

# Amplitude Division Multiple Access Using Uniqueness of Prime Factorization

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**Abstract**—A new method of amplitude division multiplexing (ADMA) is proposed, where a single channel can be used to transmit multiple digital signals simultaneously using the concept of prime number factorization. This method contrasts with the currently used methods such as frequency-division multiple access (FDMA), in which the total bandwidth available in a channel is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal. Comparison of the proposed method with a popular PAM technique-2B1Q method is made. Distinct advantages of the proposed method and a few applications are presented.

**Index Terms**—Frequency division multiple access, PAM, Time division multiple access, Internet of Things, Data transfer.

## 1 INTRODUCTION

IN frequency division multiple access (FDMA) [1], the available bandwidth in a communication channel is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal. Due to the necessity of noise margins, the number of carrier frequencies that can be possibly used in a band-limited channel is limited irrespective of the power that can be made available. To transmit multiple signals on the same frequency, the concept of time division multiple access (TDMA) [1] is used. In this technique, a signal is split into its constituent parts sequentially and when multiple signals of this type are to be transmitted, the constituent parts of these different signals are transmitted one at a time. Together, FDMA and TDMA are used in tandem as an integral part of code division multiple access (CDMA) [1], which has been one of the most popular mobile communication techniques ever. In CDMA, the limitations of FDMA, are not overcome. Although, TDMA allows multiple users to utilize the same frequency at different

time slots, it leads to the slowing down of the rate of communication for individual users. In an ever increasing demand for high speed communication, especially with the rise of Internet of Things (IoT) [2], [3], and several mobile applications, such as internet streaming of entertainment multimedia [4] and server based gaming platforms [5], it has become necessary for very high rate of data transmission.

In this paper, we propose a novel technique of data transmission for multiple users using a single frequency simultaneously. We make use of the concept that the product of  $m$  prime numbers can be used to resolve this product uniquely into the same  $m$  prime numbers.

## 2 AMPLITUDE DIVISION MULTIPLE ACCESS (ADMA)

We consider simultaneous transmission of  $n$  signals, one from each of the  $n$  user transmitters. The  $n$  users are all connected separately to a

TABLE 1  
Assignment of prime numbers to transmitters

| User ID | Prime Number Assigned | For Bit Zero | For Bit One |
|---------|-----------------------|--------------|-------------|
| A       | 2                     | 1            | 2           |
| B       | 3                     | 1            | 3           |
| C       | 5                     | 1            | 5           |
| D       | 7                     | 1            | 7           |

single router. The router assigns a different prime number to each of these  $n$  transmitters. Each transmitter sends a sequence of bits. Upon the router receiving the individual binary sequence, the following operation is performed. If the bit received is a zero, a variable corresponding to that transmitter is assigned the value one. If the received bit is one, the value assigned to the variable is the prime number assigned to that user by the router. Upon completing the operation for each of the bits sent by all the transmitters, the values of the variables assigned to each of the individual users is multiplied, which results in a single number. The carrier frequency is now modulated with the resultant product. Schematic of the procedure is shown in Fig. 1.

For example, consider the following scenario with four transmitters. These transmitters labeled  $A, B, C, D$  are respectively assigned the prime numbers 2, 3, 5, and 7 as shown in Table 1.

Table 2 shows the possible outcomes. The receiver receives the signal as one of the possible product values. It decomposes this product into its constituent prime numbers. It then proceeds to extract the  $n$  bits. This procedure requires *a priori* knowledge of the number of initial transmitters. Since, most standardized communication protocols contain the knowledge of source and destination addresses in packet headers, the knowledge of the prime numbers assigned to each of those initial transmitters is not necessary at the receiver end.

The decomposition is performed as follows. The product is first decomposed into its prime factors using an algorithm like Pollard's rho factorization algorithm [6]. On decomposition, the number of prime factors and the prime factors

TABLE 2

$B$ s take the values zeros and ones of the transmitters.  $V$ s are assigned ones in case of zeros and prime numbers in case of ones. The last column shows the products of the assigned prime numbers.

| $B_A$ | $B_B$ | $B_C$ | $B_D$ | $V_A$ | $V_B$ | $V_C$ | $V_D$ | Product |
|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| 0     | 0     | 0     | 0     | 1     | 1     | 1     | 1     | 1       |
| 0     | 0     | 0     | 1     | 1     | 1     | 1     | 7     | 7       |
| 0     | 0     | 1     | 0     | 1     | 1     | 5     | 1     | 5       |
| 0     | 0     | 1     | 1     | 1     | 1     | 5     | 7     | 35      |
| 0     | 1     | 0     | 0     | 1     | 3     | 1     | 1     | 3       |
| 0     | 1     | 0     | 1     | 1     | 3     | 1     | 7     | 21      |
| 0     | 1     | 1     | 0     | 1     | 3     | 5     | 1     | 15      |
| 0     | 1     | 1     | 1     | 1     | 3     | 5     | 7     | 105     |
| 1     | 0     | 0     | 0     | 2     | 1     | 1     | 1     | 2       |
| 1     | 0     | 0     | 1     | 2     | 1     | 1     | 7     | 14      |
| 1     | 0     | 1     | 0     | 2     | 1     | 5     | 1     | 10      |
| 1     | 0     | 1     | 1     | 2     | 1     | 5     | 7     | 70      |
| 1     | 1     | 0     | 0     | 2     | 3     | 1     | 1     | 6       |
| 1     | 1     | 0     | 1     | 2     | 3     | 1     | 7     | 42      |
| 1     | 1     | 1     | 0     | 2     | 3     | 5     | 1     | 30      |
| 1     | 1     | 1     | 1     | 2     | 3     | 5     | 7     | 210     |

themselves are known. It then becomes obvious to assign bits zero or one to the bit streams, since the number of users is already known. For example, if the receiver receives the value 30, then the decomposition algorithm decomposes the values into the prime factors 2, 3, and 5. Since, it is known that there are four transmitters, the prime factors are in the sequence 2, 3, and 5, the receiver interprets that the transmitters  $A, B$ , and  $C$  have transmitted the value one and the transmitter  $D$  has transmitted the bit zero. A comparison of the processing speed between the 2B1Q [7] and ADMA shows that the ratio of the former to the latter is 5/3 for transmission and reception of two bits. The complexity of the circuit of ADMA is lower than that of 2B1Q and also that ADMA does not require a look up table.

### 3 OPTIMIZATION AND ERROR CORRECTION

In the scenario described in the previous section, the prime numbers are assigned randomly to the transmitters. This will be inefficient when a packet from a transmitter with a large number

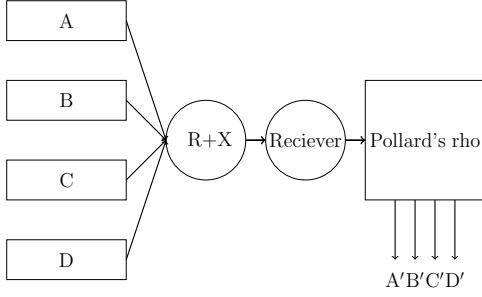


Fig. 1. Simulation results for the network. Schematic of ADMA:  $A, B, C, D$  are transmitters,  $R$  is the router,  $X$  is the product multiplier.  $A', B', C',$  and  $D'$  are the output bit streams

of ones is assigned a higher prime number. It is prudent to assign a low prime number for packet from a transmitter with a large number of ones. Similarly, a packet from a transmitter with a large number of zeros can be assigned with a larger prime number. Assuming packets of equal size, the optimization can be carried out at the router as follows.

- Calculate the probability of occurrence of ones in each of the packets recieved from the transmitters
- Arrange the packets in the ascending order of probabilities of occurrence of ones
- Assign prime numbers to the packets to the above generated list in the descending order starting from the lowest prime number, which is 2.

Since, unlike transmission of only two levels as in regular binary data, in this procedure, very large values of products of primes are involved. This requires us to use nonlinear scaling techniques so as to enable transmission of reasonably acceptable signal strengths. However, this increases the susceptibility of the signal to noise. Hence, we need to provide a preliminary method to screen for correctness of the recieved value. Scaling down using some optimal monotonic nonlinear function is performed at the router. This is received and then scaled up at the reciever using the inverse. However, this process of scaling up will significantly increase the channel noise. The factorization of this data with noise may not necessarily yield the

intended decomposition. Two possible scenarios of incorreced decomposition are:

- 1) Occurence of the same prime number
- 2) Occurence of a prime number inconsistent with the number of transmitters

In the case of the former, multiple occurrence of the same prime number indicates that the recieved value is incorrect. This is because, it is impossible for the router to assign the same prime number to different transmitters. It is also impossible for the same transmitter to have transmitted more than one bit in a single bit cycle. In the case of the latter, for example, consider transmitters  $A, B, C,$  and  $D$  transmitting the bits: 1, 0, 1, 1 respectively. Also assume that the transmitters have been assigned the values 2, 3, 5, and 7 respectively. The intended value to be recieved at the reciever is 70. Due to noise, let us assume that the recieved value is 69. Decomposition of 69 into its prime factors yield 3 and 23. The value 23 is inconsistent with the fact that there are only four transmitters and the highest prime number assigned would be 7. The following procedure should be used as a preliminary error correction test.

- 1) Choose the nearest integer after recieving and scaling up the recieved data
- 2) Check for inconsistencies in the scaled up data as above
- 3) In case, an inconsistency is found, use the immediately neighbouring integers as the intended transmission
- 4) Perform the decomposition on the aforementioned values until a decomposition consistent with the original number of transmitters is found

However, this procedure cannot guarantee for correct reception of bits and must be coupled with error correcting codes like Hamming code [8] or CRC codes [9].

## 4 APPLICATIONS

The potential applications for the proposed method are

- 1) Areas in which a large number of sensors have to continuously transmit data with least possible delay, such as VANET [10] coupled with RSUs. In such scenarios, time is of essence and using only TDMA significantly reduces the efficacy of such Vehicular Ad-hoc Networks (VANET). This can be avoided using ADMA working in tandem with Road Side Units (RSU)
  - 2) In situations that require high data speeds such as real-time computer gaming, ADMA can offer a very significant speed boost.
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## 5 CONCLUSION

A novel method called amplitude division multiple access (ADMA) of using prime numbers to transmit data from multiple users using a limited bandwidth is proposed. The method makes use of the fact that a given integer can be uniquely decomposed into its factors. We have pointed out a few applications where this method has distinct advantages over the conventional transmission methods. Since, the transmitted values are very large depending on the number of transmitters, we suggest scaling the resultant prime products suitably and then check for consistencies. The great advantage of the method is its use in transmission of data in low bandwidth channels. It also does not require any modification of hardware at the user level. Further work needs to be done mainly in the areas of scaling without significantly increasing the susceptibility to noise.

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