

## Chapter 78

# Energy-Efficient MAC Protocols in Distributed Sensor Networks

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### ABSTRACT

*As an enabling network technology, energy efficient Medium Access Control (MAC) protocol plays a vital role in a battery-powered distributed sensor network. MAC protocols control how sensor nodes access a shared radio channel to communicate with each other. This chapter discusses the key elements of MAC design with an emphasis on energy efficiency. Furthermore, it reviews several typical MAC protocols proposed in the literature, comparing their energy conservation mechanism. Particularly, it presents a Collaborative Compression Based MAC (CCP-MAC) protocol, which takes advantage of the overheard data to achieve energy savings. Finally, it compares the performance of CCP-MAC with related MAC protocols, illustrating their advantages and disadvantages.*

### INTRODUCTION

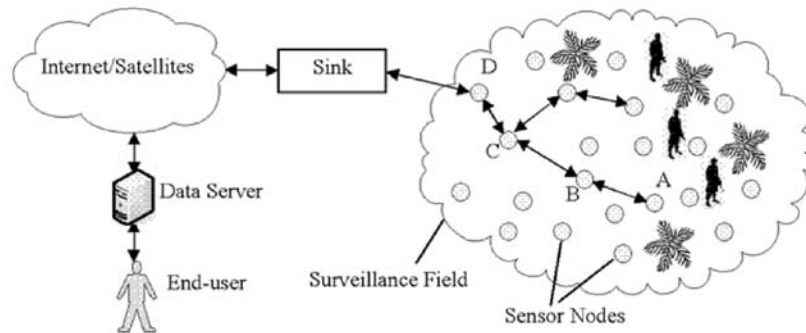
Wireless Sensor Networks (WSNs) consist of large numbers of small, resource constrained sensor nodes that communicate in a multi-hop network (Akyildiz, et al., 2002; Willig, 2006). By commanding these distributed sensor nodes, WSNs provide an economical solution for a variety of potential applications, including environmental monitoring, enemy tracking, emergency alerting

and so on (Zhang & Cao, 2003). Monitoring the volcanic activities is one of the representative applications for WSNs (Sohraby, et al., 2007). Figure 1 shows the WSNs' common communication architecture under field monitoring application.

Deployed far away from the permanent energy source available, WSNs depend on its own battery energy to carry out the information collecting and transmission. Differing from traditional wireless networks, WSNs have to take the energy efficiency into account. Although the average power consumptions of sensor nodes are as little as

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*Figure 1. WSNs' communication architecture for field surveillance application*



100mW given the state of arts in this domain, the operation efficiency are strongly depending on the specific application scenario and network deployment.

There are also quite a few energy harvesting methods, including solar energy, wind energy and vibration energy. However, these methods can only provide a small amount of energy about 20mw or less to power these sensor nodes (Mainwaring, et al., 2002; Raghunathan, et al., 2002). The idea of maintaining and recharging these sensor nodes is impractical with regard to the expenses of keeping the massive distributed sensor network operational. Another alternative is to employ energy efficient data delivery and processing algorithms to manage the network operations. The energy efficient MAC protocols can help address this issue.

As an underlying protocol, energy conscious MAC protocols for WSNs have attracted a plethora of research interests, such as S-MAC (Ye et al, 2004), T-MAC (Dam & Langendoen, 2003), B-MAC (Polastre, et al., 2004), SCP-MAC (Ye, et al., 2006) and RI-MAC (Sun, et al., 2008), etc. However most of these contention based schemes still keep the root of traditional IEEE 802.11 protocol (Xu & Saadawi, 2002) and mainly focus on the energy-delay tradeoff (Demirkol, 2006; Muneeb, 2006). With regard to the data correlation in WSN, an innovative protocol so-called CC-MAC (Vuran & Akyildiz, 2006) was proposed to reduce

the data transmitted to the sink nodes under the help of a subset of representative sensor nodes. On the other hand, there are many traditional TDMA based protocols, like LEACH (Heinzelman, et al., 2000). This kind of MAC protocol has a natural advantage of energy conservation, since the duty cycle of the radio is reduced and there is no contention-introduced overhead and collisions. However, relying on the fundamental cluster based topology, TDMA protocols must restrict the nodes to communicate within the cluster. Managing inter-cluster communication and interference is an ad hoc task.

Depending on the coordinated sleep/wakeup mechanism at the underlying physical and link layer, almost all of contention based MAC protocols mainly utilize the overhearing avoidance technique to achieve significant energy savings. Actually when a sensor node overhears the data packets which do not intend for itself, before going back to sleep, it has to perform the RTS/CTS, MAC header or a long preamble check operation which already consumes considerable energy. Therefore the overhearing avoidance under a high deployment density and heavy load network also will result in a significant waste of energy. Quiet differing from prior works, CCP-MAC (Hu, et al., 2009; Hu, et al., 2011) which will be discussed in this chapter, acts as another class of MAC protocol. Instead of simply avoiding or discarding all overhearing, CCP-MAC takes advantage of the

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