the routes dynamically.

In this chapter, we focus on the MAC and routing problems in WSN, and particularly on their cross-layer integration. Because of the specific constraints in WSN, we must implement a cross-layer approach: energy has to be optimized in all the layers. In the same way, information has to be mutualized in order to reduce the memory fingerprint. Since an exhaustive study is unpractical for such a vast topic, we illustrate this issue by examining first the metric definition problem, and then focus on the integration of the two emerging standards in WSN.

This chapter is organized as follows. We first introduce very shortly existing MAC and routing protocols in WSN, since we must understand how they work before putting the different pieces of the puzzle together. Then, in the next section, we discuss on the metrics we should use in the layers 2 and 3: could we use the same metric to measure the MAC and routing efficiency? Finally, we study the specific problem of the IEEE 802.15.4 and RPL integration (two major standards for WSN). Can they be executed without any close integration? How can we optimize their performances?

## BACKGROUND

We present here the different MAC and routing protocols existing in Wireless Sensor Networks. Then, we expose why cross-layer is required in this kind of networks, and the current mainstream approaches.

### MAC Protocols

Medium Access Control is in charge of distributing bandwidth to contending nodes: which node is allowed to transmit one frame, and when. Wireless Networks present several constraints:

- Low bitrate: because they consume little energy, radio components in wireless sensor networks offer a low bandwidth (typically 250kbps in IEEE 802.15.4). The MAC layer has to distribute efficiently this bandwidth: even with a small amount of data, congestion may appear quickly;
- Sleeping: to save energy, a smart sensor should switch-off its radio: as demonstrated by Feeney et al. (2001), this represents the only way to save energy efficiently;

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