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Research on Characteristics of Internet Bottleneck Delay in AS Autonomous Domain and Analysis of Evolution

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Abstract

The research, made from IP measurement level, which is on behavior characteristics that affect network bottleneck delay, is a little limited.So the research scope is expanded to AS autonomous domain in this paper, which is about characteristics of propagation behavior of bottleneck delay and its evolution. This paper can serve as a reference for the further research on basic characteristics and geographical distribution

Keywords: *network delay; AS autonomous domain; bottleneck delay; evolution analysis*

With the rapid development of the Internet, people expect more and more from the Internet and depend on it more and more. The Internet has become the most booming industry with greater market potential in China. Nevertheless, a survey shows that 48.8 percent of Internet users are satisfied with its performance and speed, and only 38.9 with the whole. That's why the problems of network reliability, network performance, and network quality of service (QoS) have drawn the attention of Internet users and relevant scientific researchers. So it is necessary to make a deeper understanding and analysis of network topology and network behavior, which can help to find out the bottleneck of the network, to optimize the network configuration, and to further find out the potential risks in the network.

In recent years, with the rapid development of network, many scientific researchers have studied the behavior characteristics of network delay, but they have done fewer studies of evolution of the delay, especially fewer studies of bottleneck delay in AS Autonomous Domain. This paper analyzes the characteristics of network delay by using real mass topological data obtained from ARK detection project by CAIDA(The Cooperative Association for Internet Data Analysis).

1. Basic Definitions

Definition 1.1 Path: In the process of a data packet traveling from the source node (SRC) to the destination node (DST), the data packet passes node R1, R2,..., Rn-1, R= (SRC, R1, R2,... , Rn-1,), so R is called a path from SRC to DST, while the corresponding n is called traveling diameter). If all the nodes respond to the ICMP probe packets and return the corresponding information to the source node along the way, the path is called a complete valid path. All paths selected in this paper are valid ones.

Definition 1.2 Link: In a complete path R= (SRC, R1, R2,... , Rn-1, DST), SRC, R1, R2,... DST, Rn-1 are nodes through which a data packet pass, so the connection between any two adjacent points (SRC, R1), (R1, R2),... , (Rn-1, DST)is called the first links, second links,... n link.

And the time spent on each link, namely {t1j, T2j, t3j,... Tnj}, {t1j, T2j, t3j,... Tnj, are called link delays on path j, among which tmaxj=max{tij|i=1,2,... Tmaxj, is the maximum

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link delay.

Definition 1.3 Network Delay: If sending a probe packet from monitoring source node to the destination node, and if the packet arrives at the destination node wholly, the time that the packet spends is called a valid network delay.

Definition 1.4 Bottleneck Delay: tmaxj=max{tij|i=1,2,... , n}, if tmaxj ≥ ε T (ε correction parameters, 0< ε <1, and n>>1/ ε), when ε >30%, tmaxj is named the bottleneck delay over the path, and the link where the bottleneck delay occurs is called delay bottleneck. when ε >50%, tmaxj is named the absolute domination delay over the path—Tmaxj occupies the absolute dominant position in the path.

2. The Internet Topology Data Hierarchy

Obtaining real complex systemic topological connecting data, is essential for the next-step topological structure research and analysis of evolution law. If the target data is accurate, a valid analysis can be made, and the characteristic of the research object as well as the evolution law can be found out.

Internet topology data, the basic statistics topological data , are usually divided into three levels: level IP, routing and AS. Different topological data at different level make great difference, and correspondently, the different data should be analyzed from different perspectives. Therefore,

The definitions of topology at different levels should be illustrated, and suitable analyzed targets can be chosen according to the characteristics of different levels.

Definition 2.1 IP level topology: The routing path, obtained by traceroute mechanism measurement is of IP level path, and except the last jump, any other address is matched with a router interface address. And the topological graph generated directly from IP level path is called IP level topology graph, each node on which is an IP address.

Definition 2.2 Router level topology: A router level topology is one formed by interconnection, where each node represents a router, and a sideline is a connection of two routers which usually obtained by the IP level topology after processing.

Definition 2.3 AS level topology: After a IP address in IP level topology is cast on a As number by BGP chart, you can get the connection between each, namely the AS- level topology. More than one sideline can be formed by transforming. This paper focuses on the research on AS topology connection, so one sideline is used to represent connection of any two autonomous domain.

3. Effects of the Max Link Delay on Network Delay

After analyzing the relationship between the ratio of the maximum link delay to network delay and the cumulative distribution of the percentage of the number of paths, you can learn how the maximum link delay affects network delay. The analysis is shown in chart 1.

As you can see from Chart 1: (1) The percentage of the maximum link delay and network delay in about 90 percent of the paths is above 1/3. (2) The ratio of the maximum link delay to network delay in about 50% of the paths is over.50%.

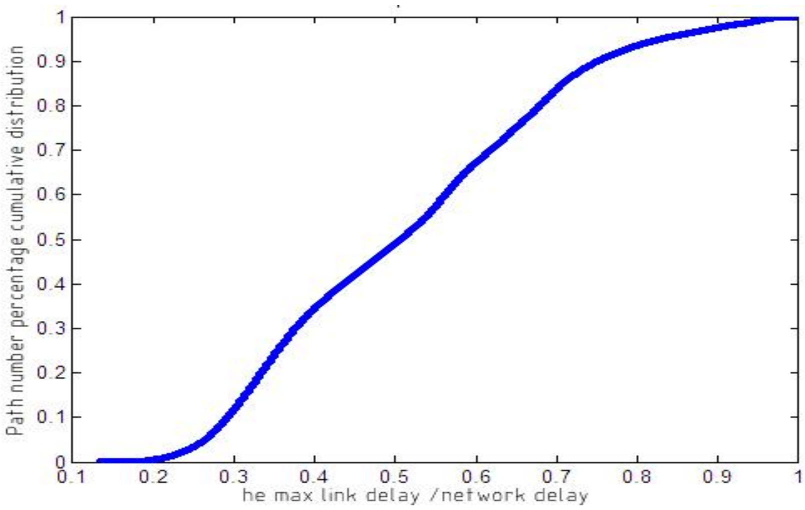

Chart 1. The Relationship between the Percentage of the Max Link Delay and that of Numbers of Paths

In order to further study the relationship between the maximum link delay and the network delay, the ratio of the maximum link delay to the network delay as well as its analysis of distribution statistic are shown in Chart 2.

As is seen from chart 2: (1) The longer the network delay is, the higher the ratio of the maximum link delay to the network delay. (2) When the network delay is longer than 40ms, the ratio of the maximum link delay to the network delay is over 30%. (3) When the network delay is longer than 85ms, the ratio of the maximum link delay to the network delay is over 50%, which means the maximum link delay plays an important role. (4) When the network delay is longer than 140ms, the ratio of the maximum link delay to the network delay is over 75%, which means the maximum link delay plays absolutely dominant role.

So a conclusion can be drawn that when the network delay of a path is longer than 85ms, the maximum link delay is one of the key factors affecting the network delay and that if you could manage to reduce the maximum link delay in the path, then the network delay will be reduced by more than 50%, and the network efficiency can be significantly improved.

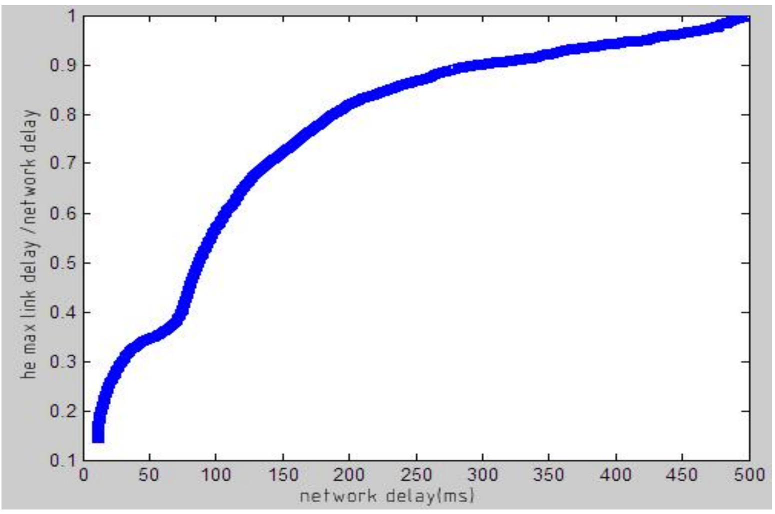

Chart 2. The Relationship between the Percentage of the Max Link Delay and the Network Delay

According to the definition of bottleneck delay, when the ratio of the maximum link delay to the network delay is over 30%, the maximum link delay path is the bottleneck delay. So from the above analysis, it can be concluded that the bottleneck delay is one of the major factors affecting network transmission efficiency and that the study of the bottleneck delay is helpful to reduce network delay.

4. The Reasons Why Bottleneck Delay Occurs

What on the hell causes a bottleneck delay? Is there a relationship between geographical distance and the bottleneck delay?

Suppose the distance between the bottleneck delay end to IP address end is L (km), casts the two ends of the bottleneck delay on two points on the map, namely point A and point B. Then uses R (the radius of the earth) as its radius, and uses arc AB to represent the distance between the bottleneck delay end to IP address end, and finally draw the scatter diagram of bottleneck delay varied with distance L, which is shown in Chart 3.

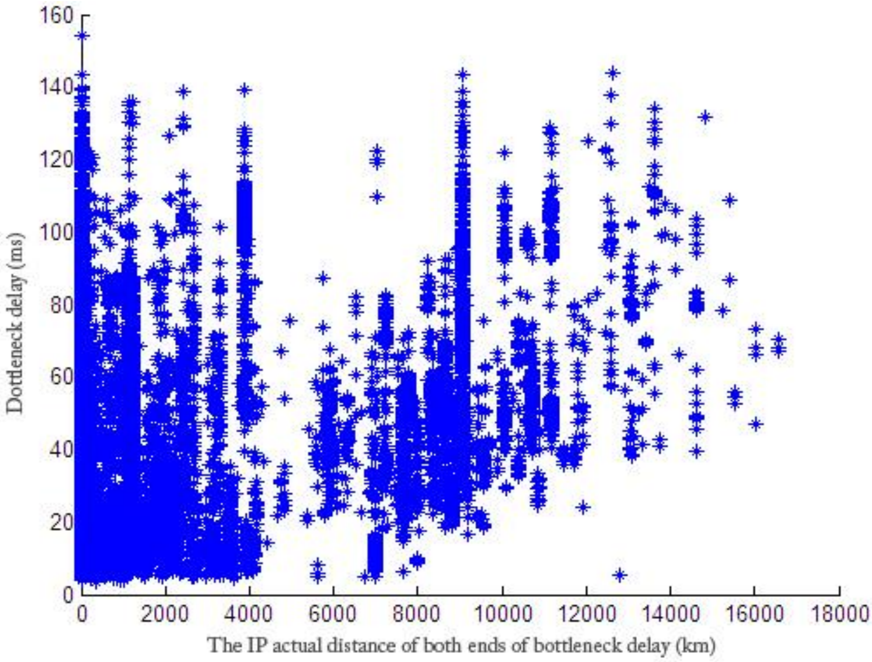

Chart 3. The Scatter Diagram of Bottleneck Delay varied with Distance L

In Chart 3, obviously, the bottleneck delay distribution plot is divided into two areas [0, 4000] and [6000, 16000]. In the interval [0, 4000] distribution of bottleneck delay is denser, while in the interval [6000, 16000], the bottleneck delay distribution is less concentrated and more divergence than that in the [0, 4000], and the amount of data is less than the former, but generally, with the distance extending, the bottleneck delay in latter part increases, and the distribution of bottleneck delay in the two section focus on the interval [3,140].

Is there a certain relationship between bottleneck delay and geographic distance, or part distance? In order to answer this question, the relationship between the bottleneck delay and geographic distance L (km) is discussed next.

First work out the transmission delay in the path, then the ratio of propagation delay to bottleneck delay. In a given bottleneck delay, set the ratio to ratio-pro and to B, and corresponding propagation delay to P, the ratio of P and B is ratio-pro=P/B,0r≤ ratio-pro<1.

Calculate the value of ratio-pro in each path; then arrange distance L (km) data in ascending order, and then divide the sorted data into interval according to the distance. The interval size is 1000km, and because the data volume in interval 0km is extraordinarily large, it is classified into a separate interval. Divide the range 0km to 16000km into 17 intervals, then calculate the average of distance L (km), bottleneck delay, the propagation delay, and the ratio-pro; Finally, taking distance L (km) as the dependent variable, draw a map which can show the relationship between distance and the average of bottleneck, propagation delay, ratio-pro, which is shown in Chart 4.

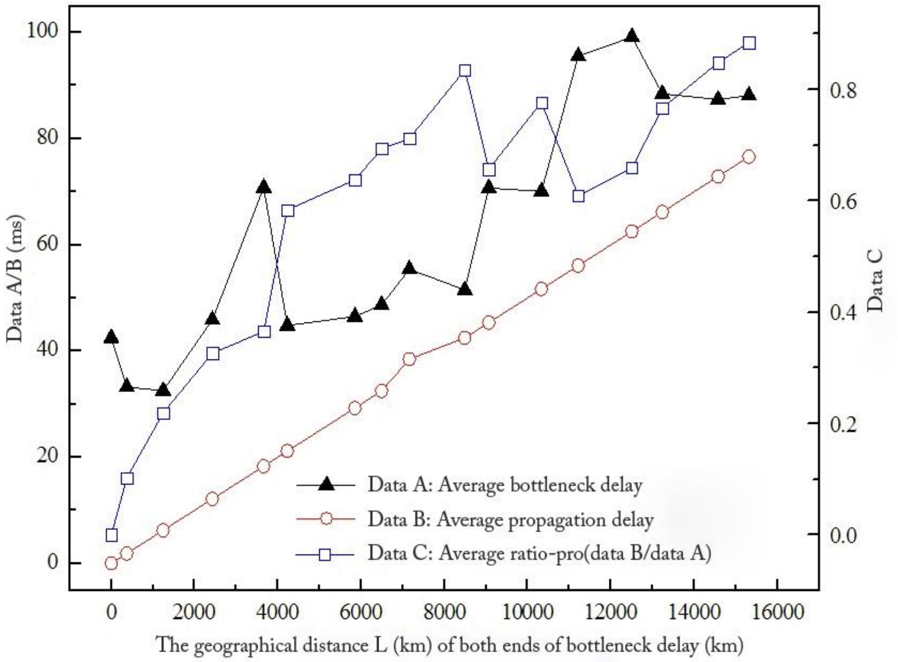

Chart 4. The Relationship between Distance and the Average of Bottleneck, Propagation, Ratio-Pro

As can be seen from chart 4, with the increase of distance, the value of propagation delay, bottleneck delay and ratio-pro increase on the whole, but the propagation delay curve is close to a linear , and in the middle the downward trend can be seen. But the whole chart shows the trend of increase. When the distance of the two ends is longer than 4000km, the ratio of propagation delay to bottleneck delay can reach 50%. So of all the factors that affect bottleneck delay, distance (L>4000km) factor is one which can not be ignored.

What affects bottleneck delay in a short distance? Generally speaking, the factors affecting the network delay from the microcosmic aspect are the propagation delay, the transmission delay, the queuing delay and the processing delay. The range of processing delay is usually no more than several "us", even in the worst case, no more than 10ms, so in general can be neglected. Propagation delay mentioned above, is related to distance. Transmission delay is determined by the link bandwidth and the size of the data packet. Inherent link delay includes propagation delay and transmission delay, which reflect some intrinsic characteristics. As is discussed above, propagation delay caused by the long distance is the important factor affecting bottleneck delay. In terms of transmission delay, while CAIDA ARK projects exploring the Internet, the size of data packet is only 56 bytes, the transmission delay on the 1Mbps-wide -band Internet is 1ms or less, which can be neglected in relation to tens of ms bottleneck delay. The last factor affecting bottleneck delay is queuing delay, the maximum value of which is determined by the speed and size of the buffer on the interface card in the network, and the speed is from several hundred milliseconds to 1 ~ 2 seconds. Now have a look at the bottleneck delay data, the distance between two Ip addresses on 47% paths is zero, so the bottleneck delay in this segment has nothing to do with propagation delay. The distance between two Ip addresses on 60% paths is no more than 200km, and the correlation coefficient of bottleneck delay and the ratio-pro value is -0.12 in this section, which can be neglected. The distance between two Ip addresses on 80% paths is no more than 4000km, and the correlation coefficient of bottleneck delay and the ratio-pro value is -0.23 in this section, which is little related to bottleneck delay. From the above analysis, a conclusion can be drawn that transmission delay doesn't affect bottleneck delay. Excluding propagation delay, transmission delay, processing delay, only queuing delay is one factor that affects bottleneck delay. And the bottleneck delay that occurs within the range of [0, 4000] is especially affected by queuing delay.

5. Characteristics of Propagation Behavior of Bottleneck Delay in AS Autonomous Domain

There are two reasons why the research on propagation behavior of network delay is made before research on propagation behavior of bottleneck delay. Firstly, bottleneck delay is an important part of network delay, and secondly, a comparison between the two behaviors can be made. In the end, an analysis of the characteristics of propagation behavior of bottleneck delay in AS autonomous domain can finally be made.

5.1. The Analysis and Research of AS Level Network Delay

The Internet, due to heterogeneity of its own, is divided into many different AS domains. This research is made by transforming IP data obtained by amw detection nodes into AS data. On the Internet, each AS domain has AS number, used as a mark in the BGP border gateway protocol. The As number is designated by IRR (Internet Routing Registers). Each AS contains a lot of IP address, following the same internal routing protocol in the same AS number. If two Ip addresses in two different As communicate with each other, the BGP border gateway protocol should be followed. At first, cast all IP addresses of detection data on the corresponding As numbers, which are stored in the BGP routing table. After finding AS numbers, you can find all the corresponding IP addresses on a link. If the two IP address share the same AS it means that the two IP addresses are in the same AS domain, and If the two IP address don't share the same AS number, it means that the two IP addresses are in different AS autonomous domains. While traveling from the source node to the destination node, the data packet Casts all the IP address on AS autonomous domains, and calculates the number of AS, and records the number with letter N, which is AS level network diameter.

5.2. The Analysis and Research of AS Level Bottleneck Delay

When casting IP addresses, obtained at two ends of an Ip link, you get two corresponding As numbers, named ASx-ASy, which is called bottleneck delay AS autonomous domain. So the research of bottleneck delay is a research of ASx-ASy. After getting ASx-ASy, calculate the number of ASx and ASy in the same AS domain and that in different AS domains, then make a pie chart with the results obtained. In Chart 5, 60.28% represents the AS autonomous region, and 38.41% represents the AS inter domain.

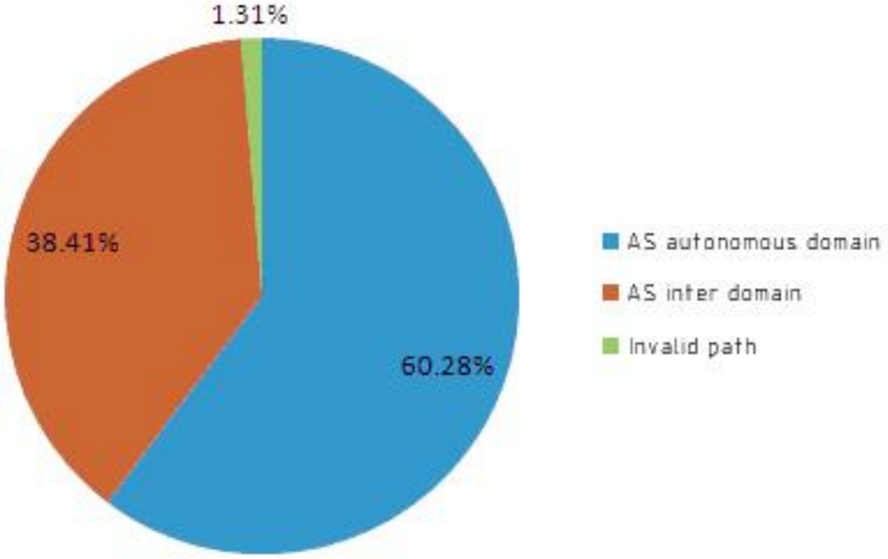

Chart 5. The Distribution of Bottleneck Delay in AS Autonomous Domain

As shown in Chart 5, some IP address of bottleneck delay can not be cast on As numbers. These IP address are of private ones which are generally classified into A, B and C. Just because they are private address, their corresponding AS numbers can't be found, and that's why they are of invalid addresses. 38.41% Ip addresses at the two ends of bottleneck delay are distributed in different AS autonomous domains, while 60.28% Ip addresses at the two ends of bottleneck delay are distributed in the same AS autonomous domain. These two figures, compared with the results in Bi Jingping and Li Chao's paper written several years ago, the percentage of 38.41 is a little higher than their result of 0ne third, and the percentage of 60.28 % is a bit less than their result. According to the result, there are more than half of the data, whose bottleneck delay appears in the AS domain, despite that AS level access diameter is only about 4, the probability of bottleneck delay in AS domain is higher than the probability of bottleneck delay appearing in the AS inter domain.

6. The Evolution of the Bottleneck Delay in the AS Domain

When casting IP addresses, obtained at two ends of an Ip link, you get two corresponding as numbers. Then calculate the number of ASx and ASy in the same AS domain and that in different AS domains. If the two IP address share the same AS it means that the two IP addresses are in the same AS domain. And If the two IP address don't share the same AS number, it means that the two IP addresses are in different AS autonomous domains, and in this case, the link delay is across the AS domain. The sample data are CAIDA's AMW detection node data, and the time span is five years (2009 -2013). In one period (3 days as a circle) of May in each year, data are gathered. Each year's bottleneck delay evolution characteristics in AS domain can be seen in Chart 6.

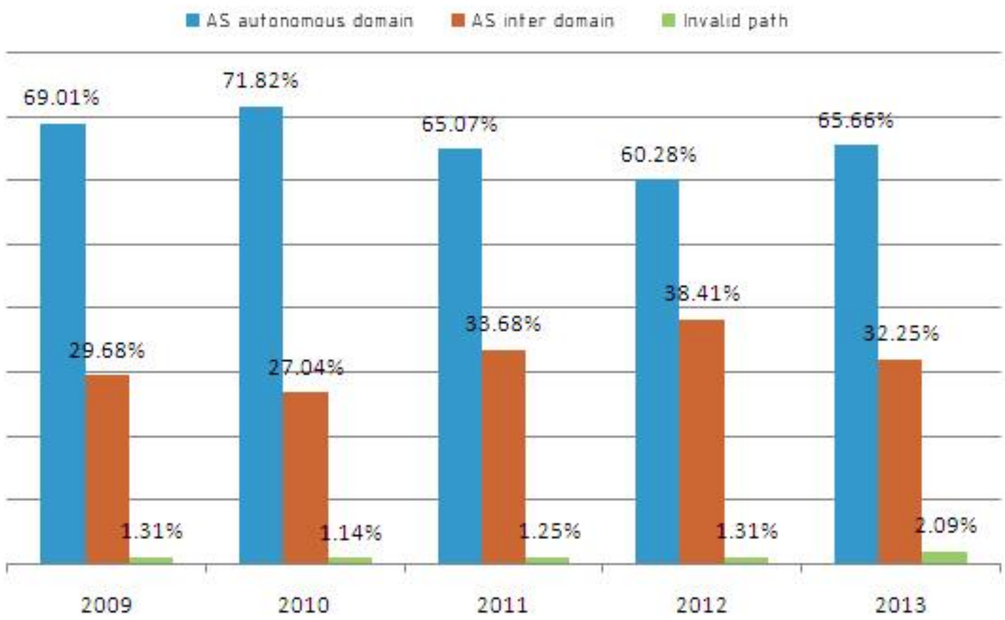

Chart 6. Evolution of Bottleneck Delay in AS Autonomous Distribution

As shown in Chart 6, 3 long strips from left to right represents the distribution of bottleneck delay in AS domain, AS inter domain and invalid path respectively. As can be seen: (1) Most bottleneck delay is in AS domain. In five years, with time going on, there is a trend that bottleneck delay is reduced, and as a whole, two thirds bottleneck delay in paths is within AS inter domain. (2) The bottleneck delay distribution in AS inter domain has increased year by year, although the bottleneck delay distribution in AS inter domain declines in 2013, but on the whole, the bottleneck delay distribution in AS inter domain shows an increase trend, but the change is not stable, which needs to be further tested with more data.

7. Conclusion

In the evolution process, the distribution of bottleneck delay in AS autonomous domain is higher than that in inter domain. It shows that most of bottleneck delay occurs in the AS domain, instead of in AS inter domain.

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