Treating Traffic Asymptotics with Care

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Main Message

Why do we care about traffic asymptotics (limit)?

- use traffic limit as an approximate model for the traffic

However, using the traffic limit as a model MAYNOT ALWAYS be appropriate.

- queueing property of the traffic may not be approximated by that of the limit

When we can use the limit as an approximation depends on the nature of our study.

Why?

- difference between the traffic and its limit may become significant depending on the nature of the study
- queueing: exchange of the limit condition and the queueing functional may not hold

We will illustrate this using two examples.

Traffic Limit 1: Fractional Brownian Motion (FBM)

Packet traffic is asymptotically self-similar and long-range dependent.

- Ethernet LAN *(On the Self-Similar Nature of Ethernet Traffic, Leland et. al, 1994)*
- Internet traffic, video traffic

Theoretical justification: superposition of n on-off processes.

- if we superpose n on-off processes with heavy-tailed on/off time, then the cumulative packet count process tends toward FBM when $n \to \infty$ AND THEN cumulative time scale $\to \infty$. *(Proof of a Fundamental Result in Self-Similar Traffic Modeling. Taqqu et. al, 1997)*
- delicacy of limits: a limit of stable Levy motion when cumulative time scale $\to \infty$ AND THEN $n \to \infty$

Queueing property of the superposed traffic $\overset{n\to\infty}{\not\Longrightarrow}$ queueing property of a FBM, for a queue of constant service rate, with fixed utilization and a buffer size scales with n.

- queue size of a FBM input process: Weibullian tail (*Norros, 1994*)
- queue size of the superposed traffic of n on-off processes as $n \to \infty$: tail behaviour ONLY depends on the on-time distribution
  (Overflow behavior in queues with many long-tailed inputs. M. Mandjes and S. Borst, 2000)
  - light-tailed on-time, heavy-tailed off time: exponential tail
  - Pareto on-time: Pareto tail

Traffic Limit 2: Poisson Arrival with Independent Sizes

Internet packet arrivals tend toward Poisson with independent sizes with increasing statistical multiplexing (superposition). Long-range dependence (LRD) of Internet traffic dissipates with superposition.

- empirical study of 2526 Internet packet header traces (*Cao et al. 2001, 2002*)
- superposition theorem of marked point processes (*Daley and Vere Jones, 1988*)

Internet traffic can not necessarily be substituted by Poisson traffic.

- example: packet count process not independent, fixed correlation function
- why: diminishing LRD component of packet arrivals brings back a non-diminishing dependence of packet counts due to increased packet aggregation

Queueing property of the superposed traffic from n i.i.d. packet arrival processes
Let *BEP* be the buffer exceedance probability. For a queue with constant service rate,

- fixed utilization and buffer size (*Cao and Ramanan 2002*)
  BEP(superposed traffic) $\overset{n\to\infty}{\Longrightarrow}$ *BEP*(Poisson, independent sizes)
- fixed utilization, buffer size scales with n:
  BEP(superposed traffic) $\overset{n\to\infty}{\not\Longrightarrow}$ *BEP*(Poisson, independent sizes)
  (but rather depends on the traffic characteristic of a single source traffic)
  (*Botvich+Duffield 95, Courcoubetis+Weber 98, Likhanov+Mazumdar 98, Simonian+Guibert 95, Mandjes+Borst 00*)

Conclusion

- be careful when using traffic asymptotic limit as a model
- model the traffic itself rather than using the limit
- check whether the queueing property of the traffic match that of the model