Network Dynamics: Network Calculus

Anne Bouillard

ENS-INRIA

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Network calculus

Model

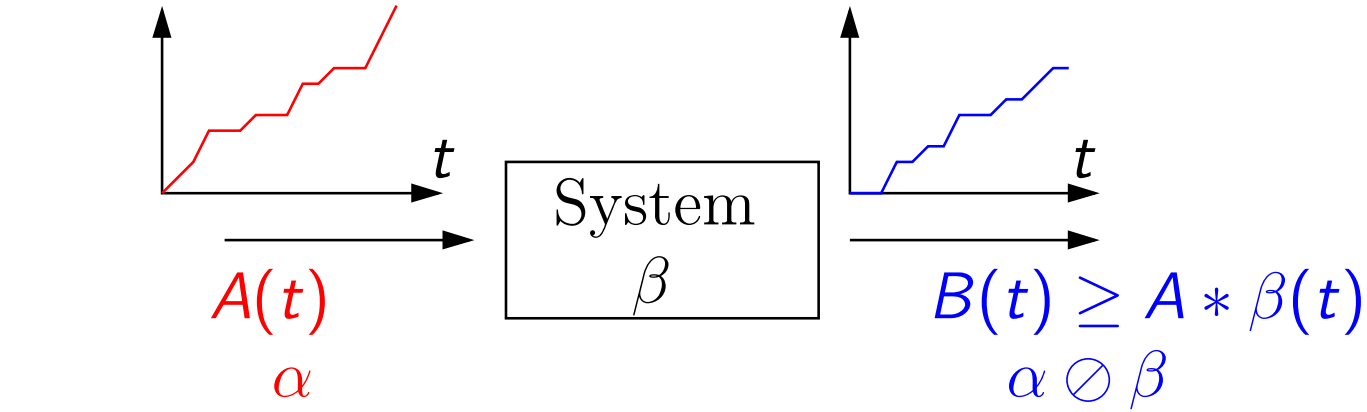
In a network, network elements, such as servers and data flows are modeled by functions in the (min,plus) algebra.

- the propagation of the characterisrics of the flows is made by algebraic computations
- deterministic performance bounds can be obtained by simple operations.

Challenges

1. The bounds are over-pressimistic
2. Several related models that induce some confusion.
3. Applications: originally, for the analysis of communication networks, now, mainly for embedded networks

Network calculus



- $A : \mathbb{R}_+ \to \mathbb{R}_{\min +}$: process of the cumulative arrivals, non-decreasing function
- $B : \mathbb{R}_+ \to \mathbb{R}_{\min +}$: process of the cumulative departures, non-decreasing function
- Causality constraint : $A \geq B$

Achievements

Model

- Comparison of the models
- Packetisation operator

Algorithms

- Efficients algorithms for operations on (min,plus) functions
- Implementation: scibal toolbox, (min,plus) console

Performances

- Tight performance bounds in feed-forward networks
- Improve existing bounds for some service policies

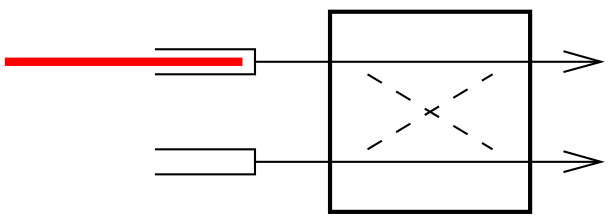
ZOOM 1: packetization

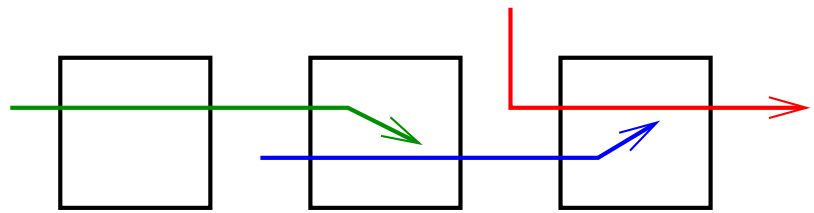
[Bruno Gaujal (INRIA, Mescal) & Nadir Farhi (IFFSTAR)]

- **Arrival curves:** $\underline{\alpha}(t-s) \leq A(t) - A(s) \leq \overline{\alpha}(t-s)$ bound the number of arrivals between time s and t.
- **Packet curve:** $\underline{\pi}(y-x) \leq P(y) - P(x) \leq \overline{\pi}(y-x)$ bound the number of packets contained between the x-th and y-th bit of data that arrived for the flow.

Improves the bounds for the (generalized) Round-Robin policy.

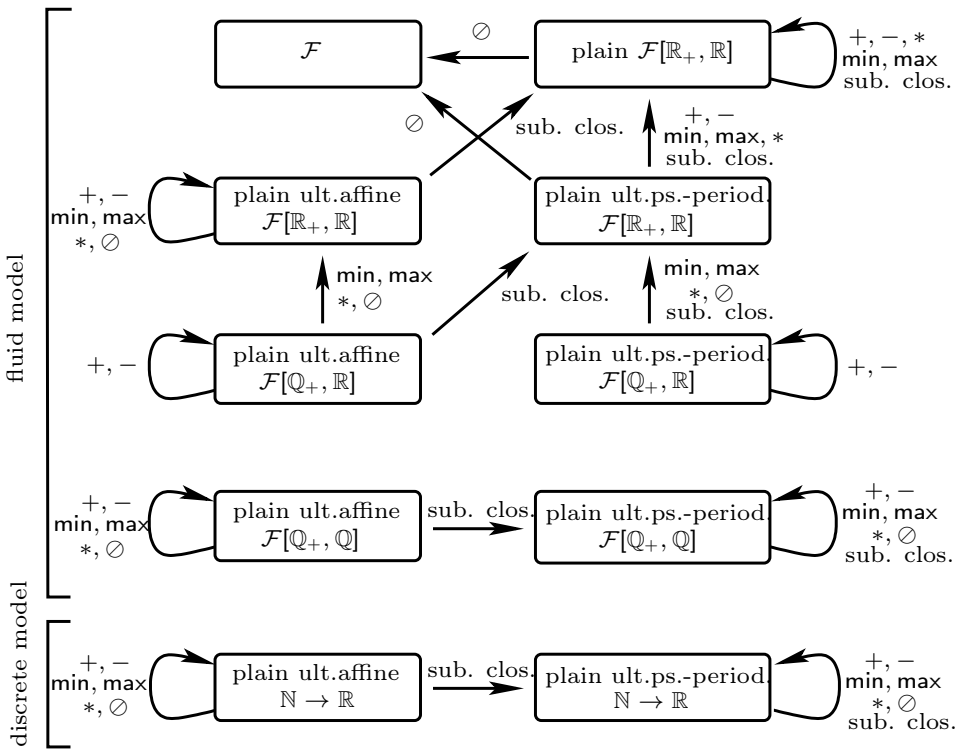
Target application: wormhole routing, network-on-chip.





ZOOM 2: algorithms and implementation

[Éric Thierry (ENS Lyon), Nicolas Navet et al. (INRIA, RT@W), Marc Boyer (ONERA)]

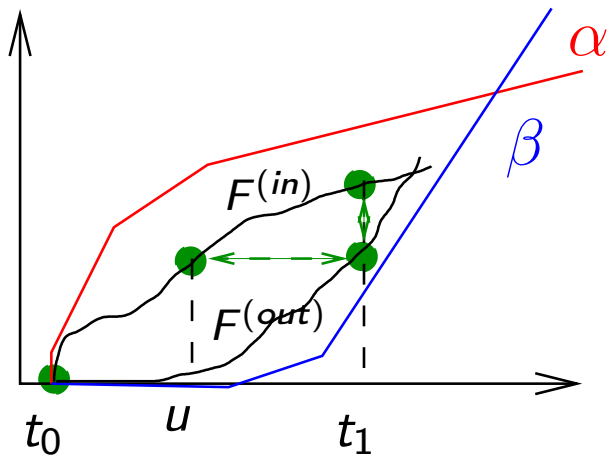


Implementation

1. Scilab toolbox (COINC toolbox)
2. (Min,plus) console and PEGASE prototype - can be used to validate AFDX network (used inlarge civil airplanes).

ZOOM 3: performances

[Éric Thierry (ENS Lyon), Aurore Junier (INRIA, DistribCom)]

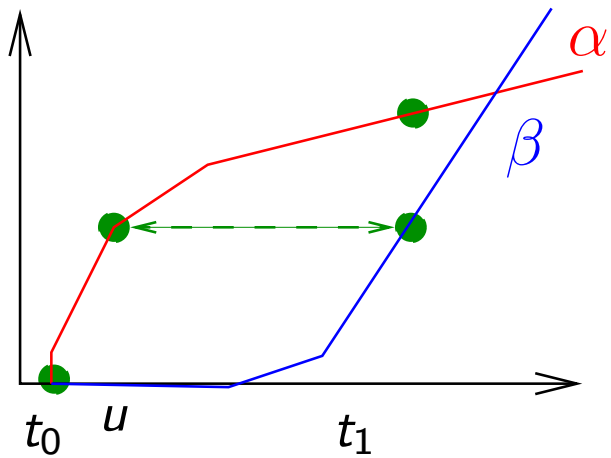


Objective

- Maximum delay: Maximize $t_1 - u$ with $F^{(in)}(u) \geq F^{(out)}(t_1)$
- Maximum backlog: Maximize $F^{(in)}(t_1) - F^{(out)}(t_1)$.

ZOOM 3: performances

[Éric Thierry (ENS Lyon), Aurore Junier (INRIA, DistribCom)]



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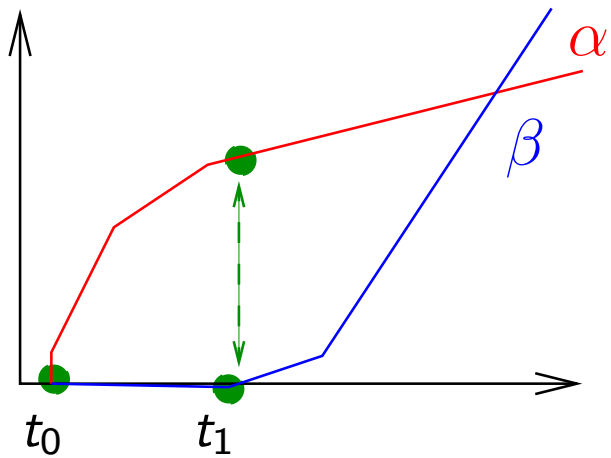

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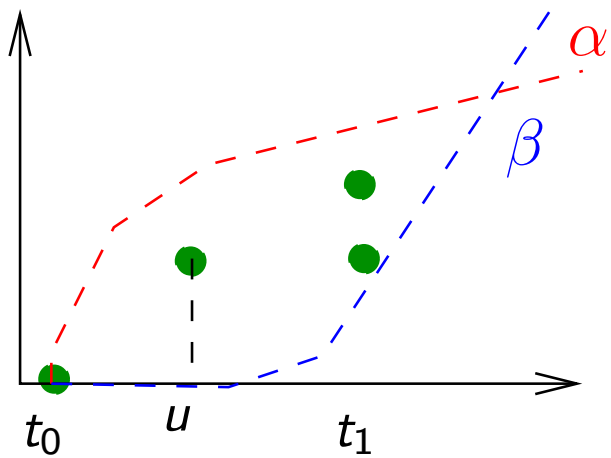

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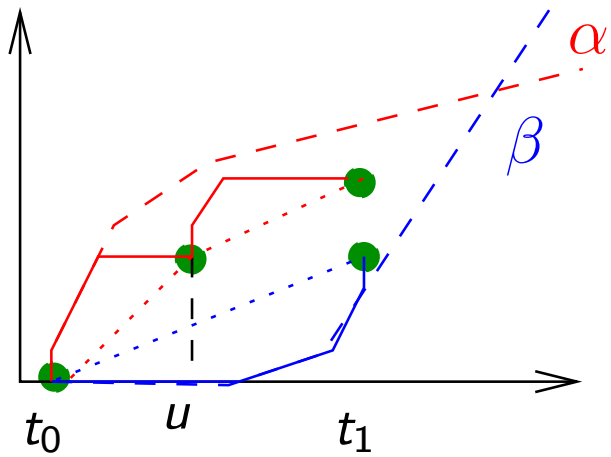

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- Arbitraly multiplexing:

  (min,plus) algebra $\rightarrow$ over-pessimistic

  linear programming $\rightarrow$ **exact bounds**

- Static priorities: improvement of the existing bounds

Collaborations

ANR Pegase

- with M. Boyer (ONERA), E. Thierry, B. Gaujal, N. Navet, Thalès
- Applications: wormhole routing, AFDX

1. Univ. Pisa (G. Stea): FIFO queues [performances]
2. INRIA, DistribCom (A. Benveniste): LTTA modeling [model]
3. INRIA, Ipso (E. Faou) and Paris 6 (M. Zavidovique): weak KAM integrators [algorithms]

Ongoing and future work

Network Calculus

- Starting collaboration on stochastic network calculus and traffic modeling (Ludivic Noirie, Alcatel, LINCS)
- Network calculus for wireless networks (with Bartek)

Perfect sampling

With Ana - submission of an ANR proposal led by A. Jean-Marie (INRIA Maestro).

Algorithms for dynamic graphs

Master student.