UWB MAC Protocol Design and Analysis

Chen Ji
F0603002
Email:jicheninsjtu@hotmail.com

Jingtao Zhang
F0603002
Email: zjthahaha@sjtu.edu.cn

Lu Chang
F0603002
Email:clerecl@163.com

Ying Cui
F0603002
Email:cuiyingleo@gmail.com

***Abstract*—In this report, we introduce the basic idea of UWB and the concept of MAC. We list several kinds of current MACs that exploit different wireless communication technology and analyzed their advantages and disadvantages.**

I. Introduction

A. UWB

1) large UWB (Ultra Wide Band) Introduction: According to FCC, it's a kind of fractional bandwidth which is measured at the -10dB points,

$$totalBW > 500MHz$$

or

$$(f_H - f_L)/f_c > 20\%$$

It's unique and outstanding in that it has wide bandwidth, it makes very high data-rate possible, it enables CMOS transmitters to work at very low power and it requires low cost. It's also suitable for short-distance communication.

2) problem solving: There's no one single solution to this MAC layer technology no matter what physical layer key technology we adopt.

No matter applying the 802.11 protocol or the 802.15.3 bluetooth protocol, these multiple access proposal can not effectively guarantee channel resources for multi users which in the end result in a hurt to the efficiency in the use of limited wireless resources.

Thus, we need to design a new and improved protocol according to the characteristics of wireless LAN. We should think over and determine which to choose and which to neglect by terms of priority. That is to say, we need to balance among energy consumption and rate efficiency, allowing interference or enforcing mutual exclusion and whether power control is beneficial.

This new MAC protocol should be able to make full use of channel resources and it may reach a high throughput capacity as well as a low cost and timid delay for network.

B. An introduction to MAC and Principles of Mac Designing

1) A Brief Introduction to MAC: The Media Access Control (MAC) data communication protocol sublayer is a sublayer of the Data Link Layer specified in the seven-layer OSI model (layer 2). The MAC sublayer acts as an interface between the Logical Link Control (LLC) sublayer and the network's physical layer. It emulates a full-duplex logical communication channel in a multipoint network. This channel may provide unicast, multicast or broadcast communication service [1].

MAC sublayer is described by a MAC protocol, which tries to ensure that no two nodes are interfering with each other's transmission, and deals with the situation when they do. The protocol determines how a transmission node sends data to the shared medium. It provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multipoint network.

MAC sublayer is especially important in LANs, many of which use a multicast channel as the basis for communication.

2) Classification of MAC Protocols: MAC protocols are mainly divided into two categories: distributed MAC protocols and centralized MAC protocols, based on whether or not a control center is required for the protocol. Protocols can be further classified based on the mode of operation into random access protocols, guaranteed access protocols, and hybrid access protocols [2].

- Random Access Protocol
  Random access protocols are contention-based protocols that can operate in either infrastructure-based wireless networks or infrastructureless (ad hoc) networks. When only one node makes a transmission attempt, the packet is delivered successfully. When multiple nodes make a transmission attempt, a collision results. Nodes resolve the collisions in an orderly manner according to rules defined by the contention resolution algorithm (CRA).
  One example of random access protocol is ALOHA [3]. If the transmission collides with another transmission, it retries after a random period. This slotted version of ALOHA is called S-ALOHA.
- Guaranteed Access Protocol
  Guaranteed access protocol are contention-free protocols in which stations access the medium in an orderly manner, and thus a certain level of quality of service (QoS) can be provided. There are two ways to implement these protocols. One is to use a master-slave configuration, where the master polls each node and the node sends data in response to the poll. These protocols are called *polling protocols*. The second is to operate in a distributed manner by exchanging tokens. Only the station with the token can transmit data. Each station, after transmitting data, passes the token to the next station. These protocols are called *token-passing protocols*.
- Hybrid Access Protocols
  Hybrid access protocols combine the best qualities of

the above two protocols. They can achieve flexibility, efficiency and QoS provisioning. Most hybrid access protocols are based on request-grant mechanisms. Each node sends a request to the base station indicating how much time or bandwidth is required to send the data currently resident in its buffer. The request is sent using a random access protocol. The base station then allocates an upstream time slot for the actual data transmission and sends a grant to the node indicating that time slot.

Random access protocols can operate in either distributed or centralized architecture. Hybrid access protocols and polling protocols require a central node. Therefore they fall into the category of centralized MAC protocols. Token passing protocols could be used as distributed protocols but are not because of robustness considerations. Due to the time varying nature of the wireless channel, token loss would be common and token recovery is a huge overhead. As a result, all proposed distributed MAC protocols are random access protocols [4].

3) Basic Principles of MAC Protocol Designing: Generally, we should pay attention to the following three factors [5] in MAC protocol designing:

- Throughput: the average rate of successful message delivery over a communication channel.
- Latency: the average time of waiting to be dealt with in MAC layer.
- Fairness: whether all nodes have the same chance to access the medium.

Ideal MAC protocol is supposed to maximize throughput, minimize latency and ensure fairness. But in practical situation, the three factors can not always be optimized at the same time. Therefore, tradeoff among the three should be taken into consideration.

C. A new MAC for UWB

Nowadays, Random Access is the main approach in conventional Multiple Access protocol in distributed wireless communication systems, for example, CSMA [8]protocol. But ad hoc use the multi-hop structure to share the resources, leads the transmit node and recieve node in different sense channel situation which is called the Problem of Hidden Terminal and Exposed Terminal.Multiple Access with Collision Avoidance(MACA) [**?**]protocol, MACAW(MACA for wireless) [10] protocol and 802.11 [11]DCF protocol use RTS/CTS handshake information to avoid collision in some extent. But single-band restriction can't solve the problem of Exposed Terminal, besides handshake signal brings the system extra cost which decrease the efficient of the wireless communication system. Otherwise, single-band MAC protocol's collision and backoff in heavy net load situation cause the waste of channel band which leads to low efficiency of the protocol.thus, dividing the channel band into multiple simultaneously usable bands can reduce collisions and increase protocol efficiency better, examples are Dual Busy Tone Multiple Access(DBTMA) [12] protocol, DCMA [13]protocol,etc.Both theory and simulation shows that dual band protocol has better efficiency than single band protocol and solve the Exposed Terminal problem throughly [7].Meanwhile, all kinds of spread spectrum technology(DSSS,FHSS) are about to mature,dividing whole spectrum into multi-band logically,marking each band with a unique key.If the numbers of band are good enough for a certain net size, every nodes that are need to communicate can get a channel to pass information which reduce the collisions and increase the throughput and protocol efficiency. Multi-band protocols(CHMA [14],HRMA [15],CARMA-MC [16],etc) divide the whole spectrum into one control band and several data bands, control band use random access protocol to compete resources whereas transmit the data in data bands.But this is not the best way to allocate the resources, it may cause a huge waste in certain extent.In wireless personal net, nodes' capability of memory and ability to compute are limited, channel's feature are complicated,it is necessary to design a new MAC protocol that solve the problem of Hidden Terminal and Exposed Terminal as well as increase the network's performance.

5The conclusion goes here.

REFERENCES

[1] Media Access Control http://en.wikipedia.org/wiki/Media_Access_Control

[2] Lin X. Cai, Kuang-Hao Liu, Humphrey Rutagemwa, Xuemin (Sherman) Shen, and Jon W. Mark "Performance Analysis of Hybrid Medium Access Protocol in IEEE 802.15.3 WPAN" ,Consumer Communications and Networking Conference, 2007. CCNC 2007. 2007 4th IEEE Jan. 2007 Page(s):445 - 449

[3] The ALOHA protocol http://en.wikipedia.org/wiki/ALOHAnet#The_ALOHA_protocol

[4] Medium Access Control (MAC) Layer Protocolshttp://webhome.csc.uvic.ca/~wkui/Courses/topic/

[5] Yong Yu"Research on MAC Protocols Based on Ultra-Wideband Technology in Wireless Personal Network" ,2006

[6] Jin Ding, Li Zhao, Sirisha R. Medidi and Krishna M. Sivalingam "MAC Protocols for Ultra-Wide-Band (UWB) Wireless Networks: Impact of Channel Acquisition Time" in Proc. SPIE ITCOM2002

[7] Yong Yu,"Reserach on MAC Protocols Based on Ultra-Wideband Technology In Wireless Personal Network

[8] KLEINROCK L, T'OBAGI F A."Packet switching in radio channels: part I carrier sense multiple-access modes and their throughput-delay characteristics", Transaction on Communication, 1975, Vol Com 23: P1400 1416

[9] PKARN"MACA—a new channel access method for packet radio networks"., ARRL/CRRL Amateur Radio 9'" Computer Networking Conference, 1990, P 134-140

[10] LUNDY G M, ALMQUIST M, ORUK T, "Specification, simulation of a wireless LAN protocol: MACAW", Military Conference, 1998, Volume 2: P565-569 verification and Communications

[11] IEEE std 802.11-1999, Wireless LAN medium access control (MAC) and physical specifications

[12] ZYGMIJNT J H, JING DENCG"Dual Busy Tone Multiple Access (DBTMA)-A Multiple Access Control Scheme for Ad Hoc Networks, IEEE Transaction on Communications, June 2002, Vol S0, No.6: P97S-98S

[13] ZHIFENG ZHAO, SHAOREN ZHENCG, Personal Mobile Communications Conference, 2003 5th European (Conf. Publ. No. 492):22-25, April 2003:P3236

[14] TZAMALOUKAS A, GARCIA-LUNA-ACEVES access", IEEE ICC'2000, New Orleans, Louisiana, June J J, "Channel-hopping multiple 2000: P415-419

[15] TANG Z, GARCIA-LUNA-ACEVES J J," Hop-reservation multiple access (HRMA) for ad hoc networks", IEEE INFOCOM'99, New York, March 1999:P194-201

[16] GARCES R, GARCIA-LLTNA-ACEVES J J, ”Collision avoidance and resolution multiple access for multichannel wireless networks”, IEEE INFOCOM’2000, Tel Aviv, Israel, March 2000: P595-602.