Energy Saving of Optical Access Systems

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Abstract: This work reviews the standardization work of optical access networks in the field of energy saving, and introduces the development and application of energy-saving technologies for optical access networks.

1. Background

Fixed broadband networks have entered the F5G era [1], using optical access network (OAN) technology represented by 10G passive optical network (PON) [2] to provide bandwidth guarantees for diverse services such as Internet access and cloud access for households and enterprises. With the development of communication networks and technological progress, energy consumption and carbon emission also need attention. For the carbon emissions of fixed networks, ITU-T proposed in L.1470 to achieve a reduction of about 50% or more by the end of 2030 [3]. Green and low-carbon have become one important strategy for the development and evolution of many operators, and many initiatives have been carried out to achieve energy saving.

2. Energy consumption distribution of OAN

An OAN generally consists of optical line terminal (OLT) equipment, optical network unit (ONU) equipment, and a passive optical distribution network (ODN). ODN are all composed of passive facilities such as optical fibers and splitters, so they do not consume energy in operation. Therefore, in the actual operation of the OAN, energy consumption is mainly distributed in OLT and ONU equipment.

OLT devices generally contain multiple PON line cards, main control boards, backplanes, power supplies, fans, and other components. In addition, the different PON technologies used in the PON line cards and whether QoS/IP is enabled or not have a corresponding impact on the power consumption of the OLT equipment. COC v8.0 [4] gives a complete description of this and presents the average power consumption requirements leveled to a single PON port for different OLT configurations. OLT equipment is typically located in the operator's server room, so the operator typically bears energy consumption costs.

ONU devices generally contain WAN ports, LAN Ethernet ports, Wi-Fi, and internal forwarding module functions. Meanwhile, ONU devices can be divided into different states such as off-state, on-state, and idle-state according to their operating conditions, which correspond to different power consumption requirements. The power consumption distribution of a typical GPON home gateway is shown in Figure 1. COC v8.0 [4] provides corresponding power requirements for different configurations of ONU devices in the home network state. Home network-type ONU devices are usually located in the user's home, so the energy cost is usually borne by the user.

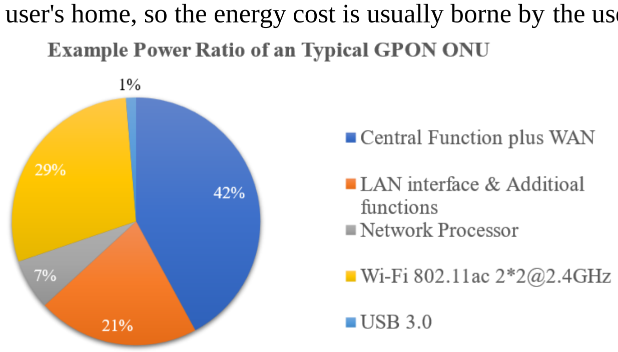
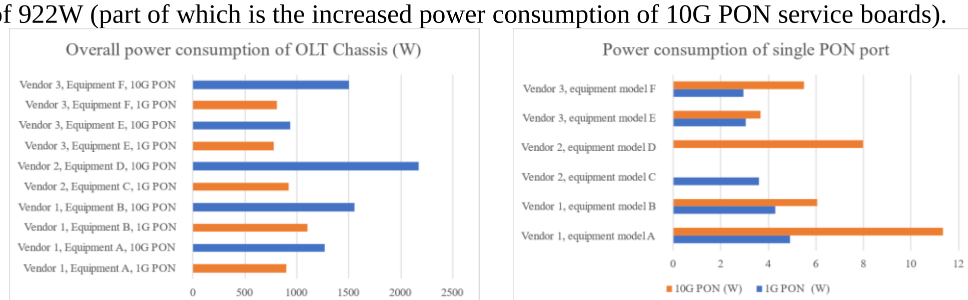


Figure 1 Example of power consumption distribution of GPON home gateway

3. OAN power consumption survey

To evaluate the energy consumption of OLT equipment, the research team first determined a typical configuration model for OLT. In the OLT frame, dual masters are used and configured to turn on dual 10GE master uplink ports, the remaining slots are fully equipped with PON service boards, and all PON ports are in working state, i.e., they are down-mounted with ONU terminals and configured for upstream and downstream service traffic. The model only distinguishes two types of OLT equipment, 1G PON (EPON or GPON), and 10G PON (10G-EPON or XG-PON).

The survey data shows that in the smooth upgrade process from 1G PON to 10G PON, the power consumption of the whole OLT equipment generally has increased significantly, as shown in Figure 2a. The specific reasons for the increase in power consumption include: first, the system capacity of the 10G PON OLT frame has increased, for example, the whole 10G PON OLT equipment of manufacturer 2 supports 272 10G PON ports, which is more than the number of 256 PON ports in the whole 1G PON OLT equipment; second, the power consumption of 10G PON service boards (including 10G PON optical modules) is more than that of 1G PON OLT equipment. For example, if the power consumption of the whole machine is converted into the power consumption of a single PON port, the power consumption of a single 10G PON port is increased to a maximum of 6.43W compared with that of a 1G PON port (based on the power consumption of 10G PON and 1G PON OLT from vendor 1, the relevant data are shown in Figure 2b); finally, 10G PON is generally For example, the power consumption of vendor 2 10G PON OLT equipment reaches 2168W, which is 1246W higher than the power consumption of its 1G PON OLT equipment of 922W (part of which is the increased power consumption of 10G PON service boards).



a) b)

Figure 2 1G PON and 10G PON OLT whole-chassis power consumption survey results

4. OAN energy-saving mechanisms

OAN Energy-saving mechanisms can be divided into two categories, such as PON link energy saving and device level energy saving. The goal of PON link energy saving is to reduce the energy consumption of ONU through a standardized protocol mechanism between OLT and ONU to turn off the ONU optical transmitter and/or optical receiver during idle time. Device level energy saving, on the other hand, targets the power consumption of internal devices or modules within the OLT or ONU equipment by various means, such as on/off and adaptive adjustment.

As the ITU-T PON standard evolves, the ONU energy-saving mechanism is also being optimized, and the GPON and XG-PON TC layer standards define two ONU energy-saving modes, such as Doze sleep mode and cyclic sleep mode. Starting from NG-PON2 and XGS-PON, these two modes are combined into watchful sleep mode. Of course, based on backward compatibility with older ONUs, Doze, and cyclic sleep modes will still be compatible and supported. In addition, the ITU-T OMCI standard defines the Power Shedding management object, which allows ONUs to perform controlled power-down, i.e., to shut down specific services when the ONU is operating under battery power. The OLT discovers the power management capabilities of the ONU and to configure the appropriate power management mode. In operation, the ONU and the OLT maintain a pair of power management state machines that operate in coordination to enable control of the ONU's power management behavior. The signaling used to coordinate the state machines between the OLT and the ONU is based on the messages Sleep_Allow and Sleep_Request defined in the transmission convergency (TC) layer, which can be used to enable the ONU to switch between full-power and low-power states. The TC layer standard is designed with an additional forced wake-up function for accelerating or waking up a sleeping ONU.

The energy consumption of OLT equipment mainly comes from the power consumption of PON service boards and main control boards, power supply boards, fan boards, and uplink boards. These two types of mechanisms can be further subdivided from the practical operation point of view: the fan speed regulation mode can be divided into zonal dynamic speed regulation and zonal step-less speed regulation; the deep energy saving mode contains three different operations: automatic shutdown of unused ports, automatic shutdown of unused interfaces and automatic shutdown of unused boards. Currently, the OLT equipment deployed in the operator's network's scale has supported these two types of energy-saving technologies.

The fan speed regulation mode combines the fan working state and the real-time demand of OLT equipment cooling to optimize the fan speed to achieve energy saving, and the OLT equipment deploys temperature sensors at the air inlet of the main control board, the fan control board veneer, and some core devices to monitor the system environment temperature and core device temperature in real-time, and adjusts the fan speed to different states from 10% to 100% adaptively. For example, the fan speed is set to 30%~40% during normal operation, and the fan speed can be further increased when the core devices are abnormally high, thus considering the low power consumption, low noise, and high system reliability of the whole frame.

Fan speed control energy-saving mechanism can be subdivided into the whole machine speed control and zoning speed control. The whole machine speed control is the most traditional fan speed control technology, all the fans of OLT equipment unified on or off, and according to the uniform speed operation, cannot achieve a good energy-saving effect. Zoned speed control generally uses dynamic speed control technology to divide different areas in the OLT equipment frame, and adjust the fan speed in each zone dynamically in real-time according to the temperature detection of temperature sensors in different areas. For some low-temperature areas in the OLT frame, the fan speed can be reduced or even shut down to achieve energy saving.

Deep energy-saving mode is a new application-based dynamic energy-saving technology, that enables the automatic shutdown of unused ports, unused interfaces, or unused boards. Different levels of operation exist according to different application states, including turning off idle components, turning off redundant components, and reducing idle resource allocation. First, shutting down idle components can be done by querying the data configuration of the system and shutting down unconfigured ports, unconfigured boards, unconfigured network elements, and unconfigured channels, which has no impact on user services. Second, shutting down redundant components can shut down standby master boards, standby fans, standby uplink boards, and even standby power modules based on service traffic monitoring or prediction. This shutdown of redundant components can reduce the reliability of the system. Finally, reducing global resource allocation by reducing Trunk working links, working forwarding engines and working CPU cores when the service is idle can also be used as a means and measure for deep energy saving. However, the service performance and quality may be reduced at this time, for example, when bursting high-traffic service scenarios, which may cause short-time packet loss or false code.

5. Perspectives on energy-saving technologies for OAN

The energy-saving technology of OAN follows the inter-generational evolution of PON and the development of new IT technology, which is also iterating and evolving. The main future development direction of OAN energy saving is a higher energy efficiency ratio and real-time monitoring and visualization of energy consumption. Higher energy efficiency can be achieved through a combination of ways: 1) optimization of PON convergence layer protocol standards, data transmission as centralized as possible, and entering low-power mode when idle; 2) OLT and ONU in the optical module transmit power according to the actual distance of the ODN adaptive reduction, the realization of this function requires optical module chip function support; 3) the use of a more advanced degree, and advanced process of optoelectronic chip; 4) the introduction of new technologies such as AI, and service awareness combined to help OLT more effectively achieve deep energy savings. Real-time visibility of energy consumption requires new technical means to provide real-time and accurate monitoring of energy consumption in existing equipment and serves as a big data basis for the development of energy-saving technologies.

6. References

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