Series Editor
Guy Pujolle

Deterministic Network Calculus

From Theory to Practical Implementation

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Marc Boyer
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Color section

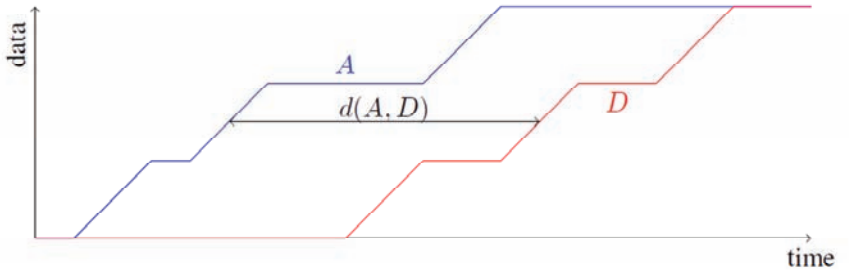


Figure I.3. *Delay from the cumulative functions*

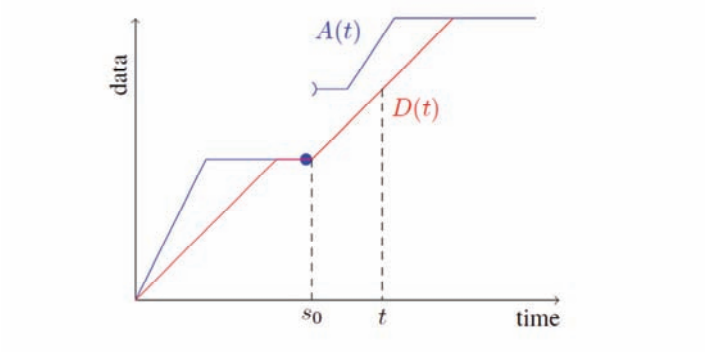


Figure 1.3. *Input/output relation for a constant-rate server*

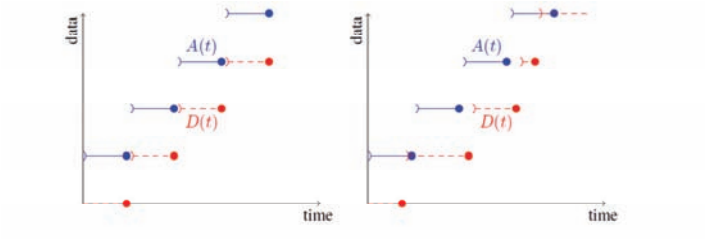


Figure 1.5. *Non-determinism of the server*

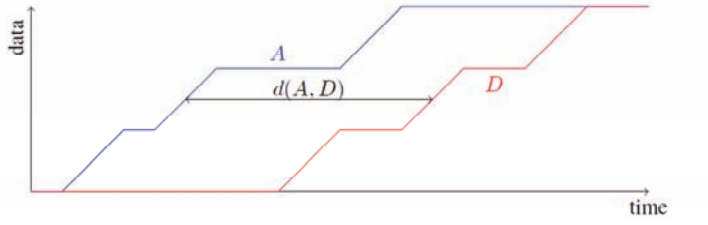


Figure 1.6. *Illustration of delay*

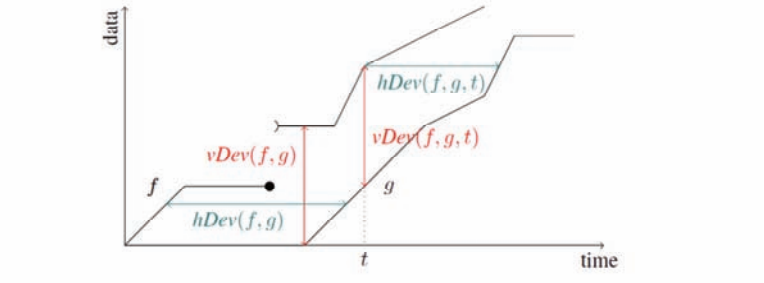


Figure 1.7. *Horizontal and vertical deviations*

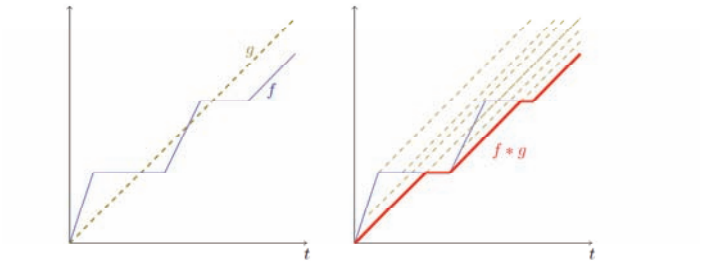


Figure 2.1. *The convolution can be obtained by sliding one function over the other: g (dashed) slides over f (plain). The minimum hull (thick) is f ˚ g*

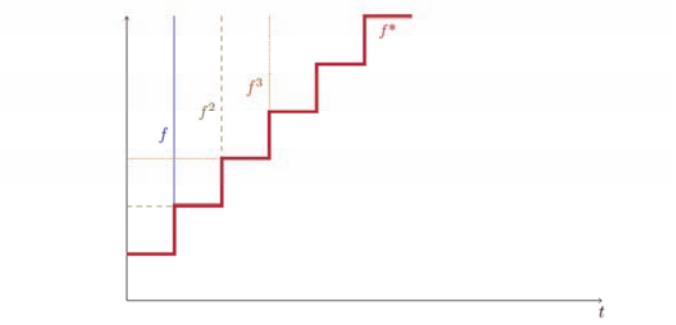


Figure 2.2. *Computation of the sub-additive closure of a function*

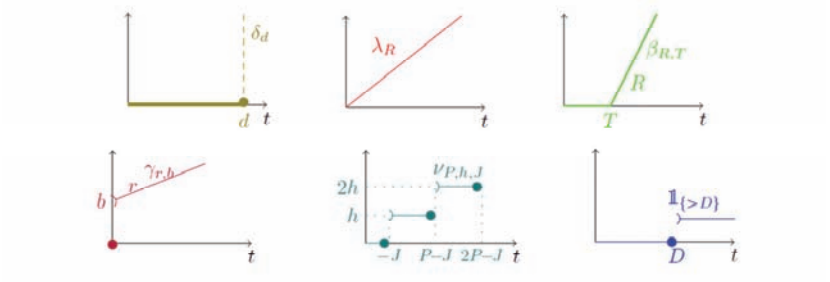


Figure 3.1. *Usual functions*

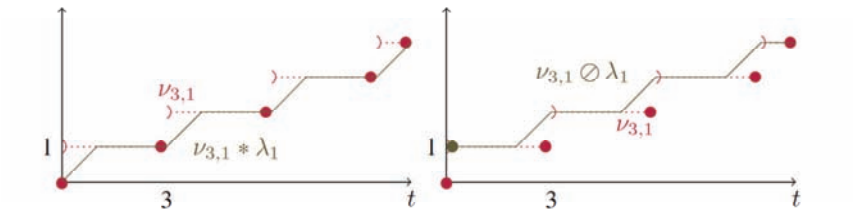


Figure 3.2. *Convolution and deconvolution of a staircase function*

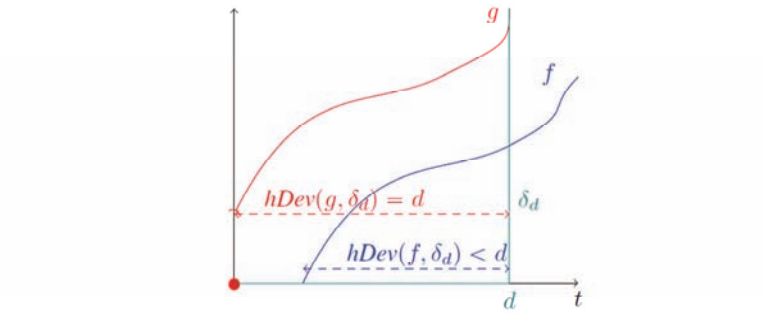


Figure 3.3. *Horizontal deviation and pure delay functions*

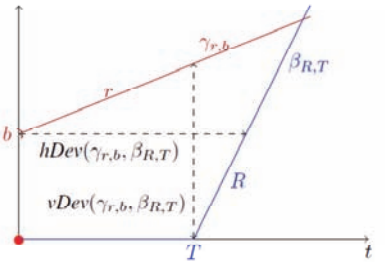


Figure 3.4. *Horizontal and vertical deviations for token-bucket and rate-latency functions*

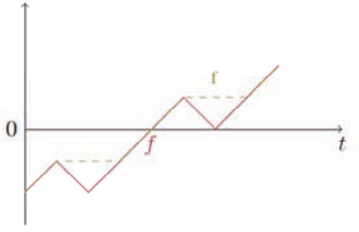
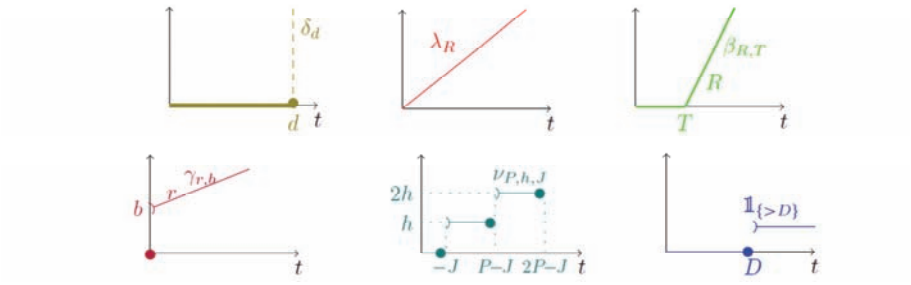


Figure 3.5. *A function f and its non-decreasing closure $f\grave{o}$*



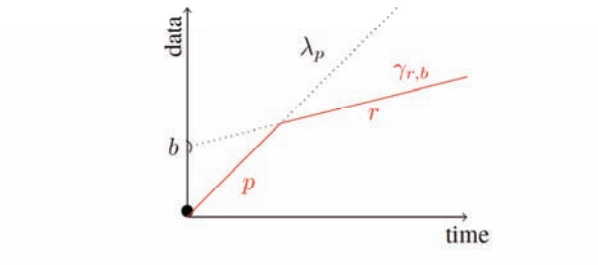


Figure 4.1. *IETF TSpec flow specification*

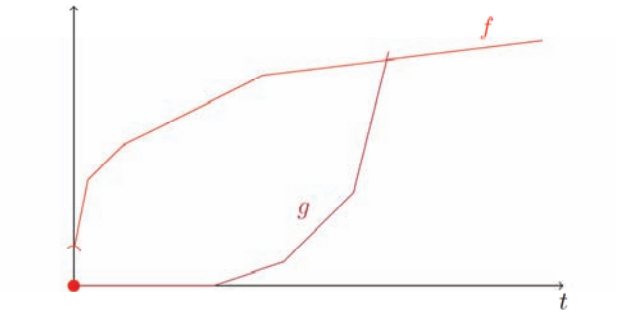


Figure 4.2. *Piecewise linear functions: f is concave and g is convex*

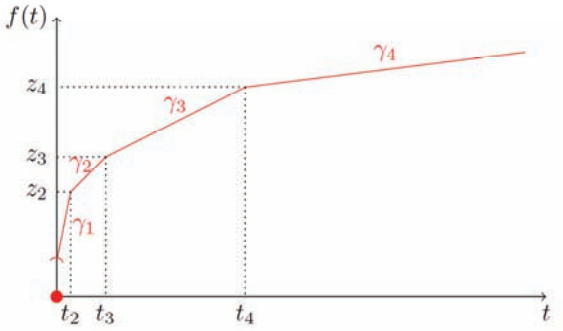


Figure 4.3. *Concave piecewise linear functions*

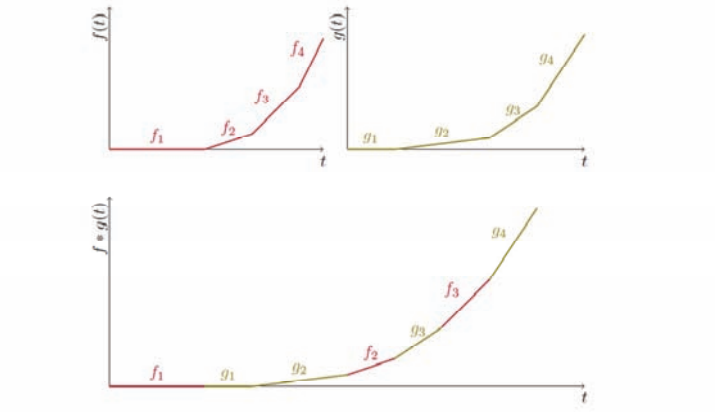


Figure 4.4. *Convolution of two piecewise linear convex functions*

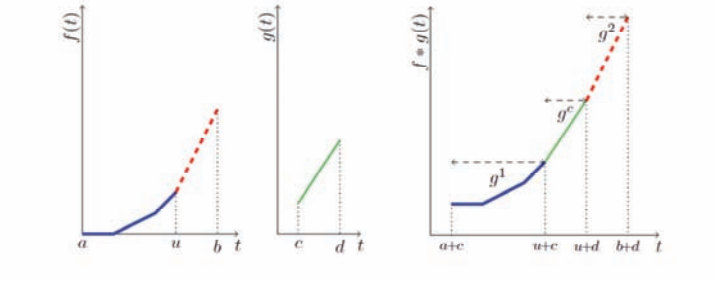


Figure 4.5. *Convolution of a convex function by a linear function and decomposition into three functions*

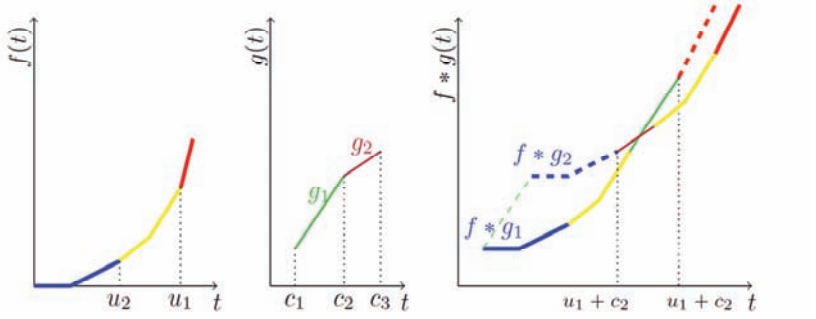


Figure 4.6. *Convolution of a convex function by a concave function*

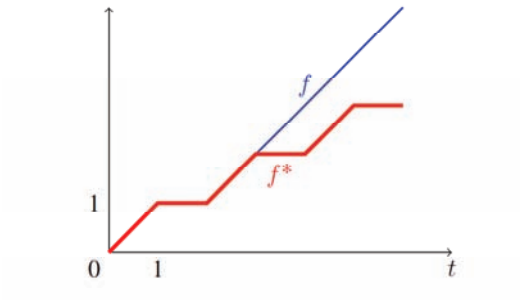


Figure 4.7. *Ultimately linear functions are not stable by the sub-additive closure*

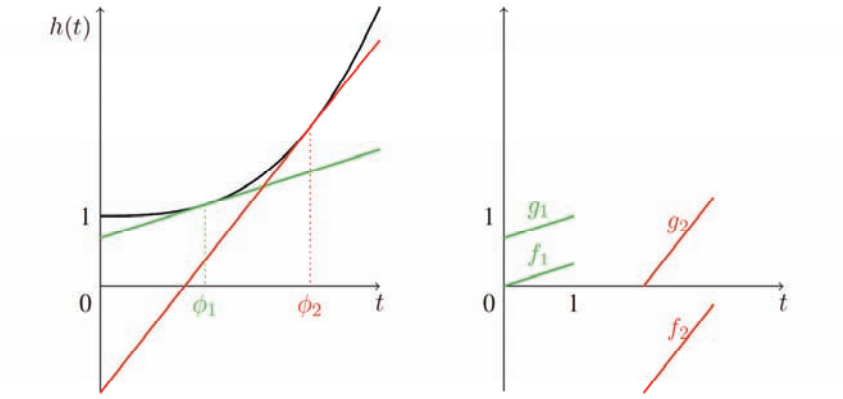


Figure 4.8. *A C_1 function from the deconvolution of piecewise linear functions*

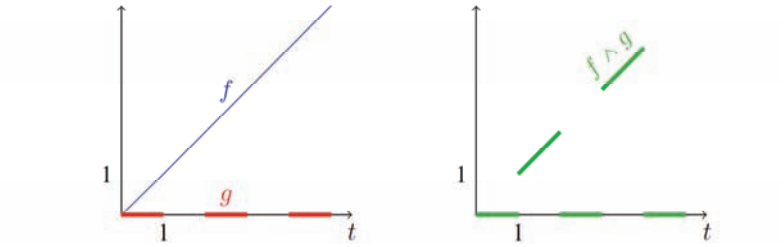


Figure 4.9. *Periodic non-plain functions are not stable*

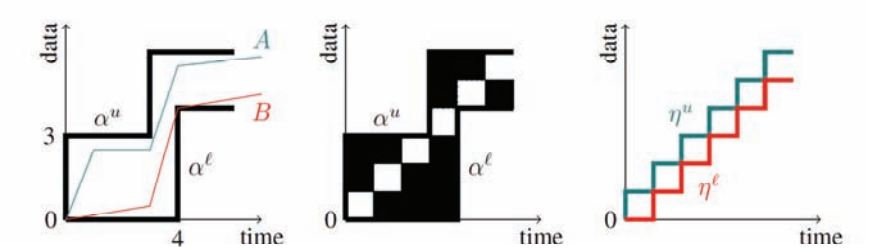


Figure 5.3. *Combining minimal and maximal arrival curves. Left: a and b are in between the maximal arrival curve α_u and the minimal arrival curve $\alpha_\_$, but do not satisfy both constraints. Center: the forbidden regions are black. Right: the new pair of arrival curves*

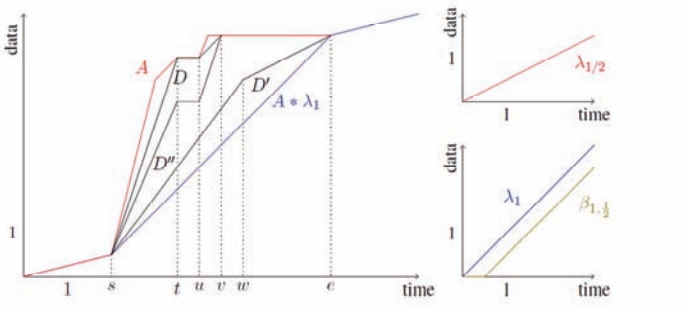


Figure 5.4. *Min-plus and strict service curves do not coincide*

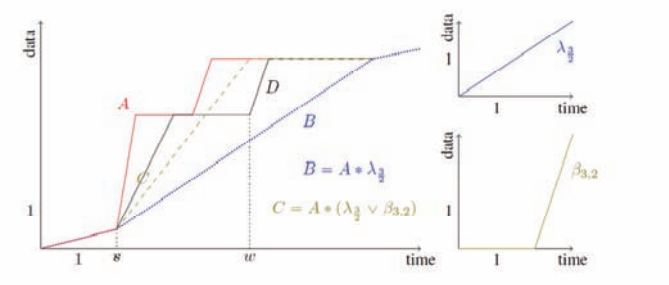


Figure 5.5. *No maximum between min-plus and strict service curves*

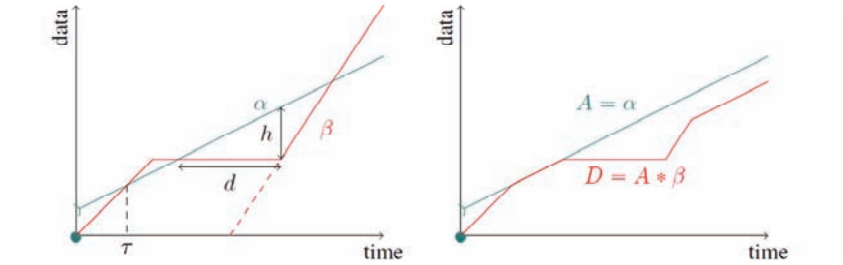


Figure 5.7. *Super-additivity is required to limit the maximal deviation interval*

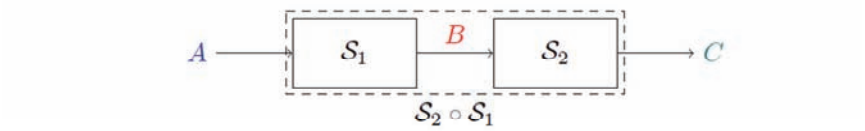


Figure 6.2. *Concatenation of servers*

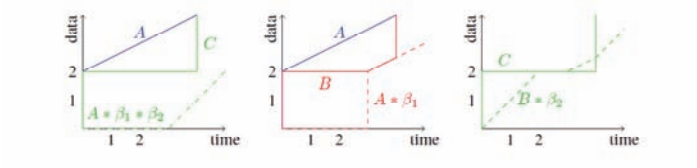


Figure 6.3. *Smppβ2q ˝ Smppβ1q Ĺ Smppβ1 ˚ β2q. Left: A ě C ě A ˚ β1 ˚ β2; center: A ě B ě maxpC,A ˚ β1q; right: C and B ˚ β2 cannot be compared*

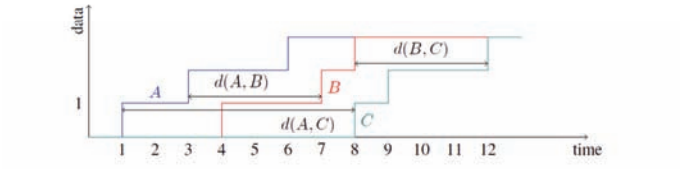


Figure 6.4. *Pay burst only once phenomenon*

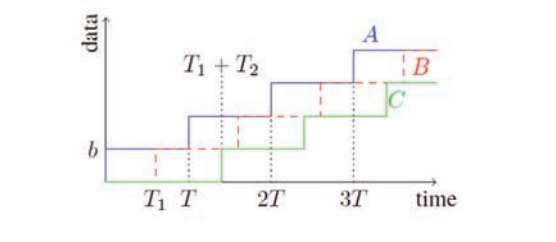


Figure 6.5. *No strict service curve for two servers in tandem*

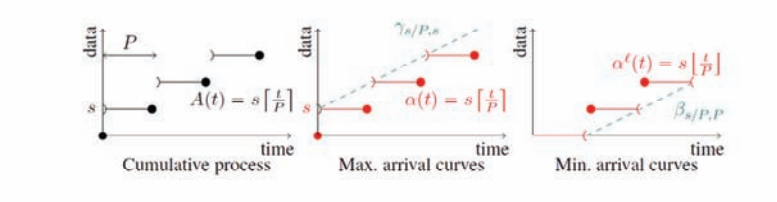


Figure 6.11. *A periodic flow and its arrival curves*

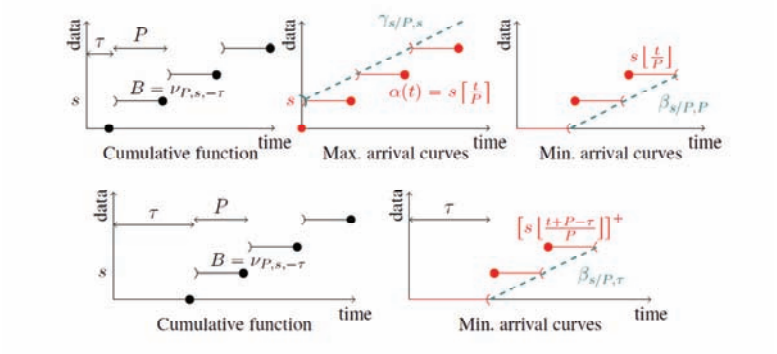


Figure 6.12. *A time-shifted periodic flow and its arrival curves*

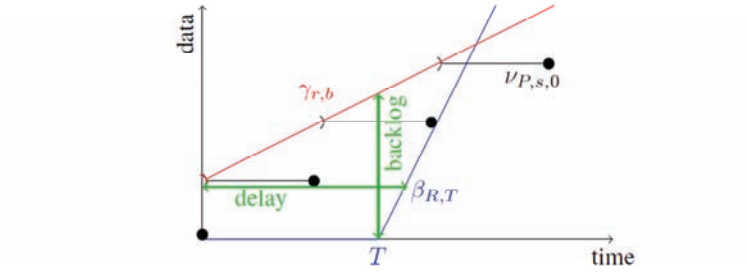


Figure 6.14. *Performance bounds for a periodic flow crossing a rate-latency server*

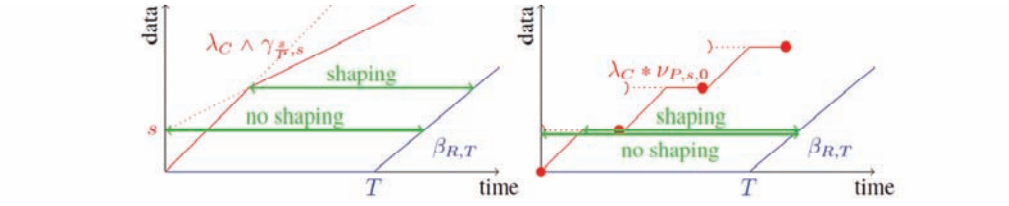


Figure 6.15. *Shaping vs. no shaping of arrival curves. Left: token bucket arrival curve; right: staircase arrival curve*

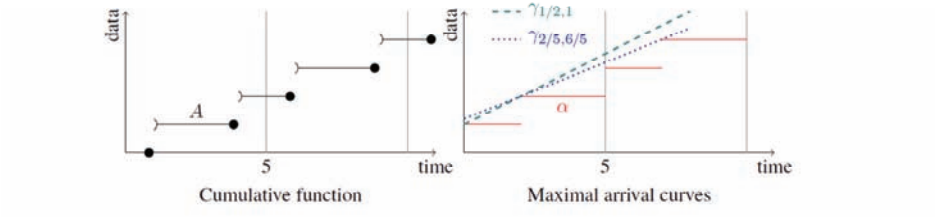


Figure 6.16. *An example of pattern-based process and its arrival curves*

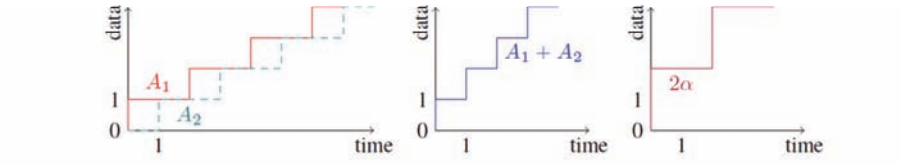


Figure 7.1. *Loss of accuracy in the aggregation of arrival curves*

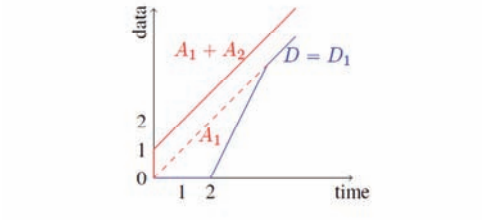


Figure 7.3. *Min-plus service curve for the aggregate server is not valid*

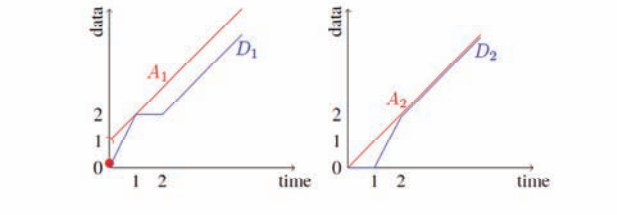


Figure 7.4. *Residual service curves are not necessarily strict*

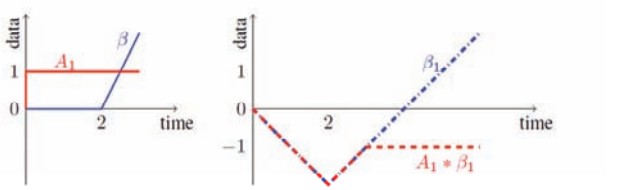


Figure 7.5. *The residual service curve in Theorem 7.3 can be negative*

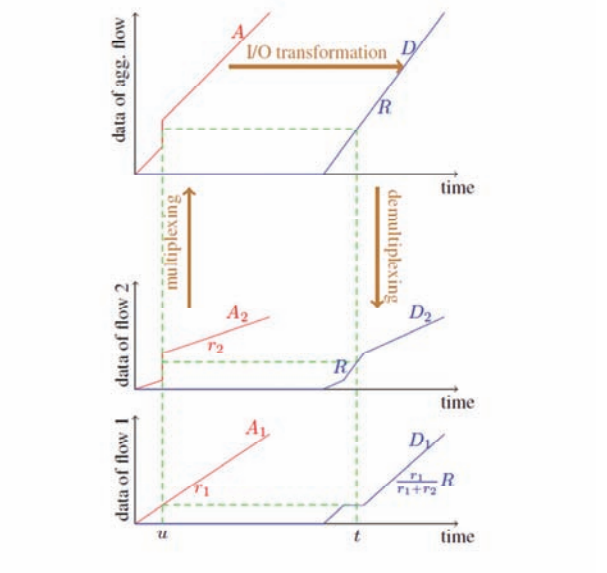


Figure 7.6. *FIFO multiplexing for cumulative processes*

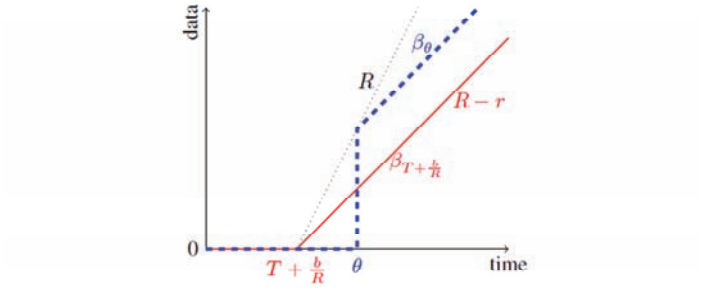


Figure 7.7. *A residual service curve for a FIFO server with a rate-latency service curve and affine arrival curves*

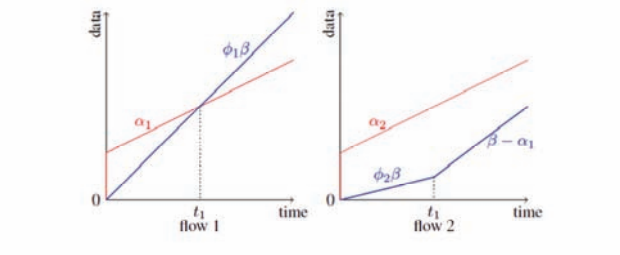


Figure 7.8. *Residual service curve for a GPS server*

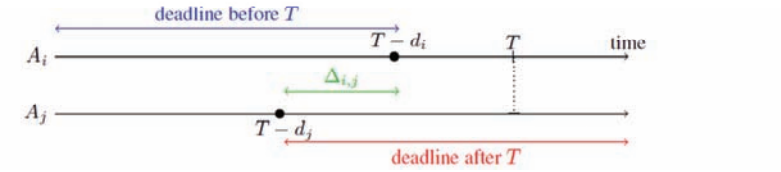


Figure 7.9. *EDF scheduling*

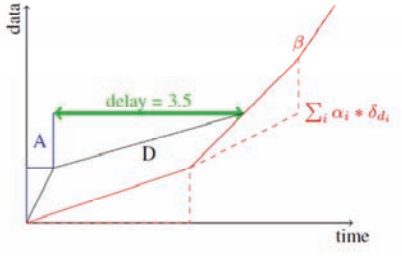


Figure 7.10.

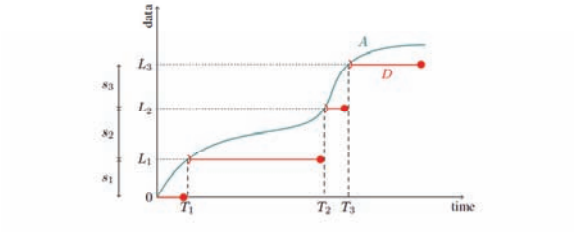


Figure 8.1. *Example of a packetizer*

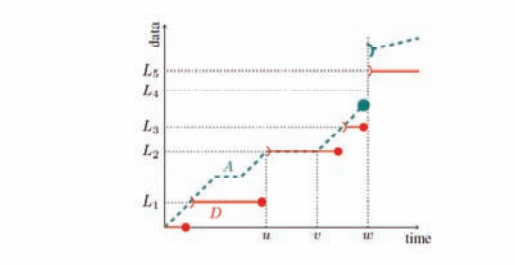


Figure 8.2. *Some special cases of a packetizer*

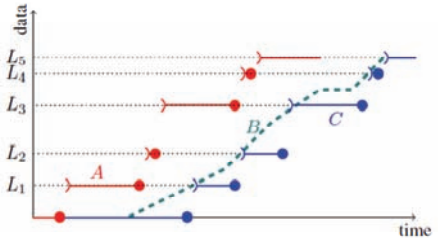


Figure 8.4. *Cumulative functions in a combined system*

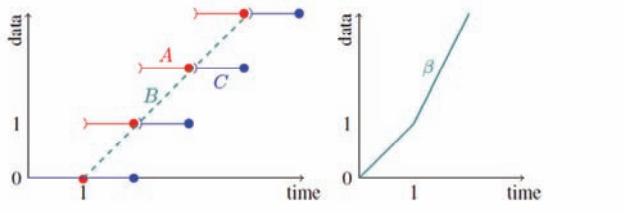


Figure 8.5. *Combined system and strict service*

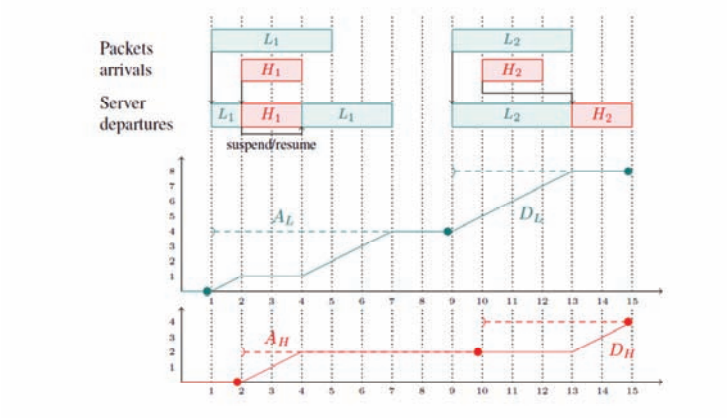


Figure 8.6. *Preemptive vs. non-preemptive scheduling*

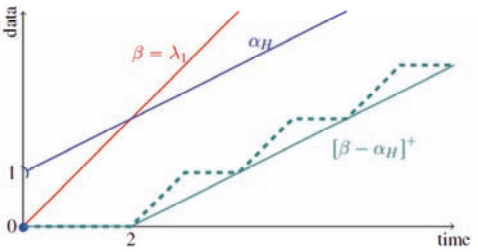


Figure 8.7. *Non-preemptive static priority with a constant rate service: the lower priority packets are served at this rate. Solid line: the service curve obtained with Theorem 8.3; dashed line: a better service curve taking into account the service rate of the packets*

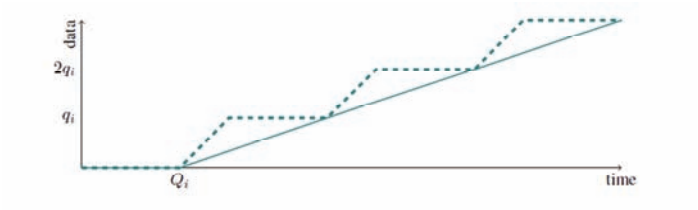


Figure 8.8. *Linear versus shaped staircase residual service curves. Solid line: the service curve obtained with equation [8.12]; dashed line: the one obtained using equation [8.11]*

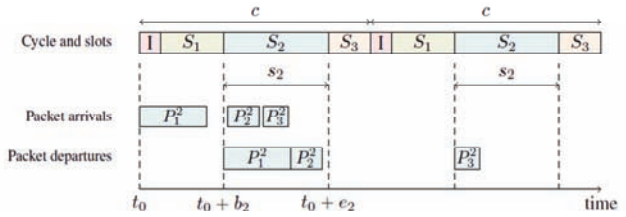


Figure 8.10. *The TDMA principle*

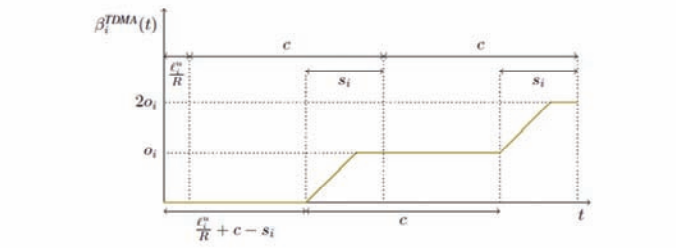


Figure 8.11. *TDMA residual service curve*

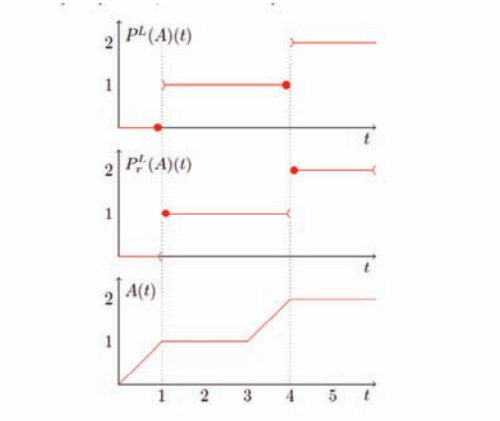


Figure 8.12. *Illustration of the continuity issues in a packetizer*

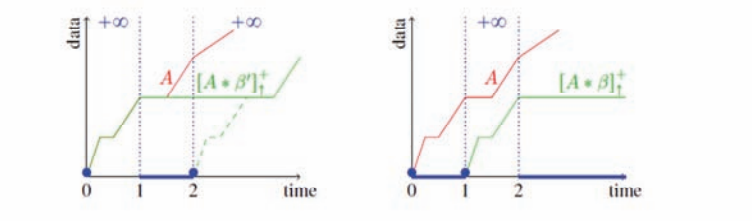


Figure 9.2.

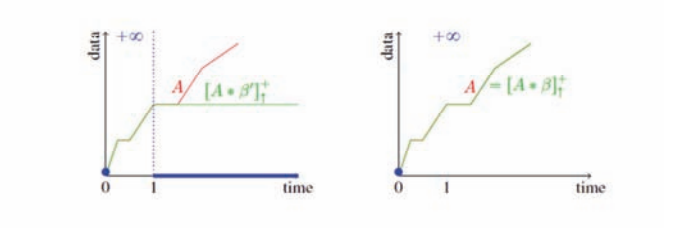


Figure 9.3.

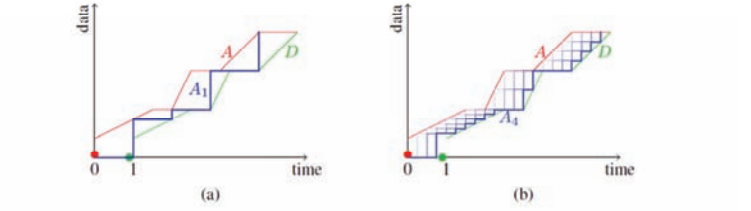


Figure 9.4. *Example of output service curve after 1 and 4 servers in tandem*

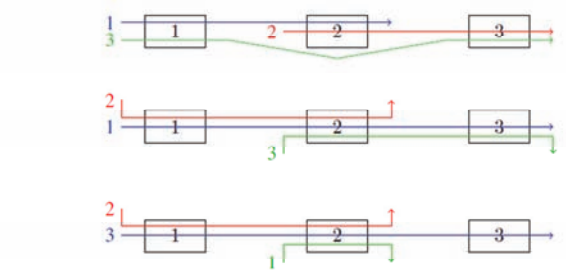


Figure 10.1. *Examples of topologies of networks. Top: a feed-forward network but not tandem; middle: a tandem network but not nested; bottom a nested tandem network*

Figure 10.2. *Network with two flows and two servers to illustrate the pay multiplexing only once phenomenon*

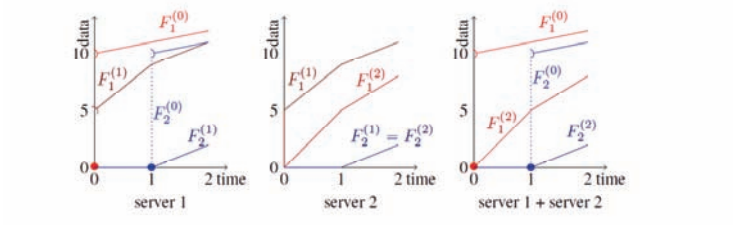


Figure 10.3. *Two GPS servers in tandem is not a GPS server*

Figure 10.4. *Sink-tree tandem network*

Figure 10.5. *Grouping flows according to the arcs of the network*

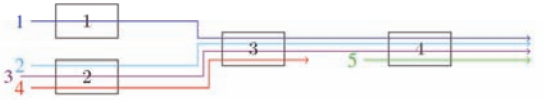


Figure 10.6. *Network example for the group flow analysis*

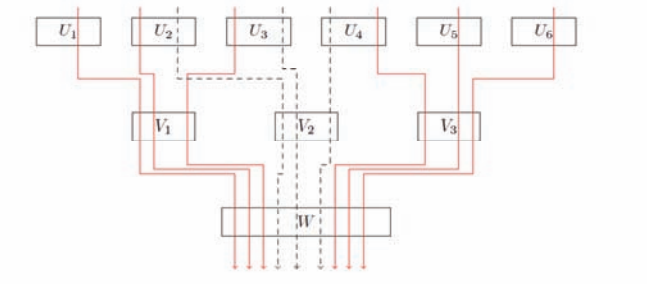


Figure 10.7. *Transformation of an instance of X3C into a network*

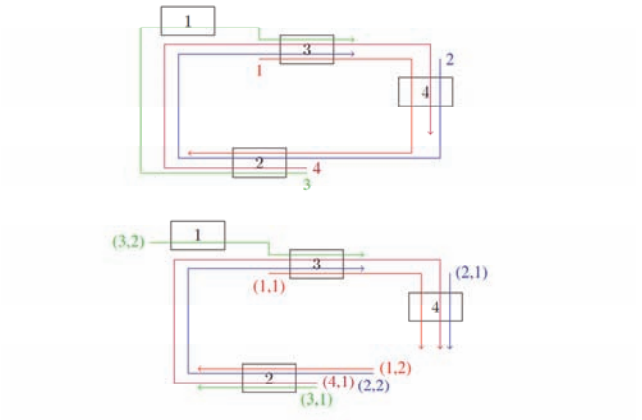


Figure 12.1. *Top: cyclic network of Example 12.1; bottom: its feed-forward transformation*

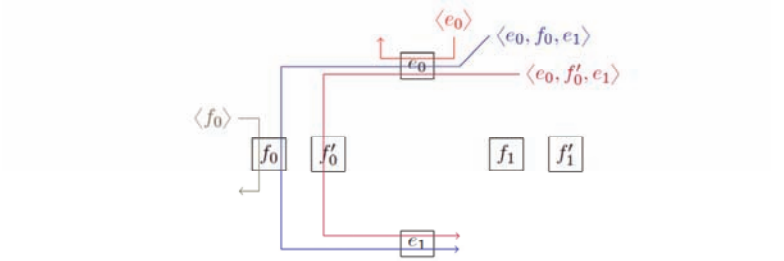


Figure 12.3. *Flow description for one phase of the instability in SDF*

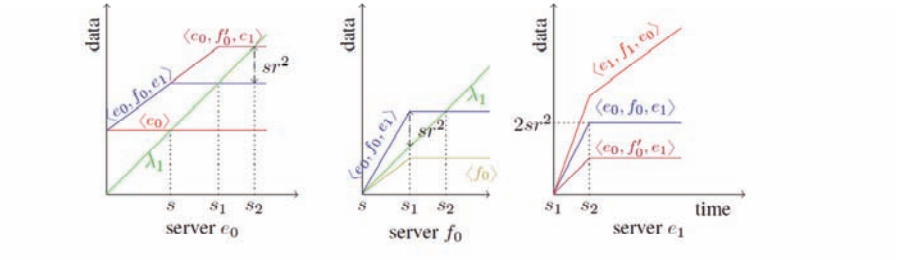


Figure 12.4.

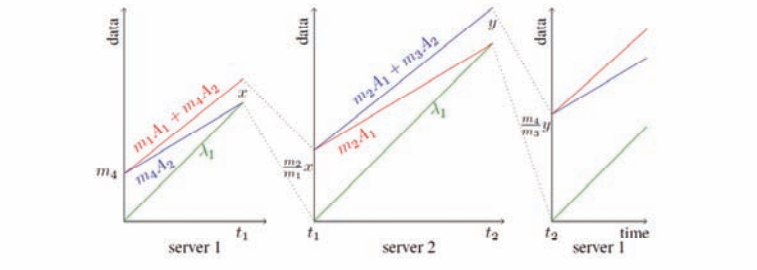


Figure 12.6. *Evolution of the backlogs in the unstable network*