Design of Experiments
Option PDES

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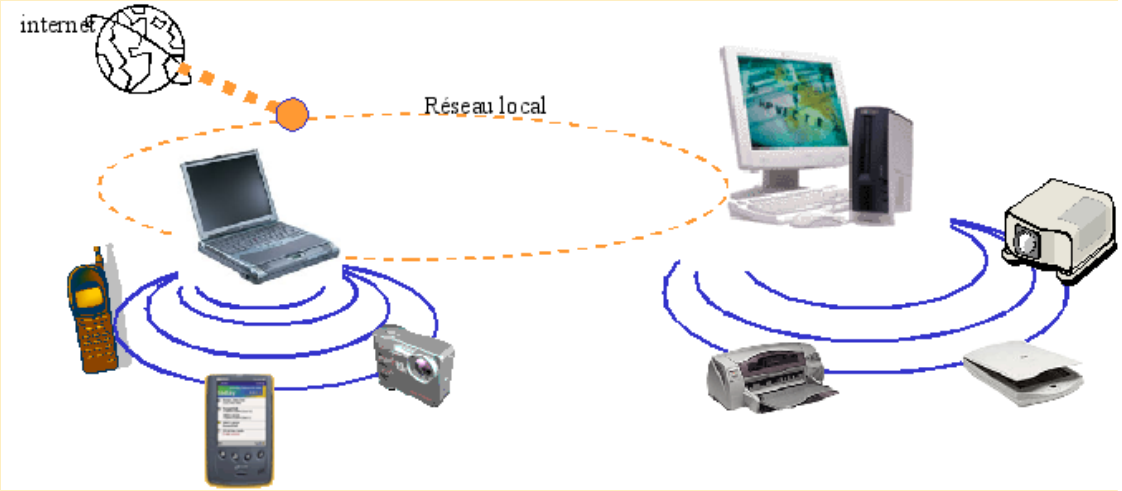
Équipe-Projet MESCAL

Some elements for the design of experiments : an example

Wireless environment

Environment



- Wireless Devices
  - Laptop computers,
  - Personal digital assistants (PDAs),
  - Mobile phones, ...
- Wireless Ad-Hoc Network
  - WIFI,
  - Bluetooth, ...

Principle

Devices share services and collaborate to maintain the community.

General distributed system problem

→ Dynamical control of the architecture.
→ State of the system observation and distributed decision process.

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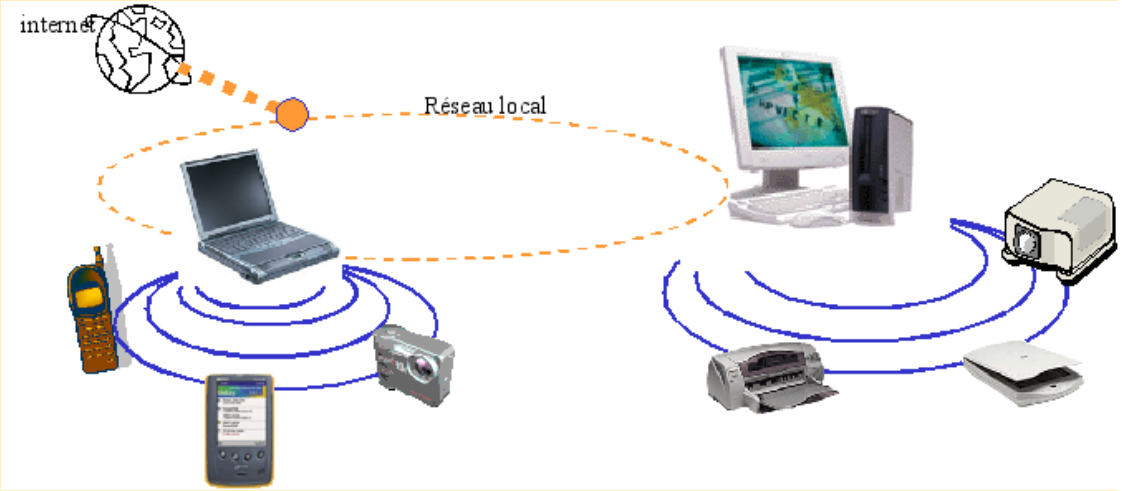

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Operating systems on a wireless network

Dynamic Architecture

- Heterogeneity of devices
- Behavior of wireless devices $\rightarrow$ connections / disconnections
- Behavior of wireless network
  - Unreliability of communications
  - Variability of latencies

Solution to maintain the consistency of the community

- Design and adapt distributed algorithms ;
- to make some distributed decisions.
- (consensus, election, atomic broadcast, group membership,...)

The Consensus Problem

The impossibility of Fisher, Lynch & Paterson [Fischer-Lynch-Paterson 85]

Some approaches to circumvent this impossibility result :

- Probabilistic algorithms [Canetti-Rabin 93]
- Self-Stabilizing algorithms [Tixeuil 00]
- An approach with partial synchrony [Dwork-Lynch-Stockmeyer 88]
- ....

$\Rightarrow$ The selected approach :

Consensus + unreliable failure detectors [Chandra-Toueg 96]

Interest :

Dynamicity analysis of the environment is concentrated only inside failure detectors.

Objective :

Guarantee a quality of service for failure detectors.

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Unreliable Failure Detectors

Principle :

For each remote device, build an estimation of the global state.

Local view of the global system.

$\rightarrow$ List of suspected devices

Properties

- Accuracy : a correct process should not be suspected
- Completeness : an incorrect process should be suspected

Quality of service

Quality of information and reactivity

false suspicion rate = *function*(*reactivity*)

- false suspicion type 1 : correct process suspected
- false suspicion type 2 : crashed process not suspected

Risk analysis

Implementation

Unreliable Failure Detectors

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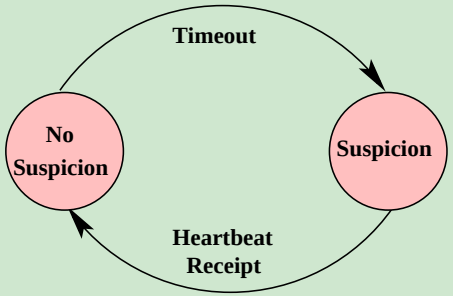

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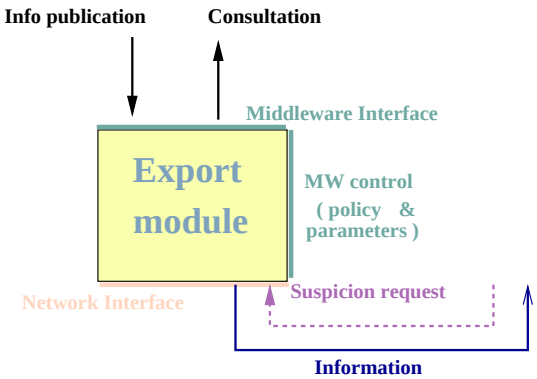
Failure Detectors Implementation

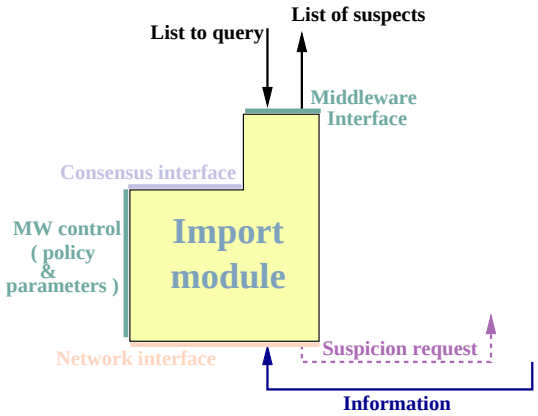
Need of information on remote devices

- Export local data
- Collect and analyse data coming from remote devices

Informations Export

→ Broadcast of information by anticipation (Heartbeat mecanism)





Informations Import

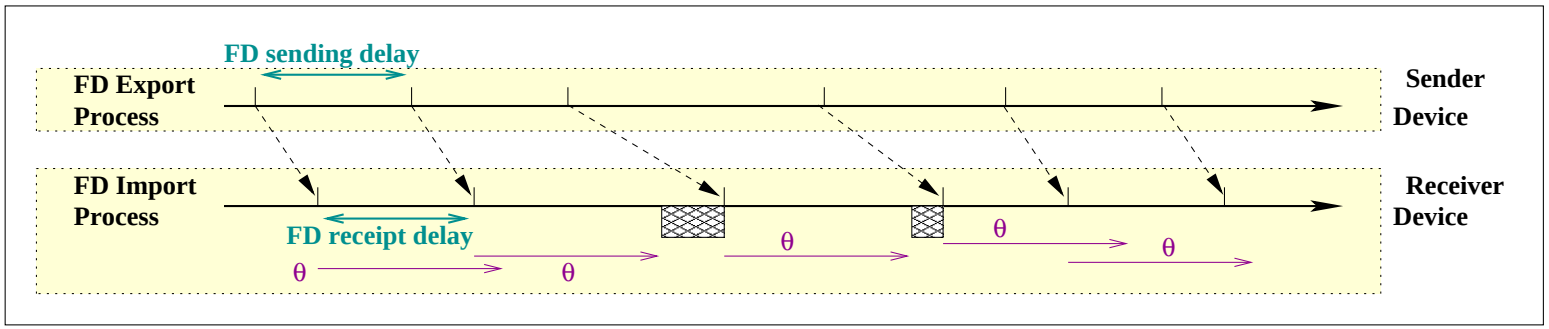
→ Collect information

→ Estimate the state of remote devices

Failure Detectors Parameters

The running principle :

Implemented mecanism : "heartbeat".



Parameters

- Heartbeat sending period.
- Estimate function of suspicions (timeout). [Bertier-Marin-Sens 03]

Goal

Estimate the timeout values according to the expected quality of service.

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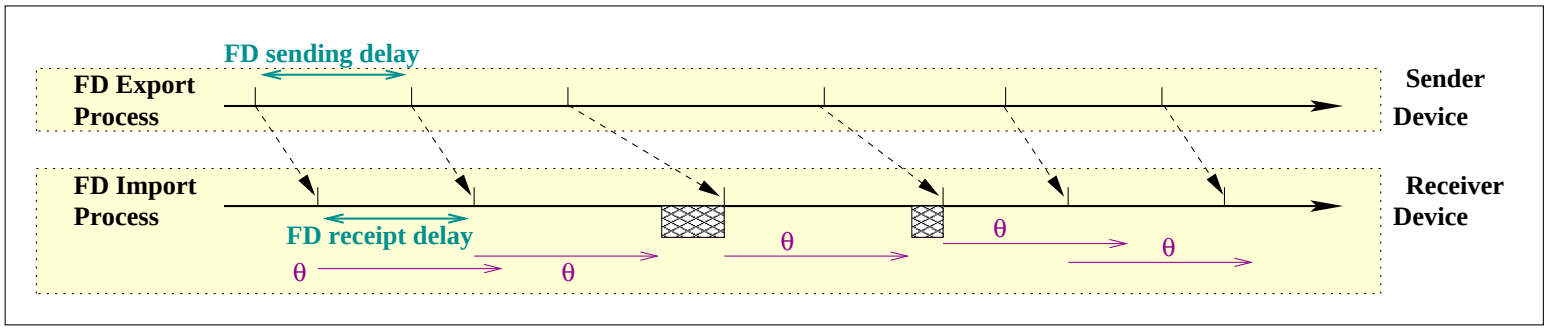

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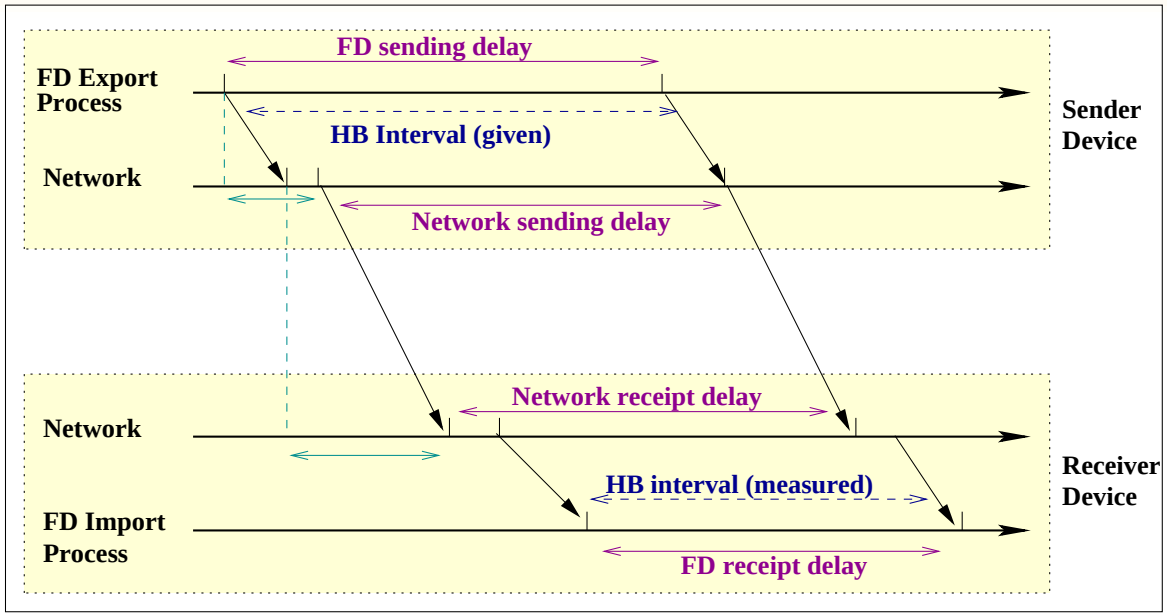

Variability of HB arrivals

- λ_0 = emission beat rate
- X_i = Heartbeat inter-arrivals.
- $\lambda = \frac{1}{HB\ period}$ (assumption : few losses $\lambda = \lambda_0.(1 - \text{loss probability})$

Statistical Description

False Detection Probability

$\theta =$ suspicion threshold (timeout)
$\phi_I(\theta) =$ asymptotic false suspicion rate

$$\phi_I(\theta) = \lambda \lim_{n \to \infty} \frac{1}{n} \sum_{i=1}^{n} (X_i - \theta)^+$$

If the inter-arrivals $\{X_i\}$ of beats are independent and identically distributed, then :

$$\phi_I(\theta) = \lambda \mathbb{E}_\pi [X - \theta]^+$$

where π is the distribution of X_i. (renewal process)

Independent assumption Model

Variable Sending Delay

Hypothesis : $\{X_i\}$: renewal process (iid)

	Model	*suspicion rate*
no information on variance	Exponential	$\phi_I(\theta) = e^{-\lambda\theta}$
low variation coefficient	Erlang(k,kλ)	$\phi_I(\theta) = e^{-k\lambda\theta} P_k(\lambda\theta)$
high variation coefficient	Pareto(α)	$\phi_I(\theta) = \frac{1}{(1+\frac{\theta}{\alpha-2})^{\alpha-2}}$

Suspicion probability related to reactivity

Erlang model :

Pareto model :

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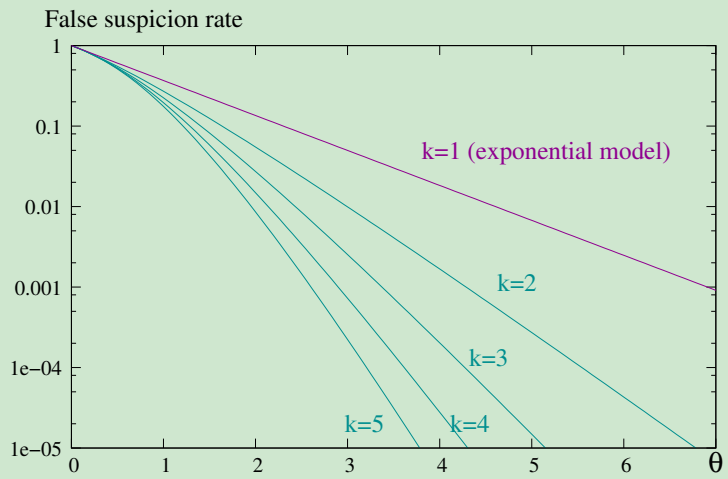
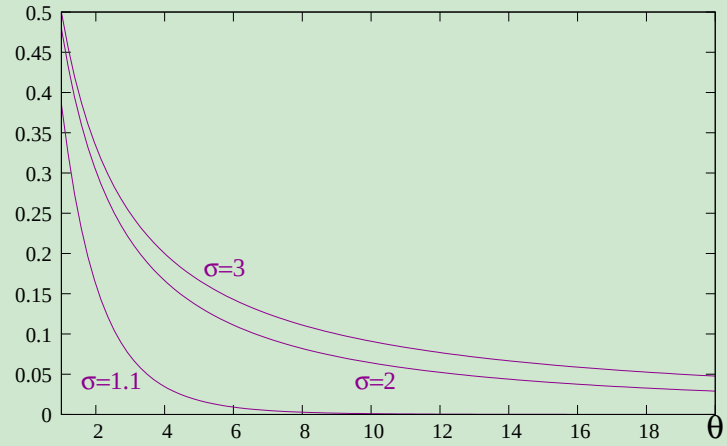


Pareto model :

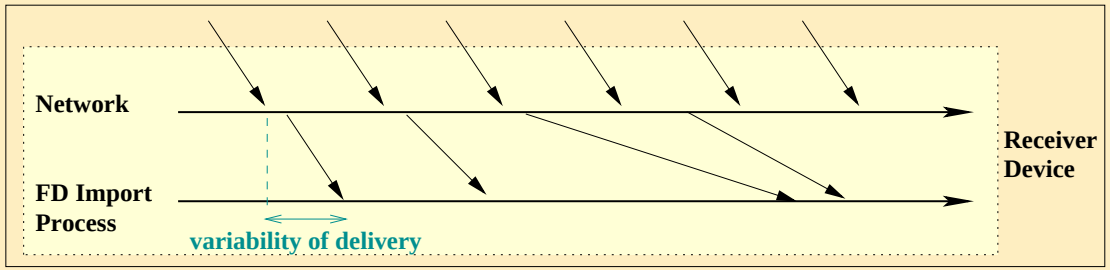


Contention on receiver (1)

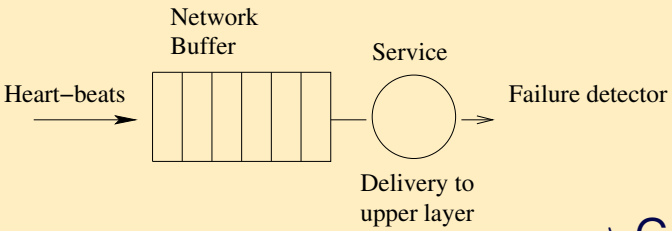
Variability of Heartbeat Arrivals

Depends on the type of receiver (Laptop or PDA)

\+ Correlation between inter-beats arrival periods



$\Rightarrow$ HB contention on the receiver



- input process : $\{A_n\}_{n\in\mathbb{N}}$
- service model : $\{S_n\}_{n\in\mathbb{N}}$
- hypothesis : deterministic arrivals

$\rightarrow$ GI/M/1 queue

Contention on receiver (2)

Output process of a D/M/1 queue $\rightarrow$ Suspicion rate computation

Inter-output period : $A = \frac{1}{\lambda}$; β unique solution of $\beta = \mathcal{L}_A(\mu(1-\beta)) = e^{-A\mu(1-\beta)}$

$$f_Z(x) = \begin{cases} \frac{\mu}{2-\beta} e^{-\mu(1-\beta)A}((1-\beta)e^{\mu(1-\beta)x} + e^{-\mu x}) & \text{if } x < A; \\ \frac{\mu}{2-\beta} e^{-\mu x}(e^{-\mu(1-\beta)A} + (1-\beta)e^{\mu A}) & \text{if } x \geq A. \end{cases}$$

Rate of false suspicion : $\theta > A$

$$\phi_I(\theta) = \frac{1}{A(2-\beta)\mu} e^{-\mu\theta}(e^{-\mu(1-\beta)A} + (1-\beta)e^{\mu A}) \qquad \theta \geq A$$

False suspicion probability, D/M/1 model

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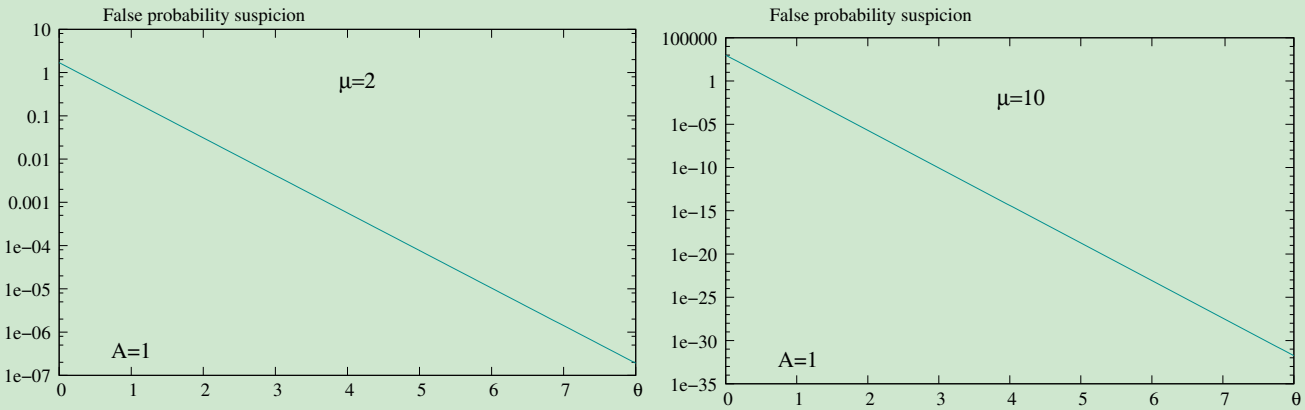
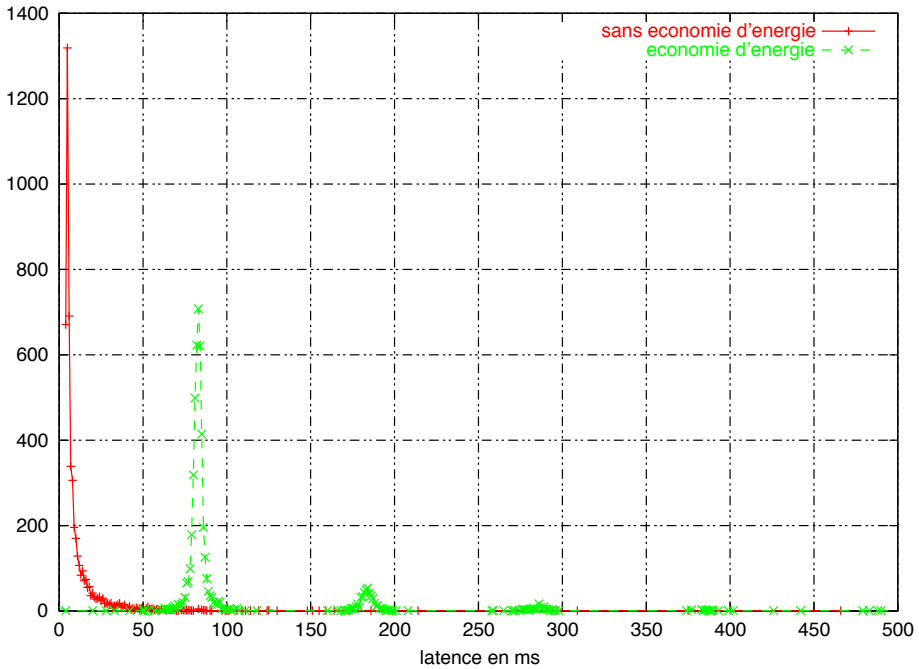


Experimental environment

Contexte Expérimental - Latences (2)

Pocket PCs en mode ad-hoc



Taille échantillon : 5000 mesures

→ ping (délai : 1 s)

Experimental environment

Orthogonal Array $L_8(2^7)$

TRIAL NUMBER	FACTORS						
	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	1	1	1	1
3	0	1	1	0	0	1	1
4	0	1	1	1	1	0	0
5	1	0	1	0	1	0	1
6	1	0	1	1	0	1	0
7	1	1	0	0	1	1	0
8	1	1	0	1	0	0	1

Contexte Expérimental - Latences (3)

→ Grand nombre de paramètres

Facteurs influents retenus :

- Distance
- Nb obstacles
- Nb entités
- Charge réseau
- Type émetteur
- Type récepteur
- Economie NRJ

Contexte Expérimental - Latences (3)

→ Grand nombre de paramètres

⇒ Plan d'expérience :

→ Méthode de Taguchi (à 2 niveaux)

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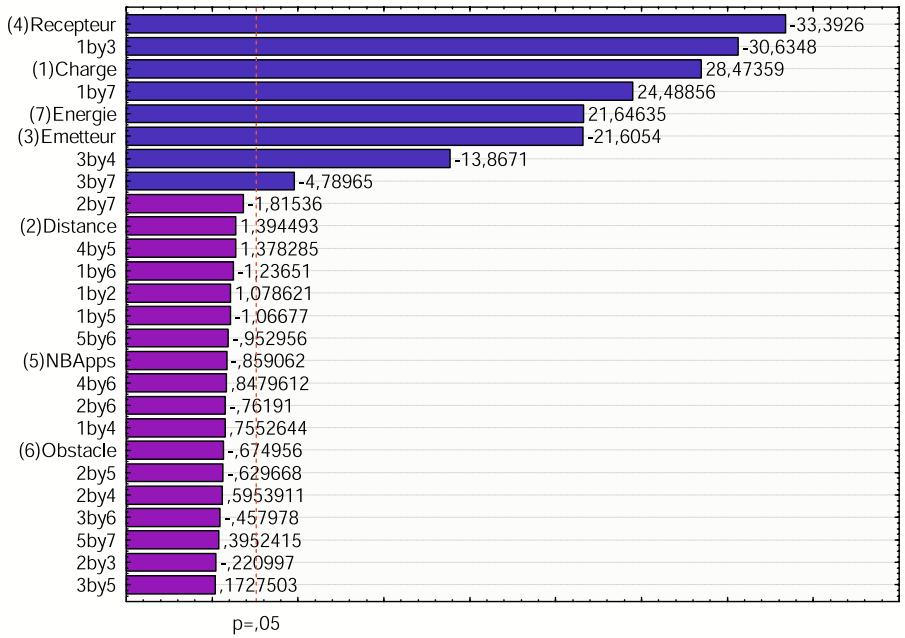

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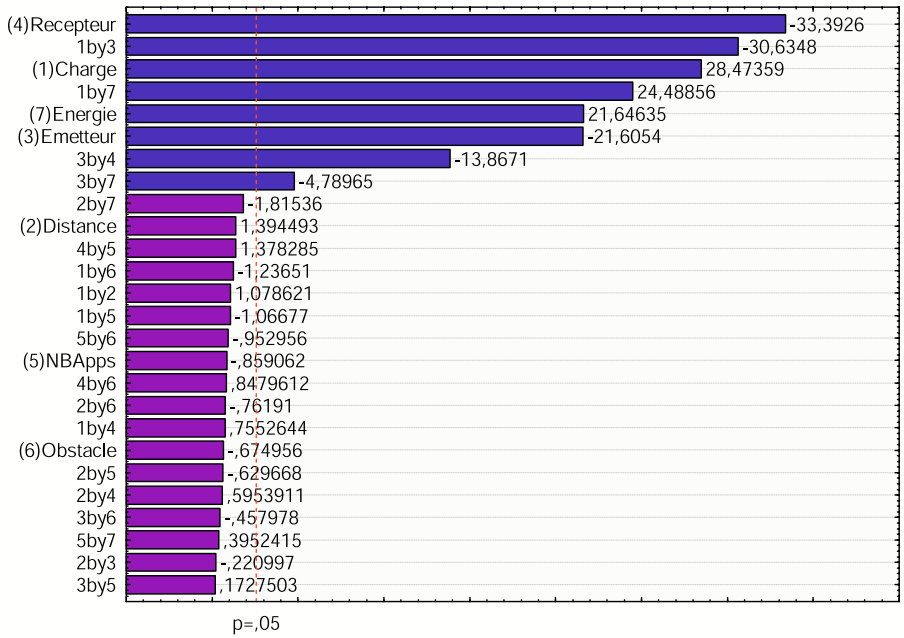

Facteurs prépondérants:

- Type récepteur
- Charge réseau
- Economie NRJ
- Type émetteur

Interactions

Experimental environment

Experimental Design :

- Devices (same OS, Java) :
  - Architecture 1 : 4 devices (2 Laptops + 2 PDAs)
  - Architecture 2 : 6 devices (2 Laptops + 3 PDAs + 1 sensor
- Interconnection : 802.11b ad-hoc network
- Experimental duration : 15 min ($\rightarrow$ about 10,000 measurements)

HB parameter Settings :

	Architecture 1 Highly loaded	*Architecture 2 Ideal Setting*	*Architecture 2 Perturbed Environment*
HB emission period	100 ms	500 ms	500 ms
Timeout	none	none	none

Reception process analysis

Density of the delivery process
$\Rightarrow$ timeout tuning

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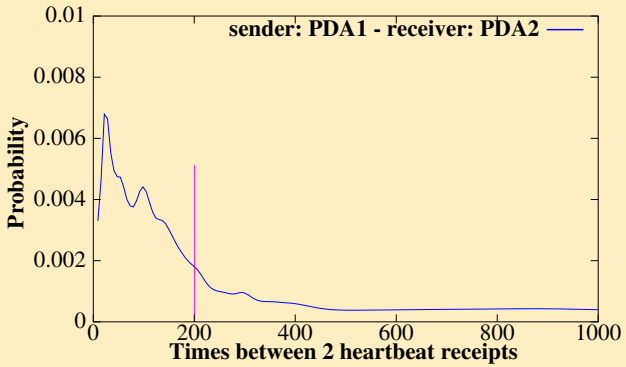
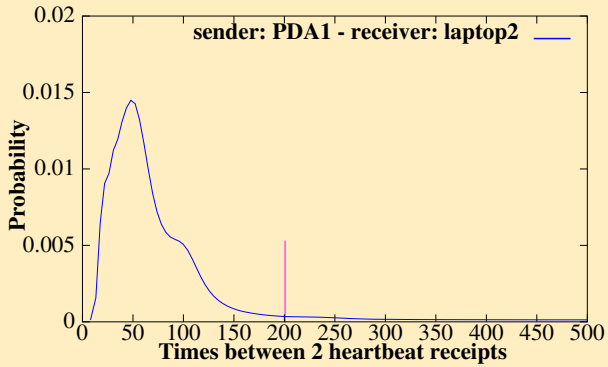
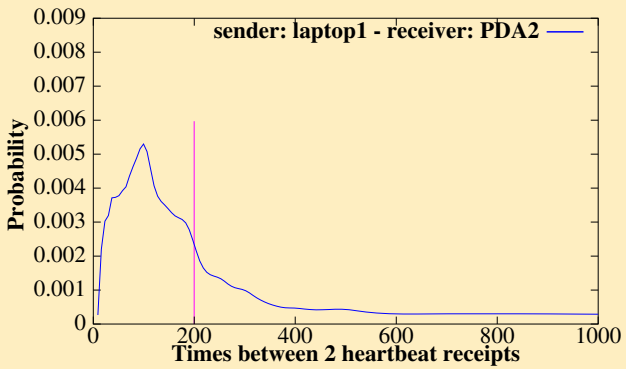
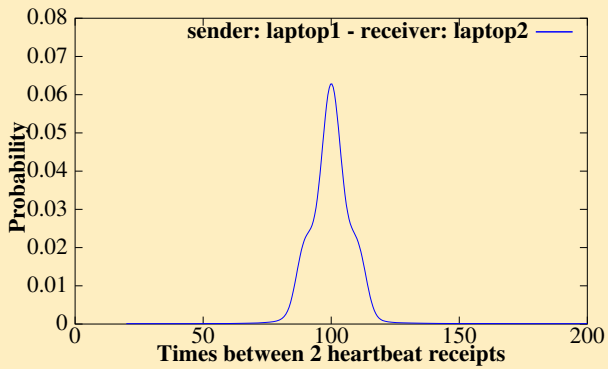
Highly loaded system

Distribution of the update times :









If timeout value = 200 ms

→ Quality of service highly depends on the type of the receiver

Highly loaded system

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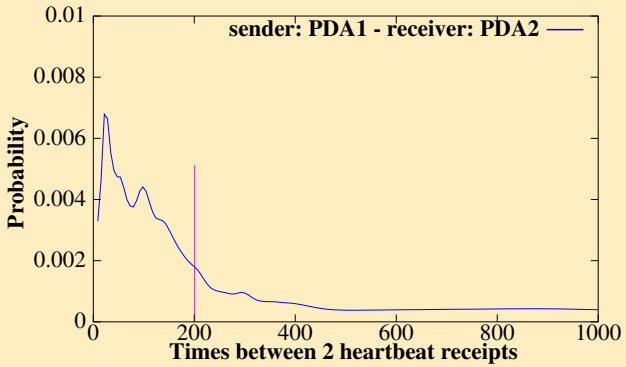

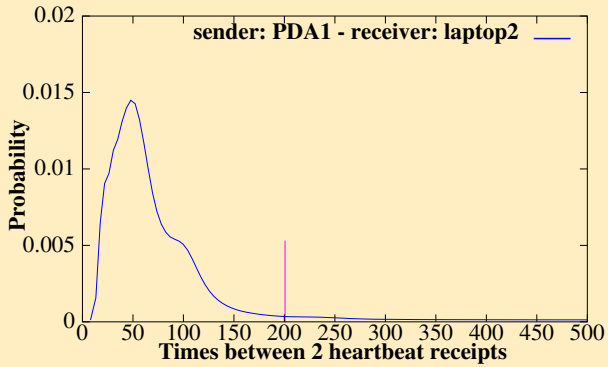

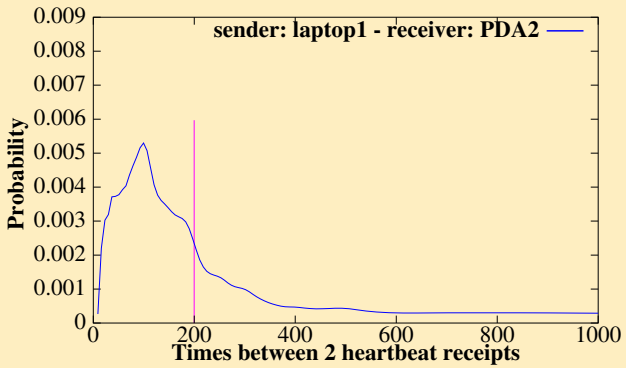

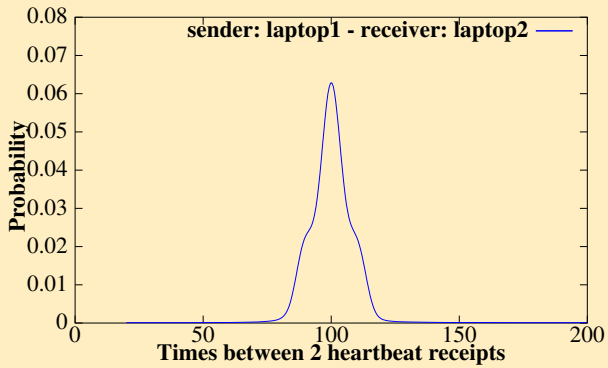

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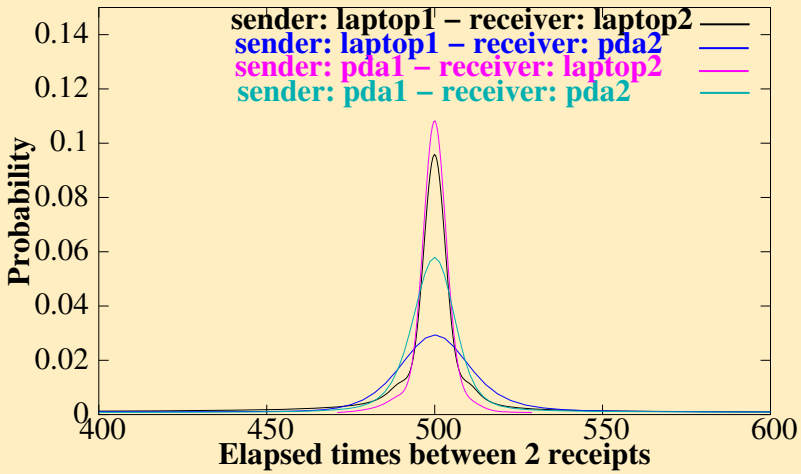

Timeout value :

- If the timeout value = 2∗ (HB period time)
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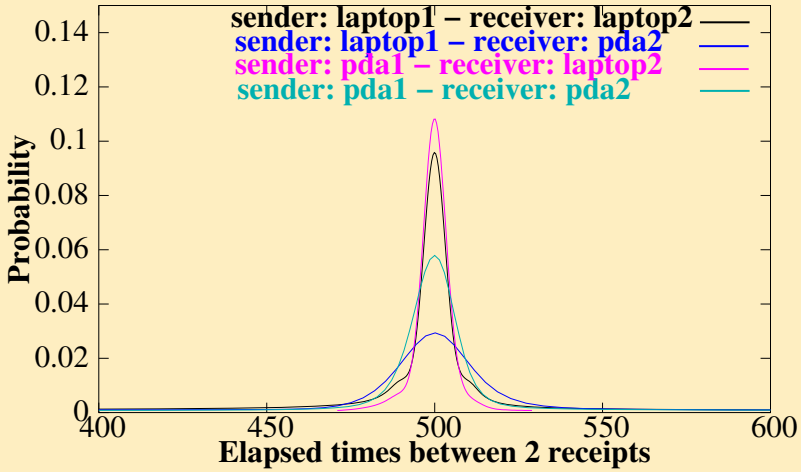

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Experimentation in perturbed environment

Perturbation control :

An external device is used to generate an external load (ping with 200kbytes/s)

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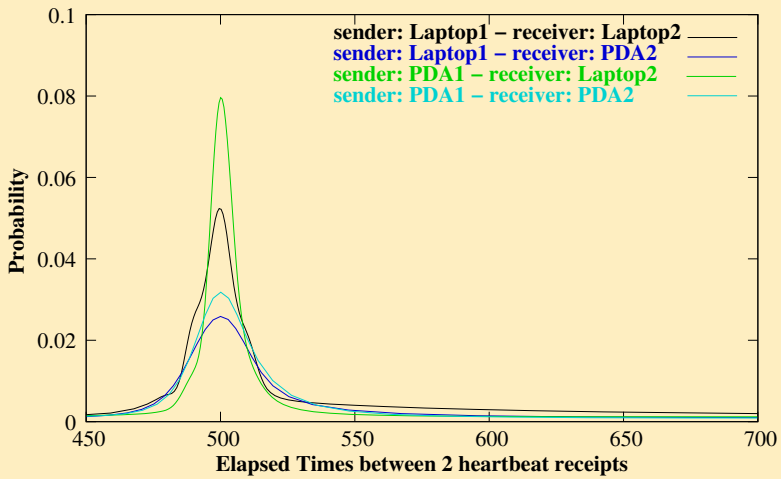

Results :

- Long non receiving period for PDA
- Some very small delays between HB receipts (after a long waiting time)

$\Rightarrow$ Correlation between succesive waiting times of two HB (bursty receptions)

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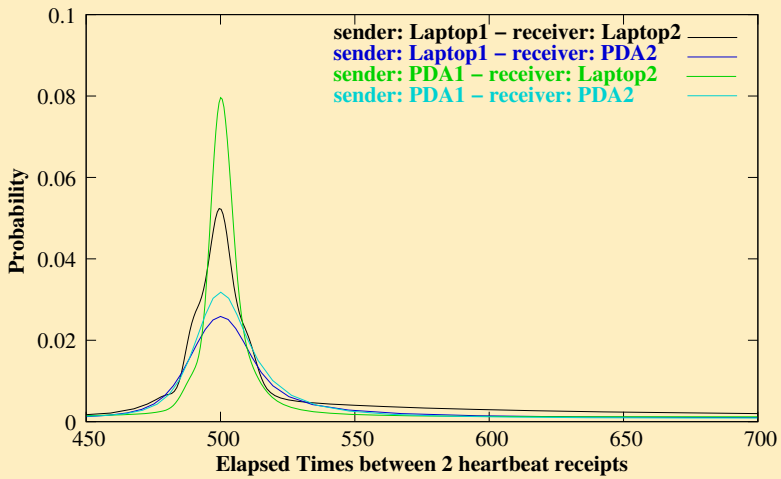

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Guideline (Montgomery)

1. Recognition of and statement of the problem
   series of small experiments
   factors screening
2. Selection of the response variable
3. Choice of factors, levels, and ranges potential design factors (nuisance factors)
   factors controllability
   cause and effects diagram (fishbone diagram)
4. Choice of experimental design
   randomization, replication, blocking
   factorial planning
5. Performing the experiment
6. Statistical analysis of the data
7. Conclusions and recommendations

Références I

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