Research works on WSNs
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Ph.D

- INSA Lyon (The biggest French Engineering School)
- 11.2004 to 05.2008
- 4 research teams:
  - INRIA ARES project (a part of CITI lab)
  - FT R&D Skills Centre IPv6
  - FT R&D Grenoble : PACIFIC team
  - FT R&D Beijing Centre, Chine
- Half time in FT R&D Beijing centre
- Half time in CITI Lab, INSA Lyon
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Contextes

- Multi-hop wireless networks
  - Ad hoc networks, wireless mesh networks
  - WPAN
  - **Wireless sensor networks**
    - Infrastructureless
    - Easy deployment
    - Large scale
    - Limited energy resource
    - Limited processing capability

- Target applications
  - Intelligent building, environment monitoring
Key mechanism

• Self-organization
  – Provide a logical topology based on the flat network
  – From local interactions

• Why … ?
• How …?
• What for … ?
Why?
- quantifying with entropy

- Self-organization
  - Set up order in the networks
  - Local interactions
  - Emergent behaviors
- Concept from statistical thermodynamic entropy
Definition

- **Formulation:**
  \[ E = \sum_{u,v \in X} -p(u, v) \log p(u, v) \]

- \( p(u, v) \): local interaction probability
  - **Dynamics of nodes:**
    - \( u \) exists with probability \( p \)
    - \( u \) is absent with probability \( q = 1 - p \)
  - **Link quality:**
    - A radio link \((u, v)\) works with probability \( c \)
  - **Way of organization**

- **Entropy variation: adaptability**
  \[ \Delta E = E_{T_0} - E_{T_0 + \Delta T} \]

Application of entropy

• Example
  – Flat network
  
  – Link (1) exists with probability:

\[ p_1 = c \cdot (p^4 + 2qp^3 + q^2p^2) = c \cdot p^2 \]

  – Entropy:

\[ E_{\text{flat}} = -6p_1 \log p_1 \]
Example

- LMST

Links (1) – (4) exist with probability:

\[ p_1 = c \cdot (p^4 + 2qp^3 + q^2p^2) \]

Links (5) and (6) exist with probability:

\[ p_5 = c \cdot q^2p^2 \]

Entropy:

\[ E_{LMST} = - [4p_1 \log p_1 + 2p_5 \log p_5] < E_{flat} \]
Analyses

Entropy for 200 nodes with radius of 0.14

Entropy for 200 nodes with p=0.8
How?
FISCO

• A first step of setting WSN
  – Address allocation
  – Communication structure

• A dynamic, adaptive basis for other features
  – Cope with network dynamics
  – Local decisions
  – Emerging behavior

• Low control overhead
  – Hello Message free
  – Active Time
  – Energy

FISCO – logical view

1. FISCO backbone
2. FISCO snapshot
3. FISCO logical address view

Address Space

Address Pools

L1

L2

L3

L4

L5

1 2 3 4 5 6 7 8

1 2 3 4 5 6 7 8

1 2 3 4 5 6 7 8

1 2 3 4 5 6 7 8

1 2 3 4 5 6 7 8

1 2 3 4 5 6 7 8
FISCO - Organization

- Comparing to self-organization works
  - CDS
  - LMST

- Complete self-organization solution
  - Joining procedure
  - Departure procedure
  - Partition management
  - Local re-organization (activity scheduling)
    - New metric available for active nodes
    - Residual energy, degree of local structure

Based on self-organization

Two-level Dynamic address allocation
  - High level: Dynamic address pool allocation
  - Low level: Stateful function on each Leader

Comparing to other address allocation schemes
  - Address conflict detection based:
    - No flooding
    - Independent of routing protocol
  - Distributed DHCP
    - Avoidance of periodical one-hop Hello on each node

Analysis

• For a given area and a given radius, the number of leaders is bounded.

\[ 7 \cdot \left[ \frac{a+2R}{(2+\sqrt{3/2})R} \cdot \frac{a+2R}{2.5R} \right]. \]

• Complexity

<table>
<thead>
<tr>
<th>Algo</th>
<th>Information</th>
<th>Message</th>
<th>Complexité en calcul</th>
<th>Complexité en message</th>
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</thead>
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<tr>
<td>CDS</td>
<td>localisé</td>
<td>HELLO/1-saut</td>
<td>( O(\Delta^2) )</td>
<td>( O(n) )</td>
</tr>
<tr>
<td>MPR-CDS</td>
<td>localisé</td>
<td>HELLO/1-saut</td>
<td>( O(\Delta^2) )</td>
<td>( O(n) )</td>
</tr>
<tr>
<td>MIS</td>
<td>distribué</td>
<td>HELLO+contrôle/1-saut</td>
<td>( O(\log(\Delta) \cdot \log(n)) )</td>
<td>( O(n) )</td>
</tr>
<tr>
<td>LMST</td>
<td>localisé</td>
<td>HELLO/1-saut+pos</td>
<td>( O(\Delta) )</td>
<td>( O(n) )</td>
</tr>
<tr>
<td>RNG</td>
<td>localisé</td>
<td>HELLO/1-saut+pos</td>
<td>( O(\Delta^2) )</td>
<td>( O(n) )</td>
</tr>
<tr>
<td>FISCO</td>
<td>localisé</td>
<td>LDBR</td>
<td>( O(\Delta) )</td>
<td>( O(1) )</td>
</tr>
</tbody>
</table>
Simulations

• JIST-SWANS
  – JAVA based
  – Large scale simulation

• Configurations
  – Square zone
  – IEEE802.15.4
  – BMAC : pre-ambuling
  – Random deployment
Performance evaluation

Messages

FISCO

Strong DAD

Prophet

Nombre moyen des messages envoyés par noeud

Nombre moyen des messages récues par noeud
Performace evaluation

FISCO Backbone

Performance evaluation

Consommation d'énergie

Consommation d'énergie de FISCO et de CDS localisé

![Graph showing energy consumption comparison between FISCO and CDS localisé](image)
What for?
SODA

- Target application: Monitoring in intelligent buildings

- Contributions
  - Data disseminations
    - Set up paths based from sensor nodes to sinks
  - Mobile sink management
  - Data aggregations
    - Spatial: Data fusion on Leader nodes
    - Temporal: Adaptive ARMA
SOD – A-ARMA

Data samples

If the accuracy (RMS) is not adequate → then compute new ARMA(p,q)

ARMA(p,q): p+q+1
Analysis

- No aggregation: 720
- ARMA(2,2)
  - Accuracy: poor
- ARMA(400,250)
  - Accuracy: 0.029 degree per sample
  - Complexity: too high
  - Parameters: 651
- A-ARMA(2,2)
  - Accuracy: 0.029 degree per sample
  - Complexity: low
  - Parameters: 66 *5 → 330

Real indoor data samples
Aggregation Impact

Consommation d'énergie dans une collecte des données

- Sans agrégation
- SODA
- Fusion des paquets au niveau des leaders
- A-ARMA
Conclusions

- Applications
- Mobile sink
- Dissemination
- Aggregation
- PHY & MAC

FISCO
- Self-organisation (LEGOS)
- Self-configuration (LEADS)

SODA

Entropy
Join work

- Imote2 testbed FT R&D Beijing
  - 30 Imote2
  - Embedded Linux
  - FISCO

- Declarative networking (Ubiquest FP7)
  - A declarative language
  - Validation of FISCO
Future works

• Directional sensor networks
  – Directional sensors
    • Coverage
  – Directional antennas
    • Partial neighboring information
    • Connectivity
  – Combining problems in
    • Self-organization
    • Coverage
Publications

International Journals


Patent


International Conferences


