行政院國家科學委員會專題研究計畫成果報告

雙網路對等節點架構之分波多工網路

Dual Network Twin Node Architecture for WDM Networks

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一、中文摘要

我們提出一個雙網路隊等節點(DNTN)的於分波多工(WDM)網路架構,以有效且可靠的方式連結區域及都會區網路以形成大型廣域網路．許多常見的網路型態可以應用於 DNTN 架構，而我們發覺有些型態組合可以獲致高可靠度，低平均躍點數以及簡單的路由法則．我們發覺一個結合環型網路及心型網路的 DNTN 架構,稱為輻射型網路,具有相當良好的特性．　我們研究 WDM 輻射型網路，而由分析結果認為它是未來寬頻 WDM 網路的良好選擇．

關鍵詞:WDM 網路、網路架構．

Abstract

We propose a novel architecture dedicated for WDM optical networks. The Dual Networks Twin Nodes (DNTN) architecture originated from the consideration to efficiently and reliably connect many existing local or metropolitan area networks into a wide area network (WAN). Many familiar network topologies could be adopted in the DNTN structure and we find that some excellent combinations can achieve high reliability, low mean hop distance as well as simple routing algorithm. Based on the DNTN architecture we find a new network topology constructed by a RING and a STAR subnet, being named as the Radiation network. The construction turns out to be perfect combination of RING and STAR networks. A WDM based Radiation network is studied. From the analysis results, we see that alternative routing algorithms can be employed to improve the system waiting time.

二、緣由與目的

The continuing improvement on wavelength division multiplexing, tunable optical transceivers and optical devices accelerates the spreading of optical fiber infrastructure. Blooming Internet raises network density and shows the need to connect the related functional networks. An immediate question arises out of interconnecting these existing but variant networks：how to link them by a simple and effective strategy ? The question may occur when connecting community networks or campus networks as well as when building international links between countries.

We propose a novel architecture for effective connection of existing networks.

Let N_a, N_b, N_c, N_d and N_e be local networks and it is necessary to connect them into a large network. For reliability consideration, we choose two nodes from every local network and name each pair of nodes as twin nodes, e.g. (A, A'), (B, B'), (C, C'), (D, D'), and (E, E') are the selected twin nodes out of each local network. When connecting all these five local networks, we cluster A, B, C, D and E into Net-I and construct another Net-II consisting of A', B', C', D' and E' nodes. Net-I and Net-II are independent networks, in fact, they are always constructed based on their respective considerations according to those nodes for which they serve. Net-I and Net-II together with those existing links between twin nodes form the resulting network interconnecting these five local networks. We named this special approach as the Dual Networks-Twin Nodes (DNTN) architecture due to the existence of two subnets and the many twin nodes.

三、結果與討論

In this section we apply the DNTN architecture to WDM networks. We are particularly interested in the DNTN structure composed of a RING subnet and a STAR subnet as discussed previously. It does have a small mean hop number and higher reliability as mentioned. Moreover, each subnet compensates for the weakness of the other. The RING topology with a large mean hop number and the STAR topology with poor reliability both make their improvements. We name this special DNTN architecture as the Radiation network because that its topology mimics a radiation pattern.

3.1 The Routing Algorithm

The RING subnet and the STAR subnet in the Radiation network, in general, can be assigned by different routing algorithm. Though, many alternatives can work well in the DNTN architecture, we apply the wheel routing in the RING subnet, and the passive STAR routing in the STAR subnet. We consider the following physical constraints in the network. The number of usable wavelengths in a fiber is limited and denoted as N_λ. In a wheel, a service node is linked to r close neighbors and r is often called as the system order being equal to the number of transceivers owned by a service node. Wheel (m, r) is denoted as a wheel with order r which has m nodes. The limited number of wavelengths in a fiber leading to the following constraint on the order r:

$$1+2+\cdots+r=\frac{r\cdot(r+1)}{2}\le N_a$$

$$\Rightarrow r\le\frac{\sqrt{8N_a+1}-1}{2}\approx\sqrt{2N_a} \qquad (1)$$

In a STAR network, each node sends packets via different wavelength channels, being combined by a central star coupler and then forwarded to every node. let s denote the number of different wavelength transceivers at each node, the limitation of N_λ wavelengths in a fiber leading to the following constraint on s :

$$s\le\frac{N_a}{m} \qquad (2)$$

where m is the number of nodes in the STAR network.

The RING topology has a large mean number of hops, even wheel routing is assigned physically as the optical connectivity. As to a passive STAR, only one hop is needed for a packet from a source node to the destination node. It has the smallest mean number of hops but poor reliability. In the view of static performance, RING with wheel routing can reduce mean hop number by connecting with a STAR as a DNTN structure and both of the two subnets improve their reliability.

In WDM networks, rather limited wavelengths can be used for a node in a passive STAR. Suppose that only up to 32 wavelengths can appear in a fiber, then a RING network with wheel routing may be constructed as a system of order 7, i.e. seven transceivers can be set up in a node. For the same constraint, any node in the STAR can have only 2 transceivers (order $R=2$) for a system of 16 nodes and only one transceiver (order $R=1$) for a system of 32 nodes. The passive STAR does have shortest mean hop but any service node concurrently processes only 2 packets (for a 16-node system) and only one packet (for a 32-node system) at a unit time. It results in a large system waiting time.

After constructing a Radiation network, more links to connect twin nodes raise the maximum order that a node can have. We can see the improvement in a DNTN structure of 32 nodes. The 16 nodes in the RING subnet can have a large order comparing with the original limited order 7. And the 16 nodes in the passive STAR subnet can also have a large order comparing to the original order 2. Higher order means more powerful processing capability that owned by a service node. Obviously, the multi-loop RING with wheel routing gets a much smaller mean hop by way of the twin node link and the passive STAR reduces waiting time by distributing some traffic to the RING subnet.

3.2 Mean hop number s

Here we study a system of 2n nodes, being composed of a RING subnet of n nodes and a STAR subnet of n nodes. All the wavelengths are reusable in different fiber links but no more than N_a wavelengths can appear in the same fiber.

A source node in the RING subnet has a different mean hop number from that of a source node in the STAR subnet. The formulas below are listed to calculate the mean hop number for different source nodes.

¿ For a source node in the RING, the mean hop number is

$$H_r = \frac{5n-3r-4}{2\cdot n-1} \qquad (3)$$

À For a source node in the STAR, the mean hop is

$$H_s = \frac{3n-2}{2\cdot n-1} \qquad (4)$$

Á Average mean hop for the whole system

$$H = \frac{1}{2}\cdot(H_r + H_s) = \frac{8n-3r-6}{2(2n-1)} \qquad (5)$$

For a large network we find that the

mean hop number of the Radiation network is nearly unaffected by the number of transceivers in the RING subnet. This is because of the presence of the STAR subnet that provides a shortcut for most packets so that mean hop number is limited to a maximum of 3. This property is different from a single RING network with wheel routing, whose mean hop number is inversely proportional to the number of transceivers.

3.3 Maximum network throughput

To evaluate the maximum throughput of the Radiation network we plot the traffic flow of a twin node in Fig. 5. In the figure s and r represent the number of transceivers to the local network of a node in the STAR subnet and in the RING subnet, respectively, whereas trs and tsr represent the number of transmitters between the twin nodes. Owing to the wavelength limitation of RING and STAR subnet, we have

$$s \le \frac{N_a}{n}, \qquad r \le \sqrt{2N_a} \qquad (6)$$

In the steady state , we assume $\Gamma_{s,in}=\Gamma_{s,out}$, $\Gamma_{r,in}=\Gamma_{r,out}$. To keep a balanced input and output traffics, we obtain:

$$t_{rs} = s \le \frac{N_a}{n}, \qquad t_{sr} = r \le \sqrt{2N_a} \qquad (7)$$

From Eqs.(6) and (7) we estimate the maximum network throughput as

$$C = \frac{n \cdot (s + t_{sr}) + n \cdot (r + t_{rs})}{H} \le \frac{2n \cdot (\frac{N_a}{n} + \sqrt{2N_a})}{H}$$

We find that due to the mutual compensation of the two subnets, the limitation imposed by the available wavelengths is much relaxed in the Radiation network so that the maximum network throughput is much larger than that of a RING or a STAR network.

四、成果自評

We proposed the DNTN architecture to connect many existing networks into a larger network. By this approach, a pair of nodes is selected from each existing network and further we construct them into two groups. No constraint is set in designing the two groups. Our study shows that the DNTN architecture is a simple and efficient approach to build a large WDM network.

五、參考文獻

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