# A distributed approximation scheme for sleep scheduling in sensor networks

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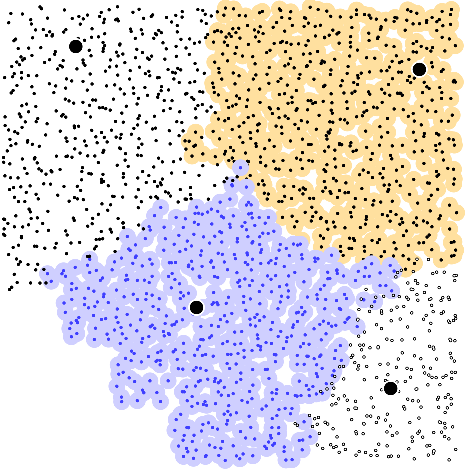

SECON
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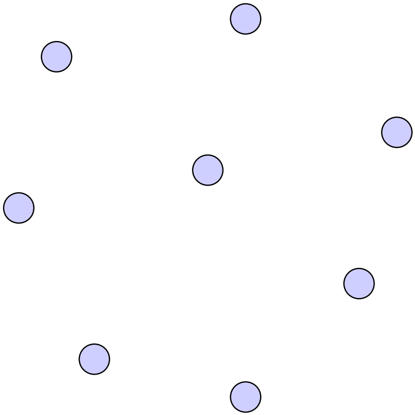
# A sensor network

Battery-powered sensor devices

Maximise the lifetime by letting each node sleep occasionally

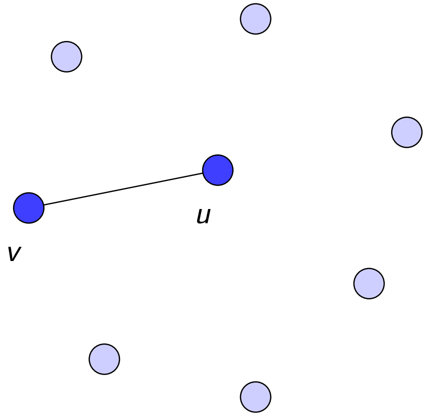


# Pairwise redundancy relations

Two sensors close to each other may be pairwise redundant

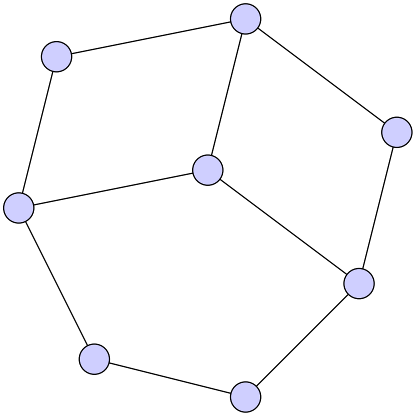
If $v$ is active then $u$ can be asleep and vice versa

Detecting pairwise redundancy: e.g., Koushanfar et al. (2006)



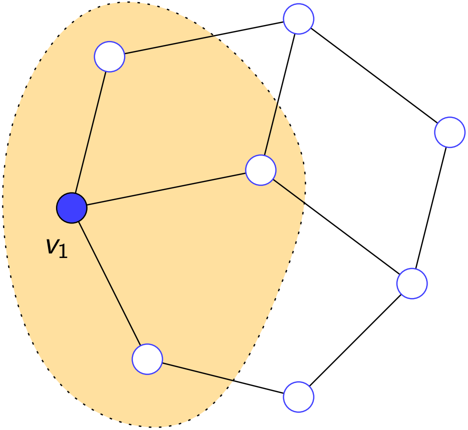
# Redundancy graph for the sensor network

All pairwise
redundancy relations



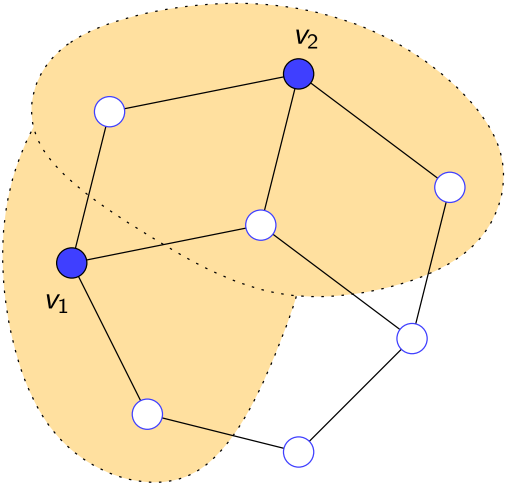
# A dominating set in the redundancy graph

If $v_1$ is active
then its neighbours
can be asleep



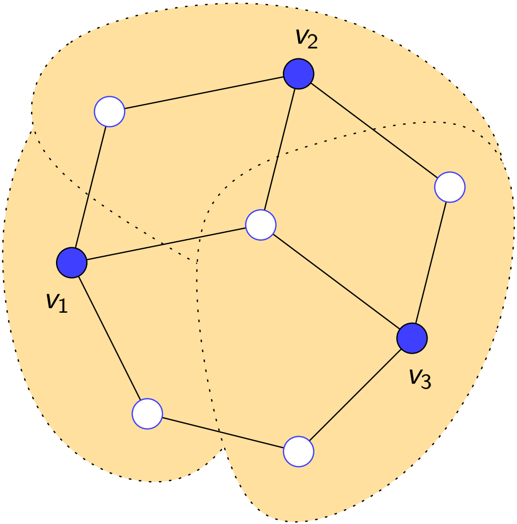
# A dominating set in the redundancy graph

If $v_2$ is active
then its neighbours
can be asleep



# A dominating set in the redundancy graph

If $v_3$ is active
then its neighbours
can be asleep



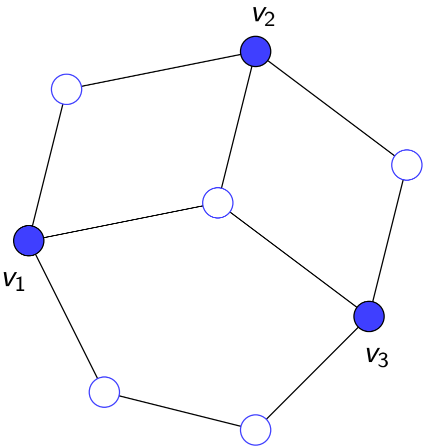
# A dominating set in the redundancy graph

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

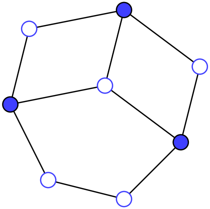
$$\Updownarrow$$

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

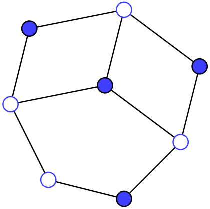
**Task:** find multiple dominating sets and apply them one after another



# Fractional domatic partition



$\frac{1}{2}$ units



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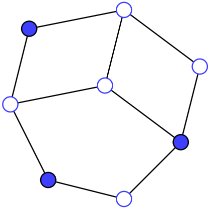
Achieved lifetime:
$\frac{5}{2}$ time units

Each node active for 1 time unit



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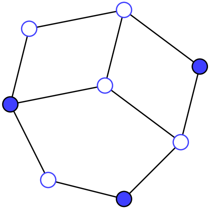

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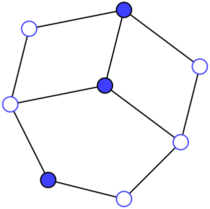

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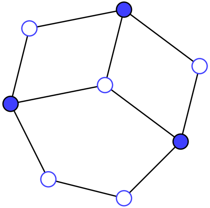
# Towards the distributed algorithm

Optimal sleep scheduling =
optimal fractional domatic partition

- Hard to optimise and hard to approximate in general graphs
- Centralised solutions are not practical in large networks



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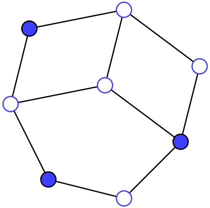
Plan:

- Identify the features of typical redundancy graphs
- Exploit the features to design a distributed approximation scheme



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# Features of a typical redundancy graph

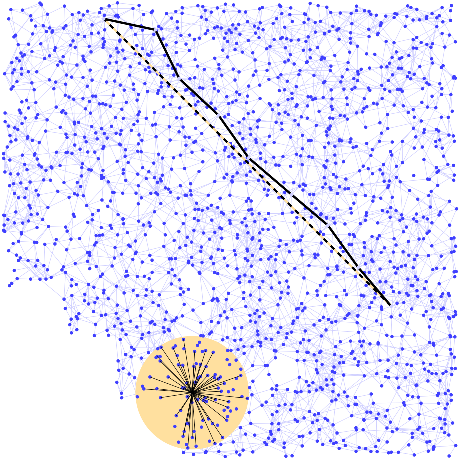
Communication graph

1. Density of nodes
2. Length of edges
3. Geometric spanner

Redundancy graph

- Any subgraph

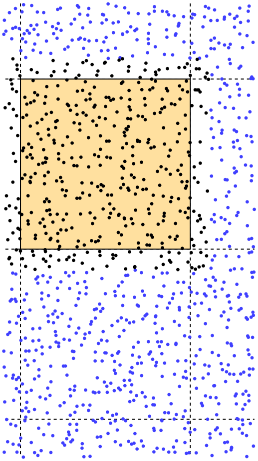
Given these assumptions, there exists a distributed approximation scheme



# The distributed approximation scheme

Idea 1:

1. Partition the graph into small cells
2. Solve the scheduling problem locally in each cell
   - Nodes near a cell boundary help in domination
   - Local optimum at least as good as global optimum
3. Merge the local solutions



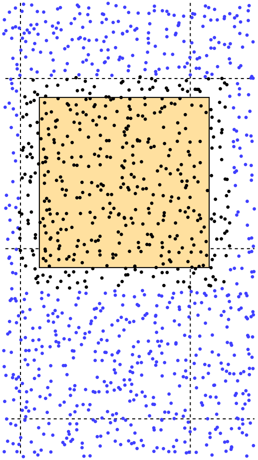
Problem:

- Nodes near a cell boundary work suboptimally

# The distributed approximation scheme

Idea 2: shifting strategy
(e.g., Hochbaum & Maass 1985)

1. Form several partitions
2. Make sure no node is near a cell boundary too often
3. Construct a schedule for each partition and interleave



Works fine if the nodes know their coordinates

Can we form the partitions without using any coordinates?

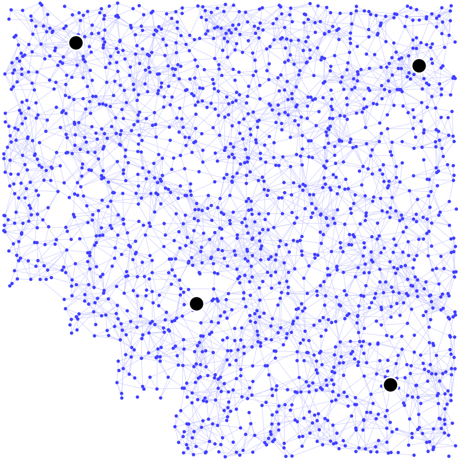
# The distributed approximation scheme

Install anchor nodes

Or use a distributed algorithm to find suitable anchors: e.g., any maximal independent set in a power graph of the communication graph

Not too sparse,
not too dense

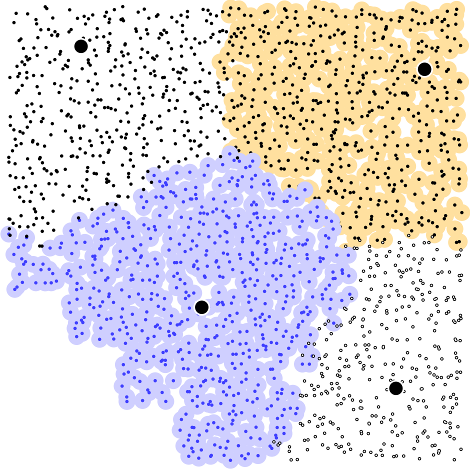
1 bit of information:
"I am an anchor"



# The distributed approximation scheme

Finding one partition is now easy: Voronoi cells for anchors

- Metric: hop counts in communication graph



How do we get more partitions?

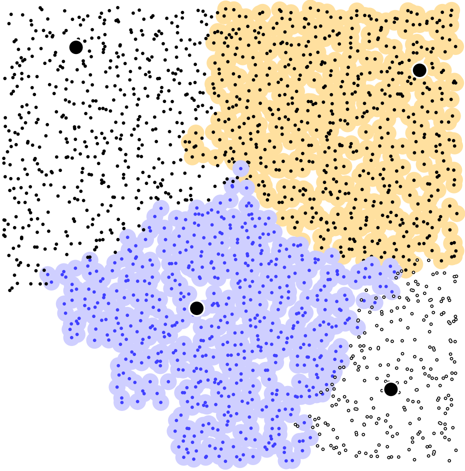
No global consensus on left/right, north/south

# The distributed approximation scheme

Assumption: locally unique identifiers for anchors

- MAC addresses
- Random numbers

Shift borders towards those anchors with larger identifiers



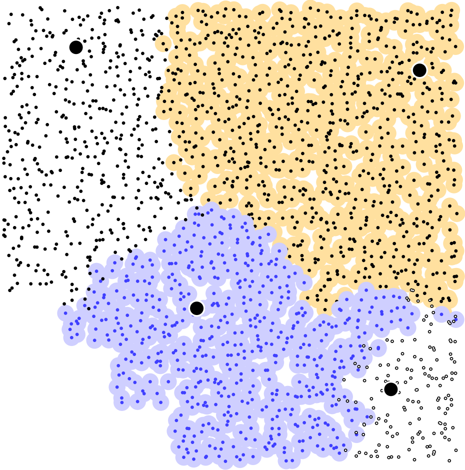
**Key lemma**

No node is near a cell boundary too often

# The distributed approximation scheme

A constant number of partitions suffices

Cell size is bounded

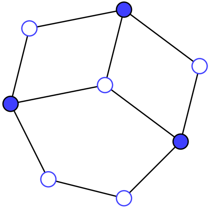


**Main result**

For any $\epsilon > 0$,
with suitable anchor placement,
sleep scheduling can be approximated within $1 + \epsilon$ in constant time per node

# Summary

- Sleep scheduling in sensor networks = fractional domatic partition
- Formalise the features which make the problem easier to approximate
- Anchors suffice, coordinates are not needed
- A distributed approximation scheme, constant effort per node
- Demonstrates theoretical feasibility – more work needed to make the constants practical



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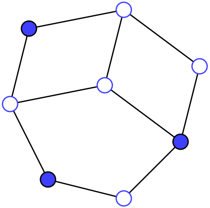

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