An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks

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Introduction

- Sensor networks consist of a large number of ultra–small autonomous wireless sensor nodes.
  - Limited in power
  - Transmission range
  - Computational capacities
  - Memory
- Need energy-efficient routing protocol for data communication.

Introduction

- Two alternative routing approaches
  - Flat multi-hop
  - Clustering
- It may be advantageous to organize the sensors into clusters.
  - Communicating data over smaller distances
  - Low energy cost

Related Work

- Many clustering algorithm have been proposed.
  - LCA, LCA2
  - Weighted Clustering Algorithm (WCA)
  - Etc.
- All of above are suitable only for networks with a small number of nodes.

Related Work

- MAX-Min d-cluster Algorithm
  - generates d-hop clusters with a run-time of *O(d)* rounds.
  - Does not ensure energy efficient.
- LEACH
  - Rotate cluster-head election.
  - Assumption is not reliable.

Single-Level clustering Algorithm

- Each sensor in the network becomes a cluster-head (CH) with probability *p.*
  - We call these CH the Volunteer cluster-heads.
- Advertises to the sensors within its radio range and forward advertisement no more than *k* hops away from the cluster-head.
- Any sensor that receives such advertisements and is not itself a cluster-head joins the cluster of the closest cluster-head.

Single-Level clustering Algorithm

- If a sensor does not receive a CH advertisement within time duration *t* it can infer that it is not within *k* hops of any volunteer cluster-head and hence become a forced cluster-head.

Single-Level clustering Algorithm

- The energy used in network will depend on the parameters p and k,
  - Find p & k that ensure minimization of energy consumption.

- Basic idea
  - Define a function for energy wasted.
  - find the values of parameters that would minimize it.

Single-Level clustering Algorithm

- Spatial Poisson process
  - Consider a homogeneous highway segment of length l miles.
  - Each year an average of λ highway accidents occur per mile on this type of highway.
  - Then the number of highway accidents that occur in the segment of length l miles can be modeled as a **Poisson** random variable with mean λl

Single-Level clustering Algorithm

- Pre assumption:
  - The sensors in the wireless sensor network are distributed as per a homogeneous spatial Poisson process of intensity λ in 2-dimensional space.
  - All sensor have the same radio range r.
  - A distance of *d* between any sensor and its cluster-head is equivalent to *d/r* hops.
  - Error- and contention-free.

Single-Level clustering Algorithm

- Compute **D_i** (length from a sensor to the processing center)
- Compute **N_v** (the number of non-CH in each cluster)
- Compute **L_v** (total length of all segments connecting the non-CH to the CH in a cluster)
- Compute **C_2** (total energy spent by all the sensors communicating 1 unit of data to their respective clusterheads),

  C_3 (energy spent by the clusterheads to communicate the aggregated information to the processing center)

Single-Level clustering Algorithm

- Finally the energy function is as follow:

$$E[C \mid N=n] = E[C_2 \mid N=n] + E[C_3 \mid N=n]$$

$$= \frac{np}{r}\frac{(1-p)}{2p^{3/2}\sqrt{\lambda}} + \frac{0.765npa}{r}. \quad = \lambda A\left[\frac{1-p}{2r\sqrt{p\lambda}} + \frac{0.765pa}{r}\right].$$

- P is given by

$$p = \left[\frac{1}{3c} + \frac{\sqrt[3]{2}}{3c(2+27c^2+3\sqrt{3}c\sqrt{27c^2+4})^{1/3}} + \frac{(2+27c^2+3\sqrt{3}c\sqrt{27c^2+4})^{1/3}}{3c}\cdot\frac{1}{\sqrt[3]{2}}\right]^2$$

Single-Level clustering Algorithm

- Compute k

$$k_1 = \left\lceil \frac{1}{r} \sqrt{\frac{-0.917 \ln(\alpha / 7)}{p_1 \lambda}} \right\rceil$$

such that all sensors being within k hops from at least one volunteer cluster-head is very high

Single-Level clustering Algorithm

- The output with p=0.1 and k=2
- 500 sensors distributed uniformly in 100 square units.

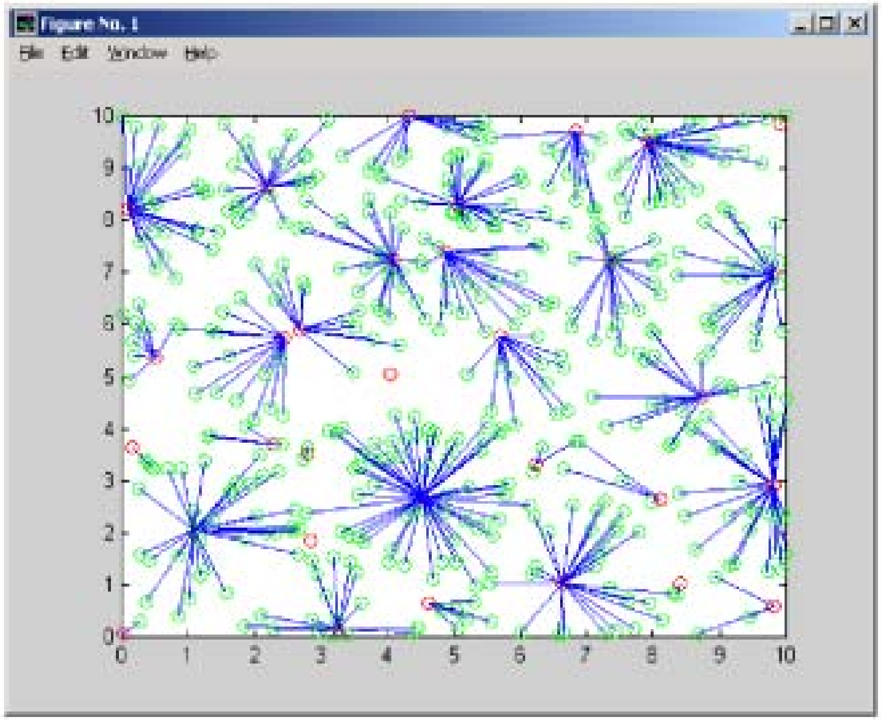

Figure 1. Output of simulation of the single level clustering algorithm

Hierarchical clustering Algorithm

- Similar to Single-Level clustering Algorithm
- Each sensor decides to become a level-1 CH with certain probability p_1
- Advertise to k_1-hop of neighbors
- Neighbor joins the cluster of the closest level-1 CH.

Hierarchical clustering Algorithm

- Level-1 CHs then elect themselves as level-2 CHs with a certain probability p_2
- Advertise to k_2-hop of neighbors.
- Level-1 CHs join the cluster of the closest level-2 CH.
- ...

Simulation

TABLE I. ENERGY MINIMIZING PARAMETERS FOR THE ALGORITHM

Number of Sensors (n)	Density (d)	Probability (p_{opt})	Maximum Number of Hops (k)
500	5	0.1012	5
1000	10	0.0792	4
1500	15	0.0688	3
2000	20	0.0622	3
2500	25	0.0576	3
3000	30	0.0541	3

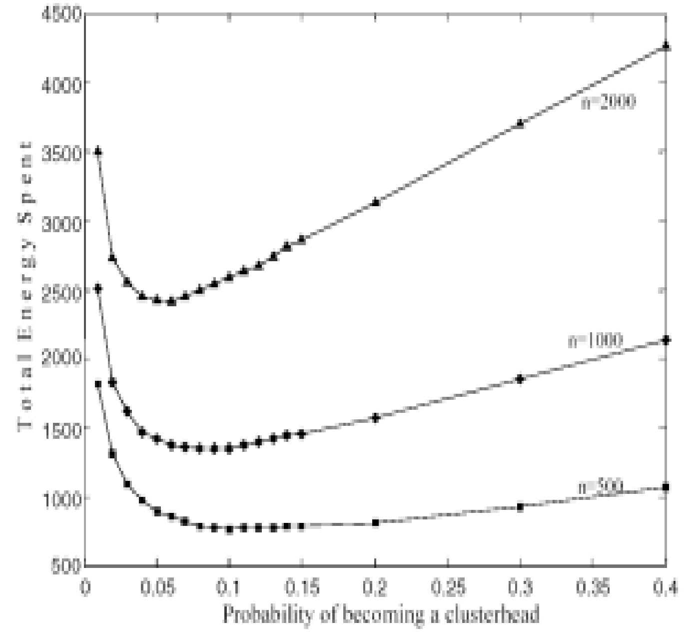

Figure 2. Total Energy Spent vs. probability of becoming a clusterhead in algorithm in Section III.

Simulation

- Compare to Max-Min d-cluster algorithm.

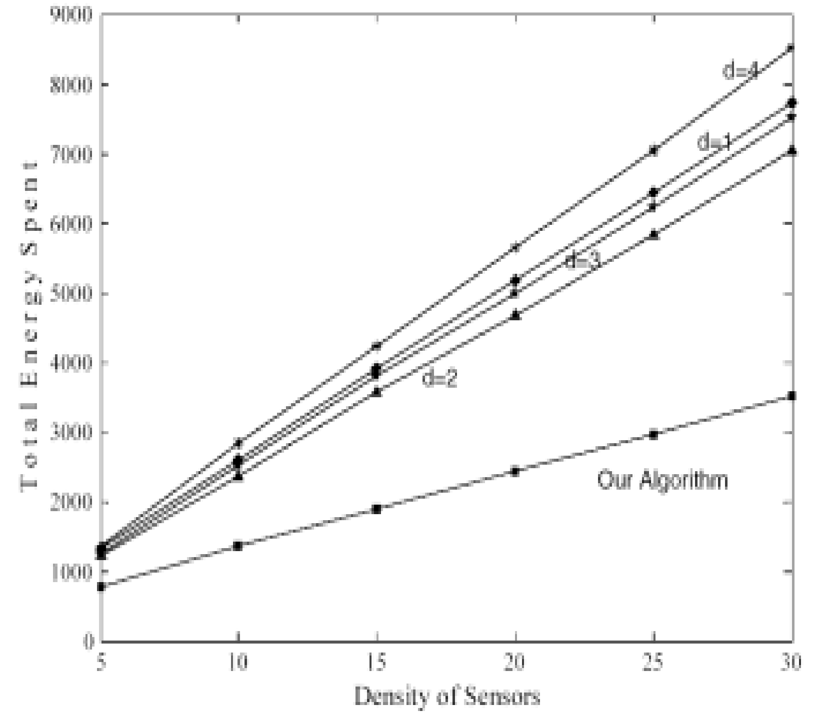

Figure 3. Comparison of Our Algorithm and the Max-Min D-Cluster Algorithms .

Simulation

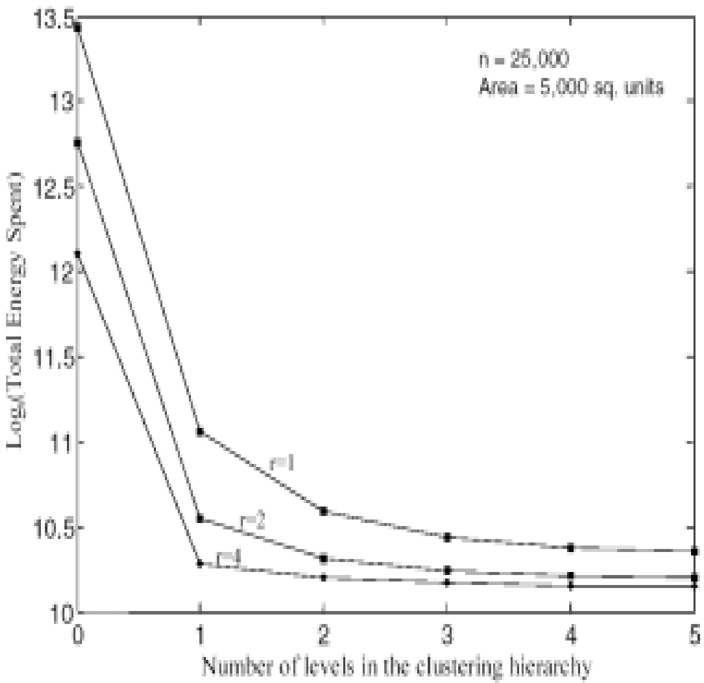

Figure 4. Total Energy Spent vs. number of levels in the clustering hierarchy in a network of 25000 sensors with communication radii *r* distributed in a square area of 5000 sq. units.

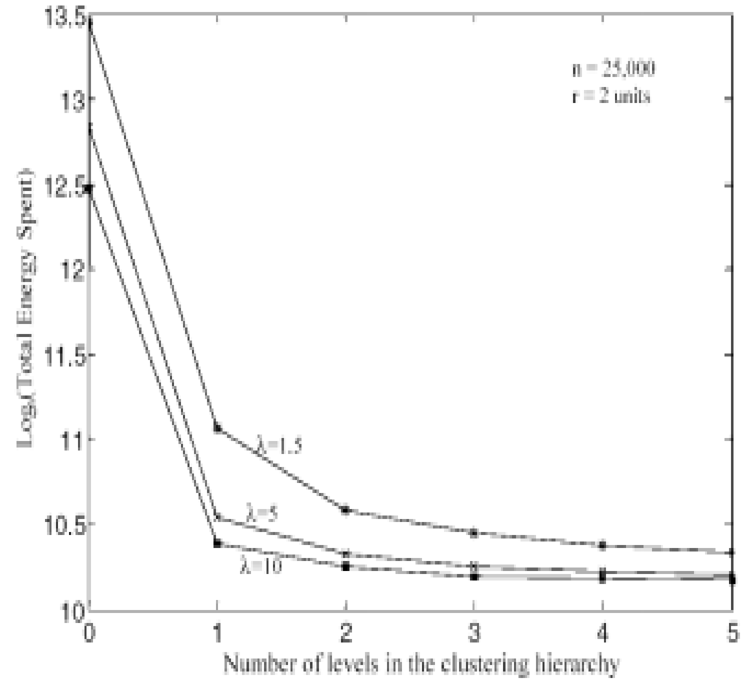

Figure 5. Total Energy Spent vs. number of levels in the clustering hierarchy in a network of 25000 sensors of communication radius 2 distributed with spatial density λ.

Conclusion

- A new distributed hierarchical clustering algorithm is proposed.
  - optimal parameter values for energy function.
  - Energy efficient
- Still need to solve heavy load of CH.
- Need to modify the assumption of “contention- and error-free environment” to real world environment

Reference

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