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Research on Planning and Software Transformation of WDM / OTN Transmission Network Based on Machine Learning

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Abstract

With the rapid development of Internet, e-commerce and mobile technology, in order to meet the explosive growth demand of data bandwidth, and comply with the growth of continuous business, the demand of transmission bandwidth is met through WDM function. At present, the existing transmission network cannot meet the requirements of unified, integrated bearing, end-to-end unified network management, service distribution and other business distribution and maintenance needs. Based on this, this paper first analyses the OTN technology principle and network planning concept, then studies the transmission network planning and design methods, and finally gives the power WDM/OTN transmission network planning design and software transformation method based on machine learning.

Keywords: *WDM/OTN Transmission Network,Software Transformation, Machine Learning ;*

1. Introduction

With the continuous development and application of networked and intelligent information technology, the digital service based on internet big data technology makes the communication network traffic subject constantly upgrade and change, and the communication network architecture is developing towards packet switching network in several aspects as shown in Figure 1 below. The technical upgrading and operation management of network hardware equipment need to be further improved based on the planning and design of power transmission network.

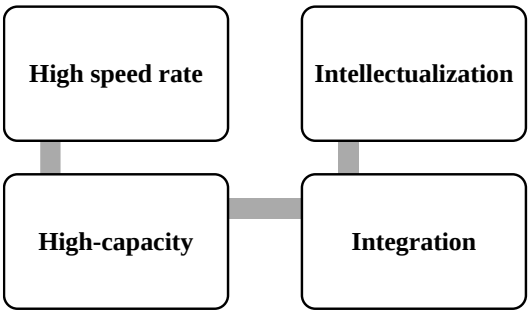

Figure1. The Architecture of communication network.

Based on WDM/OTN as the basic carrier network, the development of data network and mobile network has laid a new opportunity and carrier. On the other hand, the speed and efficiency of current network planning optimization and operation and maintenance has been difficult to meet the expansion and growth of optical transmission network scale and network resource data. It is urgent to optimize network planning in software, tool and automation. Power transmission network planning

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and design, based on WDM/OTN routing and wavelength assignment, is mainly to do multi-objective design for the whole network. Secondly, it is necessary to make targeted configuration based on the actual situation of network resources and power business[1].

The planning, design and software transformation of WDM/OTN need to be integrated with the development of business and network, so as to construct the overall idea and workflow of network planning, and develop the network planning tool software matching with the business requirements. As the basis of all kinds of business carrying network, transmission network is not only the core platform of information application, but also the concentrated performance of high-quality bearing pipeline of customers[1]. At present, with the continuous improvement of network quality and service requirements of users, as well as personalized and diversified service requirements, the deployment, planning and options of high-quality transmission network pipeline are more severe challenges, and they are more sensitive to cost and efficiency. In this context, transmission network operators need to build an efficient bearer network based on a variety of comprehensive considerations.

As an upgrade variant of OTN, packet enhanced OTN has the following characteristics as shown in Table 1, so as to realize the separation of transmission and control modules of equipment. In addition, WDM / OTN system can meet the needs of saving optical cable and providing high bandwidth channel for network extension when network extension is difficult. Moreover, WDM / OTN can provide hard pipes and packet-based capabilities, which can be compatible with Ethernet networking mode, and provide targeted network support modes to different customer groups, such as multi service, large bandwidth, high cost performance optical transport network evolution, etc.

Table 1. The characteristics of packet enhanced OTN.

Aspects	Advantages	Characteristics
Network form	Flexible service scheduling & protection, reliable network	Efficient bandwidth, fibre saving, smooth upgrade
Service delivery	Comprehensive processing capacity	TDM service and other related packet services
Equipment	Integrated management	Control platform, transmission platform, management platform
Management platform	Integrated management	Management bus connected with control, transmission, DCN model
Control platform	Separation of transmission and control module	Control bus connected with transport platform model and the DCN platform

At present, the existing transmission network cannot meet the requirements of unified, integrated bearing, end-to-end unified network management, service distribution and other business distribution and maintenance needs. The introduction of integrated WDM / OTN technology can not only greatly expand the bandwidth, but also effectively carry out hierarchical bearing based on the granular dimension, service type and source / destination nodes, so as to optimize the network investment

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structure, improve the equipment utilization and meet the comprehensive bearing requirements. Therefore, it is of great practical value to study the transmission network planning and software optimization transformation of WDM / OTN technology based on machine learning.

2. OTN technology principle and network planning

2.1. Working mechanism and principle of OTN technology

With the rapid development of Internet, e-commerce and mobile technology, in order to meet the explosive growth demand of data bandwidth, and comply with the growth of continuous business, the demand of transmission bandwidth is met through WDM function. OTN technology has perfect performance monitoring and multi-level nested overlapping TCM connection monitoring. Its out of band FEC, large capacity, coarse-grained scheduling, suitable for backbone network applications, such as optical signal multiplexing / demultiplexing, optical wavelength switching, scalable capacity, is most suitable for backbone network; the ideal transport network in the future should be all OTN network, and the current OTN can be regarded as a transitional application in the evolution process from transport network to all-optical network.

2.1.1. Positioning of OTN network

Biological neurons have the following typical characteristics. Firstly, biological neurons are connected to each other, and the strength of the connection between them has an important impact on the quality of their signal transmission. Secondly, the connection strength between biological neurons can be changed, which can be realized by learning and training. In addition, the strength of the connections between the neurons in the biological neural network will change adaptively with the external excitation signal. External signals can stimulate or inhibit biological neurons. Biological neurons have specific thresholds, and the cumulative effect of received signals will play a decisive role in the state of neurons.

2.1.2. OTN network hierarchy

The OTN network hierarchy consists of three layers as shown in Figure 2, namely optical channel (OCh) sublayer, optical multiplexing segment layer (OMS) and optical transport segment layer (OTS). The optical channel (OCh) sublayer can be divided into three structures: optical channel payload unit, data unit and transmission unit. The functions and features of these three units are shown in Table 2 below.

Table 2. The functions and features of optical channel sublayer.

Units	Functions	Characteristics
OPUk	The client signal is mapped into a fixed frame structure	STM-N, IP packet, ATM cell, Ethernet frame
ODUk	Provide connectivity, connection protection and monitoring	Data channel layer
OTUk[V]	Provide optical segment layer protection and monitoring	Digital segment layer

The optical channel payload unit is the mapped customer signal and the corresponding overhead, the data unit is used for the channel layer connection of payload unit and the transmission unit is used for error correction of segment layer connection.

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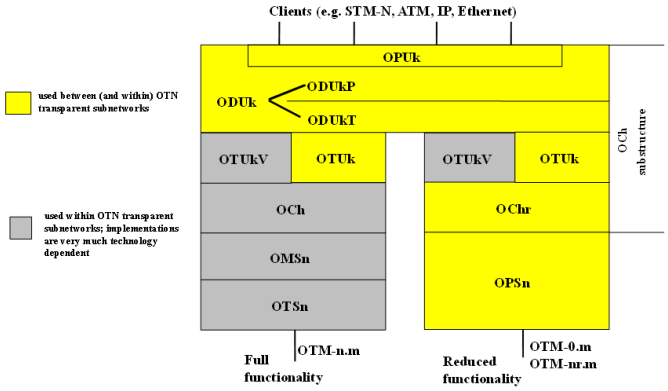

Figure2. The hierarchy of OTN network.

The optical multiplexer layer contains the OMS payload and uncorrelated OMS overhead. The OMS payload consists of multiplexed OCh. The content of oms-oh is transmitted through an independent optical auxiliary channel. OMS supports optical multiplex segment layer connection and connection monitoring. With OMS, service providers can isolate and eliminate the faults in a DWDM network segment in OTN, and monitor and manage the wavelength groups through multiple service provider networks.

Optical transport segment layer contains OTS payload and OTS overhead. The OTS payload consists of N optical multiplexers. The OTS overhead consists of maintenance and operational functional information that supports the optical transport segment. OTS overhead is transmitted through an optical auxiliary channel. The OTS layer allows service providers to manage and monitor the physical fiber segments between network units. Faults can be isolated at the physical fiber level. At the same time, it can report the attributes such as laser signal power level, dispersion and signal loss to network operators to facilitate fault isolation.

2.1.3. OTN frame structure

OTN frame structure is designed to load services into OTUk frames. Various services are loaded into payload, and the overhead is related to service mapping. In electric layer processing, OTUk is composed of electric regeneration, electric layer cross scheduling and OPUK plus some maintenance and management overhead. The ODUk frame can be transmitted in optical fibre, and the overhead is used for external transmission. The OTN frame structure is shown in Figure 3.

The OPUK frame is a part of the ODUk frame, and the ODUk frame is a part of the otuk frame. That is, in the OTUk frame, the part related to the service mapping constitutes the OPUK, and the OPUK plus some maintenance and management overhead constitutes the ODUk, and the ODUk plus a part of the maintenance and management overhead constitutes the otuk. OTUk frame is designed to enable ODUk frame to be transmitted in optical fibre. OTUk frame is formed by adding some overhead or processing operation suitable for external transmission.

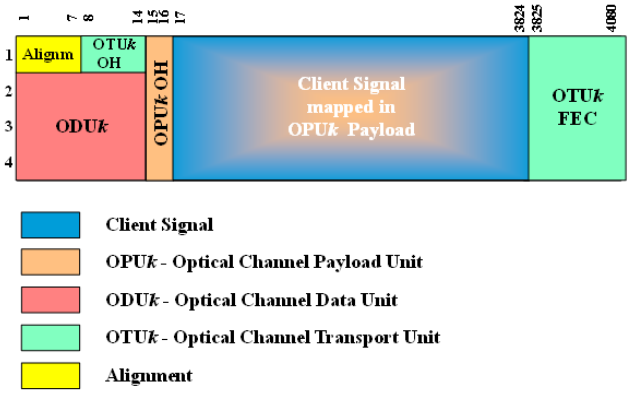

Figure3. The frame structure of OTN network.

OPUK frame is a part of ODUk frame. OPUK frame is designed to load service into OTUk frame. The main function of OPUK frame is to install various services into payload part of OPUk frame, and then add the overhead related to service mapping.

2.1.4. Electric layer technology

All kinds of customer signals are packaged into OTUk frames, and then OTUk frames are transmitted between networks. The WDM technology is used to realize high-capacity service transmission. Relying on the cost of electric layer and optical layer to realize the powerful network maintenance and management function, relying on the unified standard, realizing the interconnection of OTN equipment of different manufacturers, reducing the network level, thus reducing the cost of

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operators.In a narrow sense, OTN is OTUk frame. OTUk frame is the frame format of OTN signal in the electrical layer. OTM can be understood as the simultaneous transmission of n OTUks.

OTN maintenance signal is realized by setting most of the bytes in ODUk frame to the same fixed byte. Since the payload is also filled with fixed bytes, the service cannot be transmitted at this time. The format of OTN maintenance signal is shown in Figure 4 below.

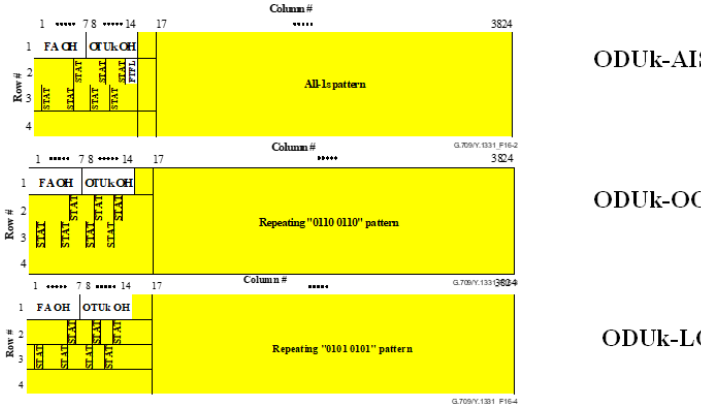

Figure4. The format of OTN maintenance signal.

2.2. Key features of OTN

OTN and SDH network operate independently and carry different types of services. In principle, SDH network is used to carry small granular services, and large granular services are recommended to be directly carried by OTN. At the customer service relationship level, it is suitable for OTN line rate higher than SDH line rate, which can improve the utilization of link resources. At the same time, using the scheduling and protection capabilities of OTN network can improve the survivability of the system.

The relationship between ASON based on SDH and OTN network is consistent with that of traditional SDH network in the transmission plane. When OTN has intelligent control plane, their intelligent control plane should support interworking. In the customer service model, there should be a cross layer protection and recovery function coordination mechanism.

2.3. Electric layer mapping

Electrical layer technology mapping includes asynchronous mapping and bit synchronous mapping. The asynchronous mapping has different clocks at both ends of the mapping, and the frequency difference is very small. It is usually applied to SDH mapping and OTN system internal mapping. The mapping signal of bit synchronization mapping uses the original data clock to fully synchronize the frequency before and after the mapping, which only applies to the general mapping procedure of service signal mapping. Asynchronous mapping adopts the form of local clock plus fixed padding and plus pointer adjustment, while general mapping uses Cn to record the number of customer signals carried by ODU, and uses padding for rate adaptation.

2.4. OTN service loading

OTN services are loaded with asynchronous mode and bit synchronization mode to map CBR to OPUk. The PPM required for clock synchronization of OPUk and user data is different from that of OPUk and user data. The byte in OPUk overhead is responsible for adjusting the opportunity byte PJO, NJO and reserved byte res. Because the payload area of OPUk is not an integral multiple of ATM cells, some ATM cells must span two OPUk frames[2]. ATM cell content should be mapped after wrapping. In the process of de-mapping, the code should be unwrapped. In the case of GFP mapping into OPUk, the rewind code needs to be added before GFP frame mapping.

ATM mapping to OPUK. Since the payload area of OPUK is not an integral multiple of ATM cells, some ATM cells must span two OPUK frames. Transfer STM-256 to OPU3, where D is the storage unit of 8bit[3]. Positive and negative adjustments can be made.The OTN service loading framework is shown in Figure 5.

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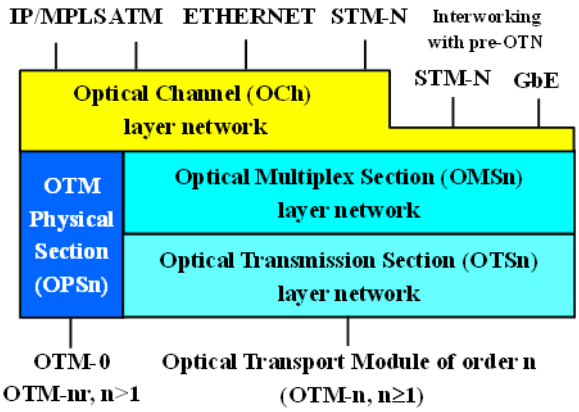

Figure 5. The OTN service loading framework.

2.5. Recovery of light layer protection

The head end signal is permanently bridged to the working path and the protection path for transmission, and the signal is received optimally and switched at one end. There is no need for protocol communication between the head and the tail on the protection process. The implementation is simple and the switching time is very short. Under normal circumstances, the protection channel also transmits services at the same time, which cannot provide resource sharing, resulting in bandwidth waste. Switch to the protection path, interrupt the service recovery, and monitor the quality of the two signals at the tail end, and determine the receiving channel preferentially. It adds the process of APS protocol overhead transmission and processing, increases the switching time, and the protection path can transmit low-level unprotected extra services under normal conditions, and improves the network utilization. The recovery protection architecture of electric layer protection is shown in Figure 6 below.

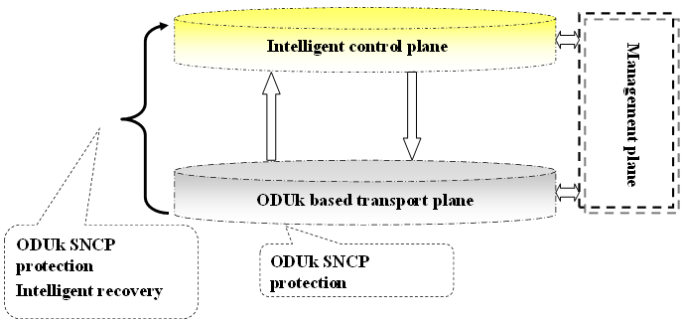

Figure 6. The recovery protection architecture of electric layer protection.

3. Planning and design of transmission network

3.1. Demand status and challenges of transmission network

With the continuous growth of convergence service flow, the rapid development of high bandwidth applications, the increase of router port rate, the increasingly complex optical network structure, the market demand for network capacity, flexibility and power consumption are constantly improving and developing, which brings new challenges to the planning and design of transmission network[4].

In the capacity demand level, it shows the characteristics of super capacity switching, super traffic convergence, ultra-high-speed transmission, large-scale networking and ultra-wideband new services. At the level of flexibility requirements, it shows the characteristics of multi granularity reconfigurable, flexible business facilitation, automatic connection establishment, dynamic resource allocation and controllable performance perception. At the power demand level, the new requirements and characteristics of unit module design, function component optimization, green energy saving management, system dynamics reduction and power domain processing are presented.

3.1.1. Challenges of transmission network

At present, with the rapid growth of system capacity, the growth of single channel rate has developed to TB level, so the transmission network is required to develop in the direction of improving all-optical spectrum efficiency[5]. Secondly, in the aspect of flexibility, the trend development of large amount of information, streaming transmission and multicast capability of converged services, and the development trend of heterogeneity, openness, dynamics, distribution and autonomy of IP packet network require the mode of carrying, switching, control, management and security of transmission network to realize all-optical elasticity. In addition, at the power consumption level, with the increase of power limited bandwidth, switching is transferred to

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all-optical layer. These aspects bring great challenges to the planning and design of transmission network and software transformation.

3.1.2. Development status of transmission network

At present, the development of transmission network mainly includes trunk transmission network, metropolitan area transmission network, trunk / metro core and metro access and convergence. These different transmission modes also make the planning and design of transmission network have many differences. With the evolution of the composition of the current bearer traffic, higher requirements are put forward for the transport network in terms of service broadband, network convergence, intelligent transmission, traffic burst, interface unity and network security. Among them, in the service broadband level, large granule / large flow service scheduling is required; in the network integration level, multi service bearing and transmission is required; in the transmission intelligent level, automatic switching and service perception are required. In addition, dynamic bandwidth adjustment is required at the traffic burst level, simplified bearer network and improved efficiency are required at the interface unified level, and carrier level OAM and reliability are required in network security level.

3.2. Planning and design of transmission network

3.2.1. Purpose of transmission network planning and design

The purpose of transmission network planning and design is to determine the goal, steps and methods of network development in the future[6]. To seek the most reasonable network structure, the minimum investment risk and the optimal cost performance ratio. Thus, the development goal, direction, development speed and significant proportion of the transmission network are worked out. Secondly, IT should explore the law and trend of the development of transport network. This paper puts forward the relevant major construction projects and technical and economic analysis in the planning period, so as to formulate the feasible implementation scheme of transmission network planning.

3.2.2. Transmission network planning theory

The centre of the network is the minimum of the maximum shortest path at all ends, and the corresponding node is the centre of the network. The midpoint of the net is the end with the shortest average diameter and the smallest length. Accordingto the series configuration, the effect of configuring *N* identical components in series is to lower the overall reliability.In a series configuration the overall reliability is only as good as that of the least reliable component. The structure of the series-parallel configuration is shown in figure 7 below.

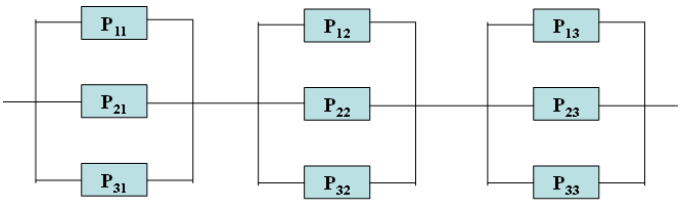

Figure 7. The structure of the series-parallel configuration.

In the parallel configuration, the overall system reliability is higher than that of any induvial component. In the parallel configuration, the system reliability is at least as great as that of the most reliable component.

3.3. Economic evaluation method of transport network planning

The economic evaluation of transmission network planning is a process of estimating the total investment of planning and calculating the demand of construction funds on the basis of studying and preliminarily determining the technical scheme, equipment scheme, engineering scheme and so on. Total present value of investment for construction:

$$K_{P0} = \frac{K_0}{(1+i)^0} + \frac{K_1}{(1+i)^1} + \frac{K_2}{(1+i)^2} + \ldots + \frac{K_{n-1}}{(1+i)^{n-1}} \quad (1)$$

The time value of capital is the capital of investment, and its value increases geometrically with the passage of time according to a certain compound interest rate[7]. The time value of capital

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is the capital of investment, and its value increases geometrically with the passage of time according to a certain compound interest rate. Annuity final value:

$$F = A\frac{(1+i)^n - 1}{i}$$
$$= A(F/A, i, n) \quad (2)$$

$(F/A, i, n)$ is the coefficient of equal serial compound interest sum, which also known as the final value coefficient of annuity, in order to judge the financial feasibility of the plan, the financial income and expenses are predicted, the financial statements are prepared, the evaluation indexes are calculated, and the financial profitability and solvency are analyzed, so as to complete the evaluation process.

4. Power WDM/OTN transmission network planning and software transformation based on machine learning

4.1. Design of routing decision parameter model based on machine learning classification algorithm

In the design principle level of routing decision parameter model, based on the historical sample data principle of route selection and resource allocation, the sample decision is mined by machine learning algorithm, and the factor weight parameters are used for the planning of new service channel and wavelength routing of new service. Secondly, in the level of network resource data and data preprocessing, it mainly includes two processes: network resource data and data preprocessing.

In addition, the ratio between the estimated distance of the station and the longest estimated distance of other optional stations is calculated based on the estimation cost calculation method of path search algorithm. The smaller the estimated distance ratio is, the better it is to shorten the total length of the final route.

Table 3. The comparison of different algorithms.

Algorithms	Advantages	Disadvantages
Naïve Bayesian classification	Low operation cost, supports incremental operation, highly explanatory	Not suitable for properties with strong correlation
Decision tree	Easy to extract rules, easy to visualize and fast to test	Cannot be parameterized, and easy to over fit
Logistic regression	The operation cost is low and the implementation is simple	May be under fitted

The construction of routing decision parameter model based on decision tree is mainly based on Bayesian classification model and logistic regression classifier. For the analysis and performance evaluation of different algorithms, which mainly analyze the characteristics of different algorithms and the performance index of the model, so as to select the most appropriate algorithm. The advantages and disadvantages of different algorithms are analyzed as shown in Table 3.

4.2. Software transformation design of 0tn network planning system

The link parameter model training module is the core module of OTN network planning system. Based on logistic regression classifier, the parameter model of influencing factors of topology decision and resource decision is generated. The data preprocessing and algorithm under the OTN network planning system module serve for the topology impact parameter learning and resource impact parameter learning, and the parameter persistence part saves the learning results to the database as the network attribute data to provide the routing basis for the routing module.

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Secondly, at the level of planning and location module, it mainly upgrades the overall function based on the link parameter model learning module to realize the location of topology planning resources and the solution of network problems. In addition, in the user interaction module level, based on the user interface, the result planning is extracted, and the parameter model is determined and updated. Through the software transformation configuration, it could change the learning results of the parameter model and optimize the parameters in time.

4.3. Power WDM/OTN transmission network planning and design based on machine learning

First of all, it should divide the area, introduce new technology and build a simple network. Based on the dimensions of service source and destination, service granularity and network construction, the network construction idea is mainly carried out in the way shown in Figure 8 below. Secondly, it is necessary to set up experimental area and build comprehensive carrying network through block construction. Based on the personalized needs of customers, network status and the principle of client-to-end access nearby, the construction is carried out in accordance with the principles of partition, scene, step and cycle.

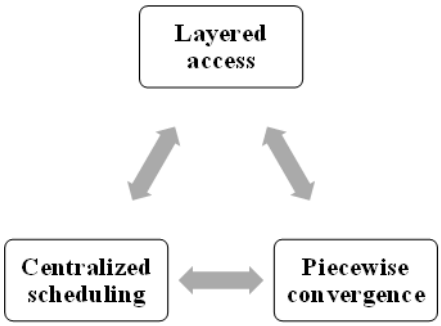

Figure 8. The network construction idea process.

In addition, it should refine the business, tap the potential resource chain, frame the service bearing principle, and select different access methods based on the business characteristics. It should also be based on the principle of network reconstruction and carrying network first to ensure the foresight of network construction. Finally, at the level of transmission network construction scheme, it is necessary to compare and select the planning and construction schemes, divide the regional construction schemes, and give priority to the areas with large business volume, many types of customers and high investment benefits, so as to effectively protect the realization of economic benefits.

5. Conclusion

In summary,the planning, design and software transformation of WDM/OTN need to be integrated with the development of business and network, so as to construct the overall idea and workflow of network planning, and develop the network planning tool software matching with the business requirements. As the basis of all kinds of business carrying network, transmission network is not only the core platform of information application, but also the concentrated performance of high-quality bearing pipeline of customers. In this context, transmission network operators need to build an efficient bearer network based on a variety of comprehensive considerations.

In this paper, through the research of OTN technology principle and network planning concept and principle, including the analysis of OTN network hierarchy, frame structure, technical characteristics, laid the foundation of its transport network planning and design. Secondly, through the research of transmission network planning and design, the paper points out the challenges faced by the current transmission network planning, as well as the economic evaluation method of transmission network planning. Finally, the paper studies the power WDM/OTN transmission network planning and software transformation based on machine learning, including the design of routing decision parameter model based on machine learning classification algorithm, the software transformation design of OTN network planning system, and the

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planning and design method of power WDM/OTN transmission network based on machine learning.

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