Available Bandwidth Estimation Problem Network Calculus in Practice

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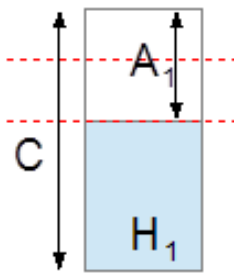
Outline

1. Introduction and motivation
2. Simulations
3. Results of experiments in the ISP environment
4. Conclusions

Available bandwidth at the node

Available bandwidth **A** is the difference between the capacity of the system **C** and current bandwidth usage **H**.

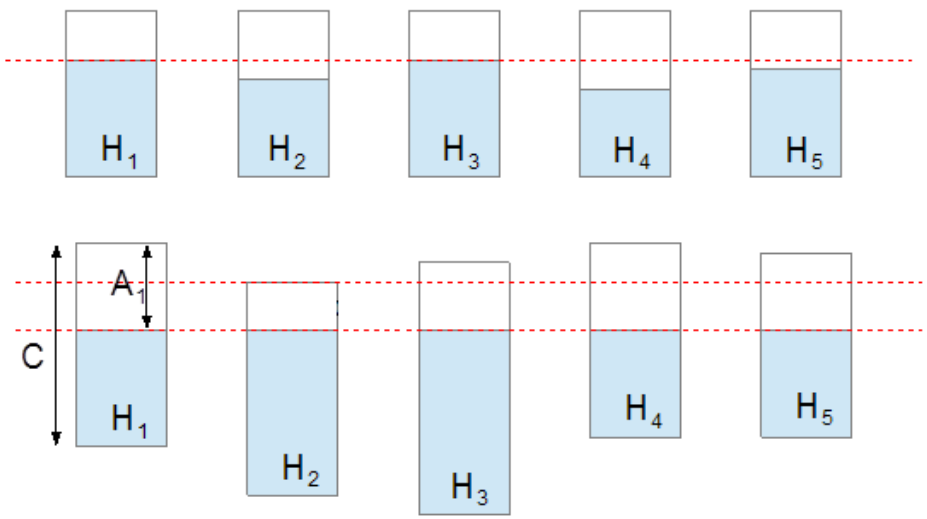


Available bandwidth on the path

Available bandwidth B on the route at the time t means **unused bandwidth** which an application can use without any influence on the transmission quality of existing flows on this route.

$$B(t) = \min_{1 \leqslant i \leqslant n} \{A_i(t)\}$$

- verification of SLA
- route selection
- network traffic engineering
- resource access control

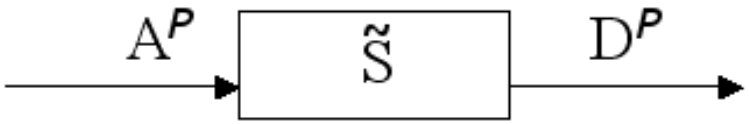


Available bandwidth estimation methods

There are a lot of different available bandwidth estimation methods **but no one is perfect**

LFV method

Passive measurement based method



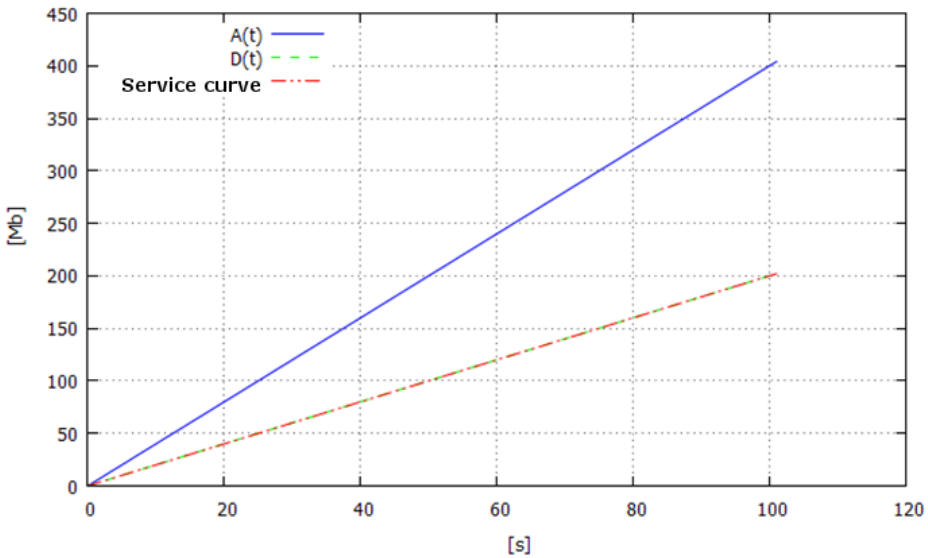
A^p and D^p are the arrival and departure functions measured from a traffic trace of one or more flows.

$A^p(t)$ **is the sum of bits incoming to the system in time from 0 to t.**
$D^p(t)$ **is the sum of bits outcoming from the system in time from 0 to t.**

Service curve $\tilde{S}$ is the best possible estimate of the actual service curve S (describing available bandwidth) that can be justified from measurements of A^p and D^p ($\tilde{S} \leqslant S$).

J. Liebeherr, M. Fidler, S. Valaee, A system-theoretic approach to bandwidth estimation, IEEE/ACM Transactions on Networking, vol. 18, no. 4, pp. 1040-1053, 2010

Simulation



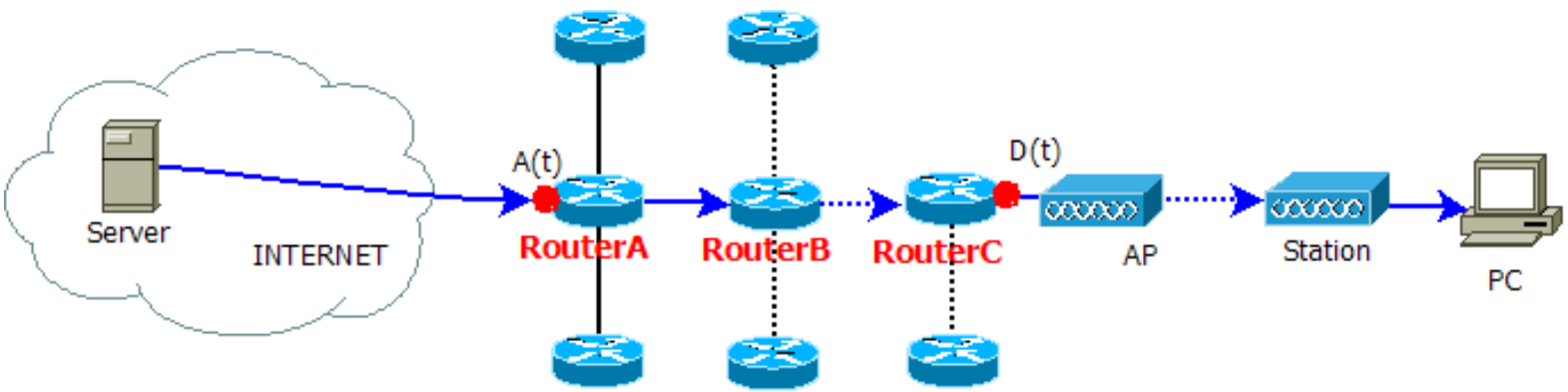
- Traffic arrives faster than it can be served
- $D(t) \leqslant A(t)$
- The estimate of the service curve covers the departure function $D(t)$

- $A(t) = 4t$
- $D(t) = 2t$

Notice that we have no information about capacity of the system.

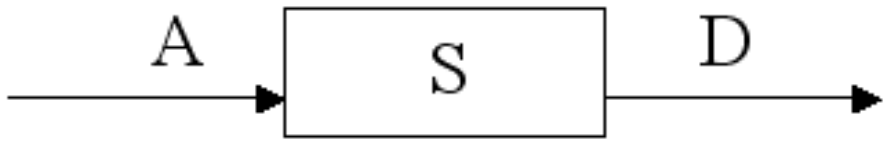
The objective

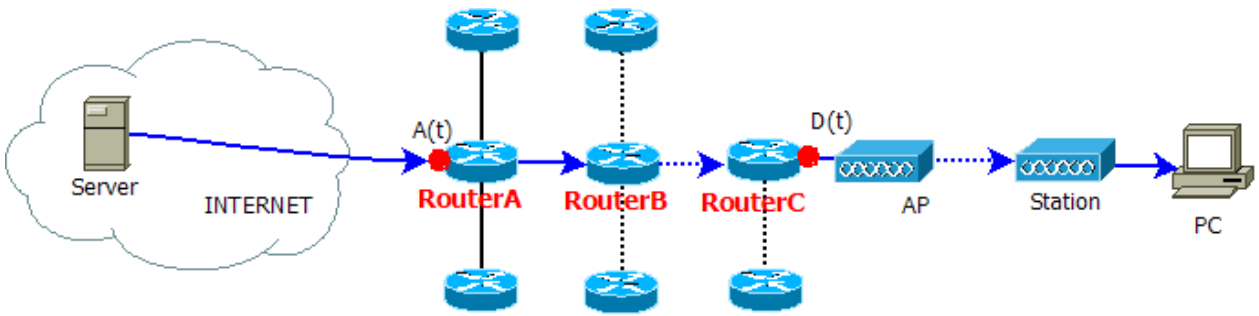
To use and verify the service curve $\tilde{S}$ based on the measurements in the **real ISP network**



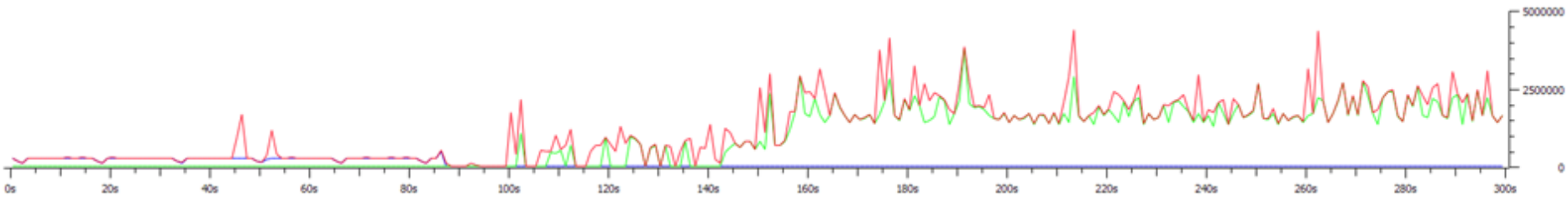
Methodology

1. Capture the Internet traffic on the selected interfaces
2. Generate time series for $A(t)$ oraz $D(t)$ functions
3. Calculate values of the service curve $\tilde{S}$ (LFV method)

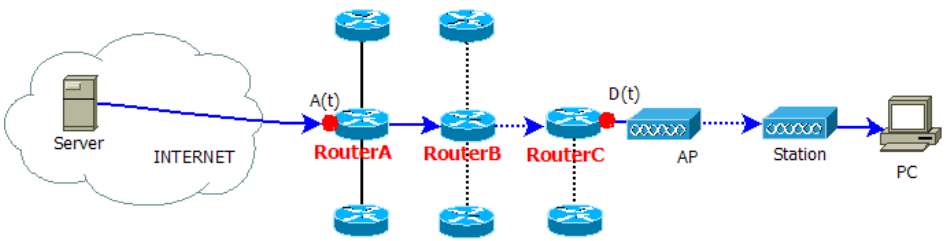




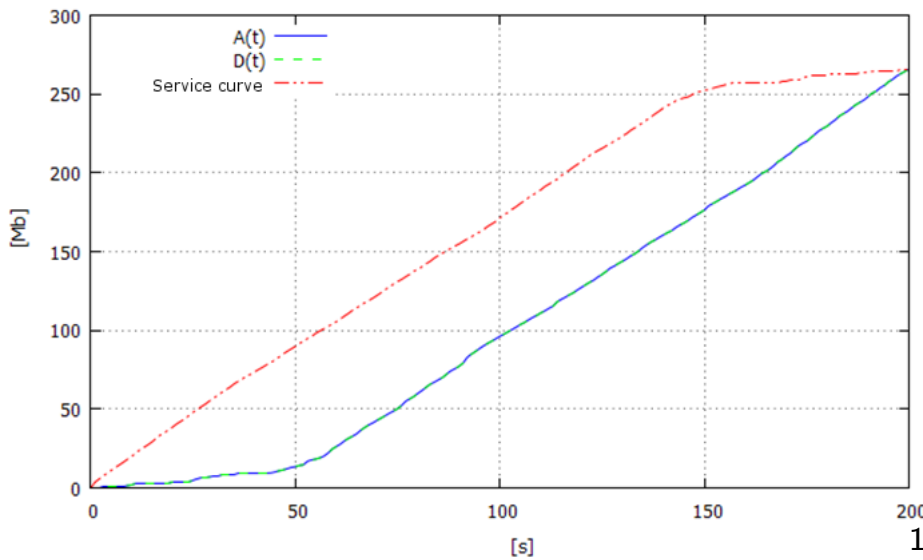
CASE 1: Network service curve - aggregated flows (1/2)



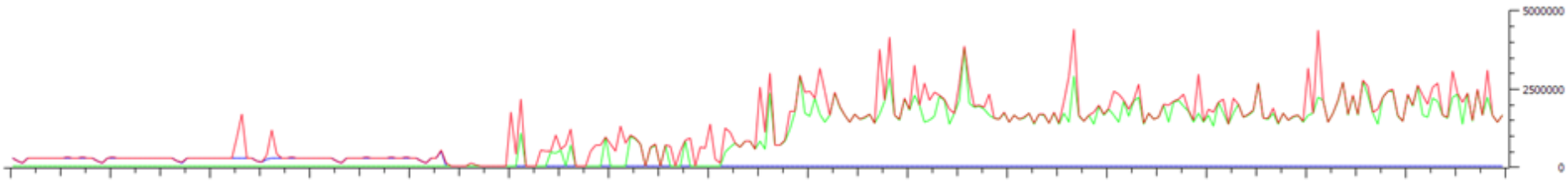
Red color - the total traffic generated to the customer
Green color - the sum of flows F_1-F_4
Blue color - the flow F_5

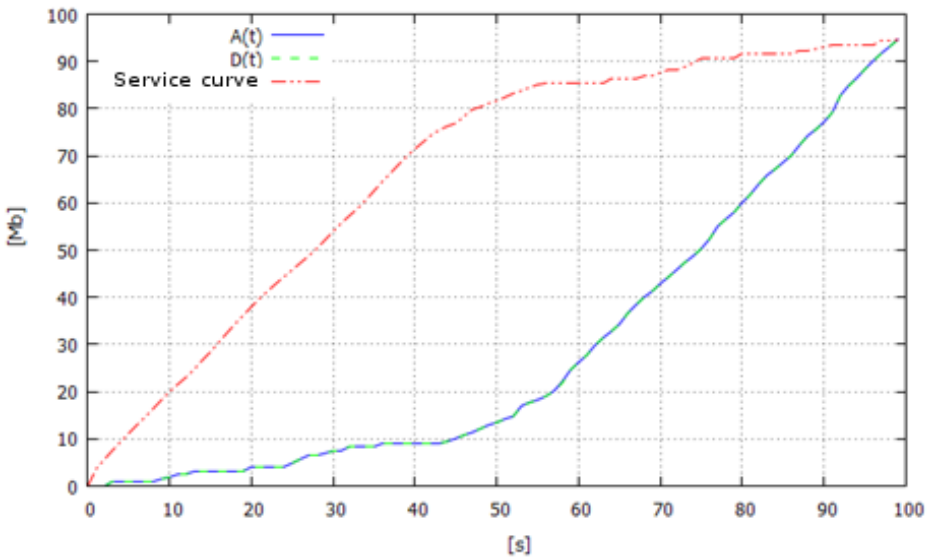


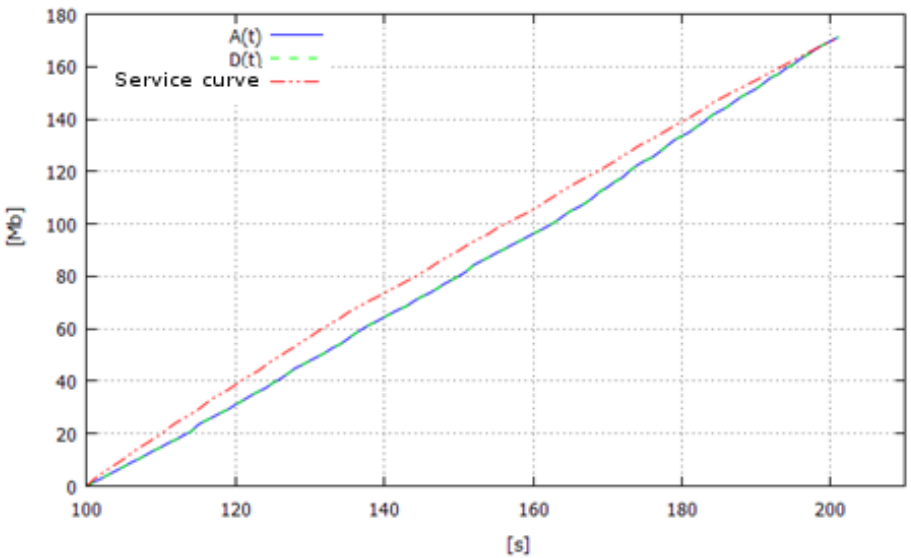
- Measurement length F_1-F_4: 200 s (from 100th to 300th)
- Amount of data: 265,86 Mb
- Average rate: 1,329 Mb/s
- Max rate: ok. 1,7 Mb/s
- Possible rate: 6,41 Mb/s
- Difference: ok. 4,7 Mb/s



CASE 1: Network service curve - aggregated flows (2/2)







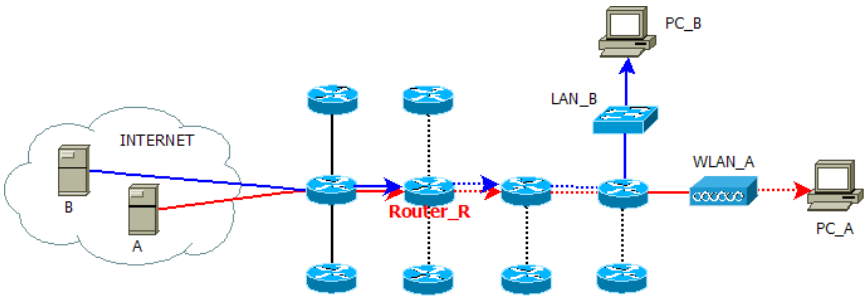
- Data: 94,64 Mb = 11,83 MB
- Average rate: 0,946 Mb/s

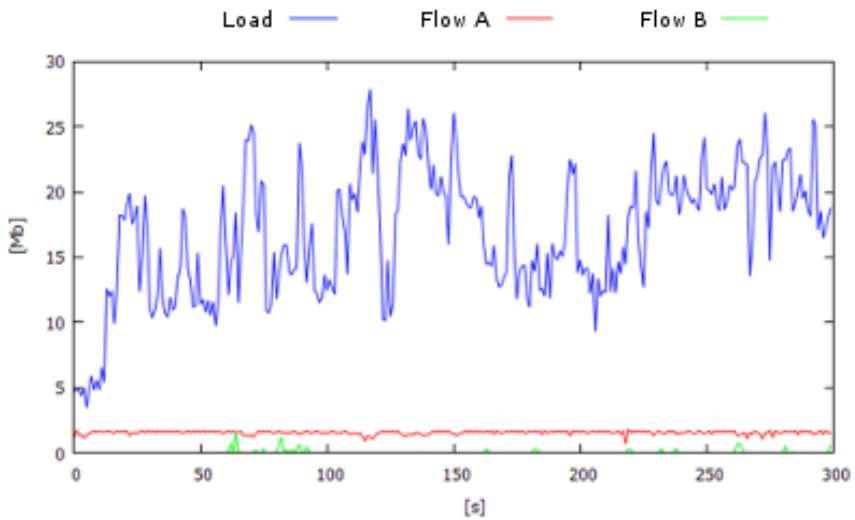
- Data: 171,23 Mb = 21,40 MB
- Average rate: 1,712 Mb/s

Specification of traffic probes

Direction	Duration	Time scale	Amount of observations
Service curve of the node			
Download	5min	1s	300
	1min	100ms	600
	1s	1ms	1000
	100ms	100μs	1000
Upload	5min	1s	300
	1min	100ms	600
	1s	1ms	1000
	100ms	100μs	1000
Network service curve			
Download	5min	1s	300
	1min	100ms	600
	1s	1ms	1000
	100ms	100μs	1000
Upload	5min	1s	300
	1min	100ms	600
	1s	1ms	1000
	100ms	100μs	1000

CASE 2: Traffic flows (A - HTTP, B - HTTPS) (1/4)

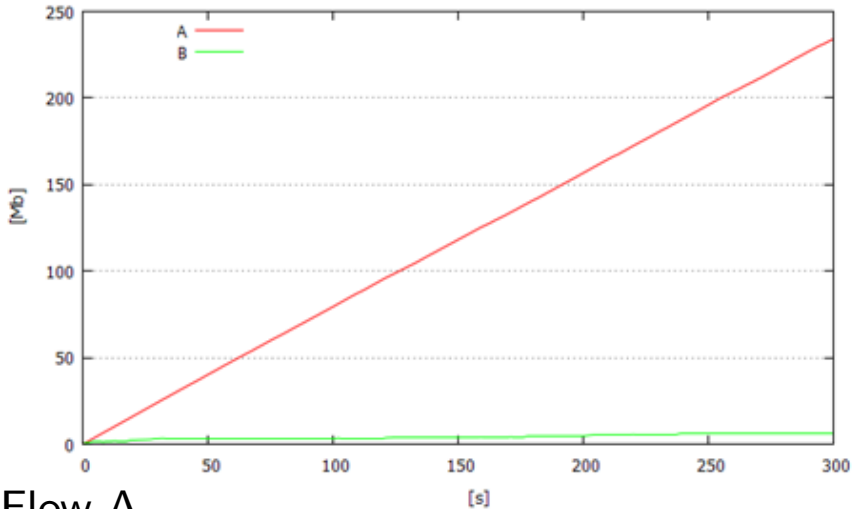




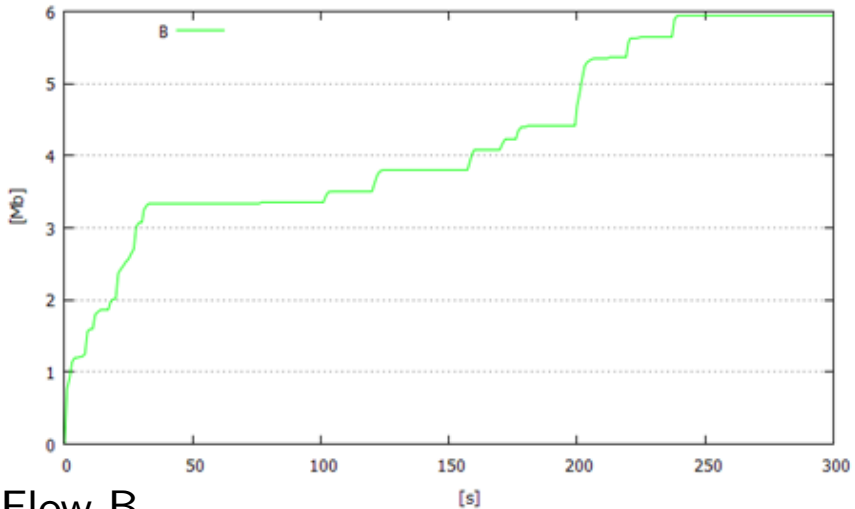
Average rate in the node: 17,7 Mb/s

	Amount of packets	Amount of data which arrive to the node [B]	Average rate [Mb/s]	Amount of data which leave the node [B]	Average rate [Mb/s]
Flow A	21497	30670366	0,818	30670366	0,818
Flow B	812	780366	0,026	779694	0,026

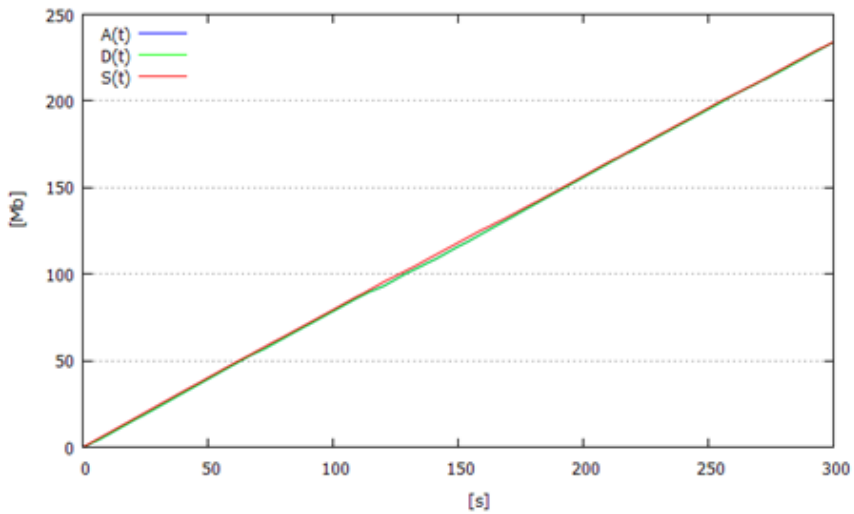
CASE 2: Traffic flows (A - HTTP, B - HTTPS) (2/4)

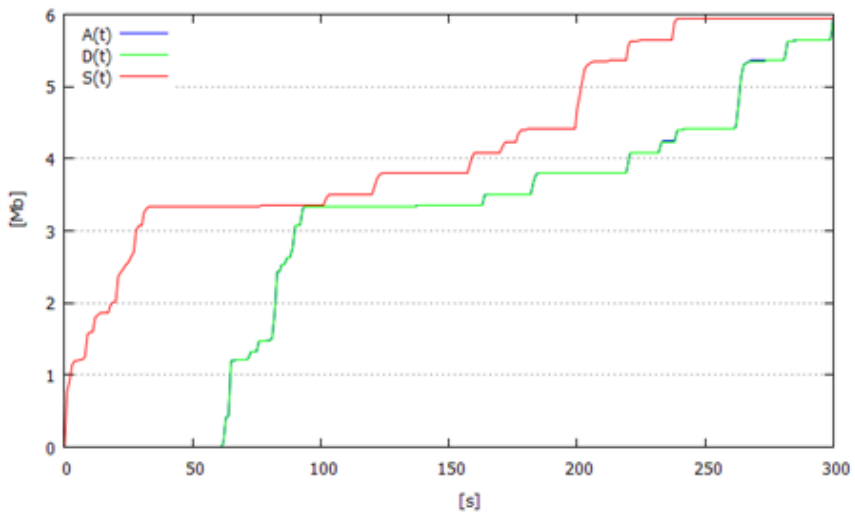


Flow A



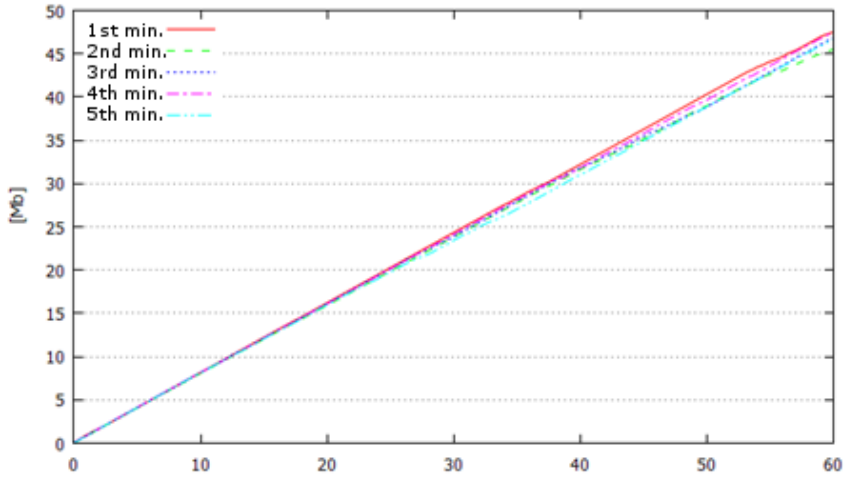
Flow B

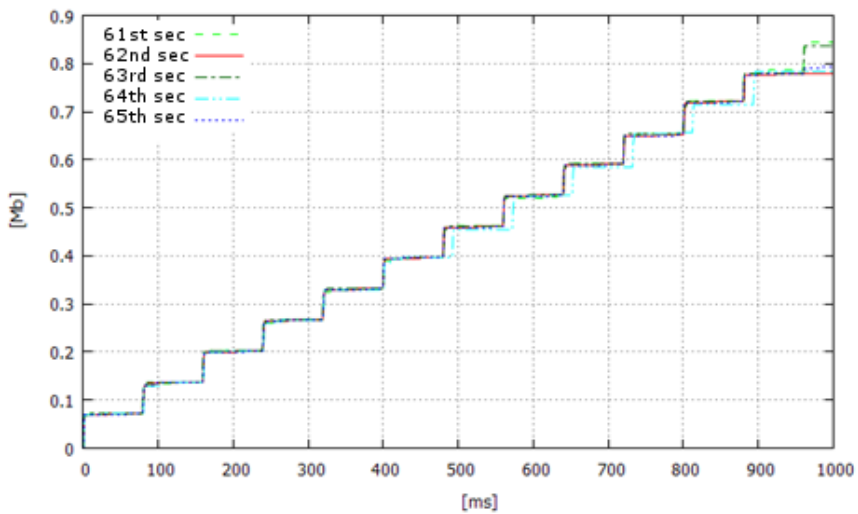




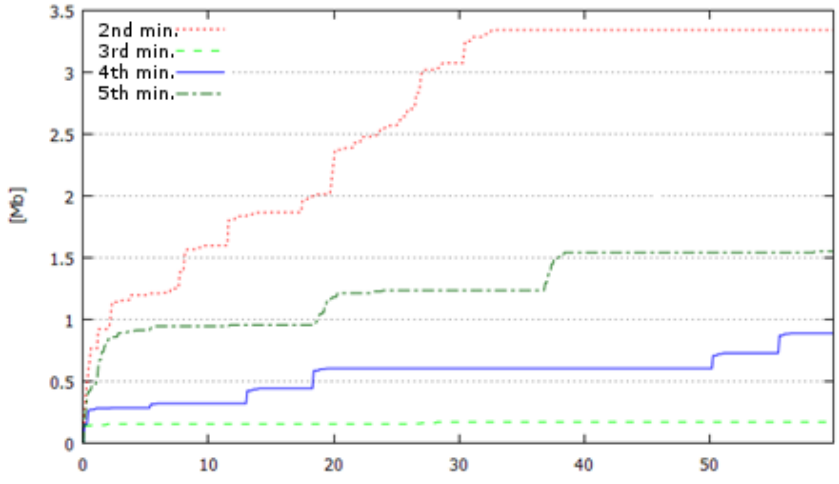
CASE 2: Traffic flows (A - HTTP, B - HTTPS) (3/4)

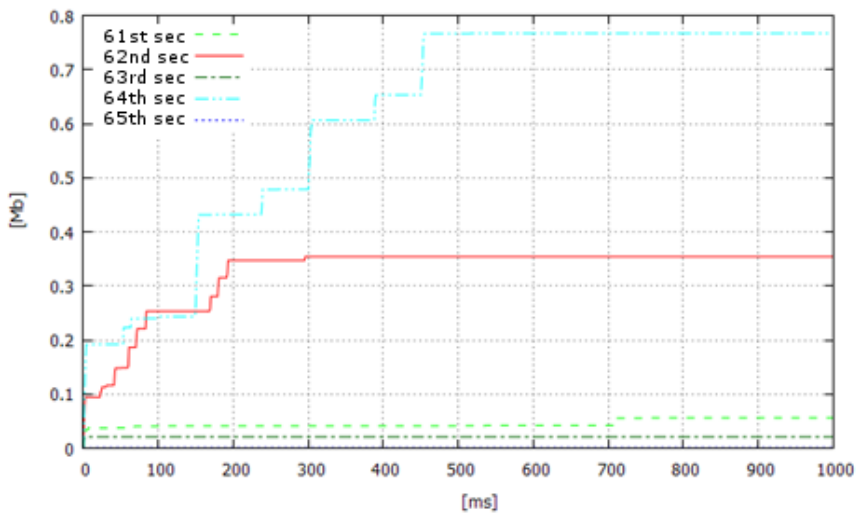
Flow A





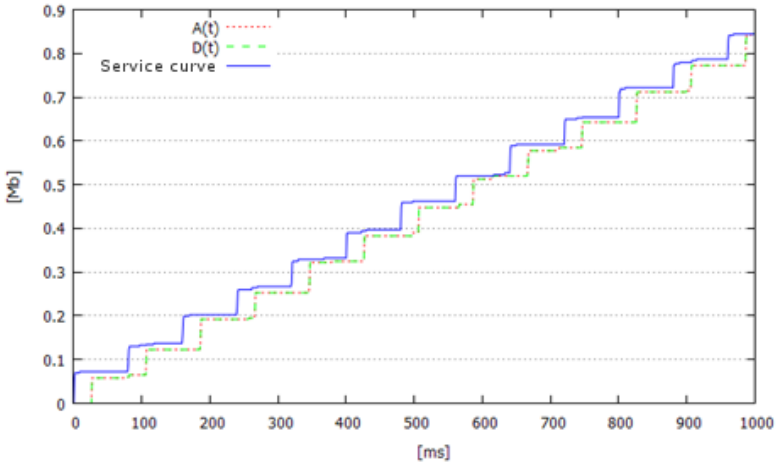
Flow B





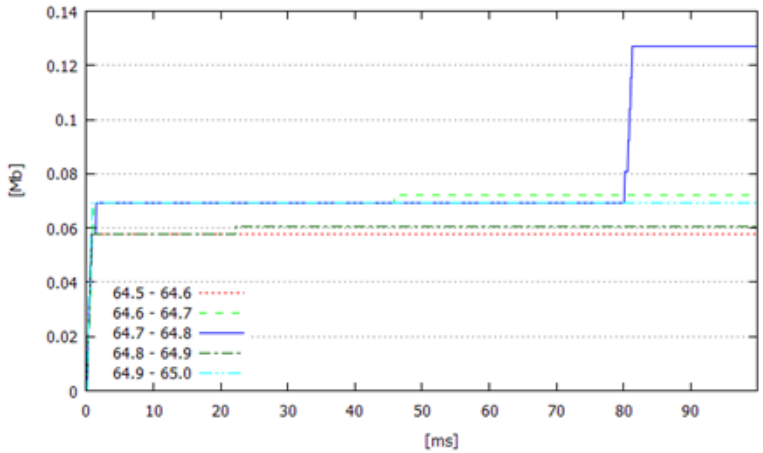
CASE 2: Traffic flows (A - HTTP) (4/4)

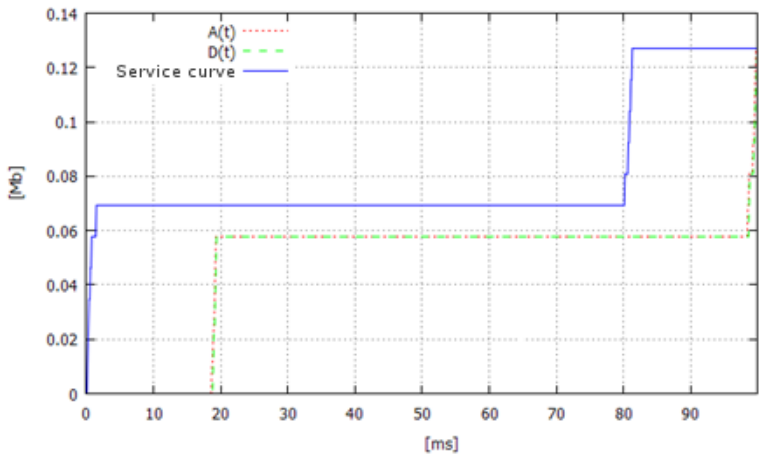
61. sec, duration: 1s, time scale: 1ms



Time [s]	Incoming data [b]	A(t)	Outcoming data [b]	D(t)
61.824	0	673712	0	673712
61.825	0	673712	0	673712
61.826	12112	685824	0	673712
61.827	60560	746384	72672	746384
61.828	0	746384	0	746384
61.829	0	746384	0	746384

61. sec, duration: 100ms, time scale: 100μs





Conclusions

- The estimate of service curve based on the LFV method represents **possibility of bandwidth usage** and provides the evaluation of available bandwidth for the selected traffic at the single node as well as on the path of interconnected nodes
- Estimation of available bandwidth based on LFV is possible for selected single flow as well as agregats of flows (IP addresses, single IP address, services)
- LFV method has advantages and disadvantages
- The shorter time scales give more accurate (but not always useful) results

Thank you

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