9A3-5

Next Generation Hybrid OCDMA-WDM-PON with Soft Capacity

Liwei Yang, Hanyi Zhang, Xiaoping Zheng, Bingkun Zhou, Yili Guo, He Wen
State Key Laboratory on Integrated Optoelectronics / Tsinghua National Laboratory for Information Science and Technology
Department of Electronics Engineering, Tsinghua University, Beijing, 100084, China

***Abstract*--This paper proposes and theoretically demonstrates OCDMA-WDM-PON system supporting 16,000-32,000 available subscribers. Chaotic spread spectrum sequences are investigated to break a new path for encoding. Simulation results indicate that 10^{-12} BER can be achieved.**

I. INTRODUCTION

Recently, organizations such as ITU and FSAN have shown an interest in passive optical network (PON) allowing for higher data rates and higher number of users[1]. The convergence of optical code division multiple access (OCDMA) and wavelength division multiplexed (WDM)-PON could be attractive for last mile solution.

The introduction of WDM is an important advance for PON as multiple channels are used in bidirections. It is a promising approach for fiber to the home (FTTH) based on the capability of handling the ever-increasing bandwidth demands[2]. The key problem is the high cost and capacity limitation due to the number of available wavelengths. To take advantage of the huge-bandwidth in the optical domain, coexistence of legacy and new services architectures is a critical issue for future optical access[3]. Coherent OCDMA over WDM-PON has been proposed as an alternative solution[4].

In this paper, we integrate incoherent OCDMA and WDM to coexist at the same platform as incoherent encoding is simpler and more practical. It is known that the performance of OCDMA depends primarily on the code properties. So an important problem is to generate a powerful sequence with best correlation properties and large cardinality. Chaotic sequences are investigated here to break a new path for spread spectrum sequences in OCDMA by taking advantages such as ease of generation, random code choice, large family size, dynamic length control and increased security. By utilizing these schemes, future soft capacity optical access networks can be constructed and the increasing broadband services demands of customers can be satisfied.

II. HYBRID ACCESS NETWORK ARCHITECTURE

We consider the hybrid access network of Fig.1. It consists of optical line terminal (OLT), optical network unit (ONU) and remote node (RN). M×N users are divided into N groups by wavelengths. M encoded signals can be transmitted over a single channel simultaneously. OCDMA allows codeword reusage per channel. The system can support broadband services such as voice, video, data and even wireless services.

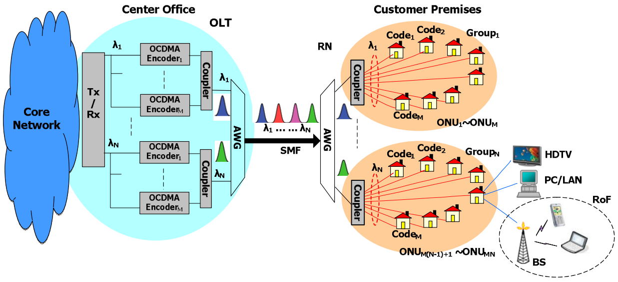


Fig.1. Configuration of hybrid OCDMA-WDM-PON

For downstream, different encoded data are multiplexed by coupler and signals with each different wavelength are multiplexed by arrayed waveguide grating (AWG) before sent to single mode fiber (SMF). After transmission, the hybrid signals are separated and detected in ONUs. Only the ONU with matched codes can recover the desired signal. We measured the optical spectrum characters when wavelengths range from 1510nm to 1570nm with 20nm wavelength spacing, shown in Fig.2.

Fig.2. Optical spectrum characters with 20nm wavelength spacing

Conventional incoherent encoding has good correlations but is relatively small in code space. To upgrade the capacity will increase the code length and complexity greatly. Hence, it is an important problem to search for novel sequences with large cardinality under acceptable performance. Chaos is a kind of deterministic, random-like process found in non-linear, dynamic system. OCDMA can effectively benefit from the noise-like feature and sensitive dependence on the initial conditions of chaotic sequences. That means it can support large number of users. From Fig.3, it can be seen that the slight difference will create completely different sequences after several iterations.

This work was supported by NSFC under grant No.60736003 and 973 Project under grant No.2006CB302805.

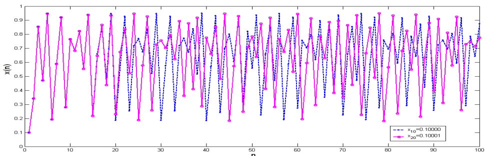


Fig.3. Sensitive dependence on initial conditions of chaotic sequences

The design of chaotic sequences and the simulation results of correlation performance are illustrated in Fig.4. Logistic-map $x_{n+1} = \gamma x_n(1-x_n), 1 < \gamma \le 4$ is used to generate real valued chaotic sequences $\{x_n\}$, Where, γ is control parameter. Then part of $\{x_n\}$ are used as initial values to generate $\{y_n\}$ and convert y_n to binary sequences. After optimization by correlations, the output sequence $\{C_n\}$ is the final one.

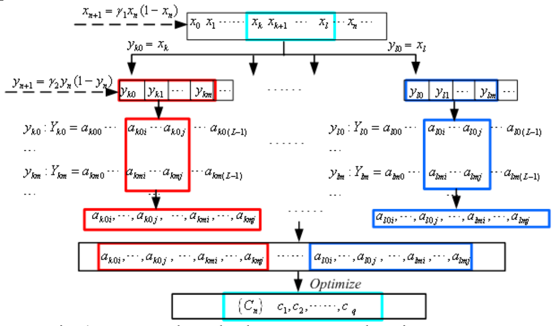


Fig.4. Proposed method to generate chaotic sequences

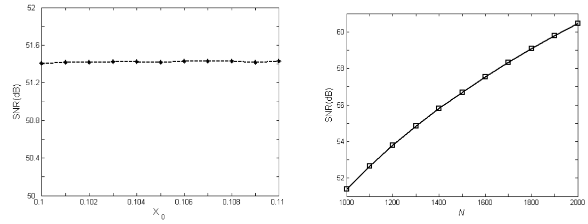
The key benefits of chaotic sequences are great number and increased security. Consider the difference of 10^{-5} for neighbor initial conditions and $x_{00} = 0.00001$ as the starting point, 10^5 sequences can be generated in the space [0, 1] under the same γ. Assume 1% optimal sequences are selected and then the number of final sequences is 1000. Choose 16/32 channels for Coarse WDM (CWDM) and Dense WDM (DWDM) respectively, the total subscribers for OCDMA-WDM-PON are 16,000-32,000 in theory, which is sufficient for FTTH. Furthermore, since a great number of control parameters can be chosen from, there is no real limitation on the number of users for OCDMA. An abundant source of almost uncorrelated signals can be discovered. That is also the main purpose of the uses of chaotic sequences.

III. Results and Discussions

The bit error rate (BER) of the proposed system under additive white Gaussian noise (AWGN) channel can be evaluated as Equation (1). Only multiple access interference (MAI) is considered.

$$BER = Q\left(\sqrt{SNR}\right) = Q\left(\sqrt{\frac{\varphi_{xx}^2(0)N}{\left(12\sigma^6 + 14\sigma^4 + \frac{9}{2}\sigma^2\right)}}\right) \quad (1)$$

Where σ^2 is the average power of noise and N is code length. Equation (1) indicates that the performance is determined mainly by the code length and auto-correlation functions.



(a) SNR versus initial point (b) SNR versus the length of sequence

Fig.5. SNR performance for chaotic sequences

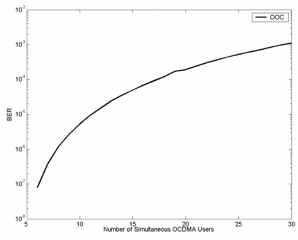


Fig.6. BER performance for OOC

SNR versus variable initial points and different N are also obtained by simulation, shown in Fig.5. The SNR maintains at about 51.4dB when x_0 changes from 0.1 to 0.11. From Equation (1), it can be calculated that 10^{-12} BER is obtained when SNR near 50 dB. With the increase of the length, SNR is also enhanced accordingly. It can be verified that the SNR performance is improved by about 9 dB from $N = 1000$ to $N = 2000$. Fig.6 presents the BER performance for optical orthogonal code (OOC). It can be evaluated that the performance degrades quickly when the simultaneous users come to a threshold. For example, only 10^{-3} BER is achieved when simultaneous OCDMA users arrive 30. Chaotic sequences are more adaptive for large-branches PON.

IV. Conclusions

This paper described the configuration of hybrid OCDMA-WDM-PON. It is a promising technology to realize soft capacity access network and high utilization of the bandwidth, as the subscribers of WDM-PON can be multiplied.

As a key issue, optical encoding schemes are discussed. Chaotic sequences are introduced and constructed. Simulation results indicate that the proposed scheme can offer favorable correlation characters, high capacity and acceptable transmission performance.

References

[1] J.B.Rosas-Fernandez, J.D.Ingham and R.V.Penty, etc, "High Performance PONs based on I-Q Modulation of Electronic CDMA Channels," OFC/NFOEC 2009, paper OWR3, 2009.

[2] J.Yu, O.Akanbi and Y.Luo, etc, "Demonstration of a Novel WDM Passive Optical Network Architecture with Source-Free Optical Network Units," IEEE Photonics Technology Letters, 19(8): 571-573, 2007.

[3] H.Tamai, M.Sarashina and H.Iwamura, etc, "Experimental Analyses of Hybrid Gigabit TDM-PON and Code Division Multiplexed PON Architecture toward Next Generation Access Network," OFC/NFOEC 2009, paper JThA76, 2009.

[4] K.Kitayama, X.Wang and N.Wada, "OCDMA over WDM PON-Solution Path to Gigabit-Symmetric FTTH," Journal of Lightwave Technology, 24(4): 1654-1662, 2006.