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Journal of Network and
Computer Applications 27 (2004) 131–150

Journal of
NETWORK
and
COMPUTER
APPLICATIONS
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Performance analysis of buffered R-ALOHA systems using tagged user approach

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Received 17 May 2003; received in revised form 12 October 2003; accepted 12 November 2003

Abstract

In this paper, R-ALOHA systems with propagation delay, finite buffer capacity and finite user population are analyzed using Tagged User Approach. The system throughput, message response time, message delay-time distribution and message blocking probability are obtained. It is assumed that each message consists of a random number of packets with a general distribution, and each user have a finite buffer capacity. To maintain the fairness to all users, it is assumed that each message in the buffer is transmitted independently that is, a user has to release the reserved slot after finishing the transmission of a message even if it has more messages waiting in the buffer. The analysis can be extended to R-ALOHA systems with infinite buffer capacity straightforwardly. The accuracy of the analysis is verified by simulations.

1. Introduction

Reservation-ALOHA (R-ALOHA) multiple access protocol was proposed in (Crowther et al., 1981) to improve the throughput of satellite channels. It is an attractive multiple access protocols for use in satellite communications and other types of communications because of its bandwidth efficiency and simplicity of implementation.

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doi:10.1016/j.jnca.2003.11.002

As a result, the basic principles of R-ALOHA are also employed in the analysis of some other multiple access protocols such as packet reservation multiple access (PRMA). PRMA is proposed for use as a wireless access protocol in the third generation wireless communications systems (Goodman et al., 1991; Wu et al., 1994, 1998; Qi and Wyrwas, 1996; Nanda, 1990), for packetized voice and data integration over a common communication channel. On reflection R-ALOHA without propagation delay can be considered as a special case of PRMA system for voice users where the maximum packet holding time is infinite.

In R-ALOHA, the time is divided into slots, which are grouped into frames. Each frame consists of a fixed number of time slots. Each slot is long enough to transmit one packet. A slot can have either a reserved or available (free) status. The system users contend for access to an available slot on the shared channel using S-ALOHA protocol. The channel is assumed to be noise free, and unsuccessful transmission is only due to collision(s). If a user is successful in transmitting in a slot, this slot is reserved for this user in the subsequent frames until the whole message is transmitted. Following the end of transmission, the slot is released for use by all users.

There are two slightly different versions of R-ALOHA, depending on whether or not an end-of-use flag is included in the header of the last packet of a message. When the end of use flag is not included it is known as R-ALOHA with (P1) otherwise it is called with (P2). With (P1), a time slot is always wasted whenever a user releases its reserved slot. Hence, (P2) gives a higher channel throughput than (P1). However, (P1) is easier to implement (Lam, 1980).

The pioneering analysis on R-ALOHA reported in (Lam, 1980) is based on the assumption that the channel propagation delay is zero, and a successful transmission would occur in each available slot with a constant probability. The study focused on the statistical behavior of the system as a whole and did not dwell on the questions of system stability and the behavior of individual users. The stability and the dynamic behavior of R-ALOHA systems are studied in Tasaka (1986) using EPA (Equilibrium Point Analysis), and the influence of propagation delay on the system behavior is considered. However, it is assumed that the number of packets contained in each message is geometrically distributed, and each user buffer can hold up to one message. EPA has been successfully applied to the analysis of PRMA (Qi and Wyrwas, 1996; Nanda, 1990). However, each talkspurt in PRMA is again assumed to consist of geometrically distributed packets. Because of the model structure employed in EPA, it seems difficult, if not impossible, to apply EPA to R-ALOHA systems where each message consists of a generally distributed number of packets, or each user has a buffer capacity of more than one message.

In this paper, R-ALOHA systems with propagation delay, where each message consists of a generally distributed number of packets, are analyzed using Tagged User Approach (TUA) proposed in (Sheikh et al., 2004). Each user is assumed to have a buffer capacity of L messages. To maintain fairness to all users, each message is treated independently. That is, a user would release its reserved slot after finishing the transmission of a message even if it has one or more messages waiting in the buffer. It is noticed that buffered S-ALOHA protocols in satellite communications (Tasaka, 1982) can be considered as a special case of R-ALOHA with (P2) where each message consists of one packet. Hence, the R-ALOHA systems studied in this paper is more general than those in Tasaka (1986, 1982) and Tasaka.