Campus Network Planning and Design Based on GPON Technology

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***Abstract*—With the continuous development of Internet applications, in order to meet the increasing demands of teachers and students for the campus network in teaching, scientific research, office work and daily life, it is necessary to build a network environment that can meet the needs of smart campuses and future new applications. This paper makes an in-depth analysis of the current situation of campus networks, uses Gigabit Passive Optical Network (GPON) technology to upgrade and transform the existing network, reduces the cost of switching equipment and maintenance difficulty, improves the network transmission rate, increases the upper limit of campus network user access, and effectively solves the problem of separation between wired and wireless networks.**

***Index Terms*—Smart Campus, Campus Network, Gigabit Passive Optical Network, Network Transmission Rate**

I. Introduction

The campus network of colleges and universities is a broadband multimedia local area network that undertakes the important task of providing advanced informatization foundations for school office work, teaching and scientific research experiments [1]. The development of various application software, network platforms and the popularization of smart classrooms have made teachers and students require higher and higher campus networks. At the same time, in order for the education industry to better connect with the social informatization environment, it should promote the campus informatization construction from the digital campus to the smart campus, and the construction of smart campuses also relies on the stable and powerful network foundation [2, 3]. Driven by the highly developed information technology and the promotion of smart campus construction, colleges and universities, as multi-personnel and high-density teaching and office sites, have higher requirements for the bandwidth, network transmission rate, security, stability and scalability of the basic campus network [4]. At present, most colleges and universities still adopt a three-layer Ethernet structure, the network backbone adopts optical cable transmission media, 10Gbps interconnection, and the access network adopts copper cable transmission media, 100Mbps to indoor. With the continuous construction of campus networks in various colleges and universities and the introduction of series standards such as Measures for the Protection and Management of Information Security Levels [5], the performance and security of the core networks of most colleges and universities have been fully improved, but there are still problems in the access network such as low transmission rate, decentralized switching equipment, difficulty in upgrading and reconstruction, and separation of wired and wireless networks, which has become a bottleneck in the performance development of the overall campus network. Therefore, designing and researching a campus network with high-performance access network is of great significance.

There is a lot of research on campus network structure. Currently more common methods include technologies based on Software Define Network (SDN), Ethernet Passive Optical Network (EPON), and fusion of multiple network technologies. The core idea of SDN technology is to separate the control plane and data plane of network devices to achieve centralized management and distributed control [6]. Ma Yaying [7] proposed to use SDN technology for the construction of smart campus networks to solve problems such as decentralized traditional network devices, complex structures, and difficulty in deploying new services. Although it has improved the performance of campus networks to a certain extent, it still cannot break through the bottleneck of campus access networks. EPON technology is a passive optical network technology based on Ethernet. It improves the performance of access networks by using optical fibers as transmission media in access networks based on Ethernet data transmission methods and network structures [8]. Tang Wuzhong and Hu Jinchu [9] applied EPON technology to campus networks to solve the ”last mile” network bottleneck. However, with the development of network technology, EPON technology is slightly inferior to Gigabit-capable Passive Optical Networks (GPON) technology in terms of bandwidth, transmission rate, service quality, security, etc. [10–12]. Zhao Zhenjie [13] proposed to reconstruct and build campus networks by combining GPON technology with traditional Ethernet, screening out application scenarios suitable for GPON technology, and using GPON technology for suitable scenarios while using traditional Ethernet for unsuitable scenarios. This method can improve network performance while controlling costs to a certain extent, but the network infrastructure is not unified, which will form a new bottleneck in subsequent campus network upgrades and reconstructions.

In view of the deficiencies of the above methods, this paper takes the campus network of Xinxiang Vocational and Technical College as an example, and designs and studies a campus network construction scheme based on GPON technology to solve the current problems of low transmission rate,

difficult upgrade reconstruction and separation between wired and wireless networks in college campus networks.

II. Campus Network Status Quo

A. Basic Structure of Campus Network

After years of construction and development, the campus network of Xinxiang Vocational and Technical College adopts a three-layer network structure. The 100Mb/s bandwidth education network, 1Gb/s China Unicom network and 1Gb/s China Mobile network are connected to the school network center machine room through dual main and standby links. The 10Gbps north-south traffic flows through the core switches to the data center area to ensure high-quality transmission of teaching management system data, financial system data, enrollment and employment platform data, website data, OA office data, monitoring and access control data, and various scientific research experiment server data. The 40Gbps east-west traffic flows through the core switches to student dormitories, office buildings, laboratory buildings and teaching buildings and other access networks. The network backbone is interconnected at 10Gbps, aggregated at 1Gbps to access switches, and connected at 100Mbps to access terminals, achieving wired coverage of all teaching and office areas. The basic topology of the school campus network is shown in Figure 1.

B. Problems of Current Campus Network

1) Low network transmission rate. The current campus network access layer uses Cat 5 twisted pair as wired transmission medium, with maximum transmission rate of 100Mb/s and maximum transmission distance of 100m. Without considering data loss during transmission, when there are 50 users accessing the network simultaneously under a port of the access switch, the average network speed is only close to 2Mb/s.

2) Large duct space occupied by access network cables, high difficulty in line reconstruction and maintenance. The diameter of Cat 5 twisted pair cable is 5mm and the cross-sectional area is about 19.625mm^2. 100m Cat 5 twisted pair cable weighs about 5kg.

3) Obsolete network switching equipment. Under the 7*24h full load working mode, most switches have exceeded the standard service life (3-5 years) and are in urgent need of renewal. Switches that have exceeded the service life but are still in use account for 72.65%, while about 60% of the switches that have not exceeded the service life are used in the core area in network structure upgrades and reconstructions in the past 3 years.

4) The school currently has about 130 switches for aggregation and access, each occupying a weak current room alone, with decentralized physical locations, large space occupation, high dependence on electricity, heat dissipation, potential safety hazards, and certain negative impacts on the natural environment.

5) The access layer wiring is not conducive to upgrade and reconstruction. The current campus network adopts the wiring method of ”access switch — cable rack — wiring trench — wiring conduit — wall — RJ45 interface panel” in the access layer. When the lines get old and damaged and need to be upgraded and reconstructed, it is difficult to replace new twisted pairs from the same location; if rewiring is required, it will cause line confusion and maintenance difficulties.

6) Separation of wired and wireless networks. At the initial stage of network construction, only wired access ports were provided for user terminals. The high-speed popularization of smart phones has greatly increased users' demand for wireless networks. Driven by this demand, the school adopted a method of building wireless coverage provided by Internet operators, resulting in the separation of equipment, lines and management of wired and wireless networks. The separation of wired and wireless networks will hinder the progress of informatization construction such as ”triple play” and ”one code universal”.

Based on this situation, after investigation and research, it was found that applying GPON technology to campus network construction can effectively solve many existing problems of the current campus network, improve the scalability of the campus network, and meet the growing network requirements of new services and applications for smart campuses.

III. GPON Technology

A. Introduction to GPON

The Passive Optical Networks (PON) architecture [14] is the recognized direction for the development of access networks in recent years. GPON technology is the latest generation access standard formed after years of PON development. Broadband Passive Optical Networks (BPON) and EPON originating from PON development are also available.

Compared with the other two standards, GPON standard has more advantages. The specific technical parameters are shown in Table I. GPON technology has higher security, more flexible split ratio and higher up/down transmission rate [10–12], which is more suitable for the usage requirements of college campus networks. Based on the above considerations, this paper studies and designs campus networks based on GPON technology to carry various teaching, research and office services.

Table I: Technical parameters of BPON, EPON and GPON

Standard	BPON	EPON	GPON
Downstream rate	622Mb/s	1.25Gb/s	2.5Gb/s
Upstream rate	155Mb/s	1.25Gb/s	1.25Gb/s
Split ratio	1:32	1:16	1:64
Security	Weak	Weak	Strong

B. GPON Network Architecture

GPON mainly consists of three parts: Optical Line Terminal (OLT), Optical Distribution Network (ODN) and Optical Network Unit (ONU) [15, 16]. The OLT is mainly deployed at the aggregation node, connected upstream to the network backbone and downstream to the splitters and other devices of the affiliated ODN. It has functions of centralized bandwidth allocation, controlling each ODN, real-time monitoring,

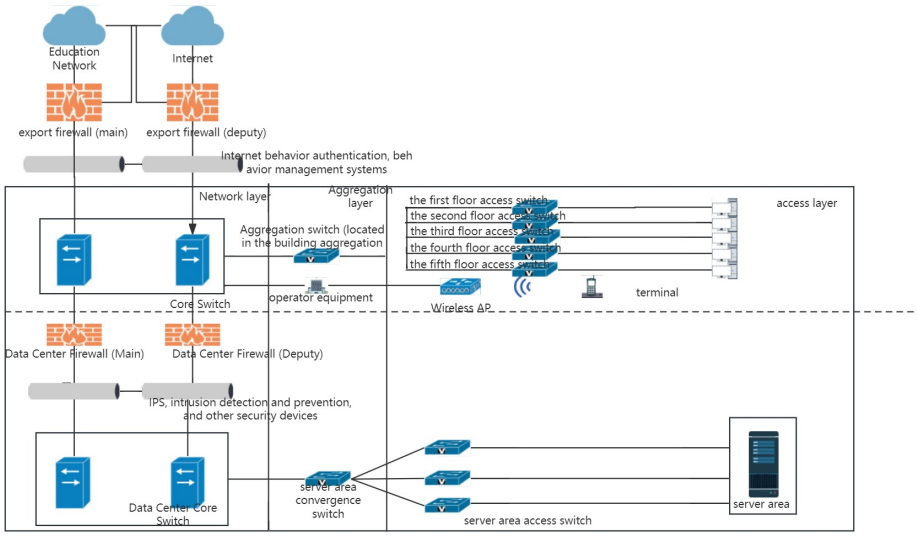

Fig. 1. Three-layer network topology of campus network

operation and maintenance management. ODN uses optical transmission media and passive optical devices to provide optical channels between OLT and ONU. ONU provides wired and wireless interfaces to user-end devices, and its main function is to selectively receive broadcast packets from OLT and upload user data to OLT at the same time. The GPON network architecture is shown in Figure 2.

The downstream transmission rate of GPON can reach 2.43Gb/s, and the upstream transmission rate can reach 1.215Gb/s. The high transmission rate of GPON depends on its transmission medium, signal multiplexing technology and data encapsulation method. GPON uses optical fiber as transmission medium, whose signal transmission method and physical properties determine its high transmission rate.

GPON uses Wavelength Division Multiplexing (WDM) technology to achieve bidirectional transmission over a single fiber. The 1290 - 1330 nm band is used as the upstream data transmission wavelength, and the 1480 - 1500 nm band is used as the downstream data transmission wavelength.

GPON provides connection-oriented communication [17]. In the downstream direction of OLT, the service data is broadcasted to all ONU devices under the port in GPON using GPON Encapsulation Mode (GEM). The GEM frame header filters out the GEM frames with matching Port-ID through the framing sublayer filter of ONU, unpacks them after filtering, and sends them to the user terminal device. The downstream working mode of GPON data is shown in Figure 3.

In GPON, a Transmission Container (T-CONT) that can achieve dynamic bandwidth allocation [18] is used to complete the upstream operation of ONU data. T-CONT is mapped to the GEM Port of the OLT side and uniquely identified by Alloc-ID. When the uplink service data is encapsulated into GEM frames, the ONU device sends it to the OLT device through the corresponding T-CONT queue according to the mapping rules between T-CONT and GEM Port. After receiving the uplink GEM frames, the OLT unpacks them and sends the data to the core network through the uplink port. The upstream data working mode of GPON is shown in Figure 4.

IV. Campus Network Design Based on GPON

A. Design Principles

1) High performance. An excellent campus network should be able to easily carry the launch of various business systems and meet the bandwidth and transmission rate requirements of users under various extreme conditions.

2) Stability. Use mature and applicable equipment and technologies to ensure the smooth progress of teaching, office work and scientific research.

3) Security. Security takes the top priority in the entire network construction, building a solid network defense system and network monitoring and management system to ensure the health and safety of the network environment for teachers and students, and ensure the confidentiality and integrity of office work and research data of the school.

4) Scalability. Scalability is a focus that must be planned in advance in campus network construction. The software, hardware equipment and cables laid should have high scalability to meet network new demands arising from the rapid development of informatization.

B. Campus Network Planning and Design Based on GPON

In this solution, 2 10Gbps firewalls are deployed at the outlet of the campus network, configured in active/standby hot backup mode to achieve imperceptible automatic primary and secondary switching, ensuring the overall security and stability of the campus network. 2 high-performance and high-scalability switches that support AP access control and multi-power supply are deployed in the central computer room as

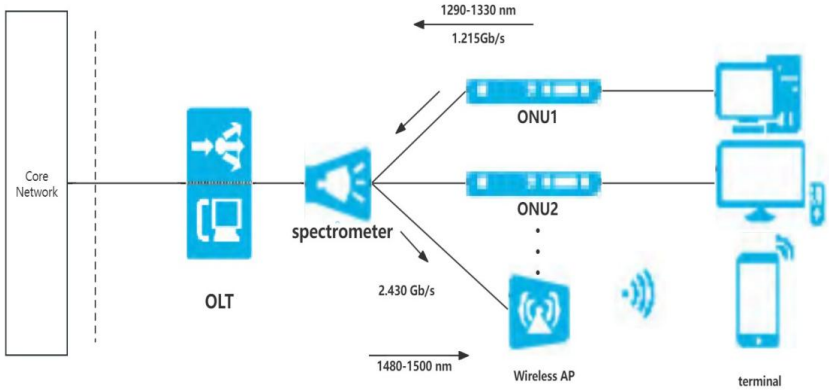

Fig. 2. GPON network architecture

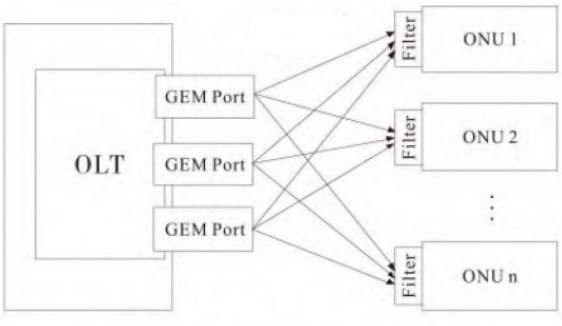

Fig. 3. GPON downstream data working mode

the core switches of the entire campus network, working in stack mode. 1 set of behavior authentication and behavior management servers are installed next to the core switches to authenticate and manage teachers' and students' Internet access. 2 10Gbps firewalls and 2 intrusion prevention devices are placed at the outlet of the data center to deeply protect the server area. Operation and maintenance audit systems (also known as bastion hosts), reverse proxy servers, vulnerability scanning servers, situational awareness systems and log audit systems are deployed in the data center management area to improve the security of various business systems in the data center area and strengthen the management capabilities of various business systems. Wireless networks are deployed, and different types of wireless access points (AP) are selected according to the number of users and scenarios. The built-in wireless access function of ONU can be used directly for office rooms, dormitories and other places without deploying additional wireless APs. Common APs are deployed in corridors and aisles of teaching buildings and office buildings. High-density APs are used in large conference rooms, classrooms, canteens and other places with high-density users to meet the WIFI access in high-density user scenarios. The selection of OLT devices depends on the scenario. Teaching buildings, student apartments, office buildings and other areas with aggregated machine rooms are configured with 2 OLT devices with 2 10Gbps uplink interfaces and 8 PON ports to achieve 1+1 redundancy backup and dual uplink protection. Places with smaller PON access demands such as canteens and gymnasiums can be configured with 2 OLT devices with 2 10Gbps uplink interfaces and 4 PON ports. An access controller (AC) is installed next to the OLT to centrally manage wireless access points. The selection of ONU devices needs to be determined according to the number of network access points required for each scenario. 4-person dormitories use models with 4 Ethernet interfaces + WIFI, dormitories with more than 4 people use models with 8 Ethernet interfaces + WIFI, small offices (less than or equal to 4 seats) use models with 4 Ethernet interfaces + WIFI, and large offices (more than 4 seats) use Models with 8 Ethernet interfaces + WIFI.

The OLT uses the Fiber To The Home (FTTH) access method to make the network access location of teachers and students more flexible. Abandon the traditional twisted-pair transmission medium and penetrate-the-wall wiring method. Wire along the top of the wall and use snap-in rectangular PVC trunking to protect and fix the fiber externally. The OLT uplink adopts dual-homing protection type B to improve the fault tolerance of network links. According to the scheme design, the overall topology of the campus network based on GPON technology is shown in Figure 5.

V. Application Effect

Applying GPON technology to campus network construction has significant performance improvements compared to the current campus network. It not only has advantages in parameters, but also solves many existing problems of the current campus network, mainly including:

Improved terminal access transmission rate. Without considering transmission loss, when the number of concurrent online users under a port of the access device is between 1-20, the average transmission rate of access users of the current campus network is above 4Mb/s, and the average network transmission rate of access users of the GPON-based campus network is

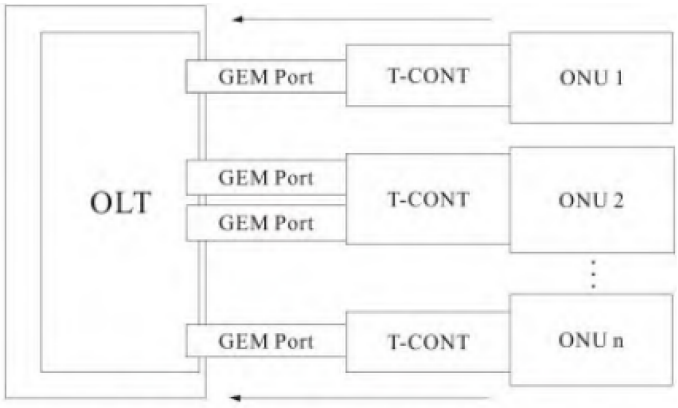

Fig. 4. GPON upstream data working mode

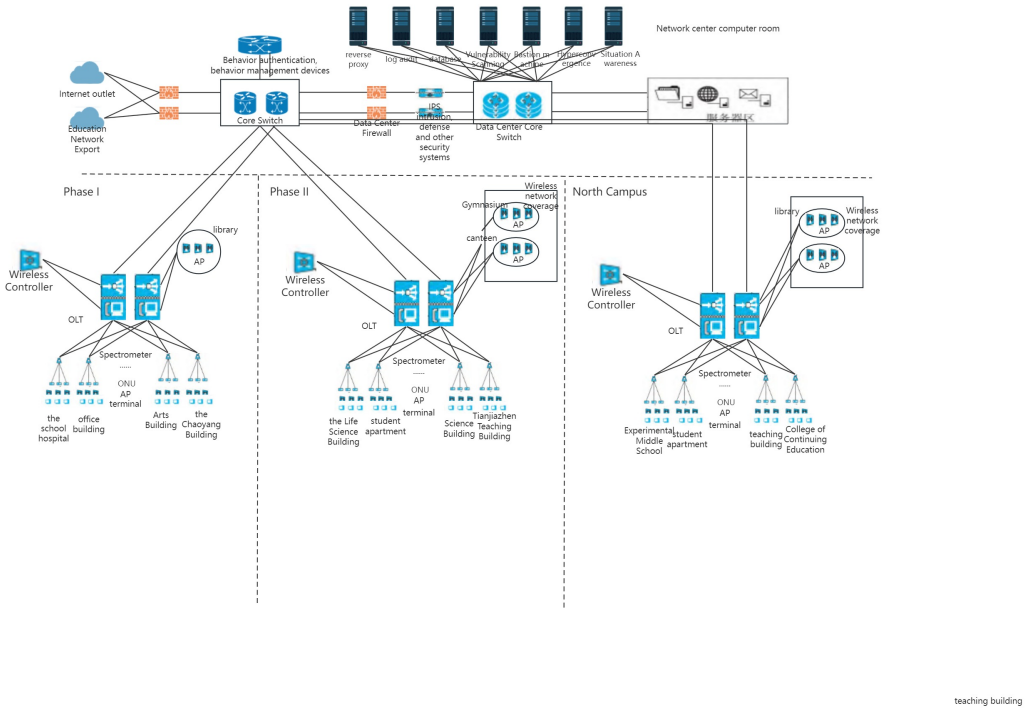

Fig. 5. Overall topology of campus network based on GPON

above 50Mb/s, which meets most network access needs. When the number of concurrent online users under a port of the access device is between 21-50, the average transmission rate of access users of the current campus network is between 2-4Mb/s, and some high-speed platforms and applications cannot be met. The average network transmission rate of access users of the GPON-based campus network is above 20Mb/s. When the number of concurrent online users under a port of the access device is between 50-100, the average transmission rate of access users of the current campus network is already between 1-2Mb/s, and phenomena such as video lag and slow resource download rate can be clearly perceived, while the average network transmission rate of access users of the GPON-based campus network is above 10Mb/s, which can still meet most network access needs. The comparison of terminal access transmission rates between GPON-based campus network and current campus network is shown in Figure 6.

Increased upper limit of access users. The current campus network uses access switches with 24 Ethernet ports, which can only support wired access for 24 user terminals without adding other devices. The campus network based on GPON technology supports a split ratio of up to 1:128. ONU devices can provide 8 wired interfaces and wireless signal access.

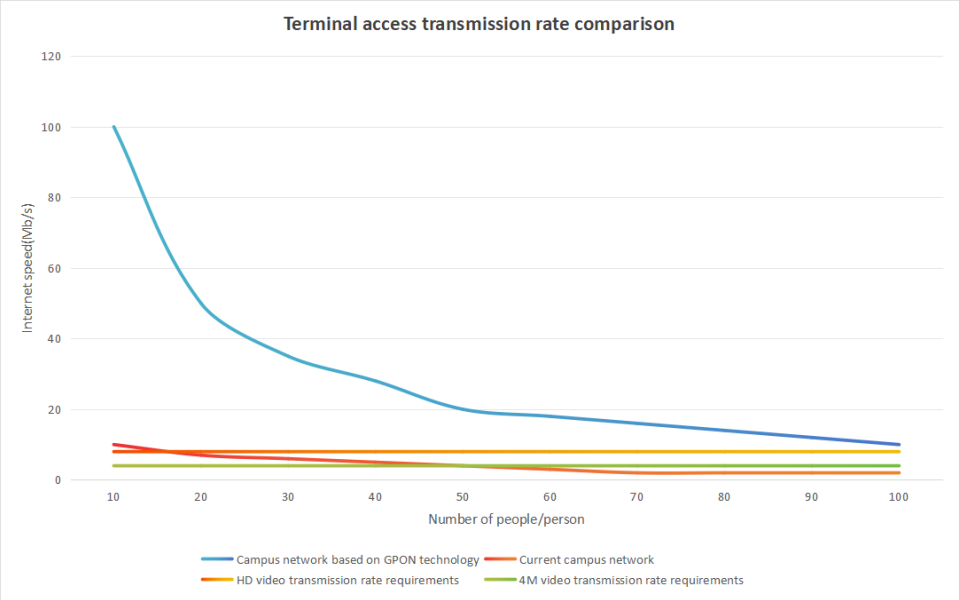

Fig. 6. Comparison of terminal access transmission rates

Therefore, 1 PON port of OLT can support access for more than 1024 user terminals. Easier addition of access ports. When the number of network terminals in the room increases, ONU devices with more access ports can be flexibly replaced to meet the access and use of more user terminals. Reduced space occupied by switching equipment. GPON-based networks do not use access switches and do not require separate weak current rooms on each floor, reducing equipment space occupation as well as school electricity consumption and heat dissipation. Reduced difficulty of network maintenance and reconstruction. The FTTH access method uses optical fiber as the transmission medium throughout, wiring along the top of the wall, and using snap-in rectangular PVC trunking to protect and fix the fiber externally, which makes it easy to add new lines and replace faulty fibers. Solved the problem of separation of wired and wireless networks. ONU devices providing terminal access have built-in wireless access functions, which can effectively provide wireless networks for users.

VI. Conclusion

GPON technology is the latest generation of passive optical network technology. Applying it to campus networks can not only solve many existing problems of the current campus network such as low network transmission rate, multiple network switches, large cable space occupation, high dependence on electricity, separation of wired and wireless networks, inconvenience for upgrade and reconstruction, but also has a crucial role in the continuous in-depth development of smart campuses. Follow-up studies will explore the integration of 5G technology and GPON technology to build a campus network with stronger performance, higher scalability and simpler structure to meet the network access needs of new services in the 5G era, and further promote the construction and development of smart campuses in colleges and universities.

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