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Abstract of Doctoral Dissertation

Study of Medium Access Control (MAC) Layer Energy Efficient Protocol for Wireless Ad-Hoc and Sensor Networks

省電力無線アドホックセンサネットワークの MAC レイヤプロトコルに関する研究

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Summary

Wireless sensor networks (WSNs) is evolving areas of research due to its wide range of application in various domains, including health-care, assisted and enhanced-living scenarios, industrial and production monitoring, control networks, and many other fields. These application fields of wireless sensor network can be divided into three main categories: Monitoring space (applications in monitoring urban air quality, glaciers, forests, mountains etc); monitoring objects (home application, building application etc); and monitoring interactions between objects and space (monitoring environmental threats like floods and volcanic activities etc.).

Wireless Sensor Networks (WSNs) consists of a large number of wireless sensor nodes that are deployed randomly. The sensor nodes are typically small, and equipped with low-powered battery. Unlike other wireless networks, it is generally impractical to charge or replace the exhausted battery. Since prolonging lifetime of the sensor nodes is very important, energy efficiency becomes the most important attribute and a critical design objective for the design of the MAC layer protocol for energy constrained WSNs. In addition, the throughput and latency performance is also important for several sensor network applications. To simultaneously achieve the seemingly contradictory goals, this thesis proposes novel mechanisms for medium access control layer (MAC) protocols to optimize the energy consumption while maintaining high throughput and low latency.

In our work, first of all, we do an extensive analysis of diverse design choices for communication protocol from the energy consumption standpoint which motivates the design choices for our proposed energy efficient MAC protocols. We investigate four important design principles to achieve energy efficiency. They are namely application specific design vs general purpose design; cross layer architecture vs layered architecture; cluster-based vs cluster-less design; and deliberation of the energy model of the targeted hardware i.e. considering the accurate and thorough energy model of the different components of the targeted hardware. In our first proposed mechanism, we present Intelligent Hybrid MAC (IH-MAC), a novel low power with quality of service guaranteed medium access control protocol for wireless sensor networks (WSNs). IH-MAC achieves high energy efficiency under wide range of traffic load. IH-MAC protocol achieves high channel utilization during high traffic load without compromising energy efficiency. IH-MAC does it by using the strength of CSMA and TDMA approach with intelligence. The novel idea behind the IH-MAC is that, it uses both the broadcast scheduling and link scheduling. Depending on the network loads, the IH-MAC protocol dynamically switches from broadcast scheduling to link scheduling and vice- versa in order to achieve better efficiency. The scheduling is done in IH-MAC with a novel decentralized approach where the nodes locally use the clock arithmetic to find the time slot, allocated for it. Furthermore, IH-MAC uses Request-To-Send (RTS), Clear–To-send (CTS) handshakes with methods for adapting the transmit power to the minimum level necessary to reach the intended neighbor. Thus, IH-MAC reduces energy consumption by suitably varying the transmit power. The typical example that we consider to evaluate of our proposed protocol is a building equipped with a WSN. The duty of sensor nodes are to monitor the power consumption of the appliance in the building. Another duty of the nodes is to work as a smoke detectors,

and report alarms to fire monitoring hubs. So, in case of the communicating the later kind of data, it is desirable to ensure lowest possible latency. Our proposed IH-MAC protocol guarantees shorter latency for this type of critical and delay-sensitive packets. And thus IH-MAC is able to serve for the applications of wireless sensor network where it is really needed to ensure the priority services for the critical data.

In our second work, we present a novel medium access control protocol, (Efficient MAC with Parallel Transmission, named as EP-MAC) for wireless sensor networks (WSNs) which is basically based on TDMA approach. The proposed EP-MAC protocol achieves high energy efficiency and high packet delivery ratio under different traffic load. The power of CSMA is used in order to offset the fundamental problems that the stand-alone TDMA method suffers from i.e., problem like lack of scalability, adaptability to varying situations etc. Novel idea behind the EP-MAC is that, it uses parallel transmission concept with the TDMA link Scheduling. EP-MAC uses the methods for the transmission power adjustment i,e, uses the minimum level power necessary to reach the intended neighbor within a specified BER target. This reduces energy consumption, as well as further enhances the scope of parallel transmission of the protocol. Simulations show that both the IH-MAC and EP-MAC protocols are energy efficient MAC layer protocol for WSNs. Moreover they significantly outperform other duty cycling protocols in terms of latency and throughput as well.