

WAVELENGTH ROUTING DEVICE

TECHNICAL FIELD

The present invention relates to optical network technologies, and in particular, to a wavelength routing device based on a wavelength cross filter.

BACKGROUND

An optical router is an important constituent part of an optical interconnection technology, and can connect transmit and receive nodes, so that an optical signal sent from the transmit node is accurately transmitted to the receive node. Optical routers can be mainly divided into two categories: a spatial router based on a spatial optical switch and a wavelength router based on a wavelength optical switch, where the wavelength router becomes a research hotspot because the wavelength router can implement self-routing of optical signal without the need to perform dynamic adjustment. An optical router based on a wavelength cross filter uses periodic characteristics of spectrum filtering of the wavelength cross filter, and therefore can effectively reduce a quantity of switch nodes in an optical wavelength router and reduce the size and time delay of the router.

In the prior art, a topology of an optical router based on a wavelength cross filter is shown in FIG. 1, and FIG. 1A is a diagram of a 9 x 9 topology in a WRON-RC technology. A routing table of an optical switch node of each stage is shown in FIG. 2. As can be learned from FIG. 2, for a switch node Λ_A , responses of the switch to optical signal with wavelengths of λ_0 , λ_3 , and λ_6 are cross, and responses to optical signal with wavelengths of λ_1 , λ_2 , λ_4 , λ_5 , λ_7 , and λ_8 are bar. In the diagram of the 9 x 9 topology, when optical signal with a different wavelength is input from an input port, for example I_0 , and optical signal with a wavelength is output from an output port, for example O_1 , optical signal needs to pass through four optical switches to finally output optical signal with a particular wavelength.

However, in the prior art, an optical router based on a wavelength cross filter still has a very complex topology, and a large quantity of optical switches are needed in a wavelength router.

SUMMARY

The present invention provides a wavelength routing device, which simplifies a topology of a

wavelength routing device, and reduces a quantity of optical switch nodes in the wavelength routing device.

An embodiment of the present invention provides a wavelength routing device, including:

a primary circuit and a secondary circuit, where

5 the primary circuit includes N 2×2 wavelength switches, the secondary circuit includes two $N \times N$ wavelength routers, and each $N \times N$ wavelength router includes at least one 2×2 wavelength switch, where a value of N is 2^n , n being a positive integer; and

10 in the primary circuit, an input port of each 2×2 wavelength switch is connected to an input stage and an output port of each 2×2 wavelength switch is connected to an input port of an $N \times N$ wavelength router of the secondary circuit, and output ports of the $N \times N$ wavelength routers of the secondary circuit are connected to an output stage.

Further, the input stage includes $2N$ input ports, where the input ports in the input stage are correspondingly and separately connected to the input ports of the 2×2 wavelength switches in the primary circuit, and the output ports of the 2×2 wavelength switches in the primary circuit are
15 correspondingly connected to the input ports of the $N \times N$ wavelength routers in the secondary circuit separately.

Further, the output stage includes $2N$ output ports, where the output ports in the output stage are correspondingly and separately connected to the output ports of the $N \times N$ wavelength routers in the secondary circuit.

20 Further, a quantity $N1$ of 2×2 wavelength switches in the wavelength routing device is determined by using a formula (1):

$$N1 = (M1/2) \log_2 M1 \quad (1)$$

where $M1$ is a quantity of the input ports in the input stage or a quantity of the output ports in the output stage.

25 Further, in the wavelength routing device, a quantity $N2$ of 2×2 wavelength switches that input optical signal needs to pass through from an input port of the input stage to a specified output port of the output stage is determined by using a formula (2):

$$N1 = \log_2 M2 \quad (2)$$

where $M2$ is the quantity of the input ports or the quantity of the output ports.

30 According to the wavelength routing device provided in the embodiments of the present invention, in the device, the primary circuit includes N 2×2 wavelength switches and the secondary circuit includes two $N \times N$ wavelength routers, which simplifies a topology of the wavelength routing device, and reduces a quantity of optical switch nodes in the wavelength routing device.

BRIEF DESCRIPTION OF DRAWINGS

To describe the technical solutions in the embodiments of the present invention or in the prior art more clearly, the following briefly describes the accompanying drawings required for describing the embodiments or the prior art. Apparently, the accompanying drawings in the following description show some embodiments of the present invention, and persons of ordinary skill in the art may still derive other drawings from these accompanying drawings without creative efforts.

FIG. 1 is a schematic diagram of a topology of a routing device in the prior art;

FIG. 2 is a schematic diagram of a routing table of wavelength switches of the routing device in FIG. 1;

FIG. 3 is a schematic structural diagram of a wavelength routing device according to Embodiment 1 of the present invention;

FIG. 4 is a schematic structural diagram of a 2 x 2 wavelength switch of the wavelength routing device according to Embodiment 1 of the present invention;

FIG. 5 is a first schematic diagram of input optical signal with the spectrum of a wavelength routing device according to the present invention;

FIG. 6A to FIG. 6D are schematic diagrams of spectral responses of output ports to input ports of a 2 x 2 wavelength switch in a primary circuit of the wavelength routing device according to Embodiment 1 of the present invention;

FIG. 7 is a schematic structural diagram of a wavelength routing device according to Embodiment 2 of the present invention;

FIG. 8 is a schematic structural diagram of a 2 x 2 wavelength switch of the wavelength routing device according to Embodiment 2 of the present invention;

FIG. 9 is a second schematic diagram of input optical signal with the spectrum of a wavelength routing device according to the present invention;

FIG. 10A to FIG. 10D are schematic diagrams of spectral responses of output ports to input ports of a 2 x 2 wavelength switch in a primary circuit of the wavelength routing device according to Embodiment 2 of the present invention;

FIG. 10E to FIG. 10H are schematic diagrams of spectral responses of output ports to input ports of a 2 x 2 wavelength switch in a secondary circuit of the wavelength routing device according to Embodiment 2 of the present invention; and

FIG. 11 is a schematic structural diagram of a wavelength routing device according to Embodiment 3 of the present invention.

DESCRIPTION OF EMBODIMENTS

To make the objectives, technical solutions, and advantages of the embodiments of the present invention clearer, the following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the
5 embodiments of the present invention. Apparently, the described embodiments are a part rather than all of the embodiments of the present invention. All other embodiments obtained by persons of ordinary skill in the art based on the embodiments of the present invention without creative efforts shall fall within the protection scope of the present invention.

FIG. 3 is a schematic structural diagram of a wavelength routing device according to
10 Embodiment 1 of the present invention, and FIG. 4 is a schematic structural diagram of a 2×2 wavelength switch of the wavelength routing device according to Embodiment 1 of the present invention. The routing device provided in this embodiment is a wavelength router based on a wavelength optical switch, is applicable to an optical interconnection technology, and can implement transmission of an optical signal between transmit and receive nodes. Referring to FIG.
15 3 and FIG. 4, the wavelength routing device of this embodiment may include: a primary circuit and a secondary circuit.

The primary circuit includes $N \ 2 \times 2$ wavelength switches Λ_A , the secondary circuit includes two $N \times N$ wavelength routers, and each $N \times N$ wavelength router includes at least one 2×2 wavelength switch Λ_A , where a value of N is 2^n , n being a positive integer.

In this embodiment, the $N \ 2 \times 2$ wavelength switches Λ_A and the two $N \times N$ wavelength
20 routers are combined to form one $2N \times 2N$ wavelength routing device. For example, when the value of N is 2, a 4×4 wavelength routing device includes two 2×2 wavelength switches Λ_A and two 2×2 wavelength routers. In this case, each 2×2 wavelength router includes only one 2×2 wavelength switch Λ_A , and therefore, it may be considered that the 4×4 wavelength routing device includes
25 four 2×2 wavelength switches Λ_A . When the value of N is 4, an 8×8 wavelength routing device includes four 2×2 wavelength switches Λ_A and two 4×4 wavelength routers, and the corresponding 4×4 wavelength routing device when the value of N is 2 may be used as the 4×4 wavelength router, and in this case, the 4×4 wavelength router includes four 2×2 wavelength switches Λ_A . Correspondingly, a 16×16 wavelength routing device includes eight 2×2 wavelength switches Λ_A
30 and two 8×8 wavelength routers, where the composition of the 8×8 wavelength router is the same as the composition of the 8×8 wavelength routing device.

In this embodiment, in the primary circuit, an input port of each 2×2 wavelength switch Λ_A is connected to an input stage and an output port of each 2×2 wavelength switch Λ_A is connected to an input port of an $N \times N$ wavelength router of the secondary circuit, and output ports of the $N \times N$

wavelength routers of the secondary circuit are connected to an output stage. Further, in this embodiment, each 2×2 wavelength switch Λ_A includes two input ports and two output ports (for example, input port 1, input port 2, output port 1, and output port 2 shown in FIG. 4). The input stage includes $2N$ input ports, for example, input ports L_{0_0} to $L_{0_ (2N-1)}$ of the input stage in FIG. 3.

5 The input ports in the input stage are correspondingly and separately connected to the input ports of the 2×2 wavelength switches Λ_A , that is, every two input ports in the input stage are correspondingly and separately connected to the two input ports of a 2×2 wavelength switch Λ_A in FIG. 4. The output ports (for example, L_{1_0} to $L_{1_ (2N-1)}$ in the primary circuit in FIG. 3) of the 2×2 wavelength switches Λ_A are correspondingly and separately connected to the input ports (for
10 example, L_{1_0} to $L_{1_ (2N-1)}$ in the secondary circuit in FIG. 3) of the $N \times N$ wavelength routers in the secondary circuit. Each $N \times N$ wavelength router includes N input ports and N output ports. The output stage includes $2N$ output ports, for example, output ports L_{2_0} to $L_{2_ (2N-1)}$ in the output stage in FIG. 3. The output ports of the output stage are correspondingly and separately connected to output ports (for example, L_{2_0} to $L_{2_ (2N-1)}$ in the secondary circuit in FIG. 3) of the $N \times N$
15 wavelength routers of the secondary circuit. For example, when the value of N is 4, for an 8×8 wavelength routing device, a quantity of the input ports of the input stage and a quantity of the ports of the output stage are both 8, and each 4×4 wavelength router has four input ports and four output ports.

According to the wavelength routing device provided in this embodiment of the present
20 invention, in the device, the primary circuit includes N 2×2 wavelength switches and the secondary circuit includes two $N \times N$ wavelength routers, which simplifies a topology of the wavelength routing device, and reduces a quantity of optical switch nodes in the wavelength routing device.

FIG. 5 is a first schematic diagram of input optical signal with the spectrum of a wavelength
25 routing device according to the present invention, and FIG. 6A to FIG. 6D are schematic diagrams of spectral responses of output ports to input ports of a 2×2 wavelength switch in a primary circuit of a wavelength routing device according to the present invention. Referring to FIG. 5 to FIG. 6D, in this embodiment, a longitudinal coordinate is optical power P and a horizontal coordinate is a wavelength λ in FIG. 5 to FIG. 6D. Further, in the foregoing embodiment, when the input optical
30 signal with the spectrum shown in FIG. 5 is separately input from the ports of the input stage, a spectrum effect of an output port 1 to an input port 1 in the 2×2 wavelength switch Λ_A in the primary circuit is shown in FIG. 6A; a spectrum effect of an output port 2 to the input port 1 in the 2×2 wavelength switch Λ_A in the primary circuit is shown in FIG. 6B, that is, after the input optical signal with the spectrum enters the input port 1 of the 2×2 wavelength switch Λ_A , optical signal

with the spectrum output from the output port 1 is $\lambda_1, \lambda_2, \dots, \lambda_N$, and optical signal with the spectrum output from the output port 2 is $\lambda_{N+1}, \lambda_{N+2}, \dots, \lambda_{2N}$; and correspondingly, a spectrum effect of the output port 1 to an input port 2 in the 2×2 wavelength switch Λ_A in the primary circuit is shown in FIG. 6C, and a spectrum effect of the output port 2 to the input port 2 in the 2×2 wavelength switch Λ_A in the primary circuit is shown in FIG. 6D, that is, after input optical signal with the spectrum shown in FIG. 5 enters the input port 2 of the 2×2 wavelength switch Λ_A , optical signal with the spectrum output from the output port 1 is $\lambda_{N+1}, \lambda_{N+2}, \dots, \lambda_{2N}$, and optical signal with the spectrum output from the output port 2 is $\lambda_1, \lambda_2, \dots, \lambda_N$.

FIG. 7 is a schematic structural diagram of a wavelength routing device according to Embodiment 2 of the present invention. FIG. 8 is a schematic structural diagram of a 2×2 wavelength switch of the wavelength routing device according to Embodiment 2 of the present invention. FIG. 9 is a second schematic diagram of input optical signal with the spectrum of a wavelength routing device according to the present invention, FIG. 10A to FIG. 10H are schematic diagrams of spectral responses of output ports to input ports of a 2×2 wavelength switch in a primary circuit of the wavelength routing device according to Embodiment 2 of the present invention. FIG. 10E to FIG. 10H are schematic diagrams of spectral responses of output ports to input ports of a 2×2 wavelength switch in a secondary circuit of the wavelength routing device according to Embodiment 2 of the present invention.

Based on the foregoing embodiments, in this embodiment, when a value of N is 2, a structure of a corresponding 4×4 wavelength routing device is shown in FIG. 7. The 4×4 wavelength routing device includes two 2×2 wavelength switches Λ_B in a primary circuit and two 2×2 wavelength routers, where each 2×2 wavelength router includes one 2×2 wavelength switch Λ_A , and therefore, the 2×2 wavelength switch Λ_A is used in this embodiment as the 2×2 router of the secondary circuit. Structures and functions of the 2×2 wavelength switch Λ_A and the 2×2 wavelength switch Λ_B (as shown in FIG. 8) in this embodiment are the same as those of the 2×2 wavelength switch Λ_A in the foregoing embodiments, and therefore, for the 2×2 wavelength switch Λ_A in this embodiment, refer to Λ_A shown in FIG. 4. Sequences for connecting the 2×2 wavelength switches Λ_A and the 2×2 wavelength switches Λ_B are interchangeable.

In this embodiment, four input ports in the input stage are represented separately by four nodes, that is, input nodes T_1, T_2, T_3 , and T_4 . Correspondingly, four output ports in the output stage are represented by output nodes R_1, R_2, R_3 , and R_4 . The four input nodes T_1, T_2, T_3 , and T_4 are correspondingly connected to input ports of the 2×2 wavelength switches Λ_B in the primary circuit, the four nodes R_1, R_2, R_3 , and R_4 are correspondingly connected to output nodes of the 2×2 wavelength switches Λ_A of the secondary circuit, and the 2×2 wavelength switches Λ_B in the

primary circuit are cross-connected to the 2×2 wavelength switches Λ_A in the secondary circuit shown in FIG. 7.

For example, when optical signal with the spectrum shown in FIG. 9 is separately input from the input nodes in the input stage, a spectral response of an output port 1 to an input port 1 of the 2×2 wavelength switch Λ_B in the primary circuit is shown in FIG. 10A, and a spectral response of an output port 2 to the input port 1 of the 2×2 wavelength switch Λ_B is shown in FIG. 10B, that is, when optical signal with the spectrum is input from the input node T_1 , wavelengths output from the output port 1 of the 2×2 wavelength switch Λ_B are λ_1 and λ_2 , and wavelengths output from the output port 2 are λ_3 and λ_4 ; and a spectral response of the output port 1 to an input port 2 of the 2×2 wavelength switch Λ_B in the primary circuit is shown in FIG. 10C, and a spectral response of the output port 2 to the input port 2 of the 2×2 wavelength switch Λ_B is shown in FIG. 10D, that is, when the optical signal with the spectrum is input from the input node T_2 , wavelengths output from the output port 1 of the 2×2 wavelength switch Λ_B are λ_3 and λ_4 , and wavelengths output from the output port 2 are λ_1 and λ_2 . After the optical signal with the spectrum passes through the 2×2 wavelength switches Λ_B in the primary circuit, λ_1 and λ_2 (input optical signal from T_1) and λ_3 and λ_4 (input optical signal from T_2) that are output from the output port 1 of the 2×2 wavelength switch Λ_B in the primary circuit are input to an input port 1 of the 2×2 wavelength switch Λ_A in the secondary circuit (as shown in FIG. 4). Correspondingly, λ_3 and λ_4 (input optical signal from T_1) and λ_1 and λ_2 (input optical signal from T_2) that are output from the output port 2 of a 2×2 wavelength switch Λ_B in the primary circuit are input into an input port 1 of the other 2×2 wavelength switch Λ_A in the secondary circuit (as shown in FIG. 4). A spectral response of an output port 1 to the input port 1 of the 2×2 wavelength switch Λ_A in the secondary circuit is shown in FIG. 10E, and a spectral response of an output port 2 to the input port 1 of the 2×2 wavelength switch Λ_A is shown in FIG. 10F, that is, after λ_1 and λ_2 (input optical signal from T_1) and λ_3 and λ_4 (the spectrum input from T_2) are input from the input port 1, λ_1 (input optical signal from T_1) and λ_3 (input optical signal from T_2) are output from the output node R_1 , and λ_2 (input optical signal from T_1) and λ_4 (input optical signal from T_2) are output from the output node R_2 . Correspondingly, a spectral response of the output port 1 to an input port 2 of the 2×2 wavelength switch Λ_A in the secondary circuit is shown in FIG. 10G, and a spectral response of the output port 2 to the input port 2 is shown in FIG. 10H, that is, after input from T_3 and T_4 and input from the input port 2 of the 2×2 wavelength switch Λ_A in the secondary circuit, λ_2 (input optical signal from T_3) and λ_4 (input optical signal from T_4) are output from the output node R_1 , and λ_1 (input optical signal from T_3) and λ_3 (input optical signal from T_4) are output from the output node R_2 .

A routing table of the 4×4 wavelength routing device in this embodiment is shown in Table 1.

Table 1 Routing table of 4 x 4 wavelength routing device

Output Port (R_x) /Input Port (T_x)	R_1	R_2	R_3	R_4
T_1	λ_1	λ_2	λ_3	λ_4
T_2	λ_3	λ_4	λ_1	λ_2
T_3	λ_2	λ_1	λ_4	λ_3
T_4	λ_4	λ_3	λ_2	λ_1

It can be learned from Table 1 that when the input node T_1 needs to communicate with the output node R_3 , the signal can be self-routed to the output node R_3 by means of the 4 x 4 wavelength routing device of this embodiment by simply modulating a signal onto a carrier with a wavelength of λ_3 at the input node T_1 .

According to the wavelength routing device provided in this embodiment of the present invention, in the device, the primary circuit includes two 2 x 2 wavelength switches and the secondary circuit includes two 2 x 2 wavelength routers, which simplifies a topology of the wavelength routing device, and reduces a quantity of optical switch nodes in the wavelength routing device.

FIG. 11 is a schematic structural diagram of a wavelength routing device according to Embodiment 3 of the present invention. Based on the foregoing embodiment, this embodiment provides an 8 x 8 routing device, that is, a corresponding routing device when a value of N is 4. As shown in FIG. 11, in this embodiment, the 8 x 8 routing device includes four 2 x 2 wavelength switches Λ_C of a primary circuit and two 4 x 4 wavelength routers of a secondary circuit, input nodes T_1 to T_8 , and output nodes R_1 to R_8 , where a connection relationship between the input nodes T_1 to T_8 and input ports of the four 2 x 2 wavelength switches Λ_C of the primary circuit is shown in FIG. 11, and the connection relationship in the 4 x 4 routing device in Embodiment 2 is used for the two 4 x 4 wavelength routers of the secondary circuit. In this embodiment, the 4 x 4 wavelength router includes four 2 x 2 wavelength switches Λ_A (as shown in FIG. 3), and for a specific implementation manner, refer to the implementation method of Embodiment 2.

Further, based on the foregoing embodiment, in this embodiment, a quantity N1 of 2 x 2 wavelength switches in the wavelength routing device is determined by using a formula (1):

$$N1 = (M1/2) \log_2 M1 \quad (1)$$

A quantity N2 of 2 x 2 wavelength switches that input optical signal needs to pass through from an input port (for example, nodes T_1 to T_8) of the input stage to a specified output port (for example, nodes R_1 to R_8) of the output stage is determined by using a formula (2):

$$N1 = \log_2 M2 \quad (2)$$

where M1 is a quantity of input ports in the input stage or a quantity of output ports in the output stage.

For example, for the 8 x 8 routing device, the quantity of input ports of the input stage is 8, and therefore, the total quantity of 2 x 2 wavelength switches in the 8 x 8 routing device is 12, and the quantity of 2 x 2 wavelength switches that input optical signal passes through from the node T₁ to the node R₈ is 3. Compared with the prior art, for a 16 x 16 routing device, when the quantity of input ports is 16, 32 2 x 2 wavelength switches are needed in the present invention, and four 2 x 2 wavelength switches are passed through (while in the prior art, four optical switches need to be passed through for even a 9 x 9 routing device); while in the prior art, a 16 x 16 routing device needs a total of 48 optical switches. For a 64 x 64 routing device, 192 2 x 2 wavelength switches are needed in the present invention, while 448 optical switches are needed in the prior art.

Therefore, in the wavelength routing device of this embodiment of the present invention, the primary circuit includes N 2 x 2 wavelength switches and the secondary circuit includes two N x N wavelength routers; in this way, on the one hand, a topology of the wavelength routing device is simplified, and on the other hand, not only a quantity of optical switches in the routing device can be reduced, where the reduction in the quantity of optical switches is more significant for a larger optical network, but also a quantity of optical switches that input optical signal passes through in the routing device can be reduced, thereby improving efficiency of the routing device.

Persons of ordinary skill in the art may understand that all or some of the steps of the method embodiments may be implemented by a program instructing relevant hardware. The program may be stored in a computer-readable storage medium. When the program runs, the steps of the method embodiments are performed. The foregoing storage medium includes: any medium that can store program code, such as a ROM, a RAM, a magnetic disk, or an optical disc.

Finally, it should be noted that the foregoing embodiments are merely intended for describing the technical solutions of the present invention, but not for limiting the present invention. Although the present invention is described in detail with reference to the foregoing embodiments, persons of ordinary skill in the art should understand that they may still make modifications to the technical solutions described in the foregoing embodiments or make equivalent replacements to some or all technical features thereof, without departing from the scope of the technical solutions of the embodiments of the present invention.

CLAIMS

1. A wavelength routing device, comprises:
a primary circuit, a secondary circuit;
wherein the primary circuit comprises N 2×2 wavelength switches, the secondary circuit comprises two $N \times N$ wavelength routers, and each $N \times N$ wavelength router comprises at least one 2×2 wavelength switch, wherein a value of N is 2^n , n being a positive integer; and
the input stage are connected to input ports of the each 2×2 wavelength switches in the primary circuit, output ports of the each 2×2 wavelength switches are connected to input ports of two $N \times N$ wavelength routers in the secondary circuit in one-to-one correspondence, and output ports of the two $N \times N$ wavelength routers in the secondary circuit are connected to the output stage in one-to-one correspondence.
2. The device according to claim 1, wherein the input stage comprises $2N$ input ports, each input port of the input stage are connected to each input ports of the 2×2 wavelength switches in the primary circuit in one-to-one correspondence, each output port of the 2×2 wavelength switches in the primary circuit is connected to each input port of the $N \times N$ wavelength router in the secondary circuit in one-to-one correspondence.
3. The device according to claim 1, wherein the output stage comprises $2N$ output ports, each output port of the $N \times N$ wavelength router in the secondary circuit is connected to each output port of the output stage in one-to-one correspondence.
4. The device according to any one of claims 2-3, wherein a quantity $N1$ of 2×2 wavelength switches in the wavelength routing device is determined by using a formula (1):

$$N1 = (M1/2) \log_2 M1 \quad (1)$$

wherein M1 is a quantity of the input ports in the input stage or a quantity of the output ports in the output stage.

5. The device according to any one of claims 2-4, wherein in the wavelength routing device, a quantity N2 of 2 x 2 wavelength switches that each optical signal needs to pass through from an input port of the input stage to an output port of the output stage is determined by using a formula (2):

$$N2 = \log_2 M2 \quad (2)$$

wherein M2 is the quantity of the input ports in the input stage or the quantity of the output ports in the output stage.