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A Bayesian decision theory approach for the techno-economic analysis of an all-optical router

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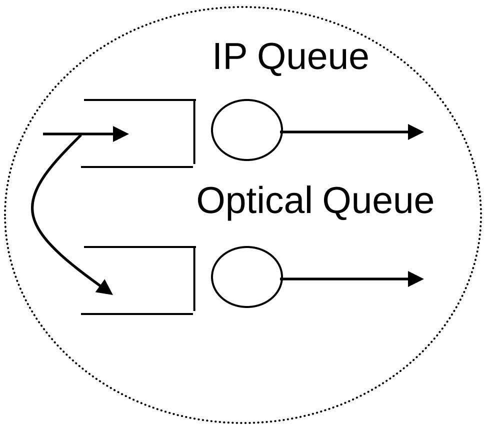
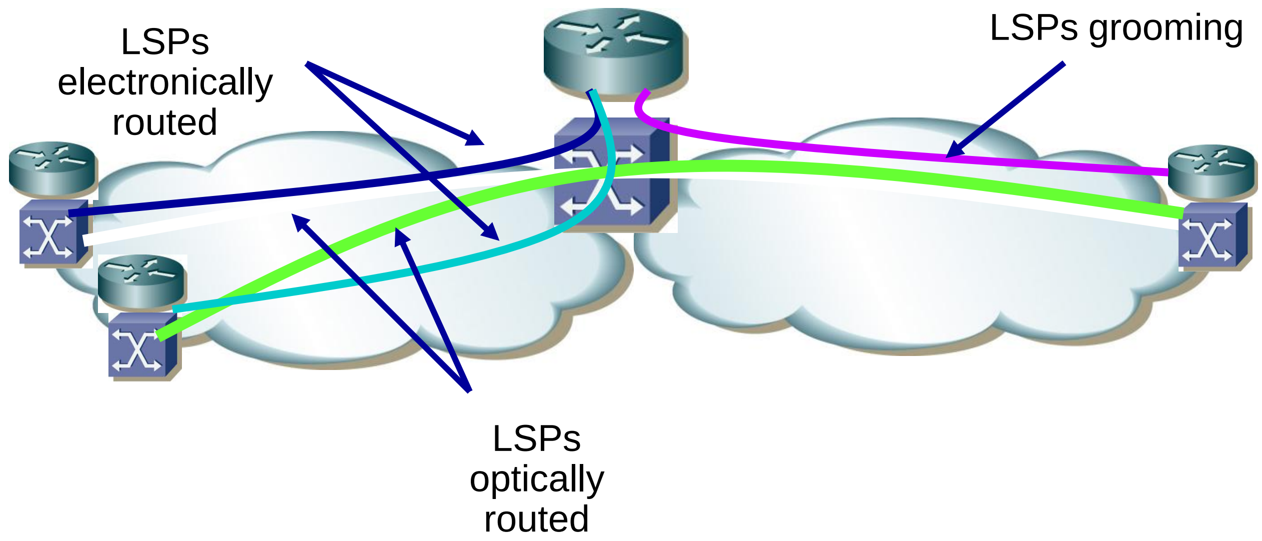
Content

- **Multilayer Scenario**
- Techno-Economic Analysis
  - Bayesian decisor
  - Utility functions
  - Cost functions
- Experiments and results
  - QoS parameters variation
  - Relative cost variation
  - Self-similarity impact
- Contributions

Multilayer scenario

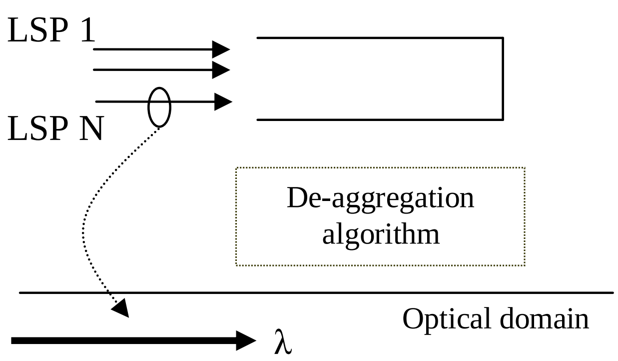
- Current optical networks are migrating to an IP over WDM scenario.
- In such scenario, a multilayer-capable router has to decide whether to perform optical or electronic switching.





Multilayer scenario

- Which is the optimal decision to switch a new incoming LSP?
  - Electrical and optical resources vs. User Utility function



Proposal of a techno-economic model to help routers take the decision of optical or electronic switching of their LSPs.

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Techno-economic analysis

- There three key aspects in our model:
  - Bayesian theory.
  - Utility functions definition.
  - Cost function definition.

Bayesian decisor

- Let N refer to the number of LSPs handled at a given random time by the multilayer router, the loss function is given by:

$$L(d_i, x) = (C_e(i) + C_o(N - i)) - U(x), i = 1, \ldots, N, x > 0$$

- Where:
  - **Ce(i) and Co(i):** cost associated to route i flows over the electrical or optical domain.
  - **U(x):** utility associated to a queuing delay of x units of time, experienced by the electronically switched LSPs.

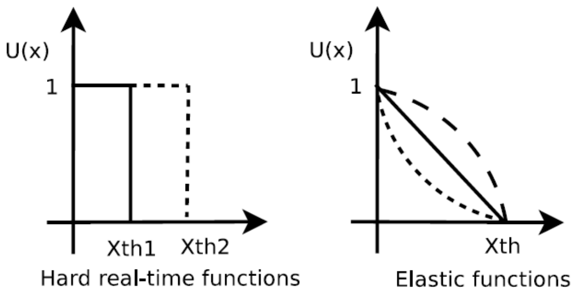
Utility function definition

- Definition:
  - Utility associated to a queuing delay of x units of time, experienced by the electronically switched LSPs.
- Assumptions:
  - The queuing delay is assumed to be Weibull distributed. [5-7]
  - In this light the probability distribution function is :

$$p(x) = (2-2H)C\frac{(C-m)^{2H}}{2K(H)^2am}(Cx)^{1-2H}\exp\left(-\frac{(C-m)^{2H}}{2K(H)^2am}(Cx)^{2-2H}\right)$$

- Where:
  - » m: input traffic mean, H: Hurst parameter, $am=\sigma^2$.

Utility function definition



- We define three utility functions:
  - **Delay based utility**
    - The utility function is opposite to the queuing delay *x*.

$$U_{delay}(x) = -x$$

  - **Hard real-time utility**
    - Hard real-time applications are those which tolerate a T_{max} delay.
      - » ITU-T Y.1541 [10] and 3GPP S.R0035[11] defined service classes based on thresholds.

$$U_{\text{step}}(x) = \begin{cases} 1 & \text{if } x < x_p \\ 0 & \text{otherwise} \end{cases}$$

  - **Elastic utility**
    - Services, which are degraded little by little, till they reach $T_{max.}$
      - » Exponential function used to describe the degradation of elastic services [9].
      - » G.107 “E model” [12], for voice service degradation.

$$U_{\exp}(x) = \lambda e^{-\lambda x}$$

$$\lambda = \frac{1}{T_{\max} \log(1 - 0.9)}$$

Cost function definition

- Definition:
  - $C_e(i)$ and $C_o(N-i)$ represent the cost associated to switching *I* LSPs in the electronic domain and $N-i$ in the optical domain.

$$C_e(i) = Ki$$

$$C_o(N-i) = R_{\text{cost}} K(N-i)$$

  - Where R_{cost} is the ratio at which the optical cost increases with respect to the electronic cost.

Bayes risk

- The Bayes risk equals:

$$R(d_i) = E_x[L(d_i, x)] = (C_e(i) + C_o(N - i)) - E_x[U(x)]$$

- The goal is to obtain the optimal decision *d** such that the Bayes risk *R*(*d**) is minimum:

$$\text{find } d^* \text{such that } R(d^*) = \min_{d_i, i=1,\ldots,N} R(d_i)$$

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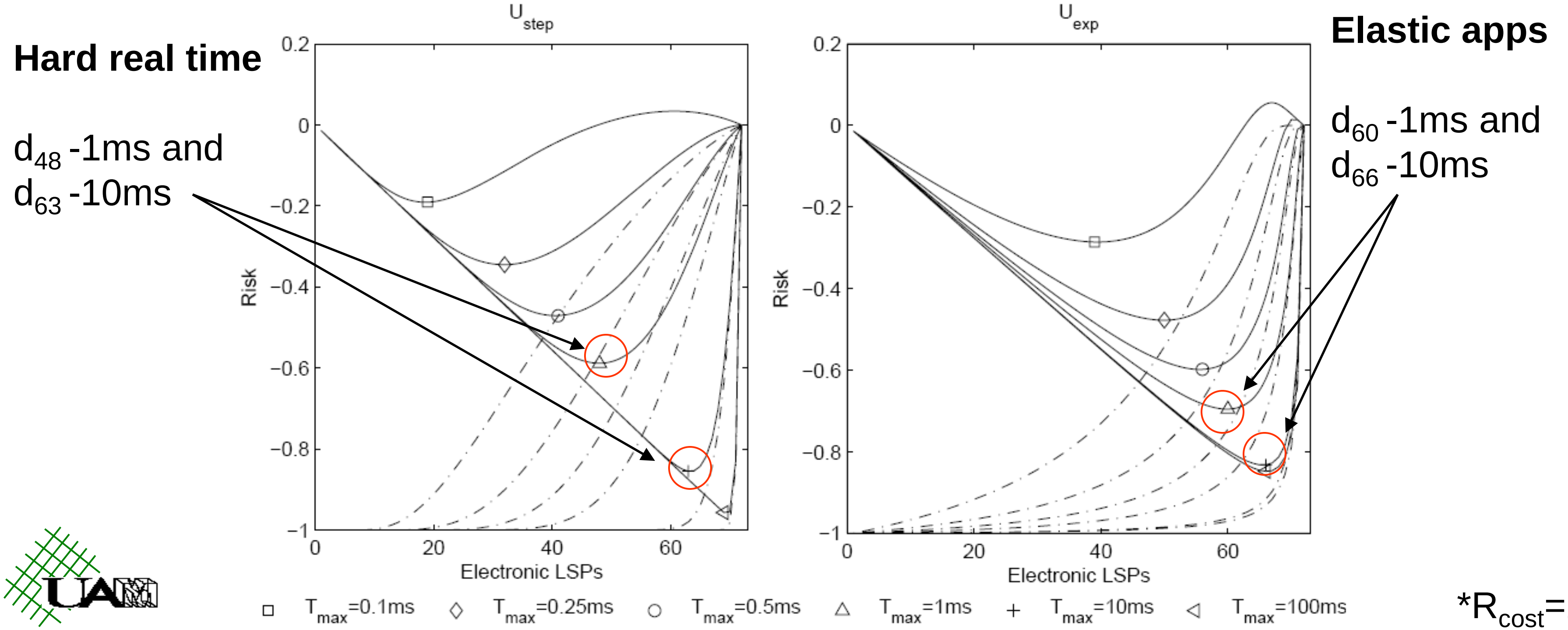
Experiments and results

- Scenario:
  - 2.5 Gbps core network link.
  - N = 72 standard VC-3 LSPs (m = 34.358 Mbps).
  - Hurst parameter: H = 0.6 [13]
  - a=σ/m = 0.3.
  - $K = 1/N$, to normalized electrical cost in range [0, 1].
- Experiments:
  1. **Range of QoS** (T_{max})
  2. **Range of cost** (R_{cost})
  3. **Range of Self-similarity** (Hurst parameter)

QoS parameters

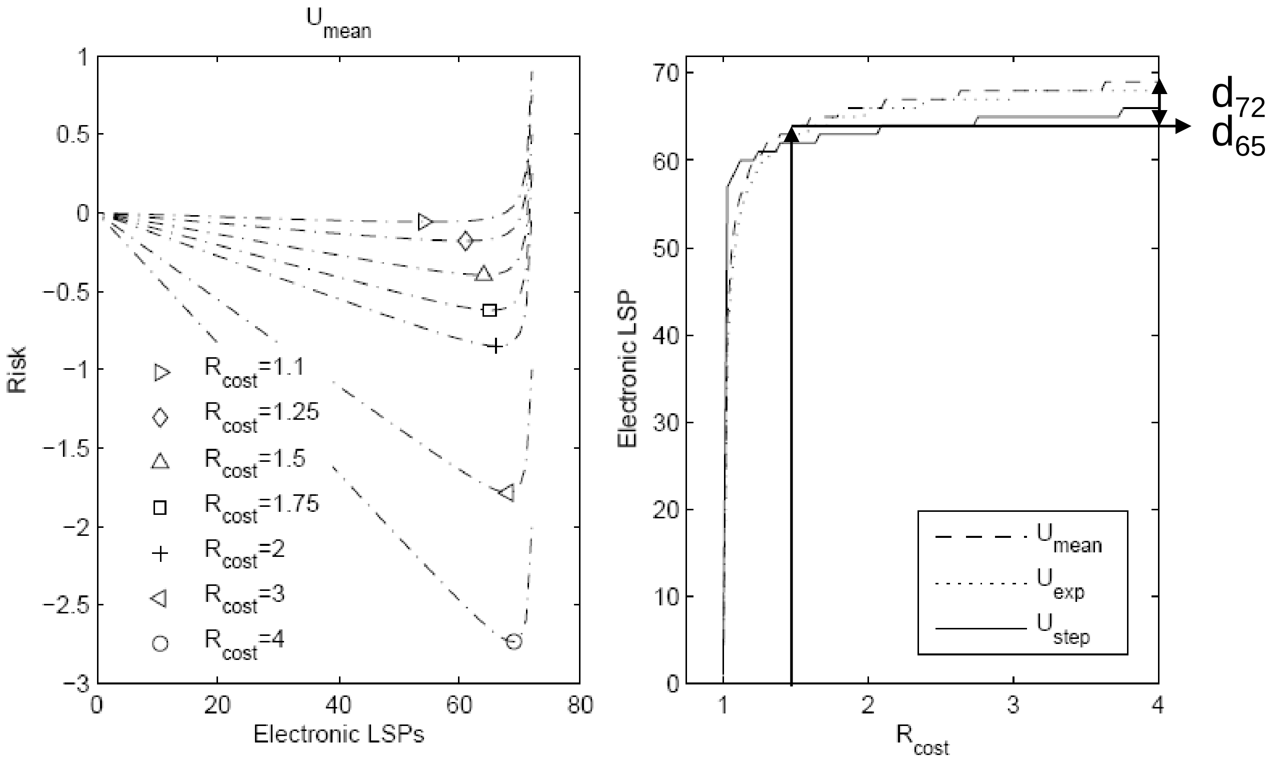
- T_{max} variation from 0.1 ms to 100ms.*
  - Optically-switched LSPs increase with T_{max}.
  - Delay requirements for hard real-time applications are tighter than those for elastic applications.



*R_{cost}=2

Cost variation

- R_{cost} variation from 1.1 to 4.*
  - The more expensive optical switching is the less number of LSPs are switched optically.
  - If $R_{cost} \geq 1.5$, the optimal decision does not depend on other parameters.



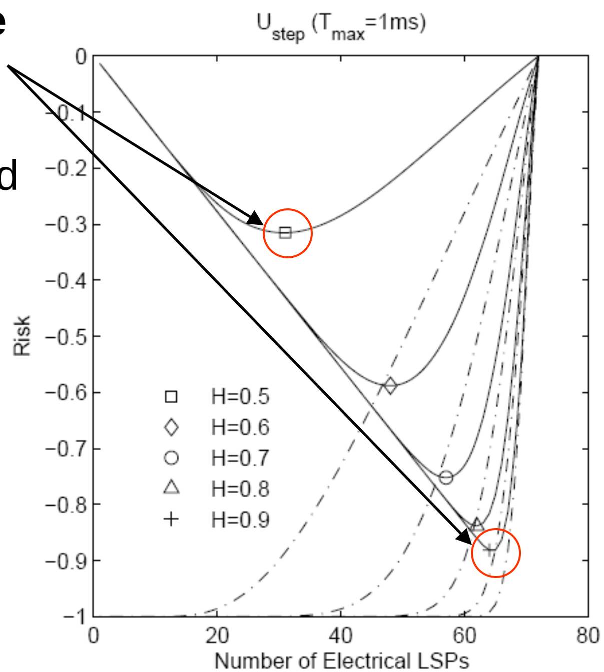
*T_{max}=10ms

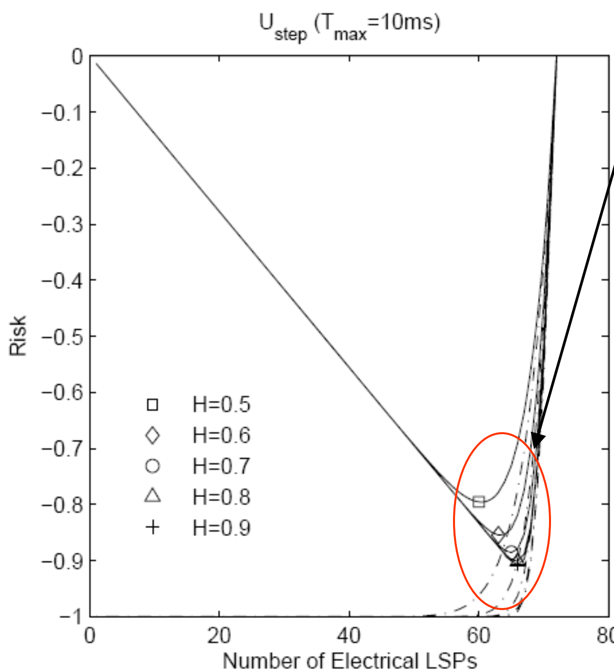
Self-similarity

- Hard real time applications:
  - H variation from 0.5 to 0.9.*
  - Incoming traffic characteristics impact on the bayesian decisor depends on the QoS parameters.
    - In Hard real time with Tmax=1ms has no impact.

Hard real time
T_{max}=10ms

d_{31} – H=0.5 and
d_{64} – H=0.9





Hard real time
T_{max}=1ms

Almost no difference

*R_{cost}=2

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Contributions

- Novel methodology based on the Bayesian decision theory for multilayer switching decision, QoS parameters and cost.
- The algorithm proposed is of low complexity, and can easily adapt to changing conditions.
- Future work:
  - Extensions of this mechanism, using end-to-end delay information through the whole network.

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Thank you!!
Questions?

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