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Anatomizing the Robustness of Multichannel MAC Protocols for WSNs: An Evaluation under MAC oriented Design Issues impacting QoS

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Abstract*—Traditional Wireless Sensor Networks (WSNs) were single channel-based and mainly focus on energy-efficiency and scalability. Therefore, they may readily suffer from issues such as bandwidth insufficiency, interference, jamming and so on. With the deployment of dense sensor networks and the outset of multimedia technology, the intensity of these issues was further aggravated. To address those challenges, the researchers had employed multichannel technology in WSNs with a focus on increasing bandwidth/throughput while decreasing collision/congestion, delay and energy consumption. For ascertaining a comprehensive exploration of multichannel technology in WSNs, this paper discusses in detail the important issues that are indispensable for providing high-performance and achieving Quality of Service (QoS) in multichannel WSNs. Further on, it evaluates a variety of multichannel MAC protocols under the stated design issues and classifies them into the categories highly, medium and least robust, based upon *"Aggregate of the Design Issues"* addressed by the corresponding multichannel MAC protocols for WSNs. Besides on the basis of channel access mechanism, each main category is sub-categorized into Time Division Multiple Access (TDMA), Carrier Sense Multiple Access (CSMA), Composite and Other-Novel categories whereby the functionality of the MAC protocols is briefly discussed along with relevant pros & cons. In the end, future research directions are anticipated and a reasonable conclusion is put forth.

***Index Terms*—Multichannel, MAC, Multichannel Wireless Sensor Networks, Multichannel Smart Applications, Multichannel Design Issues & Challenges, Quality of Service and Micro Electro Mechanical Systems**

I. Introduction

Wireless sensor networks are composed of tiny sensing devices which are equipped with small memory, processor, sensing unit, battery and a transceiver for data exchange [1]. These tiny devices are deployed in a challenging terrain either in a planned manner or dropped from the air [2] and may self-organize in ad-hoc manner [3] [4]. In this way, they may perform division of labor and may help human beings in environment monitoring in an efficient manner. Doing so, WSNs may perform a variety of duties such as dealing with natural calamities [5], defending against sniper attacks [6], monitoring environment [7] and oceans [8], accomplishing structural observation [9], performing target tracking [10], monitoring patients remotely in disaster regions [11] [12], health-care [13] [14] such as tele-medicine prescription [15], disaster management, combat/surveillance operations, industrial exploration [16] and so on. The survey defines relevant acronyms in Table I.

Traditionally, energy conservation (network lifetime maximization) was considered the primary design goal in WSNs [17] [16] whereas throughput, delay and fairness were regarded as secondary design objectives [17]. However, the sensitivity of a variety of applications towards low-bandwidth and high-delay has motivated researchers to focus on secondary design objectives as well e.g. structural health monitoring applications [18] may sample at high rate for identifying structural damages in buildings and therefore, require more bandwidth. Similarly, the researchers have realized that WMSNs [19] [20] [21]-based applications (such as near-shore video monitoring [22]) could perform appropriately, if the inherent sensing network fulfills bandwidth and delay requirements of real-time delay-sensitive multimedia data.

The bandwidth and delay requirements are very challenging to be accomplished appropriately using the traditional single channel approaches. This is due to the fact that the single channel approaches do not allow parallel transmissions and may suffer from interference in one-hop and two-hop neighborhoods. To address this issue, multichannel techniques are proposed which increase network throughput by affording parallel transmissions (through allocating dissimilar frequencies to adjoining nodes) [23] [24], avoiding interference (by allocating orthogonal channels to interfering nodes), minimizing delay (by performing fresh data delivery) [24] and extenuating interference, jamming and congestion (by providing more robust channels for communication) [24]. Therefore, multichannel techniques provide high performance to WSNs and outperform the single-channel approaches [25]. Additionally, the availability of radio chips such as CC2420 [26] and CC2520 [27] have practically assisted in materializing multichannel technology in WSNs. At current, numerous multichannel techniques are devised for WSNs which may handle various issues such as jamming [28] [1], interference [29] and help in reliable data transmission [30].

It is evident from the above discussion that the multichannel approach provides robustness and QoS in terms of throughput, delay, reliability and energy efficiency across a sensor network. These QoS-based metrics can be ascertained by carefully considering the underlying MAC-oriented design issues discussed in Section IV. In other words, if MAC-based design issues are contemplated exhaustively, they may result in achieving QoS

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