Efficient Key Predistribution for Grid-Based Wireless Sensor Networks

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Outline

Grid-Based Networks

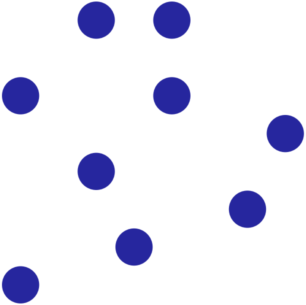
Costas Arrays

A New KPS for Grid-Based Sensor Networks

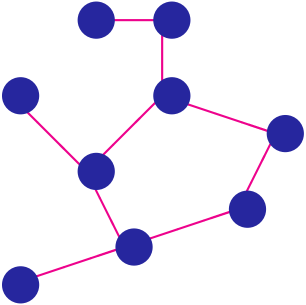
Evaluation of KPSs for Grid-Based Networks

Wireless Sensor Networks

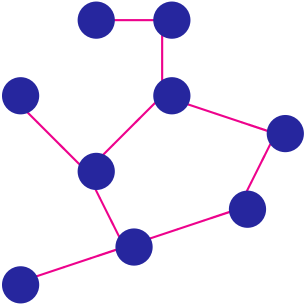
Wireless Sensor Networks



Wireless Sensor Networks

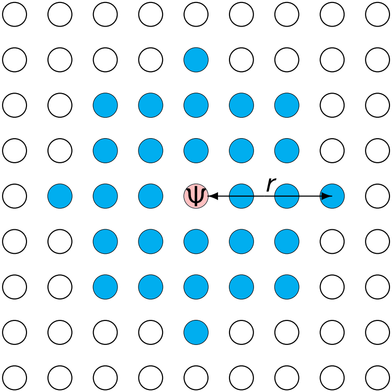


Wireless Sensor Networks

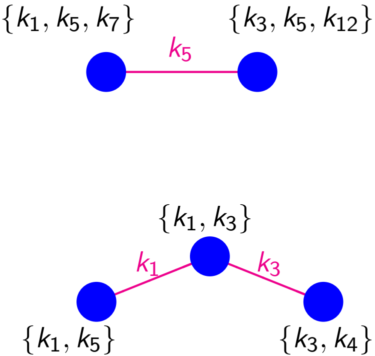


- restricted memory
- restricted battery power
- restricted computational ability
- vulnerable to compromise

Grid-Based Wireless Sensor Networks



Key Predistribution



key predistribution scheme (KPS)

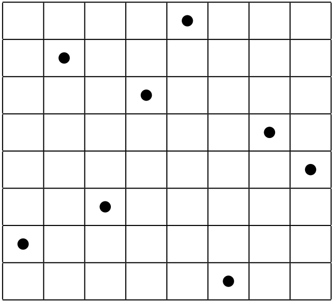
- nodes are assigned keys before deployment
- nodes that share keys can communicate securely
- two-hop path: nodes communicate via intermediate node

Goals for a KPS in a Grid-Based Network

- enable any two neighbours to communicate securely (directly or using a two-hop path)
- minimise storage
- be resilient against node compromise

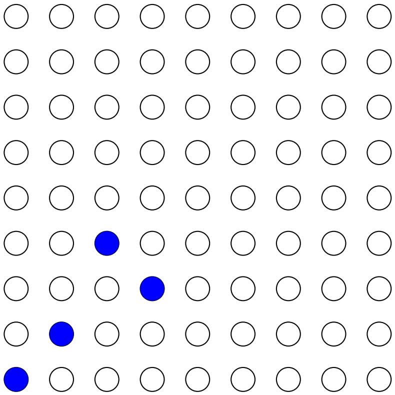
Observation: it is not necessary for two nodes to share more than one key

Costas Arrays



- one dot per row/column
- vector differences between dots are distinct
- applications to sonar, radar
- known constructions are based on finite fields

Translated Costas Arrays Overlap in at Most One Point



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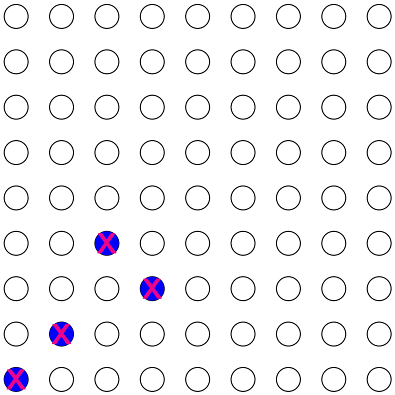

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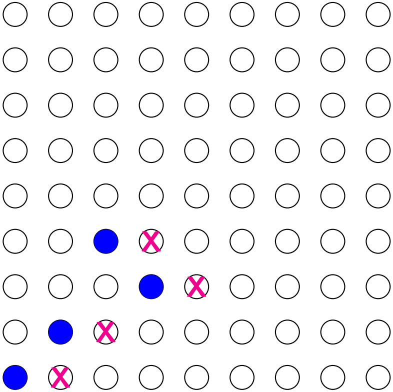

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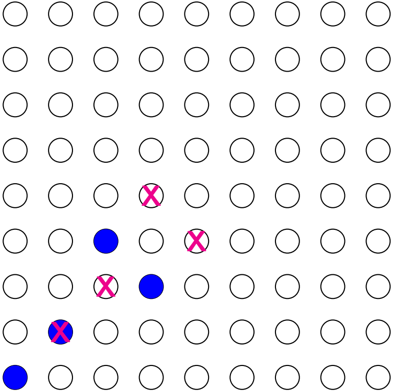

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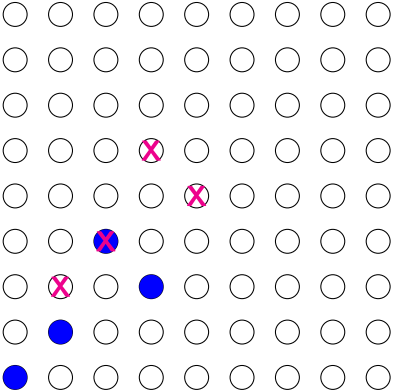
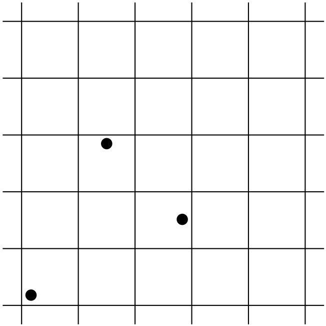


Key Predistribution Using Costas Arrays

- uses an $n \times n$ Costas array
- each sensor stores n keys
- each key is assigned to n sensors
- two sensors share at most one key
- the distance between two sensors that share a key is at most $\sqrt{2}(n-1)$



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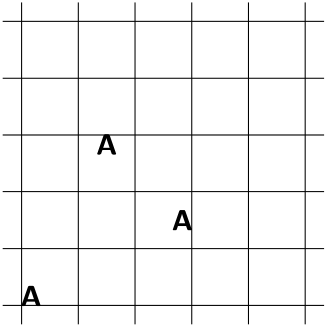

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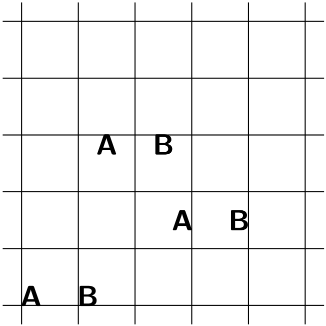

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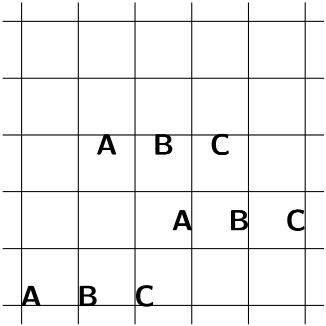

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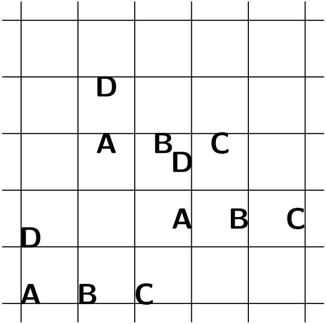

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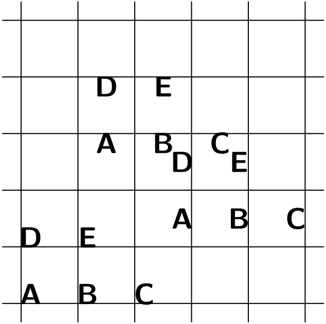

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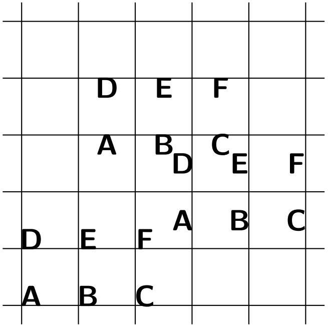

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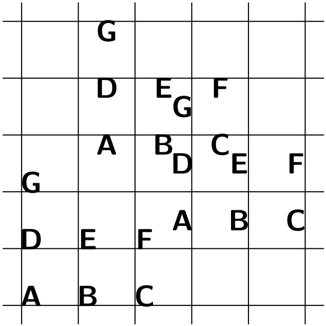

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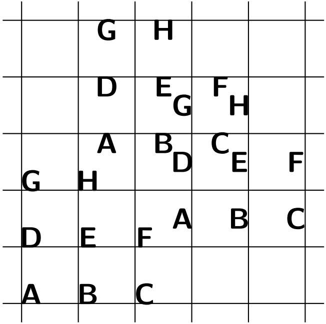

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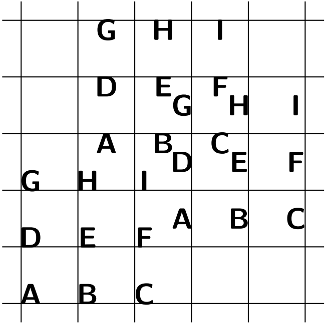
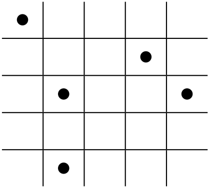


Distinct-Difference Configurations

Definition (Distinct-Difference Configuration DD(m, r))

- m dots are placed in a square grid
- the distance between any two dots is at most r
- vector differences between dots are all distinct



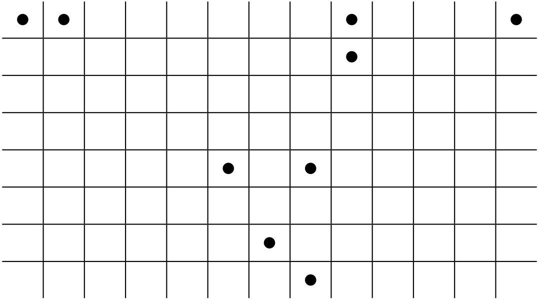
DD$(5, 8)$

- can be used for key predistribution in the same way as a Costas array
- more general than a Costas array $\Rightarrow$ more flexible choice of parameters

Maximum Two-Hop Coverage of a DD(m, r)

$m \backslash r$	1	2	3	4	5	6	7	8	9	10	11	12
2	2	4	4	4	4	4	4	4	4	4	4	4
3	-	12	18	18	18	18	18	18	18	18	18	18
4	-	-	28	46	54	54	54	54	54	54	54	54
5	-	-	28	48	80	102	118	126	130	130	130	130
6	-	-	-	48	80	112	148	184	222	240	254	262
7	-	-	-	-	80	112	148	196	252	302	346	374
8	-	-	-	-	-	112	148	196	252	316	376	$\geq$432
9	-	-	-	-	-	-	148	196	252	316	376	440
10	-	-	-	-	-	-	-	196	252	316	376	440
11	-	-	-	-	-	-	-	-	252	316	376	440
12	-	-	-	-	-	-	-	-	-	316	376	440

An optimal DD$(9, 12)$



- When $r = 12$ a node has 440 neighbours.
- A KPS based on this array ensures nodes can communicate securely with all 440 neighbours via a one-hop or two-hop path.
- This scheme requires each node to store 9 keys.

Comparison with Existing Schemes -Connectivity

Scheme	m	α	One-hop	Two-hop
Costas	8	8	56	366
DD(8, 11)	8	8	56	376
Liu & Ning	8	2	8	24
Eschenauer & Gligor	8	≈ 200	56.2	370.0
Ito *et al.*	8	≈ 8	36.2	319.6

values are averaged over 10000 trials on a 100×100 square grid

Comparison with Existing Schemes -Resilience

Scheme	m	α	Resilience	Local Res.
Costas	8	8	331	59
DD$(8, 11)$	8	8	336	59
Liu & Ning	8	2	23.87	20.3
Eschenauer & Gligor	8	≈ 200	36	36
Ito *et al.*	8	≈ 8	259	52

values are averaged over 10000 trials on a 100×100 square grid