DUAL STAGE CONTENTION RESOLUTION MAC PROTOCOL USING IMPLICIT PIPELINING

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Abstract: In wireless networks, the collision cost is much higher than wired networks since a station cannot detect collision until a transmission is over and the expected acknowledgment does not come back. Therefore, more efficient contention resolution algorithms are desired for wireless networks to reduce the collision probability among contending stations. In this paper, we propose to apply "pipelining" techniques to the design of multiple access control protocol so that channel idle overhead could be (partially) hidden and the collision overhead could be reduced. While the concept of pipelined scheduling can be applied to various MAC protocol designs in general, in this paper, we focus on its application to IEEE 802.11 DCF. In particular, an implicitly pipelined dual-stage contention resolution MAC protocol (named DSCR) is proposed. With IEEE 802.11, the efficiency of contention resolution degrades dramatically with the increasing load due to high probability of collision.

Keywords: MAC Protocol, Pipelining, DSCR.

I INTRODUCTION

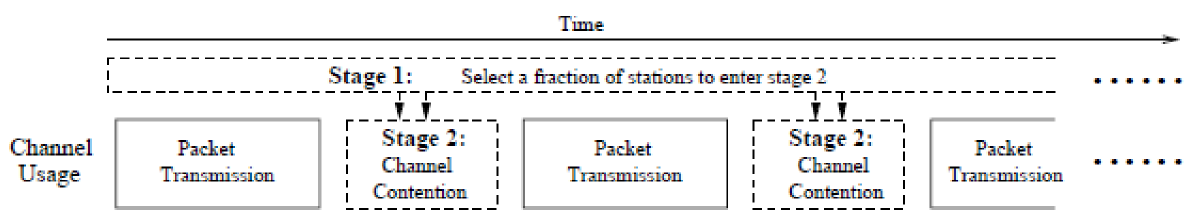

Figure 1: Dual Stage Contention Resolution

Wireless sensor networks are appealing to researchers due to their wide range of application potential in areas such as target detection and tracking, environmental monitoring, industrial process monitoring, and tactical systems. However, lower sensing ranges result in dense networks, which bring the necessity to achieve an efficient medium access protocol subject to power constraints. Various MAC protocols with different objectives were proposed for wireless sensor networks. In this paper, we first outline the sensor network properties that are crucial for the design of MAC layer protocols. Then, we describe several MAC protocols proposed for sensor networks emphasizing their strengths and weaknesses. Finally, we point out open research issues on MAC layer design. The next generation communication network is demanding more and more network capacity. Optical packet switching technology is able to deliver the enormous bandwidth of WDM networks. Besides higher bandwidth, it offers high speed, data rate and format transparency, and configurability. One of the major drawbacks in optical packet switching network is contention [1] and therefore, various techniques have been introduced to resolve contention: wavelength conversion, deflection routing and optical buffering which is usually implemented using fiber delay line (FDL) [1][2]. Optical buffers are either single stage, which consists of only one block of delay lines, or multistage which consists of several blocks of delay lines cascaded together, where each block contains a set of parallel delay lines. Optical buffers can also be classified into feed-forward, feedback, and hybrid architectures [2]. Contention resolution schemes are key determinants of packet-loss performance in any packet switching paradigm. A non-reservation scheduling algorithm is proposed for single-stage shared-FDL switch which fails to guarantee that the cells can get the desired output-port after coming out of FDL [6]. A sequential FDL assignment (SEFA) algorithm is proposed to resolve contention [7]. The proposed algorithm achieves lower packet loss rate for the sake of very high time complexity [8]. Ant colony optimization which constitutes some meta heuristic is applied to resolve contention resolution in [9]. However, meta-heuristic approach is unable to guarantee the proximity of their solutions to the optimal solution and it produces poor result very often because they converge to local optimum solutions that are far from the optimal one. However, the medium access decision within a dense network composed of nodes with low duty-cycles is a hard problem that must be solved in an energy-efficient manner. Having these in mind, Section II emphasizes the peculiar features of sensor networks including reasons of potential energy wastes at medium access communication.

II MAC PROTOCOL

Maximizing the network lifetime is a common objective of sensor network research, since sensor nodes are assumed to be dead when they are out of battery. Under these circumstances, the proposed MAC protocol must be energy efficient by reducing the potential energy wastes presented below. The types of communication patterns that are observed in sensor network applications should be investigated, since these patterns determine the behavior of the sensor network traffic that has to be handled by a given MAC protocol. The categorization of possible communication patterns is outlined, and the necessary MAC-protocol properties suitable for a sensor network environment are presented.

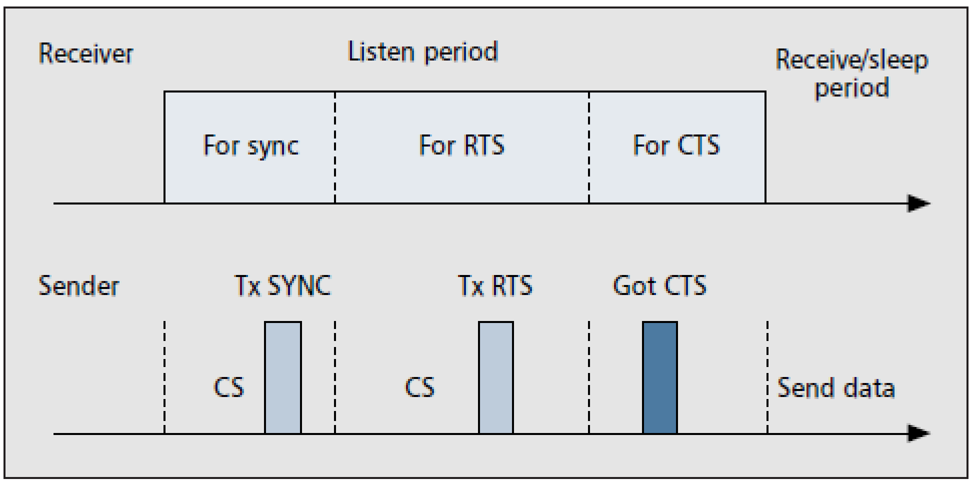

Fig 2.0 MAC Message Scenario

Our goal in this paper is to develop new MAC protocols for ad hoc networks that use such dynamic approaches. We develop two new MAC protocols. The first protocol, called extended receiver directed transmission (xRDT), uses one packet interface and one busy tone interface. Note that we differentiate between a packet interface and a tone interface to contrast our approach with similar approaches that use a separate control channel and thus two packet interfaces (see, for example, the DCA protocol). Tone interfaces are much simpler to implement than packet interfaces. The second protocol, called local coordination-based multichannel (LCM) MAC, uses a single packet interface only. We show, via extensive ns-2 simulations, that these two protocols significantly outperform similar protocols that appeared in literature recently, such as DCA and MMAC.

LOCAL COORDINATION-BASED MULTICHANNEL (LCM) MAC

The receiver directed approach described before requires an additional busy tone interface. In this section, we develop an alternative approach called LCM MAC where busy tones are not used and each node has only one interface. In LCM MAC, the neighboring nodes go through local coordination's to generate transmission schedules. A transmission schedule consists of a period when only control packets are transmitted (also called control window) followed by a period when only data packets are transmitted (a data window). Two basic rules are followed: All control packets are transmitted in the same channel during the control window. All nodes in a neighborhood are tuned to this same channel at this time. All data packets are transmitted concurrently in different channels during the data window. The first rule

helps ensure that nodes become aware of transmissions in the neighborhood (this avoids the Multichannel Hidden Terminal problem as well as the Deafness problem). Data packets are transmitted concurrently at different channels to exploit parallelism. The common channel used in the control window is called the *default* channel. Unlike the quiescent channel in xRDT, the default channel in this case is common to all nodes. The default channel is used as a control
Channel during the control window and as a data channel during the data window. The key idea in LCM protocol is to setup transmission schedules without the use of any time synchronization. Senders use a contention resolution mechanism similar to 802.11 to gain access to the default channel during the control window. A sender then negotiates a channel to be used during the data window with the intended receiver. Once the negotiation is over, it releases the channel to let other senders contend for its access. When control window gets over, the communicating nodes switch to their respective selected channels and exchange DATA and ACK. This constitutes the data window. After data window is complete, all these nodes switch back to the default channel for another round of negotiations. The time line showed in Figure 1 illustrates a simple working scenario of LCM MAC. The protocol is similar in some details to the MACA-P [2] protocol and the POWMAC [14] protocol for transmit power control. LCM also has some similarities with the MMAC [22] protocol in channel negotiations. However, MMAC follows a rigid schedule and the negotiations are for long term. Thus, its benefit is limited by traffic conditions. MMAC also requires tight time synchronization for the protocol to work whereas LCM has no such requirements.

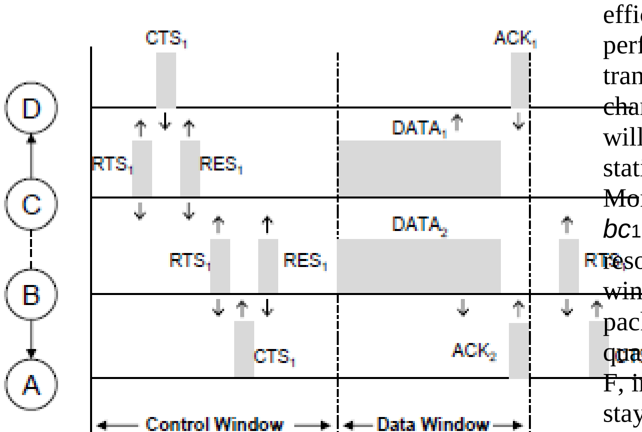

Fig 2.1 Simple Implementation of MAC With three channels.

III Dual Stage Contention Resolution

Figure illustrates the schematic diagram of the contention resolution circuit consisting of an optical flip-flop and three 40 Gb/s Wavelength Converters (WCs). Packets 1 and 2 at $\lambda 0$ along with their labels at $\lambda 3$ enter the system with direction to two separate arms. The upper arm drives the packets directly to output O/P1, while the lower arm extracts the labels with narrowband optical filtering and feeds the optical flip-flop. As a consequence optical pulses at $\lambda 0$ and $\lambda 2$ are generated at the output ports of the OFF with length slightly longer than the length of a data packet. The two outputs of the optical flip-flop, being complementary, are used as input to two subsequent SOA-OBFs. Initially, packet P4 enters the system from IN2. The packet is wavelength converted to an intermediate wavelength ($\lambda 1$) and then it is launched to the two cascaded SOA-OBF WCs. Due to the absence of a packet from IN1, the OFF remains idle, emitting $\lambda 0$ from port 1 (and no light from port 2). As such SOA-OBF_1 is activated and P4 is converted to its original wavelength before leaving the system from O/P1. Subsequently packet P3 appears in IN2 on an overlapping time slot with P2 (entering from IN1). The OFF is toggled by the P2 label and provides a packet CW signal at port 2 (and no light at port 1). Thus SOA-OBF_2 is activated and P3 is converted on a new wavelength ($\lambda 2$) enabling the multiplexing of packets in a common output. DSCR includes two *implicitly pipelined* contention resolution stages as illustrated conceptually in Figure 1. Intuitively, stage 1 function as a filter to select some stations to contend for the channel in stage 2. Since the number of stations in stage 2 is typically small, the channel contention can be resolved efficiently. As shown in Figure 1, stage 1 is implicitly performed in parallel with both stage 2 and packet transmission duration without actual consumption of channel bandwidth. At any given time, some stations will be in stage 2 while others stay in stage 1. Only the stations in stage 2 will contend for the channel access. More specifically, DSCR maintains a back off counters bc_1, a contention window CW1 for contention resolution stage 1, a back off counter bc_2, a contention window CW2 for stage 2. At the end of a successful packet transmission, the station reduces its bc_1 by a quantity F. While there are various choices possible for F, in DSCR, we choose F so that the longer a station has stayed in stage 1, the more aggressively it will reduce its bc_1, hence, a larger probability of entering stage 2. Whenever a station's bc_1 becomes less than or equal to 0, this station enters stage 2 and contends for the channel following a procedure defined for stage 2. A station in stage 2 that wins the channel transmits its packet, then resets CW1 to $CW1_{min}$ and returns to stage

1. A station that loses channel contention in stage 2 will double its CW1 and return to stage 1. Intuitively, the distribution of CW1 in a given network adapts to the number of contending stations in stage 2. If very few stations are in stage 2, then very few stations will double CW1 upon losing channel contention in stage 2. CW1 of the contending stations tends to be small. On the other hand, if the channel contention is severe in stage 2, many stations (except for the winning one) will lose the channel and double their CW1. As a result, CW1 of the contending stations tends to be large. As a feedback, the distribution of CW1 then adjusts the contention level in stage 2 accordingly. Larger values of CW1 imply smaller probability of entering stage 2.

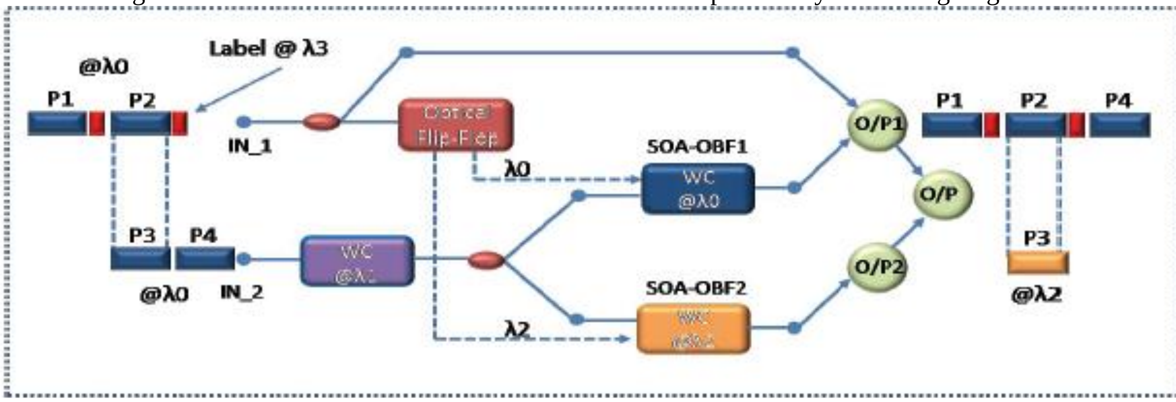

Fig 3.0 Contention resolution concept

IV. CONCLUSION

We conclude that, by using two implicitly pipelined contention resolution stages, DSCR achieves better channel utilization and lower average access delay in heavily loaded networks. DSCR is robust in multi-hop ad hoc networks with the presence of hidden terminals. The performance improvement achieved by DSCR does not rely on any burst-sensing mechanism as used in HIPERLAN/1.

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