

**tracerate: a non-intrusive method for
measuring the hop-by-hop capacity of a path**

Bandwidth Estimation Workshop

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Slides available at

http://perso.ens-lyon.fr/mathieu.goutelle/fichiers/sl_BEst2003.pdf

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- Bandwidth measurement in IP networks ;
- The Packet Pair method ;
- Our proposition: `tracerate` ;
 - ◆ Method principles ;
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- Results and validations ;
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- **Simplicity** of IP networks: no control channel, few informations provided by equipments ;
- Need of an external mean to evaluate the end-to-end performances:
 - ◆ delay, loss rate: classical and easy (ping, traceroute);
 - ◆ **Capacity**: Maximal available rate between two nodes ;
 - ◆ **Available rate**: Accessible rate between two machines given an utilization on the followed path ;

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 - ◆ **Capacity**: Maximal available rate between two nodes ;
 - ◆ **Available rate**: Accessible rate between two machines given an utilization on the followed path ;
- Use of the delay between two machines → not enough to evaluate the duration of a data transfer.

Bandwidth measurement in IP networks

- A “rate” knowledge gives a more realistic view ;
 - ◆ to estimate a transfer duration estimation ;
 - ◆ to schedule transfer in grid computing ;
 - ◆ to choose a data source or a data mirror ;
 - ◆ ...

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- **Total capacity:**

	Method	Type of measure	Measure	Protocol	Receiver
<code>pathchar</code> [Jac97]	<i>Variable Packet Size</i>	hop-by-hop	slow	UDP, ICMP	no
<code>tailgater</code> [LB00]	<i>Packet Tailgating</i>	end-to-end	fast	TCP, ICMP	no
<code>pathrate</code> [DRM01]	<i>Packet Pair</i>	end-to-end	slow	UDP	yes

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- **Issues:** high-performance network, bottleneck localization, low intrusivity.

The Packet Pair method (1)

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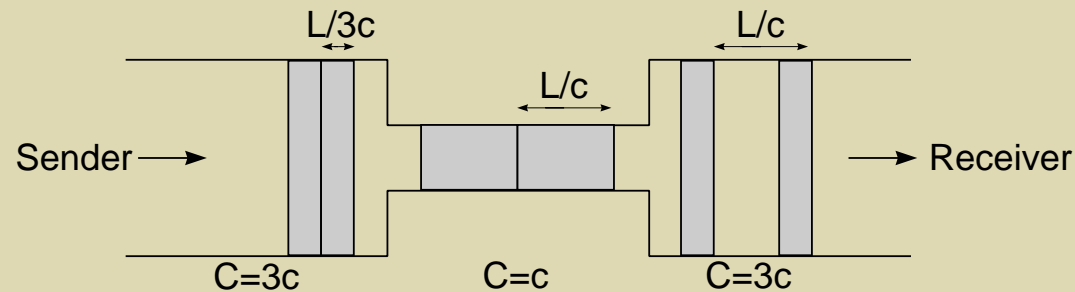
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References

- Quite old principle (Van Jacobson, 1988 [Jac88]) ;
- A path is considered as a succession of delays (queue waiting time, transmission time, *etc.*) ;
- Capacity evaluation through the dispersion (inter-packet delay) measurement of two packets sent back-to-back ;
- This delay is the consequence of the smallest link on the path:



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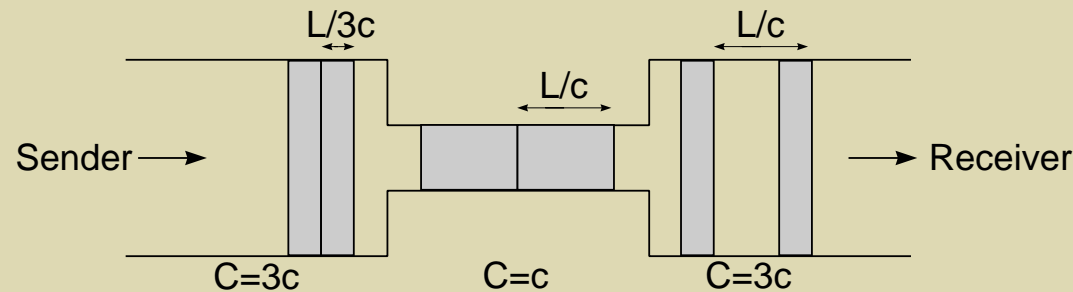
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- **Hypothesis:** No concurrent traffic!
- Otherwise, concurrent traffic may cause the measure to under- or overestimate the real path capacity.

The Packet Pair method (2)

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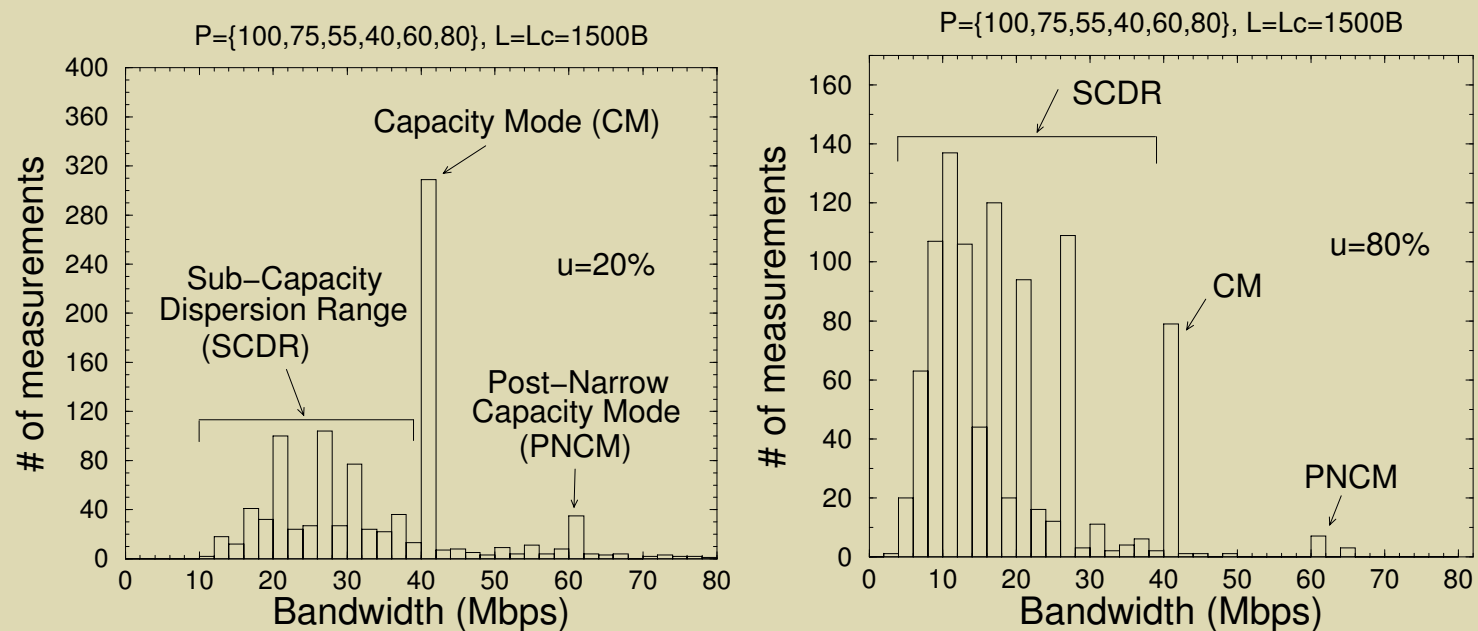
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- Due to concurrent traffic, the measurement distribution is multimodal [DRM01]:



- ◆ **under-estimation (SCDR):** A packet has spaced the two probe packets ;
- ◆ **over-estimation (PNCM):** The first probe has waited for the second in an non-empty queue.

Our proposition: tracerate

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- **Objectives:** to propose a method **little intrusive** to measure and to **localize** the bottleneck of a path. It must work in a **high-performance** environment and **without cooperation** of the destination ;

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- **Objectives:** to propose a method **little intrusive** to measure and to **localize** the bottleneck of a path. It must work in a **high-performance** environment and **without cooperation** of the destination ;
- **Proposition:**
 - ◆ We use a Packet Pair because it is more robust regarding the presence of invisible nodes [PDM03] ;
 - ◆ We measure the hop-by-hop capacity (and delay and loss) up to the path bottleneck ;
 - ◆ We eliminate “topology” parasitic modes with a better hop-by-hop knowledge of the topology (like `traceroute`) ;
 - ◆ We will be able to evaluate the hop-by-hop utilization rate up to the path bottleneck ;

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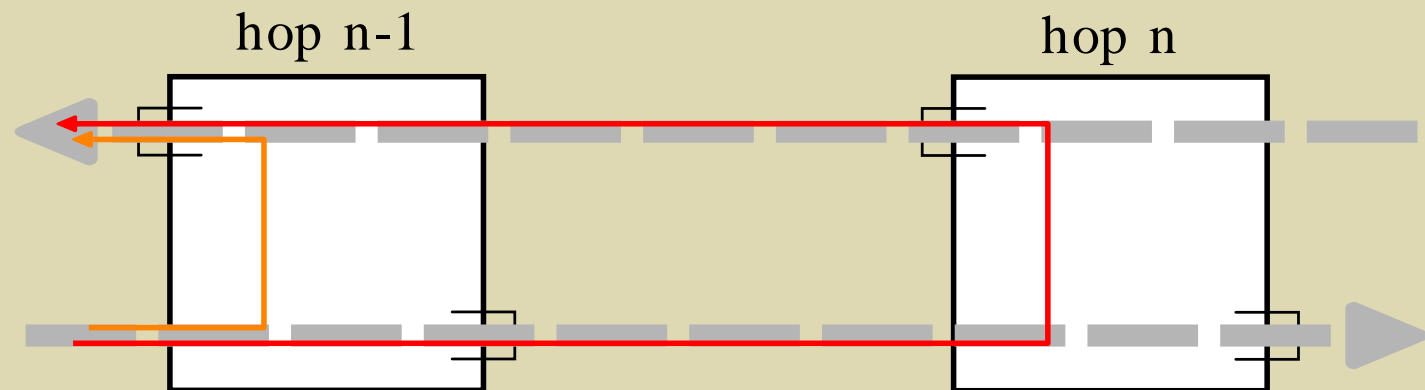
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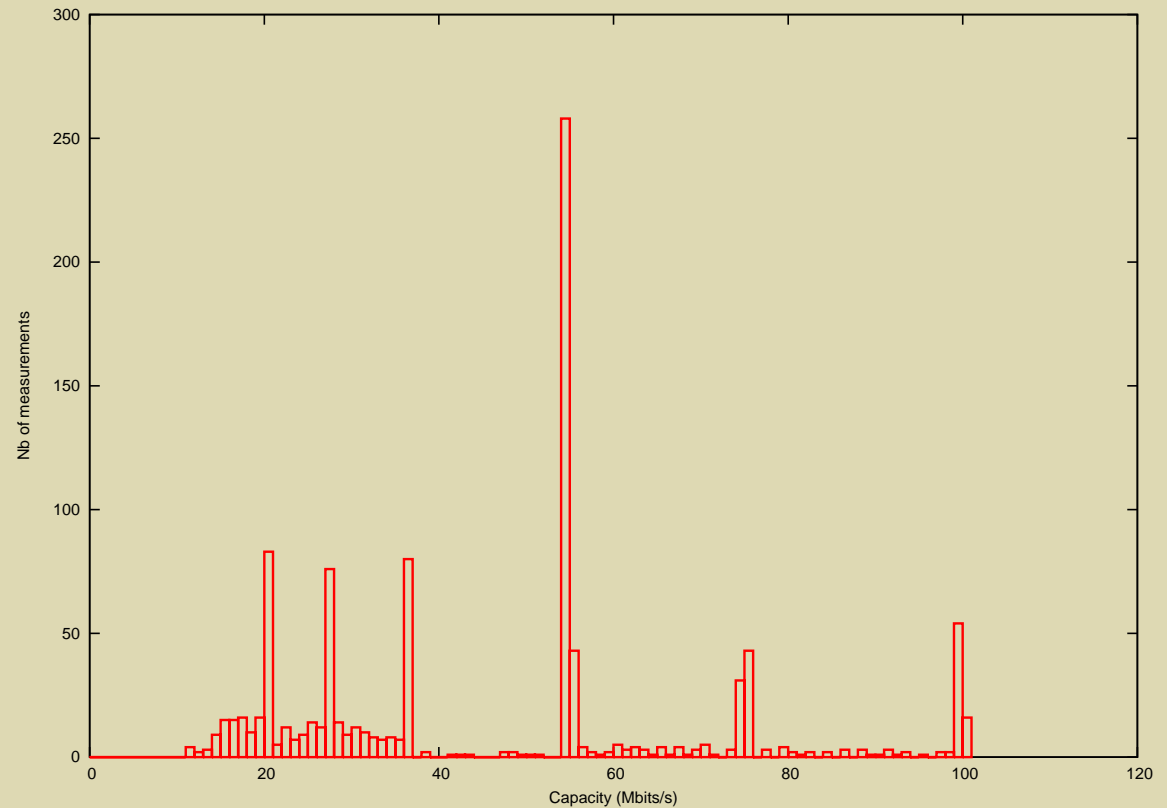
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- TTL (*Time To Live*): field in the IP header. It indicates the remaining number of equipments a packet can go through:
 - ◆ If an equipment receives a packet with a zero value TTL, it sends this packet back to the sender ;
 - ◆ Otherwise, it decreases this value and sends the packet to the next hop.
- With this mechanism, you can discover the topology with increasing TTL loops.



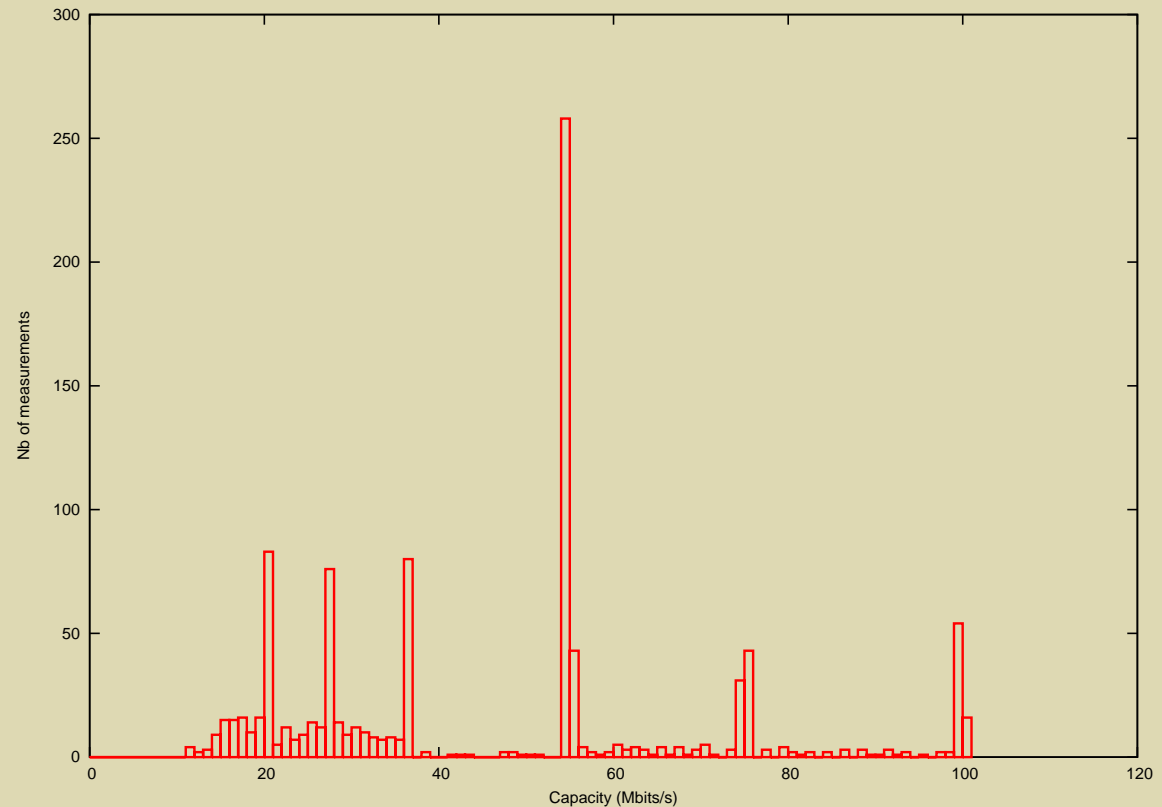
Method principles

- Measurements gathering ;
- Distribution analysis: extraction of the capacity mode.



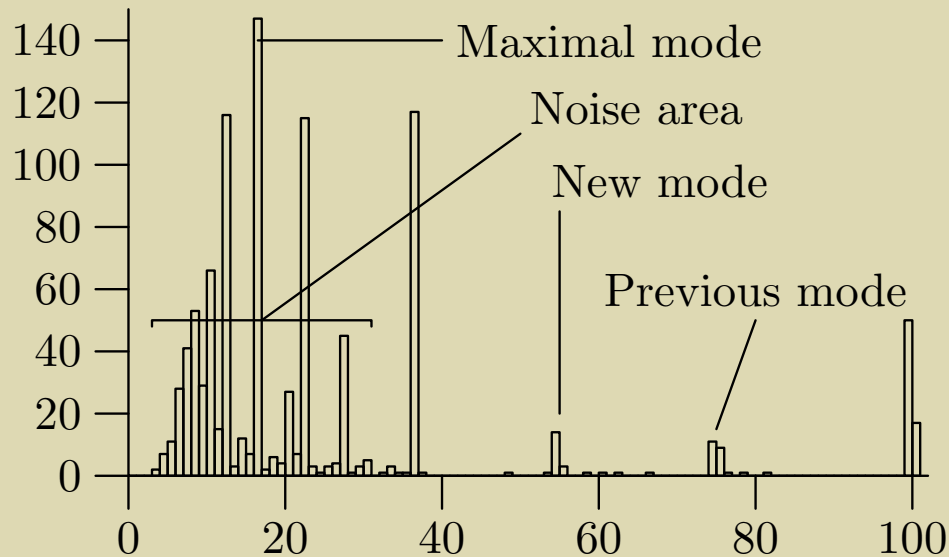
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- At step $n + 1$, we already have the capacity value for the loops up to n :
 - ◆ If there is no relatively acute mode below the previous capacity mode, the bottleneck (up to hop $n + 1$) is in the previous loop ;
 - ◆ Otherwise, a mode below the previous capacity mode has been detected and the link between hop n and $n + 1$ is the new bottleneck.

- Mode detection (increase up to a maximum and then decrease) ;
- Determination of four characteristics of the distribution:

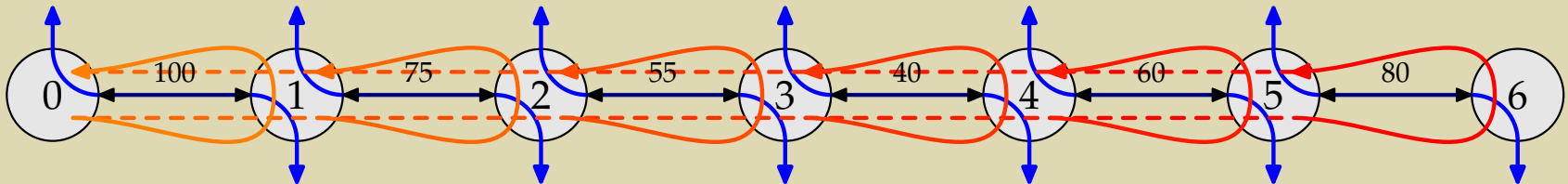


- Capacity mode extraction depending on the position and the population of the characteristics.

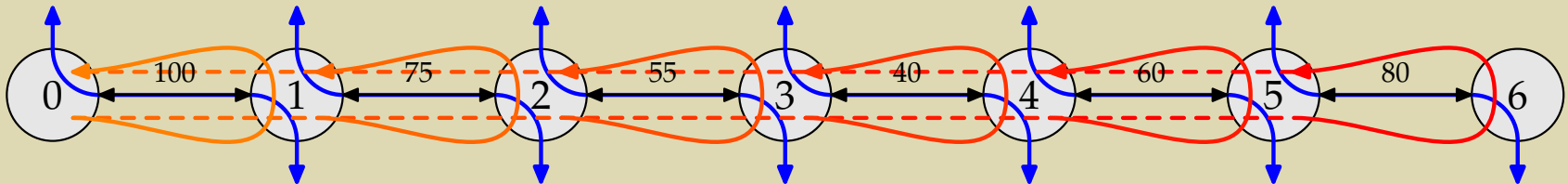
Capacity mode extraction

```
for all hop on the path do  
2:   Compute the measurements distribution  
     Determine the new, previous and maximal modes and the noise area  
4:   if max_mode = prev_mode  
     or (max_mode = new_mode and new_mode not in noise_area) then  
     capacity_mode ← max_mode  
6:   else if  $1.1 \times |\text{new\_mode}| \geq |\text{prev\_mode}|$   
     and new_mode not in noise_area then  
     capacity_mode ← new_mode  
8:   else if (max_mode not in noise_area or  $|\text{max\_mode}| \geq 0.6 \times \text{total\_pop}$ )  
     and  $|\text{max\_mode}| \geq 1.25 \times |\text{prev\_mode}|$  then  
     capacity_mode ← max_mode  
10:  else  
     capacity_mode ← prev_mode  
12:  end if  
end for
```

- Validations in simulations (NS-2) in a controlled environment (capacity, delay):
 - ◆ Behaviour consistent with the one expected ;
 - ◆ Accuracy validation of the analysis method ;
 - ◆ Robustness validation regarding the network conditions (path length, load).



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- Experimentation in a high-performance environment (DataTAG platform, <http://www.datatag.org>).

Accuracy study

- 100 simulations with a variable utilization rate from 0 up to 100% ;
- Measure of the relative error between the real capacity and the measured value for each hop:

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Relative error	hop 1	hop 2	hop 3	hop 4	hop 5	hop 6
$u \leq 0,5$	0,1%	0,1%	1,1%	2,5%	4,8%	6,9%
$u \leq 0,75$	0,1%	1,4%	4,6%	7,1%	5,9%	8,3%
$u \leq 1$	0,1%	12,4%	14,9%	15,3%	11,5%	13,7%

- Influence of the load and path length, but the quality degradation of the result remains low ;
- The method tries to be conservative: it can detect the bottleneck at one or two steps later.

Robustness study

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- 100 simulations with a random load and link capacities ;

	Correlation	Avg relat. err.
6 hops ($u < 0,5$)	0,82	0,14
6 hops ($u < 1$)	0,58	0,28
10 hops ($u < 0,5$)	0,88	0,16
10 hops ($u < 1$)	0,62	0,37

- The method is robust regarding the path length ;
- The network load may be a difficulty if it becomes high.

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- Implementation in Linux based on `tcptraceroute` ;
- Experimentation on a real platform (DataTAG):
 - ◆ It works!
 - ◆ Measure up to 1Gbit/s ;
 - ◆ Some problems with ICMP in routers: limitation due because the ICMP path is different from the normal path ;
 - ◆ it needs some extra tests to validate `tracerate`...

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■ Non-intrusivity:	Tool	Short path (4 hops)	Long path (11 hops)
	<code>pathchar</code>	11,562	31,782
	<code>clink</code>	6,002	16,400
	<code>pchar</code>	11,732	32,417
	<code>nettimer</code>	982	6,663
	<code>tracerate</code>	4,000	11,000

Utilization rate evaluation

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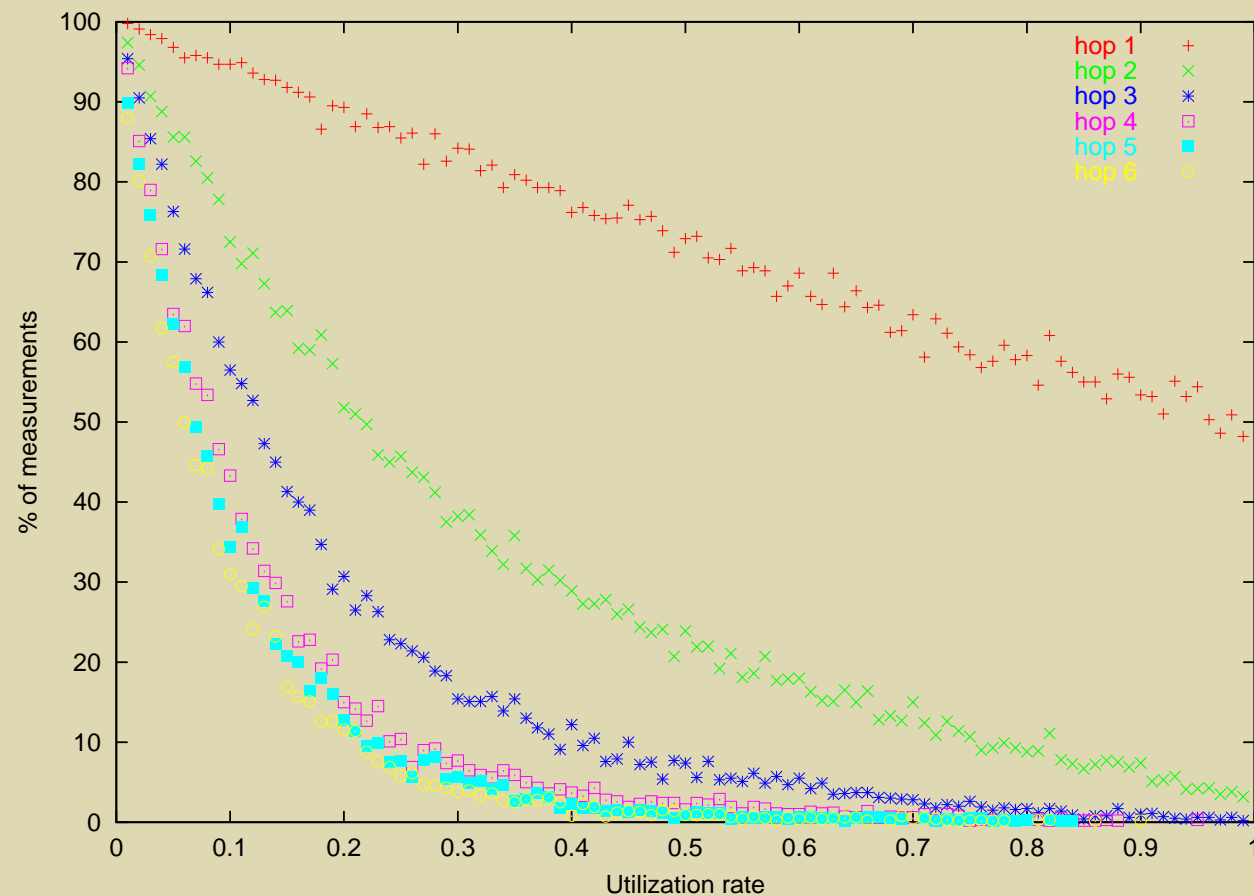
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- When you know both the capacity and the utilization rate of a path, you can deduce almost all its characteristics ;
- Given the previous measurements (distribution for each hop), we want to find a relation between the **population in the capacity mode** and the **utilization rate**.

Utilization rate evaluation

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- **Non-intrusive** method to evaluate the capacity: determination of the bottleneck and its **localization** on the path ;
- Validations in simulations ;
- Linux implementations, working in a **high-performance** environment → `tracerate` ;
- **Promising future work:** utilization rate evaluation and finalization of the implementation ;

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More details in this research report:

<http://www.inria.fr/rrrt/rr-4959.html>

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Questions?