Universidad Pública de Navarra

Characterizing Internet Load as a Non-regular Multiplex of TCP Streams

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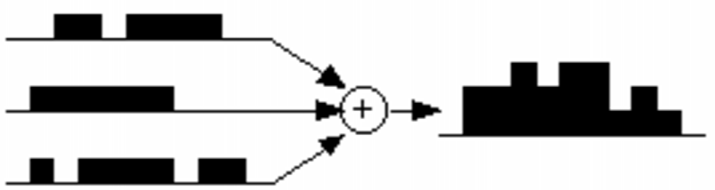
Statement of the problem

1: Most Internet traffic due to TCP

2: Interest in modeling Internet traffic as a multiplex of TCP connections [Willinger, Taqqu, Paxson, Crovella, Tsybakov, Georganas]

3: Common assumptions of previous models:

- Poisson arrivals
- Heavy-tailed size and duration
- ***Constant rate***

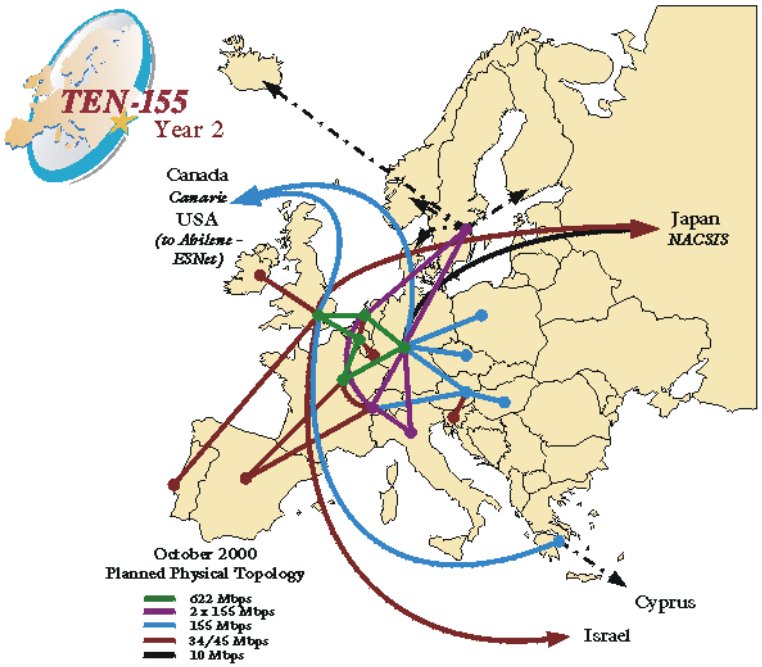


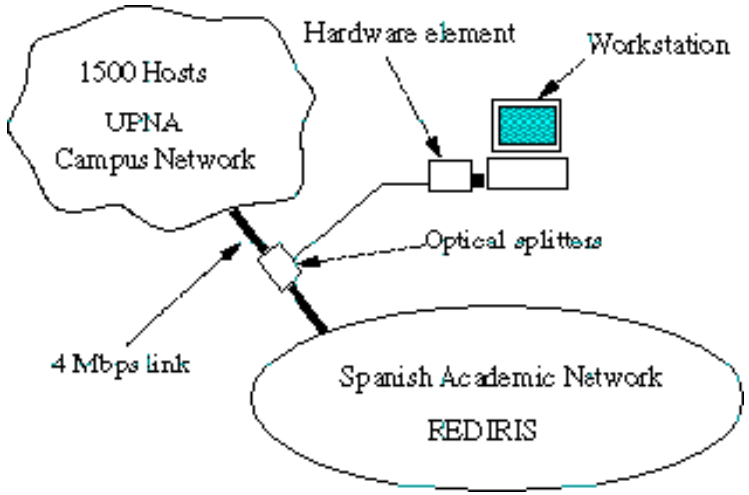
4: The resulting process is Self Similar

Methodology

Measurement tool and scenario

- Analysis and monitoring probe for OC-3 IP over ATM link





- ATM PVC 4 Mbps CBR
- European Network and links to USA

Methodology

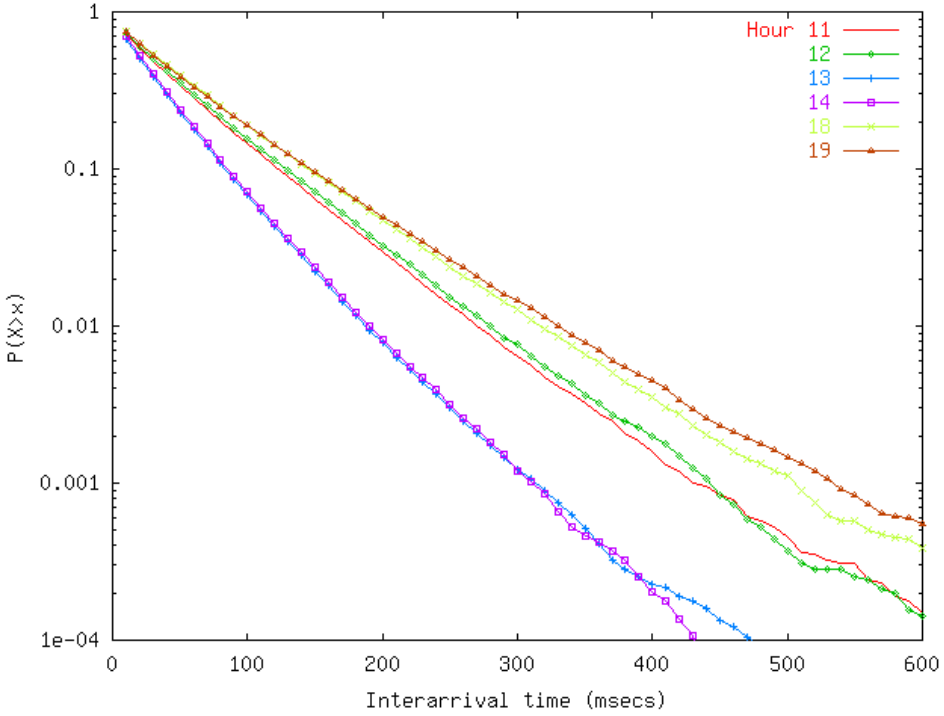
Trace characteristics

- One day worth of data: Monday 02/14/2000
- More than 1 million TCP connections
- More than 1 thousand users
- Access link is not the bottleneck

Assumption #1: Connection arrival process, Poisson?

- Stationarity?
  - No, hourly intervals
- Best model?
  - Independent users
  - Exponential interarrival times

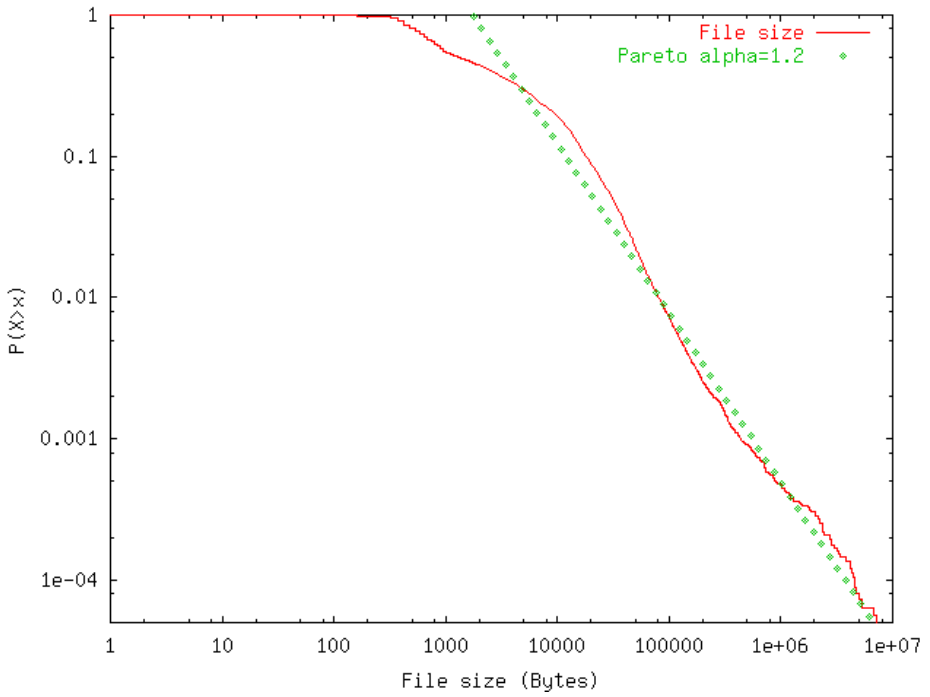
$$\log P(X > x) = -\mu x$$



Assumption #2: Connection size, heavy-tailed?

- Tail: $\alpha \approx 1.2$
- Infinite variance of file sizes
- Heavy tailed

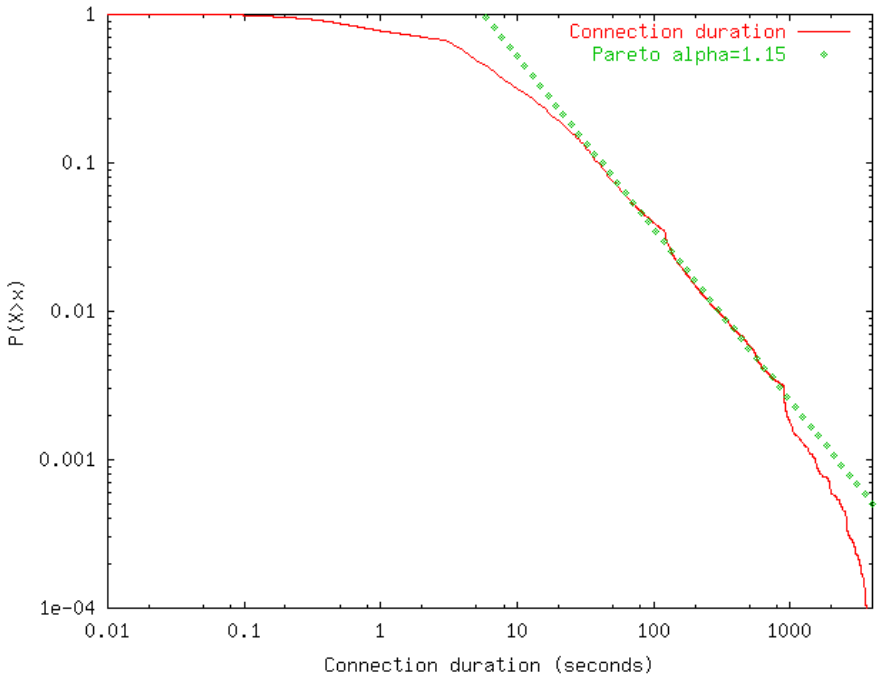
$$\log P(X > x) = -\alpha \log x$$



Assumption #3: Connection duration, heavy-tailed?

- Tail: $\alpha \approx 1.15$
- Infinite variance
- Greater variability
  - TCP dynamics
  - Packet loss

$$\log P(X > x) = -\alpha \log x$$

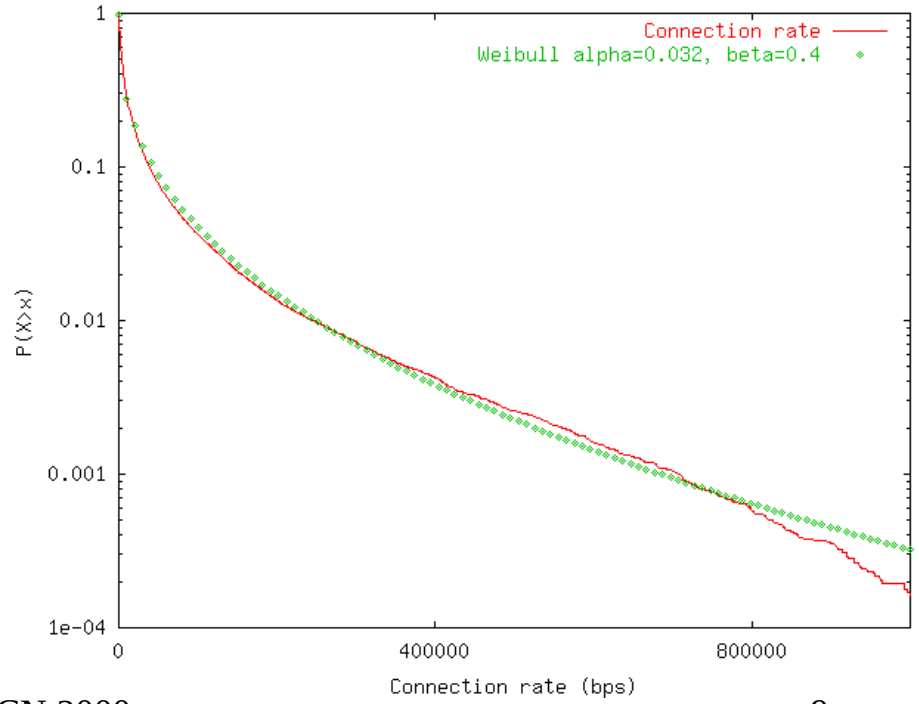


Assumption #4: Connection rate, constant?

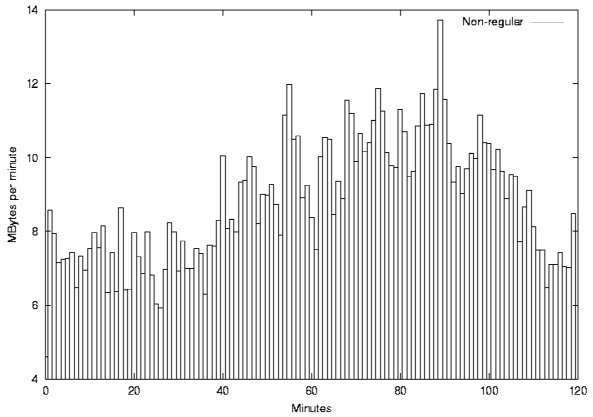
- Rate = $\frac{\text{Bytes transferred}}{\text{Connection duration}}$

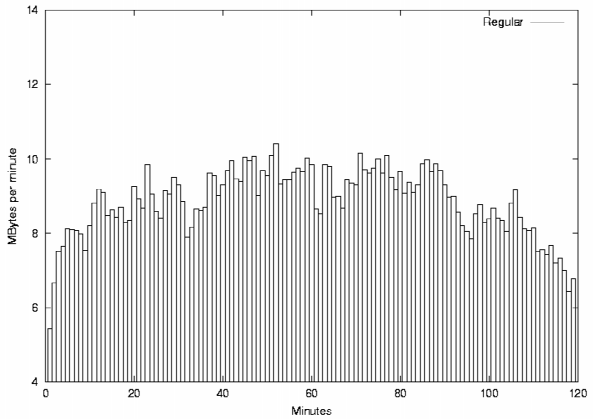
$$\log P(X > x) = -\alpha x^{\beta}$$

- Not heavy tailed
  - Size and duration correlated
- Weibull distribution



Is this significant?





- Factors that affect queueing performance:
  - Correlation: well modeled with constant rate assumption
  - Variance of the marginal distribution: optimistic estimation with constant rate
- For FBT:

Hurst parameter

$$P(X > x) \sim exp\left(-\frac{(C-m)^{2H}}{2k(H)^2 am} x^{2-2H}\right)$$

Variance coefficient

Proposal of a new model for Internet traffic as a multiplex of TCP connections

Regular model

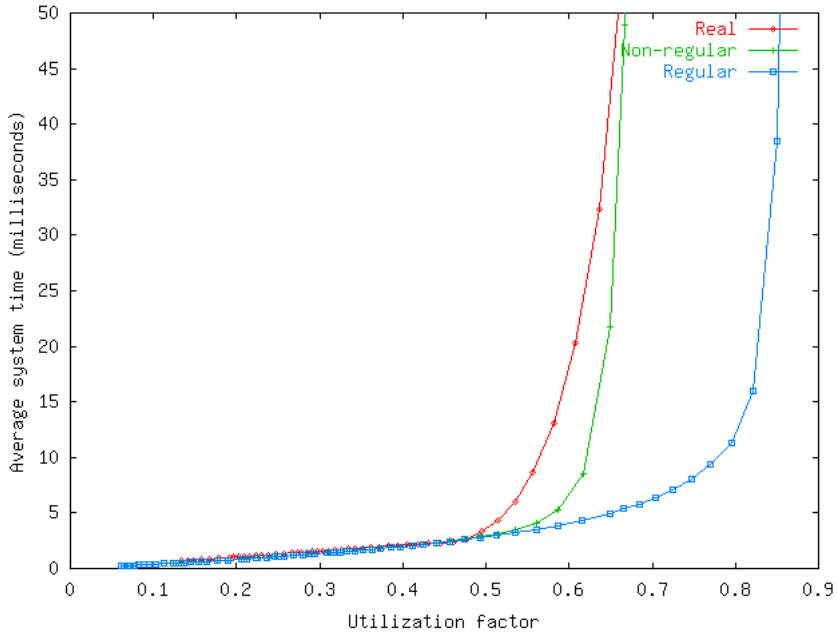
- Poisson arrivals
- Heavy-tailed duration
- *Constant rate*

Non-regular model

- Poisson arrivals
- Heavy-tailed duration
- *Weibullian rate*

Model performance

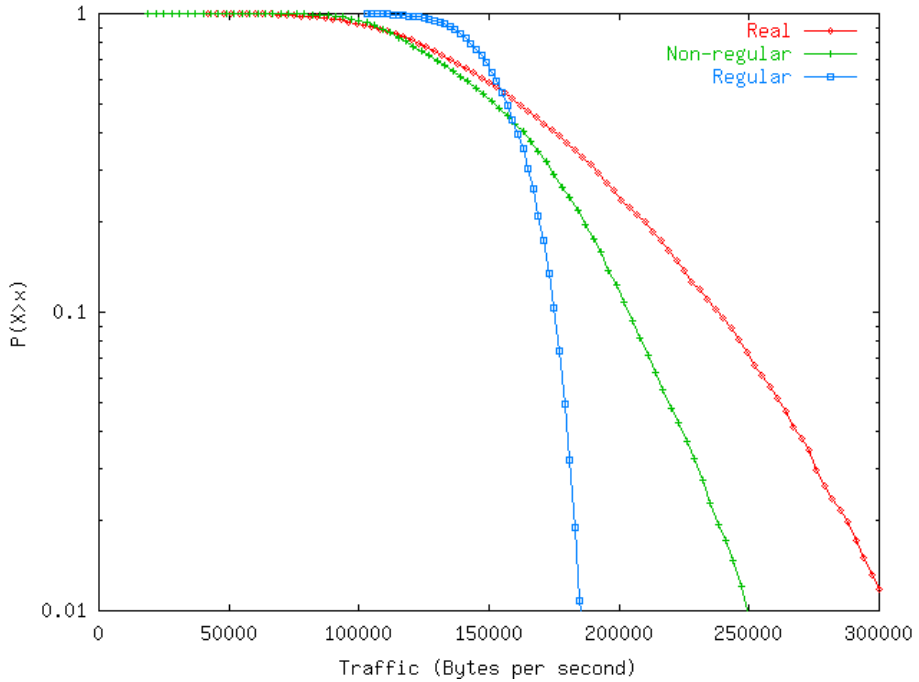
- Real arrival times and connection duration
- Regular: Constant rate
  - Optimistic
- Non-regular: Real rate
  - Performance drop
- Real: Original data trace



Proposed model follows closely real-trace performance

Discussion

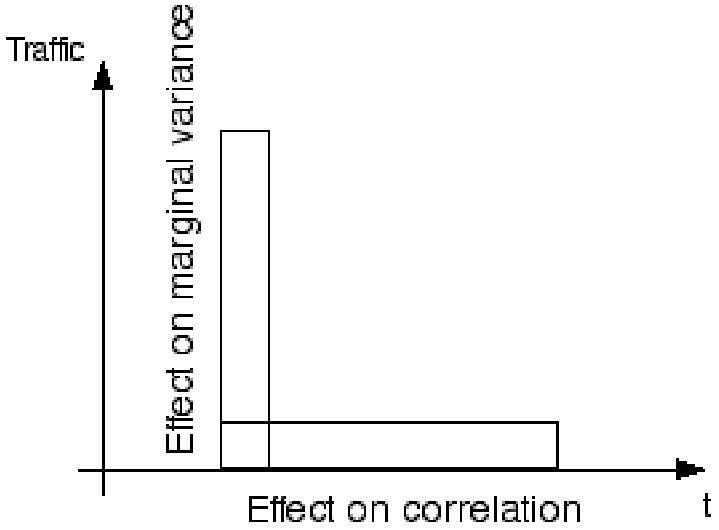
- Server under SS-input.
- Queue size depends on:
  - H (correlation structure)
  - Marginal distribution:
    - Mean
    - Variation coefficient



- **Proposed model has a marginal distribution closer to the experimental one.**

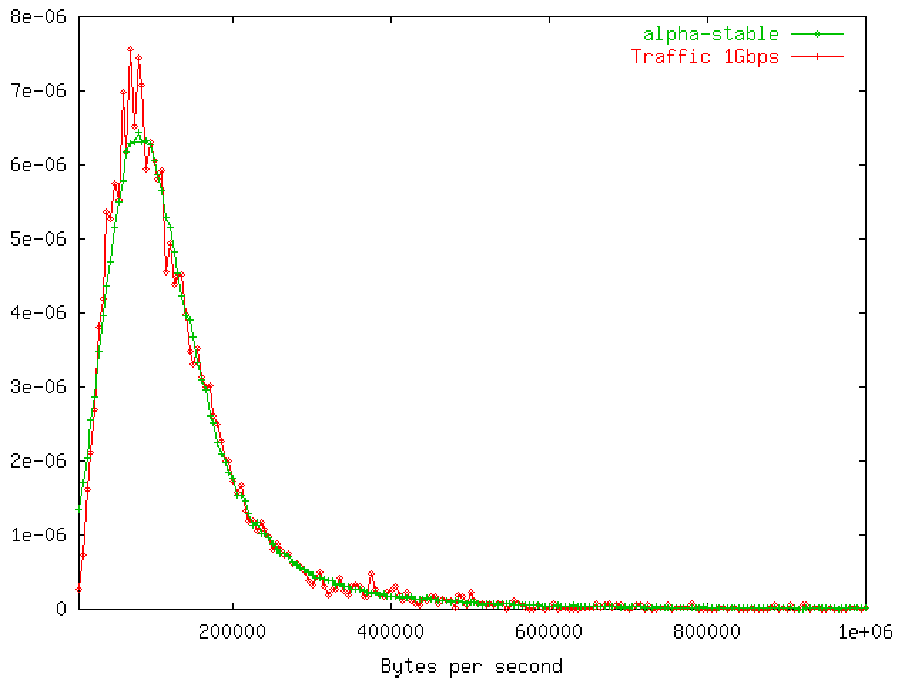
Evolution of Internet traffic

- Internet performance depends on LRD and marginal distribution variability
- New optical technologies give Tbps with burst transfer modes
- LRD fades away
- Marginal distribution will be the limiting factor



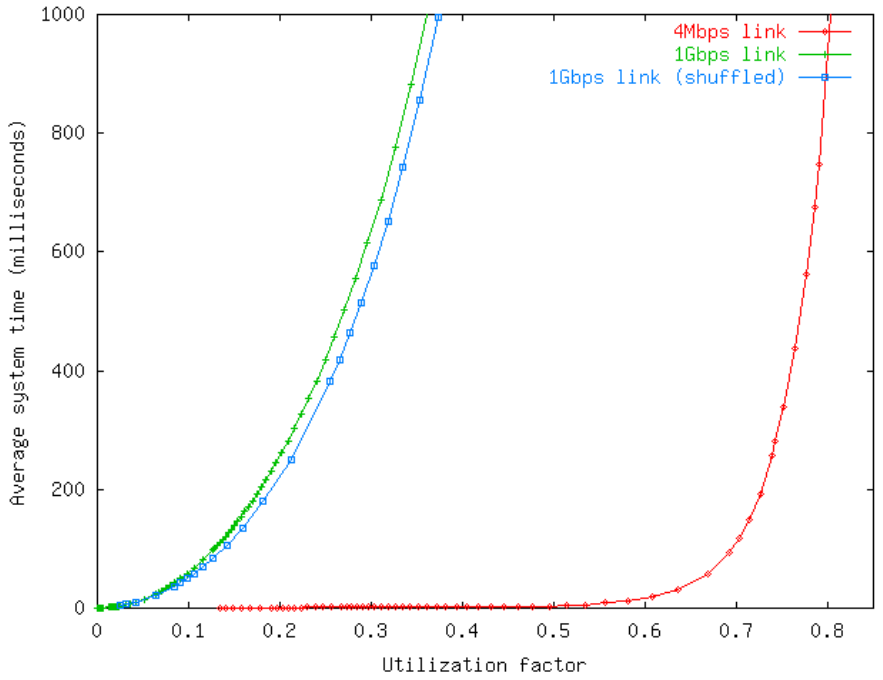
Evolution of marginal distribution

- Connection trace in a 1 Gbps link
- α-stable non-gaussian marginal
- Small connection durations
- Infinite variance due to heavy-tailed file sizes



Correlation ⟷ Variability

- Short durations and Poisson arrivals gives Independent increments
- Burstiness due to marginal distribution



Conclusions

- Internet traffic presents higher variability in the marginal distribution than the one predicted by constant rate models
- New model: multiplex of TCP connections with no constant rate
- Performance closer to real traffic
- In hypothetic high-speed burst-switching scenario variability is the limiting factor