

# Transmission Control Using Channel State Information for CDMA Networks with Linear MMSE Multi-user Receivers

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*Abstract* — We consider the use of channel state information to vary the transmission probability for ALOHA based CDMA networks employing a LMMSE multi-user receiver. It is shown that through the use of channel state, with an arbitrarily small power, it is possible to achieve an asymptotic stable throughput (AST) that is lower bounded by the spreading gain of the network.

## I. SUMMARY

Consider a random access network where  $n$  users are communicating with a base station over a common channel. Each user has an infinite buffer which stores the incoming packets. The number of packets that arrive in each slot is random and the arrival process is independent and identically distributed among users and slots. The channel between the  $m^{\text{th}}$  user and the base station during slot  $t$  is parametrized by  $\gamma_m^{(t)}$ . It is assumed that the quantities  $\gamma_m^{(t)}$  for  $m = 1, \dots, n$  and  $t \in \mathbb{N}$  are independent and identically distributed with probability distribution  $F(\gamma)$ . Further, we assume that the user  $m$  has access to the uplink CSI  $\gamma_m^{(t)}$  at time  $t$ . We assume that in slot  $t$ , user  $m$  transmits a packet with a probability  $s(\gamma_m^{(t)})$  where  $s(\cdot)$  is the transmission control that maps the channel state to a probability. At the end of slot  $t$ , the base station broadcasts the indexes of those users whose packets it was able to demodulate successfully.

We assume that each user is assigned a particular signature waveform that is used to modulate the data. Each packet starts with sufficient training symbols that the receiver can use to form an equalizer. The packet is assumed to be successfully demodulated if the signal to interference ratio after the LMMSE multi-user receiver is greater than  $\beta$ . Due to the heuristics in [4], we will use the following reception model for the LMMSE multi-user receiver. Given that  $K$  users transmit,  $\gamma_i$  is the power received from user  $i$ ,  $\sigma^2$  is the noise variance, user  $i$  goes through if and only if

$$\frac{\gamma_i}{\sigma^2 + \frac{1}{N} \sum_{k=1, k \neq i}^K \frac{\gamma_i \gamma_k}{\beta \gamma_k + \gamma_i}} > \beta. \quad (1)$$

We characterize the asymptotic stable throughput (AST), which is the maximum stable throughput of the network as the network size goes to infinity (see [1] for a formal definition). Denote  $C_k(T(\cdot))$  as the average number of packets successfully demodulated when  $k$  users transmit and their channel states are drawn from the distribution  $T(\cdot)$ . We then have the following results (For details, please refer to [1].)

**Proposition 1** *If the sequence of transmission control  $s_n(\gamma)$  is chosen to be independent of  $\gamma$  but a function of  $n$  alone, then the maximum possible AST is given by [3]*

$$\lambda^* = \sup_x e^{-x} f(x, F). \quad (2)$$

where  $F(\gamma)$  is the distribution of  $\gamma$  and

$$f(x, F) = \sum_{k=1}^{\infty} \frac{x^k}{k!} C_k(F(\cdot)). \quad (3)$$

Let  $T(\cdot)$  be a distribution function such that  $T \ll F$ , and let  $\frac{dT}{dF}$  be the Radon-Nikodym derivative, then the following proposition holds.

**Proposition 2** *With the sequence of transmission controls chosen as*

$$s_n(\gamma) = \min \left( \frac{x}{n} \frac{dT}{dF}, 1 \right), \quad (4)$$

the asymptotic stable throughput is given by

$$\lambda = e^{-x} \sum_{k=1}^{\infty} \frac{x^k}{k!} C_k(T(\cdot)). \quad (5)$$

It can be seen that through a judicious choice of transmission control sequence, it is possible to achieve an AST of

$$\lambda_c^* = \sup_{x, T(\cdot) \ll F(\cdot)} e^{-x} \sum_{k=1}^{\infty} \frac{x^k}{k!} C_k(T(\cdot)) = \sup_{x, T(\cdot) \ll F(\cdot)} f(x, T). \quad (6)$$

The following theorem summarizes the importance of CSI for the reception model under consideration at small powers.

**Theorem 1** *Assume  $\beta > 1$  and  $F(\gamma) = 1 - e^{-\frac{\gamma}{P_T}}$ , then*

$$\lim_{P_T \rightarrow 0} f(x, F) = 0. \quad (7)$$

However, for any given  $P_T$ , the maximum achievable AST with CSI satisfies

$$N \leq \lambda_c^* \leq N + \frac{N}{\beta}. \quad (8)$$

## REFERENCES

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