Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
April 2016, 23(2): 91–96
www.sciencedirect.com/science/journal/10058885
The Journal of China Universities of Posts and Telecommunications
http://jcupt.bupt.edu.cn

Hierarchy echo state network based service-awareness in 10G-EPON

Bai Huifeng (✉), Wang Dongshan, Wang Licheng, Wang Xiang

Beijing SmartChip Microelectronics Company Limited, Beijing 102200, China

Abstract

Aimed to enhance the supporting ability for diversified services, this paper proposes a hierarchy echo state network (HESE) based service-awareness (SA) (HESN-SA) mechanism in 10 Gbit/s Ethernet passive optical network (10G-EPON). In this HESN-SA, hierarchy architecture is adopted to realize echo state network (ESN) classification based SA. According to the network architecture of 10G-EPON, the parent-ESN (p-ESN) module works in the optical line terminal (OLT), while the sub-ESN (s-ESN) module is embedded in optical network units (ONUs). Thus, the p-ESN plays the main function of SA with a total view of this system, and s-ESN in each ONU conducts the SA function under the control of p-ESN. Thus, resources allocation and transport policy are both determined by the proposed mechanism through cooperation between OLT and ONUs. Simulation results show that the HESN-SA can improve the supporting ability for multiple services.

Keywords passive optical network, service-awareness, hierarchy echo state network, echo state network

1 Introduction

As multiple services develop with diverted requirements on both quality and quantity, passive optical network (PON) technologies are undergoing great challenges brought by services-diversity [1]. In fact, the services-diversity includes diversified characteristics and diversified requirements or demands. Moreover, those multi-services are merging rapidly with increasing demand on network capability, reliability and dynamic. Therefore, this trend has presented requirement of service-aware ability on supporting network architecture for future-proof. With high capacity to provide access for multiple information services, the 10G-EPON is a strong candidate to support communication demand of services-diversity [2–5]. Therefore, the 10G-EPON must be characterized by service-aware ability. However, it is an urgent problem that current 10G-EPON fails to be fully aware of characteristics and requirements of multiple services and to actively match these services with high efficiency.

The service-aware is an important issue in many fields such as network design, network management, and network security [3]. Great efforts have been made on analyzing and classifying technologies of services. Deep research on relation between statistic characteristics and service protocols has been done in Refs. [6–7]. However, those approaches are not so accurate for service-layer protocol. As furthering research, a simple data-traffic identification and classification mechanism was proposed in Refs. [6–8], which is based on the packet length, arrival time interval and arrival sequence. As one solution, a Bayesian classifier based SA (BC-SA) has been presented in Ref. [8]. This also implies that more pattern recognition algorithms also have great potential to realize SA. However, there exist several problems in current neural network algorithms, including consuming time and computational complexity and so on. The ESN [9] is a strong candidate to realize SA, as ESN has great advantages to enhance reliability, improve accuracy, and reduced complexity [10–11]. Considering the architecture of 10G-EPON, there still exists great problem to make the ESN be suitable to the 10G-EPON system, which is composed by OLT and a number of ONUs. If the ESN is directly embedded as a whole in ONUs, the complexity and cost of ONU will greatly increased. And the OLT-ONUs architecture also makes it unfeasible to allocate the whole ESN only in OLT, since ONUs fail to

Received date: 01-01-2015
Corresponding author: Bai Huifeng, E-mail: lancer101@163.com
DOI: 10.1016/S1005-8885(16)60025-0

benefit from original ESN based SA.

Aimed to solve these problems, this article proposes a HESN-SA mechanism in 10G-EPON. In the HESN-SA scheme, great improvement is made, where a hierarchy structure is adopted and the main function of ESN is centralized in OLT according to the PON architecture. In this proposed HESN-SA mechanism, the so called p-ESN in the OLT is responsible for the main task of the reservoir and the output-layer in ESN. While the s-ESN in ONU just simply performs the function of input-layer in ESN and works under control of p-ESN. Thus, complex SA function is centralized in the OLT.

The rest of this article is organized as follows. Sect. 2 discusses the principle of the ESN and ESN static classification. And Sect. 3 proposes the HESN-SA mechanism. The simulation results and analysis are given in Sect. 4. Finally, Sect. 5 concludes this paper.

2 Principle of ESN

2.1 Basic principle of ESN

As Fig. 1 shows, the architecture of the ESN is divided into three layers, including input layer, reservoir and output layer [9–11].

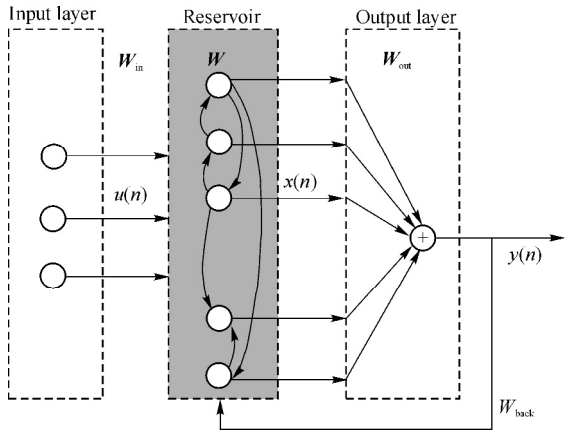

Fig. 1 ESN structure

There is great number of neurons in this dynamical reservoir with quite strong learning ability. Assume that there are L input units, M output units and N units in reservoir. Generally, the connection weight matrix is represented as $\boldsymbol{W}_{\text{in}}$ of the input layer, while its corresponding unit in the reservoir is $\boldsymbol{W}$. Thus, the dynamical learning ability and reliability of ESN can be ensured. In addition, the $\boldsymbol{W}_{\text{out}}$ is the connection weight matrix of output layer and is the goal of data training in ESN.

The basic idea of the ESN is that: the reservoir is triggered by the input signal to produce continuous state-variable within this reservoir. And the output value of ESN can be obtained by using linear regression algorithm between state-variable and output value. The state of reservoir and output are updated using Eqs. (1) and (2).

$$x(n+1)=f\left(\boldsymbol{W}_{\text{in}}u(n+1)+\boldsymbol{W}x(n)+\boldsymbol{W}_{\text{back}}y(n)\right) \tag{1}$$

$$y(n+1)=f_{\text{out}}\left(\boldsymbol{W}_{\text{out}}u(n+1)+\boldsymbol{W}x(n+1)+\boldsymbol{W}_{\text{back}}y(n)\right) \tag{2}$$

where, $u(n)$, $x(n)$ and $y(n)$ represents individually the input variable, state variable and output variable, $f(\cdot)$ and $f_{\text{out}}(\cdot)$ are the activation functions of processing units of the reservoir and the output unit.

2.2 ESN static classification

Generally, ESN has been widely used in time series field and shows great potential in classification. Different from traditional ESN, a static classification oriented ESN method has been proposed in Ref. [11], in which the relation between state variables is independent. The basic idea of ESN static classification is given in Eq. (3) and that means input signals must be kept without change until state variables are quite stable.

$$\begin{cases} x(n+1)^{(i)}=\boldsymbol{W}_{\text{in}}u(n+1)+\boldsymbol{W}x(n+1)^{(i-1)} \\ x(n+1)^{(0)}=0 \end{cases} \tag{3}$$

This method still keeps the advantage of ESN in which the training is fast and simple, and shows great performance in classification.

However, the reservoir of ESN is generated randomly in this approach. Therefore, this ESN classification approach still fails to gain the classification result with nice targeting and to satisfy the classification requirement for diversified services.

3 HESN-SA mechanism in 10G-EPON

As types of new services traffics soar, intelligent service-aware ability is required for 10G-EPON. According to the classification demands of service in 10G-EPON, key parameters to identify the type of service include: packet length, packet arrival rate and service-procession time. Those parameters of service characteristics can be gained through independently different methods. Aimed to solve the low targeting problem of current SA approaches, a HESN-SA is