Communication Efficiency in Self-stabilizing Silent Protocols

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Self-stabilization
Overhead?


Rationale

• Checking (eventually) no neighbor trivially prevents self-stabilization

• Checking all neighbors forever enables self-stabilization

• Intermediate communication cost?
Silent Protocols
Communication Efficiency


Results

• New measure for communication efficiency of self-stabilizing protocols

• Neighbor-complete protocols can not be silent self-stabilizing and eventual-$k$-stable when degree $> k$ (IDs and leader help slightly)

• It is still possible to have some nodes check less than all neighbors for some
k-Efficiency

• **Definition**
  - A protocol is *k-efficient* if at any step, a node reads from at most k neighbors

• **Intuition**
  - Round-Robin for neighbor checking
  - Local invariants may not be preserved
Communication Stability

• **k-stable**
  
  • In any execution, every node communicates with at most $k$ different neighbors

• **eventual k-stable**
  
  • In any execution, every node eventually communicates with at most $k$ different neighbors
Neighbor Completeness

- **Definition**
  - A protocol is *neighbor complete* if it is
    - Self-stabilizing
    - Silent
    - States $S_1$ and $S_2$ can be legitimate
    - For every couple of neighbors $S_1$ and $S_2$
• **Theorem**

  • There exists no eventual k-stable neighbor complete protocol in anonymous networks when degree $> k$
Impossibility I
Impossibility I
Impossibility I
Impossibility 1
Impossibility I
Impossibility I
Impossibility I
Impossibility II

• **Theorem**
  • There exists **no** k-stable neighbor complete protocol in *rooted and/or DAG-oriented* networks when degree > k
Rooted Networks
DAG-oriented Networks
I-efficient Coloring

- Use Round-Robin technique to detect inconsistencies
- Color change may trigger unknown conflicts
Coloring
Coloring
Coloring
Coloring
Coloring
Coloring
Coloring
Coloring
Coloring
Communication
Stability

- k-stable
- eventual k-stable
- eventual (x,k)-stable
  - In every execution, at least \( x \) nodes eventually communicate with at most \( k \) different neighbors
Maximal Independent Set (MIS)
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Maximal Independent Set (MIS)

- **Theorem**
  - MIS protocol is 1-efficient and eventual \((\lfloor \frac{L + 1}{2} \rfloor, 1)\) stable
Maximal Matching

• Derived from
  • Manne, Mjede, Pilard, Tixeuil, A new self-stabilizing Maximal Matching Algorithm, Sirocco 2007

• Main difference: Stay Focused
  • Interact with a single neighbor at a time
Maximal Matching

- Don’t lie about your marital status

- Don’t be picky
Maximal Matching

• Expect the best

• Accept the worst
Maximal Matching

- Keep looking

Next Neighbor
Maximal Matching
Maximal Matching
Maximal Matching
Maximal Matching
Maximal Matching
Maximal Matching
Maximal Matching
Maximal Matching
Maximal matching

- **Theorem**

  - The Maximal Matching protocol is eventual \((\lceil \frac{2m}{2\Delta - 1} \rceil, 1)\)-stable
Conclusion

• New measure for communication efficiency in self-stabilizing protocols

• Hints at efficient implementation in real networks

• Orthogonal to “graph oriented” quality of the protocols
Perspectives

• Applicability to *non-silent* protocols
• Lower bounds on $x$ for eventual $(x,k)$-stability
• Theoretical problem quality vs. practical efficiency