Random Multiple Access Protocols for Communication Systems with "Success-Failure" Feedback

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Abstract — **We consider a class of random multiple access protocols for communication systems with binary feedback of the "success-failure" type. We show that it is possible to design a stable protocol operating without dummy packets under the "success-failure" feedback.**

I. Introduction

At present there is considerable practical interest in random multiple access protocols suitable for communication systems with binary feedback of the "success-failure" (S-F) type. This feedback informs the users whether or not a given slot contained successfully transmitted packet. Several multiple access protocols operating under S-F feedback have been proposed and analyzed in recent years [1]-[2]. The main feature of these protocols is the use of dummy packets. The transmission of dummy packets enables all the users to distinguish between empty and collision slots. But the use of dummy packets may be unacceptable in practice. The question arises whether any stable strategy exists which doesn't make use of dummy packets.

B.Aazhang and B.-P.Paris [3] have described a protocol operating without dummy packets. Unfortunately, retransmission strategy of some backlogged packets has not been determined in that protocol. We propose the protocols that are based on a solution to this problem.

II. Model and Protocol

An infinite population of identical independent users is assumed. The moments of generation of new packets form a Poisson process. The feedback informs the users whether or not a given slot contained successfully transmitted packet.

The protocol operates in a cycling manner. At the beginning of cycle j the protocol enables (i.e., activates for transmission) a subset of waiting packets $X^{(j)}$. After a success, the next cycle begins and the protocol enables a subset of waiting packets $X^{(j+1)}$, $X^{(j+1)} \cap X^{(j)} = \emptyset$. After a failure, the protocol enables a subset $X_1^{(j)} \subset X^{(j)}$. If the transmission of $X_1^{(j)}$ results in a failure, the protocol enables a subset $X_2^{(j)} \subset X^{(j)}$. The subsets of $X^{(j)}$ are enabled until the first subset $X_i^{(j)} \subset X^{(j)}$ with $1 \leq i \leq k$ that generates a success feedback. The protocol makes k attempts where k is a fixed preassigned integer with $k \geq 1$. The success in $X_i^{(j)}$ indicates that $X^{(j)} \setminus X_i^{(j)}$ contains at least one packet. It is known that all the packets in a subset can be successfully transmitted without the use of dummy packets provided this subset contains at least one packet [3]. This can be done by means of an Aloha-like algorithm. The current cycle ends the same time when the Aloha-like algorithm terminates. Thus, the protocol successfully transmits all the packets in $X^{(j)}$ provided there is a success in $X_i^{(j)} \subset X^{(j)}$ with $1 \leq i \leq k$.

If in cycle j, enabling $X^{(j)}, X_1^{(j)}, ..., X_k^{(j)}$ results in $k+1$ consecutive failure feedbacks, the subset $X^{(j)}$ is delayed and another subset of the arrival process is enabled. In any cycle one subset of the arrival process can be delayed. Let $Q^{(j)}$ denote a union of the delayed subsets at the beginning of cycle j. If in cycle j subset $X^{(j)}$ is delayed, then $Q^{(j+1)} = Q^{(j)} \cup X^{(j)}$.

Consider cycle l. Assume, that $Q^{(l)} \neq \emptyset$. Let subsets $X^{(l)}, X_1^{(l)}, ..., X_{i-1}^{(l)}$ are enabled, and $i \leq k$ consecutive failure feedbacks are observed. Then $X_i^{(l)}$ is selected. Assume, that its transmission results in a success. The protocol then continues by enabling a set $Y_i^{(l)} = (X^{(l)} \setminus X_i^{(l)}) \cup \hat{Q}^{(l)}$, where $\hat{Q}^{(l)} \subset Q^{(l)}$. After a success, cycle l ends. After a failure, the Aloha-like algorithm is invoked, and cycle l ends when the algorithm terminates. Then the next cycle begins and $Q^{(l+1)} = Q^{(l)} \setminus \hat{Q}^{(l)}$.

Clearly, $Y_i^{(l)}$ contains at least one packet. Therefore, by using the Aloha-like algorithm, all the packets in $Y_i^{(l)}$ are successfully transmitted. Thus, we obtain the successful transmission of the packets in $\hat{Q}^{(l)}$.

III. Stability and Throughput

We examined a protocol, assuming $k = 2$ and $\hat{Q}^{(l)}$ coincides with one of the delayed subsets $X^{(j)}$ with $1 \leq j < l$.

The protocol designates subset $X^{(j)}$ by selecting of certain interval of the time axis. Each packet generated in the selected interval is enabled. The protocol has parameters μ, α, β, p with $\mu > 0$, $0 < \alpha < 1$, $0 < \beta < 1$, $0 < p < 1$. The interval $[(j-1)\mu, j\mu)$ corresponds to $X^{(j)}$, the interval $[(j-1)\mu, (j-1+\alpha)\mu)$ corresponds to $X_1^{(j)}$, the interval $[(j-1)\mu, (j-1+\alpha\beta)\mu)$ corresponds to $X_2^{(j)}$ for each $j = 1, 2, \ldots$.

If μ, α, β satisfy the inequality

$$\frac{\alpha\mu(e^{-\alpha\mu} - e^{-\mu} + \beta(e^{-\alpha\beta\mu} - \mu e^{-\alpha\mu}))}{1 - \mu e^{-\mu}} > 0.5,$$

then the protocol is stable, i.e., the throughput of the protocol $R > 0$. We calculate the throughput, assuming that $\alpha = \beta$. The maximum throughput is $0.316\cdots$ and is obtained with $\mu = 2.182\cdots$ and $\alpha = \beta = 0.473\cdots$. If μ, α, β don't satisfy the inequality, then the protocol is unstable, i.e., $R = 0$.

References

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