# Reyee e-Lighten Optical Solution

## Technical White Paper

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# Preface


**Abstract**

Ruijie Reyee has introduced a new series of Ethernet splitter products under the e-Lighten Optical Solution, which offers simultaneous support for passive all-optical LAN (P2MP) and traditional Ethernet network (P2P) networking modes. This solution simplifies networking and debugging for passive all-optical LANs, requiring no additional learning tasks for contractors. The e-Lighten Optical Solution comprises the e-Lighten core switch, e-Lighten APs, e-Lighten access switches, optical transceivers, and passive optical splitters. For small and medium-sized enterprises with many users and diverse network construction needs, this solution accommodates multiple networking scenarios, ensuring that different network environments can be matched with the best access method to meet customer requirements more effectively.



**Keywords**

e-Lighten Optical Solution, e-Lighten technology, e-Lighten core switch, e-Lighten access switch, e-Lighten AP, e-Lighten optical transceivers, passive optical splitter, active optical splitter, and hybrid cables (PoF)


**Terminology**

| Term | Description |
| --- | --- |
| PON | Passive Optical Network (PON) is a communication network architecture that utilizes optical cables to transmit data. This network employs passive optical splitters to distribute optical signals from the Optical Line Terminal (OLT) to multiple Optical Network Units (ONUs), enabling high-speed data transmission and Internet access. |
| OLT | An Optical Line Terminal (OLT) is a device that distributes signals to multiple Optical Network Units (ONUs) on the network, enabling high-speed data transmission and Internet access. |
| ONU | An Optical Network Unit (ONU) is a customer premises equipment (CPE) device in a PON system. It connects to the end user's clients and communicates with the OLT, responsible for converting optical signals and transmitting data. |
| ODN | Optical Distribution Network (ODN) is responsible for transmitting optical signals from the OLT to end users' clients. |
| SC connector | An SC connector is inserted with an optical transceiver that transmits and receives network signals. |
| POS | A Passive Optical Splitter (POS) is a passive optical device that connects the OLT and remote devices in a PON. It distributes input optical signals into different output channels in a specific ratio, achieving the function of optical signal splitting. |
| AOS | An Active optical splitter (AOS) integrates built-in Power over Ethernet (PoE) or PoE+ modules to centrally supply power to multiple ONUs, building on a POS. |

| Term | Description |
| --- | --- |
| Hybrid cable (PoF) | A hybrid cable (PoF) is a new access medium designed for broadband access networks. It integrates optical fibers and copper conductors into a single cable, enabling broadband connectivity, device power supply, and signal transmission simultaneously. |
| FS interface | An FS interface can be an uplink or downlink optical port. The optical signals received by the uplink optical port are distributed to all the downlink optical ports for transmission, while the optical signals received by the downlink optical ports are distributed to a single uplink optical port for transmission. |
| VoIP | Voice over Internet Protocol (VoIP) enables voice communications over the Internet using IP-based technology. It utilizes compression algorithms to compress voice signals and package them into IP data packets for transmission over the Internet, thereby reducing communication costs and offering a wide range of functionalities. VoIP phones are used to connect to telephone lines. |

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# 1 Overview

## 1.1 Background

Issue 1: In traditional Ethernet setups, the access layer uses copper cables, which can be expensive in terms of both material and labor costs. Additionally, these cables have limited transmission distances due to their physical properties.

Issue 2: The Passive Optical Network (PON) solution enables point-to-multipoint (P2MP) communication, offering several advantages such as efficient use of ports and optical transceivers, simplified network architecture, substitution of active aggregation devices with passive optical splitters (POSs), and reduced maintenance costs and power consumption. However, in a PON system, the uplink uses Time Division Multiplexing (TDM), which means that the bandwidth is shared among multiple access nodes. This can result in higher latency and reduced uplink bandwidth.

Issue 3: Implementing a passive all-optical network solution typically incurs higher construction costs. Core, aggregation, and access switches with optical ports are costly, and a significant number of optical transceivers are required for optical-electrical conversion.

Issue 4: In traditional optical network deployments, optical network units (ONUs) typically require a distributed power supply. However, ONUs are often deployed in large numbers and in special or hard-to-reach locations, with complex cabling requirements. As a result, the network deployment consumes significant manpower and resources, increases network construction costs, and extends the overall deployment time.

## 1.2 Industry Practices

The industry follows two common practices for integrating Ethernet and PON networks.

- The first practice involves deploying a PON as the backbone network, with an Optical Line Terminal (OLT) situated at the central point or data center. The OLT transmits signals to end users through optical cables, while the Ethernet network is deployed at the user end to provide local area network connectivity and internal communication. This deployment requires the installation of Ethernet switches and network devices such as PCs, servers, and routers.
- The second practice involves deploying the Ethernet network as the backbone network. Ethernet switches and network devices are deployed at central points or data centers, and OLTs are connected to the backbone network. The OLTs are then connected to multiple ONUs through Optical Distribution Network (ODN) connections.

Both of these deployment practices involve the utilization of two different types of networking equipment. This not only adds to network complexity but also presents challenges in terms of network maintenance and management. Furthermore, if the network requirements change, such as increased demands for uplink bandwidth or lower network latency, the shared uplink of a PON may fail to meet the new demands. In such cases, customers would need to replace the PON network equipment with Ethernet equipment, resulting in a loss of their existing investment. Additionally, the PON system and Ethernet utilize different packet encapsulation methods. Integrating these two networks requires knowledge of both PON and Ethernet, which adds an additional learning cost to the deployment of such integrated networks.

## 1.3 Ruijie Reyee e-Lighten Optical Solution

The e-Lighten Optical Solution leverages the existing Ethernet technology while integrating the unique features of the PON system and passive optical splitting. This solution comprises essential components, including the e-Lighten core switch (OLT), e-Lighten access switch (ONUs), e-Lighten APs (ONUs), and ODN.

- The ports of an OLT can operate in both Ethernet and PON modes and can automatically switch between them based on network requirements and configurations.
- The SC connector of an e-Lighten access switch enables P2MP communications through a POS. An optical cable connects the OLT to the POS, which then connects to various e-Lighten access switches using multiple optical cables. The downstream packets transmitted from the OLT to an ONU (switch or AP) are broadcast to all ONUs through physical splitting. Additionally, the e-Lighten access switch supports Time Division Multiple Access (TDMA) technology for bandwidth usage, and utilizes schedules provided by the OLT to time-multiplex upstream bandwidth between different ONUs.

## 1.4 Benefits of the e-Lighten Optical Solution

- Easy maintenance: The e-Lighten Optical Solution simplifies the maintenance and management by addressing the challenge of managing two different networking devices in the integration of PON and Ethernet networks.
- Flexibility: The ports of an OLT can automatically switch between Ethernet and PON modes based on the network requirements. This enhanced flexibility not only increases the network scalability but also enables more agile deployment.
- Low learning curve: The e-Lighten Optical Solution provides a user-friendly experience through Ruijie Reyee App. This intuitive app allows for easy solution feasibility validation, quick configuration, troubleshooting, and automatic detection of optical link faults within three minutes, contributing to a low learning curve.
- Low cost: Integrating the core switch and OLT into a single device helps to minimize costs.

# 2 Technical Implementation

## 2.1 Basic Concepts

- Shared fiber: The PON system uses the fiber-sharing technology, where multiple users share the same fiber for P2MP data transmission. Downstream traffic is physically split and transmitted to the end users through a POS, while upstream traffic from different users is separated using the TDM technology, which facilitates the sharing of upstream bandwidth among multiple users.
- Passive fiber distribution: Fiber distribution in the PON system is passive and employs the purely physical splitting technology. This means that no additional power or signal processing equipment is required to split the optical signals. This enables the aggregation layer to use POSs, which reduces the power consumption and maintenance cost associated with traffic transmission on intermediate links.
- Long-distance transmission: The PON system uses optical fibers as the transmission medium, allowing for long-distance transmission to cover tens of kilometers without experiencing significant signal loss or degradation.
- POS: A POS is an optical device used to divide an input optical signal into multiple output channels without the need for an external power supply or electronic control. A POS operates based on the principles of optical interference and coupling. It divides an input optical signal into different output channels in a specific ratio to achieve optical signal splitting. The specific splitting ratio and performance of a POS depend on its design and manufacturing parameters.
- Hybrid cable (PoF): A hybrid cable (PoF) is a new access medium designed for broadband access networks. It integrates optical fibers and copper conductors into a single cable, enabling broadband connectivity, device power supply, and signal transmission simultaneously.
- Active optical splitter (AOS): An AOS integrates built-in Power over Ethernet (PoE) or PoE+ modules to centrally supply power to multiple ONUs, building on a POS.
- TDMA: TDMA is a communication technology used to share transmission media or network resources among multiple users. It allows multiple users to transmit data over the same frequency by using different time slots.
- TDM: TDM is a multiplexing technique that enables multiple signals to be transmitted simultaneously over the same physical channel by dividing the channel into time slots and transmitting different signals alternately.

  Some key concepts about TDM are described as follows:

  - Time slot: In TDM, the physical channel is divided into a series of contiguous time intervals known as time slots. Each time slot has a short duration that allows for the transmission of a single data unit within that slot.
  - Frame: Time slots are organized into frames according to a specific pattern, forming a time cycle. Each frame consists of multiple time slots, and contains data from different channels.

  The implementation process of TDM is described as follows:

  a Data input: The data from multiple signal sources to be multiplexed are input into their respective buffers.

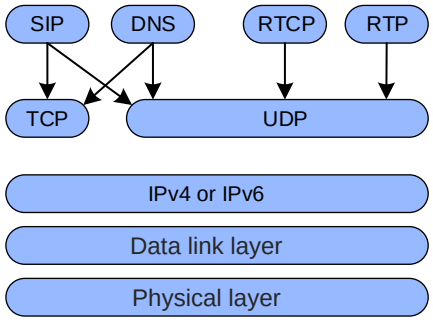
b Slot allocation: Within each time cycle, a slot allocation algorithm determines the allocation of slots for each signal source in each frame. Different signal sources can be assigned different numbers of slots to meet their specific transmission needs.

c Time-division multiplexing: Based on the slot allocation, the data from each signal source is transmitted in a sequential and alternating manner in the same physical channel. Data from each signal source is transmitted within its allocated slots, while the remaining slots remain idle.

d Data extraction: At the receiving end, the data from each signal source is extracted from the multiplexed signal based on the slot allocation.

TDM enables simultaneous transmission of multiple signals, thus improving channel utilization. By dividing the channel in the time domain, TDM allows for parallel transmission between multiple signal sources, thereby increasing transmission efficiency. In TDM, the data from different signal sources needs to be assigned time slots according to a certain pattern to ensure the data order and integrity.

- Session Initiation Protocol (SIP): SIP is an application layer protocol used to establish, modify, and terminate multimedia sessions, as shown in the following figure. SIP can be carried over different transport protocols such as User Datagram Protocol (UDP), Transmission Control Protocol (TCP), and Transport Layer Security (TLS).



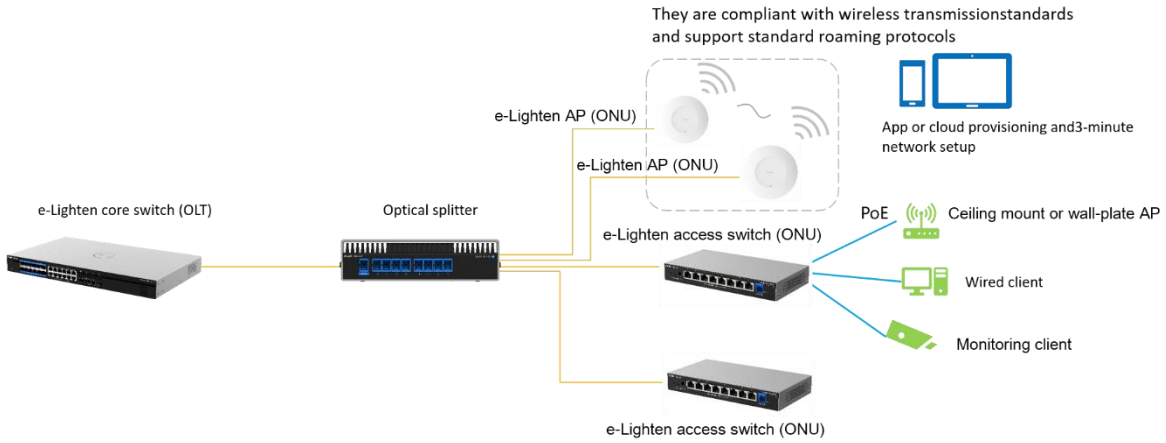

SIP needs to operate in conjunction with protocols like Real-time Transport Protocol (RTP) to complete the multimedia session process.

- SIP: Establishes a connection through signaling interactions like registration, call initiation, subscription, notification, and call release.
- RTP: Is responsible for the transport and delivery of real-time media streams after a session is established.
- Real-time Transport Control Protocol (RTCP): Is used for monitoring and controlling real-time media streams.

# 2.2 Technical Architecture

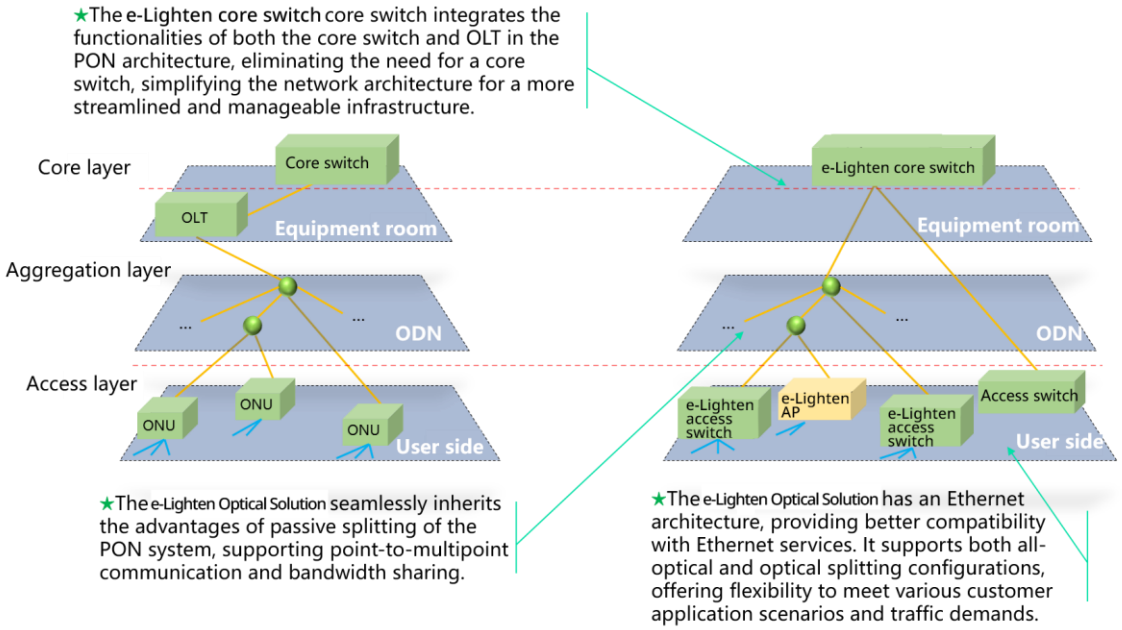
## 2.2.1 e-Lighten Optical Solution Architecture

**Figure 2-1 e-Lighten Optical Solution Architecture**




As shown in 0, the e-Lighten Optical Solution integrates PON technology and passive splitting technology with existing Ethernet technology. This innovative solution enables automatic device mode switching based on the network mode, thereby enhancing network flexibility, manageability, and ease of maintenance.

- e-Lighten core switch (OLT): As a network core device, it has Layer 3 data forwarding capability and provides PON ports. It can be connected to e-Lighten access switches and e-Lighten APs through a POS or AOS to achieve data interconnection.
- e-Lighten access switch (ONU): Operating at the access layer, an e-Lighten access switch is connected to a PON port on the uplink, enabling data transmission back to the e-Lighten core switch through the POS.
- e-Lighten AP (ONU): Its uplink PON port backhauls Internet access data of clients. Some RG-APF models can be connected to an AOS for a centralized power supply.
- Optical Distribution Network (ODN): This passive fiber distribution network consists of POSs, and is connected to the uplink e-Lighten core switch, and to downlink e-Lighten access switches or APs.




### 2.2.2 Device List

| Type | Product Series | Product Model | Remarks |
|---|---|---|---|
| OLT | RG-NBF6 series e-Lighten modular switch | RG-NBF6002M | Used with line cards |
| | Line card | MF6000M-16FS8GT2XS | 16 x 1GE PON ports, 8 x 1GE RJ45 ports, 2 x 10GE optical ports (PON ports) |
| | RG-NBF5 series e-Lighten fixed switch | RG-NBF5300M-12MFS12MG4XS | 12 x 1GE/2.5GE PON ports, 12 x 10/100/1000/2500BASE-T ports, 4 x 1GE/10GE SFP+ ports. The expansion module is not supported. |
| | RG-NBF5 series e-Lighten fixed switch | RG-NBF5200M-8FS16GT4XS | 8 x 1GE PON ports, 16 x 1GE RJ45 ports, 4 x 10GE optical ports (PON ports) |
| | e-Lighten optical transceiver | OM-GE-SFP-10KM-SM1490 | 1GE optical transceiver |
| ONU | RG-NBF2 series e-Lighten access | RG-NBF2100S-16GT1SC-P | 16 x 1GE PoE+ Ports, 1 x 1GE SC Port |

| Type | Product Series | Product Model | Remarks |
|---|---|---|---|
| | switch | RG-NBF2100S-8GT1SC-P | 8 x 1GE PoE RJ45 ports, 1 x fixed 1GE optical port |
| | | RG-NBF2100S-8GT1SC | 8 x 1GE RJ45 ports, 1 x fixed 1GE optical port |
| | e-Lighten AP | RG-APF1250 | 3 x 1GE RJ45 ports, 1 x 1GE PON port, 1 x RJ11 port |
| | | RG-APF1260(MG-P) | 3 x 1GE RJ45 ports, 1 x 2.5GE PON port, 1 x RJ11 port,1 x 1GE PoE Out port |
| | | RG-APF2260(MG) | 1 x 1GE RJ45 port, 1 x 2.5GE PON port |
| ODN | e-Lighten optical splitter | RG-SPL-2016-SC | 1:16 splitter with uniform outputs |
| | | RG-SPL-2032-SC | 1:32 splitter with uniform outputs |
| | | RG-SPL2032-SC-P | 2-In 32-Out Active Optical Splitter |

## 2.3 Principles

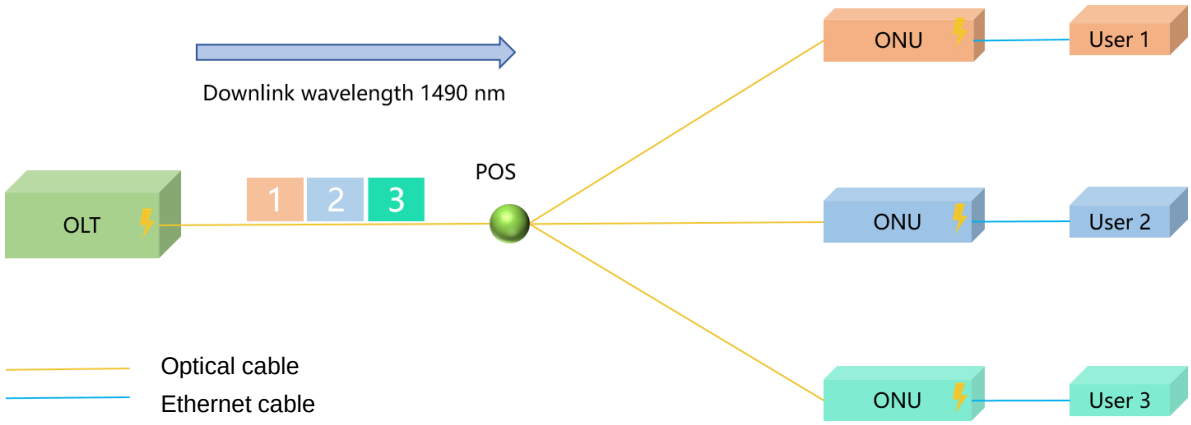
### 2.3.1 Downlink Forwarding Principles

In the e-Lighten Optical Solution, data is generally broadcast to all ONUs through the OLT's PON ports in the downlink forwarding process, enabling each ONU to receive the transmitted data. However, each ONU can only access the data intended for itself.

After receiving a packet, the ONU reads the destination MAC address and checks its MAC address table to determine the appropriate forwarding action. If the destination MAC address is found in the table, the ONU forwards the packet accordingly. Otherwise, the ONU will discard the packet, meaning it does not forward unknown unicast frames.

**Caution**

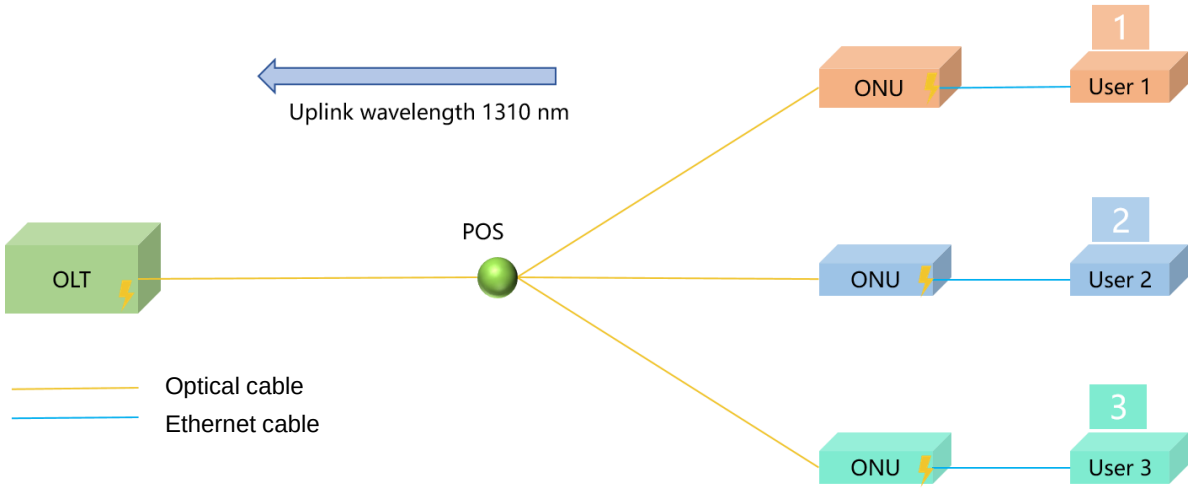
The e-Lighten Optical Solution implements passive splitting based on the Ethernet infrastructure, where the frame used is an Ethernet frame rather than a PON frame.




### 2.3.2 Uplink Forwarding Principles

In the e-Lighten Optical Solution, uplink forwarding employs the TDMA technology, enabling multiple users to utilize the same frequency for data transmission through allocated time slots. Each user uses the designated time slots for rapid sequential data transmission, allowing for the efficient sharing of the transmission medium among multiple users.

The TDM technology is adopted for uplink traffic, with the core switch dynamically allocating bandwidth and authorizing time slots for ONUs to transmit data on a burst basis within the authorized time slots.




### 2.3.3 ONU Registration Mechanism

The registration process of an ONU (e-Lighten access switch or AP) is as follows:

(1) OLT

The OLT broadcasts a message (Discovery Gate) every 100 milliseconds, containing time window information to inform ONUs about the current time window. This information can be used by ONUs to apply for registration.

(2) ONU

a After receiving the Discovery Gate message from the OLT, the ONU enters the registration state if it has not completed the registration process, or ignores the message if it is registered.

b The registration process begins with a back-off algorithm to reduce the probability of registration collisions between different ONUs.

c The ONU sends a registration request message.

d The ONU initiates a timer upon sending the registration request to monitor the reception of ordinary Gate messages. If no ordinary Gate message is received within 1 second, the ONU considers it a registration timeout and enters a waiting state for the next round of discovery message reception.

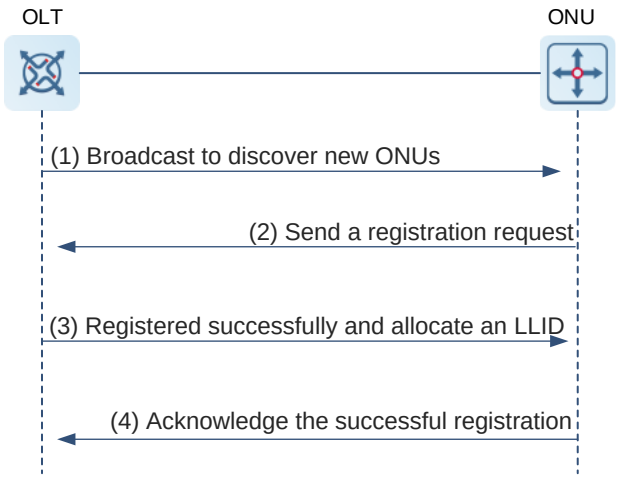
e If the ONU receives an ordinary Gate message, it considers the registration successful and sends a registration acknowledgment (ACK) message to the OLT.

(3) OLT

a When the OLT receives a registration request message from an ONU, it assigns a unique Logical Link Identifier (LLID) to that ONU, and notifies the Dynamically Bandwidth Assignment (DBA) module to allocate scheduling resources for the ONU. During the next round of ordinary Gate messages, the scheduling information specific to that ONU will be included in the message.

b After the OLT issues a new scheduling for an ONU, it waits to receive a registration acknowledgment (ACK) message from that ONU. If the OLT receives the ACK message within a certain timeout period, it considers the registration process completed successfully. Otherwise, the OLT may reclaim the allocated LLID.

c The scheduling information for all the successfully registered ONUs will be included in the ordinary Gate message sent by the OLT.



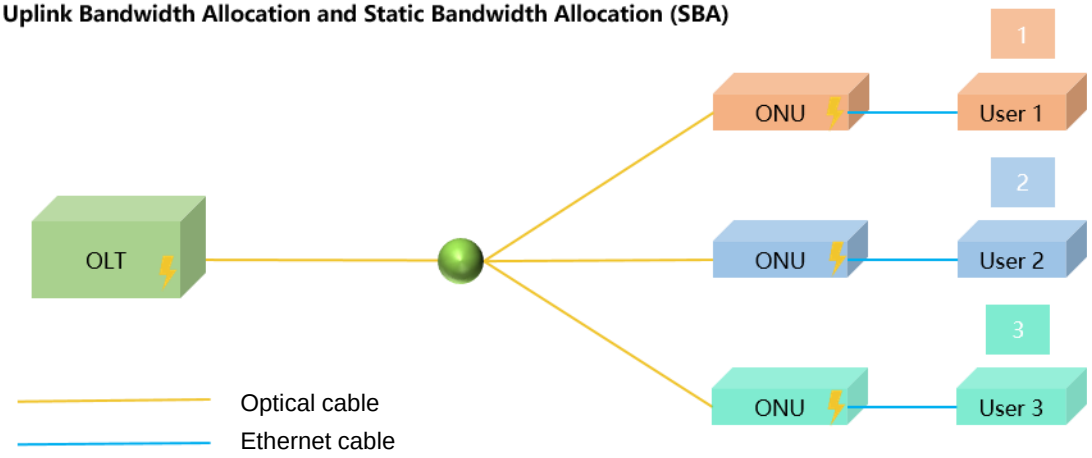

### 2.3.4 Bandwidth Allocation Mechanism

Bandwidth allocation is used to distribute network traffic to ensure the normal transmission of real-time traffic with limited bandwidth. The bandwidth allocation mechanism includes two modes: static mode and dynamic mode. By default, the static mode is used.

#### 1. Static Mode

In static mode, each ONU occupies an equal number of time slots for equal bandwidth allocation.

**Uplink Bandwidth Allocation and Static Bandwidth Allocation (SBA)**




Calculation of static bandwidth allocation (SBA): Client (PC/Smartphone/Tablet) rate = PON port rate/Number of split outputs

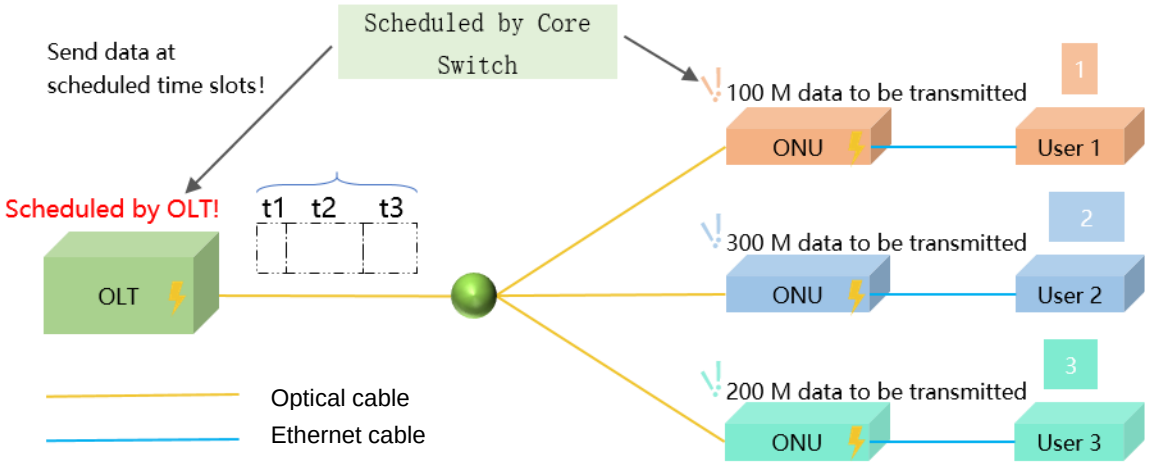
Example 1: If one FS interface is connected to a 1:16 optical splitter at the downlink, and each splitter output port is connected to an ONU, then the client rate = 1000 Mbps/16 = 62.5 Mbps.

Example 2: If one FS interface is connected to a 1:16 optical splitter at the downlink, and only eight output ports are connected to ONUs, then the client rate = 1000 Mbps/8=125 Mbps.

## 2. Dynamic Mode

In dynamic mode, each ONU occupies an unequal number of time slots, resulting in different bandwidth allocation for each ONU.

**Uplink Bandwidth Allocation and DBA**

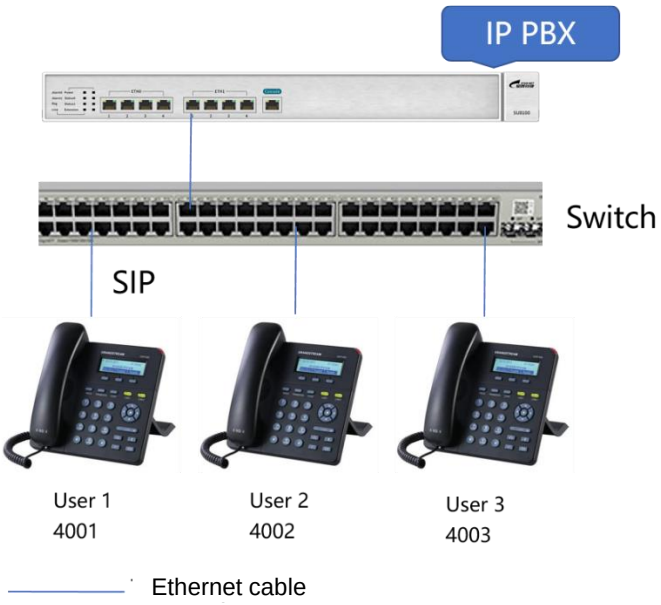



**DBA Calculation:**

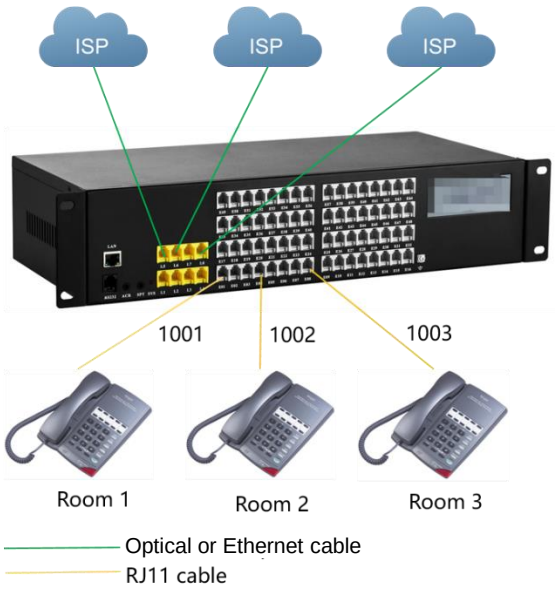
Each ONU is assigned a default assured bandwidth (you can also set a larger assured bandwidth for a specific ONU to ensure it has a larger basic time slot). This corresponds to the initial time slot. The idle bandwidth outside the assured bandwidth is subject to dynamic allocation to handle burst traffic. If no ONU reports burst traffic, the transmission will be scheduled based on this assured bandwidth.

### 2.3.5 VoIP Solution

IP telephony is a communication method based on IP networks. IP phones are registered to the VoIP gateway, commonly known as an IP Private Branch Exchange (PBX), using SIP. On an IP phone, you can configure the SIP extension number, password, and the IP address of the VoIP gateway server. A VoIP gateway can be considered as a type of voice server, which is responsible for creating and managing the usernames and passwords for IP phones in the IP telephony system.

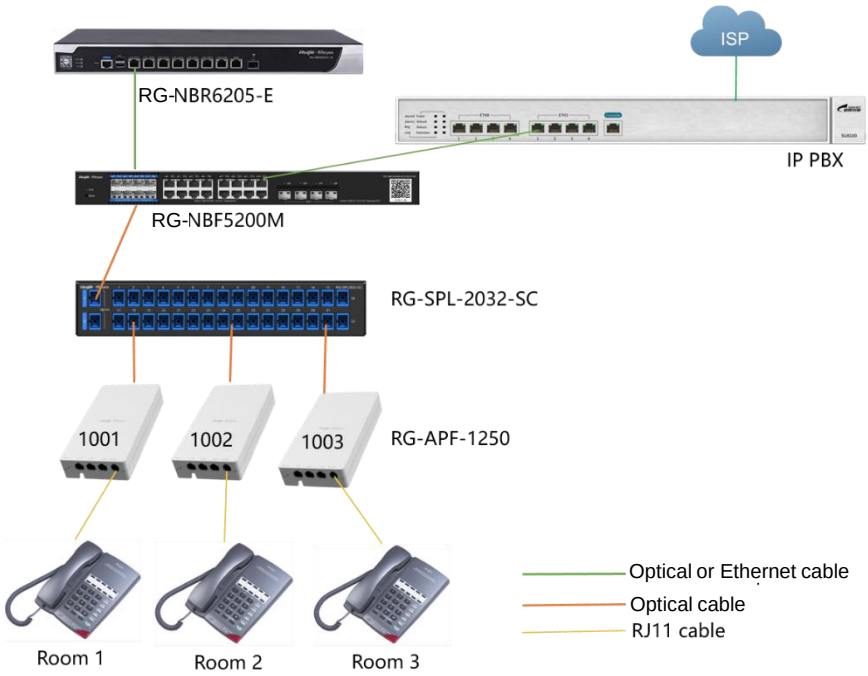



Analog telephony operates through a PBX system. Analog telephones are connected to the outside phone lines via a PBX's designated interface, and each analog phone is assigned an extension number that is configured on the PBX's interface.




In the e-Lighten Optical Solution, the e-Lighten AP can be registered as a SIP client to the VoIP gateway, and can connect to analog phones for communication. An IP telephony system can be established by combining e-

Lighten APs with analog phones, enabling communication using analog phone lines over a single optical cable in each hotel room.



# 3 Typical Applications

## 3.1 Hospitality Solution

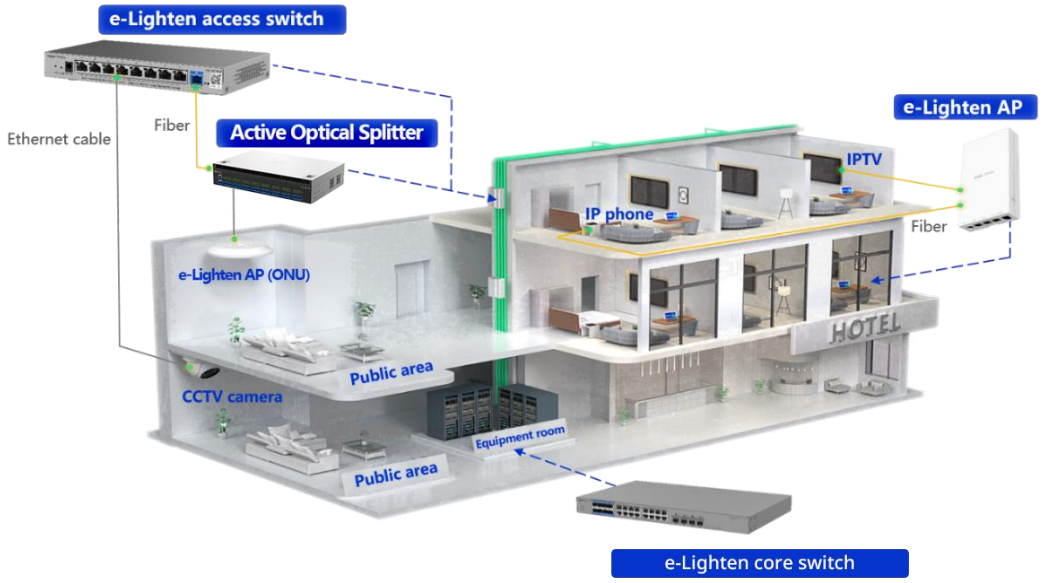
### 3.1.1 Description

Reducing the comprehensive construction cost of hotel networks while meeting service requirements is a major concern for hotel owners. The main issues faced by hotel owners are as follows:

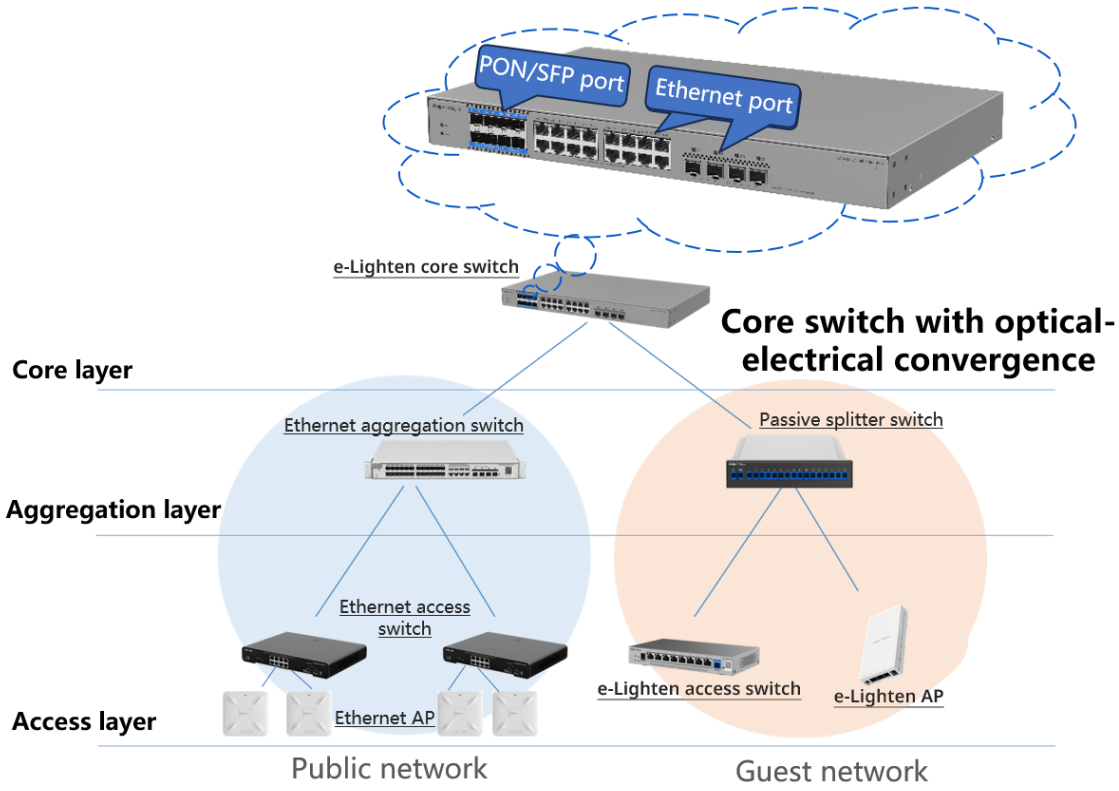
- 1: The deployment of multiple lines to support Internet access, IP phones, IPTV, guest control, and other services incurs significant costs attributed to network cabling, manual wiring tasks, and extended lead time.
- 2: Conventional copper cables incur significant material expenses and present obstacles in the construction and maintenance of network overlays.
- 3. The "one room, one network" solution offered by ISPs fails to meet the service demands of mid-range boutique hotels.
- 4. The guest Internet experience is a priority for mid-range boutique hotels, yet they encounter difficulties related to the quality of the Optical Network Terminal (ONT) and the proficiency and promptness of installation and maintenance personnel.
- 5. Powering ceiling mount APs in corridors, lobbies, and similar areas is challenging, leading to higher deployment costs.

### 3.1.2 Solution

The e-Lighten Optical Solution achieves cost savings through the integration of multiple services and the use of passive optical splitting technology to reduce the need for numerous switches in corridors. Data is transmitted via optical cables to lower overall engineering costs. The PON design reduces energy consumption, minimizes faults, and simplifies maintenance by reducing the three-layer network architecture to a two-layer network architecture. The "one room, one fiber" approach and the use of a single e-Lighten AP in each hotel room can handle various services such as PCs, IPTV, telephones, room control, and Wi-Fi, reducing the cost of deploying multiple lines. The integration of the optical network in the guest room and the Ethernet network in public areas allows for seamless roaming from guest rooms to banquet halls. In addition, AOSs can be used in network scenarios with power supply difficulties to facilitate device deployment.

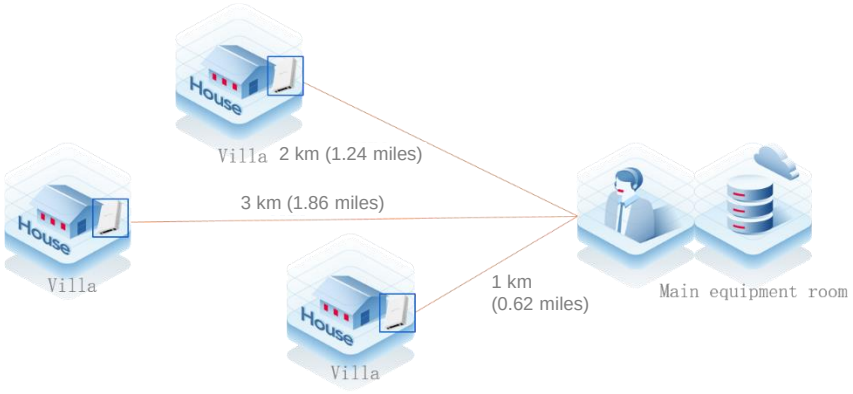



A single core switch can simultaneously support both PON and passive all-optical networks, with its ports automatically switching working modes based on the network mode to achieve flexible networking and unified network operation and maintenance (O&M).




The e-Lighten Optical Solution enables long-distance transmission of service data to villa hotels using optical connections. Within the hotels, ONUs are used for access. Compared to Ethernet optical switches, this setup

can save up to 50% in investment costs. Additionally, a single ONU can support multiple services such as voice, Wi-Fi, IPTV, and room control, eliminating the need for deploying multiple systems.




## 3.2 Campus Network ELV Solution

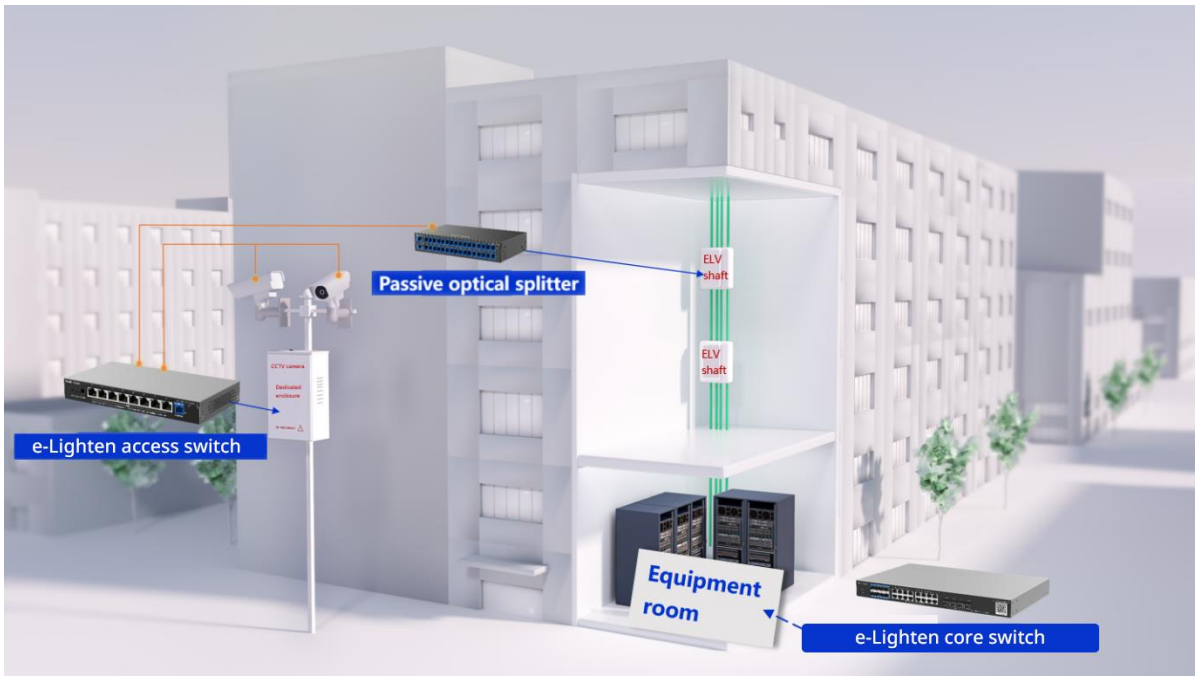
### 3.2.1 Description

Campus networks, such as factory and industrial parks, face the following issues:

- 1: The O&M site is characterized by the presence of numerous overcrowded waterproof cabinets.
- 2: The high amount of equipment, heavy maintenance workload, and lengthy cables in new construction projects result in escalated construction costs. For renovation projects, a significant number of aggregation switches and network cables are present, which makes it difficult to handle.
- 3: Current PON solutions have low usability, making it difficult to develop proposals during pre-sales, configure the system during sales, and perform complex maintenance during post-sales support.

### 3.2.2 Solution

By deploying the e-Lighten Optical Solution, the number of equipment in the equipment room is reduced, and a significant amount of optical transceivers are eliminated. The optical network layout is also simplified. Additionally, compared with PON solutions, the e-Lighten Optical Solution adopts an integrated optical and Ethernet solution, eliminating the need to purchase a separate OLT. In addition, the e-Lighten Optical Solution reduces the number of aggregation nodes and maintenance points, utilizes POSs in the aggregation layer, and deploys e-Lighten switches at the downlink for Gigabit Ethernet connectivity. Compared to traditional waterproof cabinets, the e-Lighten Optical Solution offers a more streamlined approach. It reduces the need for optical transceivers and the Reyee access switches support PoE, leading to a more organized waterproof cabinet setup. Ruijie Reyee App provides features such as solution feasibility validation, 3-minute all-optical network setup, and automatic detection of optical link faults.


Passive optical splitter
ELV shaft
ELV shaft
e-Lighten access switch
Equipment room
e-Lighten core switch