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Application of Fuzzy Logic Control to Dynamic Channel Allocation of WiMedia UWB Networks

Dong-Keun Jeon[1], Yeonwoo Lee[*2]

[1] Dept. of Mechatronics, School of Mechanical Engineering,
Incheon National University, Incheon, Korea
dkjeon@incheon.ac.kr
[*2] Dept. of Information and Communications, College of Engineering,
Mokpo National University, Chonnam, Korea
Corresponding Author: ylee@mokpo.ac.kr

Abstract. This paper reviews applications of fuzzy logic to ECMA-368 based WiMedia UWB networks and proposes a fuzzy logic control scheme for dynamic channel allocation with combined prioritized contention access (PCA) and distributed reservation protocol (DRP). Such WiMedia UWB network is applicable to a wireless ship area pico-network for supporting both high-quality multimedia services on shipboard and shipboard instrument control data. It is expected that the proposed fuzzy logic control based dynamic channel allocation can provide reliable mixed HD-video stream services and shipboard control data with high priority as well.

Keywords: WiMedia, UWB, fuzzy logic, ECMA-368, channel allocation, ship area network

1 Introduction

The supported data rate in the ship area network (SAN) is typically limited to 125 kbps, and thus such networks cannot provide the increasing need for large amount of data transmission on board between a bunch of instruments and an integrated gateway. However, for satisfying the increasing need for various data services within a vessel, a wireless transmission between devices and a gateway had been proposed in our previous research works in [1], with aiming at achieving high-speed data support and reliable and easy network deployment.

As a wireless transmission technology for a wireless gateway, WiMedia ultra wideband (UWB) MAC is a very reasonable option, since it has been verified to satisfy the demand of multimedia video traffic services with high quality in a wireless home network environment [2]. The supported data rate by WiMedia UWB systems ranges from 53.3 to 480 Mbps over distances up to 10 meters, as in standardized by

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the ECMA-368 standard [3]. The ECMA-368 standard defined physical and MAC layers for high data rates wireless personal area networks (WPANs). The WiMedia UWB provides two channel allocation MAC protocols such as a contention based prioritized channel access (PCA) for synchronous data communication service and a reservation based distributed reservation protocol (DRP) for isochronous service.

However, in order to provide HD video stream service and mixed shipboard control data service with higher priority, an intelligent decision making algorithm such a fuzzy logic control is essential to dynamically decide the near-optimal channel allocation irrespective of complicated traffic conditions. Thus, this paper considers an application of fuzzy logic into WiMedia UWB MAC protocol to support dynamic channel allocation to either HD-video stream device or shipboard control data device. Section 2 in this paper describes the WiMedia UWB (ECMA-368) MAC protocol for WiMedia based ship area pico-network as a background study. Section 3 presents a fuzzy logic controller applicable to WiMedia UWB channel allocation MAC protocols as a proposed study, followed by the conclusion.

2 Research Background

2.1 WiMedia UWB MAC Protocols

In such WiMedia UWB MAC, the channel time is divided into a time unit of a superframe, which has has a fixed length of time windows, called a medium access slot (MAS). The superframe consists of 256 MASs. The length of the superframe is 65.536ms, and the length of each MAS is 256 μs. Each superframe starts with a beacon period (BP), which extends over one or more contiguous MASs. A BP consists of beacon slots, and each device sends its own beacon in a non-overlapping beacon slot with others. As shown in Figure 1, a data period is divided into two types of MAS blocks. A contention based protocol works during PCA slots and a reservation based protocol works during DRP slots [3].

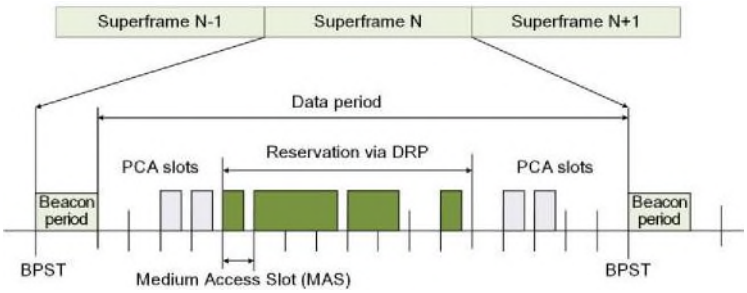

Fig. 1. The structure of channel allocation with WiMedia MAC protocols such as DRP and PCA.

2.2 WiMedia UWB based Ship Area Pico-network

In this paper, we applie WiMedia UWB wireless gateway structure between shipboard control network and instrument network, which had been presented in our previous work in [1]. Based on this conceptual structure, a WiMedia UWB based wireless gateway model supporting mixed video stream traffic and shipboard control data can be depicted as shown in Figure 2, wherein WiMedia UWB WPAN piconet composes wireless coverage within the integrated network architecture of the SAN.

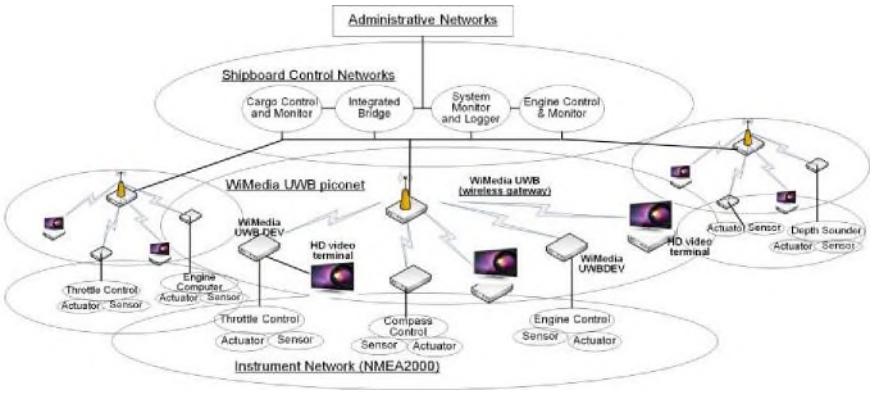

Fig. 2. WiMedia UWB based ship area pico-network supporting mixed video stream data and shipboard control data.

3 Proposed Fuzzy Logic Control of Dynamic Channel Allocation

When the target problem are difficult to model with typical mathematical approaches, fuzzy logic based algorithm is an attractive technique with easier to understand at the same time. The rule-based decision making achievable by fuzzy logic enables efficient inclusion of incomplete information. The flexibility provided by the decision making architecture has proven to be suitable for dynamic and distributed environment. In addition, it provides savings in computational complexity [6].

A fuzzy controller is based on three procedures such as fuzzification, rule-based control and decision, and defuzzification. In this paper, as shown in Figure 3, we use fuzzy logic at each channel (superframe) to estimate the paramters of utility function, which is defined by *U(L(i), P(i), q(i))*. Based on this utility function, the decision of dynamic channel allocation at each superframe, which decides each number of MAS slots allocated to DRP hard, DRP soft and PCA. The process of rule evaluation used in this paper is a set of IF-THEN rules to determine the value of output variables. We use link congestion measurement (*L(i)*, “high”, “medium”, “low”) as indicator of traffic load in each superframe, and prioritized shipboard control data traffic meas-

urement (*q(i)*, "high", "medium", "low") as indicator of high priority data existence. Then, based on the fuzzified link congestion measurement and prioritized shipboard control data traffic measurement, the inference rules are used to get information on traffic condition. The inference rules can be expressed as follows:

Rule R_k: IF (*L(i)* is c_x) AND (*P(i)* is c_x) AND (*q(i)* is c_x), THEN (*U(i, k)* is *U(i)*),

where c_x is fuzzy set and can be either "high", "medium", or "low". For example, if the first rule is applied. The inference rule reads as "IF is he link congestion measurement is "high" AND the prioritized traffic is "high" AND the link quality measurement is "high", THEN the utility of superframe *i* for allocating MSA is *U(i,k)*. The estimated utility can be calculated by Σ Σ_____ . The decision on channel allocation is made based on *U(i)*. This channel allocation scheme is executed periodically. The WiMedia MAC protocol decides the appropriate portion of MAS slots, which is allocated to DRP hard, DRP soft and PCA based on the utility function value. If the utility function value is the highest, the MAC protocol strictly allocates time slots DRP hard first, for ensuring high prioritized shipboard control data service as well as HD video streaming service, rather than release MAS slots for contention based allocation. That is, the utility function decides the strictness of DRP allocation.

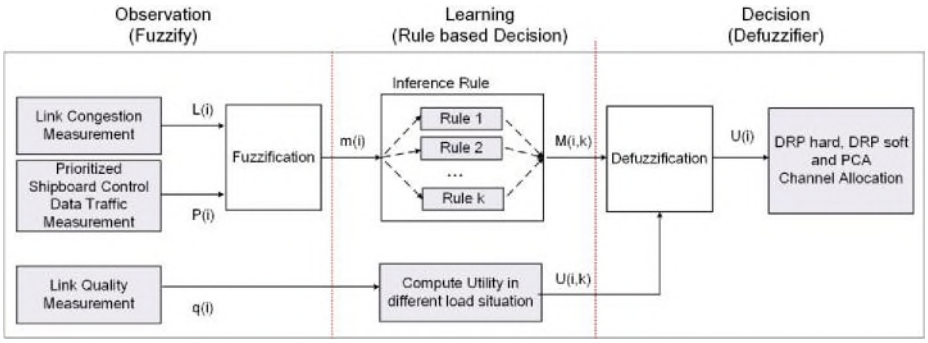

Fig. 3. Fuzzy logic control based dynamic channel allocation scheme

For further study, we simulate this fuzzy logic control based dynamic channel allocation, comparing with the conventional dynamic channel allocation in case of video and data traffic only condition and mixed data traffic condition as well.

4 Conclusion

In this paper, the fuzzy logic control scheme for dynamic channel allocation of ECMA-368 WiMedia UWB with combined prioritized contention access (PCA) and distributed reservation protocol (DRP) was proposed. Such WiMedia UWB network is applicable to a wireless ship area pico-network for supporting both high-quality

multimedia services on shipboard and shipboard instrument control data. It is expected that with the proposed fuzzy logic control based dynamic channel allocation, the WiMedia MAC protocol can intelligently allocate the mixed HD-video stream services and high-prioritized shipboard control data.

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