A Novel TDM-OFDM method for enhanced transmission in passive Optical Networks

Snoek | Trummel
Department of Electronics and Communication Engineering, La Trobe University, Australia

Abstract—Presently, digital signal process strategies are widely studied and varied DSP primarily based schemes are appointive for next-generation passive optical network (PON). A hybrid technique is projected which mixes time-division-multiplexing (TDM) design with advanced DSP strategies to attain high spectrum-efficiency colorless transmission. Orthogonal frequency division multiplexing (OFDM) with frequency-domain exploit, is chosen for each upstream and downstream transmissions. A DSP-based evolution theme from customary TDM-PON to TDM-OFDM-PON is usually recommended and through an experiment analyzed by upgrading the optical line terminal (OLT), which might maintain this optical distribution network (ODN). This paper proposes and through an experiment demonstrates the chaos scrambling for a secure time division multiplexing with orthogonal frequency-division-multiplexing passive optical network (TDM-OFDM-PON) supported. The provision map is adopted for the chaos mapping. The chaos scrambling algorithmic program the confidentiality of the physical layer is increased by dynamically portion the scrambling matrices for various OFDM frames in step with the initial condition, that enhance therefore a secure transmission at physical layer is achieved in TDM-OFDM-PON for encryption. The results indicate the strength against eavesdropping, therefore enhances the standard of service.

Keywords—OFDM-PON, orthogonal frequency division multiplexing (OFDM), passive optical network (PON), TDM-OFDM-PON, Scrambling.

1. INTRODUCTION

The term PON refers that there are not any active components between the CO and therefore the client. that's it doesn't need any power or active direction. Passive optical network (PON) is widely deployed round the world and immeasurable users have benefited from the increasing information measure of PON compared with the cable or phone line. variety of passive optical networks (PONs) are standardized to produce broadband access services together with APON, BPON, GPON, EPON. Once all services become video targeted, the traffic patterns of the access network can considerably take issue from that of this data-centered services. Video-centric services demand not solely broad information measure however conjointly a top quality of service (QoS). additionally, subscribers can demand multiple and synchronous services throughout specific time intervals. because the quickly growing demands on information measure and capability, orthogonal frequency division multiplexing (OFDM) technology has been thought to be a promising candidate for future access network. The OFDM-PON is versatile as a result of that the OFDM frames will understand two-dimensional resource allocation in each time and frequency domain, as shown in Fig. 1.

However, resource allocation in frequency domain totally different for various load can induce severe fluctuation of received power attributable to optical interference result once the optical carriers from different load area unit mixed in one palladium with direct detection. therefore wavelength management becomes a key downside.

To solve the colorless downside, the TDM design is combined with OFDM modulation to propose TDM-OFDM-PON, that allocates the resource solely in time domain, as shown in Fig. 2.

Fig. 2 Resource allocation of TDM-OFDM-PON

Every of the multiple subscribers connected to the PON occupies the total on the market information measure and transmits OFDM frames at dedicated time slots, rather like typical TDM-PON. The design of the projected TDM-OFDM-PON is represented in Fig. 3. For the upstream transmission, only 1 ONU transmits OFDM signal at when slot to avoid the interference with alternative load. For the
downstream transmission, OFDM frames are unit incessantly broadcast to all or any load, and every ONU selects its own packets in step with the address.

TDM-OFDM-PON can do colorless transmission simply with one upstream wavelength and one receiver within the OLT, which might scale back cost (CAPEX) and operational expenditure (OPEX) greatly. The TDM-OFDM-PON will improve spectrum potency with multi-level modulation and accomplish higher transmission performance with economical dispersion. The cyclic prefix (CP) of OFDM image may scale back the necessities for time synchronization and travel.

Considering the massive quantity of subscribers and freedom flexibility in OFDM-PON, there’s a robust demand to produce a non-public and security communication service. the physical layer could be a clear pipe for users and services, the encoding on physical layer will inherently forestall the vicious attacks like denial of service attack, eavesdropping Associate in Nursingd masquerading Associate in Nursingd an ONU, which might be thought to be a clear secure strategy.

Due to the convenient digital process of OFDM signal, it's possible to appreciate encryption at the physical layer while not dynamic any optical module or electrical device. Chaos-based communication has emerged as a promising thanks to give knowledge confidentiality attributable to its high initial condition sensitivity. The transmitted signal is hid with chaos carrier or sequence, that encompasses a extremely unpredictable and random-look nature. The chaos sequence is sensitivity to variables’ and parameters’ changes and a tiny low variation of anybody (variable) changes (the outputs) significantly. Therefore it will expeditiously counteract the malicious users in TDM-OFDM-PON.

II. TDM-OFDM-PON

A chaos-based scrambling for secure system at physical layer in TDM-OFDM-PON is projected. the info stream is encrypted through provision mapped chaos scrambling of OFDM symbols to attain a confidential transmission. It will more portion totally different scrambling matrices to different OFDM frames to reinforce the system security. results show high secure key sensitivity and strength against eavesdropping.

Data is transmitted from optical line terminal to the optical network unit through the fiber optic channel. Channel is split into multiple sub time slots. when slot is occupied with individual OFDM image as shown in Fig.4, when slot with the actual is transmitted to the dedicated users. Considering multiple users in TDM-OFDM-PON there's a necessity to produce security. therefore in every OFDM frame a chaos scrambling is applied for encoding and secret writing of knowledge for transmission over a passive optical network with none loss of signal.

III. WORKING PRINCIPLE

The OFDM transmitter consists of a strong electrical DSP modulation unit Associate in Nursingd an optical modulation unit. On the opposite hand, the DSP reception unit in Associate in Nursing OD receiver may be changed to support threshold call for OOK signals.

IFFT in OFDM is employed to convert the signal from frequency domain to time domain the thought in OFDM generation, the transmitter accepts a stream of knowledge and converts them to symbols victimisation modulation technique. S/P conversion stage the info represent as a perform of frequency. FFT in OFDM is applied to convert the signal to frequency domain from time domain.FFT is applied within the reception unit. The orthogonality permits for economical modulator and rectifier implementation victimisation the FFT algorithmic program on the receiver facet, and inverse FFT on the sender facet. The time to figure the inverse-FFT or FFT rework should take but the time for every image.

SCRAMBLE/DESCRAMBLE

A scrambler is a device that transposes or inverts signals or otherwise encodes a message at the transmitter to make the message unintelligible at a receiver not equipped
with an appropriately set descrambling device. Whereas encryption usually refers to operations carried out in the digital domain, scrambling usually refers to operations carried out in the analog domain. Scrambling is accomplished by the addition of components to the original signal or the changing of some important component of the original signal in order to make extraction of the original signal difficult. A scrambler (also referred to as a randomizer) is a device that manipulates a data stream before transmitting.

The manipulations are reversed by a descrambler at the receiving side.

**S/P & P/S**

The series and parallel convertor is taken into account to appreciate the thought of parallel knowledge transmission. During a typical serial system, the symbols area unit transmitted consecutive, with the frequency spectrum of every knowledge image allowed to occupy the complete on the market information measure. The spectrum of a personal knowledge part commonly occupies solely atiny a part of on the market information measure.

**LASER**

The process of mapping the knowledge bits onto the signal constellation plays a basic role in crucial the properties of the modulation. Demapping is performed at the receiver facet. Associate in Nursing OFDM signal consists of a total of sub-carriers, every of that contains M-ary section shift keyed (PSK) or construction amplitude modulated (QAM) signals.

The diagram for secure OFDM-PON network is shown in Fig. 4. a 1 dimensional provision map is adopted as chaos model, that is given by [18].

\[
X_{n+1} = \mu X_n \left(1 - X_n\right) \quad (1)
\]

Where \( \mu \) is bifurcation parameter, \( x_n \) is that the ordinal worth iterated by (1) \( x_0 \) and may be Associate in Nursing whimsical worth between zero and one. Whereas the management parameter \( \mu \) is determinate, for any initial worth \( x_0 \), the provision map will tell a novel sequence. Striped type of \( X_0 \) can lead to nice distinction of sequence behavior. once \( \mu \) falls into the domain three,569945&lt; \( \mu \leq \) four , the sequence can comprise chaos [18].

In the projected theme, Associate in Nursing N-order scrambling matrix denoted as \( W \) to cypher the frequency info of OFDM signal is adopted. The time domain sample of OFDM are often represent as

\[
s_n = \text{IFFT} \left( S_n \times W \right)
\]

Where \( S_n \) is the OFDM input symbol, and \( W \) can be written as

\[
W_k = ( w_k, w_{k+1}, \ldots, w_{k+N-1} )
\]

Where \( w_k \) is row vector of scrambling matrix and \( k \) denotes \( k^{th} \) scrambling matrix. Then define the initial value \( W_0 \) when \( k=0 \), and equally divide the chaos domain \( x \in (0,1) \) into \( N \) subdomains from 1 to \( N \), and each subdomain represents an initial value of iteration in (1).

In order to obtain \( W_k \), a \( N \times N \) “0–1” inheritance matrix \( Q \) is defined as

\[
Q = \begin{bmatrix}
\alpha_{11} & \beta_{12} & \alpha_{1n} \\
\beta_{21} & \alpha_{22} & \alpha_{2n} \\
\alpha_{n1} & \alpha_{n2} & \beta_{nn}
\end{bmatrix}
\]

\( \alpha_{ij} = 0, \beta_{ij} = 1 \) (4)

In the inheritance matrix, each row has only one “ \( \beta \)” and no two rows are the same. \( \beta_{ij} \) records the initial value’s position for each row of \( W_k \). If we want to get \( W_k \), we have

\[
X = W_{k-1} \times Q
\]

The nonzero components of \( X \) indicate the initial iteration values for \( W_k \) in (1), attributable to the chaotic nature of the sequence, even constant position can get totally different initial worth. therefore \( X \) are often thought as hit and miss matrix. therefore with a given initial worth \( W_0 \) Associate in Nursing inheritance matrix \( Q \), the iterations can continue in step with chaotic provision map till traversal the matrix.

For each ONU, the info stream is encrypted by an exact variety of scrambling matrices and therefore the matrices area unit reversible on descramble the info at the ONU. it’s troublesome to extract the info from the signal while not the data of initial values and therefore the inheritance matrix of the scrambling matrices. The orthogonality of the OFDM signals still hold as the chaos scrambling before the inverse quick Fourier rework (IFFT) is performed. Since the scrambling is dead within the electrical domain, it are often designed into any technique of digital optical communications while not dynamic any optical module.
IV. RESULTS ANALYSIS

As shown in Fig. 4, the first bit streams are first off QPSK image mapped and then a serial-to-parallel conversion. The image streams for one ONU are encrypted by a bunch of dynamic scrambling matrices that are determined by the initial value and therefore the inheritance matrix. For an order of sixty four, a sixty four × sixty four inheritance matrix is adopted.

Fig. 5(a) and (b) show the normalized correlation between any 2 of sixty four symbols when encoding, once victimisation the incorrect secure key there’s no correlation peak is achieved. To qualitative analysis the system security, first take into account the exhaustive search attack at the malicious ONU.

Assuming the order of inheritance Matrix $N = 2^k$ is (the same for scrambling matrix), there are $2^k$ potential combination for the matrix, excluding the potential values of initial matrix within the domain $(0,1)$, therefore it’s unworkable to go looking for the secure key for every OFDM frame. As mentioned higher than, $k=6$ with sixty four × sixty four matrix to review the system performances is chosen and analysed. For every ONU, a selected W0 and Q is allotted, and altered the scrambling matrix each fifty OFDM frames.

The BER curves of the malicious ONU with and while not chaos scrambling are represented in Fig. 6(a) and (b). The bit error rate or bit error magnitude relation (BER) is that the variety of bit errors divided by the full variety of transferred bits throughout a studied amount. BER could be a unit less performance live, typically expressed as a share.

The BER curve of malicious ONU while not chaos scrambling conjointly indicates the OFDM while not encoding, and there’s regarding zero.6 dB power penalty compared with the signal with encoding, that is especially attributed to the code gain when chaos scrambling.

V. THROUGHPUT ANALYSIS

As the signal to noise ratio increases throughput also increases.

The throughput graph of SNR vs throughput is obtained. The above figure explains the throughput analysis for TDM PON.
As shown in Fig. 7, the throughput analysis is calculated for TDM OFDM PON with and without chaos scrambling.

VI. CONCLUSION

In this paper, a TDM-OFDM-PON is intended and high QOS is obtained. And a secure TDM-OFDM-PON in physical layer supported chaos scrambling is projected. The mapping methodology will effectively forestall the malicious ONU from attack. Scrambling matrices of 64-order area unit adopted in our experiment that ends up in an endeavor variety of more than 10^90. The results show a decent resist against attack and guarantee a confidential communication within the physical layer.

REFERENCES