Breaking the Bidirectional Link Paradigm

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Abstract: Ethernet links are unidirectional, but are currently routed on bidirectional equipment with identical capacities in each direction. Using measured traffic from over 100 metro networks, we explore the potential savings by treating each direction independently.
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1. Introduction

Internet traffic continues to grow at a very high rate and it is becoming increasingly important to make the transport networks more cost-efficient. In this paper we focus on the cost of the network equipment needed to transport traffic. Studies such as [1] have shown that traffic in metro-area networks will surpass inter-city long-haul traffic in 2015, and will account for 66% of total IP traffic by 2019. In this paper we explore the possibility of savings in metro-area networks for a large ISP, using asymmetric connections built from unidirectional circuits. This work is an extension of our previous study [2], in which we quantified the potential savings using unidirectional equipment on a major ISP's backbone network.

Metro-area network architecture typically consists of aggregation routers that deliver the aggregated traffic to two large metro-core routers (sometimes referred to Provider Edge (PE) routers). Density of the aggregation routers in a metro-area varies significantly depending on the demographics of the geographic location. Measurements made on several metro areas have indicated that the asymmetry of the real traffic is significant. Capacity on dense-wavelength-division-multiplexed (DWDM) networks is currently deployed in a symmetrical manner—wavelength circuits provide the same capacity in both directions, with the result that capacity is often wasted in one. Our previous work in [2] has explored the possibility of achieving network savings by using unidirectional circuits. We apply the same approach to for metro-area networks to explore the possible cost benefits of changing this basic convention of network design.

The rest of the paper is organized as follows: in Section 2, we quantify the network symmetry and present measured data from a sample metro-area network. In Section 3, we present information on multiple metro-networks, describe the network design when uni-directional links are used, and the calculated savings; we conclude the paper in Section 4.

2. Quantifying asymmetry in the network

The first step in our exploration of asymmetrical connections in a network is the quantification of the symmetry of real traffic. We define the symmetry ratio of a link as:

$$\rho = \frac{\min(t(a \to z), t(z \to a))}{\max(t(a \to z), t(z \to a))} \quad (1)$$

where t is the amount of traffic (in bits/sec) traveling from node a to node z on the link $a \leftrightarrow z$. ρ will be between 0 and 1, $\rho = 0$ for a link with traffic flow in just one direction, and $\rho = 1$ for a link with identical traffic volumes in the two directions. We can generalize this definition to an entire network:

$$\rho_{network} = \frac{\sum_i [t(Z_i \to A_i)]}{\sum_i [t(A_i \to Z_i)]} \quad (2)$$

where for each link i, we have defined the A→ Z direction to be the direction with the highest peak bandwidth, so

$$t(Z_i \to A_i) = min\big(t(a_i \to z_i), t(z_i \to a_i)\big) \text{ and}$$
$$t(A_i \to Z_i) = max\big(t(a_i \to z_i), t(z_i \to a_i)\big) \quad (3)$$

We analyzed a week of link traffic utilizations for various geographic metro areas in the continental US. These links are between two aggregation routers and/or links between two routers in different metro areas. Because the link capacities need to be engineered for the peak traffic, we calculated the peak traffic for each metro link in each direction and then used those peak values for computing network symmetric ratio described in Eq. (2). Fig. 1 presents the peak traffic for each link in each direction in a particular metro-area network over a one week duration. For each link we have chosen to define the A→Z direction to be the direction with highest peak traffic over the entire week period. We have also sorted the links based on the peak traffic from A→Z, with link 1 having the greatest recorded peak traffic over the entire week. Using the data and Eq. (2), we calculate the network symmetry of a certain metropolitan area $\rho_{network}$=0.5 over this one week period.

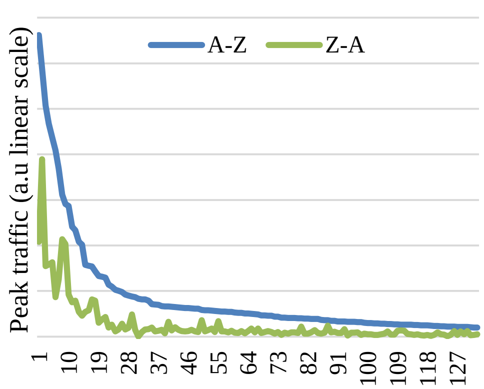

Fig.1 Peak traffic measured over one week interval on links of a particular metro area network. The network symmetric ratio for this metro area network was calculated as $\rho_{network}$=0.5

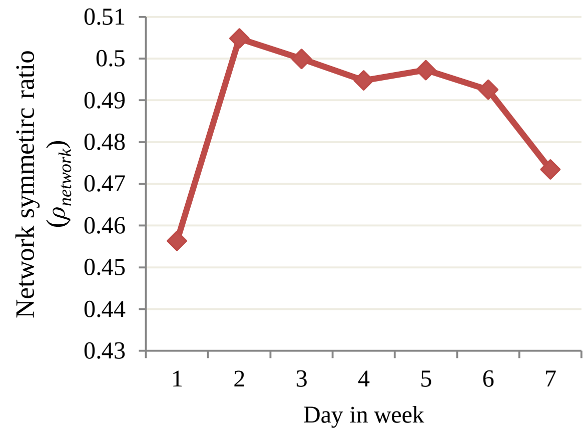

Fig. 2 Overall network symmetry, considering all metro-areas in a typical North American network.

Fig. 2 shows the variation in $\rho_{network}$ over a week. In calculating the daily network symmetry in Fig. 2, the direction of the link is kept constant over the entire week. The weighted symmetric average in Fig. 2 shows that links in the metro area exhibit consistent traffic asymmetry over the measured period.

3. Network Design

The assumed architecture is shown in Fig. 3. For simplicity in modeling network equipment cost, we assumed 40 Gbps interfaces were used. In our present cost calculations, we prorate the transport cost. In Fig. 3 the links from A←Z require 80 Gbps and A→Z requires 30 Gbps. In Fig. 3(a) 4 bidirectional transponders are required, whereas in Fig. 3(b) we require 3 receivers and 3 transmitters. In this example, if we assume each unidirectional transponder is 60% of a bidirectional transponder so two unidirectional transponders cost 20% more than a bidirectional transponder), we achieve about 10% savings in transponder cost.

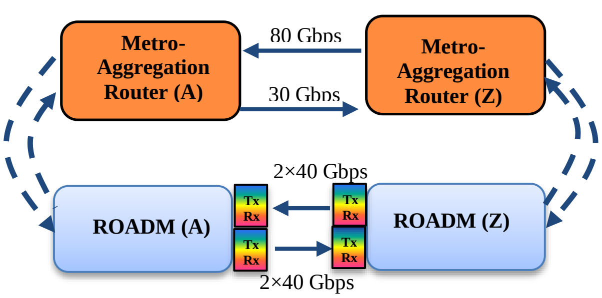

Fig. 3(a) Example of network planning for a metro-link between A and Z when bidirectional equipment is used.

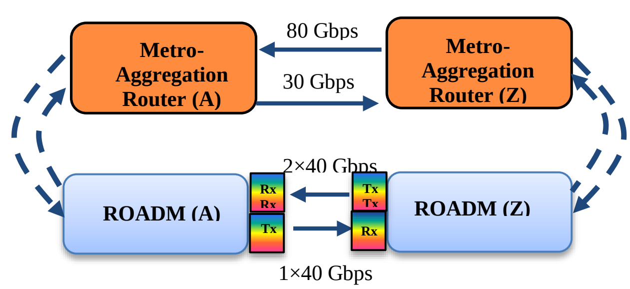

Fig. 3(b) Example of network planning for a metro-link between A and Z when unidirectional equipment is used.

Using both network designs (Fig. 3a and Fig. 3b) we have estimated the overall network cost for each metro-region. The overall network cost includes: router ports, transponders and regenerators. Table 1 presents the relative costs of unidirectional to bidirectional equipment per port (e.g., a value of 0.5 corresponds to no premium for the unidirectional equipment, as a bidirectional port can be made out of two unidirectional ports). For metro-router ports we have assumed a 15% premium and for unidirectional transponders and regenerators we have used a 20% premium.

In Fig. 4 we show the percentage of saving in each metro-area when using the unidirectional equipment (very small metro-areas have been eliminated). As each metro-area varies based on the network size and traffic, we see significant variation in the saving percentage. In Fig. 4 we also show the weighted symmetric ratio of each metro network. From Fig. 4, we observed that some metro-areas are highly symmetric, while others are asymmetric. The negative percentage savings indicate that the network is highly symmetric and hence the bidirectional design costs are lower than unidirectional design cost in such areas. From Fig. 4 we typically see a lower saving for highly symmetric networks. Considering all the metro-area networks, we still see a total savings of nearly 6% for using unidirectional design.

Equipment	Cost Ratio Unidirectional/ Bidirectional
Transponder	0.6
Regenerator	0.6
Router port	0.55

Table 1: Relative port costs

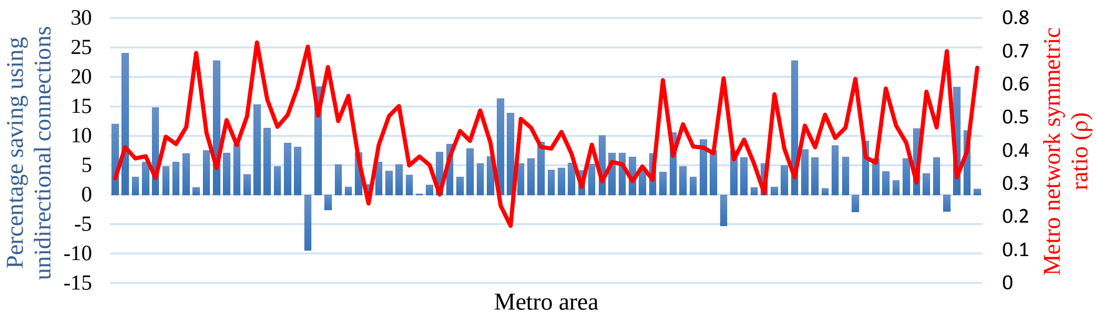

Fig.4 Left side y-axis (blue) indicates the percentage saving in a metro-area for using unidirectional connections. Right y-axis (red) indicates the symmetric ratio based on Eq. (2).

The saving percentage indicated in Fig. 4 were based on 20% premium for the unidirectional transponder and regenerator port. Fig. 5 shows the saving percentage of the overall network (considering all metro-areas) versus the premium paid for unidirectional transponders and regenerators, keeping other costs the same as in Table 1. If unidirectional transponder cost is half the cost of the bidirectional transponder (premium = 0%), we see about 11% overall metro-area-network cost saving. With 20% premium on the unidirectional transponder ports, we see 6% saving on total network cost.

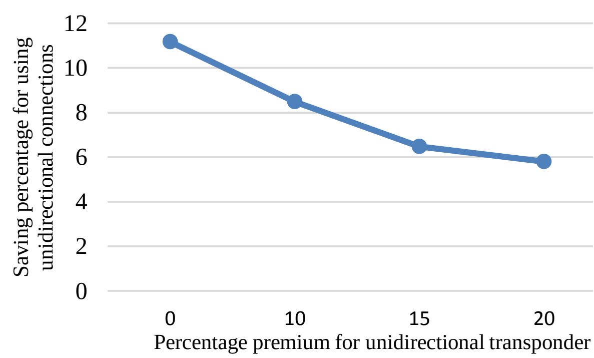

Fig. 5: Percentage saving of overall network cost as function of unidirectional port cost.

4. Conclusion

We have presented data on the traffic symmetry found in various geographic metro-area networks. Using the network symmetry $\boldsymbol{\rho_{network}}$, we quantified the traffic asymmetry across metro networks, and found it be around 0.5 ($\boldsymbol{\rho_{network}}$= 1 when traffic is symmetric). Our results are similar to those found in a backbone network [2]. Even assuming that unidirectional equipment costs 15%-20% more than conventional equipment, we achieved a total network cost saving of approximately 6%.

Acknowledgements

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5. References

[1] Cisco Visual Networking Index: Forecast and Methodology, 2014-2019 White Paper.

[2] S. L. Woodward, W. Zhang, B. G. Bathula, G. Choudhury, R. K. Sinha, M. D. Feuer, J. Strand, and A. L. Chiu, “Asymmetric Optical Connections for Improved Network Efficiency,” J. Opt. Commun. Netw. **5**, 1195-1201 (2013)