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Distributed algorithms in a (highly) dynamic context

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LaBRI, Université Bordeaux 1

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Based on

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Outline

- Secured fleets of autonomous communicating mobile terminals
- Dynamic graphs and (secured) fleets of autonomous communicating mobile terminals
- The relationship of hardware design and security
- Example applications

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Secured fleets of autonomous communicating mobile terminals

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Outline

- Context
- Current approaches
- Real life
- Our approach, our target platforms

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Ref : 0001@2012-jan-05@12-53@1-1-1 : From ref : keynote workkcomp 2010

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[Context]

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Goals and research topics of the Muse research group at LaBRI

Contribute to the definition and development of supporting middleware, tools and mechanisms formally validated that make it possible to take advantage of the resources (static or mobile) connected to the network (wired or wireless) and to develop applications on top of these resources.

Target systems

Secured fleets of autonomous communicating mobile terminals

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[Context]

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We target real world networks

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[Context]

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Nodes can move/appear/disappear

[Context]

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Nodes can move/appear/disappear

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[Context]

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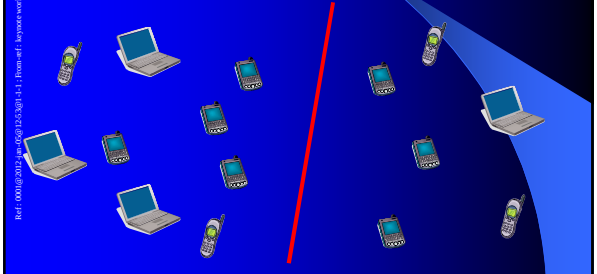
The network can become disconnected



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[Context]

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Summary of context and consequences

- (really) mobile Ad-hoc Networks (MANets)
  - → beyond Delay/Disruptive Tolerant Networks (DTN)

➔ High instability
- ➔ Very limited neighbourhood relationship
  - ➔ No communication guarantee
  - ➔ Routing is not a solution
  - ➔ Brute flooding is not a sufficient solution

➔ Users are most of the time not known in advance
- ➔ Unsecure boundaries

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Outline

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- Current approaches
- Real life
- Our approach, our target platforms
- Associated models
- Example applications

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Current approaches

Applications have a **global** vision/knowledge

middleware

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Current approaches

- Their goal is to hide the u… aspect by providing (c… ng to provide):
  - Routing
  - Sync… aranteed) communications

STOP TALKING ABOUT ROUTING!!!!!!!!!!!!
(in this precise context)

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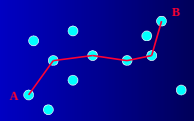
The routing based approach

- Proactive
  - OLSR, DSDV
- Reactive
  - AODV, TORA, DSR



[Current approaches: their limitations]

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Basic asumption

- At any time a route can be established between two mobile units of the network, i.e. the network is connected and virtually stable
- → classical applications can be used
- → classical security techniques can be used
  ex.: Certification Authority
  (the problem of keys distribution remains)

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[Real life]

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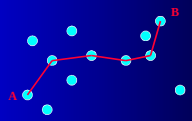
In the real life …

- Example:
  - Network of cars
  - Students on a campus
  - Tactical military networks
  - Crisis management
  - Home networking
  - …



[Real life]

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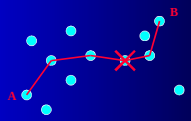

[Real life]

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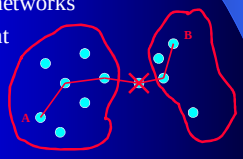

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[Real life]

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In the real life …

- Example:
  - Network of cars
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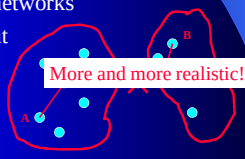
  - Tactical military networks
  - Crisis management
  - Home networking
  - …

More and more realistic!



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[Real life]

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The nature of the network changes

➔ The nature of applications changes
  – group/community based, dynamic, …
    ➔ the Internet of Things

➔ The management of security changes

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[Real life]

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Paradigm shift for applications

How many people are there ?

Are there many people ?
(or approximate number)

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[Real life]

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Impact on applications

- The objectives must be lowered because of high instability
- Examples:
  - counting → lower bound
  - covering tree→ covering forest
- But .. this is real life ☺

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[Real life]

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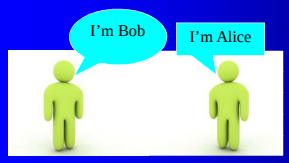
Paradigm shift for security



Share keys, authenticate

Recognize
- individually
- group/topic based

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[Real life]

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Impact on security

- The objectives must be lowered because of unsecure boudaries
- Examples:
  - Entity based keyes → group/topic based keyes
  - authenticate → recognize
- But once again … this is real life ☺

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Our approach

The middleware is never seen as something global
➔ the applications interact locally

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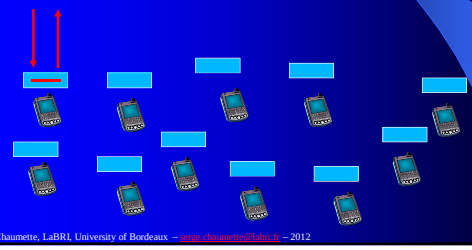
Applications management
Local – local primitives

Local impact
Local computation
Examples: one way communication



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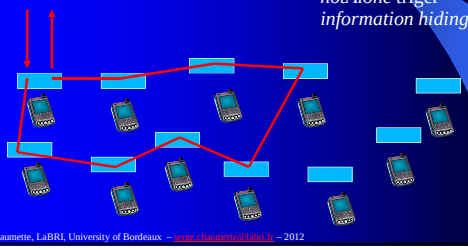
Applications management
Local – remote primitives

Local impact
Distributed/remote computation
Examples: *haveBeenHeard* triger
notAlone triger
information hiding



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Security management

[Our approach]

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A vertical approach

application

Distributed algorithms (P2P), specialized languages

Middleware

- P2P communication
- hardware heterogeneity
- management
  - . adaptation to the environnement
  - . code generation

hardware

- unstability
  - . of the network
  - . of the drones
- security
  - . based on smart cards
  - . wired dedicated features
- adaptation
  - - security, radio, etc.

+ validation, modelisation and verification

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[Our approach]

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A tentative taxonomy

- Wireless Networks
  - Ad hoc
    - Mobile
      - MANets
      - VANets
      - UAVNets
      - SensorNets
      - MEMSNets
    - Static
      - SensorNets
      - MEMSNets
  - Infrastructured

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[Our approach]

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Our target systems

Secured fleets of autonomous communicating mobile terminals

- Fleets of mobile phones
  - – 100 Android phones
- Fleets of robots
  - – 10 prototypes being built → fleet of 200
- Fleets of UAVs
  - – Fly-n-Sense + DGA (French army)

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Fleet of Android mobile phones

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Underlying constraints

- Behavior of the fleet members
  - unpredictable mobility
  - unpredictable volatility
- Possible controls of the fleet members
  - none

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Fleet of robots

- This work is being carried out with Olivier Ly and Hugo Gimbert
  - Mobility
  - XBee Communication
  - Localization (?)
  - Infra-red targeting (?)

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Underlying constraints

- Behavior of the fleet members
  - partially predictable mobility
  - unpredictable volatility
- Possible controls of the fleet members
  - partial mobility control

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[Our approach]

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Fleet of UAVs

- Collaboration
  - Fly-n-Sens, IMS, ENAC
    - SYMM project labeled by the world competitivity cluster Aerospace Valley
  - DGA (french Army)

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Underlying constraints

- Behavior of the fleet members
  - partially predictable mobility
  - unpredictable volatility
- Possible control of the fleet members
  - (almost) total mobility control

[Our approach]

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[Our approach]

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[Our approach]

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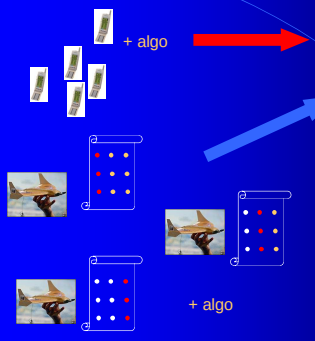

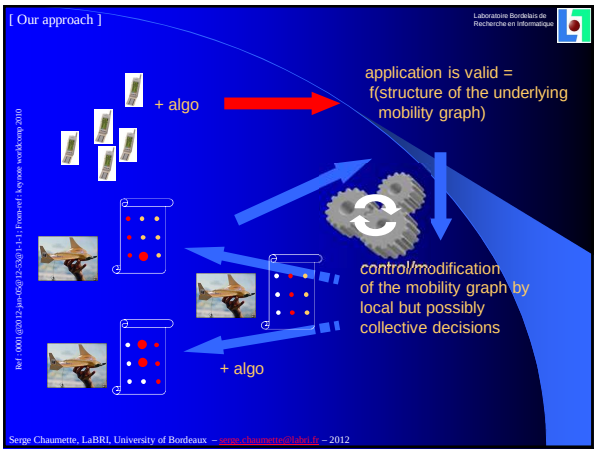
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+ algo
application is valid = f(structure of the underlying mobility graph)
control/modification of the mobility graph by local but possibly collective decisions
+ algo
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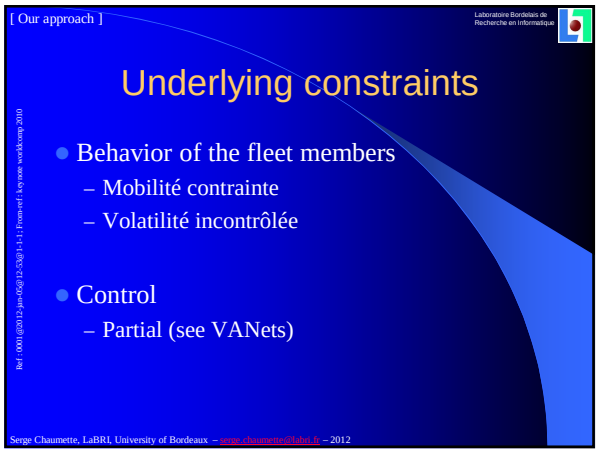
[Our approach]
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Underlying constraints
Behavior of the fleet members
– Mobilité contrainte
– Volatilité incontrôlée
Control
– Partial (see VANets)
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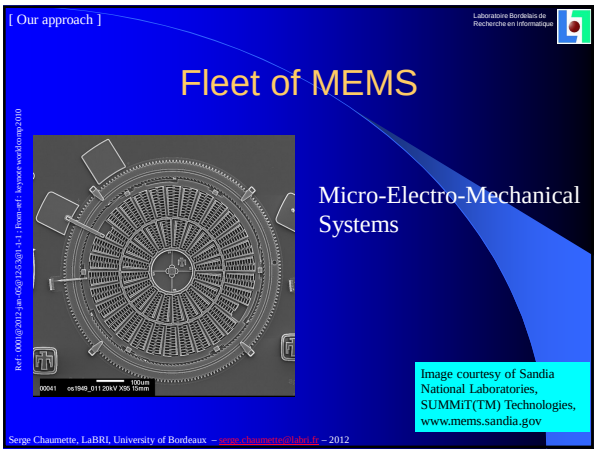
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Fleet of MEMS
Micro-Electro-Mechanical Systems
Image courtesy of Sandia National Laboratories, SUMMiT(TM) Technologies, www.mems.sandia.gov
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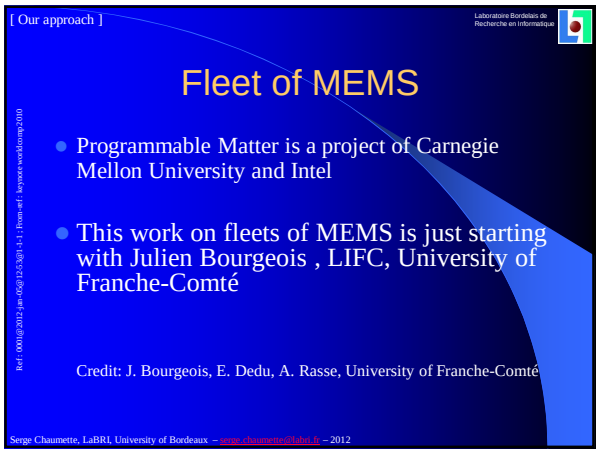
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Fleet of MEMS
Programmable Matter is a project of Carnegie Mellon University and Intel
This work on fleets of MEMS is just starting with Julien Bourgeois , LIFC, University of Franche-Comté
Credit: J. Bourgeois, E. Dedu, A. Rasse, University of Franche-Comté
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Main problems

Volatility (unstability)
- of terminals
- of the network

Redesign of algorithms (no routing, no global knowledge, disconnected network, etc.)

Security is a major problem

Using Smart Cards

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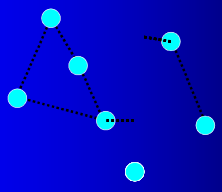
Dynamic graphs and (secured) fleets of autonomous communicating mobile terminals



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[Approach]

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Approach

- Local computation

graph relabeling

- (other approach: CCS/CBP (Milner, Prasad) like models - work in progress -)

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[Graph relabeling]

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Graph relabeling

- Static graphs → Sirocco-2000-2-2
- Dynamic, évolutive graphs → Sirocco-2000-3-55-7
- The dynamic aspect must be taken into account by the applications
  - Example of the spanning forest → PhD-AC-2007-11-11

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[Relabeling over graphs]

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Relabeling over graphs

- Static graphs
  - →see [Litovsky, Metivier, Sopena 1999]

- extension to dynamic graphs
  - →see [Casteigts, Chaumette, Ferreira 2009]

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[Relabeling over static graphs]

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Relabeling over static graphs

- Local computation in static graphs
  - A node can only interact with a direct neighbor
  - Nodes/communication links are static
- Example :
  - the rule
    will eventually make all the nodes red

More complex example: an algorithm that creates a spanning tree

→ I. Litovsky, Y. Metivier, and E. Sopena. Graph relabelling systems and distributed algorithms. In World Scientic Publishing, editor, Handbook of graph grammars and computing by graph transformation, volume III, Eds.

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[Relabeling over static graphs / the spanning tree example]

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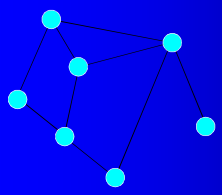
The spanning tree example



Node of the tree
Possible radio com.
Edge of the tree

Relabeling rule

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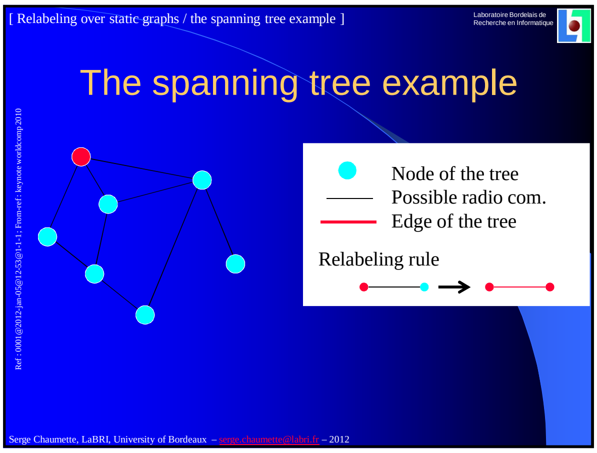
[Relabeling over static graphs / the spanning tree example]
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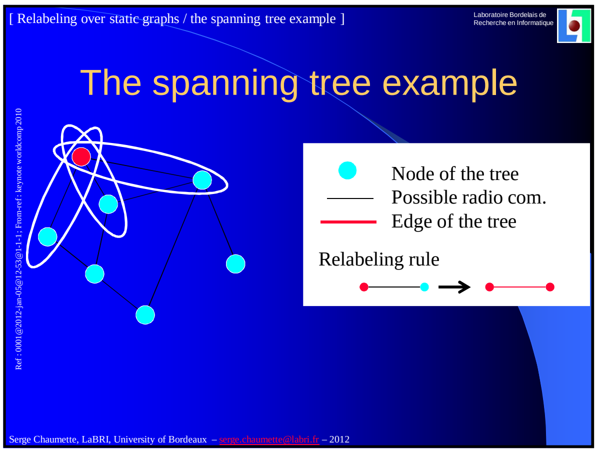
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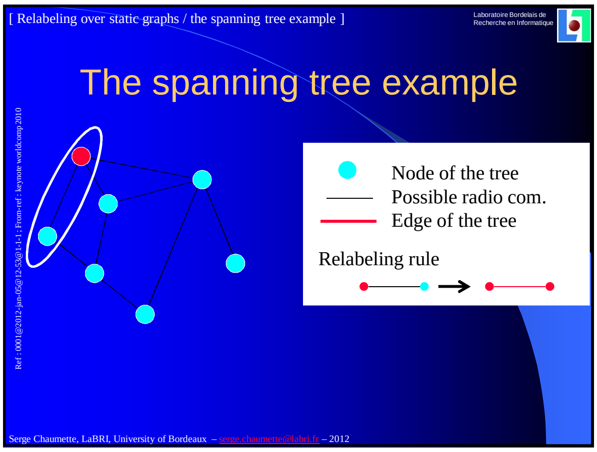
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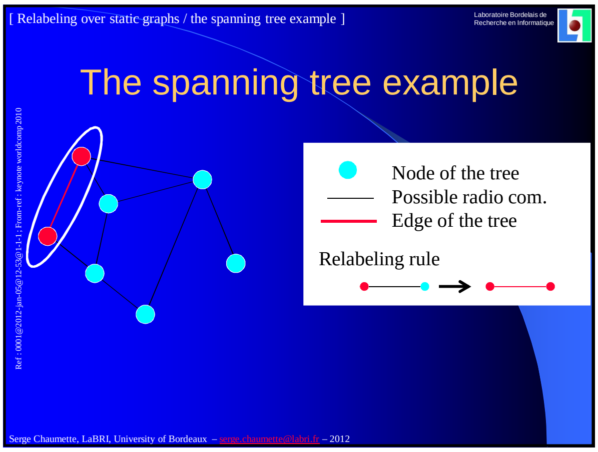
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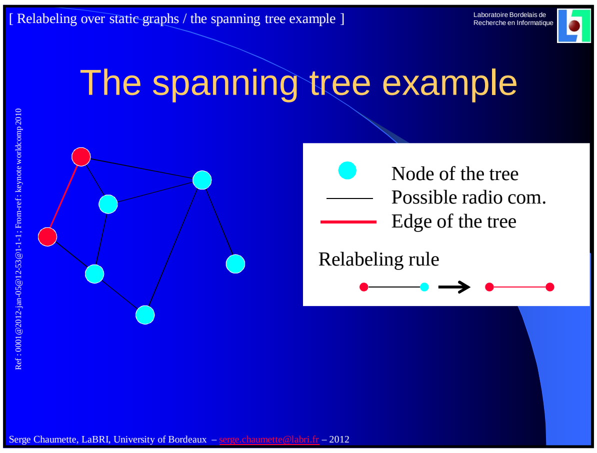
[Relabeling over static graphs / the spanning tree example]
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The spanning tree example
Node of the tree
Possible radio com.
Edge of the tree
Relabeling rule
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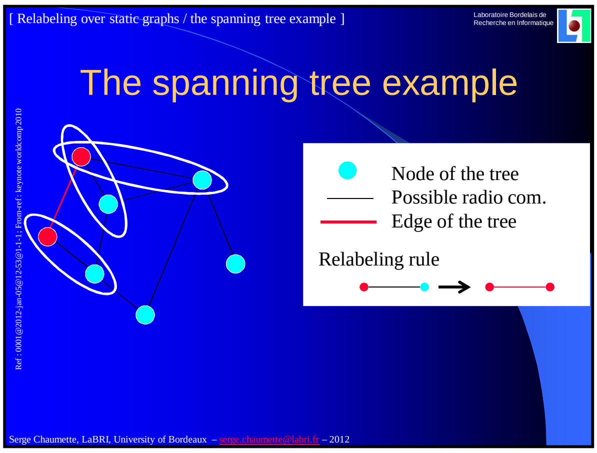
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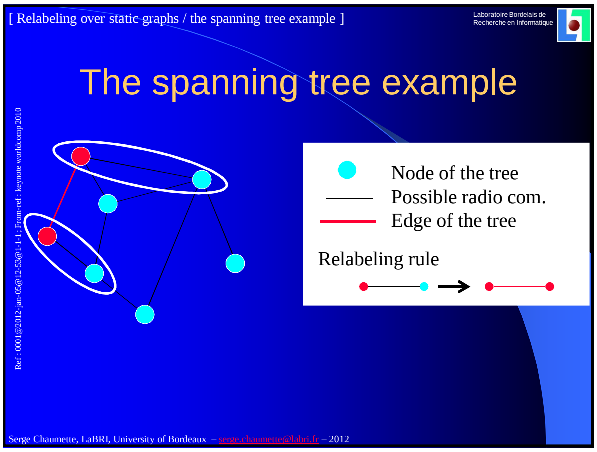
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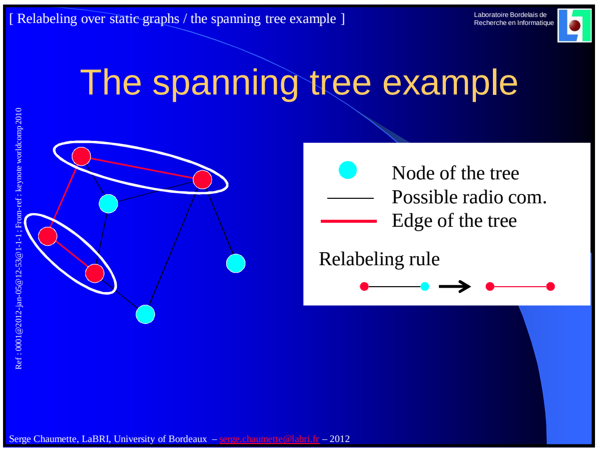
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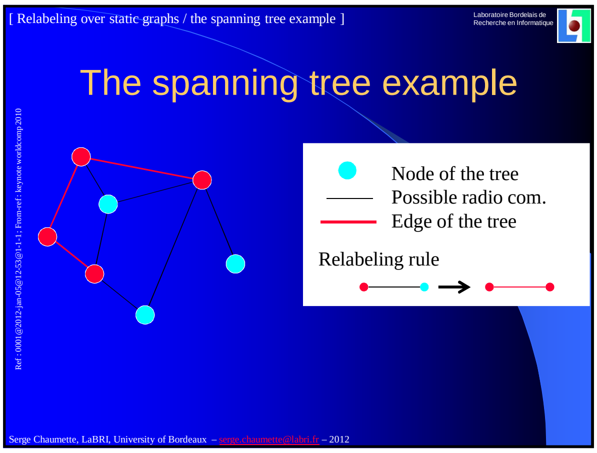
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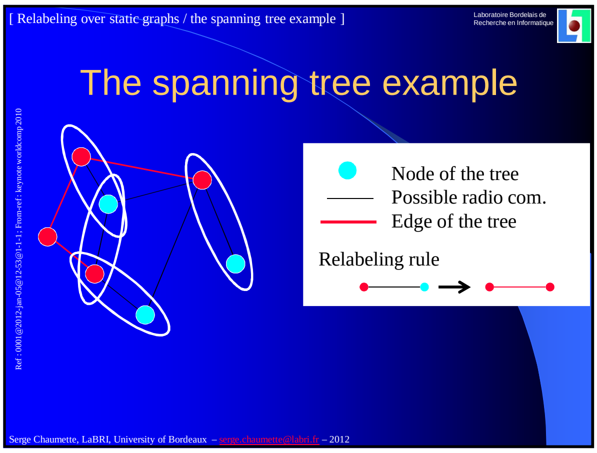
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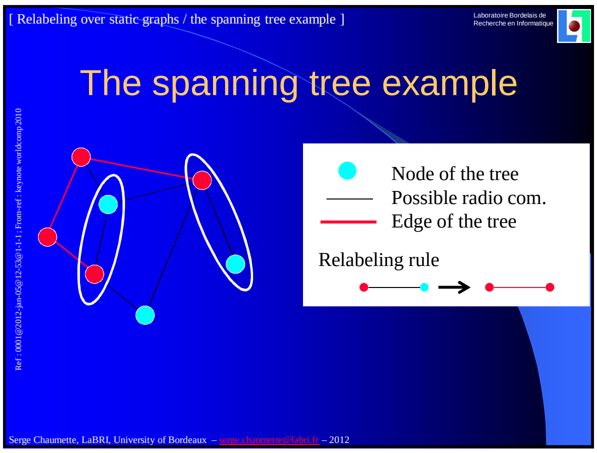
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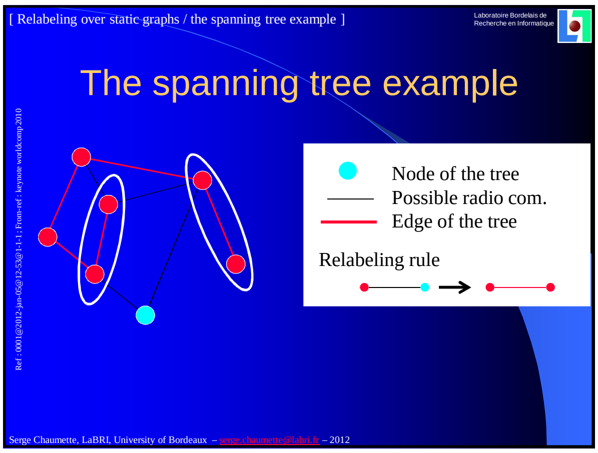
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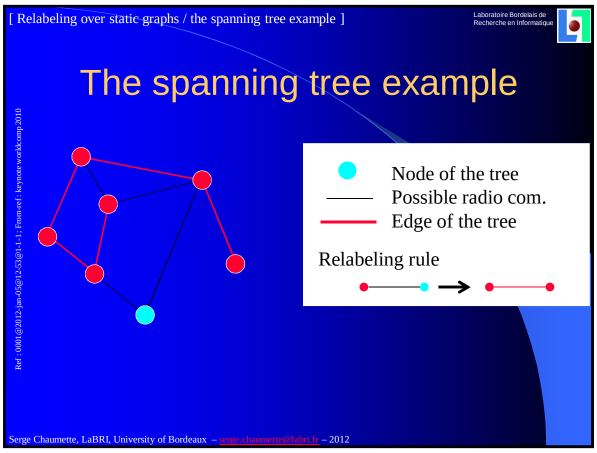
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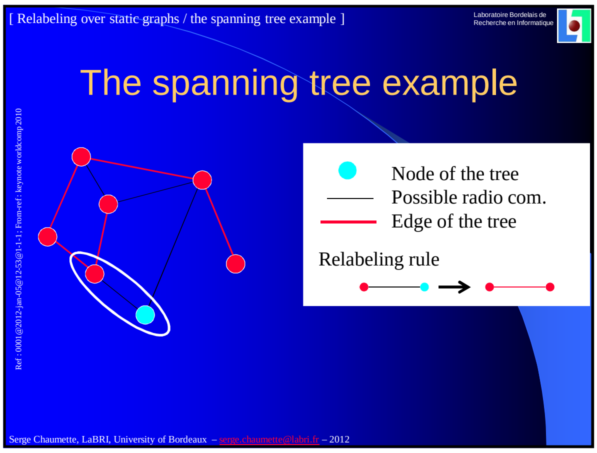
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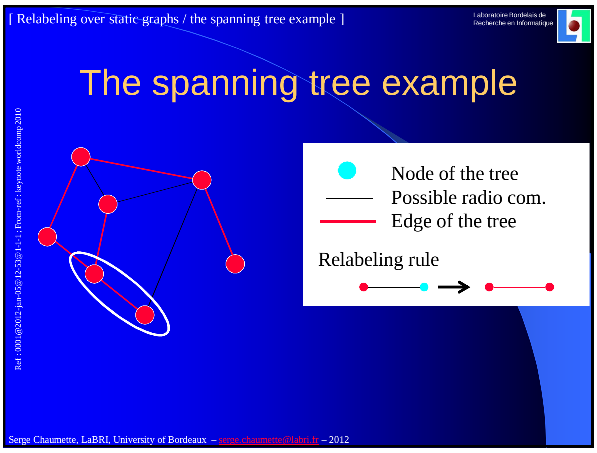
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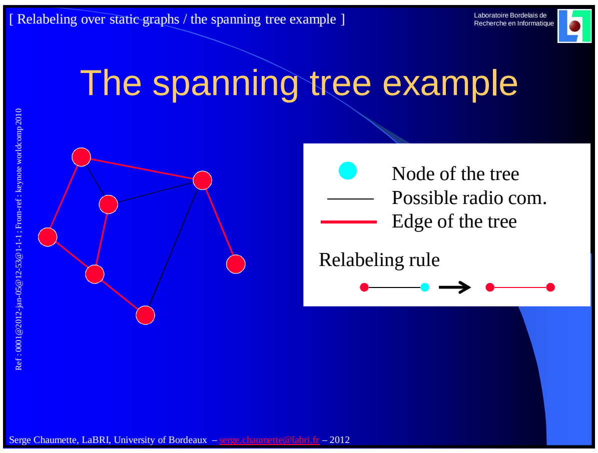
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[Relabeling over static graphs]

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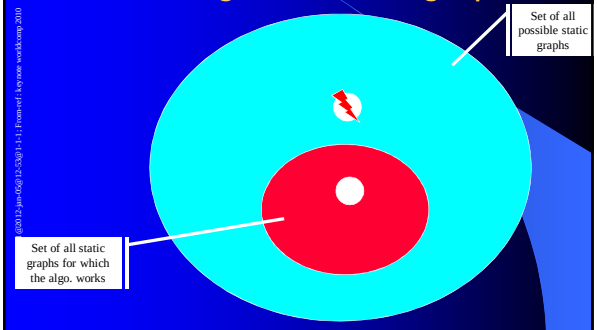
Relabeling over static graphs



Ref : 001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkcomp 2010

[Relabeling over dynamic graphs]

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Relabeling over dynamic graphs

- Relabeling rules as for static graphs

- Management of appearing vertices

- Management of disappearing vertices

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[Relabeling over dynamic graphs]

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Model

- Local computation in dynamic graphs
  - A node can only interact with a direct neighbor
  - Nodes/com.links can appear/disappear at any time
- Example :
  - the rule

will not necessarily make all the nodes red

More complex example: an algorithm that maintains a spanning forest with nodes arriving and leaving at any time and with unstable communication links

→ Arnaud Casteigts, Serge Chaumette, Afonso Ferreira: Characterizing Topological Assumptions of Distributed Algorithms in Dynamic Networks. SIROCCO 2009: 126-140

http://hal.archives-ouvertes.fr/docs/00/37/67/01/PDF/RR-1457-09.pdf

Ref : 001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkcomp 2010

[Relabeling over dynamic graphs / The spanning forest example]

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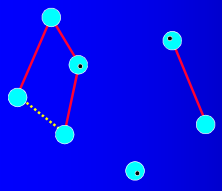
The spanning forest example



Node of one of the trees
Token
Possible radio com.
Edge of one of the trees

→ At any time each node is inside one and only one tree (that also has one and only one token)

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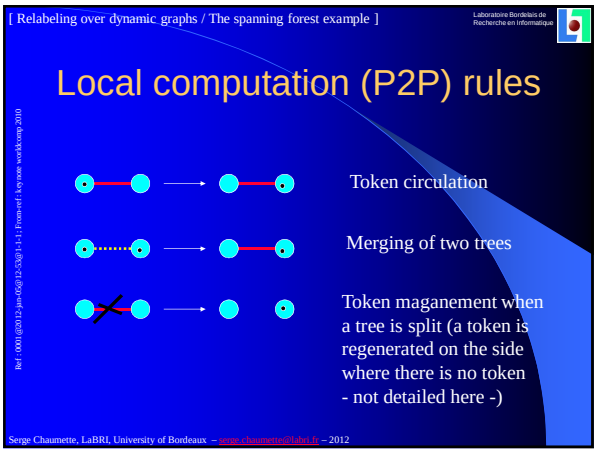
[Relabeling over dynamic graphs / The spanning forest example]
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Local computation (P2P) rules
Token circulation
Merging of two trees
Token maganement when a tree is split (a token is regenerated on the side where there is no token - not detailed here -)
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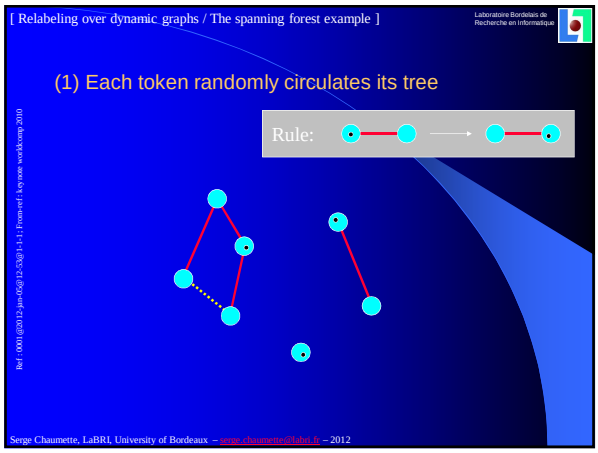
[Relabeling over dynamic graphs / The spanning forest example]
Laboratoire Bordelais de Recherche en Informatique
(1) Each token randomly circulates its tree
Rule:
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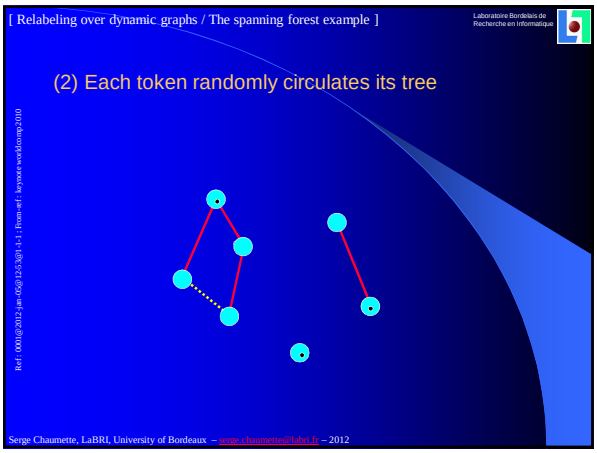
[Relabeling over dynamic graphs / The spanning forest example]
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(2) Each token randomly circulates its tree
Ref : 0001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkcomp 2010
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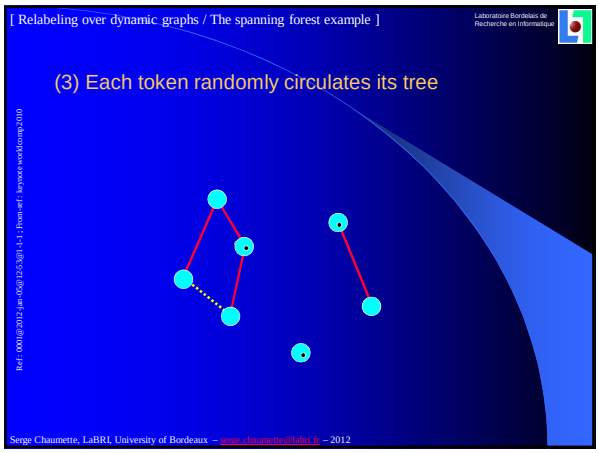
[Relabeling over dynamic graphs / The spanning forest example]
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(3) Each token randomly circulates its tree
Ref : 0001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkcomp 2010
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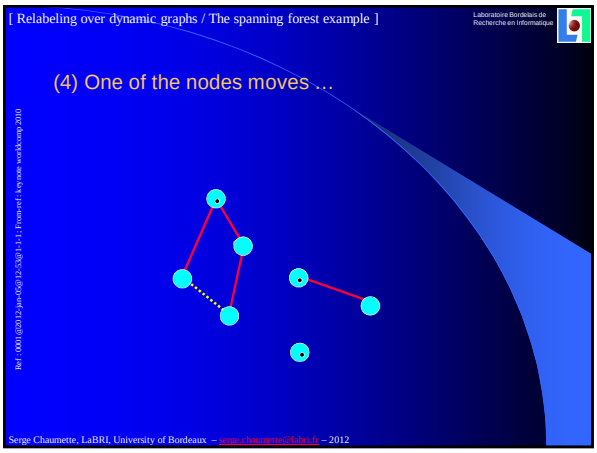
[Relabeling over dynamic graphs / The spanning forest example]
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(4) One of the nodes moves …
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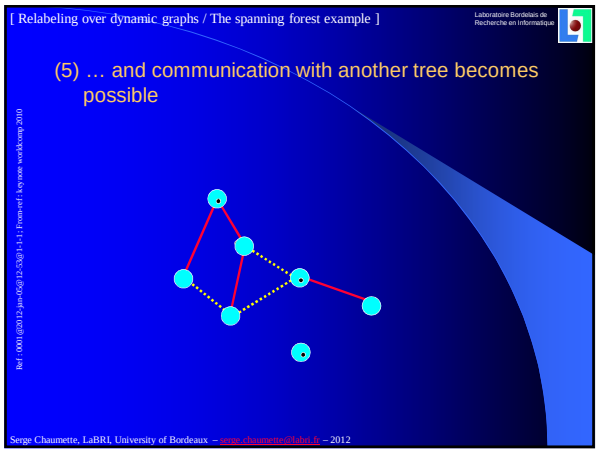
[Relabeling over dynamic graphs / The spanning forest example]
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(5) … and communication with another tree becomes possible
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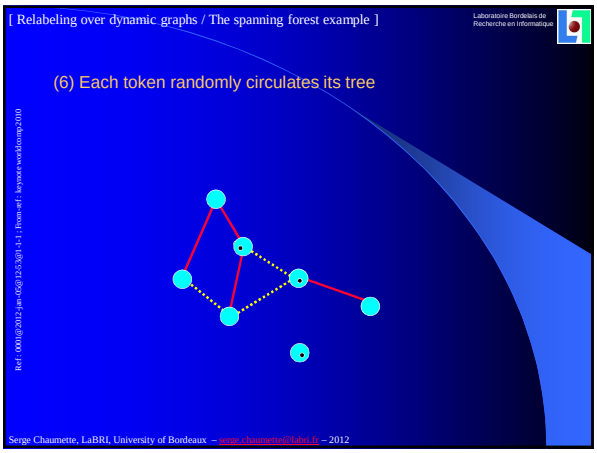
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(6) Each token randomly circulates its tree
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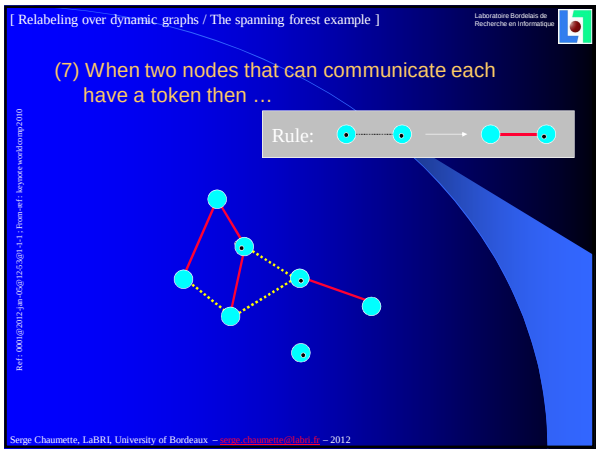
[Relabeling over dynamic graphs / The spanning forest example]
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(7) When two nodes that can communicate each have a token then …
Rule:
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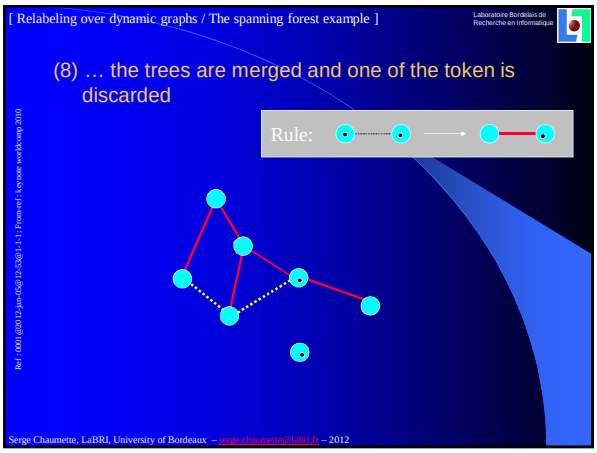
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(8) … the trees are merged and one of the token is discarded
Rule:
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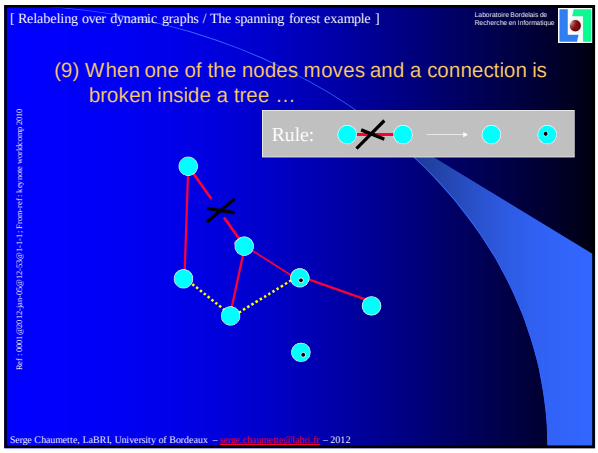
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(9) When one of the nodes moves and a connection is broken inside a tree …
Rule:
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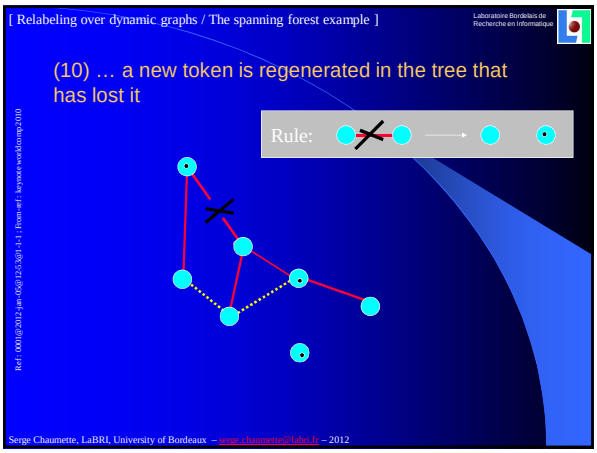
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(10) … a new token is regenerated in the tree that has lost it
Rule:
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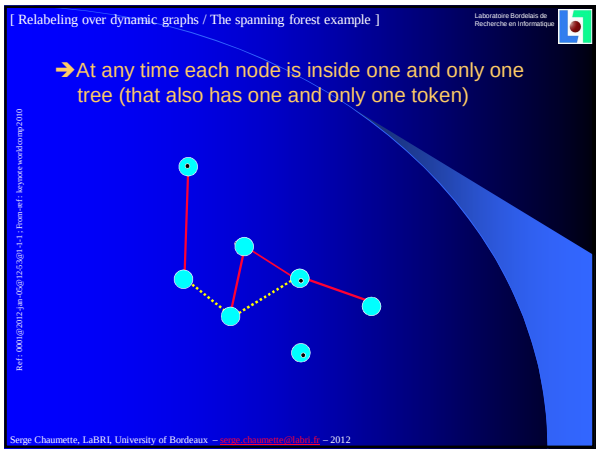
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Evolving graphs

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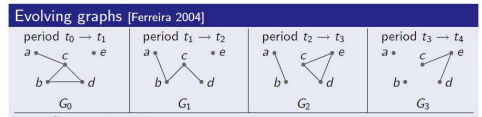
Formalism to represent dynamic topology

Evolving graphs [Ferreira 2004]

period $t_0 \rightarrow t_1$ | period $t_1 \rightarrow t_2$ | period $t_2 \rightarrow t_3$ | period $t_3 \rightarrow t_4$

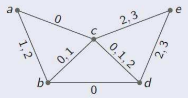


G_0 G_1 G_2 G_3

$\mathcal{S}_T = t_0, t_1, t_2, t_3, t_4$
$\mathcal{S}_G = G_0, G_1, G_2, G_3$
$G = \bigcup_{G_i \in \mathcal{S}_G} =$ 

$\} \; \mathcal{G} = (G, \mathcal{S}_G, \mathcal{S}_T)$
is the corresponding *Evolving Graph*.

↓ graphical representation ↓



A.Casteigts, S.Chaumette, A.Ferreira
Characterizing Topological Assumptions of Dist. Algo. in Dynamic Networks 5 / 15

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Ref : 0001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkomp 2010

DAGRS over evolving graphs

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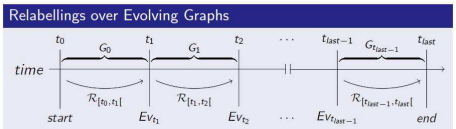
Combination

Relabellings over Evolving Graphs



An execution is an alternated sequence of relabellings and topological events:
$X = \mathcal{R}_{\mathcal{A}_{[t_{last-1},t_{last}[}} \circ Event_{t_{last-1}} \circ .. \circ Event_{t_1} \circ \mathcal{R}_{\mathcal{A}_{[t_1-1,t_1[}} \circ .. \circ Event_{t_1} \circ \mathcal{R}_{\mathcal{A}_{[t_0,t_1[}}(G_0)$

We note $\mathcal{X}_{\mathcal{A}/\mathcal{G}}$ the set of all possible execution sequences of an algorithm $\mathcal{A}$ over an evolving graph $\mathcal{G}$

Topology-related necessary condition: $\neg\mathcal{C}_{\mathcal{N}}(\mathcal{G}) \implies \nexists X \in \mathcal{X}_{\mathcal{A}/\mathcal{G}} \mid success.$
Topology-related sufficient condition: $\mathcal{C}_{\mathcal{S}}(\mathcal{G}) \implies \forall X$ in $\mathcal{X}_{\mathcal{A}/\mathcal{G}}$, *success*.

A.Casteigts, S.Chaumette, A.Ferreira
Characterizing Topological Assumptions of Dist. Algo. in Dynamic Networks 6 / 15

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DAGRS over evolving graphs

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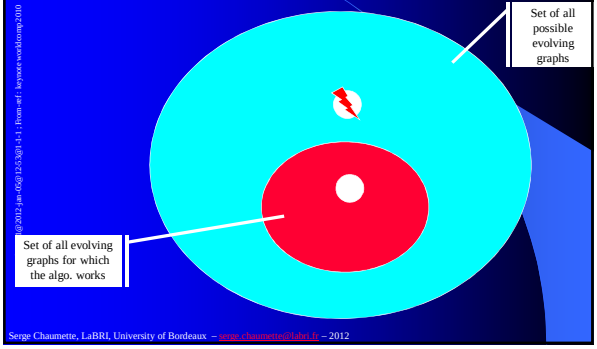

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Ref : 0001@2012-jan-05@12-53@1-1-1 ; From ref : keynote workkomp 2010

Fleet of mobile phone

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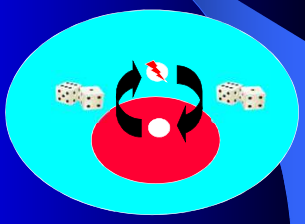
- The mobility is not known in advance
- The volatility is not known in advance

- There is no control over mobility



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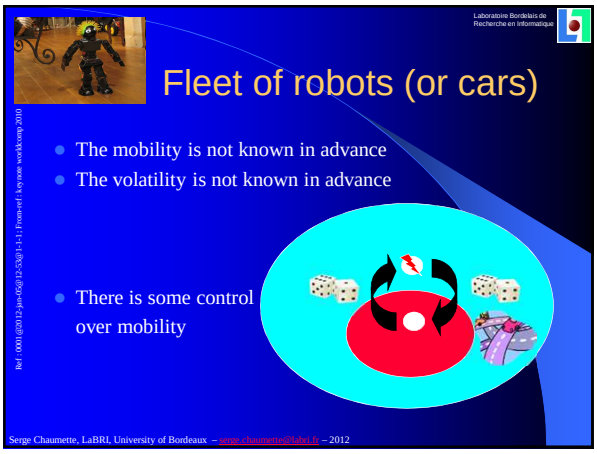
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Fleet of robots (or cars)
The mobility is not known in advance
The volatility is not known in advance
There is some control over mobility
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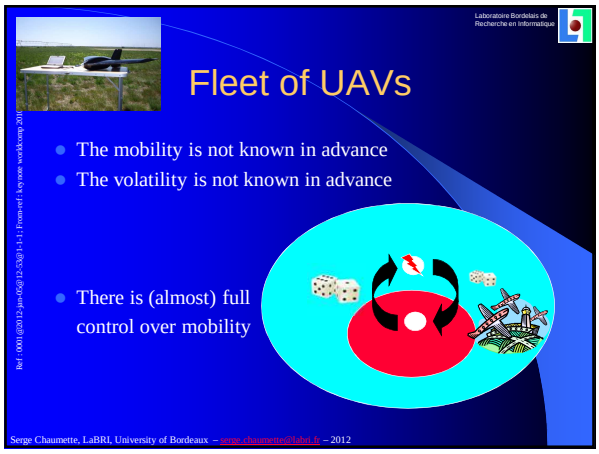
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Fleet of UAVs
The mobility is not known in advance
The volatility is not known in advance
There is (almost) full control over mobility
Ref : 0001@2012-jan-05@12-53@1-1-1 : From ref : keynote workkcomp 2010
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CCS-bx [work in progress]
Synchronous communication
Asynchronus communication
Message loss
Delayed reception when broadcasting
Mobility of nodes and messages
Ref : 0001@2012-jan-05@12-53@1-1-1 : From ref : keynote workkcomp 2010
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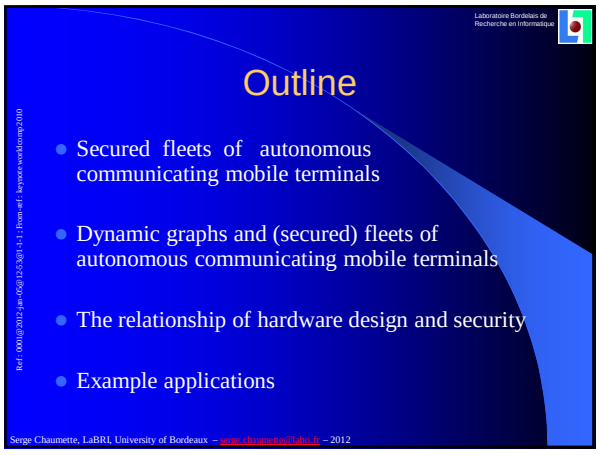
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Outline
Secured fleets of autonomous communicating mobile terminals
Dynamic graphs and (secured) fleets of autonomous communicating mobile terminals
The relationship of hardware design and security
Example applications
Ref : 0001@2012-jan-05@12-53@1-1-1 : From ref : keynote workkcomp 2010
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The relationship of hardware design and security

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Outline

- Identities
- Components interconnections
- Add-ons

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Identities

- Identities (even if not avaibale at user level) are usefull to solve some effective problems:
  - election
  - routing
  - …

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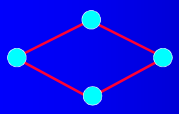
Why they cannot be generated



There is no way to make any différence between any two nodes.

Any algorithm will be executed the same way and will thus produce exactly the same values on each node

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« The » reference paper

Dana Angluin
Local and global properties in networks of processors
(Extended Abstract)
Proceedings of the twelfth annual ACM symposium on Theory of computing, p.82-93, April 28-30, 1980, Los Angeles, California, United States

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Hardware approaches

- Crypto based approach
  - Based on RNGs
    - are TRGNS really available in mobile devices?
    - probabilistic result
- TPM based
  - Additional cost (hard)
  - Expensive to secure (personnalization)
  - How to link it to the rest of the hardware ?
- Physical Unclonable Function based (see *'project proposal'* later) as a solution ?

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Components interconnections

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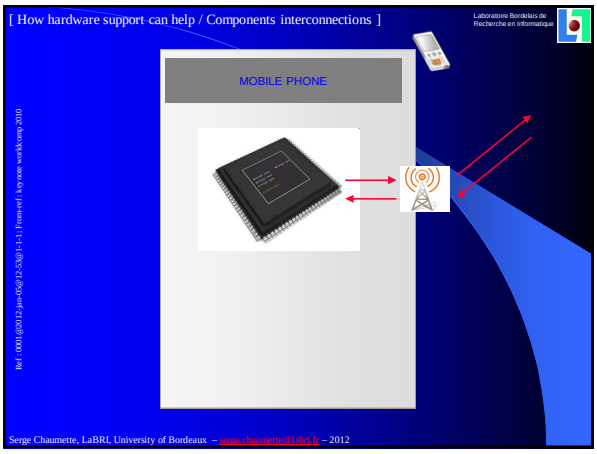
From an application perspective

- Non functional properties
  - Secure the application itself
  - Secure secret/public keys
- Functional properties

→What is the best you can do to send a message ?

→ What is the best you can do to properly handle an incoming message ?


[How hardware support can help / Components interconnections]
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MOBILE PHONE
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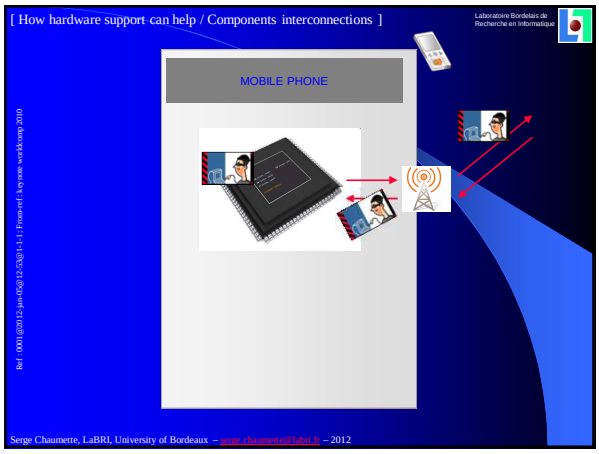
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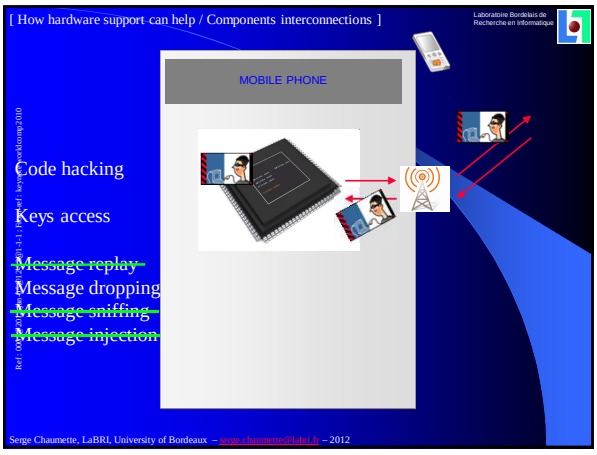
[How hardware support can help / Components interconnections]
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MOBILE PHONE
Code hacking
Keys access
~~Message replay~~
Message dropping
~~Message sniffing~~
~~Message injection~~
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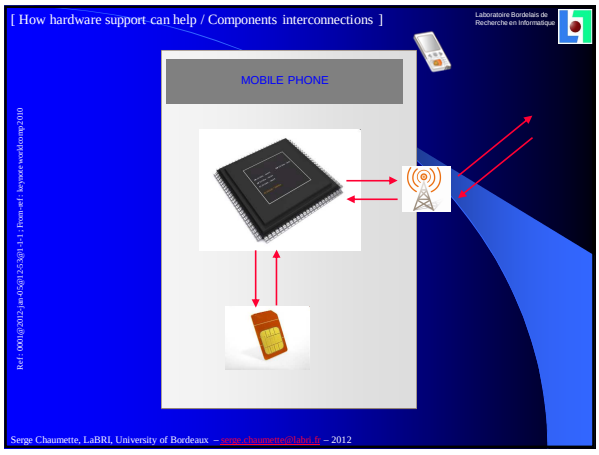
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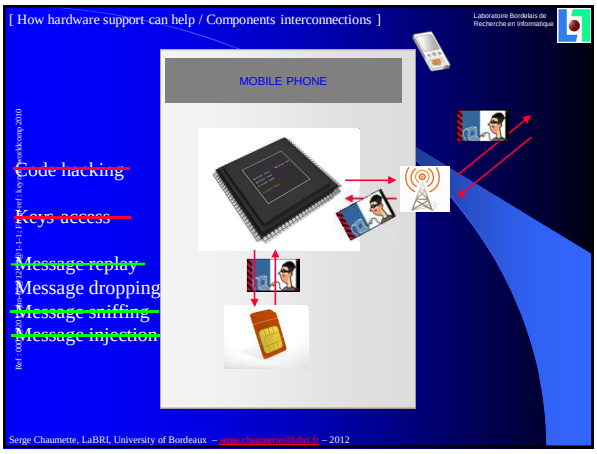
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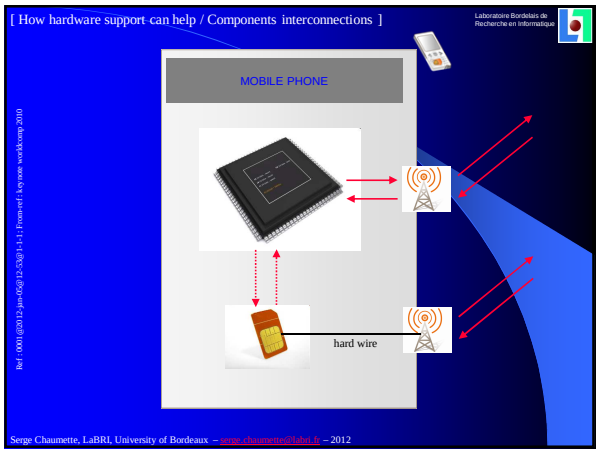
[How hardware support can help / Components interconnections]
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MOBILE PHONE
hard wire
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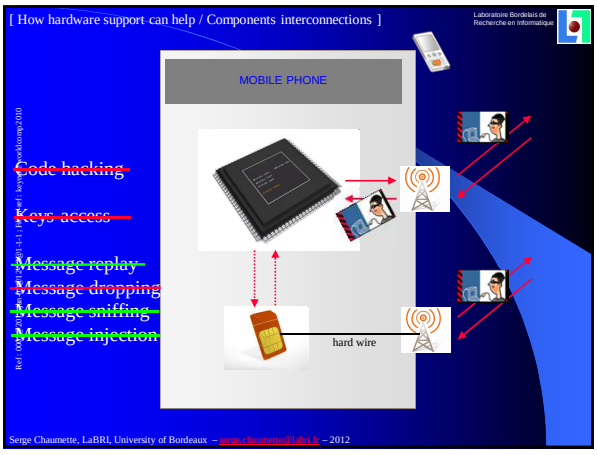
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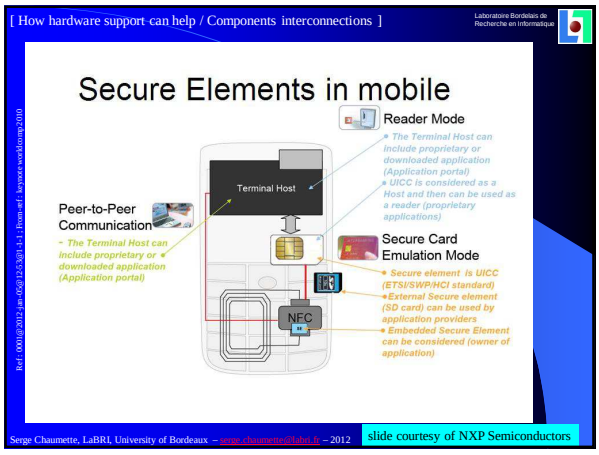
[How hardware support can help / Components interconnections]
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Secure Elements in mobile
Reader Mode
The Terminal Host can include proprietary or downloaded application (Application portal)
UICC is considered as a Host and then can be used as a reader (proprietary applications)
Terminal Host
Peer-to-Peer Communication
The Terminal Host can include proprietary or downloaded application (Application portal)
Secure Card Emulation Mode
Secure element is UICC (ETSI/SWP/HCI standard)
External Secure element (SD card) can be used by application providers
Embedded Secure Element can be considered (owner of application)
NFC
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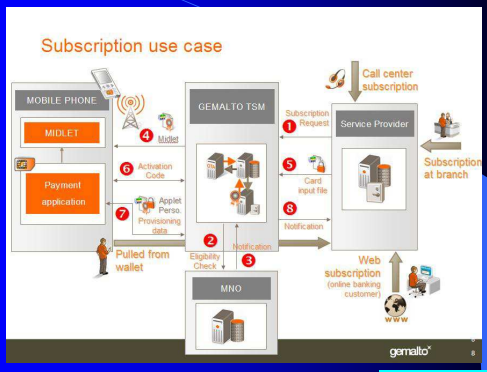
slide courtesy of NXP Semiconductors

Global impact



Slide courtesy of gemalto

[How hardware support can help / add-ons]

Add-ons

The case of NFC technology

- Phones hardly available (Nokia from 2011)
- Extra cost for (yet) little usage opportunities
- Responsibility of manufacturers for embedding untested (on a large scale) technology

➔ add-ons provide an on demand solution

[How hardware support can help / add-ons]

source tyfone.com

[How hardware support can help / add-ons]

source www.icarte.ca

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Outline

- Secured fleets of autonomous communicating mobile terminals
- Dynamic graphs and (secured) fleets of autonomous communicating mobile terminals
- Example applications

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Example applications (based on collaborations)

- With the industry
  - Gemalto, Thales, NXP, Oberthur, Orange, G&D
  - Verisign
  - Intelligere
  - Fly-n-Sense
  - …
- With gouvernemental bodies
  - Ville de Caen
  - Pôle de compétitivité Aerospace Valley (AESE)
  - Région Aquitaine
  - DGA
  - …
- With Univesities
  - Université de Caen ; Laboratoires LITIS, XLIM, Valoria
  - ENAC
  - …

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Strategic map sharing

Map sharing (DGA)
[IEEE milcom]

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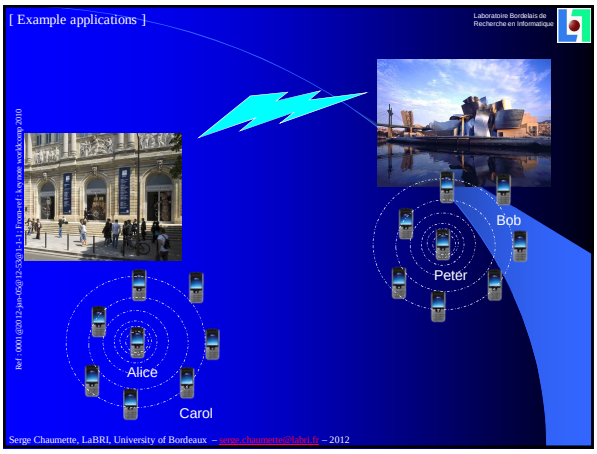
Museum Quest

- European project (ITEA2)
  - Smart Urban Spaces
  - http://www.smarturbanspaces.org/
- 25 partners, 4 countries
  - Gemalto, Thales, NXP, …
  - VTT, LaBRI, University of Caen
  - Valence, Bordeaux, Bilbao, …


[Example applications]
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Bob
Peter
Alice
Carol
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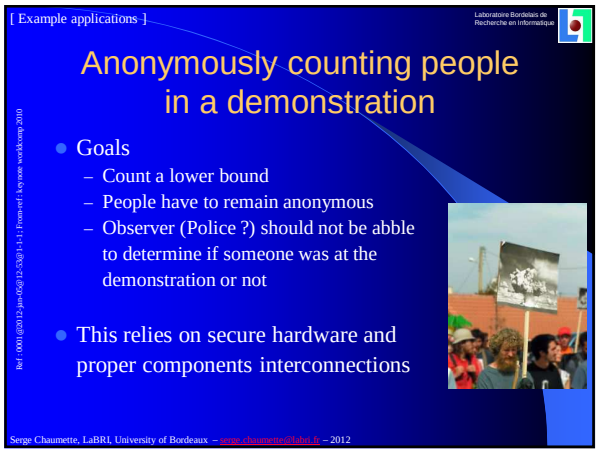
[Example applications]
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Anonymously counting people in a demonstration
Goals
Count a lower bound
People have to remain anonymous
Observer (Police ?) should not be abble to determine if someone was at the demonstration or not
This relies on secure hardware and proper components interconnections
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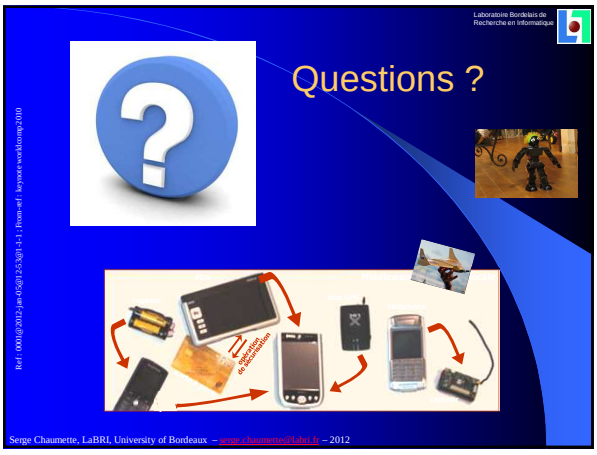
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Questions ?
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