ClusterHead Rotation via Domatic Partition in Self-Organizing Sensor Networks

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Presented By

Rajiv Misra
Research Scholar
School of Information Technology
Indian Institute of Technology, Kharagpur

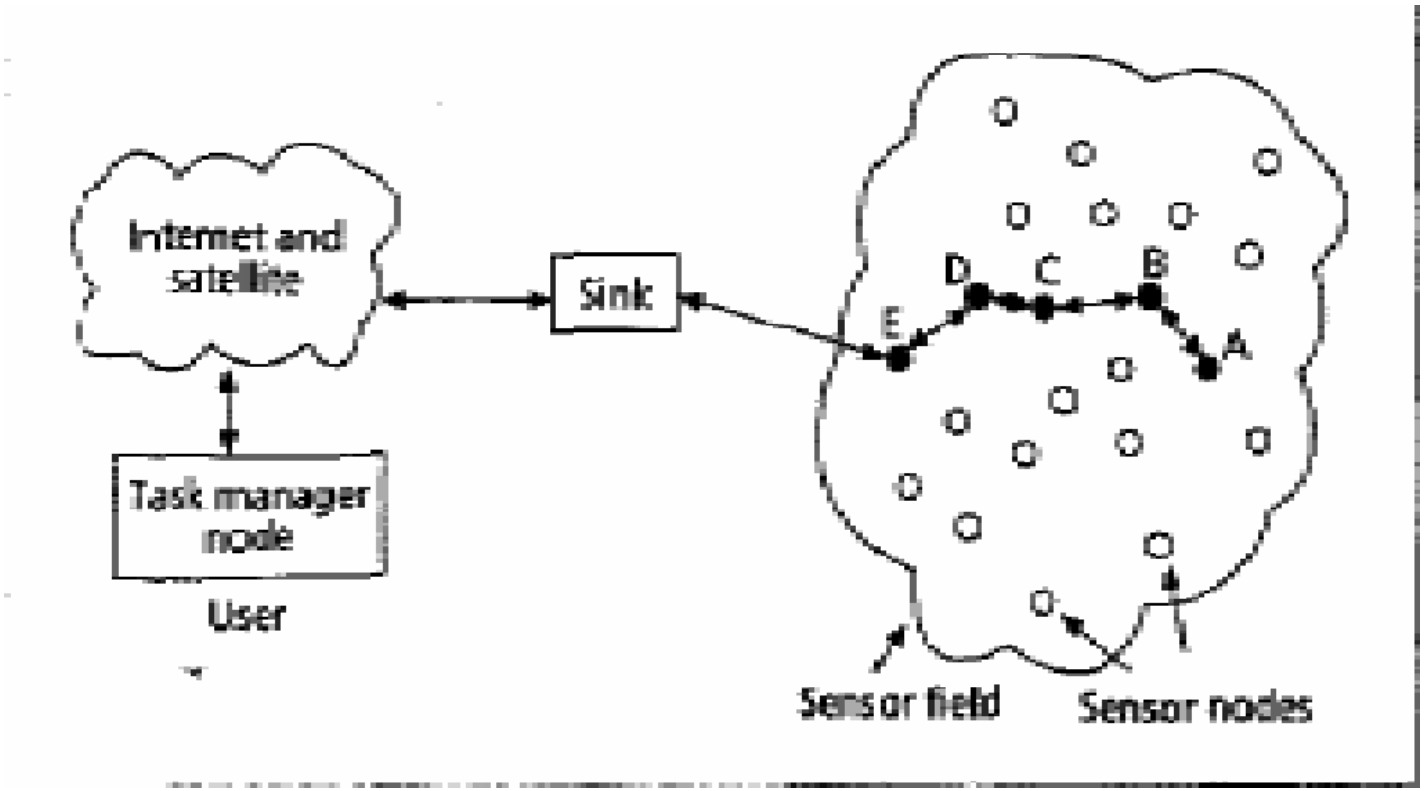
Introduction

- Deeply networked system embedded into physical world

  Pervasive computing, smart environment etc.
- Sensor node capable: Sensing , Computing and Communicating wirelessly sensed data .
- Due to VLSI,MEMS,etc. made possible Small form factor and low cost devices to deploy by hundreds/thousands

Introduction

Sensor Network Constraints:-
Energy,Computation,Communication



Wireless Sensor Networks

- A network that is formed when a set of small sensor devices that are deployed in an ad hoc fashion cooperate for sensing a physical phenomenon.
- A Wireless Sensor Network (WSN) consists of base stations and a large number of distributed, connected, and coordinated sensor nodes.
- Collectively forms massively distributed sensor network with increased capability in comparison to single node

Related Works

Clustering Protocols

- LEACH (Low Energy Adaptive Clustering Hierarchy)
- PEGASIS (Power Efficient Gathering in Sensor Information Systems)
- HEED (Hybrid Energy Efficient Distributed Clustering)

Approximating Domatic Number

- Seminal paper by Feige, Halldorsson, Kortasrz, Srinivasan [SIAM 2002]on approximating domatic partition in polynomial time.
- Other works by Sriram and Wattenhofer are based on above paper.
- None of these have considered Domatic Partition approach for Clusterhead Rotation in Self-Organizing Sensor Networks

Drawbacks in Clustering Protocols

- LEACH suffers – reclustering overhead in CH position rotation.
- HEED suffers- re-clustering overhead, so assumes interval of network operation is large than setup interval to reduce overhead.

Our Approach !

- High node density implies that only a subset of nodes need to be active.
- Dominating set problem – All the nodes need to be covered by subset of nodes
- Domatic Partition problem- set of all the disjoint dominating set i.e. vertex partitioning in Disjoint DS
- Idea: Pick a Dominating set from Domatic set
- number of dominating sets DS1, DS2, ..., DSm and use these one by one
- Question: How long? Scheduling!

In Brief

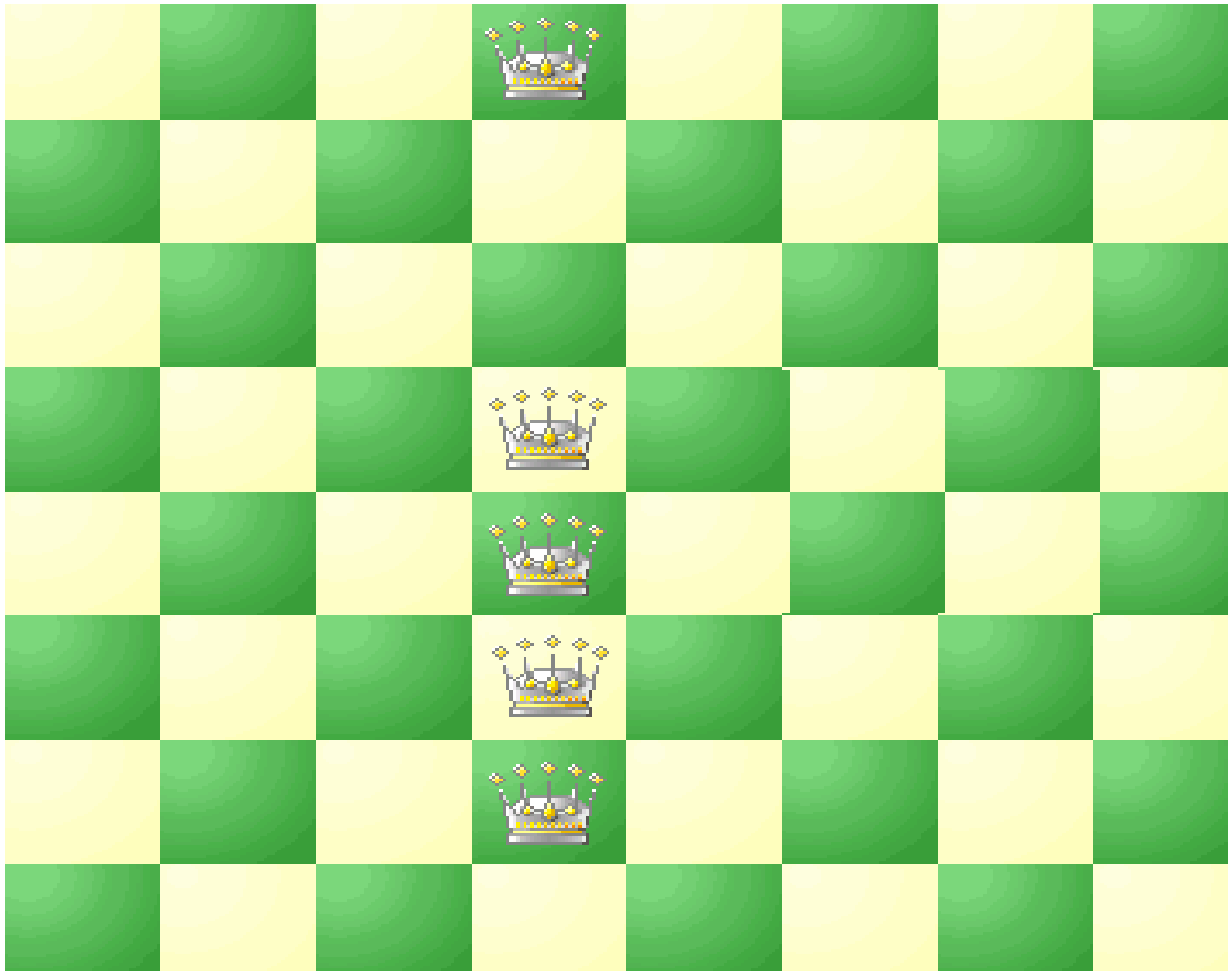
- In Mobile Adhoc virtual backbone using Connected Dominating Set having localized maintenance
- In Sensor Adhoc use Domatic Partition (disjoint dominating sets) to activate DS one at time for Lifetime Maximization
- Extending the Lifetime of Wireless Sensor Networks while ensuring coverage

Problem Formulation

- To maximize network lifetime, the role of clusterheads needs to be rotated among nodes.
- Rotation of Clusterheads is Scheduling of Disjoint Dominating set periodically so as to Maximize Lifetime

!Unfortunately very less work has been done for Domatic Partitioning in Sensor Networks!

A Dominating Set! Ore's Example



Dominating Sets, Domatic Partition

- A *dominating set* of a graph G = (V,E) is a subset $D \subseteq V$ of vertices such that each $v \in V$ is at most 1 hop away from some node in D
- A *domatic partition* is a partition $D = \{D_1, D_2, \ldots, D_r\}$ of V such that each block D_i of D is a dominating set of G.
- Generalization: A *k-domatic partition has each block as k-dominating set. In k-dominating set, all vertices are atmost k hops away from some node in set.*

Domatic Fullness

- Let δ= the minimum vertex degree in G. Size of largest domatic partition $\leq \delta$+1.
- If domatic number = δ+1 then graph is said to be *Domatically Full.*
- *Example:- 3-d hypercube is domatically full.*
- *Domatic fullness problem is NP-Complete*

Unit Disk Graph

- Let Nodes in G reside in 2-dimensional Euclidean space.G is a *unit disk graph* (UDG)
- $\{u, v\} \in E \Leftrightarrow |uv| \leq 1$.
- Sensor Networks with unit transmission radius can be modeled as UDG

Domatic Partitioning

- Bounded Density Clique Partitioning

  Consider Circular (R) target Area,

  If we reduce the transmission radius to ½

  it results in bounded clique.

  Partition the Area (R) with bounded clique

  to obtain clique partition of bounded density

- Clique Partition to Domatic Partition

Algorithm1:Ordered Domatic Partition

Input: Domatic number (d)

1. Election for ClusterHead (Ch) for t1 time
2. Elected ClusterHead (Ch) broadcasts its ID
3. Nodes join to form clusters and identify its neighbors
4. Nodes within ½ range forming clique broadcasts its Id & neighbor list
5. Nodes ½ range receives, forms set S(d),sorts in non-descending order.
6. S(d) of size d forms elements of domatic partition
7. ClusterHead broadcasts S(d) to form domatic partition set.

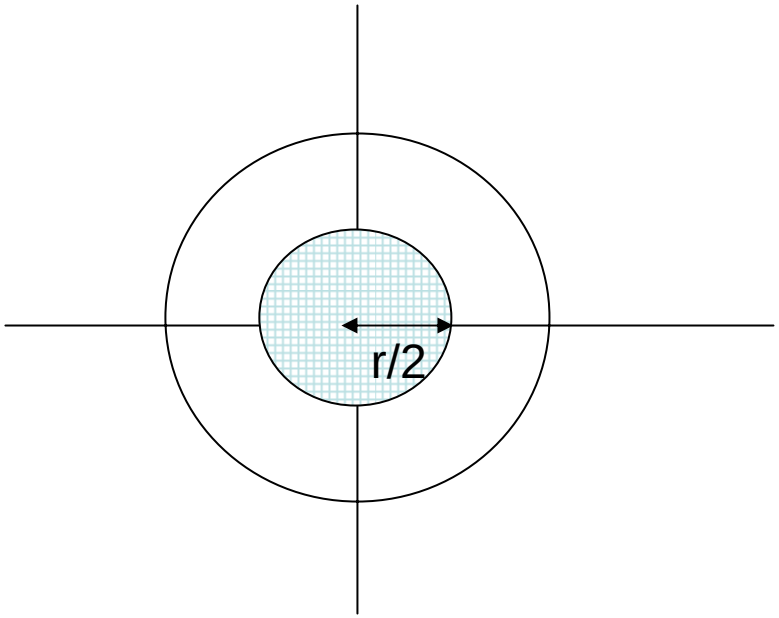
Algorithm2: Rotation of ClusterHead Role

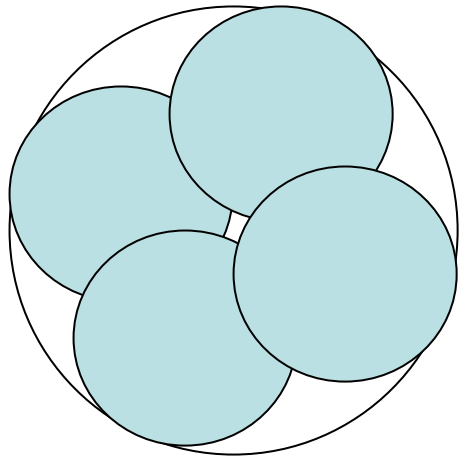
Input: Ordered Domatic Partition S(d)

1. Switch the Ch Role to the next node in S(d)
2. Self-Organize the cluster around new Ch
3. Uncovered nodes elect new Ch

Some Implementation Aspects

- The Clique Region





Packing of ½ disks in 1-disk

Domatic Number

- Let $D_1, D_2, \ldots D_r$ be vertex subsets computed using r colors
- CLAIM: For any r, $1 \leq r \leq (\delta + 1)/c$, the set D_r

  is a dominating set of G.
- Generalization: k-domatic partition is an easy of the above in which each block D_i

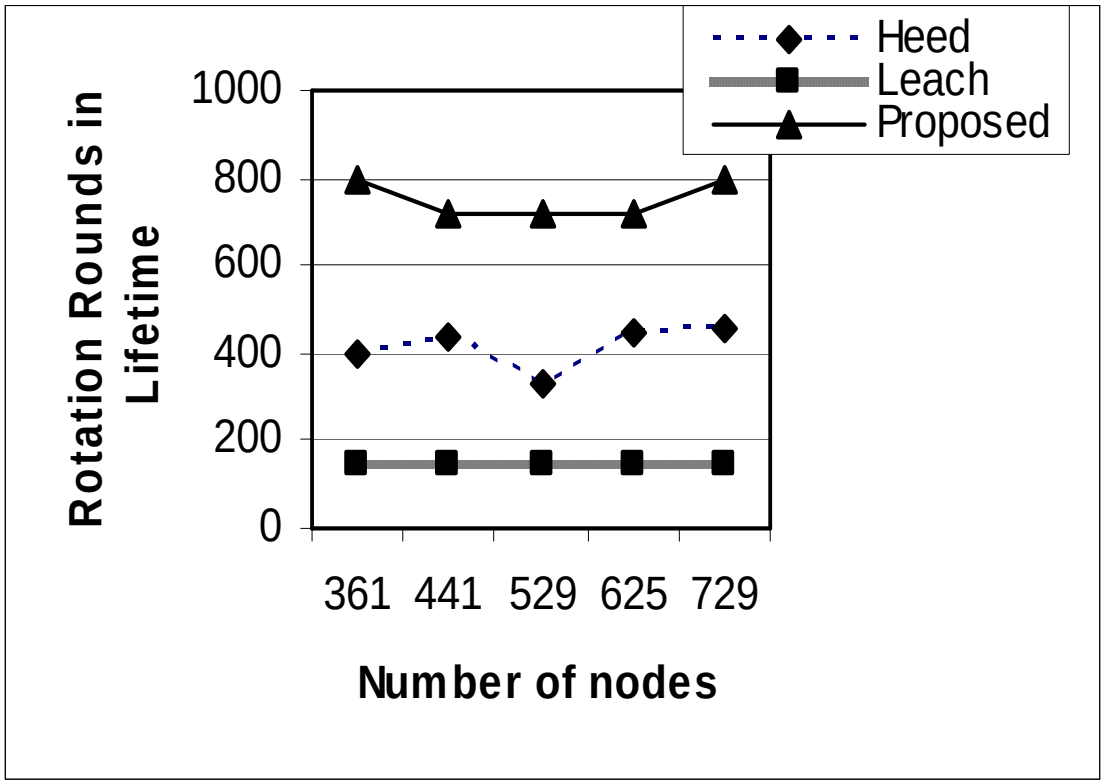
  is k-dominating set.
- Theorem: Domatic number is atleast $\frac{\delta_{k-1}}{c}$

  for constant c.

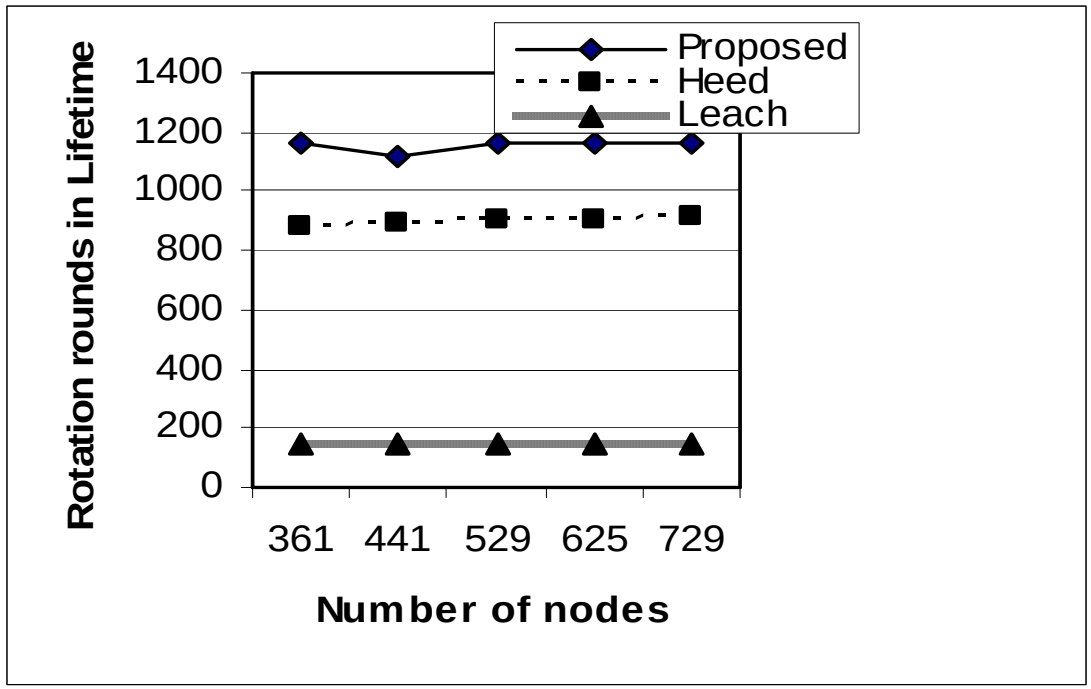
Results

- 50% increase in Lifetime compared to HEED,LEACH

Simulation Results: Network-Lifetime until First node dies



Simulation Results: Network-Lifetime until Last node dies



Conclusion

- WSNs are battery powered. Hence, prolonging the network lifetime is highly desirable
- Schedule the Dominating Set to activate among Disjoint Dominating Set
- Finding Maximum Number of Disjoint Dominating set is *Domatic Partition Problem*, is NP-complete
- Dominating Set based partitioning are better than Clustering based partitioning
- Domatic Partitioning extends Lifetime of sensor network

Conclusion

Our contributions:

- Propose Domatic Partition approach for Role Rotation in Sensor Networks
- Propose Self-Organizing Distributed Construction
- Propose an efficient heuristic using localization

Thank You !