VOL. 4, NO. 8, OCTOBER 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

BANDWIDTH OPTIMIZATION OF INDIVIDUAL HOP FOR ROBUST DATA STREAMING ON EMERGENCY MEDICAL APPLICATION

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ABSTRACT

This paper presents a new bandwidth estimation method for individual hop for high-speed, non-invasive, and faster convergence transmission in multiple medical data networks. Available Bandwidth Estimation Technique for individual Hops (ABETH) has been developed employing parameters like Hop (H), Capacity (C), Bandwidth (B), Available Bandwidth (AB) etc. Bandwidth estimation techniques, tools and methods are considered to develop the technique and it represents an effective combination of different other existing techniques aiming to exploit the positive aspects of them. More precisely, the technique which is implied in the method modifies and integrates the one recent tool SPRUCE which estimates available bandwidth and the IP layer capacity estimation formula which measures capacity. This technique provides a linear combination of capacity versus bandwidth which satisfies the link utilization demand.

Keywords: available bandwidth, hops, capacity, utilization factor, dispersion.

1. INTRODUCTION

The term "bandwidth" frequently distinguishes the amount of data that the network preserves transfer per unit of time. Bandwidth estimation is of concentration to users wishing to optimize the performance of individual hop. Techniques for accurate bandwidth estimation are also important for traffic engineering and capacity planning support. Currently available bandwidth estimation tools utilize a diversity of strategies to measure these metrics. Bandwidth also relates to the spectral width of electromagnetic signals or to the propagation characteristics of communication systems. In the context of data networks, the term bandwidth quantifies the data rate that a network link or a network path can transfer. The concept of bandwidth is central to digital communications, and specifically to packet networks, as it relates to the amount of data that a link or network path can deliver per unit of time [1-4]. For medical applications, such as patients' video streaming, image processing, the bandwidth available to the application directly impacts application performance. It is needed to develop the method to optimize the usage of the bandwidth for individual hop.

In data networks, generally users can only approximate the bandwidth of links or paths from end -to-end measurements, without any information from network routers [1]. To transfer high data rate information and perfect synchronization, every node needs to know the bandwidth of the individual hop. There is some works on bandwidth estimation for different applications. Existing bandwidth estimation tools measure one or more of three related Metrics like capacity, available bandwidth, and bulk transfer capacity (BTC). All existing techniques like variable packet size (VPS) probing, packet pair/train dispersion (PPTD), self-loading periodic streams (SLoPS), trains of packet pairs (TOPP) and tools PATHLOAD, SPRUCH measure end to end available bandwidth are described in details. Mehmet *et al.* implemented the bandwidth estimation technique in a video streaming simulation environment that also included a delay-constrained rate adaptation algorithm at the sender [5]. Liu Min et al. redefined the available bandwidth based on probability and statistics and evaluated their method in controlled and reproducible environment using NS2, and the simulations showed the method was accurate, efficient, quick and non-intrusive [6]. P. Koutsakis proposed a new dynamic satellite bandwidth allocation technique which was based on accurate videoconference traffic prediction, and the work was shown to provide very good throughput and delay results [7]. Alim *et al.* modified two bandwidth efficient AB estimation mechanisms-ProbeGap and Resource Friendly Bandwidth Estimation (RFBE), and evaluated their performance over a crypto- partitioned red-black network [8]. Haohuan *et al.* paper proposed an efficient method for Wireless Bandwidth Detection (WBD) using packet probing approach on mobile nodes [9]. Polychronis proposed and evaluated the work for the efficient integration of high quality video traffic with web data packet traffic over a burst-error wireless channel of very high capacity [10]. Estimation of available bandwidth for individual hop is a challenging task. It is extremely essential to employ bandwidth efficiently. If we know the individual hop's bandwidth then we can send sufficient data for individual hop and we do not face synchronous problem. For this reason, we can use bandwidth efficiently which is helpful to bandwidth optimization. If we know individual hop bandwidth then we can design a network efficiently and this design can maintain required available bandwidth at the endpoint. This paper focuses on the optimization of bandwidth measurement techniques performed by the link hosts of a path without requiring administrative access to transitional routers along the path and provides a linear combination of capacity versus bandwidth which satisfies the link utilization demand.

VOL. 4, NO. 8, OCTOBER 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

2. BACKGROUND AND THEORY

The general working principle of bandwidth estimation with the metrics, especially capacity, available bandwidth has been introduced. The incorporation of Bandwidth optimization of individual hop for robust data streaming and the existing theoretical background of related fields has also been considered. Internet, for example, most data packets need to go through several routers before they reach their final destination. Each time the packet is forwarded to the next router, a hop occurs. The more hops, the longer it takes for data to go from source to destination.

A layer 2 link, or segment, can normally transfer data at a constant bit rate, which is the transmission rate of the segment. For instance, this rate is 10 Mb/s on a 10BaseT Ethernet segment, and 1.544 Mb/s on a T1 segment. The transmission rate of a segment is limited by both the physical bandwidth of the underlying propagation medium as well as its electronic or optical transmitter/receiver hardware. At the IP layer a hop delivers a lower rate than its nominal transmission rate due to the overhead of layer 2 encapsulation and framing. Specifically, suppose the nominal capacity of a segment is c_{L2}. The transmission time for an IP packet of size L_{L3} bytes is

$$\Delta_{L3} = \frac{L_{L3} + H_{L2}}{C_{L2}} \quad \text{................................ (1)}$$

Where H_L is the total layer 2 overhead (in bytes) needed to encapsulate the IP packet. So the capacity c_{L3} of that segment at the IP layer is

$$C_{L3} = \frac{L_{L3}}{\Delta_{L3}} = \frac{L_{L3}}{\frac{L_{L3} + H_{L2}}{C_{L2}}} = C_{L2} \frac{1}{1 + \frac{H_{L2}}{L_{L3}}} \quad \text{...... (2)}$$

Note that the IP layer capacity depends on the size of the IP packet relative to the layer 2 overhead. For 10BaseT Ethernet, c_{L2} is 10 Mb/s and H_{L2} is 38 bytes (18 bytes for the Ethernet header, 8 bytes for the frame preamble, and the equivalent of 12 bytes for the interframe gap). So the capacity the hop can deliver to the IP layer is 7.24 Mb/s for 100 byte packets, and 9.75 Mb/s for 1500-byte packets.

From the above equation, the maximum transfer rate at the IP layer results from MTU-sized packets. Extending the previous definition to a network path, the capacity c of an end-to-end path is the maximum IP layer rate the path can transfer from source to sink. In other words, the capacity of a path establishes an upper bound on the IP layer throughput a user can expect to get from that path. The minimum link capacity in the path determines the end-to-end capacity C that is,

$$C = \min_{i=1,\dots,H} C_i. \quad \text{...................................... (3)}$$

Where C_i is the capacity of the ith hop, and H is the number of hops in the path. The hop with the minimum capacity is the narrow link on the path [1].

In a link of capacity C_i and for a packet of size L, the transmission delay is $Bt_i = L/C_i$. A packet pair experiment consists of two packets sent back-to-back, i.e., with a spacing that is as short as possible, from the source to the sink. Without any cross traffic in the path, the packet pair will reach the receiver dispersed by the transmission delay in the narrow link. So, the receiver can calculate the capacity C of the path from the measured dispersion Δ, as C = L/Δ. Another important metric is the available bandwidth of a link or end-to-end path. The available bandwidth of a link relates to the unused or spare capacity of the link during a certain time period. So even though the capacity of a link depends on the underlying transmission technology and propagation medium, the available bandwidth of a link additionally depends on the traffic load at that link, and is typically a time-varying metric. At any specific instant in time, a link is either transmitting a packet at full link capacity or idles, so the instantaneous utilization of a link can only be either 0 or 1. Thus, any meaningful definition of available bandwidth requires time averaging of the instantaneous utilization over the time interval of interest. The average utilization $\bar{u}(t-\tau, t)$ for a time period $(t-\tau,$ t) is given by

$$\bar{u}(t-\tau,t) = \frac{1}{\tau}\int_{t-\tau}^{t} u(x)dx, \quad \text{........................ (4)}$$

Where u(x) is the instantaneous available bandwidth of the link at time x and the averaging effect illustrated in Figure-1.

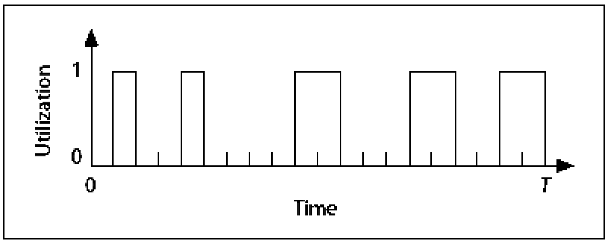

Figure-1. Instantaneous utilization for a link.

In this example the link is used during eight out of 20 time intervals between 0 and T, yielding an average utilization of 40 percent. Let us now define the available bandwidth of a hop i over a certain time interval. If C_i is the capacity of hop i and u_i is the average utilization of that hop in the given time interval, the average available bandwidth Ai of hop i is given by the unutilized fraction of capacity,

$A_i = (1-u_i)\, C_i$.

Extending the previous definition to an H-hop path, the available bandwidth of the end-to-end path is the minimum available bandwidth of all H hops,

VOL. 4, NO. 8, OCTOBER 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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$$A = \min_{i=1,\ldots,H} A_i. \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The hop with the minimum available bandwidth is called the tight link1 of the end-to-end path.

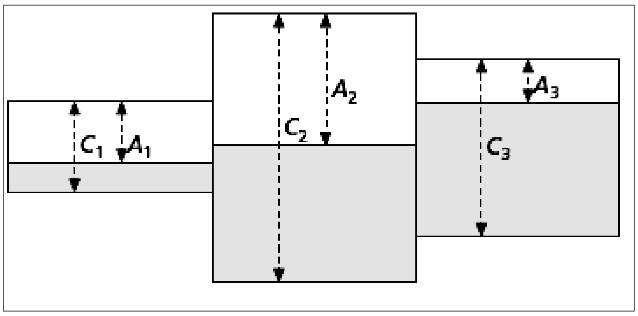

Figure-2. A pipe model with fluid traffic.

Figure-2 shows a pipe model with fluid traffic representation of a network path, where each link is represented by a pipe. The width of each pipe corresponds to the relative capacity of the corresponding link. The shaded area of each pipe shows the utilized part of that link's capacity, while the unshaded area shows the spare capacity. The minimum link capacity C_1 in this example determines the end-to-end capacity, while the minimum available bandwidth A_3 determines the end-to-end available bandwidth. As shown in Figure-2, the narrow link of a path may not be the same as the tight link. Several methodologies for measuring available bandwidth make the assumption that the link utilization remains constant when averaged over time (i.e., they assume a stationary traffic load on the network path). While this assumption is reasonable over relatively short time intervals, diurnal load variations will impact measurements made over longer time intervals [1].

Since the average available bandwidth can change over time, it is important to measure it quickly. This is especially true for applications that use available bandwidth measurements to adapt their transmission rates. In contrast, the capacity of a path typically remains constant for long time intervals. Therefore the capacity of a path does not need to be measured as quickly as the available bandwidth [1].

3. RESULTS AND DISCUSSIONS

After the analysis of previously cited techniques, a necessity of a technique to measure available bandwidth of individual hops has been approached. The method proposes Available Bandwidth Estimation Technique for individual Hops that represent an effective combination of different techniques aiming to exploit the positive aspects of them. More precisely, the technique of this method modifies and integrates the one recent tool SPRUCE for available bandwidth estimation and the IP layer capacity estimation formula for measuring capacity for individual hop.

From the capacity estimation formula, we get the capacity which is delivered by the hop to the IP layer is 9.75 Mb/s for 1500-byte packets. Here Capacity, C = 9.75 Mb/s and Packet Size, L = 1500 byte = 1500*8 bits = 12000bits.

We know from the formula that $C = L/\Delta$. So $\Delta = L/C = 12000/(9.75*10^6) = 1.2308$ms. For Available Bandwidth Estimation Technique for individual Hops (ABETH), we have to introduce C_i is the capacity of the i^{th} hop and A_i is the available bandwidth of the i^{th} hop. Here i = 1, 2, 3… H. H is the number of hops in the path. For available bandwidth measurement there is a delay occurs in hop. We consider delay d_i occurs in the i_{th} hop then the capacity formula can be modified as $C_i = \dfrac{L}{(\Delta + d_i)}$. If delay is increased linearly then delay difference between hop to hop is same. And if 0.001ms is delay increased linearly per hop and variable Packet Size, L = 1500 byte = 1500*8 bits = 12000 bits. From the definition we get the available bandwidth of a hop i over a certain time interval. If Ci is the capacity of hop i and ui is the average utilization of that hop in the given time interval, the average available bandwidth Ai of hop i is given by the unutilized fraction of capacity, Ai = (1–ui) Ci. At any specific instant in time, a link is either transmitting a packet at full link capacity or idles, so the instantaneous utilization of a link can only be either 0 or 1. So for utilization 1 available bandwidth is zero and we get the following table (Table-1) and figure (Figure-3).

Table-1. AB estimation parameters for different capacities using utilization 1.

#	$\Delta + d_i$ (ms)	$C_i = \dfrac{L}{(\Delta + d_i)}$ (Mb/s)	$A_i = C_i$ (Mb/s)
1	1.2308+0.001	9.742	0
2	1.2308+0.002	9.734	0
3	1.2308+0.003	9.726	0
4	1.2308+0.004	9.718	0
5	1.2308+0.005	9.702	0
6	1.2308+0.006	9.695	0
7	1.2308+0.007	9.687	0
8	1.2308+0.008	9.671	0
9	1.2308+0.009	9.663	0
10	1.2308+0.010	9.656	0

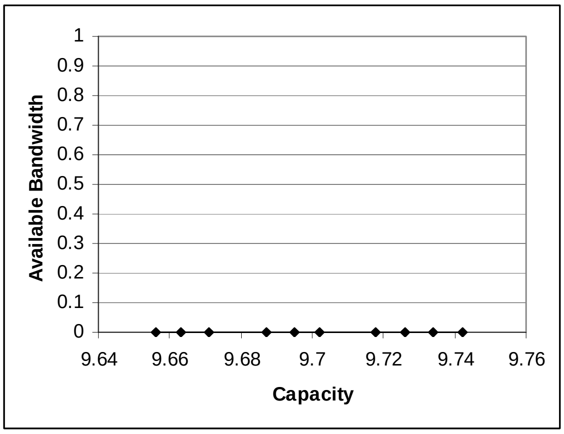

Figure-3. AB estimation graph for different capacities using utilization 1.

If we use ABETH technique to measure C_i, for utilization 0 technique then we get the following table (Table-2) and figure (Figure-4).

Table-2. AB estimation parameters for different capacities using utilization 0.

#	$\Delta + \mathbf{d_i}$ (ms)	$C_i = \frac{L}{(\Delta + d_i)}$ (Mb/s)	$\mathbf{A_i = C_i}$ (Mb/s)
1	1.2308+0.001	9.742	9.742
2	1.2308+0.002	9.734	9.734
3	1.2308+0.003	9.726	9.726
4	1.2308+0.004	9.718	9.718
5	1.2308+0.005	9.702	9.702
6	1.2308+0.006	9.695	9.695
7	1.2308+0.007	9.687	9.687
8	1.2308+0.008	9.671	9.671
9	1.2308+0.009	9.663	9.663
10	1.2308+0.010	9.656	9.656

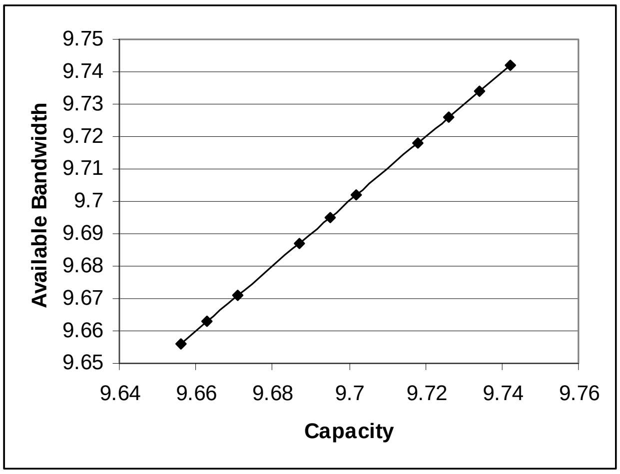

Figure-4. AB estimation graph for different capacities using utilization 0.

From SPRUCE, if gin is the spacing of back-to-back probe packets on the tight link and gout the spacing measured at the receiver, the AB is calculated as:

$A = [1- \{(g_{out} - g_{in}) / g_{in}\}]\ C.$

With SPRUCE, the tight link and narrow link are assumed to be the same. But utilization 100% or 0% do not occur in a link. Again SPRUCE tool can be used for tight link and applicable for end to end. So here we considering all aspects introduce a new parameter called link used factor l_u, which can be used for all link.

$l_{ui} = R_i / (T_i + l_i).$

Where l_{ui} = link used factor for i^{th} hop.
R_i = packet or bit received at the end of i^{th} hop.
T_i = packet or bit transmitted at the starting of i^{th} hop.
l_i = loss in the i^{th} hop.
Here i = 1, 2, 3… H. H is the number of hops in the path.

The available bandwidth of a hop i can be measured by the following new formula

$A_i = (1 - lu_i)\ C_i.$

Or, $A_i = (1 - (R_i / (T_i + l_i)))\ (L/ (\Delta + d_i)).$
If T_i = 4 unit, R_i = 3 unit and l_i = 0.5 unit then lu_i = 0.67.

Table-3 and Figure-5 shows the results of the final attained parameters.

Most of the works related to this field consider the parameter of link utilization which is subtracted from the total link utilization recline in always 1. In AB definition, utilization is considered as 1 or 0; it means link will be used 100% or 0% which is practically impossible.

In SPRUCE, it considers back to back packet space for tight link and back packet space measuring in the

Table-3. AB estimation parameters with ABETH using different capacities.

#	$\Delta + \mathbf{d_i}$ (ms)	$C_i = \frac{L}{(\Delta + d_i)}$ (Mb/s)	**Ai = (1 – lu$_i$) Ci** (Mb/s)
1	1.2308+0.001	9.742	6.527
2	1.2308+0.002	9.734	6.522
3	1.2308+0.003	9.726	6.516
4	1.2308+0.004	9.718	6.511
5	1.2308+0.005	9.702	6.505
6	1.2308+0.006	9.695	6.500
7	1.2308+0.007	9.687	6.495
8	1.2308+0.008	9.671	6.485
9	1.2308+0.009	9.663	6.480
10	1.2308+0.010	9.656	6.474

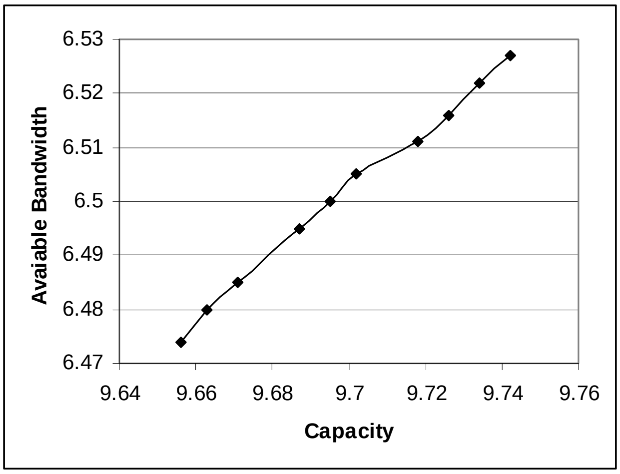

Figure-5. AB estimation graph with ABETH using different capacities.

receiver. But we use a parameter called link used factor which is practically applicable for all cases. We use transmitting packets or bits in starting of the hop, receiving packets or bits at the end of the hop and loss occur in the hop for each link. This is practically acceptable for link utilization portion. Suppose for transmitting 100 bits, 80 bits have been transmitted at the starting of this link and 70 bits have been received at the end of the link. 10 bits have been lost in the case. So link utilization portion will be between 70-80%. Now we verify our link used factor l_u, which can be used for all link.

$l_{ui} = R_i / (T_i + l_i)$.
$l_{ui} = 70/(80+10) = 0.77 = 77\%$.

This is similar to the link used fraction as expected. Proper inclusion and detail understanding in the above that the proposed available bandwidth estimation for individual hop behaves linearity in all cases in terms of the variable of utilization factor where as the existing method for individual hop give the output in terms of the value of utilization factor either is 0 or 1.

4. CONCLUSIONS

In this paper, a new bandwidth estimation method for individual hop which signifies an effective combination of different other techniques has been optimized. Parameters like Hop (H), Capacity (C), Bandwidth (B), Available Bandwidth (AB) etc. have been used to integrate the technique. Different existing schemes have been employed to attain stable detection results, so that the method can achieve a high accurate hop bandwidth estimation result. The graphical representations of the technique and the comparative analysis with other techniques have also been stated. Synchronization problem of the existing system have been eliminated by the technique executed by the link hosts of a path and provided a linear combination of capacity versus bandwidth existed which satisfied the link utilization demand in a link

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