An Optimized Workload for Failure Data Analysis of Mobile P2P over Bluetooth Ad-Hoc Networks

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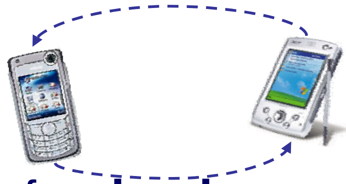
::. Outline

- Motivations
- Bluetooth Background
- Problem Statement
- The proposed solution
- MobP2PSim Simulator
- Real Testbed & Experimental Results
- Conclusions and Future Work

::. Motivations

- Many mobile devices equipped with wireless communication technologies
- **Mobile P2P** recognized as the base paradigm for mobile applications (mobile conferencing, file-sharing) and the Mobile Internet



- Growing interest in using mobile P2P for **business and mission critical scenarios** (e.g. instant messaging to help disaster survivors' rescue, sensor networks for environmental monitoring)…
- …**dependability** becomes a major concern!

::. Why Bluetooth?

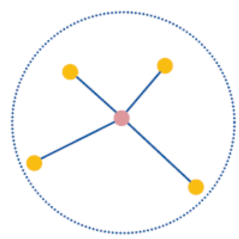
- The Bluetooth (BT) wireless technology is nowadays integrated in several mobile-enabled appliances, such as laptop, PDA, tablet PC, smart phones;
- BT is widely used as an enabler for Mobile ad-hoc P2P applications (e.g. ad-hoc file exchange over RFCOMM).

::. Bluetooth Background

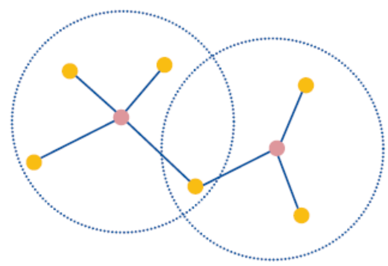
- A wireless technology working in ISM 2.4 GHz unlicensed band
- Goals of specification:
  - ✓ Low power
  - ✓ Low cost < $5 US for the antennas
  - ✓ Interoperability between terminals from different vendors
- Proposed using:
  - ✓ Short-range radio technology
  - ✓ Ad hoc piconetworking and file exchange
  - ✓ Dynamic device discovery

::. Bluetooth Background

- Two or more Bluetooth nodes (up to 8) are connected to form a piconet.
- One of them acts as the master, the other act as slaves
- Two or more interconnected piconets form a scatternet.

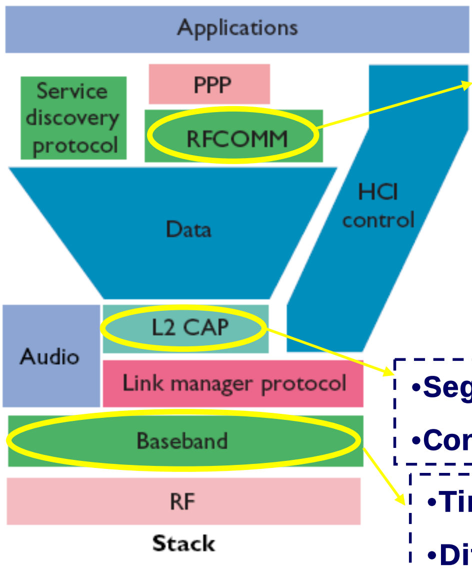


Piconet



Scatternet

::. Bluetooth Protocol layers



- Emulates full 9-pin RS-232 serial communication over an L2CAP channel (cable replacement)
- Supports flow control on individual channels
- Serial Port Profile (SPP) defines how to establish an RFCOMM connection between two nodes
- OBEX protocol uses RFCOMM channels to exchange files between nodes

- Segmentation and reassembly
- Connection-oriented and connectionless communication

- Time division and multiplexing
- Different packet types
- Integrity checks and retransmission mechanisms

::. The need for proper workload ...

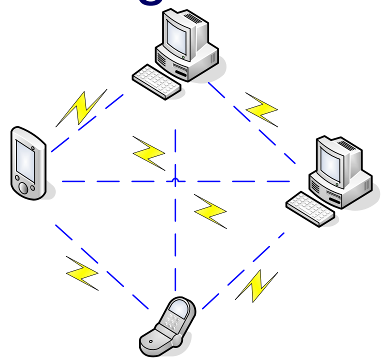
- Since mobile P2P networks are operational systems, their dependability behavior may be studied through **Field Failure Data Analysis** (FFDA) campaigns

- Due to spot usage of the terminals, dependability analysis of mobile environments needs an ad hoc synthetic workload (different from those for server farms or networked systems, available in literature)
  - ✓ Peers in a mobile P2P network are not used *uniformly*.

- FFDA campaigns require the network to be exercised continuously, so that:
  - ✓ continue dependability measures can be estimated (MTTF,MTTR);
  - ✓ the amount of collected data is maximized during the collection period (statistical significance)

::. Objective

Design an optimized workload for a P2P mobile network in charge of orchestrating peers and allowing FFDA campaigns.



::. Problem Statement

- What does ***optimized workload*** mean?

  In order to let the failure distribution be not influenced from network load, peers have to be *orchestrated*, i.e.:

  - Each peer has to equally perform the role of client as well as the role of server;
  - Each peer has to be connected the same way to every other peer (i.e. the same number of connection has to be established between each pair of nodes).

::. Problem Statement

- Let the network S be a tuple composed of:
  - ✓ The set of peers P;
  - ✓ A binary connection matrix C;
  - ✓ A timing function τ which represents a snapshot of the network state in terms of active nodes and established connections at a given instant *t*

$$s = (P, C, \tau)$$

where

$$P = \{p_1, p_2, \dots p_n\}$$

$$C(n \times n) : c_{p_i p_j} = \begin{cases} 1 & \text{if} \quad p_i p_j \quad \text{are} \quad \text{connected} \\ 0 & \text{otherwise} \end{cases}$$

$$\tau : t \rightarrow P(t) \times C(t)$$

::. Problem Statement

- Let's introduce the following parameters:
  - ✓ *Time server (client) $T_{s[i]}$ ($T_{c[i]}$):* time interval time during which i-th peer acts as server (client);
  - ✓ *Number of connections Nc[pi,pj]:* # of connections between p_i and p_j. N_c is a (n x n) matrix;

- Let Δt = [0,T] be the observation period

::. Problem Statement

- The optimization problem is formulated as follows:

OBJECTIVE FUNCTIONS

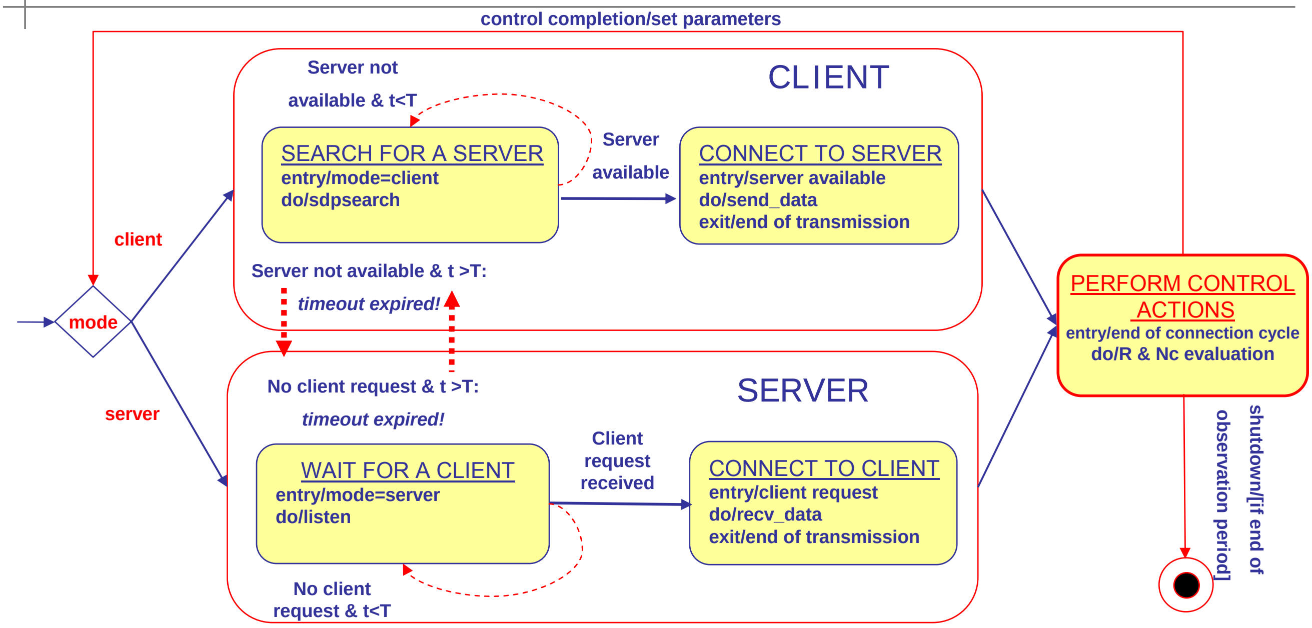
$$\begin{cases} R[p_i] = \dfrac{Ts(i)}{Tc(i)} = 1 & \forall i = 1.....n \\ Nc[p_i, p_j] = Nc[p_i, p_k] & \forall i = 1.....n \quad \forall j \neq k \quad k \neq i \quad t = T \end{cases}$$

$$subject \quad to$$

CONSTRAINTS

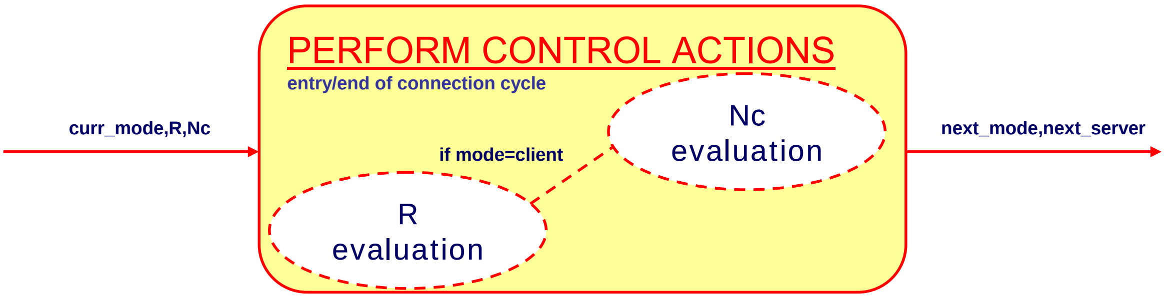
$$\begin{cases} \sum_{j=1}^{n} c_{p_i, p_j} = 1 & \forall i = 1.....n \\ \sum_{i=1}^{n} c_{p_i, p_j} = 1 & \forall j = 1.....n \\ T_s[p_i], T_c[p_i] \geq 0 & \forall i = 1.....n \\ c_{p_i, p_j} = 0/1 & \forall i, j = 1.....n \end{cases}$$

::. Our heuristic solution



Closed Loop control strategy

::. Our heuristic solution



•R evaluation :

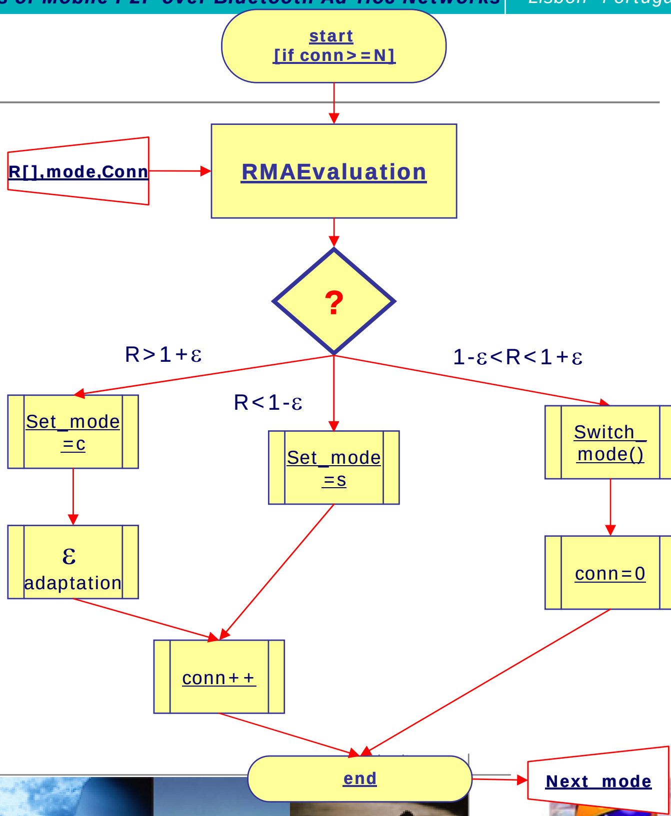
at the end of each connection cycle, each peer establishes its next mode following the law → E(Ri)=1 ;

•Nc evaluation:

for each client node, the server to which it should be connected in the next cycle is established aiming at Nc[pi,pj]=Nc[pi,pk]

::. R evaluation

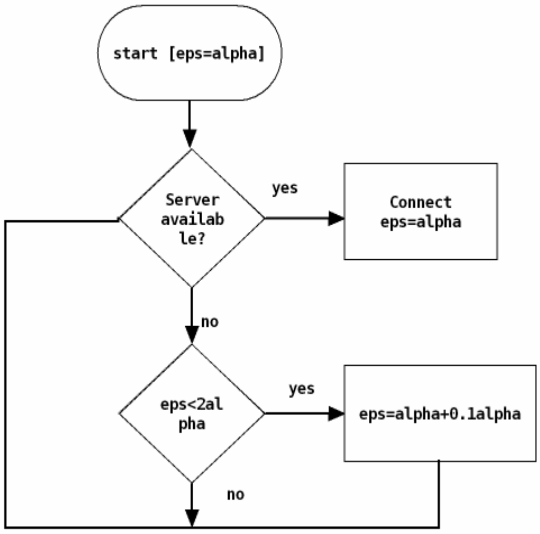
- Each peer periodically evaluates R and, if the current R is *not balanced,* corrective actions are undertaken;
- The control action is performed periodically, i.e each *N* connection cycles, in order to let the network evolve naturally for the most of the time.



::. Threshold adaptation strategy

- If there are no available servers the client threshold is gradually increased so as to force it to switch its mode to server.

- This strategy causes the overall number of servers and clients to be more balanced.

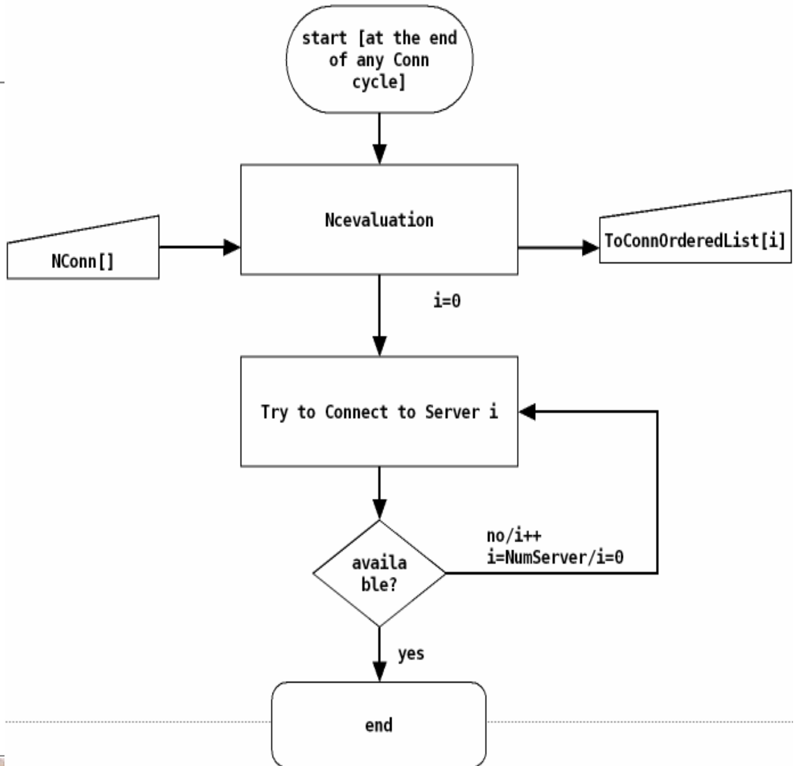


::. Nc Evaluation

- Each client firstly tries to connect to the server it has been connected the less to;

- Servers are ordered in a priority list: *the lower is the number of connections, the higher is its priority.*

  If the server *i* not available, the client tries to connect to the server *i+1*;

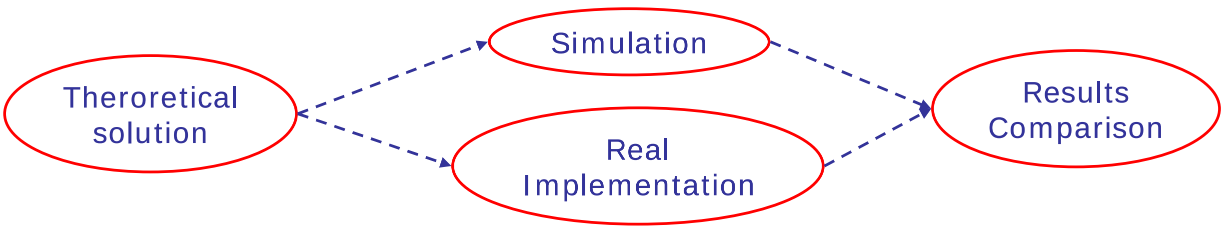


::. Modeling Failures: Network dinamicity

- In a P2P mobile network a node is free to leave and to join the network
- Peers' mobility is generally meant as a failure:
  - Different statistical distributions have been used to model such a failure. We used an exponential distribution [13] for failure duration time. A peer can fail with a probability (namely ***mobility***) of 1%.

::. Validating the proposed solution...

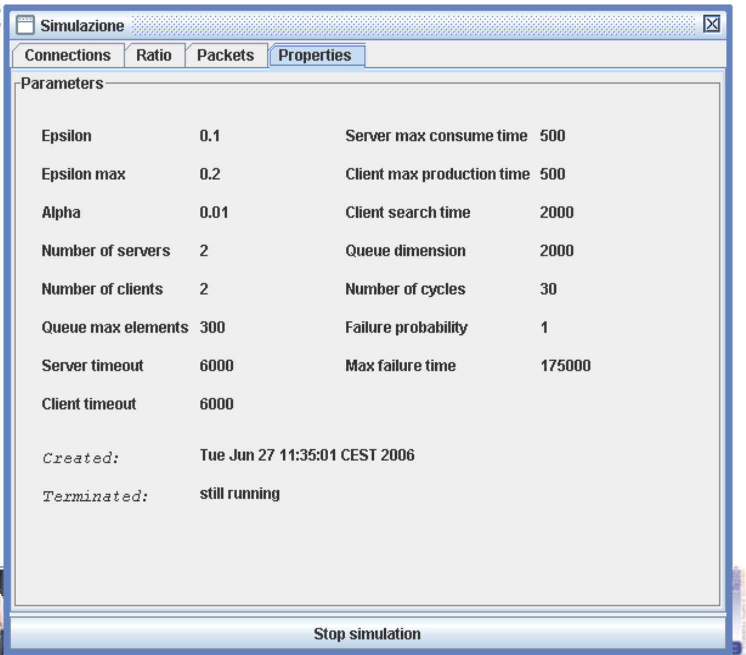
- The proposed solution has been validated via:
  - simulation experiments;
    - » *MobP2PSim*
  - the setup of a real Bluetooth testbed. Each node run the designed workload. Real collected data have been analyzed….

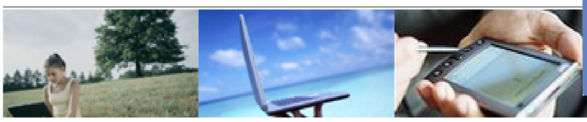


::. MobP2PSim simulator

- We realized a Java based simulator to assess our solution
- User reproduces the behavior of P2P mobile networks by specifying several parameters, including:
  - **Epsilon threshold**
  - **Maximum epsilon value**
  - **Alpha**
  - **Number of servers**
  - **Number of clients**
  - **Server timeout**
  - **Client timeout**
  - **Number of cycles**
  - **Failure probability**
  - **Maximum failure time**
- Simulator available at:

www.mobilab.unina.it/P2PSimulator.html

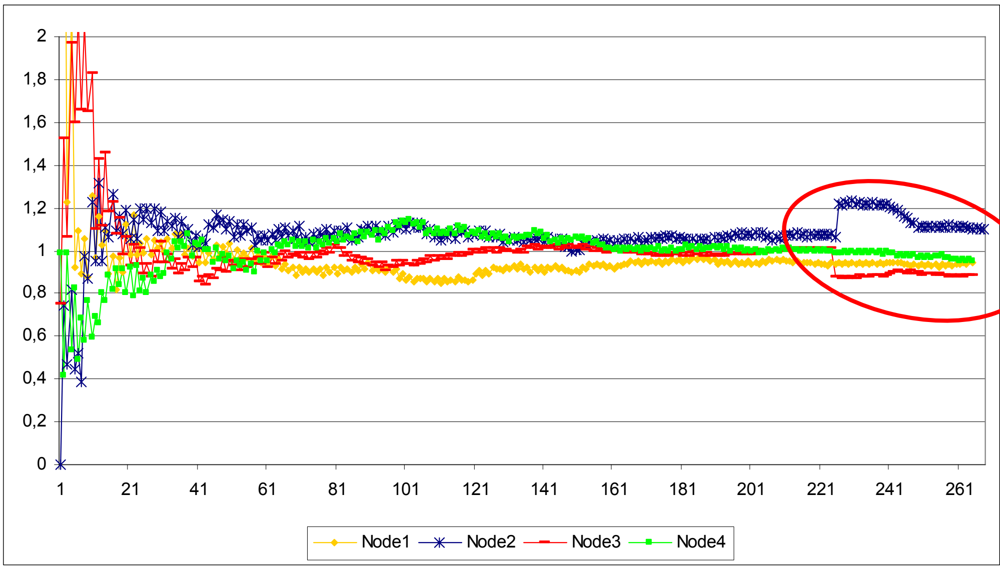




MobP2PSim: snapshots

::. Simulation Results

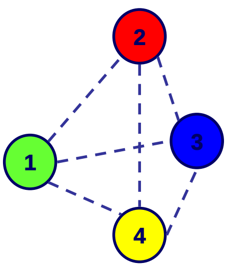
- Evolution of R WRT the number of connections, for a piconet with 4 nodes

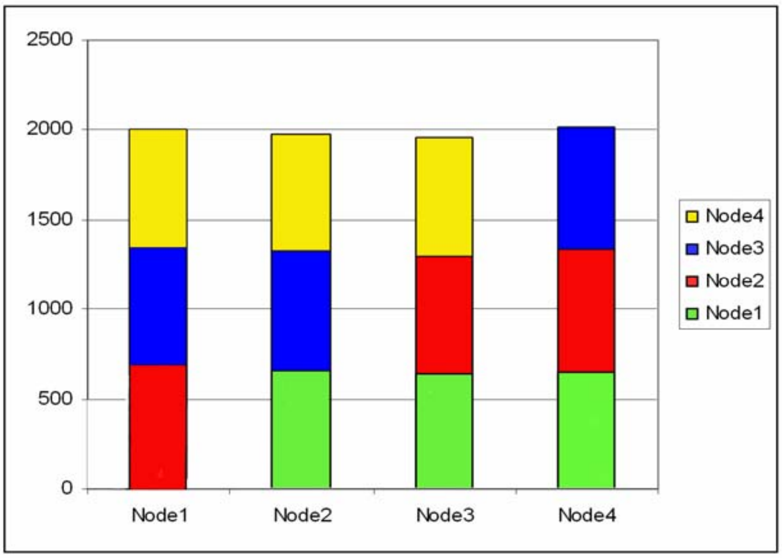


::. Simulation Results

- Number of peer connections (network: 4 nodes)

Number of Conn=618;
StdDev=1.34%





::. Robustness evaluation

P(fault)=0.01
FaultDuration ~Exp(90s.)

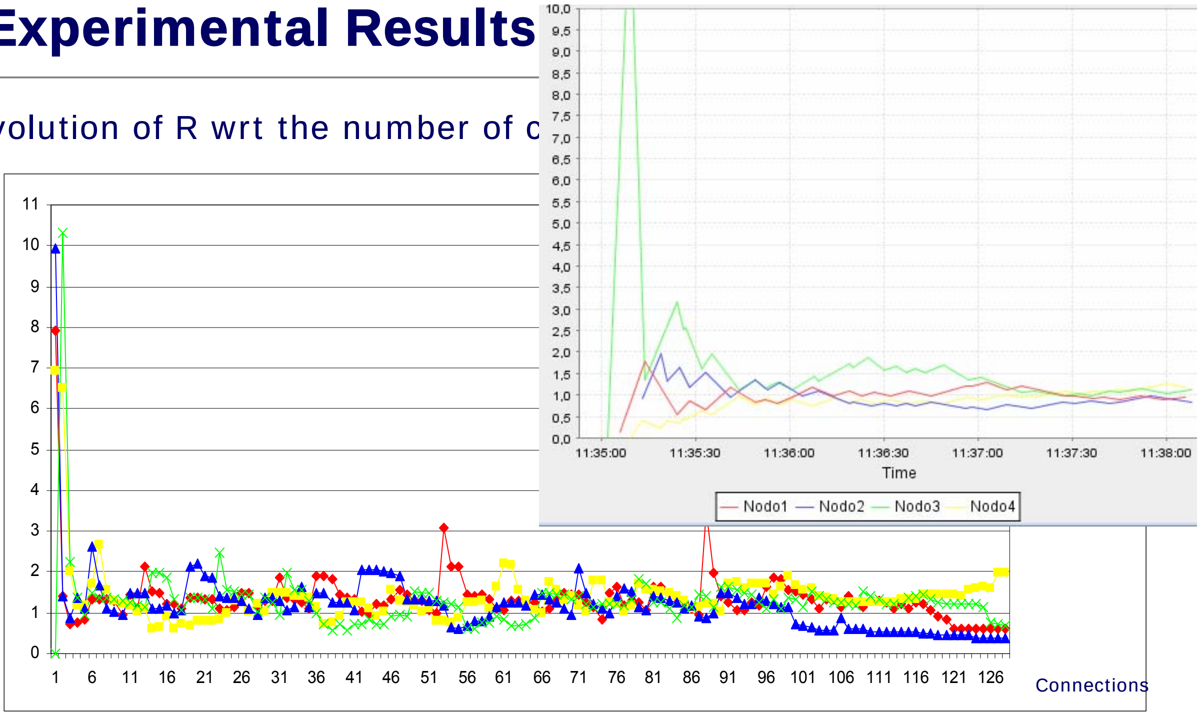
Number of peers=8			
Mobility = true			
R		Nc	
Avg 1,082	Var 0,025	Avg 157,482	Var 11,954
Mobility = false			
R		Nc	
Avg 1,093	Var 0,036	Avg 157,589	Var 9,987

std_dev=3.456%

std_dev=3.16%

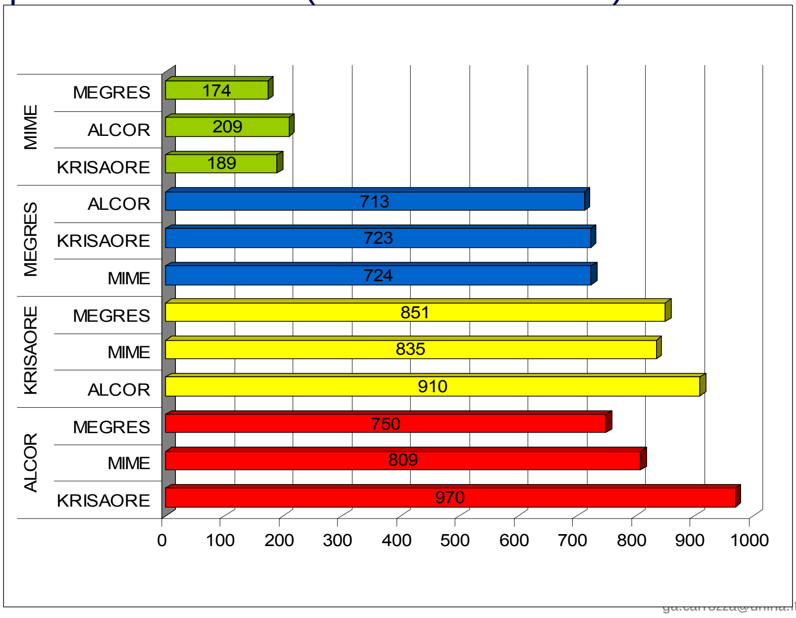
::. Experimental Results

- Evolution of R wrt the number of c



::. Experimental Results: a real BT network

- Number of peer connections (network: 4 nodes)



Mean Number of Conn=650; StdDev=2.34%

::. Conclusion and Future Works

- We have defined a workload to characterize the dependability of Mobile P2P over Bluetooth ad-hoc networks
- We plan to assess the workload in more a massive field failure data campaign
- Even if designed for and tested over Bluetooth networks, we believe that the proposed methodology is general enough to be extended to other wireless ad-hoc technologies

Any question?

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MobiLab An Optimized Workload for Failure Data Analysis of Mobile P2P over Bluetooth Ad-Hoc Networks
SIUMI 2006
July, 4th
Lisbon -Portugal

::. Problem solution

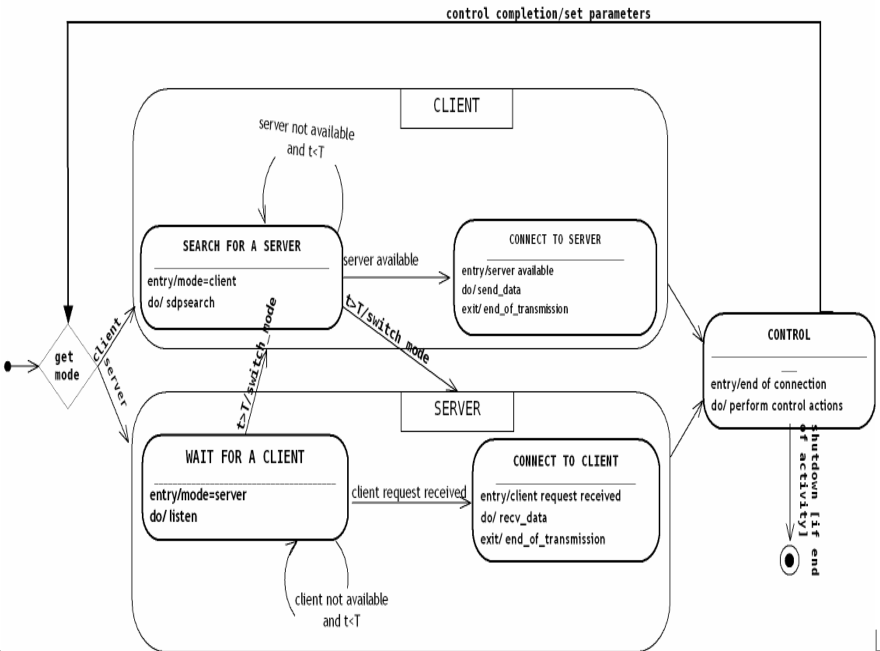
- The problem is hard to solve in exact terms since:
  - ✓ it is subject to equality and binary constraints;
  - ✓ the objective functions are equality statements rather than inequalities.

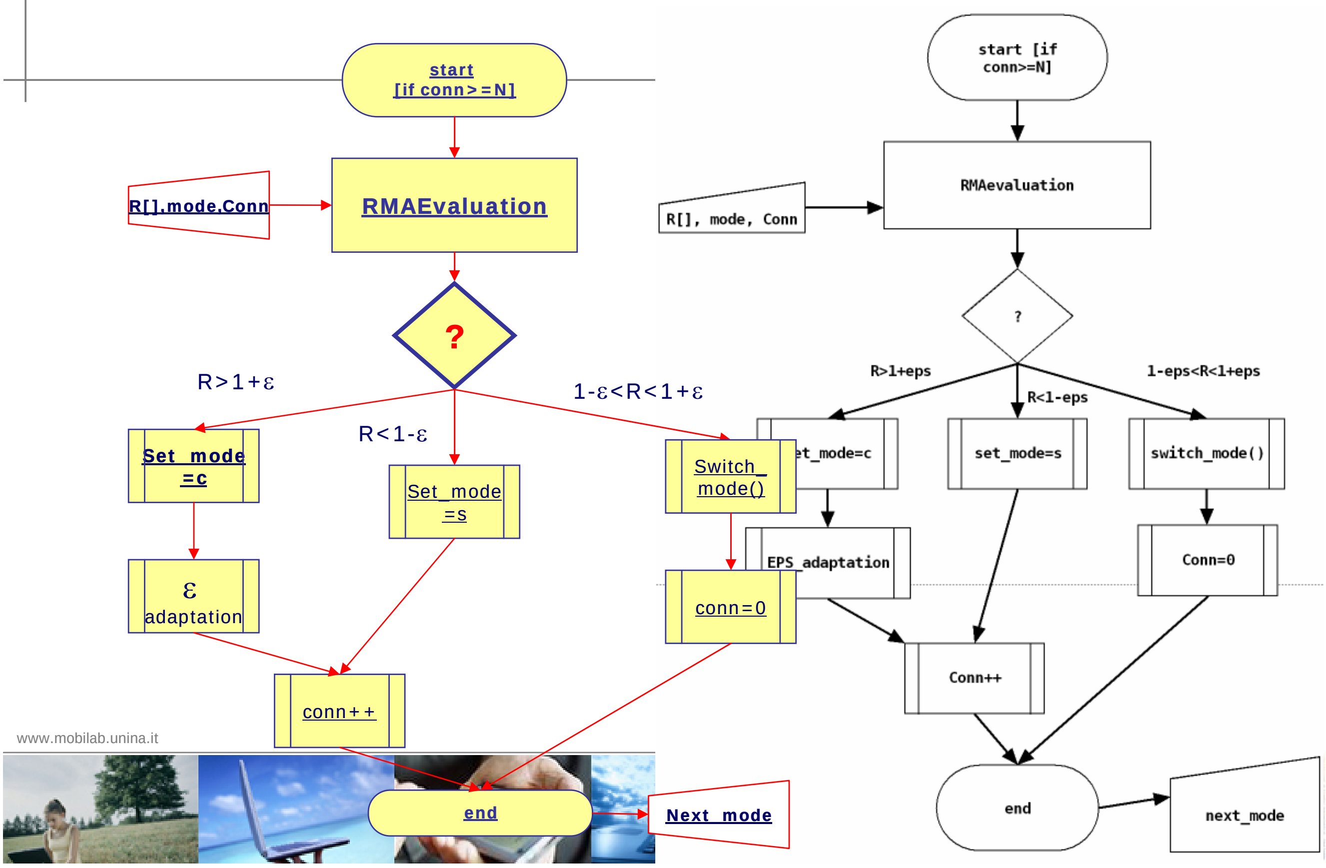
Heuristic Solution

www.mobilab.unina.it ga.carrozza@unina.it

Establishing Next Mode

$$NextMode = \begin{cases} C & if\ 1 - R < -\epsilon \\ S & if\ 1 - R \geq \epsilon \\ Switched & if\ -\epsilon < 1 - R < \epsilon \end{cases}$$




start
[if conn>=N]
R[].mode.Conn
RMAEvaluation
?
R>1+ε
R<1-ε
1-ε<R<1+ε
Set_mode
=c
Set_mode
=s
Switch_
mode()
ε
adaptation
conn=0
conn++
end
Next_mode
start [if
conn>=N]
R[], mode, Conn
RMAevaluation
?
R>1+eps
R<1-eps
1-eps<R<1+eps
set_mode=s
switch_mode()
EPS_adaptation
Conn=0
Conn++
end
next_mode