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CDMA Based Optical Lan

K.S. Shaji Britto and P.E. Sankaranarayanan
Department of Electronics and Communication, Sathyabama Institute of Science
and Technology (Deemed University) Jeppiaar Nagar, Old Mamallapuram Road, Chennai, India-600 119

Abstract: In this study we discuss CDMA based Optical LAN. The CDMA based technique enables multiple users to transmit data across a serial link at any given time simultaneously unlike the method followed with Ethernet. With security being the prime demand of today's world, allowing multiple users to access the channel simultaneously may be critical, but in this respect the CDMA technology proposed by us since uses unique codes for each user, would also provide a solution to the problem. We have done simulation using Mat Lab to study the effectiveness of the scheme proposed and the results are presented in this study.

Key words: CDMA, optical lan, PN sequences, spread spectrum, factor codes, product codes

INTRODUCTION

Communication in today's world has proceeded in a huge step forward and has now advanced step by step up to wireless communication and networking. Even though wireless communication has been very efficient, communication in the Internet/Intranet system still uses cables as transmission medium. There are various transmission media, but the most efficient and the fastest transmission is the optical cable as on date. Present day LANs mostly use the popular Ethernet technology that enables transmitting information between computers (Viterbi, 1995). The vast majority of computer vendors provide equipment with Ethernet attachments, making it possible to link all manner of computers with an ethernet lan. Because of this widespread use there is a large market for Ethernet equipment, which helps keep the technology competitively priced. Each Ethernet-equipped computer, also known as a station, operates independently of all other stations on the network and in general there is no central controller. All attached stations are connected to a shared media system. Signals are broadcast over the medium to every attached station. In the CSMA/CD protocol usage, in order to send an Ethernet packet a station first listens to the medium and when the medium is idle the station transmits its data. If two stations happen to transmit at the same instant their signals collide, the stations are notified of the collision and they reschedule their transmission. To avoid another collision, the stations involved each choose a random time interval to schedule the retransmission of the collided frame. This essentially means that simultaneous transmission of information is not possible. In this study we have proposed using the CDMA technology to allow multiple users to transmit data sequences across the channel at a time, simultaneously.

PRESENT DAY TECHNOLOGY

When a number of computers are connected in an optical lan each computer transmits the data across the channel. In optical lan, different wavelengths are assigned to each station. Stations with different wavelengths may transmit simultaneously without interference, so in theory the total capacity is the sum of the capacities on all the wavelengths. If station A wants to transmit data to station B on a wavelength λ, it must make sure that B's receiver is tuned to λ and no other station must transmit at the same wavelength. A protocol is then necessary to coordinate the receivers and transmitters. Alternatively, if the lan functions like an ethernet with no coordination protocol, then collisions would occur, but they are sensed and the transmitter then backs off for a random amount of time before retrying as in CSMA/CD. Suppose the distance between lan stations is 5 km, the transmission rate is 1 Gbps and transmitters send 1 kb packets. The propagation time is then 10 μs (2 μs km^{-1}) and the packet transmission time is 1 μs. So the ratio alpha of propagation to the transmission time is 10. The efficiency of this scheme is 1/(1+5a) = 1/50, which is very low (Pruchal *et al.*, 1996). So CSMA/CD techniques are not suitable for optical lans, unless the transmission times, i.e., the packets are very large.

For example if we have an optical lan as shown in Fig. 1, if the comp1 transmits the data 1 to comp5 and comp2 transmits data 2 to comp6 and comp3 transmits

Corresponding Author: K.S. Shaji Britto, Department of Electronics and Communication, Sathyabama Institute of Science and Technology (Deemed University) Jeppiaar Nagar, Old Mamallapuram Road, Chennai, India-600 119

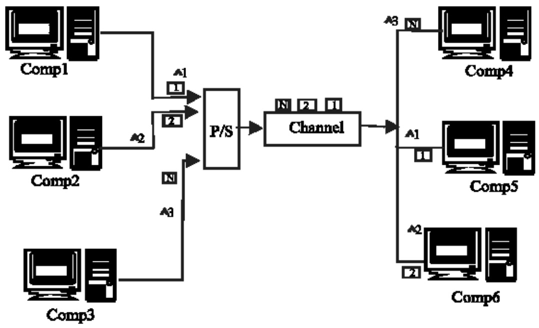


Fig. 1: Schematic of an optical lan

data N to comp4, we can see that the first data 1 is transmitted across the channel to comp5 in the wavelength λ1 followed by data 2 to comp6 in the wavelength λ3 and then finally data N to comp4 in the wavelength λ5. Thereby each user will have to wait till the previous user of the channel has finished transmitting his or her data across the channel. Hence only one user will be able to transmit the data whereas the rest of the users have to wait till the current user finished using the channel and each computer must be assigned with different wavelength λ1, λ2 and λ3. We can thereby see that even at the maximum efficiency of the channel only a single user can access the channel. Thereby there is a lot of time wastage and as each user is transmitting in different wavelength, the hardware complexity is also more. To avoid this wastage of time, we now propose implementing the most efficient mode of multiplexing that is used in the wireless media. This scheme is called the CDMA technique that uses unique codes to transmit the data across the channel.

PROPOSED TECHNOLOGY

Before we discuss the proposed technology, we give a brief introduction to the application of CDMA technique in wired LAN.

CDMA in wired lan: Code Division Multiple Access (CDMA) systems (Viterbi, 1995) are based upon several forms of spread spectrum techniques, the most popular being Direct Sequence Spread Spectrum (DS-SS). Within a DS-SS system, the data being transmitted is spread across a wide radio spectrum using a pseudo random binary sequence (Schwaz, 2001; Sankaranarayanan, 1968) unique to each user. Every data bit of a user signal is multiplied by many bits of a pseudo random binary sequence. A Pseudo-random Noise (PN) sequence/code is a binary sequence that exhibits randomness properties but has a finite length and is therefore deterministic. This sequence is created by a PN generator and often referred to as a PN-code. The PN-codes used within a CDMA system (George, 2001; Lnacio, 1999; Millerte, 2000) possesses mathematical properties that enable them to coexist in the same spectrum with minimal interference. In order to achieve these objectives, the coding sequences require special correlation properties referred to as auto correlation and cross correlation. It is these properties that enable multiple users to exist in the same radio spectrum and hence leads to the term Multiple Access in CDMA. In such a system, each one of the multiple user signals in the receiver is assigned a unique PN code. It is necessary to use a set of PN sequences that have a small cross correlation between each other in order to reduce an effect called adjacent channel interference. If the cross correlation between two PN sequences is not small, there is a possibility that data coded from one user is incorrectly identified and assigned to another user because the two codes had a reasonable correlation.

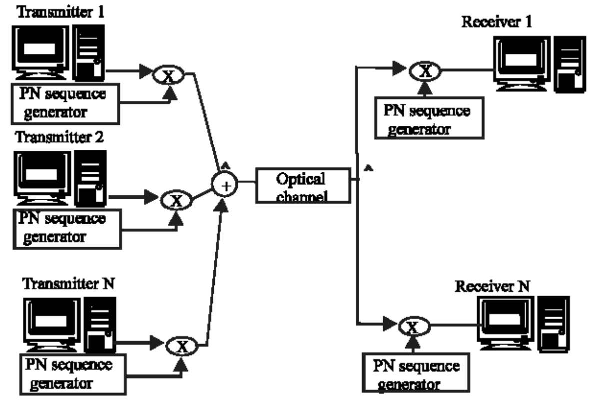


Fig. 2: Schematic of the CDMA based optical lan

In Fig. 2 we can clearly see that the transmission across the channel will be in sequential, i.e., each comp transmits its data across the channel one by one. In the above we can clearly see that if the Trans1 transmits the data 1 to Reciever1 and Trans2 transmits data the data 2 to Receiver N and Trans3 transmits data N to Receiver 1 in wavelength λ with one PN sequence followed by data 2 to Receiver N in the wavelength λ with another PN sequence and then finally data N to Receiver1 in the wavelength λ with another PN sequence. Thereby each user doesn't have to wait till the previous user of the channel has finished transmitting his or her data across the channel. Hence all the users will be able to transmit the data of the users using the same optical channel. We can thereby see the maximum efficiency of the optical channel used by all the users.

Each data sequence will be multiplied with a unique PN Sequence code and then sum them and transmit it over the channel. In the receiver end we will be thereby multiplying the respective PN Sequence code to decode the data. Only the respective receiver knows the required code. The rest of the sequences will appear as noise to the particular user. Only the server will know the PN Sequence codes of all the users. Hence the summed up sequence will be sent to the server and then the server decodes the required data with the respective code and transmits it to the respective receiver users. The general block diagram of the proposal is as shown in Fig. 2. Number of PN sequences that is needed Depends on the number of computers that is being connected to the LAN. This can be achieved either by using different feed back taps in the LFSR or by using the product codes of the sequence. We will now discuss some aspects of spread Spectrum and CDMA.

Spread spectrum and CDMA: Code Division Multiple Access (CDMA) systems (Schwaz, 2001) are based upon several forms of spread spectrum techniques, the most popular being Direct Sequence Spread Spectrum (DS-SS). Within a DS-SS system, the data being transmitted is spread across a wide radio spectrum using a pseudo random binary sequence (George, 2001; Lnacio, 1999) unique to each user. Every data bit of a user signal is multiplied by many bits of a pseudo random binary sequence. A Pseudo-random Noise (PN) sequence/code is a binary sequence that exhibits randomness properties but has a finite length and is therefore deterministic. This sequence is created by a PN generator and often referred to as a PN-Code. The PN-Codes used within a CDMA system (Lnacio, 1999; Millerte, 2000; Sankaranarayanan, 1971) possess mathematical properties that enable them to coexist in the same spectrum with minimal interference. These objectives are achieved, through the special correlation properties referred to as auto correlation and cross correlation of the coding sequences used. It is these properties that enable multiple users to co-exist in the same spectrum and hence leads to the term Multiple Access in CDMA. In such a system, each one of the multiple user signals in the receiver is assigned a unique PN code. It is therefore necessary to use a set of PN sequences that have a small cross correlation between each other in order to reduce an effect called adjacent channel interference.

If the cross correlation between two PN sequences is not small, there is a possibility that data coded from one user is incorrectly identified and assigned to another user because the two codes had a reasonable correlation. With security being the prime demand of today's world, allowing multiple users to access the channel simultaneously would be critical, but as the CDMA technology uses unique codes this would not be a problem, as the respective user will only know his required data and the rest would appear to him as unwanted noise.

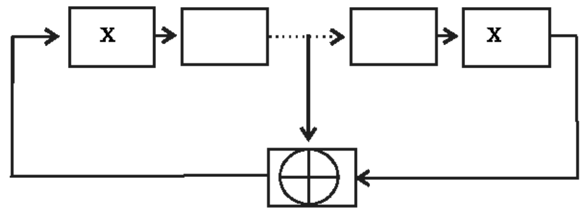


Fig. 3: Schematic of a PN code generator

PN code generation: PN codes are generated using Linear Feedback Shift Registers (LFSRs). The maximum length of such sequences is $(2^n - 1)$ bits, where n is the number of delay elements in the LFSR. In the technique that is normally followed, the outputs from predefined registers or taps (George, 2001) are XOR-ed together and fed back to the first delay element in the register. The use of PN code sequences in CDMA applications are for the following:

- Spreading the bandwidth of the modulated signal over a wide radio spectrum.
- Uniquely coding the different user signals that occupy the same transmission bandwidth in a multi-access system.
- Synchronization in CDMA systems (Fig. 3).

In order to achieve these objectives, the coding sequences require special correlation properties referred to as auto correlation and cross correlation as mentioned in the previous section. The auto and cross correlation functions are a measure of how well a signal can differentiate between itself and every time-shifted variant of itself. In the example shown in Table 1, the sequence 0111001 has a good auto correlation property as it provides a clear difference in the correlation value between itself and any time-shifted variant of itself shown below it. It is essentially a two level function.

Cross correlation is defined as the correlation between two different signals. Cross correlation is also calculated by subtracting the disagreements from the agreements, between two different sequences.

Consider a PN sequence of seven bit generated using XOR at time t = 0 and another PN sequence of same length generated using XNOR at time t = 0. If the seven bits of the second series to be repeating in discrete time steps then there are only six time shifted replicas .If each bit of the first series is compared with each bit of every time shifted replica of the second series, then there are a number of Agreements (A) and Disagreements (D), then when subtracted provides a measure of correlation.

Table 1: Auto-correlation example

Sequence	Time shift	A	D	(A-D)/(A+D)
0111001	0	7	0	1
1110010	1	3	4	-1/7
1100101	2	3	4	-1/7
1001011	3	3	4	-1/7
0010111	4	3	4	-1/7
0101110	5	3	4	-1/7
1011100	6	3	4	-1/7

Table 2: Cross-correlation example

XOR sequence	XNOR sequence	Time shift	A	D	A-D/A+D
0111001	1000110	0	0	7	-1
0111001	0100011	1	4	3	1/7
0111001	1010001	2	4	3	1/7
0111001	1101000	3	4	3	1/7
0111001	0110100	4	4	3	1/7
0111001	0011010	5	4	3	1/7
0111001	0001101	6	4	3	1/7

From the Table 2, it can be seen that the cross correlation is not only a two level function but the value is always below a threshold of 1/7. There are many combinations of taps that produce small cross correlation m-sequences. Consequently it is possible to define a set of taps that produce a collection of small cross correlation m-sequences for a constant length shift register. Kasami, Gold and walsh sequences are such small cross correlation maximal length PN codes.

Product codes: A Product code (Lnacio, 1999) as discussed in the context of this paper is the XOR-ing of two PN sequences generated using LFSRs, to achieve a third sequence which is called the product code. The two codes, which make up the product code, are termed as factor codes. Gold codes are product codes of two different Factor Maximal length sequences (codes) with the same lengths. The two factor codes are able to generate a family of many non-Maximal Product Codes. An important subset of a family of gold codes is preferred pair gold codes. These are gold codes whose cross-correlation spectrum is three valued. The number of three valued cross-correlated pProduct codes that can be generated with a pair of maximum length sequences, is equal to the number of phase differences, which can be set between the two generators by adjusting the fills of one or both generators. For a gold code generator using two 7-stage PN generators the number of different combinations equals 127 Non-maximal product code possibilities plus the two original maximum length codes for a total of 129 codes (Sankaranarayanan and Shaji Britto, 2004). For a CDMA system this means 129 different code possibilities with 127 of which having a three-valued cross-correlation spectrum. Also there is a possibility of using truncated PN sequences (Shaji Britto and Sankaranarayanan, 2004) but their auto correlation function may not be two valued always.

A new set of PN codes: We have investigated the possibility of generating various maximum length sequences using the LFSRs. The various techniques that we have investigated are the following.

- Feed back using XOR (now being normally used)
- Feedback using XNOR
- The mirror image sequence of the XOR sequence
- The mirror image sequence of the XNOR sequence
- The inverted sequence generated using XOR
- The inverted sequence generated using XNOR
- The mirror image sequences of the above inverted sequences and
- The product codes using some of the combinations of the above sequences

Direct factor codes: We will now explain the above scheme by taking the 7 bit code shown in Table 1 as an example and this would be the code obtained using XOR in the feedback path.

- Feedback using XOR : 1110010
- Mirror image sequence of the sequence : 0100111
- Inverted sequence of the one shown in (a): 0001101
- Inverted sequence of the one shown in (b): 1011000
- Feedback using XNOR: 0110100
- Mirror image sequence of the above sequence: 0010110

The product codes can be generated using the above direct factor sequences as under.

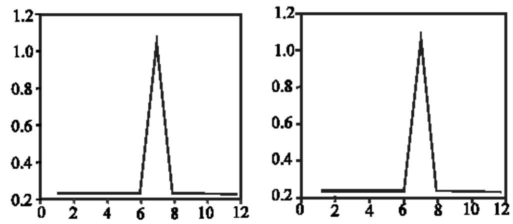
- Uing the XOR and XNOR sequences
- Uing the mirror image sequences of the XOR and XNOR sequences
- Uing the XOR sequence and the mirror image of the XNOR sequence
- Uing the XNOR sequence and the mirror image of the XOR sequence
- Ad many more

As an example, the auto and cross correlation properties in respect of sequences generated using a 3, 4 and 5 stage LFSR, are shown in Fig. 4-6 as representative samples.

CDMA scheme does exist in the wireless domain, but there has been no usage of it as for date. Henceforth, introducing the CDMA technology into the wired systems would lead to faster communication in the wired systems.

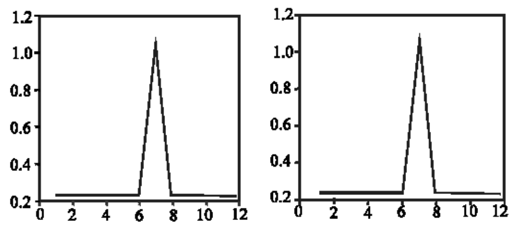
SIMULATION

We have investigated the optical lan with two and six computers and this is done with datas of length one



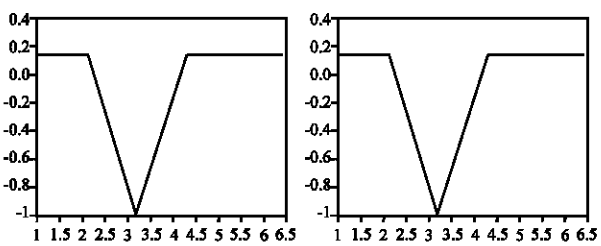
Mirror image of XOR   Feedback using XNOR

Fig. 4: Auto correlation function



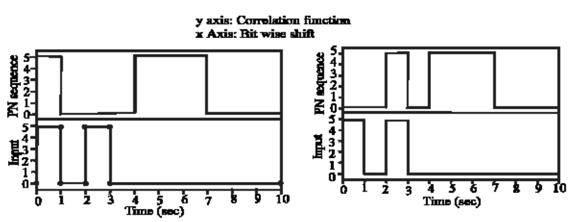
XOR and XNOR   Mirror image of XOR and XNOR

Fig. 5: Auto correlation function of product code



XOR and XNOR   Mirror image of XOR and XNOR

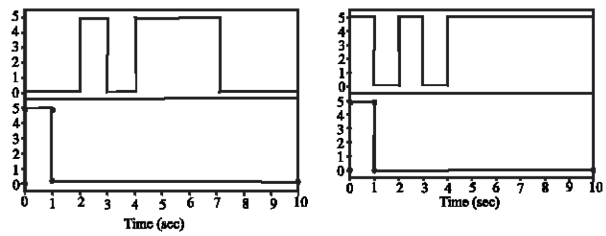
Fig. 6: Cross correlation function



PN sequence and input   Transmitted data and output

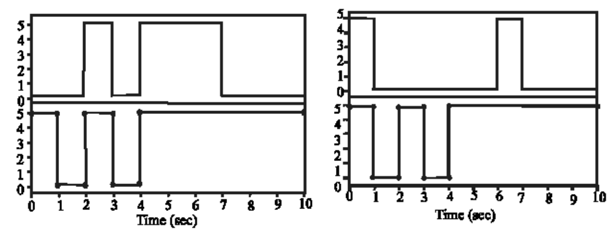
Fig. 7: Optical lan with 3 bit data

bit, three bits, four bits and six bits using Mat lab simulation and are shown in Fig. 7-9. Based on the simulated results it is felt that this system can be extended



PN sequence and input   Transmitted data and output

Fig. 8: Opical lan with 1 bit data



PN sequence and input   Transmitted data and output

Fig. 9: Opical lan with 6 bit data

for any number of users. The PN sequences that are used for the spreading and de spreading of these datas are generated using different methods. The correlation properties of such codes are also shown in the results. Based on the simulated results, it is felt that such sequences are possible with LFSRs having more that 10 stages also. It can now be seen from the example, that these new sets of PN sequences can be ideally used for spreading and despreading operations in CDMA systems since their auto and cross correlation functions are two valued in case of direct factor codes and also of product codes. Also the run time properties have remained the same. Also more number of sequences with two valued auto correlation and cross correlation functions are now available and as such there will be a lot of improvements in the performance of the CDMA system during code tracking. Another advantage is that the two-valued cross correlation function is below the threshold level of 1/N, where N is the sequence length.

CONCLUSIONS

It was seen that the transmission of 1, 3, 4 and 6 Bit Data sequence on an optical link using CDMA technology was simulated successfully. So it can be expanded for any number of bits. Hence this scheme if used in the wired technology will lead to faster communication and more efficient use of the channel. In the present day world the people wants every aspect to be fast. This would thereby produce very high speed communication and high efficiency with out any data loss and low traffic for long and short distances.

Taking into account of security as we had seen in the above chapters it would not post any problems as only unique codes were used. As many users will be accessing the channel simultaneously, there will be no problems of collision. In the simulation process we had considered Single user. As it works successfully the same can be used for N-number of users.

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