Investigating self-similarity and heavy-tailed distributions on a large-scale experimental facility

Patrick Loiseau, Paulo Gonçalves, Guillaume Dewaele, Pierre Borgnat, Patrice Abry, Pascale Vicat-Blanc Primet

Université de Lyon - INRIA (RESO Team) - CNRS
ENS Lyon, France - LIP (UMR CNRS - ENS Lyon - UCB Lyon - INRIA 5668) - Laboratoire de Physique (UMR CNRS - ENS Lyon 5672)

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Metrology – Motivations

- Global objective – Develop a metrology activity on a grid environment for a better understanding of the traffic in order to improve Quality of Service.
- TCP-IP protocols were designed for the internet : are they adapted to a grid environment, for distributed computation ?
- A grid is a great testbed to perform experiments in order to understand the traffic characteristics and their links to the QoS.

$\longrightarrow$ focus on the LRD parameter: H

Metrology – Relevant parameters

- Long Range Dependance has been observed on internet traffic

Theorem (Taqqu, Willinger, Sherman, 1997)

A simple ON/OFF source model with heavy tail distributed periods generates LRD in the aggregated throughputs.

Tail index α and LRD parameter H rely according to:

$$H = \frac{3-\alpha}{2}$$

- What is the influence of LRD on the QoS ?
  - force the flow size distribution to impose a given H
  - prescribe the LRD index H and measure the QoS
- We need to validate Taqqu's relation in a real large scale environment

Long Range Dependance : definition

Model — fractional Gaussian noise (fGn – derivative of fractional Brownian motion fBm) with Hurst exponent $0 < H < 1$:

- $H < 1/2$ short range correlation
- $H = 1/2$ white Gaussian noise
- $H > 1/2$ long range correlation

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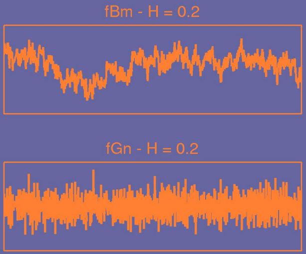

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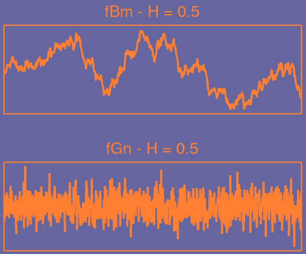

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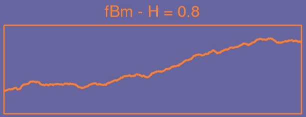
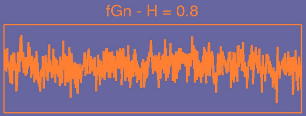
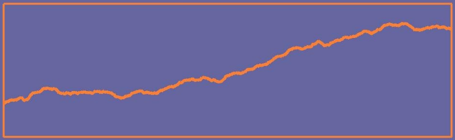




Long Range Dependance and QoS

fBm - H = 0.8

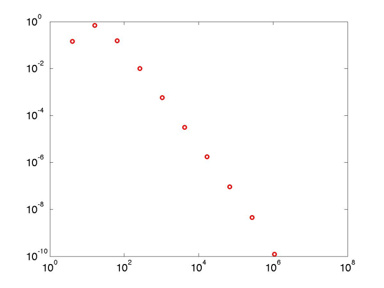


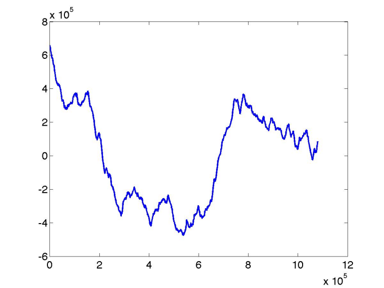
- Quality of service – The correlation decrease slowly : big values of the bandwidth increase the probability to observe bigger values ⇒ Congestion
- Impact of the LRD on the QoS observed by Park, Kim and Crovella, 1997
- The study was performed using ns2 simulator

Heavy Tails and LRD

- f_i : frequency of i-size flows ($\propto \mathrm{P}(S = i)$)
- Heavy Tail: $f_i \sim \frac{1}{i^{(\alpha+1)}}$, tail index α

- X_i : number of packets in time interval $[i\Delta, (i+1)\Delta]$
- LRD: $\mathbb{E} X_i X_{(i+\tau)} \sim |\tau|^{2H-2}$ LRD param H



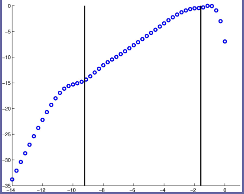


Parameters estimation

α: wavelet based method

- never used in the internet community
- efficient and robust estimation, even with small samples
- Possible to predict theoretical bounds of scaling range

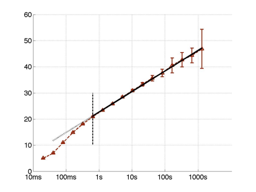
$$\log \mathbb{E}\Psi(2^j S) \sim \alpha j + \log C$$



H: wavelet based method

- massively used in the internet community
- efficient estimation
- supplies error bars

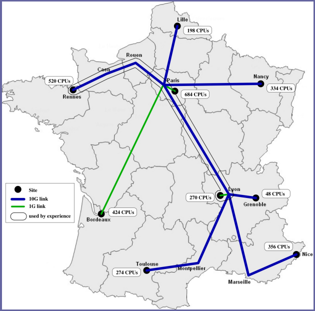
$$\mathbb{E}|\langle \psi_{j,k}, X \rangle|^2 \sim 2^{j(2H+1)}$$

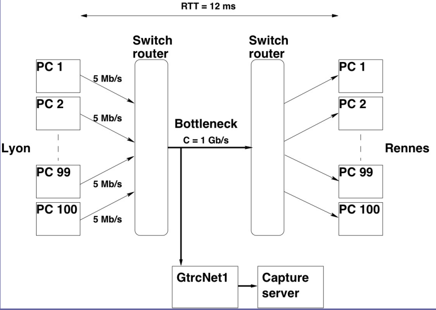


Experimental methodology

- Use a large scale facility: Grid5000
- Generate fully controlled traffic based on the ON/OFF scheme with 100 sources (with limited rate to avoid congestion)
- Impose HT flow size distributions: controlled tail index α
- Measure the aggregated traffic at packet-level on a core link
- Estimate the parameters $\widehat{H}$ and $\widehat{\alpha}$
- Study the validity domain of Taqqu's relation with respect to some potentially influent parameters:
  - the protocol used (TCP or UDP)
  - the rate limitation mechanism used (TCP, HTB, PSP)
  - the mean flow duration (mean ON period)
  - the OFF period distribution

Experimental system





- GtrcNet-1 performs 52-Bytes header extraction with 60 ns accurate timestamp on a 1 Gb/s link
- Captured headers train are processed with original tools to:
  - retrieve flow size distributions and estimate α
  - form packet count series and estimate H

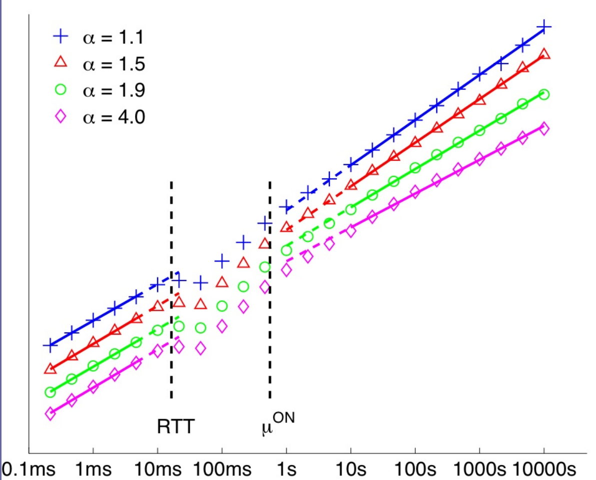
Experiments description

- Experiments time: 8 hours of stationary traffic

	Proto.	Rate limit.	α_{ON}	α_{OFF}	mean flow size	measured parameter
A	TCP	PSP HTB TCP	1.1 – 4	-	100	LRD param. $\widehat{H}$ HT param. $\widehat{\alpha}$
	UDP	iperf				
B	TCP	TCP	1.1 – 4	-	100 1000	scaling range
C	TCP	TCP	-	1.1 – 4	1000	$\widehat{H}$, $\widehat{\alpha}$
D	TCP	TCP	1.1 – 4	-	100	local regularity
	UDP	iperf				

Results – LD description

- Series A: mean flow size $= 100 \rightarrow \mu^{\mathrm{ON}} = 0.24$ s



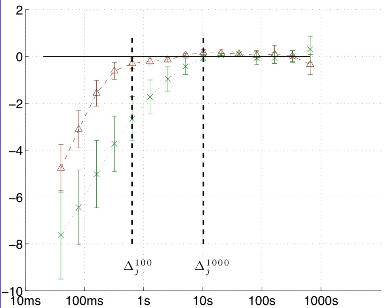
Results – coarse scaling range: the "knee"

- Series B:

  mean flow size = 100 $\rightarrow \mu^{\mathrm{ON}} = 0.24$ s

  mean flow size = 1000 $\rightarrow \mu^{\mathrm{ON}} = 2.4$ s

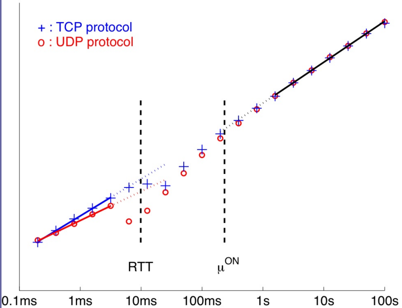
- average normalized LDs over different values of α

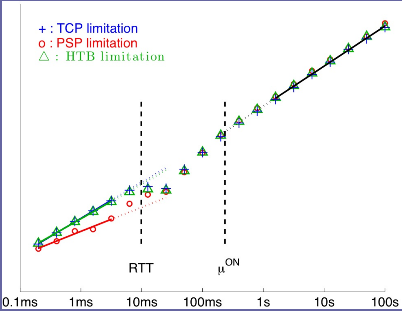


- Location of the "knee" introduced by Hohn et al., 2003

Results – Influence of the protocol and of the source rate limitation: Coarse scales

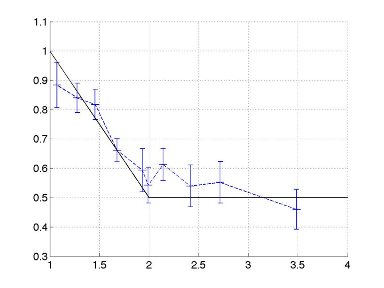
- Series A: mean flow size $= 100 \rightarrow \mu^{\mathrm{ON}} = 0.24$ s

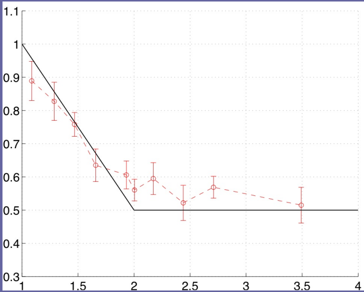




Results – H versus α_{ON}

- Series A: mean flow size $= 100 \rightarrow \mu^{\mathrm{ON}} = 0.24$ s
- With heterogeneous RTT





- Study of the relation between H and α_{ON} by Park, Kim and Crovella, 1996, on ns2

Results – H versus α_{ON}

- Series A: mean flow size $= 100 \longrightarrow \mu^{\mathrm{ON}} = 0.24$ s
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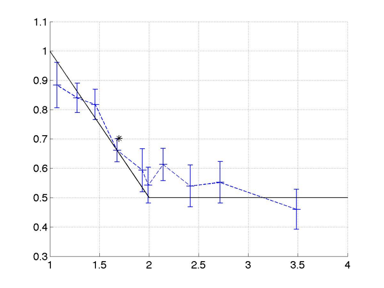
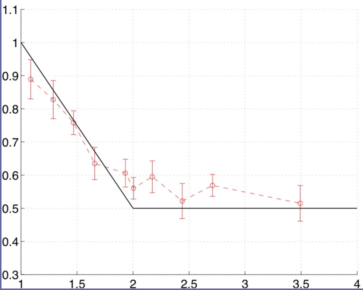
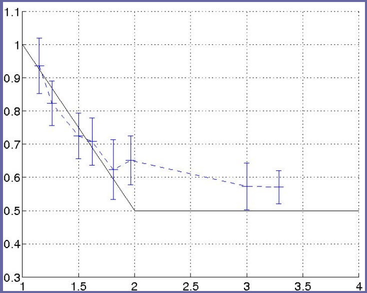




- Study of the relation between H and α_{ON} by Park, Kim and Crovella, 1996, on ns2

Results – H versus α_{OFF}

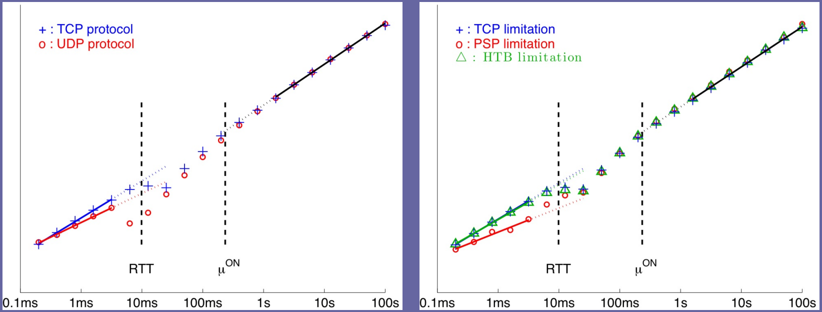
- Series C: mean flow size $= 1000 \rightarrow \mu^{\text{ON}} = 2.4$ s



- Study of the relation between H and α_{OFF} by Park, Kim and Crovella, 1996, on ns2

Results – Influence of the protocol and the rate limitation: Fine scales

- Series D: mean flow size = 100 $\rightarrow \mu^{\mathrm{ON}} = 0.24$ s



- Scaling behavior in fine and intermediate scales:

  Guo, Crovella and Matta, 2001

  Figueireido, Feldmann et al., 2005

Conclusion and future work

Conclusion:

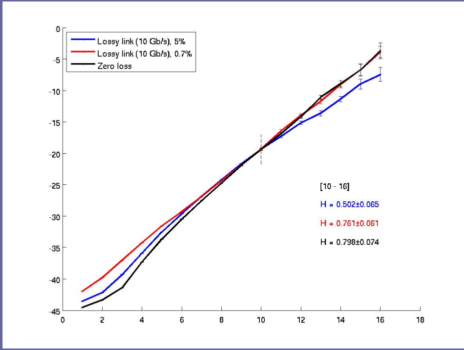
- In our experimental conditions (no congestion), Taqqu's relation between LRD (coarse scales) and HT is well verified independently of:
  - the protocol used
  - the rate limitation mechanism
- We also checked that the relation is verified when OFF periods are HT distributed instead of ON periods

Future work:

- Study Taqqu's relation in congested situations and in lossy contexts
- Study the impact of LRD on queueing delays and dynamics

Results with Loss

- mean flow size $= 1000 \rightarrow \mu^{\text{ON}} = 2.4$ s
- Lossy link with three loss rates: 0% (black), 0.7% (red) and 5% (blue)



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