A distributed approximation scheme for sleep scheduling in sensor networks

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Geru project – http://www.hiit.fi/ada/geru

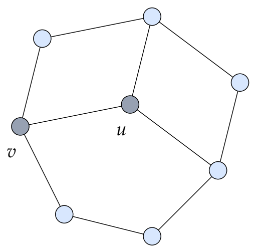
1 Redundancy graph

Battery-powered sensor nodes

Nodes v and u are *pairwise redundant*: if v is active then u can be asleep and vice versa

- E.g., u and v are very close to each other

Identify all pairwise redundancy relations, present them as a graph



2 Dominating sets

If nodes $\{v_1, v_2, v_3\}$ are active then all other nodes can be asleep

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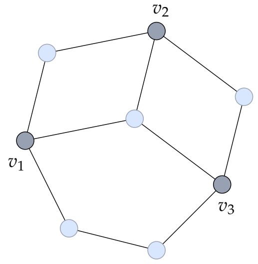
$D = \{v_1, v_2, v_3\}$ is a *dominating set* in this redundancy graph

Energy conservation scheme: assign a time period to each dominating set



3 Sleep scheduling

Equal to *fractional domatic partition*

Objective:

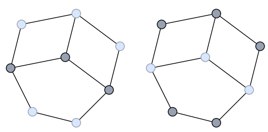
$$\begin{aligned} &\text{maximise} && \textstyle\sum_D x(D) && \textit{(network lifetime)} \\ &\text{subject to} && \textstyle\sum_D D(v)x(D) \le 1 \ \text{ for all } v, && \textit{(battery capacity constraint)} \\ & && x(D) \ge 0 \ \text{ for all } D. && \textit{(duration is nonnegative)} \end{aligned}$$

- v ranges over all nodes
- D ranges over all dominating sets in the redundancy graph
- $D(v) = 1$ if $v \in D$ and $D(v) = 0$ if $v \notin D$

4 Examples of sleep schedules

A domatic partition

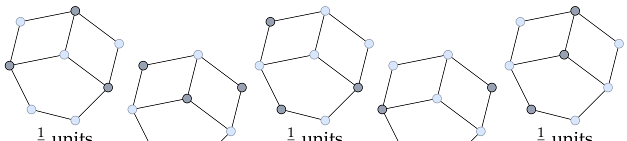
Achieved lifetime 2 units, each node active for 1 time unit



1 time unit   1 time unit

A fractional domatic partition

Achieved lifetime $\frac{5}{2}$ units, each node active for 1 time unit



$\frac{1}{2}$ units $\frac{1}{2}$ units $\frac{1}{2}$ units $\frac{1}{2}$ units $\frac{1}{2}$ units

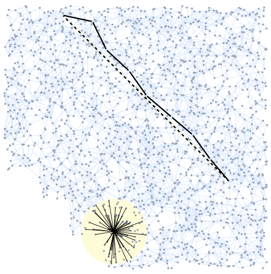
5 Assumptions on the problem structure

Communication graph

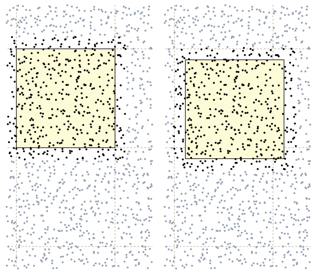
1. Bounded density of nodes
2. Bounded length of edges
3. Geometric spanner

Redundancy graph

- Any subgraph of the communication graph



6 Shifting strategy



Use a grid to partition the graph; solve each subproblem locally; merge the local solutions

Shift the grid to form several partitions; construct a schedule for each partition; interleave

Works fine if the nodes know their coordinates – can we form the partitions *without using coordinates*?

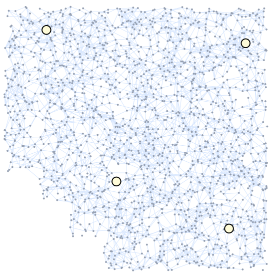
7 Add or choose anchors

Label some nodes as *anchors*

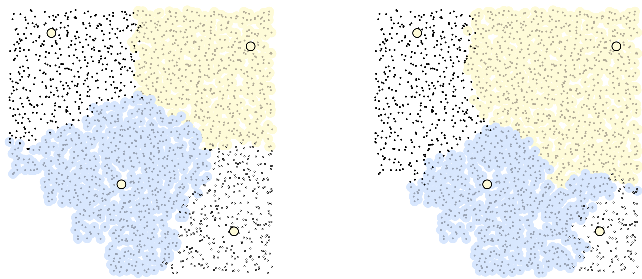
Minimal amount of extra information: 1 bit per node (anchor vs. non-anchor)

Some requirements on anchors:

- Not too sparse
- Not too dense



8 Distributed approximation scheme



Voronoi cells for anchors   Shift the borders towards those anchors with larger identifiers

References

P. Floréen, P. Kaski, and J. Suomela. A distributed approximation scheme for sleep scheduling in sensor networks. *Proc. SECON 2007.*

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