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智能电网的10G-EPON中基于贝叶斯分类的业务感知机制

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摘　要:随着智能电网的发展及其多种信息业务的涌现,10G-EPON作为业务接入技术日益成为重要支撑;然而业务的多元化对10G-EPON的多业务支撑能力提出了重要挑战.为了适应电力系统中多种不同类型业务的需求,本文对智能电网的信息业务特性进行分析,提出了一种基于贝叶斯分类的10G-EPON业务感知机制;并且根据10G-EPON中OLT与ONU的主从式网络架构特点,提出了业务感知的主从式实现方式.该机制使用贝叶斯网络分析数据包的特征,进而确认待传送业务的类型.在贝叶斯业务分类的基础上,通过OLT和ONU之间的交互决定业务的资源分配和传输策略.为了验证新机制的有效性,分别从时延和丢包率两方面进行系统仿真.仿真结果表明,所提出的基于贝叶斯分类的业务感知机制在时延和丢包率具有显著的优势,能够实现业务与10G-EPON的高效匹配,提高10G-EPON在智能电网应用中多业务的区分支持能力.

关键词:无源光网络;业务感知;贝叶斯分类;智能电网
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Bayesian Classifier Based Service-aware Mechanism in 10G-EPON for Smart Power Grid

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Abstract: With emerging of multiple services brought by smart power grid, the rapid evolution of 10G-EPON (10 Gigabit Ethernet Passive Optical Network) provides great access for multiple services with high capacity. However, newly emerging multiple services have diversified characteristics and demands, which presents great problems for current 10G-EPON to match these services with high quality and matching degree. To satisfy requirements of diversified types of services in power electirc system, services charactrisetcs and demands of smart power grid are discussed, and a Bayesian Classifier based Service Awareness (BC-SA) mechanism of 10G-EPON is proposed for smart power grid. According to the "master-slave" architecture between OLT (Optical Line Terminal) and ONUs (Optical network Units) in 10G-EPON, a similar "master-slave" structure is adopted and designed in the proposed BS-SA mechanism. By using Bayesian classifier, the BC-SA mechanism is able to be aware of the type of service. On the basis of Bayesian classification, resources allocation and transport policy are both determined by the proposed mechanism throught cooperation between OLT and ONUs. In order to verify the reasonability of this BC-SA, system simulation is conducted in domains of delay and packet-loss-

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rate. Simulation results show that the BC-SA is able to achieve greatly better performance of both delay and packet-loss-rate, and improve the supporting ability for data services of smart power grid with better matching degree.

Key words: Passive optical network; Service aware; Bayesian classifier; Smart power grid

0 Introduction

With development of the energy internet as an important part of smart power grid, newly emerging services with diversified characteristics and requirements are brought by the energy internet[1]. These services come from generation, transmission and distribution procedures in smart power grid, and must be closely monitored and forecasted with the aim to better the energy schedule[1-2]. Following this trend, the 10G-EPON (10 Gigabit Ethernet Passive Optical Network) is a strong candidate with high capacity to provide access for multiple information services produced by the energy internet[3-7]. However, one key challenge of the 10G-EPON is to support the diversified nature of services, while new services are being deployed on the smart power grid and some new services, such as sensing services, are becoming popular. Therefore, the 10G-EPON must be characterized by "service-aware" ability for future-proof. 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 important in many areas such as network design, network management, and network security[8]. However, with the emerging of multiple services in terms of number and type of services, traditional data traffic classification techniques, which are based on the well-known port numbers or packet payload analysis, are no longer effective for all types of network traffic because of privacy or security concerns for the data. Therefore, 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. [8-10]. 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. [11-12], which is based on the packet length, arrival time interval and arrival sequence. The common disadvantage of those approaches is that they fail to achieve high accuracy, because the arrival time interval in those approaches highly depends on the end-to-end delay and their statistic characteristics are tightly related to time and place.

The concept of service-aware can be considered as a feasible approach and be introduced into 10G-EPON system, in order to enhance the service access ability of 10G-EPON system. This article proposes a Bayesian classifier based service-aware (BC-SA) mechanism in 10G-EPON for energy internet in smart power grid. By using Bayesian classifier model, the BC-SA mechanism is able to be aware of the type of service and to cooperate with the DBA (Dynamic Bandwidth Allocation), with the aim to achieve high matching degree between services and 10G-EPON. In the BS-SA scheme, a dual-stage structure is adopted since the PON architecture is consist of OLT (Optical Line Terminal) and ONUs (Optical Network Units), where the first stage of BC-SA scheme is embedded into ONU and the second stage called "service-aware model" is running in OLT. Based on this BC-SA, more efficient resources scheduling can be conducted in 10G-PON system.

The rest of this paper is organized as follows. Section 2 discusses the Bayesian classifier; followed by the description of the Bayesian classifier based service-aware (BC-SA) Mechanism in section 3. section 4 gives the simulation results. Finally, section 5 concludes this paper.

1 Related works

1.1 Services characteristics of smart power grid

Following the development of smart power grid, information communication services brought by power electric system increase rapidly. Those services include: power electric distribution automation, power electric monitoring, and intelligent power utility, etc. Communication services of smart power grid mainly have the following characteristics[13-14].

1) Services diversity: communication network of smart power grid must provide support to control service, power utility data service and distributed energy service, etc.

2) Demands diversity: great differences of

demand exist among different services including delay, bandwidth and packet loss rate, etc. For example, the control service is sensitive to time delay, while power utility data service has high demand on packet-loss performance.

As types and traffic of services of smart power grid soar, intelligent service-aware ability is required for 10G-EPON. To reach this goal, the Bayesian Classification is considered to be one feasible approach to realize service awareness of 10G-EPON.

1.2 Principle of Bayesian network

The basic principle of Bayesian network is described as follows: the posterior probability of an object is calculated by Bayesian formula according to its prior probability, in order to decide which class this object belongs to; then the class with the biggest posterior probability will become the one. The Bayesian network is a directed acyclic graph, which consist of nodes and directed edges. Nodes represent variables that need to be classified, while directed edges represent relationships among these nodes. Each node in the Bayesian network has a corresponding conditional probability to determine its father node from all possible values; if there is no father node of this node, its prior probability is directly used as the conditional probability. The probability distribution of each variable in Bayesian network is defined by the Bayesian network structure and the conditional probability table of each node[15].

We assume that $\boldsymbol{X}\{x_1, x_2, \cdots, x_k, \cdots\}$ is a feature set to describe data packet of someone service, while $\boldsymbol{Y}\{y_1, y_2, \cdots, y_k, \cdots\}$ is a services-class set. B is defined as Bayesian model on $\boldsymbol{X}$, and the conditional probability of each node is gained

$$P_{\mathrm{B}}=P[A \mid F(A), A\in \boldsymbol{X}] \tag{1}$$

where the $F(A)$ is the father node set A belongs to. Thus, the joint probability distribution of Bayesian network B is given[9]

$$P(\boldsymbol{X},\boldsymbol{Y})=\prod_{A\in \boldsymbol{X}} P[A\mid F(A)] \tag{2}$$

The Bayesian classification is conducted by calculating posterior probability

$$P(y_j,\boldsymbol{X})=\frac{P(y_j,\boldsymbol{X})}{P(\boldsymbol{X})} \tag{3}$$

The mapping relationship between $\boldsymbol{X}$ and y_i can be gained by selecting y_i to obtain the maximal value of $P(y_j\mid \boldsymbol{X})$.

1.3 Bayesian classifier

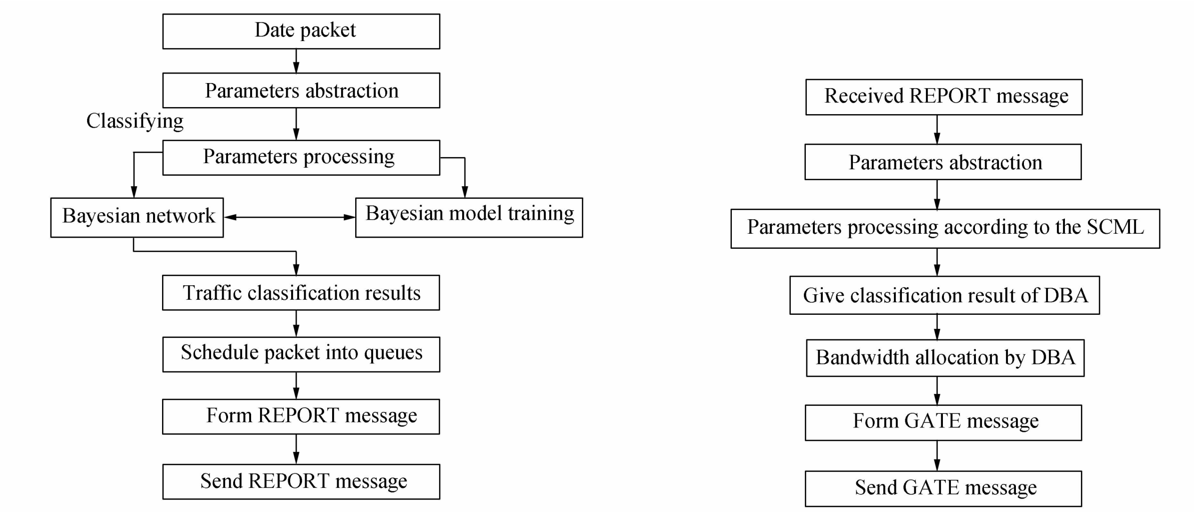
Assume that the $\boldsymbol{Q}=\{P_1, P_2, P_3, \cdots, P_i, \cdots\}$ is a set of data traffic, where P_i represent the data packet i. The length of data packet P_i is L_i, and its arrival time is T_i. The time for one service-layer protocol to complete operation of someone service is defined as "protocol-processing time", which is an important feature to differentiate various kinds of service protocols.

The basic idea of Bayesian classifier theory is depicted as follows: the prior probability of Bayesian model need to be gained by a set of training data. For each data packet of service, the ONU abstracts the characteristic parameter from data packet P_i, including the packet length L_i and packet arrival time interval T_{ri}. Moreover, the characteristic parameter $\boldsymbol{x}_i=\{L_i, T_{ui}\}$ and the feature set $\boldsymbol{X}\{x_1, x_2, \cdots, x_k, \cdots\}$ can be obtained. Later, $\boldsymbol{X}\{x_1, x_2, \cdots, x_k, \cdots\}$ is further proceeded by the trained Bayesian model and the posterior probability is calculated to judge which class this traffic belongs to. The accuracy of this method is evaluated by training the classifier using one data-set and then testing it against the remaining data sets. This process cycle of training with one data-set and training against the other data-sets is repeated once for each data-set[15].

2 Bayesian classifier based service aware mechanism of 10G-EPON

As the access network for multiple information services of smart power grid, the 10G-EPON is responsible to provide support to match service requirements. Aimed to enhance the efficient support ability of 10G-EPON for multiple-services, a Bayesian classifier based service-aware (BC-SA) mechanism in 10G-EPON is proposed, in which the packet length, packet arrival time and the arrival rate of the same type packets are considered as characteristic parameters. And the arrival rate of packets can be calculated according to the history record of the packet types, which is realized by using a feedback training module showed in Fig. 1(a).

Because 10G-PON architecture is consist of OLT (Optical Line Terminal) and ONU (Optical Network Unit), the BC-SA scheme is designed using the "master-agent" method: the "agent module" in ONU and the "master module" in OLT. The flowcharts of BC-SA scheme, including the agent module and master module, are depicted in Fig. 2.



(a) ONU stage of BC-SA　　(b) OLT stage of BC-SA

Fig. 1　Flowchart of the BC-SA mechanism

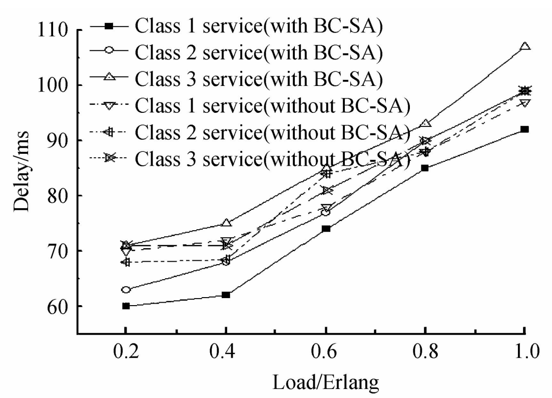


Fig. 2　Comparison of network delay

In the ONU stage of BC-SA mechanism, an "agent module" is embedded in each ONU and is responsible for the first stage procession. And there are m queues in each ONU, represented as $\{q_1, q_2, \cdots, q_m\}$. Assume that there are r parameters of one service traffic with n class for each parameter. Thus, there are R_n kinds of traffics classes and each one has different requirements from others. On the basis of traffic identification and classification of services, "service-aware module" schedules queues resources for packets according to their priority and makes sure that packet with high priority can achieve high service quality. Then, the information of traffic-identification result will be added into the REPORT message send by ONU to OLT.

One important issue must be pointed out is the calculation of IAT (Interval of Arrival Time) in the ONU stage, because of the reason of 10G-PON system architecture. As bidirectional service traffic packets between a pair of nodes carry the time stamps and the IP addresses, the IAT can be calculated by abstracting the information of time and IP addresses. Here, we assume that bidirectional packets of the same service go through the same path, and the IAT can be obtained:

$$T_{\mathrm{IAT}} = T_{Pi+1} - T_{Pi} - 2T_{\mathrm{D}} \tag{4}$$

where T_{Pi} is the arriving-time of packet i, and T_{D} is the end-to-end transport delay. Furthermore, the detailed procedure of the agent module in ONU stage of BC-SA scheme is described as follows:

Step 1: on receiving data traffic packet, the parameters information is abstracted from the data packet, including the packet length and IAT;

Step 2: parameters processing is conducted.

Step 3: the results of parameters processing are given to both Bayesian network model by classifying and Bayesian model training.

Step 4: the traffic classification results are gained through Bayesian network model;

Step 5: schedule packet into corresponding queues in ONU;

Step 6: the REPORT message is formed and send by ONU to OLT.

In the OLT stage of BC-SA mechanism, there is a so-called "master model" running in the OLT, which is responsible of the second stage procession. Additionally, the classifier module keeps a recode of service-class mapping list (SCML) that is obtained by collecting priority information from all ONU. This module works together with the DBA (Dynamic Bandwidth Allocation) module, using the SCML. Thus, the BC-SA mechanism allows OLT to set the priority level of each ONU according to the traffic priority information from REPORT messages from ONUs. The flowchart of master module in the OLT stage of BC-SA scheme is described as follows:

Step 1: receive the REPORT message from

ONU;

Step 2: the parameters information is abstracted from the REPORT message by OLT;

Step 3: parameters processing is conducted according to the SCML.

Step 4: the results of parameters processing are given to the DBA module.

Step 5: the GATE message is formed and send by OLT to ONU.

For implement, the MPCP should be extended by adding new fields into the REPORT and GATE messages, which will indicate the priority characteristics information about packets and ONUs.

3 Simulation results and analysis

In order to evaluate the performance of the proposed mechanism, we use NS2 to build a software simulation platform of 10G-EPON system with 32 ONUs. The upstream channel capacity is equal to 10 Gbps. The maximum cycle time is 2 ms and the guard time is separated two consecutive transmission windows with 5 us. The "agent module" is running in each ONU, while the "master module" works in the OLT. In this simulation, three classes of services are set to produce traffic load, and requirements of services to network are represented by two parameters: the average packet delay and the packet loss rate. Additionally, these services are divided into three class levels, where class1 is high-level and class2 is middle-level and class3 is low-level. Moreover, the class1 services and class2 services take 30% independently, and the class3 service is 40%. Both of the average packet delay and the packet loss rate are observed and analyzed in this section. The traffic load of each class service follows the Passion distribution.

The comparison of network delay is given in Fig. 2. Obviously, delay time of all services soars as the traffic load increase. Under the same traffic load condition, class1 service and class2 service with BC-SA show better value than their corresponding ones without BC-SA, while class3 service with BC-SA gets the worst value. Because the class3 service has lowest requirement on delay time, it is tolerant to this time-delay performance. Additionally, the class1 services can achieve the best performance. Another result can be observed is that all three classes of services without BC-SA fail to match diversified priorities and different services of all three classes are unable to get corresponding service qualities, because they are treated in the random manner.

Fig. 3 shows the comparison of packet loss rate. Overall, the packet loss rate of all services soars as the traffic load becomes heavy. Similar to the comparison result of network delay time, class1 service and class2 service with BC-SA show lower packet loss rate than their corresponding ones without BC-SA. And the class3 service with BC-SA still gets the worst result, since it has the lowest requirement on packet loss rate. Fig. 3 also shows that all three classes of services without BC-SA have similar performances. Thought comparison, the packet-loss-rate of all three types of services with BC-SA is much more reasonable than these ones without BC-SA. With the BC-SA scheme, the differences among those services are increasingly more obvious. Thus, the requirements of different classes of services on packet loss rate can all be better satisfied by using the BC-SA mechanism.

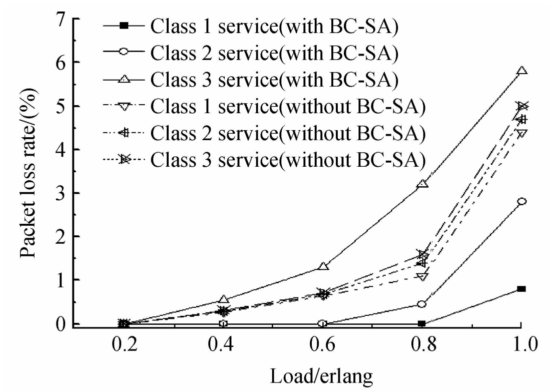


Fig. 3 Comparison of packet loss rate

Combining the comparison results of both Fig. 2 and Fig. 3, further conclusion can be drawn. Under comprehensive consideration of these three kinds of services with and without BC-SA function, the BC-SA scheme allows the 10G-EPON to match multiple services with better and more reasonable performances, while the original 10G-EPON system without BC-SA scheme failed to do so. Thus, the more tightly matching between services and 10G-EPON can be achieved by adopting the BC-SA mechanism.

4 Conclusion

The energy internet was an important service field of smart power grid. As the important access network technology to support multiple services brought by the energy internet, the 10G-EPON was required to actively be aware of the characteristics of those service and to provide support with not only high capacity but also high matching degree. However, newly emerging multiple services brought by the Energy Internet had diversified characteristics and demands, which presented great problem for current 10G-EPON to match tightly these services with high efficiency and dynamic. This article has proposed a Bayesian classifier based service-aware (BC-SA) mechanism in 10G-EPON. By using Bayesian network model, the BC-SA mechanism for different services was realized. Based on this BC-SA approach, more efficient resources scheduling was able to be conducted in 10G-PON system. Simulation results showed that the BC-SA scheme was able to match requirements by Energy Internet services with high efficiency.

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