

Design of Experiments

Option PDES

Jean-Marc Vincent¹

Laboratoire LIG

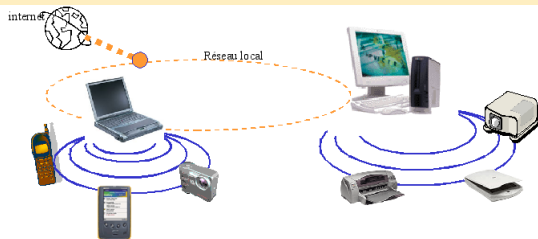
{Jean-Marc.Vincent}@imag.fr

¹ Université Joseph Fourier
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

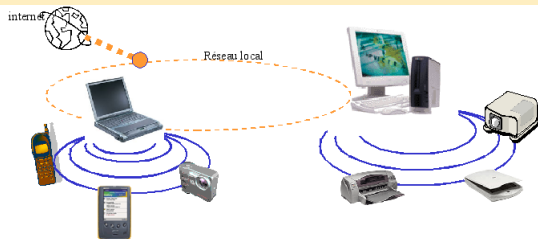
Devices share services and collaborate to maintain the community.

General distributed system problem

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

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Operating systems on a wireless network

Dynamic Architecture

- Heterogeneity of devices
- Behavior of wireless devices → 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]
-

⇒ 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.

→ 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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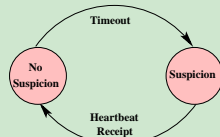
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- Risk analysis

Implementation



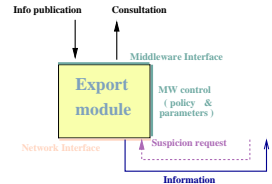
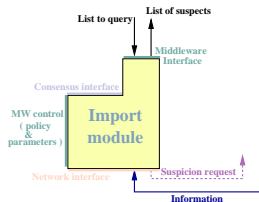
Failure Detectors Implementation

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 mechanism)



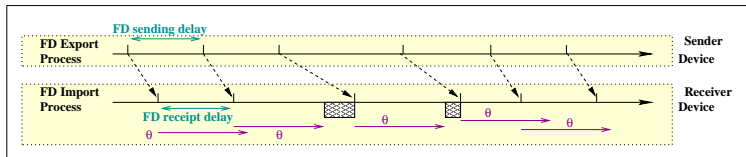
Informations Import

- Collect information
- Estimate the state of remote devices

Failure Detectors Parameters

The running principle :

Implemented mechanism : "heartbeat".



Parameters

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

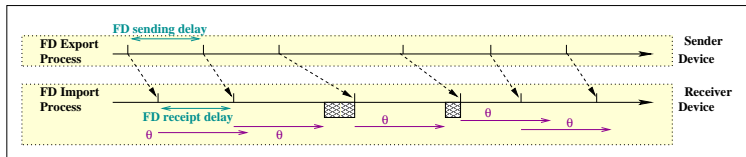
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Estimate the timeout values according to the expected quality of service.

Failure Detectors Parameters

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Implemented mechanism : "heartbeat".



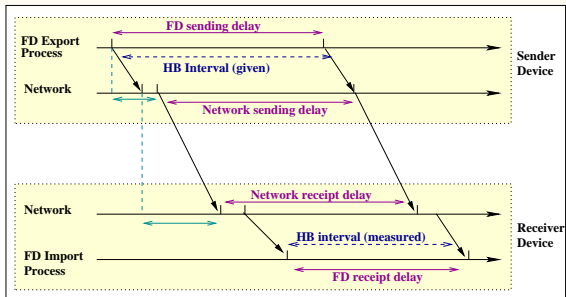
Parameters

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

Goal

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Statistical Description



Variability of HB arrivals

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

Statistical Description

False Detection Probability

θ = suspicion threshold (timeout)

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

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

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,k λ)	$\phi_I(\theta) = e^{-k\lambda\theta} P_k(\lambda\theta)$
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 :

Independent assumption Model

Variable Sending Delay

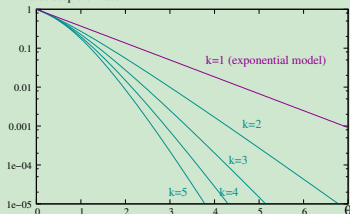
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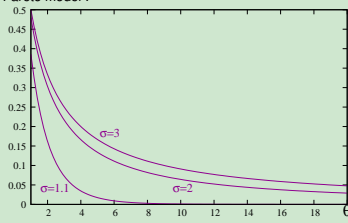
Suspicion probability related to reactivity

Erlang model :

False suspicion rate



Pareto model :

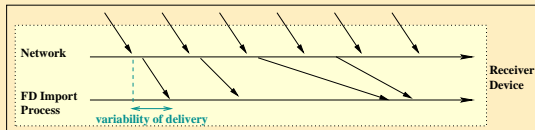


Contention on receiver (1)

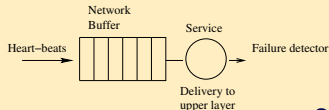
Variability of Heartbeat Arrivals

Depends on the type of receiver (Laptop or PDA)

+ Correlation between inter-beats arrival periods



⇒ HB contention on the receiver



→ GI/M/1 queue

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

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 : $\theta > A$

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

False suspicion probability, D/M/1 model

Contention on receiver (2)

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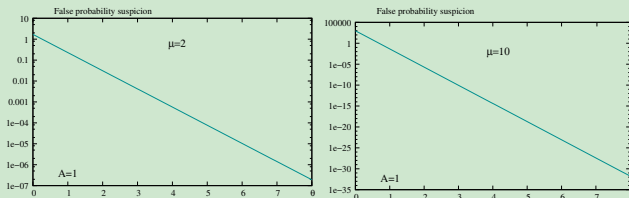
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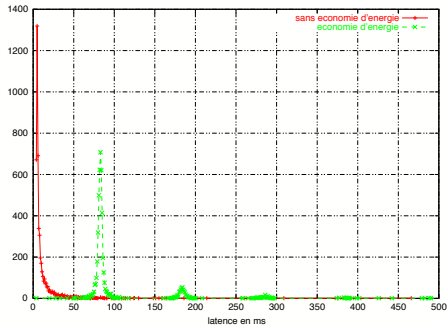
False suspicion probability, D/M/1 model



Experimental environment

Contexte Expérimental - Latences (2)

Pocket PCs en mode ad-hoc



Taille échantillon :
5000 mesures
→ ping (délai : 1 s)



Experimental environment

Orthogonal Array $L_8 (2^7)$

FACTORS							
TRIAL NUMBER	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 :

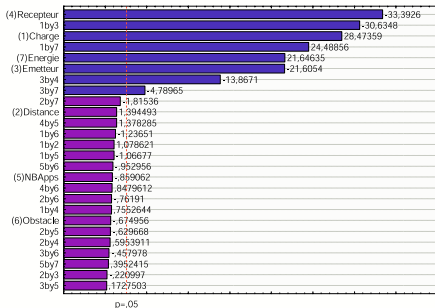
→ Méthode de Taguchi
(à 2 niveaux)

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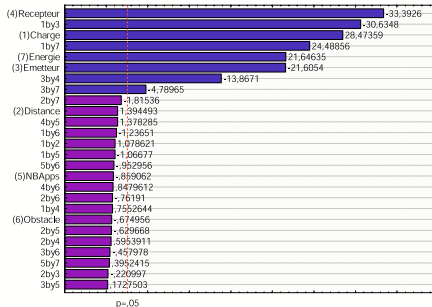


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Contexte Expérimental - Latences (3)



Facteurs
prépondérants:

- Type récepteur
- Charge réseau
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- 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 (→ about 10,000 measurements)

HB parameter Settings :

	<i>Architecture 1 Highly loaded</i>	<i>Architecture 2 Ideal Setting</i>	<i>Architecture 2 Perturbed Environment</i>
<i>HB emission period</i>	100 ms	500 ms	500 ms
<i>Timeout</i>	none	none	none

Reception process analysis

Density of the delivery process
⇒ timeout tuning

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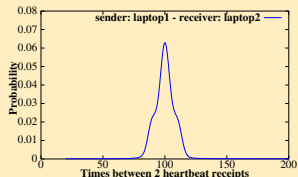
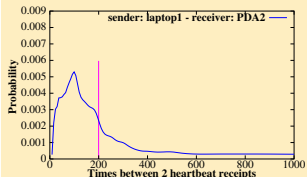
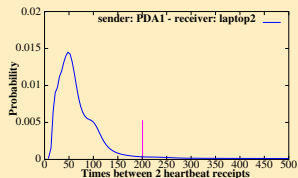
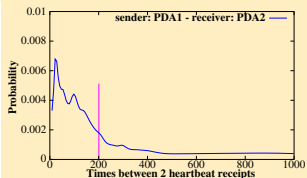
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Highly loaded system

Distribution of the update times :

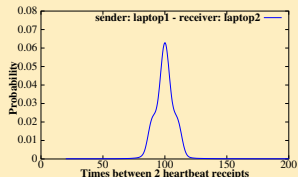
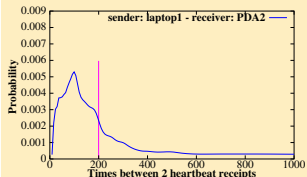
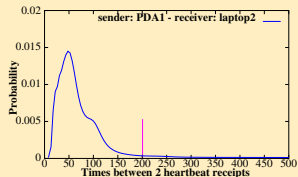
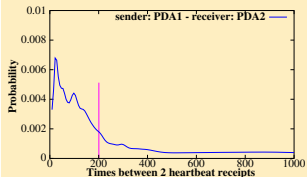


If timeout value = 200 ms

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

Highly loaded system

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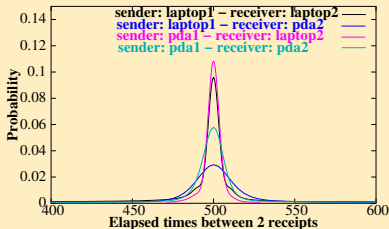


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"Ideal Setting" Experimentation

Heartbeat Reception Analysis :

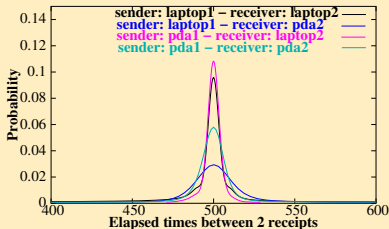


Timeout value :

- If the timeout value = $2 \times$ (HB period time)
- Then, the suspicion rate is around
 - 10^{-3} if the receiver is a laptop
 - 10^{-2} if the receiver is a PDA

"Ideal Setting" Experimentation

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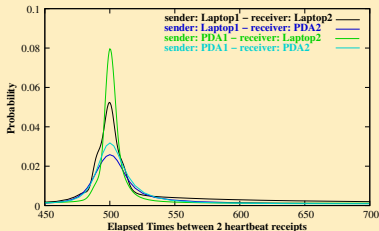
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Experimentation in perturbed environment

Perturbation control :

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

Heartbeat Reception Analysis :



Results :

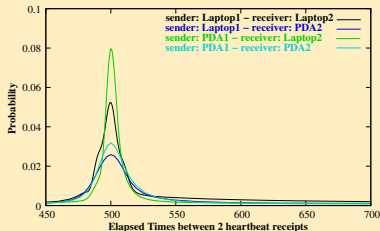
- Long non receiving period for PDA
- Some very small delays between HB receipts (after a long waiting time)
- ⇒ Correlation between successive waiting times of two HB (bursty receptions)

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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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