Gaussian Approximation of CDN Call Level Traffic

Andrzej Bąk
Piotr Gajowniczek

Warsaw University of Technology
Faculty of Electronics & Information Technology
Institute of Telecommunications

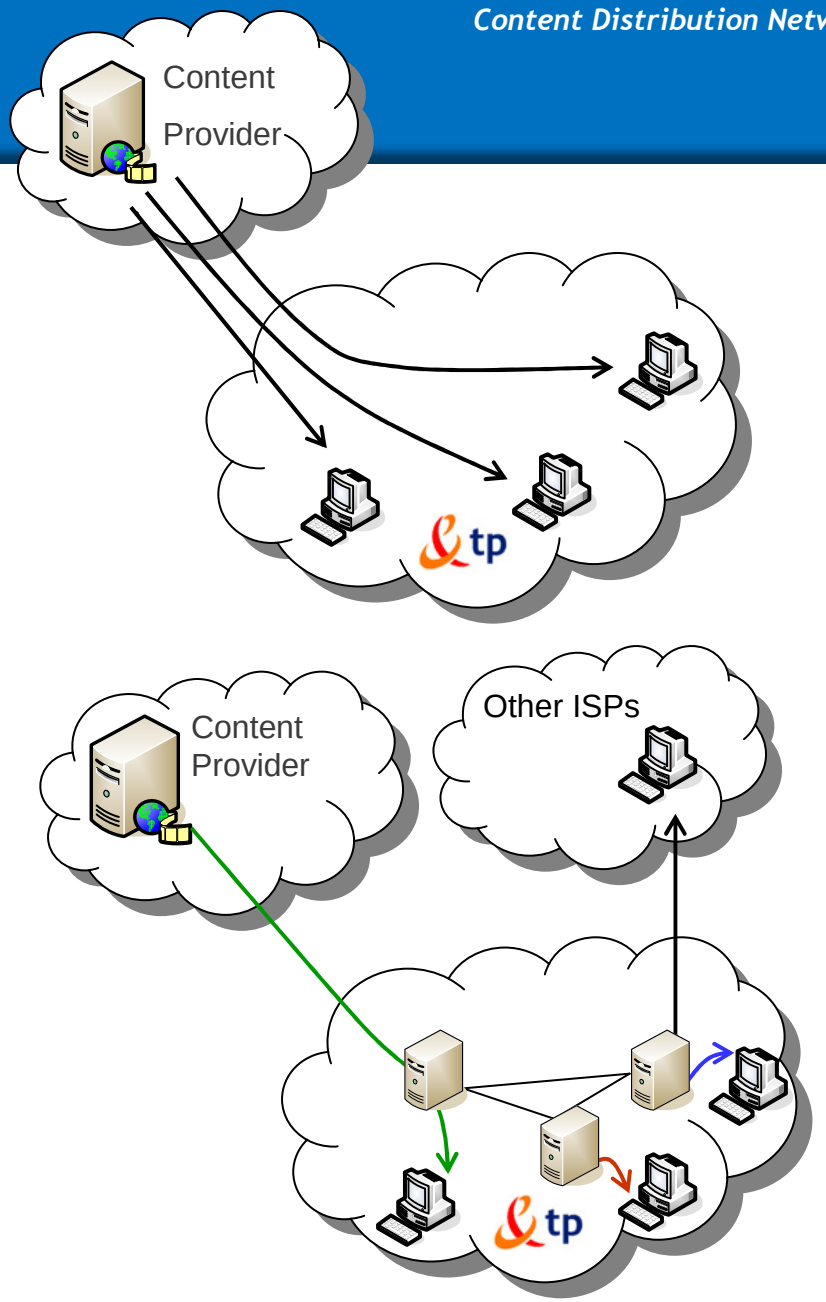
Marcin Pilarski

Orange Labs,
Telekomunikacja Polska SA

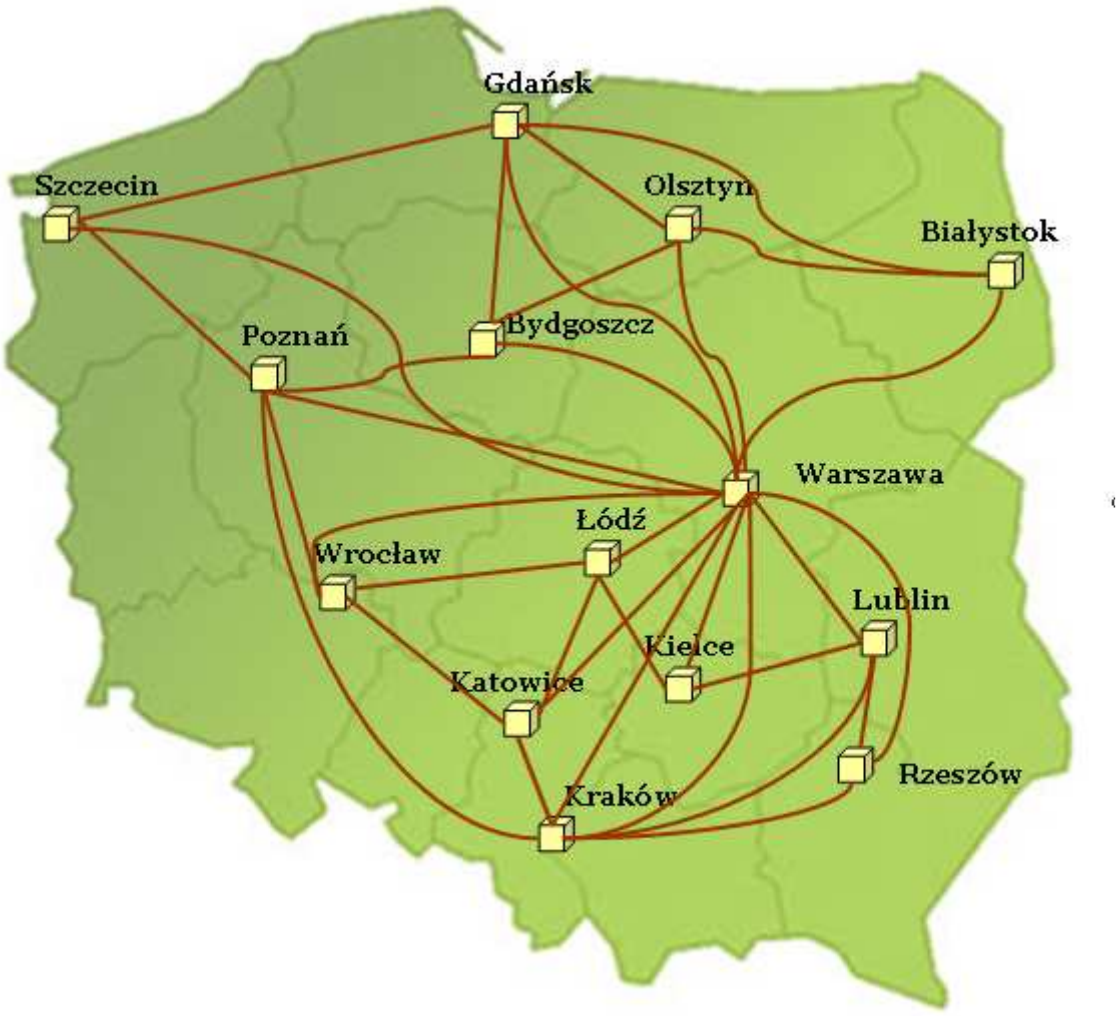
The scope of the paper:

- Analysis of the properties of the stream of requests incoming to the CDN (Content Distribution Network) – based on measurements made in the TP network
- Investigation of the applicability of Gaussian approach to modeling the CDN call level traffic

- **CDN (Content Distribution Network) - caching approach to Internet data distribution**
  - files, web pages, embedded objects …
  - video and streaming
- **CDN principle**
  - Caching infrastructure located closer to the end users
  - Data distribution and caching algorithms based on user location and content popularity
  - Requests from users routed to the optimal storage



- **CDN of Polish Telecom (Telekomunikacja Polska)**
- **Two real-life cases**
  - Upgrade of „The Witcher” game
  - Internet transmission of events related to Polish presidential plane crash



Self-similarity & LRD

- Scaling invariance of the traffic process X_i
- 2nd order self-similarity:

$$r_k^{(m)} \sim r_k \quad (1)$$

$$r_k \sim ck^{2H-1} \quad (2)$$

- *H*: (famous) Hurst coefficient

Why LRD?

- QOS impact

Traffic process

$$X_i^{(m)} = \frac{1}{m} \sum_{j=m(i-1)+1}^{mi} X_j$$

How to measure Hurst coefficient?

- Many methods (VTP, R/S, Whittle, correlation-based, wavelet-based)
- No definite estimator

R/S method

$$E\left(\frac{R_n}{S_n}\right) \sim cn^H$$

- Uses the rescaled range (R/S) statistic and its relation to Hurst parameter
- H is estimated using linear regression on the logarithmic plot of R/S for time range n versus log n

Variance-Time Plot

$$\log V^m \; vs \; \log m$$

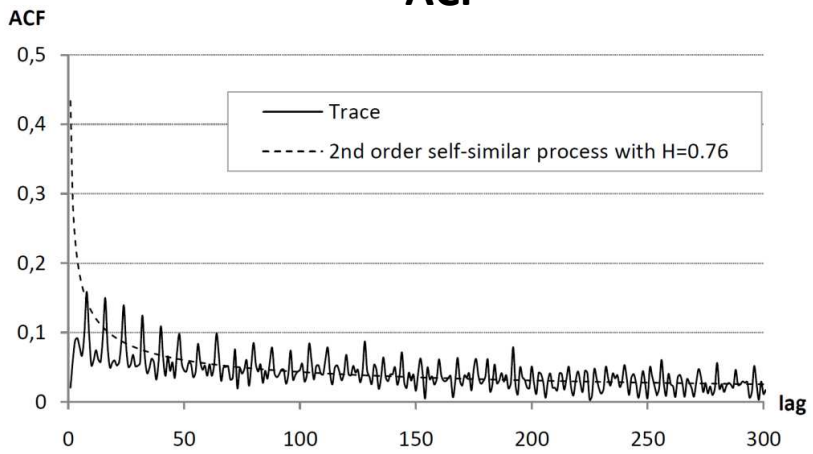
- Based on the specific behavior of variance on multiple time scales for self similar processes
- The slope of the regression line for the plot is related to Hurst parameter

Wavelet spectrum analysis

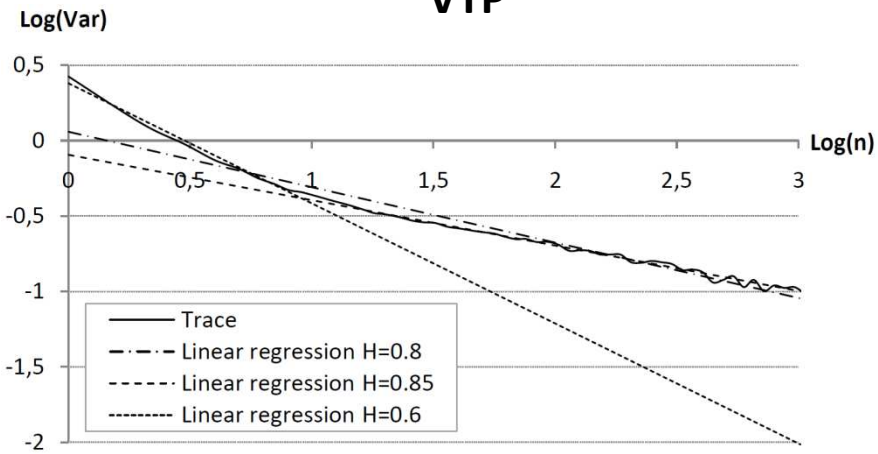
$$S_j(X) := \log_2\left(\frac{1}{N_j}\sum_{k=1}^{N_j} d_{j,k}^2\right) \sim j(2H-1)$$

- Based on the shape of the wavelet spectrum, obtained from the DWS coefficients
- H is estimated using linear regression as well

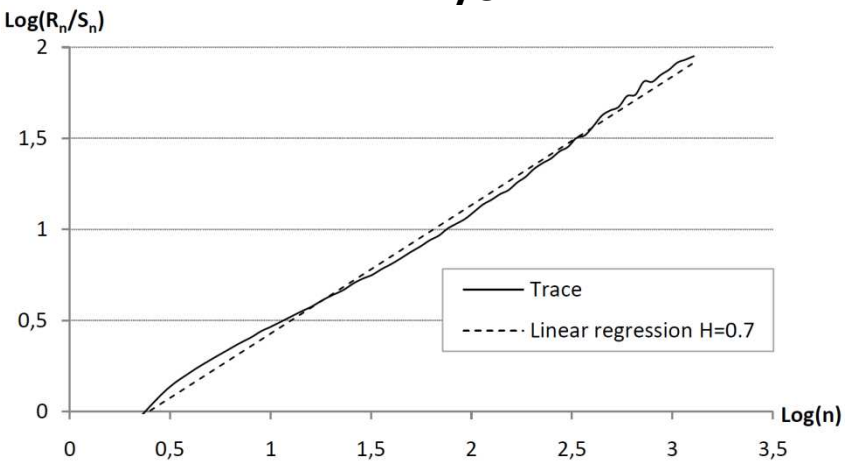
ACF



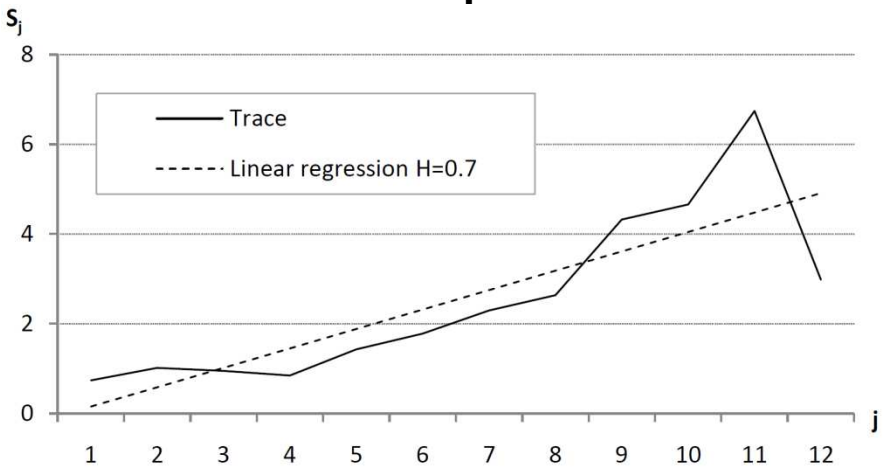
VTP



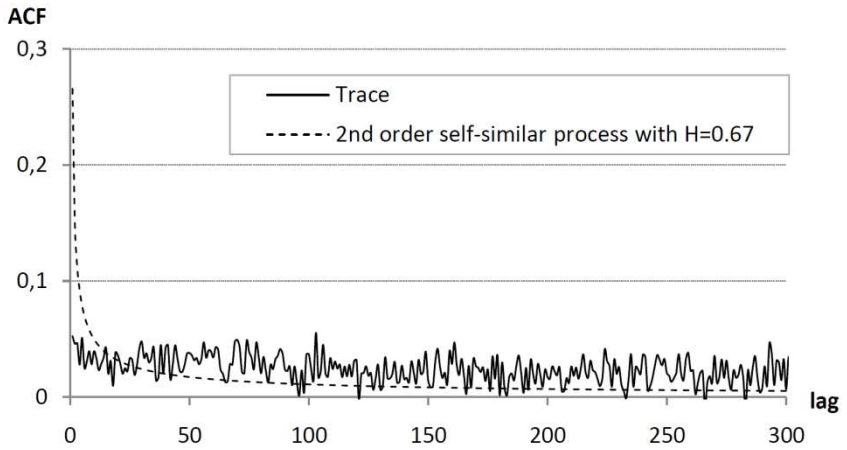
R/S



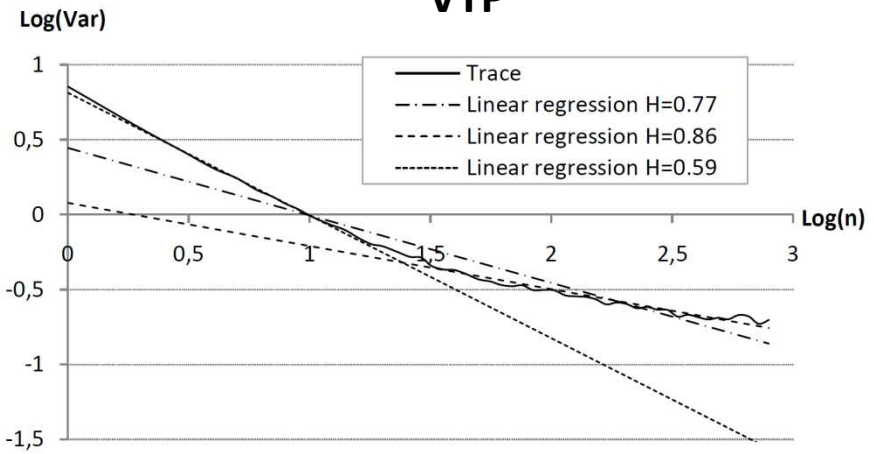
Wavelet spectrum



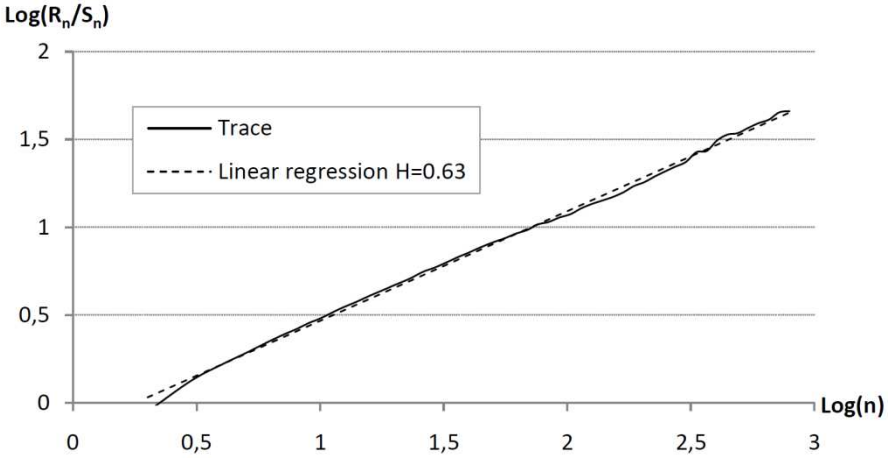
ACF



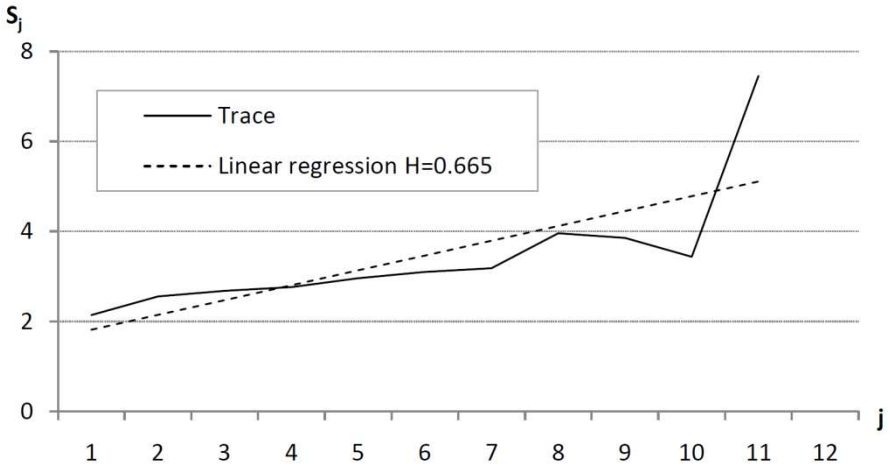
VTP



R/S



Wavelet spectrum

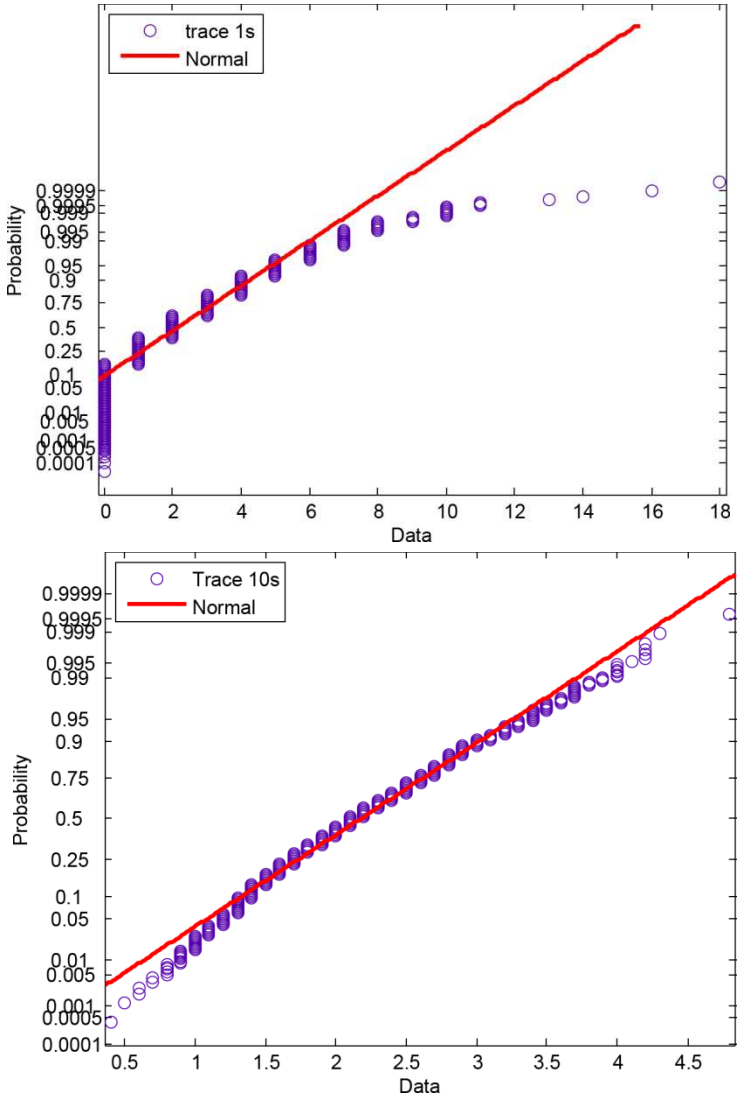


Q-Q plot
„The Witcher" data
1s and 10s aggregation

- **Gaussian model**

$$A_{s,t} = Norm\left(\lambda_{t-s}; \sigma^2_{t-s}\right)$$

- **Why Gaussian?**
  - $A_t = \sum_{i=1}^{n} A_{i,t}$
  - Correlation structure is determined only by the variance function
  - Whole spectrum of self-similar processes can be covered
  - Queueing models with analytical solution exist for Gaussian traffic
- **FGN (Fractional Gaussian Noise)**
  - Well-known incremental process with Gaussian properties
  - Can be effectively generated based on three parameters: mean, variance and Hurst coefficient

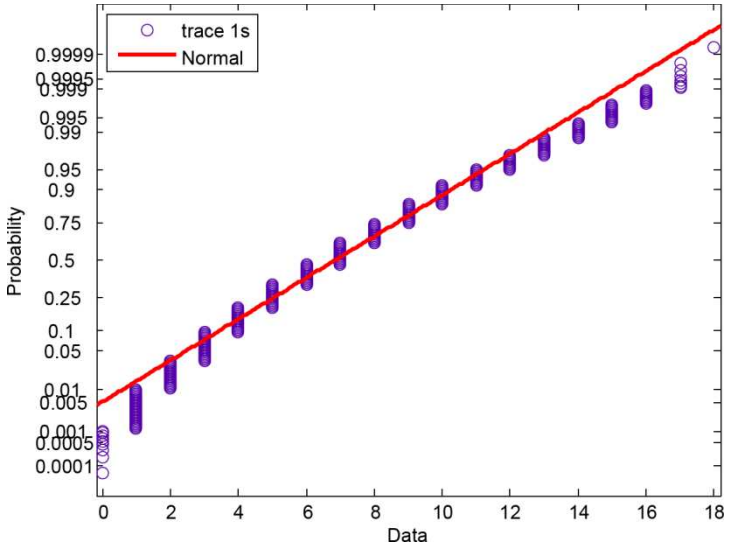


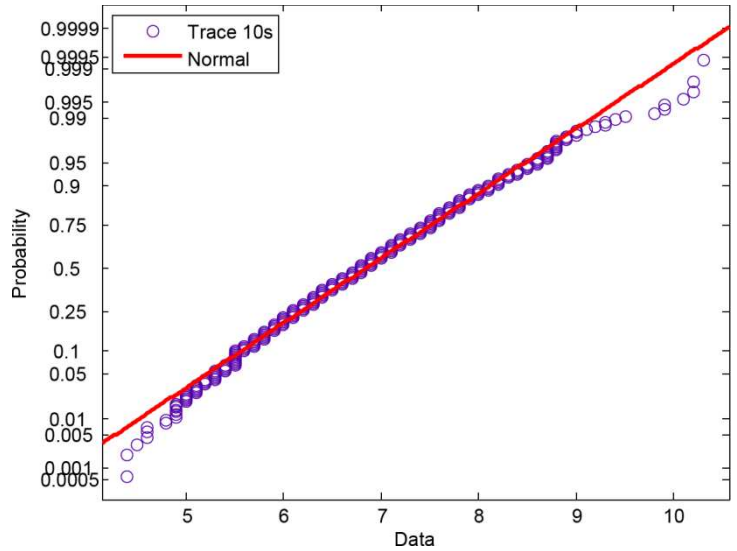
Q-Q plot
„Livestream" data
1s and 10s aggregation

- **Gaussian model**

$$A_{s,t} = Norm\left(\lambda_{t-s}; \sigma^2_{t-s}\right)$$

- **Why Gaussian?**
  - $A_t = \sum_{i=1}^{n} A_{i,t}$
  - Correlation structure is determined only by the variance function
  - Whole spectrum of self-similar processes can be covered
  - Queueing models with analytical solution exist for Gaussian traffic
- **FGN (Fractional Gaussian Noise)**
  - Well-known incremental process with Gaussian properties
  - Can be effectively generated based on three parameters: mean, variance and Hurst coefficient



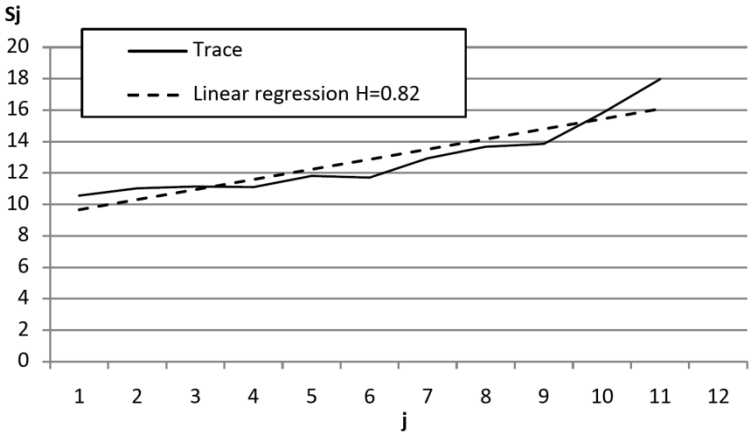


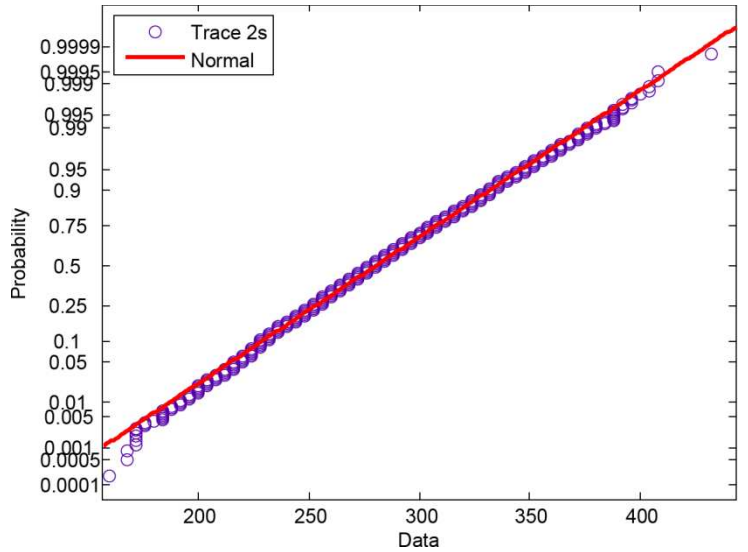
Q-Q plot
Compound stream
2s aggregation

- **Gaussian model**

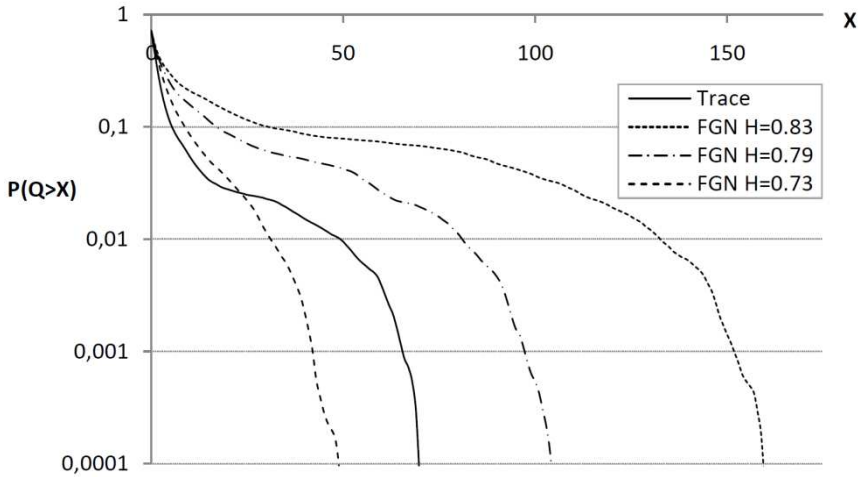
$$A_{s,t} = Norm\left(\lambda_{t-s}; \sigma^2_{t-s}\right)$$

- **Why Gaussian?**
  - $A_t = \sum_{i=1}^{n} A_{i,t}$
  - Correlation structure is determined only by the variance function
  - Whole spectrum of self-similar processes can be covered
  - Queueing models with analytical solution exist for Gaussian traffic
- **FGN (Fractional Gaussian Noise)**
  - Well-known incremental process with Gaussian properties
  - Can be effectively generated based on three parameters: mean, variance and Hurst coefficient

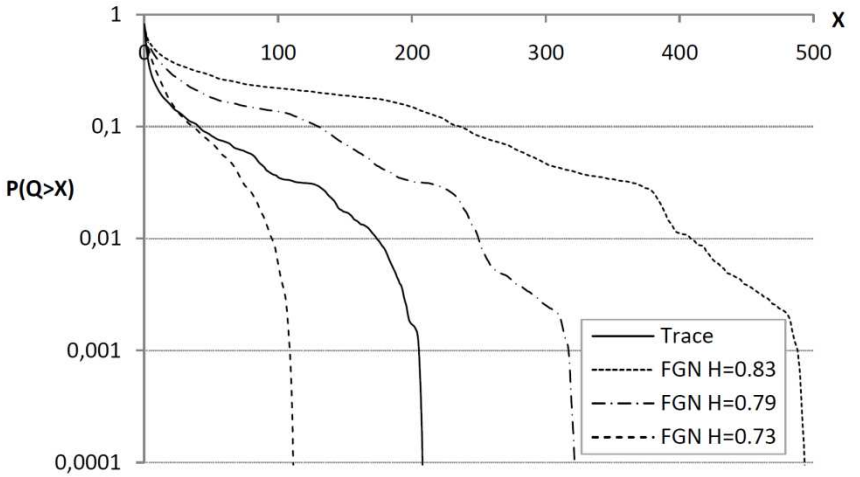




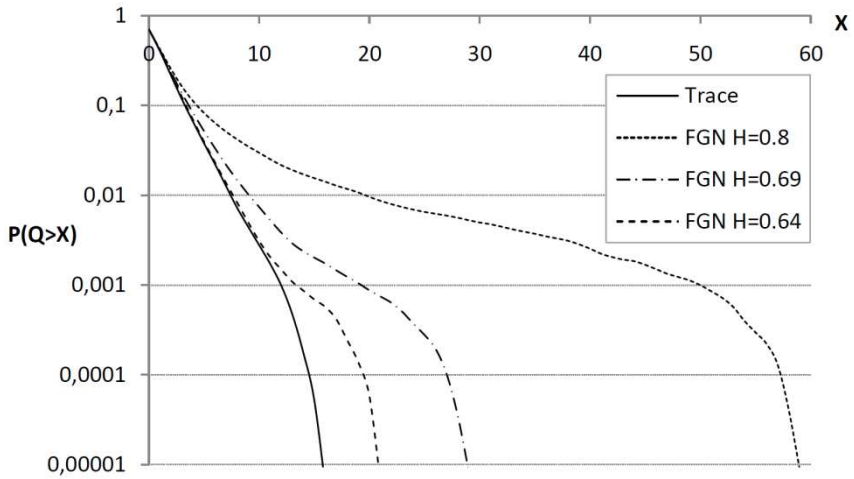
„The Witcher" trace, load factor 0.7



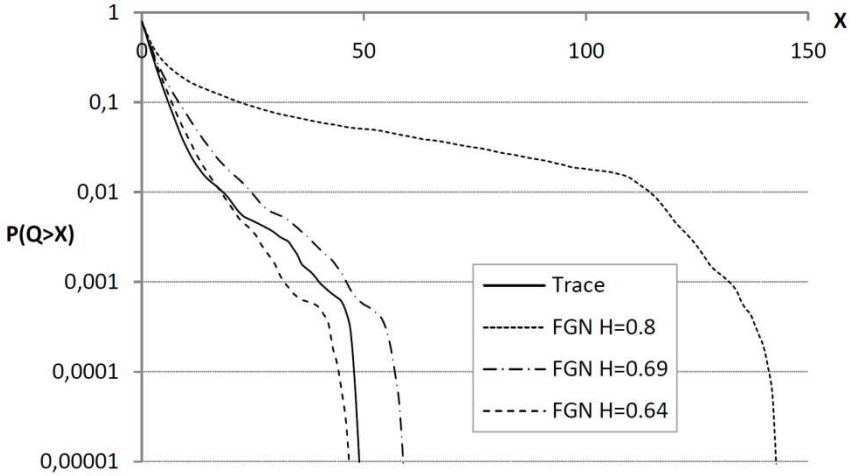
„The Witcher" trace, load factor 0.8



„Livestream" trace, load factor 0.7



„Livestream" trace, load factor 0.8



- We have investigated the properties of the stream of cache retrieval requests incoming to the CDN on the base of measurements
- The traces that were analyzed are self-similar & long range dependent, so there's a need to use appropriate traffic models that are able to take these properties into account
- We have investigated the Gaussian properties of the analyzed traffic to justify the use of Gaussian traffic models for CDN call level traffic

Thank you for your attention