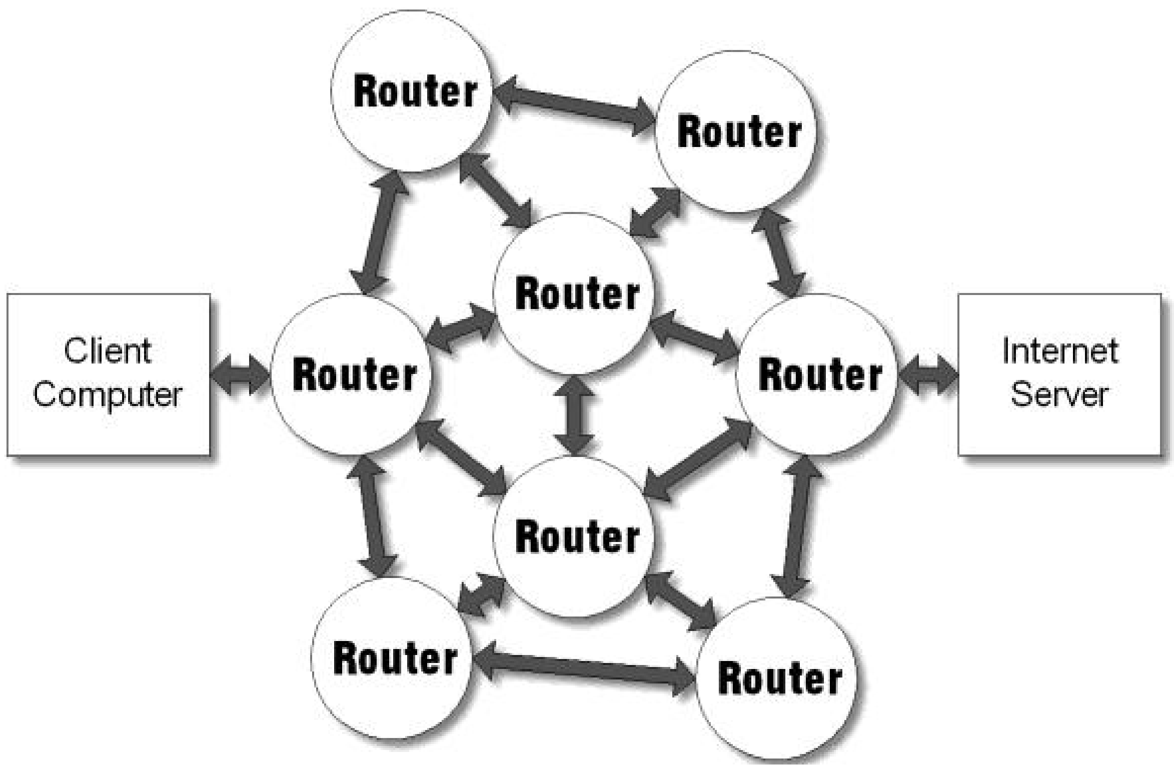
Modeling of telecommunications network traffic

Traffic statistics are important for

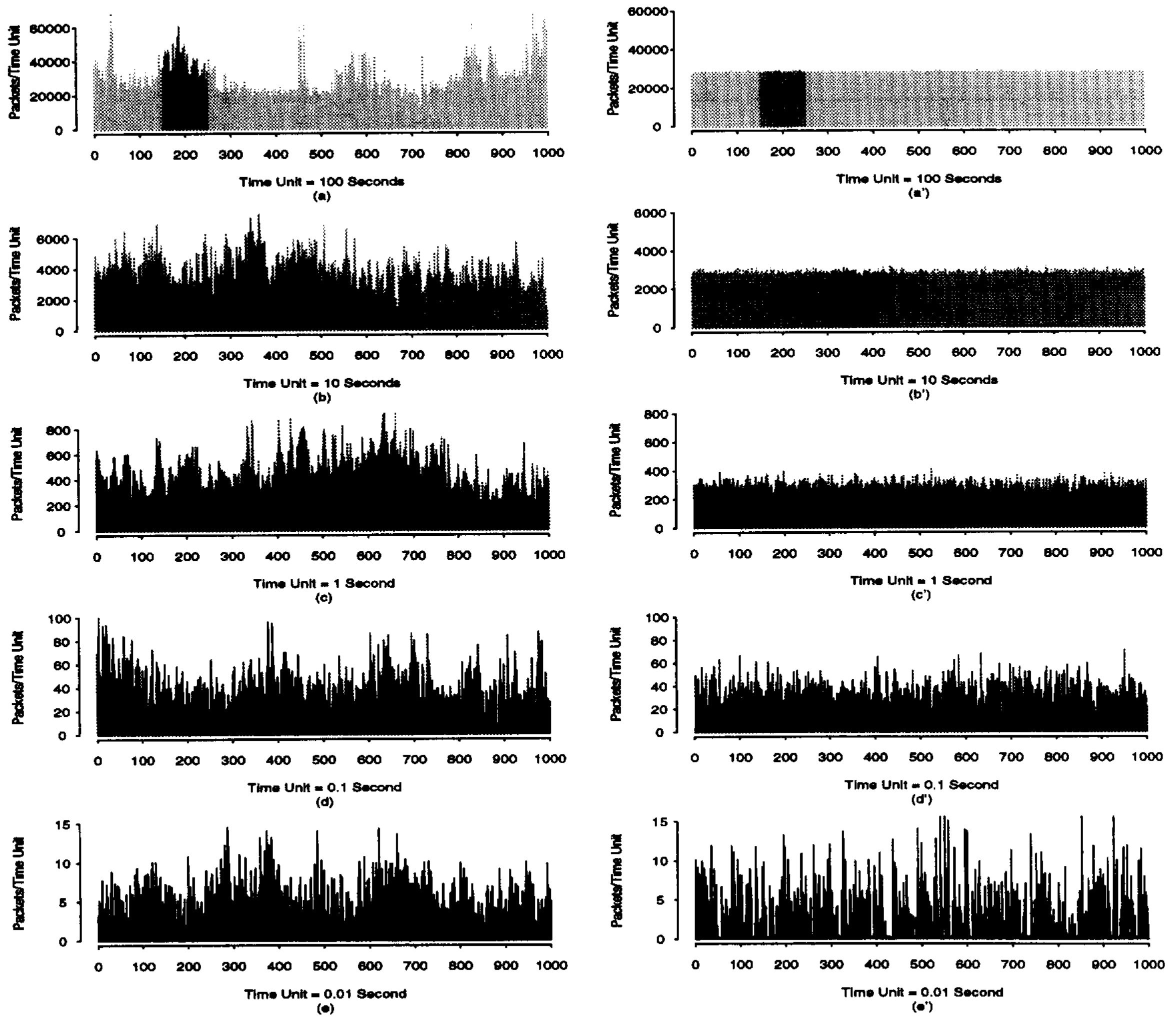
- evaluating performance of a network
- ensuring quality of service
- the design and sizing of electronic processing and switching systems



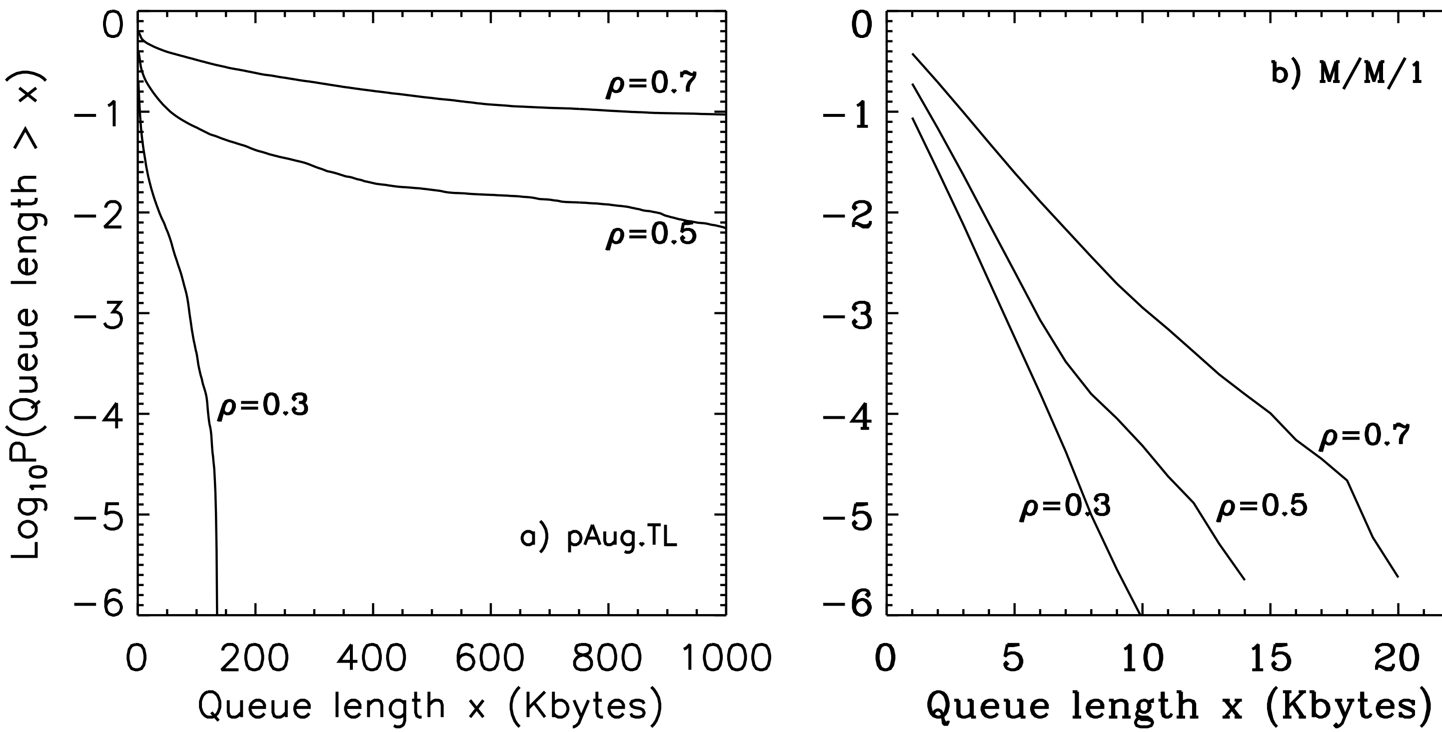
- Throughput
- Delay
- Delay jitter
- Packet loss prob.

What is “Fractal Traffic”? varies over many or all time scales

Left: real traffic; right: Poisson model (Leland et al. (1994))



Failure of Poisson modeling



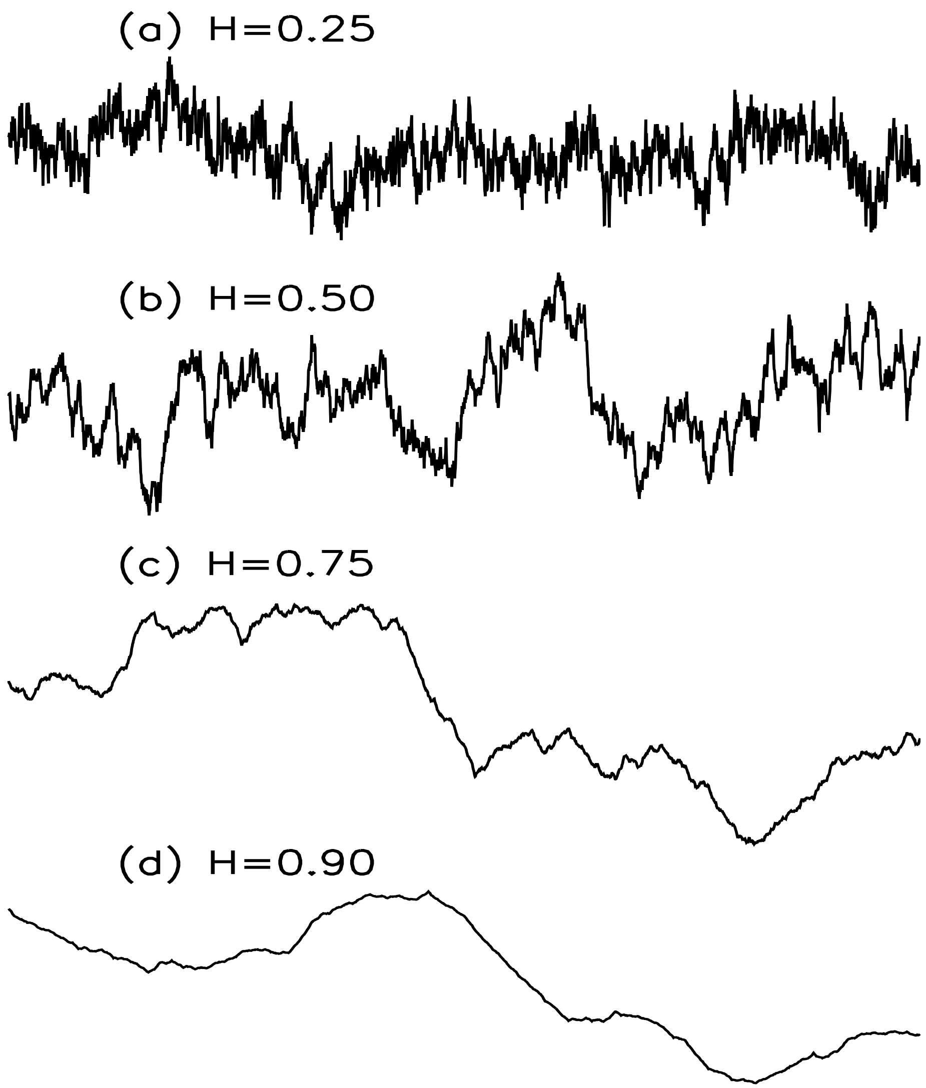
When the buffer size is q_0, then Prob(Queue length $>$ q_0) estimates the packet loss probability; Queue size$/C$ + service time = delay

Poisson modeling underestimates buffer size, packet loss probability, or packet delay time by several orders of magnitude !!!

Fractional Brownian motion (fBm) $B_H(t)$

- Gaussian process with mean 0 & stationary increments
- Variance:
$$E[(B_H(t))^2] = t^{2H}$$
- Power spectral density
$$f^{-(2H+1)}$$
- H: Hurst parameter.
$1/2 < H < 1$: long memory (long-range-dependence (LRD))
$H = 1/2$: standard Brownian motion
$0 < H < 1/2$: anti-persistence
- Applications to a wide range of problems (including Hollywood movie making—fancy landscape)

Examples of fBm processes with different H

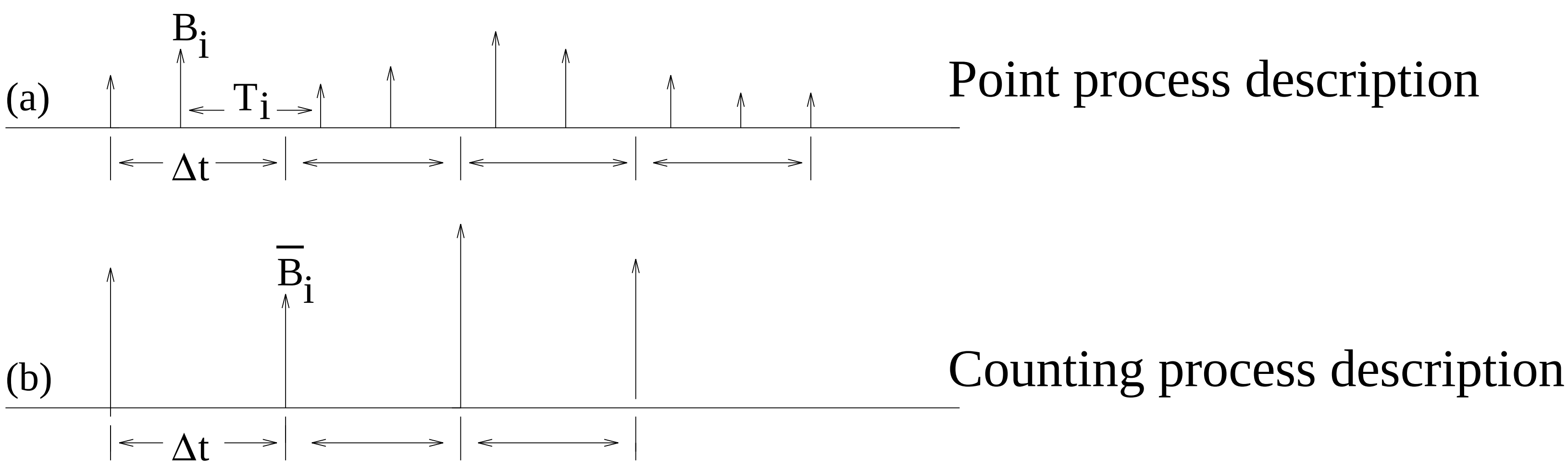


Ubiquity of $1/f$ processes

- Many old references can be found in Press (1978), Bak (1996), Wornell (1996) **(Voss: $1/f$-music)**
- Increment process $\{x_1, x_2, \cdots, x_n\}$: power spectral density $f^{-(2H-1)}$;
  Random walk process $\{y_n\}$, $y_n = \sum_{i=1}^{n} x_i$, $f^{-(2H+1)}$
  — H Hurst parameter
- Kolmogorov's turbulence energy spectrum $E(f) \sim f^{-(2H+1)}$, $H = 1/3$
- Engineering: noise in device; network traffic; power-outage
- Human cognition & coordination; DNA sequence; distribution of prime numbers; multistable visual perception; neuron inter-spike interval data (——, draw a line with the same length—error sequence is a $1/f$ process)
- **Mechanism for $1/f$ processes?**

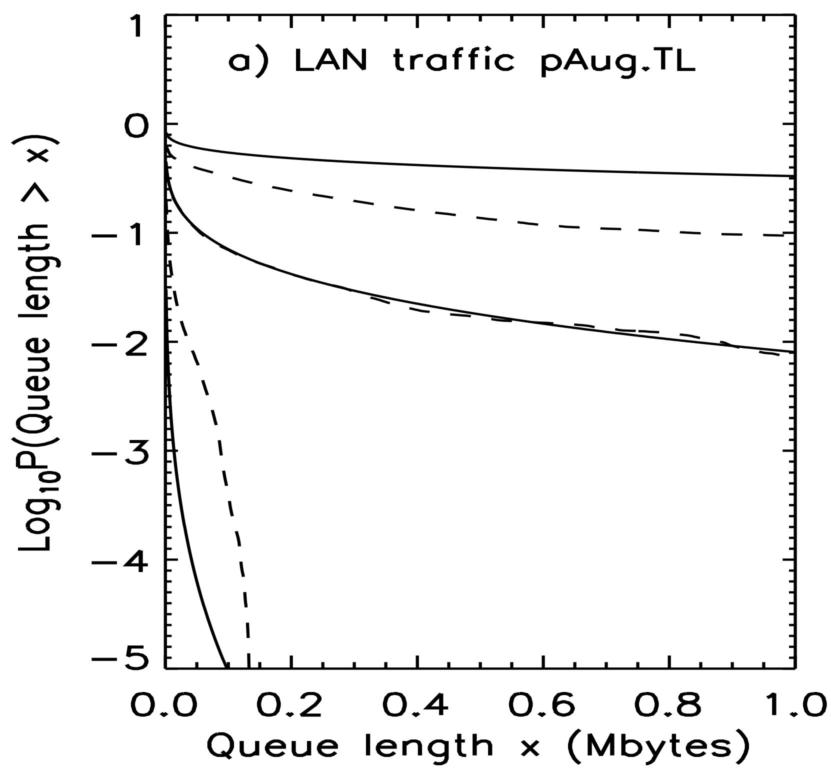
Modeling LRD traffic by the fBm process

- fBm is used to model counting process of network traffic
  - The mean traffic loading to a network in each time slot Δt is m
  - The variation of traffic around m is modeled by fBm
- Two parameters are involved: H and a variance coefficient characterizing how significant this variation around the mean level is



Performance of the fBm model as a long-range-dependent traffic model

(Gao & Rubin)



Better than Poisson model. But much room for further improvement!

(Monofractal models are not sufficient)