

Internet Traffic Growth
Analysis of Trends and Predictions

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[Kunal Mittal](#)

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Abstract

Internet traffic is approximately doubling each year. This growth rate applies not only to the entire Internet, but also to a large range of individual institutions. We will use the extrapolation method combined with the L. Applegate four-phase theory, to forecast the growth rate of Internet traffic of Congress Library, the traffic from the U.S. to the British JANET academic network, traffic from the Internet to the University of Waterloo, and traffic from U.S to SWITCH. After the analysis and prediction of the Internet Traffic over the next five years, I will present some conclusions and make suggestions for the Management of Information Systems to support this growth.

1. Introduction

Internet traffic is approximately doubling each year. This reflects complicated interactions of technology, economics, and sociology, similar to those that have produced “Moore’s Law” in semiconductors. In considering prospects for future growth, one approach is to simply look at the historical record. Since the Internet has been growing at about 100% a year for this entire history, one can then extrapolate this growth rate into the future, and predict that traffic will continue to double each year.

However, is this simple extrapolation true? The growth rate applies not only to the entire Internet, but also to a large range of individual institutions. Such a growth rate would have several important implications. They may upgrade their Internet connections; spend money on the network equipments and bandwidth subscription. If they can’t get the correct prediction, then traffic congestion will appear, or the utilization rate will be low and they will waste money.

In this paper we will study the historical growth rates in Internet traffic. We have records going back several years that exhibit the rate of growth. Even when there are no obvious bottlenecks, traffic tends not to grow much faster. This paper addresses the analysis and prediction of Internet traffic growth by studying the traffic of Congress Library, the traffic from the U.S. to the British JANET academic network, traffic from the Internet to the University of Waterloo, and traffic from U.S to SWITCH.

We will also use L. Applegate Four-phase theory to analyze the Internet Traffic growth. The extrapolation method combined with the four-phase theory will be used to predict the Internet traffic growth. For a particular site, it may be in data traffic growth stage, hence, it is wise to predict the data traffic of this site before making decision on buy what kind of servers and routers. After the analysis and prediction, this report will give the conclusion and suggestion for the Information System Management regarding to Internet Traffic Growth.

2. Overview of Internet Growth

Almost all references to Internet growth claim astronomical rates of increase; the usual phrase is that “Internet traffic is doubling every three months.” Even serious observers echo such claims. For example, former Federal Communications Commission Chairman Reed Hundt recently wrote, “In 1999, data traffic was doubling every 90 days...”. Financial markets also appear to accept such estimates. During the meeting with financial analysts to discuss the report for the 3rd quarter of 2000, James Crowe, head of Level 3 Communications, cited the “doubling of Internet traffic every three or four months” as proof that the supply of fiber in the United States could not possibly meet demand within the next few years. If this were true, the resulting imbalance in supply and demand would produce very pleasing revenue and profit prospects for carriers such as Level 3. There continue to be voices skeptical of the growth prospects of the Internet. In particular, A. Michael Noll, Director CITI, has been a persistent naysayer.

Back in 1991, Noll estimated what the maximal feasible volume of data transfers could be (pp. 171–175 of [14]). Since that time, the volume of data traffic has surged far beyond his original prediction. The main reason for this development is that he did not foresee the arrival of graphics-rich content, such as Web pages. His estimates assumed only text would be transmitted, and people would process all of it. While that prediction has turned out to be wrong, he continues predicting that data traffic will not exceed voice traffic unless multimedia begins dominating the Internet [15]. While our estimates do confirm that there

is still more voice traffic than data traffic, Noll's estimates for data traffic are far too conservative.

As an example, one can examine the publicly available statistics for data traffic at the University of Southern California, where Noll is a professor. These statistics are available at <http://foo.usc.edu/netstats>, and in early 1999 showed a considerably higher volume of data flow than Noll estimated [15]. (By early 2000, the volume of data flow at USC had grown by about 70%, from an average of about 20 Mb/s to the campus and 10 Mb/s out from the campus to about 30 Mb/s in and 20 Mb/s out.) While there are some skeptics about the prospects for the Internet, there are vastly larger ranks of people who claim astronomical growth rates. However, they invariably talk only of rates of increase, and never cite precise verifiable figures. The most common claim one hears is that "Internet traffic is doubling every three or four months." As was pointed out in [6], many of these claims appear to trace back to statements of John Sidgmore of MCI WorldCom's UUNet or his colleagues.

A March 2000 news report [10] cites MCI WorldCom president Bernard J. Ebberts as saying that his company "has recently had to add capacity to its global network at a rate of 800 percent annually to keep up with soaring demand for Net traffic." Yet the February 10, 2000 press release by MCI WorldCom that accompanied the earnings report for the fourth quarter of 1999 refers to "gains in data services ... measured by an 87 percent increase in Voice Grade Equivalent (VGEs), which capture the volume of local data circuits." The

two statements may refer to different parts of the MCI WorldCom data network. However, eventually capacities of long distance links are unlikely to grow much faster than those of local ones. Hence we are inclined to believe that the “87 percent increase” of the official press release describes overall growth more accurately. Revenue increases from data services for MCI WorldCom (reported in their audited financial statements) are also far more consistent with annual growth rates of 100 percent than 800 percent.

It could be that the phrase “doubling of Internet traffic every three (or four) months” has lost its literal meaning. Perhaps it is being used as a figure of speech, in the way that many people use “exponential growth” (which in mathematics has a precise meaning) to describe any fast growth. There are just too many examples where such statements are either implausible or even demonstrably incorrect.

For example, Keith Mitchell, executive chairman of LINX, the London Internet Exchange, Ltd., is quoted in [12] as saying in March, 2000, that “LINX traffic doubles every hundred days or so.” This rate of growth would increase traffic over a year by a factor of 12. Yet an examination of the publicly available statistics for LINX showed that between the end of March 1999, and the end of March 2000, traffic through LINX increased by a factor of about 3 (from about 360 Mb/s to 1.1 Gb/s). That is certainly fast, but corresponds to a doubling of traffic every 230 days, not every 100 days.

Whether Internet traffic doubles every three months or just once a year has huge consequences for network design as well as the telecommunications equipment industry and information system managers. Much of the excitement about and funding for novel technologies appear to be based on expectations of unrealistically high growth rates [4].

3. Prediction via Extrapolation

So now the question arises, what's the real traffic growth rate? For an institution, the Internet traffic growth rate will be different between the whole Internet traffic. As most access links, there is much more traffic from the public Internet to the institution than in the other direction. Hence we concentrate on this more congested link, since it offers more of a barrier. In this section, we will use the extrapolation method to forecast the growth rate of Internet traffic of Congress Library, the traffic from the U.S. to the British JANET academic network, traffic from the Internet to the University of Waterloo, and traffic from U.S to SWITCH, to see the difference.

3.1 Internet Traffic Growth of the Library of Congress

The growth rates we observe among the institutions that make traffic statistics publicly available vary tremendously. For example, Table 1 presents data for the Library of Congress, taken from the online statistics at <http://lcweb.loc.gov/stats/>. For each year, the table shows total traffic in gigabytes during February of that year and the rate of increase over the previous year. There is a pronounced slowdown in the growth rate of traffic.

Year	GB/m	Increase Rate
1995	14.0	
1996	31.2	123%
1997	109.4	251%
1998	282.0	158%
1999	535.0	88%
2000	741.1	39%

Table 1: Growth in data traffic at Library of Congress.

We present two methods to predict the future situation. One is Polynomial extrapolation, another one is using the increasing rate of last year to predict next year's data traffic.

Year	GB/m	Increase Rate
1995	14.0	
1996	31.2	123%
1997	109.4	251%
1998	282.0	158%
1999	535.0	88%
2000	741.1	39%
2001	741.1*139%=1030	23%
2002	1030*123%=1267	12%
2003	1267*112%=1419	7%
2004	1419*107%=1518	4%
2005	1518*104%=1579	2%

Table 2: Prediction of Internet Traffic of Library of Congress

The figure below shows the Expon extrapolation of its increasing rate. Here we forecast to year 2005. The equation is “ $y = 9.3642e^{-0.6171x}$ ”.

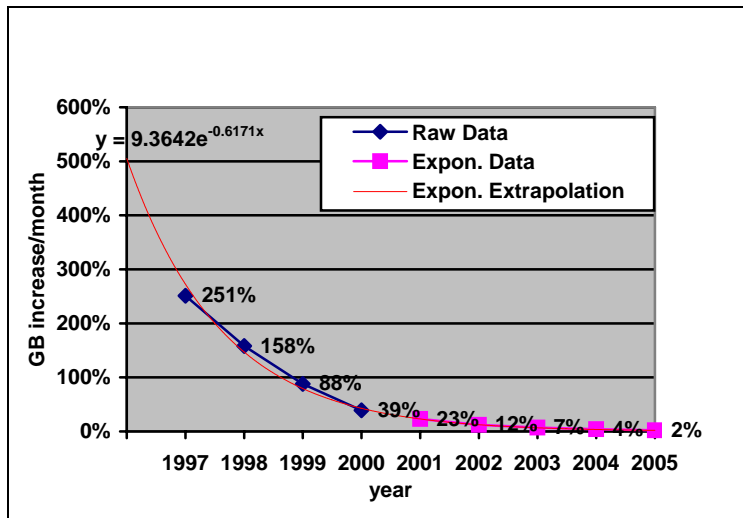


Figure 1: Expon Extrapolation (Library of Congress)

The figure below shows the Polynomial extrapolation of its traffic data. Here we forecast to year 2005. The equation is “ $y = 29.338x^2 - 53.371x + 27.33$ ”.

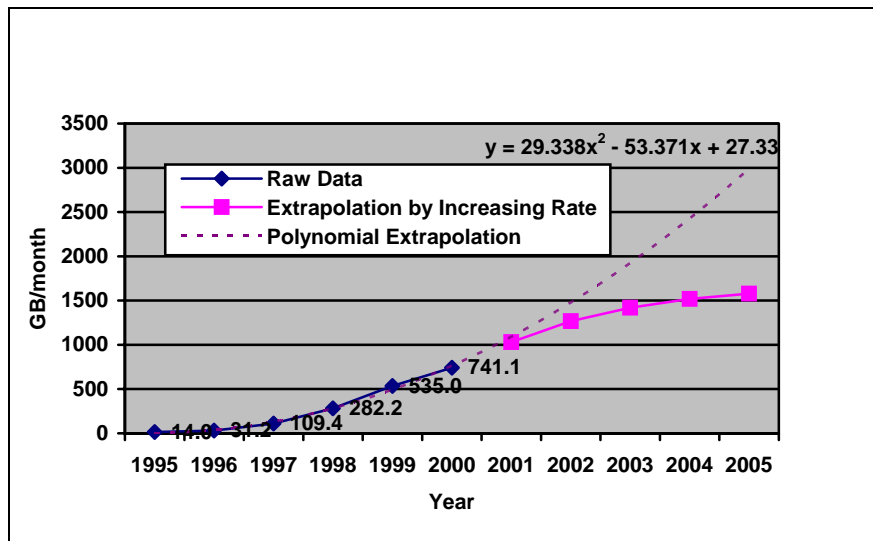


Figure 2: Polynomial Extrapolation (Library of Congress)

3.2 Internet Traffic Growth of U.S. to the British JANET

Faster growth rates are seen on links that serve wider constituencies. Table 3 shows statistics for the transatlantic link of the JANET network, which provides connectivity to British academic institutions. (See table 4, more complete data is available at <http://bill.ja.net/>). There are several interesting features of this data. One is the increasing asymmetry of the traffic, with the preponderance of traffic from the U.S. over that to the U.S. growing. Another is that traffic with the U.S. is increasing faster than with the LINX European exchange. More relevant for this analysis is that the growth rate in the more heavily used U.S. to U.K. direction shows no signs of slowing down. This is true even

though, starting in the fall of 1998, the central JANET administration has started charging member universities for all traffic coming from the U.S. (See [19]).

The table below shows the terabytes transmitted on the link from the U.S. to the British JANET academic network in March of each year, and the rate of increase from previous year.

Year	TB/m	Increase rate
1997	3.73	
1998	8.79	136%
1999	19.52	122%
2000	48.76	150%

Table 3: Growth in JANET traffic

The figure below shows the Polynomial extrapolation of its traffic data. Here we forecast to year 2005. The equation is “ $y = 6.045x^2 - 15.643x + 13.97$ ”.

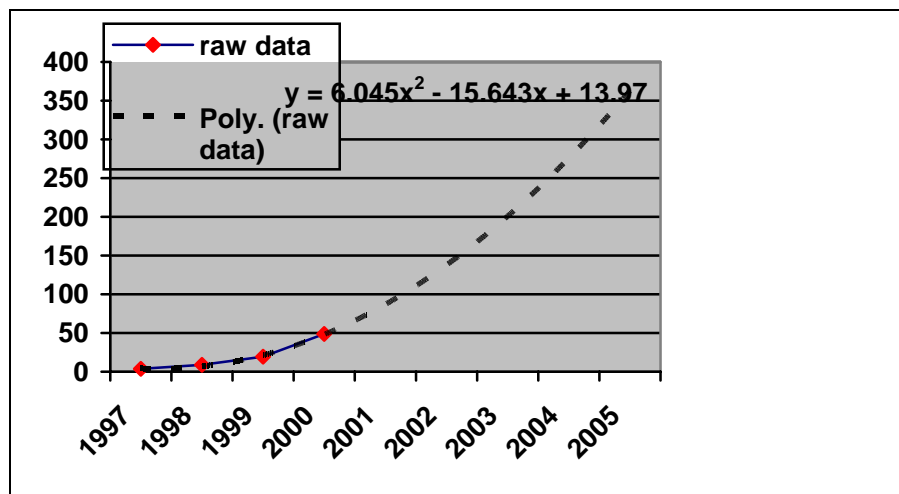


Figure 3: Expon Extrapolation (JANET traffic)

3.3 Internet Traffic Growth of U.S. to the University of Waterloo

Table 4 shows statistics for the traffic from the public Internet to the University of Waterloo over the last 7 years. (This is the longest such time series that we have been able

to obtain.) Detailed statistics for the Waterloo network are available at <http://www.ist.uwaterloo.ca/cn/#Stats>, but table 4 is based on additional historical data provided to us by this institution in paper [18]. We see that even substantial jumps in link capacity did not affect the growth rate much. Traffic has been about doubling each year for the entire 7-year period. (Overall, the growth rate at the University of Waterloo has slowed down, to about 55% from early 1999 to early 2000. This shows average traffic during the month of heaviest traffic in each school term. The step function is the full capacity of the link. (see <http://www.ist.uwaterloo.ca/cn/#Stats>)

Month	Decimal Log of Bits per second
May 1993	4.6
Sep 1993	4.65
Jan 1994	4.8
May 1994	5.0
Sep 1994	5.2
Jan 1995	5.3
May 1995	5.35
Sep 1995	5.5
Jan 1996	5.8
May 1996	5.85
Sep 1996	5.9
Jan 1997	6.0
May 1997	6.05
Sep 1997	6.1
Jan 1998	6.4
May 1998	6.4
Sep 1998	6.35
Jan 1999	6.65
May 1999	6.7
Sep 1999	6.68
Jan 2000	6.9

Table 4: Traffic on the link from the public Internet to the University of Waterloo

The figure below shows the Polynomial extrapolation of its increasing rate. Here we forecast to year 2005. The equation is about “ $y = -0.0024x^2 + 0.1637x + 4.3859$ ”.

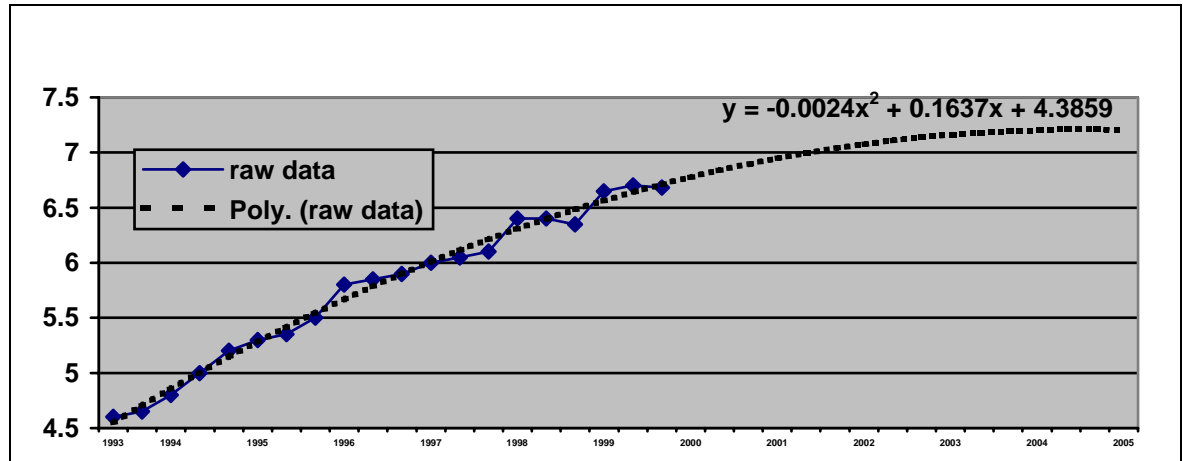


Figure 4: Expon Extrapolation (University of Waterloo)

3.4 Internet Traffic Growth of U.S. to the SWITCH

The same phenomenon of traffic that just about doubles each year, no matter what happens to capacity, can be observed in the statistics for the SWITCH network, which provides connectivity for Swiss academic and research institutions. The historical data is available at <http://www.switch.ch/lan/stat>. As is noted in [20], the transatlantic link has historically been the most expensive part of the SWITCH infrastructure, and at times was more expensive than the entire network within Switzerland. It is therefore not surprising that this link tends to be the most congested in the SWITCH network. Even so, increasing its capacity did not lead to a dramatic change in the growth rate of traffic. If we compare increases in volume of data received between November of one year and January of the following year, there was an unusually high jump from Nov. 1998 to Jan. 1999, by 42%.

This was in response to extreme congestion experienced at the end of 1998, congestion that produced extremely poor service, with packet loss rates during peak periods exceeding 20%. However, over longer periods of time, the growth rate has been rather steady at close to 100% per year and independent of the capacity of the link.

Month	Traffic flow Mb/s	Link capacity Mb/s	Average Utilization
May 1996	1.51	3	50.4%
Jul 1996	1.9	3	63.3%
Sep 1996	1.99	3	66.3%
Nov 1996	2.21	3	73.6%
Jan 1997	2.37	3	79%
Mar 1997	2.62	4	65.6%
May 1997	2.86	4	71.5%
Jul 1997	3.17	8	39.6%
Sep 1997	2.87	8	35.9%
Nov 1997	3.24	8	40.5%
Jan 1998	3.88	8	48.5%
Mar 1998	4.2	8	52.5%
May 1998	5.05	8	63.1%
Jul 1998	5.14	8	64.3%
Sep 1998	5.66	8	70.7%
Nov 1998	6.2	8	77.5%
Jan 1999	8.78	24	36.6%
Mar 1999	9.41	24	39.2%
May 1999	10.63	32	33.2%
Jul 1999	10.03	32	31.3%
Sep 1999	11.62	32	36.3%
Nov 1999	13.26	32	41.4%
Jan 2000	15.52	56	27.7%
Mar 2000	17.81	56	31.8%

Table 5: Growth in SWITCH traffic.

The figure below shows the Polynomial extrapolation of its traffic data. Here we forecast to year 2005. The equation is about $y = "0.0372x^2 - 0.3139x + 2.6604"$.

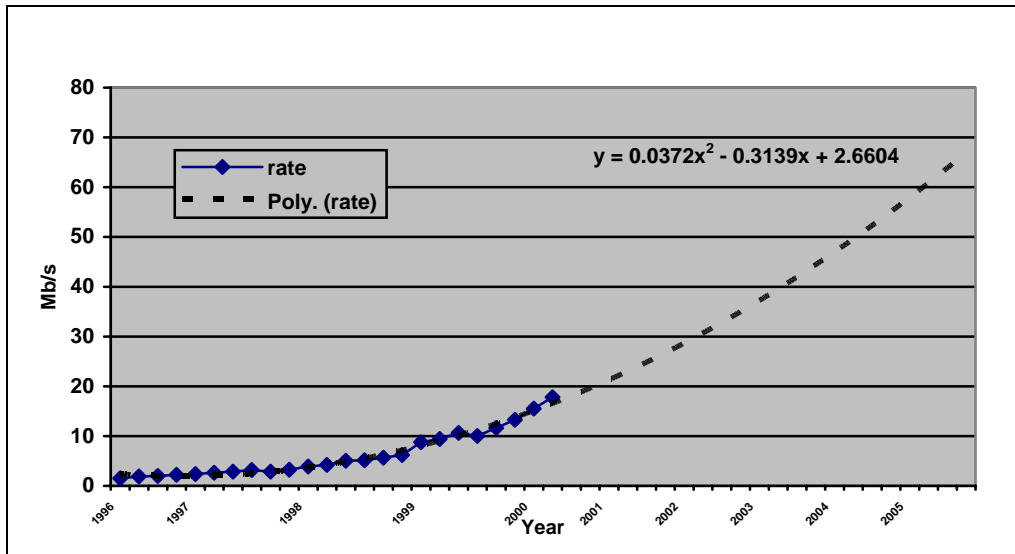


Figure 5: Traffic flow Growth (SWITCH)

The figure below shows the Polynomial extrapolation of its utilization rate. Here we forecast to year 2005. The equation is about $y = -0.0012x^2 + 0.0117x + 0.6013$.

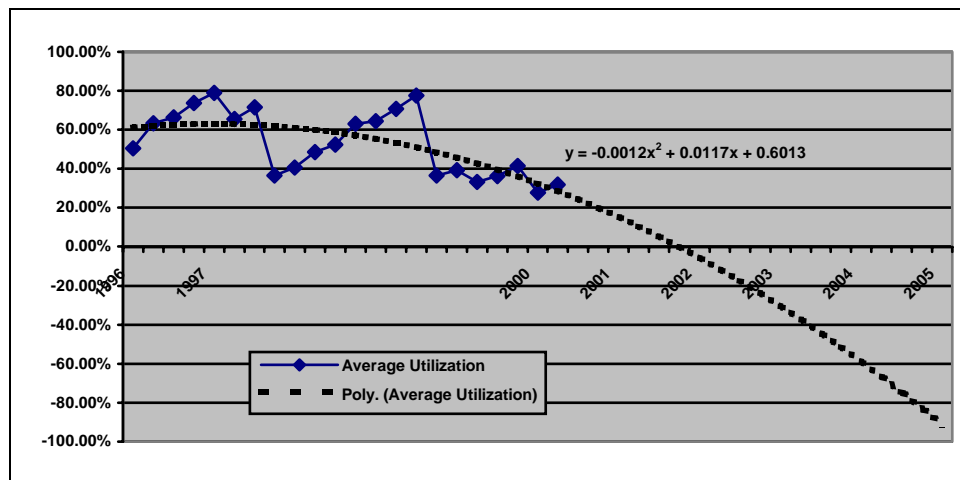


Figure 6: Polynomial Extrapolation (SWITCH)

4. Analysis of Internet Traffic Growth of the Four Individual Institutions Using L. Applegate Four-Phase Theory

Although the L. Applegate Four-phase theory [pages 226-229 of 1] is used to assimilate emerging Information Technologies, we can extend to use the concepts to analyze the growth rate of Internet traffic. The four stages are described are:

- (1) Technology Identification and Investment.
- (2) Technological Learning and Adaptation.
- (3) Rationalization / Management Control.
- (4) Maturity / Widespread Technology Transfer.

As current IP version 4 (Internet Protocol specified in RFC 791) technologies appeared in 1980's and widely used in 1990's, it reflects to the Internet traffic growth for an institution. We use this as an example to determine the level of the internet traffic prediction. Currently, the Internet Technologies could be regarded as in Stage 3. From the figures showed in section 3, we can see the stage 4 is coming. The next generation Internet technologies (IP version 6, in another word, IP-ng) will replace the current IP version 4 technologies.

4.1 Internet traffic of Congress Library

From Fig. 1 and Fig. 2, we can see in the first 2-year (1995-1996), it is in stage 1. In the second 2-year (1997-1998), it is in stage 2. Currently, it is in stage 3. But in the next

several years, it will be in stage 4, that means it won't increase rapidly in the future years, and maybe in 1995, the new IP version 6 technologies will replace current IP technologies.

4.2 Traffic from the U.S. to the British JANET academic network

Not as case 4.1, the first 3-year data shows that it is still increasing rapidly. It's still a new technology that is being adapted and need time to see how much is the stable traffic to JANET. Therefore, it is in stage 2 now. In the next years, it will go to the stage 3.

4.3 Traffic from the Internet to the University of Waterloo

Same as in 4.1, after several years increasing, currently it's in the stage 3 and is likely to go to stage 4 within the next few years.

4.4 Traffic from U.S to SWITCH

Same as in 4.1 and 4.3 this is currently in the stage 3.

5. Conclusion

From the analysis of the extrapolation of the historical traffic data of the past years, the IT manager could decide if they need to improve the device to meet the requirement of future data traffic. Here, we presented prediction the future situation in section 3. In section 3.1, we used 2 methods, one is Polynomial extrapolation, and another is using the increasing rate of last year to predict next year's data traffic. The reason that we think about the second prediction method is because we found in the Figure 2 that the curve of the increasing rate is quite smooth, and there is no particular reason that the rate may change dramatically for the following a few years. From Figure 2 we may find the extrapolation made by increasing rates is much more modest than the extrapolation made by Polynomial extrapolation. However neither of them shows doubling of its data traffic in the future, like the Internet traffic as a whole. The area bound by those two prediction curves in Figure 2 can be regarded as the most reasonable area of future data traffic. This may save a lot of money for the Library of Congress.

For the same reason we use Polynomial extrapolation to forecast other three cases. Other extrapolation samples that we present shows the average traffic flow from Internet to the University of Waterloo and from U.S. to SWITCH, the Swiss academic and research network. There are no examples where the traffic is doubled, in any of these forecasts. By Applegates theory, these are all in Stage 3, with Stage 4 on the horizon. In March 1999, JANET had two T3s across the Atlantic, for an aggregate capacity of 90 Mb/s. By March 2000, these were replaced by two OC3s, providing 310 Mb/s. Hence the utilization of the

U.S. to U.K. link has decreased from 64.8% in March 1999 to 47.0% in March 2000. The increased capacity was not filled up immediately. Figure 6 shows the utilization rate will continue to decrease. They don't need to spend more money to subscribe higher speed links in the future.

However, Figure 3 shows that the Internet traffic from U.S. to UK JANET is still increasing rapidly. This is in Stage 2 and will continue to rapidly increase for several years then stop increasing rapidly. Hence, they still need to prepare money to upgrade their link speed.

Generally, the current IP version 4 technologies will go to stage 4 as maturity, and will stop increasing rapidly, most IP version 4 addresses are assigned and the new IP version 6 technologies will replace the current IP version 4 technologies. Some networking software and hardware will be upgraded, and the stage 1 of new technologies will come, then we will enter a new four-stage cycle.

6. References

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