A Resource Allocation Method for Power Backhaul Network Based on Flexible Ethernet

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Abstract. The existing network resource allocation methods pay a greater share of attention to the requirements of low delay and high reliability of service transmission, ignoring the utilization of network resources caused by traffic scheduling and inflexibility. Flexible Ethernet can decouple the interface rate between router and transmission box, which can well meet the flexibility requirements of power backhaul network. This paper fully discusses the feasibility and effectiveness of applying FlexE technology to power backhaul network, and designs the algorithms for FlexE-unaware, FlexE-aware and FlexE-terminating in the FlexE flow scheduling process in the transmission scenario, so that each transmission device can be used more efficiently.

Keywords: Flexible Ethernet · Power backhaul network · Flow scheduling process

1 Introduction

With the vigorous development of smart grid, the types of power distribution business are increasing, and the requirements for business are becoming higher [1]. Research on a reasonable and effective resource allocation algorithm for power backhaul network can not only provide differentiated, isolated services that meet the quality of service requirements for different services, but also improve the network utilization and reduce the network operation and maintenance cost. However, the power backhaul network still faces the following challenges:

(1) Low network utilization: At present, the power communication network is built independently according to different power distribution and consumption services. This mode not only leads to repeated construction of the network and reduces the network utilization, but also requires independent management and maintenance of each network, increasing the cost of network operation and maintenance.

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(2) Ensure business isolation: The current power communication network can ensure the isolation between businesses by independently building the network according to different power distribution and consumption businesses, but this independent network building mode will bring the problems of rising network construction cost and waste of resources.

As the UNI interface between router and optical transmission network equipment [2], FlexE can realize one-to-one correspondence between the data stream bandwidth actually carried by UNI interface and WDM link bandwidth of optical transmission network NNI interface through rate matching [3], so as to greatly simplify the mapping of transmission equipment and reduce equipment complexity, investment cost (CAPEX) and maintenance cost (OPEX). As a technical architecture based on Ethernet and industrial chain expansion, FlexE technology meets the requirements of large bandwidth, flexible rate and channel isolation under the IP/Ethernet technology system, which is in line with the development trend of technology and industry [4].

Based on the above analysis, this paper proposes a resource allocation algorithm for power backhaul network, and proposes a resource allocation algorithm for power backhaul network based on three transmission modes of FlexE. Under the conditions of ensuring service isolation and low delay of intelligent distribution communication network, this paper realizes the optimal resource allocation of intelligent power backhaul network.

2 Related Work

Many studies have proposed computing models or optimization schemes for network resource allocation from different aspects. Literature [5] studies the resource allocation of competitive base stations between two different operators, and discusses sharing a common optical backhaul network infrastructure. Evolutionary game theory is proposed and applied to study the interaction between base stations and passive optical networks. Using the replicator dynamic model, the asymptotic stability of the proposed system design is proved. Literature [6] studies the joint routing and resource allocation in software defined backhaul network (SDBN) based on OFDMA. A SDBN system model is proposed, in which the control panel can use high complexity algorithms in the configuration stage to simplify the algorithms in the operation stage. By constructing the interference directed graph of the network and analyzing the vertex degree characteristics of the network, a greedy algorithm based on directed graph (DBGA) is proposed. Literature [7] studies several dynamic bandwidth allocation algorithms for user mobility and fog computing in Mobile Backhaul. The proposed algorithm can reduce the migration delay and jitter by giving high priority to the migration traffic. When slicing resources according to the traffic type, the average packet delay of non-migrated traffic can be guaranteed regardless of the migration traffic load. There are still many deficiencies in the above research, such as:

(1) The characteristics of optical network are not analyzed and the problems of service flow transmission in optical network are not solved. The services can't be logically

or physically isolated, and can't meet the service transmission requirements such as high delay and high reliability.

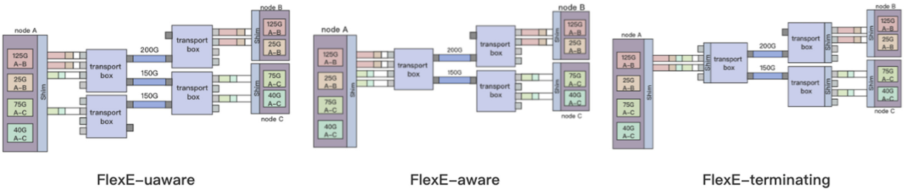
(2) Without considering the requirements of service delay and reliability, the hardware cost can't be maximized.

(3) The impact of services on each other in the transmission process is not taken into account, that is, it can't achieve good isolation effect and meet the reliability requirements of services.

Based on the above research background, this paper proposes a resource allocation method of power backhaul network based on FlexE. Because FlexE technology can flexibly allocate the underlying bandwidth to grid services with high delay and high reliability requirements, it is introduced into the power backhaul network to make the whole backhaul network have the functions of flexible bandwidth allocation and physical layer service isolation. By analyzing the characteristics of three FlexE transmission modes, a traffic allocation mechanism with physical isolation and low delay is designed. It maximizes the carrying capacity of Ethernet technology in differentiated service requirements and network bottom bandwidth, ensures the isolation of service parts and low delay, improves the utilization of network resources and realizes the efficient allocation of power backhaul network resources.

3 Problem Description

3.1 FlexE Transport Mode



FlexE–uaware

FlexE–aware

FlexE–terminating

Fig. 1. FlexE transport scenarios

The application of the FlexE paradigm in the transmission architecture determines that each router has a FlexE shim to map/demap the Ethernet physical layer between the router and the transmission box [8]. Under this mechanism, three different transmission modes are generated according to whether the transmission box has sensing ability: FlexE unaware, FlexE aware and FlexE terminating [9].

(1) In the FlexE-unaware mode, the flexible Ethernet interface is transparently hosted similar to the optical transmission network [10]. This mode can make full use of the old existing optical transmission network equipment, realize the bearing of FlexE without hardware upgrade, and realize the end-to-end Super bandwidth channel across the optical transmission network based on the FlexE binding function.

In this mode, the transmission box is functionally equivalent to the multiplex repeater. Since the transmission device has no visibility to the content of FlexE, the existing transparent transmission device can be used for traffic transmission.

(2) FlexE-aware mode is very similar to FlexE unaware mode. The difference is that the transmission box has the ability to perceive time slots. In this mode, FlexE identifies unavailable slots by filling in a special error control block data block. When the flexible Ethernet interface on the UNI side is mapped in the optical transmission network through aware mode, the optical transmission network directly discards unavailable slots, extracts the data to be carried according to the original data stream bandwidth, and then maps it to the DWDM transmission pipeline of the optical transmission network with rate matching [11].

(3) Finally, in the FlexE-terminating mode, the transport box has a shim layer, which means that the transport box can sense the transmitted FlexE group and terminate the FlexE group [12]. In this case, streams with multiple destinations can be carried in a single FlexE group because they can be separated in the transport box. Therefore, the transport box also needs to have the ability to comb and plan the flow, so as to reasonably allocate the mixed flow in the PHY to the optical channel.

3.2 Specific Description of the Problem

This paper studies how to divide the flow reasonably on the shim layer of the router into the FlexE group under three different modes, and enter the optical transmission network for transmission under the demapping of the transmission box, so as to minimize the cost of hardware resources. The mapping on the shim layer mainly considers how to logically bind PHY for different transmission modes, so that the ports can be maximized, and reuse the bound router ports and transport box ports to a large extent.

In FlexE unaware mode, since the transmission device has no visibility to the client stream, the transmission box will send all time slots in the PHY to the optical path. As shown in the example in Fig. 1(a), two 100GE PHYs are bundled, and 150G A-B client streams are sent to the FlexE group. There is only 150G effective traffic on the corresponding 200G optical path. In FlexE aware mode, the transport box has visibility into whether there is a stream in the time slot of PHY. Therefore, unused time slots in PHY can be discarded, so as to save line end ports and improve equipment utilization [13].

The FlexE-terminating mode takes advantage of the characteristics of FlexE channelization. In the same PHY or FlexE group, multiple client streams to different destinations can be accommodated at the same time. By filling the client streams sent by the source end with PHYs as much as possible, the hardware devices can be minimized, and the binding of FlexE group is also quite different from the first two modes, just bundle all PHYs used into one FlexE group. In Fig. 1(c), the content of the transport box convection has the ability to sense, and multiple streams in a group can be demapped and sent to the appropriate optical path.

4 Flow Scheduling Algorithm

4.1 FlexE-Unaware Scheduling Algorithm

For the newly arrived flow, the algorithm first attempts to accommodate it by reusing a FlexE group. If there are no reusable FlexE groups, analyze whether existing FlexE groups can be extended to accommodate new flows, and always try to reuse FlexE groups as much as possible [14]. Finally, if the existing FlexE group cannot be reused, a new group is created to accommodate the flow by activating the new port and phy and bundling them. The flow provisioning is described by the pseudocode in Algorithm 1.

Algorithm 1: FlexE-unaware Scheduling Algorithm

```
Input: All client stream sets f; all existing FlexE group sets G
Output: FlexE group set G 'after a new round of scheduling
1   Select a client stream f from F, whose starting node is s and destination node is D,
    which is recorded as f (s, d); The traffic of the client stream is recorded as CF; Select
    all FlexE group sets between nodes (s, d) from G and record them as G (s, d); Note that
    the capacity of each FlexE group in G (s, d) is CG.
2    if Cg in G(s,d)  >= Cf
                 goto step 3
         else
                 goto step 4
3    for min(F)
                 distribute(f) to G(s,d)
4    if  there are free groups in G (s, d)
                 goto step5
         else
                 goto step 14
5    for Cg in G(s,d):
             Calculate the difference between Cg and Cf of each group in G (s, d),
             record the difference as D, and select the group G with the smallest D.
6    if  portNum(g)  >= D:
                 goto step8
7   G(s,d).remove(g)
                 goto step5
8   Add PHY capable of holding D flow into g; Calculate how many additional optical
    paths (s, d) need to be added to accommodate the new PHY.
9    if  !isEmpty(transport box):
                 goto step11
10  Activate(transport box) and goto step9
11  Connect a PHY to a client port of the transmission box, and connect an optical path to
    the line end port of the transmission box according to path P.
12   if not assign(PHY):
                 goto step9
13   if  not assign(f):
                 goto step1
             else:
                 goto step17
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14    if shortestpath(s,d) >= Cf.PHY:
                    goto step16
15    stop(f(s,d))
16    Put(Cf. PHY) into g and put(g) into G(s,d)
                    goto step9
17    return G
```

The main difference of FlexE-aware mode is that it has one more step to identify blank time slots than FlexE-unaware mode, so the algorithm flow of this mode will not be repeated.

4.2 FlexE-Terminating Scheduling Algorithm

The emphasis of the terminating mode algorithm is no longer on the division of FlexE groups, but on the allocation scheme of data flow at the line end of the transmission box. As long as the allocation of data flow at the line end of the transmission box is confirmed, the usage of data port and the cost required for mode operation can be determined. According to the idea of heuristic algorithm, the greedy algorithm relying on sequential input is generally used to solve the optimal scheme of data flow allocation [15]. However, there is no reasonable allocation process in this way, so that the optimal solution can't be obtained. Therefore, this paper adopts the idea of dynamic programming algorithm to allocate all data streams on the same data link more reasonably, maximize the utilization of each optical path, and reduce the number of ports used in router data box. The flow provisioning is described by the pseudocode in Algorithm 2.

Algorithm 2: FlexE-Terminating Scheduling Algorithm

Input: Flow set $\boldsymbol{F} = \{\mathbf{f}_{\boldsymbol{k}}\}$, available transmission line capacity cap

Output: All line flow dispatching set R

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Initialize traffic collection$F = \{f_k\}$, Transmission line capacity$Cap$, Maximum flow of line combination $F_{max} = \sum_{i=m}^{n} f_i$, Single line flow collection $A_t = Map(F_{max}, \{f_m, \ldots, f_n\})$, All line flow dispatching sets $R$
While $f_k != null$ do:
    for $f_k$ in F:
        A.add ($f_k$)
        if $\sum_{i=m}^{n} f_i > Cap$
            break
        else:
            $F_{max}$.add($\sum_{i=m}^{n} f_i$)
        end if
    $\{f_m, \ldots, f_n\}$ = A.get(Max($F_{max}$))
R.add($\{f_m, \ldots, f_n\}$)
```

5 Experiments and Results

5.1 Algorithm Evaluation Index and Test Scheme

This paper takes the number of hardware ports used by the sender as the evaluation index of the algorithm. For the multi round scheduling of the three modes, multiple client streams are randomly generated in each round and input into the simulated scheduling scenario under the three modes respectively. After running the algorithm, the scheduling situation of the stream in the hardware device is obtained. According to this situation, the port usage of hardware equipment can be obtained, the usage of router port, transmission box client port and transmission box line end port in each mode can be compared horizontally, and the equipment usage characteristics of FlexE transmission modes can be summarized and analyzed.

The experiment is divided into three rounds. Each round uses the FlexE group bound by the previous round as the input. At the beginning of each round of experiment, 10 groups of flows with the same source node are randomly generated, the source node is a, and the target node is randomly generated from B–Z, which may be the same or different. After generation, three algorithms of three modes are input for calculation, and three different scheduling schemes can be obtained. Record the client stream allocation and port occupancy of each round, and start the random generation and scheduling of the next round of streams.

5.2 Horizontal Comparison of Three Modes

Comparison of Activated Router Ports. The algorithms of the three modes are tested with the same randomly generated three groups of continuously arriving client streams. The number of router ports used after flow scheduling in each round is shown in Fig. 2.

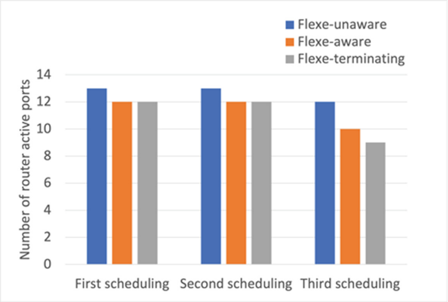

Fig. 2. Comparison of router ports in three modes

In the three-time scheduling, the number of client ports used by unaware mode and aware mode is exactly the same, because the difference between the two algorithms is only reflected in whether the transport box can be recognized free time slots are allocated and discarded, so the FlexE group bundling and port allocation on the router side are completely consistent. Similarly, because both ends of a PHY are connected to the router port and the transport box client port respectively, the occupation of the transport box client port in these two modes is also the same. For the termination mode, it can be seen that the number of router ports used is significantly reduced because the termination uses the subchannel characteristics of FlexE, so that the mixed flow can exist in the same PHY. As long as the transmission box line end allows, the remaining space in any PHY can be used as much as possible, and the useless time slots are greatly reduced, reducing the total number of PHYs required, Thus, the occupied number of router ports is reduced and the cost of hardware equipment is saved.

Comparison of the Number for Transport Box Ports. In the above three rounds of continuous experiments, the number of transmission box line end ports used after flow scheduling in each round is shown in Fig. 3.

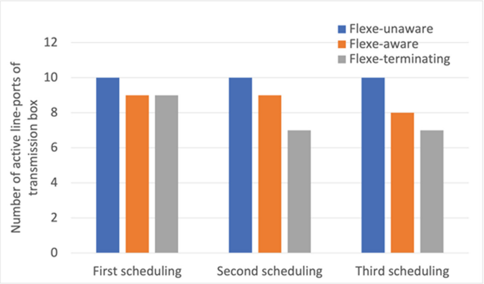

Fig. 3. Comparison of line-ports of transport boxes under three modes

During the first scheduling, the number of ports at the line end of the transmission box used in unaware and aware modes is the same, because the previous group has not been multiplexed during the first binding, and there will be no idle PHY. During the third scheduling, the unaware mode flex group will have idle PHY. Because the transmission box has no perception of PHY, it will send all PHY time slots to the line end, resulting in the occupation of redundant ports; at this time, in aware mode, you can identify the idle PHY and discard the time slot, and only transfer the effective time slot to the line end. For the terminating mode, in the subsequent scheduling, because it is not bound by the FlexE group binding, the algorithm of this mode only needs to determine the minimum line end ports that can send client streams, and allocate corresponding hardware device support to these ports from the transmission box to the router, so as to realize the normal transmission of streams.

6 Conclusion

In this paper, the algorithm design and experimental comparative analysis of the transmission architecture based on FlexE technology are carried out. Appropriate traffic scheduling algorithms are designed for the three FlexE modes, and several transmission examples are tested to investigate their efficiency in router, transmission box and interface configuration. Through experimental comparison and analysis of simulation results, the advantages and disadvantages of each transmission scenario are revealed, as well as the different application types suitable for each scenario.

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