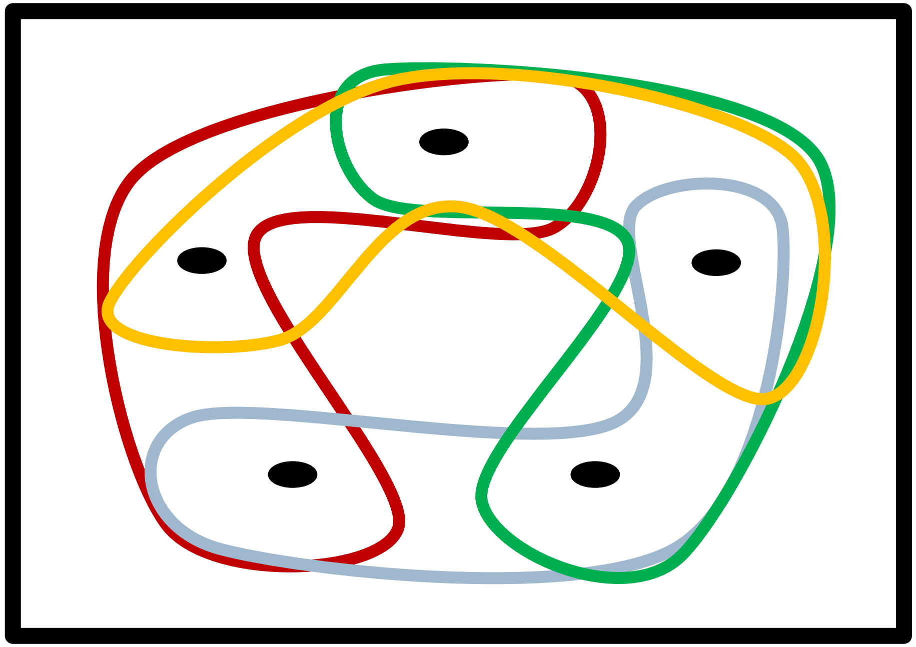


k-Zero-Divisor Hypergraphs

Pinkaew Siriwong

Department of Mathematics and Computer Sciences, Chulalongkorn University

Algebraic structures

+

Graph structures

Algebraic structures

Graph structures

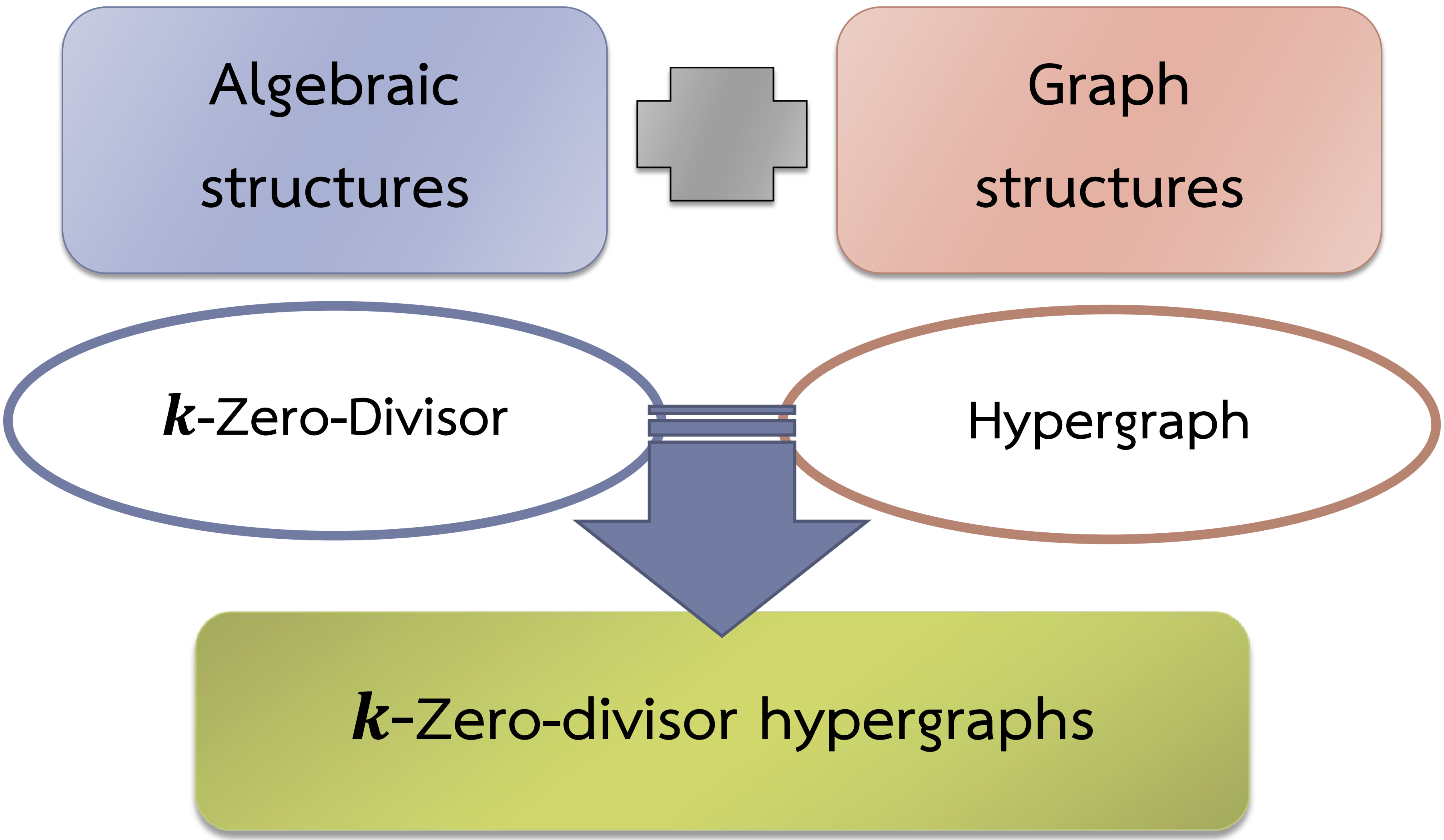
$\boldsymbol{k}$-Zero-Divisor

Algebraic structures

Graph structures

$\boldsymbol{k}$-Zero-Divisor

Hypergraph


Algebraic structures
Graph structures
k-Zero-Divisor
Hypergraph
k-Zero-divisor hypergraphs

Algebraic structures

Algebraic structures

A nonzero nonunit element z_1 is said to be

k-zero-divisor

Chelvam et.al.

Algebraic structures

A nonzero nonunit element $\boldsymbol{z_1}$ is said to be

$\boldsymbol{k}$-zero-divisor

if there exist $k-1$ distinct nonunit elements

$z_2, z_3, z_4, \dots, z_k$ differ from z_1 such that

Chelvam et.al.

Algebraic structures

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- $z_1 z_2 z_3 \cdots z_k = 0$
- the products of elements of any $k-1$ subset of $\{z_1, z_2, z_3, \dots, z_k\}$ are nonzero

Chelvam et.al.

Example of k-zero-divisor

Example of $\boldsymbol{k}$-zero-divisor

Consider $\mathbb{Z}_{\mathbf{30}}$

Example of $\boldsymbol{k}$-zero-divisor

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We know that $\bar{2} \cdot \bar{3} \cdot \bar{5} = \bar{0}$

Example of $\boldsymbol{k}$-zero-divisor

Consider $\mathbb{Z}_{30}$

We know that $\bar{2} \cdot \bar{3} \cdot \bar{5} = \bar{0}$

$\bar{2} \cdot \bar{3} \neq \bar{0}, \quad \bar{2} \cdot \bar{5} \neq \bar{0}, \quad \bar{3} \cdot \bar{5} \neq \bar{0}$

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$\bar{2} \cdot \bar{3} \neq \bar{0}, \qquad \bar{2} \cdot \bar{5} \neq \bar{0}, \qquad \bar{3} \cdot \bar{5} \neq \bar{0}$

We obtain that $\bar{2}$ is a 3-zero-divisor

Graph structures

Verrall

Graph structures

Hypergraph $\mathcal{H}(\boldsymbol{V}, \mathcal{E})$ or $\mathcal{H}$

Verrall

Graph structures

Hypergraph $\boldsymbol{\mathcal{H}(V,\mathcal{E})}$ or $\boldsymbol{\mathcal{H}}$

- V or $V(\mathcal{H})$ is a nonempty finite set of *vertices* or *vertex set*
- $\mathcal{E}$ or $\mathcal{E}(\mathcal{H})$ is a family of subsets of V, called set of (hyper)*edges* or *edge set*

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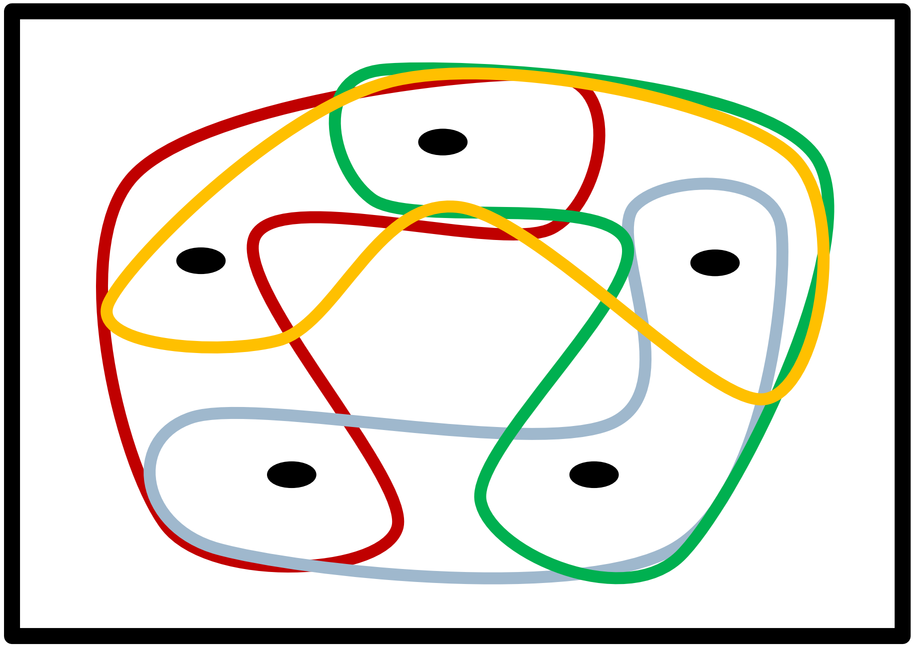
- If each edge of $\mathcal{H}$ has size l, we call $\mathcal{H}$ an l-*uniform hypergraph.*

Verrall

Example of hypergraphs

Example of hypergraphs



3-uniform hypergraph

Complete $\boldsymbol{k}$-uniform hypergraph on $\boldsymbol{n}$ vertices

Verrall

Complete $\boldsymbol{k}$-uniform hypergraph on $\boldsymbol{n}$ vertices

- $\mathcal{H}$ has all k-subsets of the n-set of vertices as edge

Verrall

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Verrall

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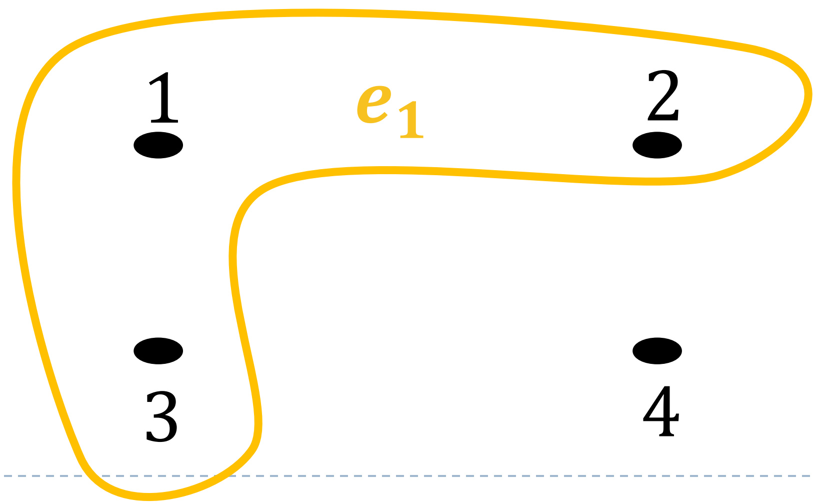

Verrall

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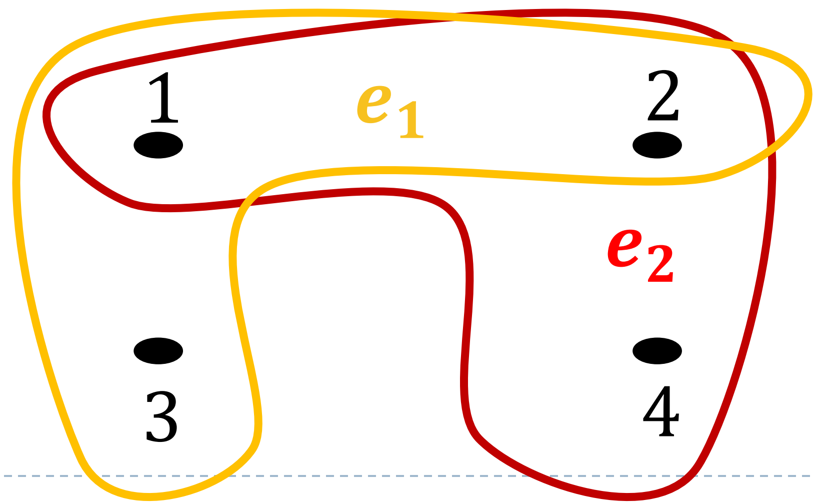

Verrall

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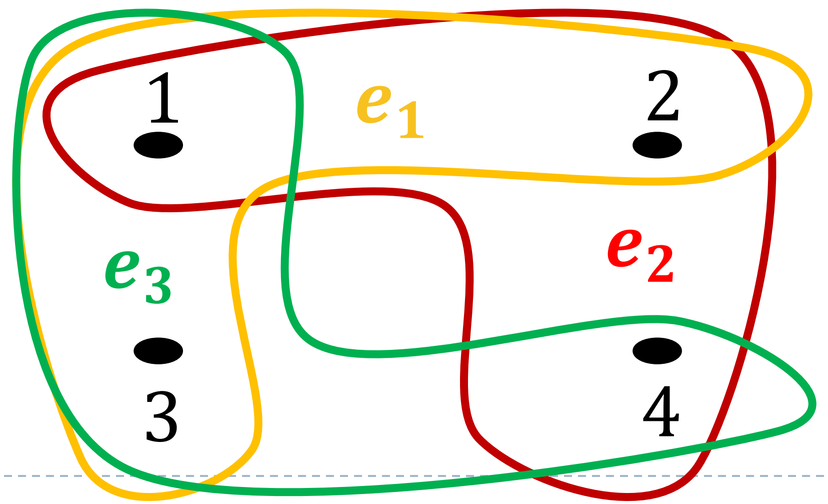

Verrall

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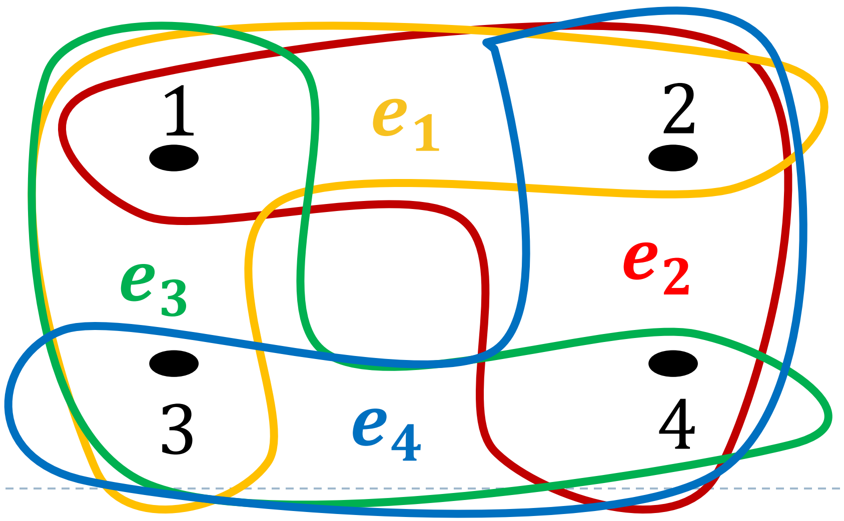

Verrall

$\boldsymbol{k}$-Partite $\boldsymbol{k}$-uniform hypergraph

Kuhl and Schroeder

$\boldsymbol{k}$-Partite $\boldsymbol{k}$-uniform hypergraph

- Vertex set V partitioned into k subsets $V_1, V_2, V_3, \dots, V_k$
- Edge set $\mathcal{E} = \{\{v_1, v_2, v_3, \dots, v_k\} | v_j \in V_j \; for \; all \; 1 \leq j \leq k\}$

Kuhl and Schroeder

k-Partite k-uniform hypergraph

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- Edge set $\mathcal{E} = \{\{v_1, v_2, v_3, \dots, v_k\} | v_j \in V_j \; for \; all \; 1 \le j \le k\}$

- <u>Complete</u> if $V_j = \left\{v_j^1, v_j^2, v_j^3, \dots, v_j^{|V_j|}\right\}$ for all $1 \le j \le k$ and

  $\mathcal{E} = \left\{\left\{v_1^{i_1}, v_2^{i_2}, v_3^{i_3}, \dots, v_k^{i_k}\right\} | v_j^{i_j} \in V_j \; for \; all \; 1 \le j \le k \; and \; 1 \le i_j \le |V_j|\right\}$

Kuhl and Schroeder

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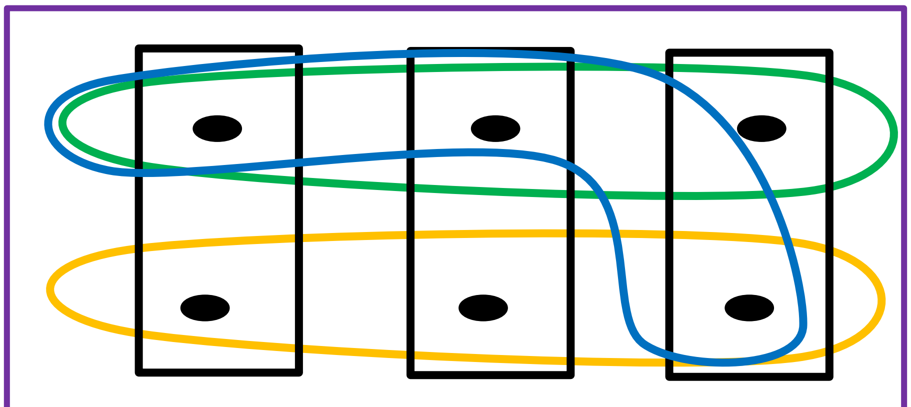

3-Partite 3-uniform hypergraph

Kuhl and Schroeder

$\boldsymbol{k}$-Partite $\boldsymbol{\sigma}$-uniform hypergraph where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

Jirimutu and Wang

$\boldsymbol{k}$-Partite $\boldsymbol{\sigma}$-uniform hypergraph where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

- Vertex set V partitioned into k subsets $V_1, V_2, V_3, \dots, V_k$
- E is an edge if $|E| = \sigma$ and $|E \cap V_i| < \sigma$ for all $1 \leq i \leq k$.

Jirimutu and Wang

k-Partite σ-uniform hypergraph where $\sigma \geq k$

- Vertex set V partitioned into k subsets $V_1, V_2, V_3, \dots, V_k$
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- Complete if $\mathcal{E} = \{E : |E| = \sigma$ and $|E \cap V_i| < \sigma$ for all $1 \leq i \leq k\}$

Jirimutu and Wang

$\boldsymbol{k}$-Partite $\boldsymbol{\sigma}$-uniform hypergraph where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

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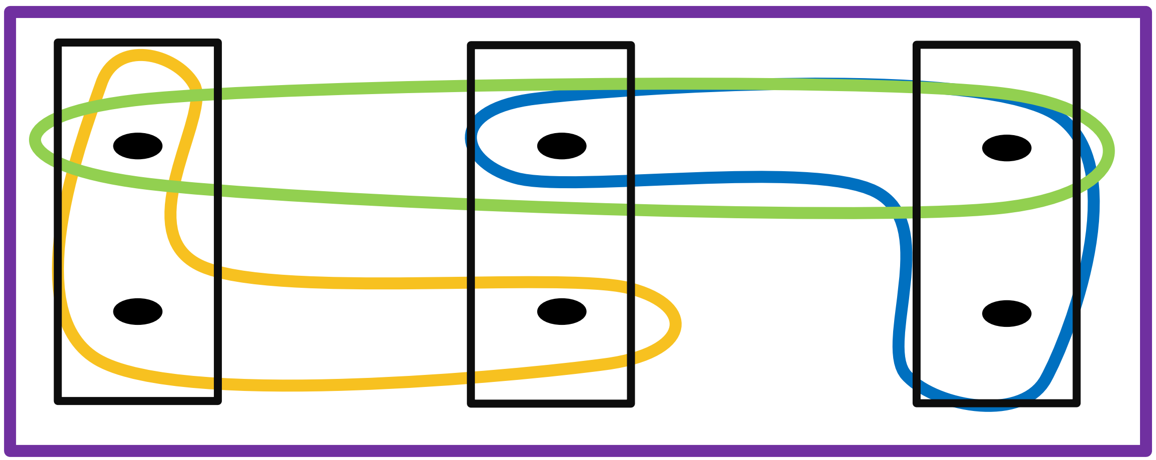
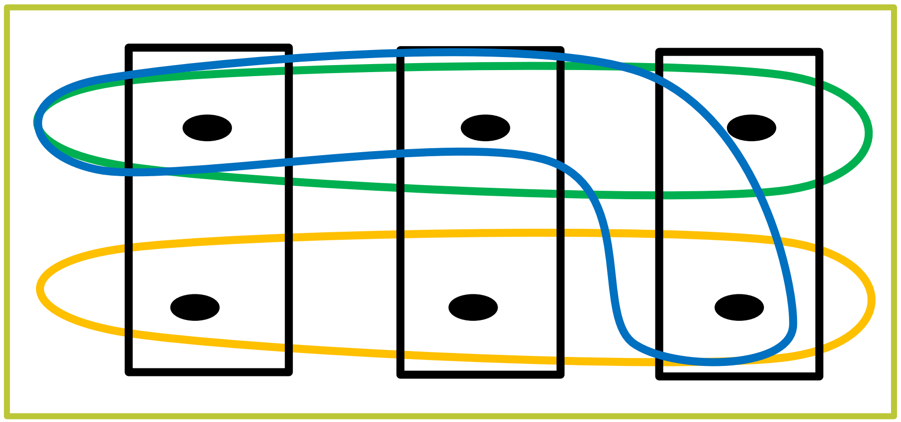


3-Partite 3-uniform hypergraph

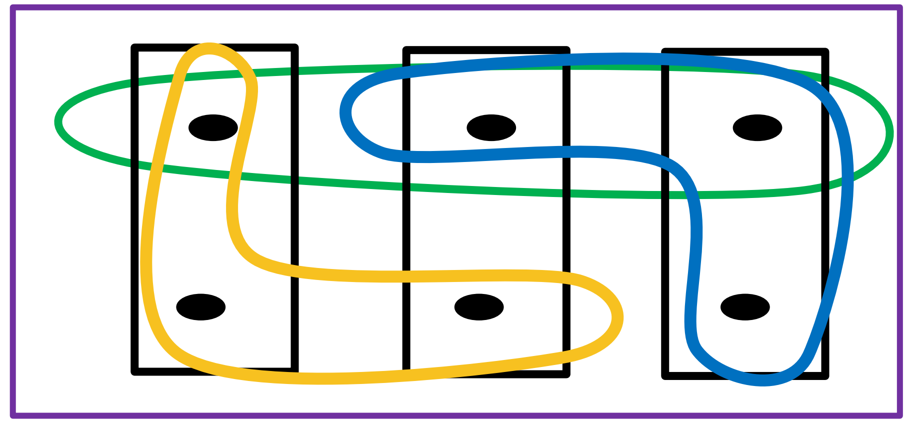
Jirimutu and Wang

$\mathbf{3}$-Partite $\mathbf{3}$-uniform hypergraph

3-Partite **3**-uniform hypergraph



Kuhl and Schroeder



Jirimutu and Wang

Path and Diameter of hypergraph $\mathcal{H}$

Ye

Path and Diameter of hypergraph $\mathcal{H}$

- A path P from x_1 to x_{s+1} is a vertex-edge alternative sequence $\boldsymbol{x_1, E_1, x_2, E_2, \ldots, x_s, E_s, x_{s+1}}$ such that $\{x_i, x_{i+1}\} \subseteq E_i$ for all $1 \leq i \leq s$ and $x_i \neq x_j, E_i \neq E_j$ with $\boldsymbol{i} \neq \boldsymbol{j}$ and $\boldsymbol{s}$ is called the length of the path P.

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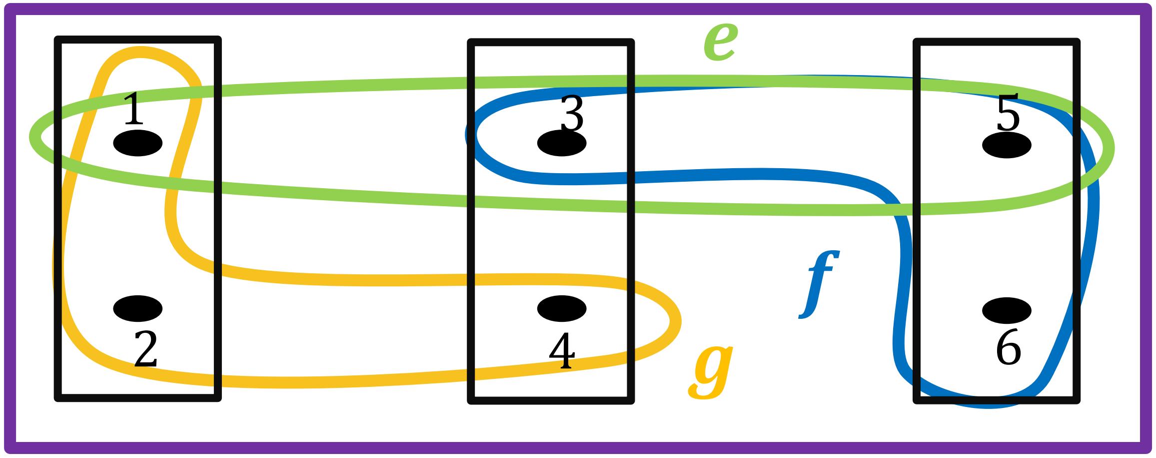
- The distance of distinct vertices $\boldsymbol{x}$ and $\boldsymbol{y}$, denoted by $\boldsymbol{d}(\boldsymbol{x},\boldsymbol{y})$, is the minimum length of all paths that connect $\boldsymbol{x}$ and $\boldsymbol{y}$.

- The diameter of $\mathcal{H}(V,\mathcal{E})$, denoted by $\boldsymbol{d}(\mathcal{H})$, is defined as $d(\mathcal{H}) = max\{d(x,y)|x,y \in V, x \neq y\}$.

Ye

Example of path and diameter

Example of path and diameter



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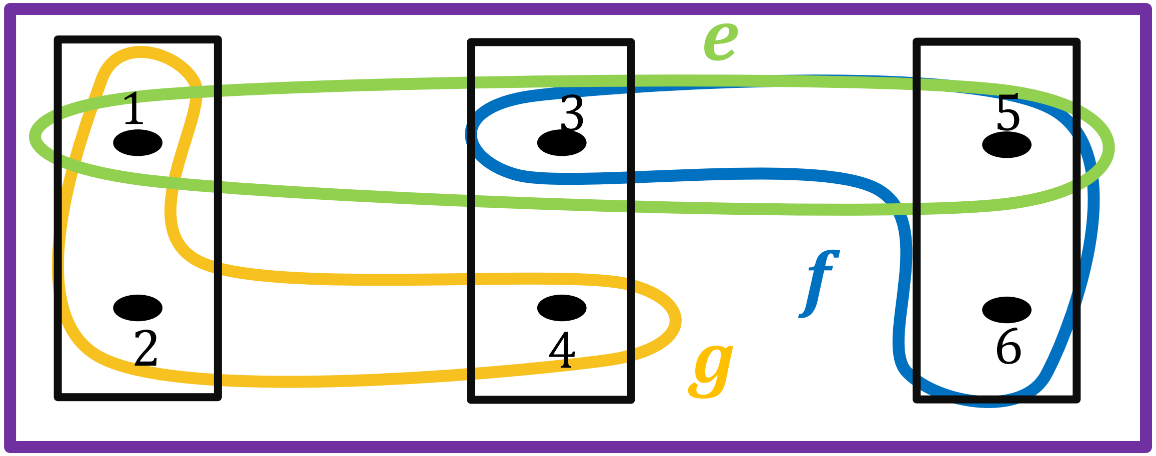
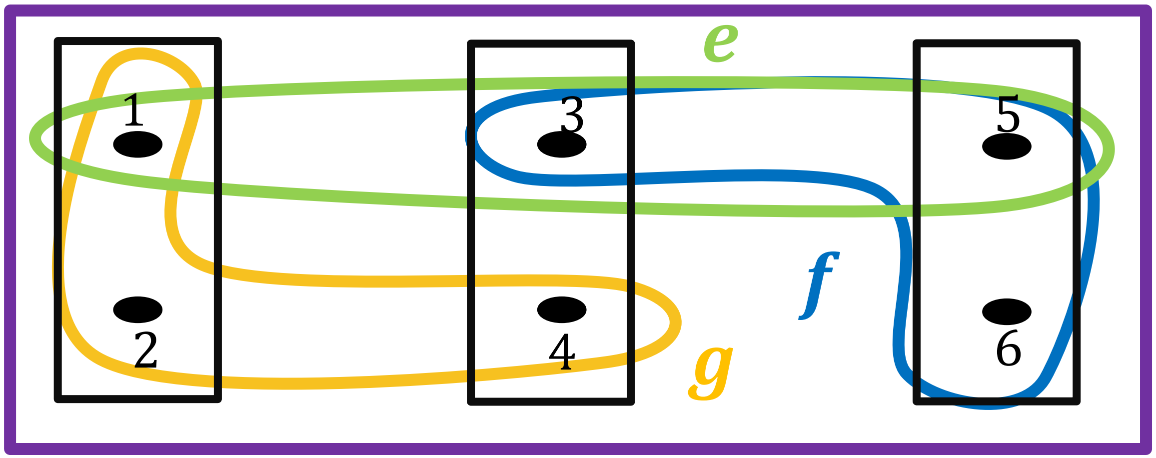


Path from 1 to 6

Example of path and diameter



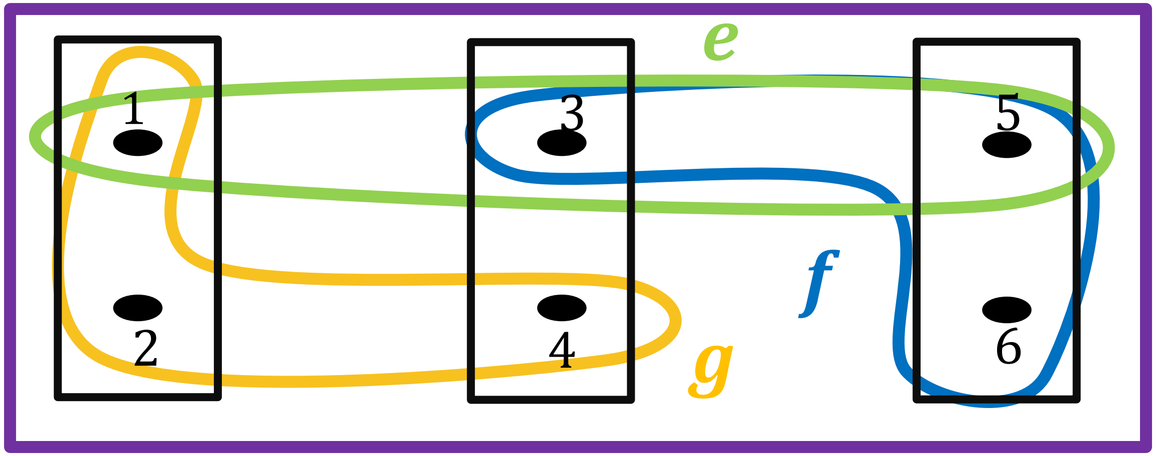
Path from 1 to 6

$1, e, 3, f, 6$

$1, e, 5, f, 6$

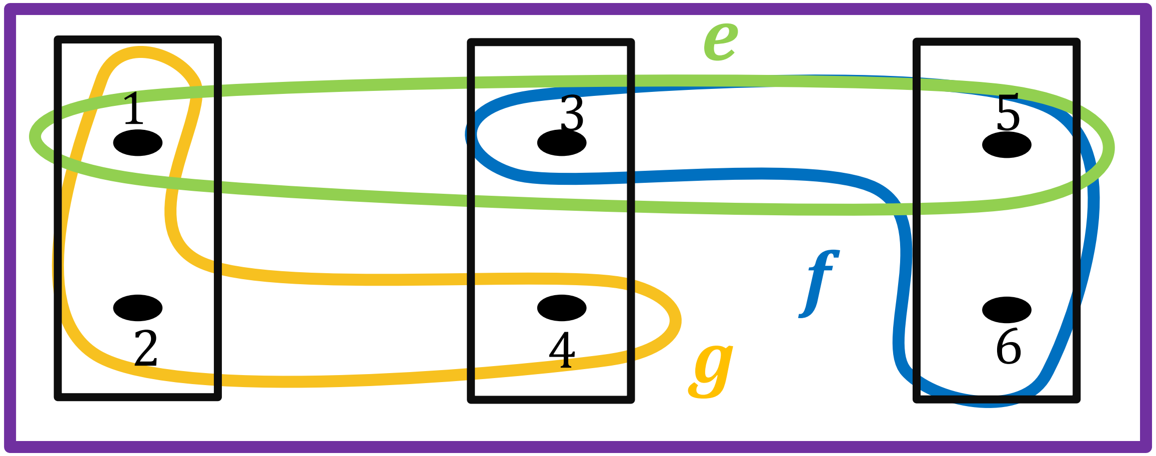
$d(1,6) = 2$

Example of path and diameter



Path from 1 to 6	$1, e, 3, f, 6$ $1, e, 5, f, 6$	$d(1,6) = 2$
Path from 4 to 6	$4, g, 1, e, 3, f, 6$ $4, g, 1, e, 5, f, 6$	$d(4,6) = 3$

Example of path and diameter



Path from 1 to 6

$1, e, 3, f, 6$

$1, e, 5, f, 6$

$d(1,6) = 2$

Consider all $d(x, y)$

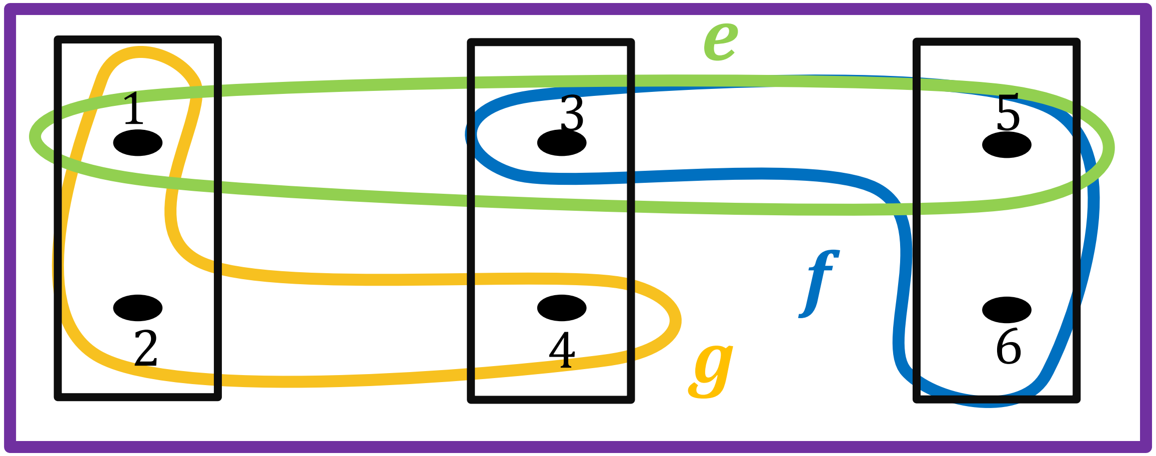
Path from 4 to 6

$4, g, 1, e, 3, f, 6$

$4, g, 1, e, 5, f, 6$

$d(4,6) = 3$

Example of path and diameter



Path from 1 to 6

$1, e, 3, f, 6$

$1, e, 5, f, 6$

$d(1,6) = 2$

$d(\mathcal{H}) = 3$

Path from 4 to 6

$4, g, 1, e, 3, f, 6$

$4, g, 1, e, 5, f, 6$

$d(4,6) = 3$

Cycle of hypergraph $\mathcal{H}$

Ye

Cycle of hypergraph $\mathcal{H}$

- Let $s \geq 2$ be an integer

Ye

Cycle of hypergraph $\mathcal{H}$

- Let $s \geq 2$ be an integer

- An $\boldsymbol{s}$-cycle is an alternating sequence, $\boldsymbol{C = x_1, E_1, x_2, E_2, \dots, x_s, E_s}$ of distinct vertices $x_1, x_2, x_3, \dots, x_s$ and distinct edges $E_1, E_2, E_3, \dots, E_s$ such that $x_1, x_s \in E_s$ and $x_i, x_{i+1} \in E_i$ for all $1 \leq i \leq s-1$ and $\boldsymbol{s}$ is called the length of cycle $\boldsymbol{C}$.

Ye

Cycle of hypergraph $\mathcal{H}$

- Let $s \geq 2$ be an integer

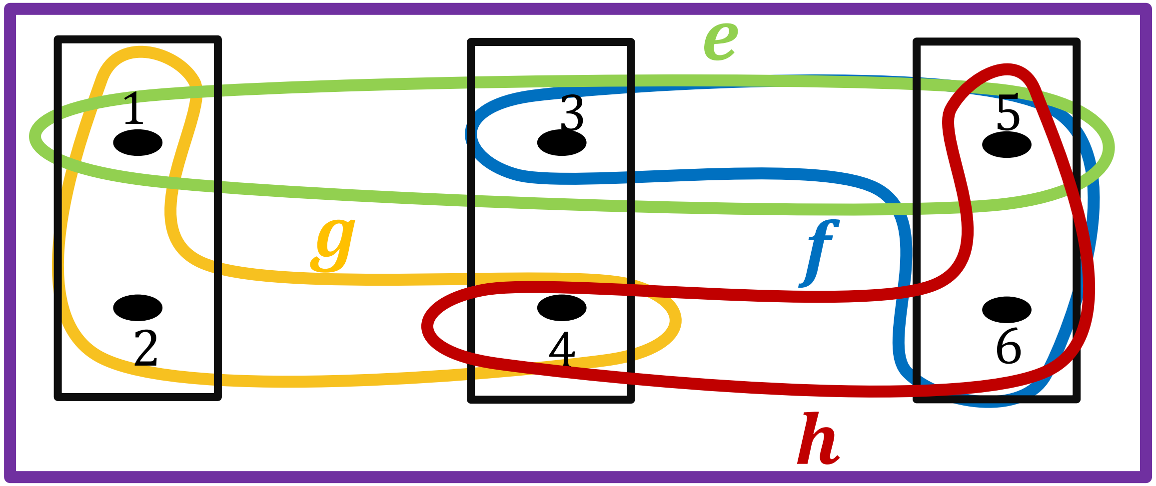
- An s-cycle is an alternating sequence, $\boldsymbol{C = x_1, E_1, x_2, E_2, \dots, x_s, E_s}$ of distinct vertices $x_1, x_2, x_3, \dots, x_s$ and distinct edges $E_1, E_2, E_3, \dots, E_s$ such that $x_1, x_s \in E_s$ and $x_i, x_{i+1} \in E_i$ for all $1 \leq i \leq s-1$ and s is called the length of cycle C.

- If hypergraph has no cycle, such hypergraph has 0-cycle or a cycle of length 0.

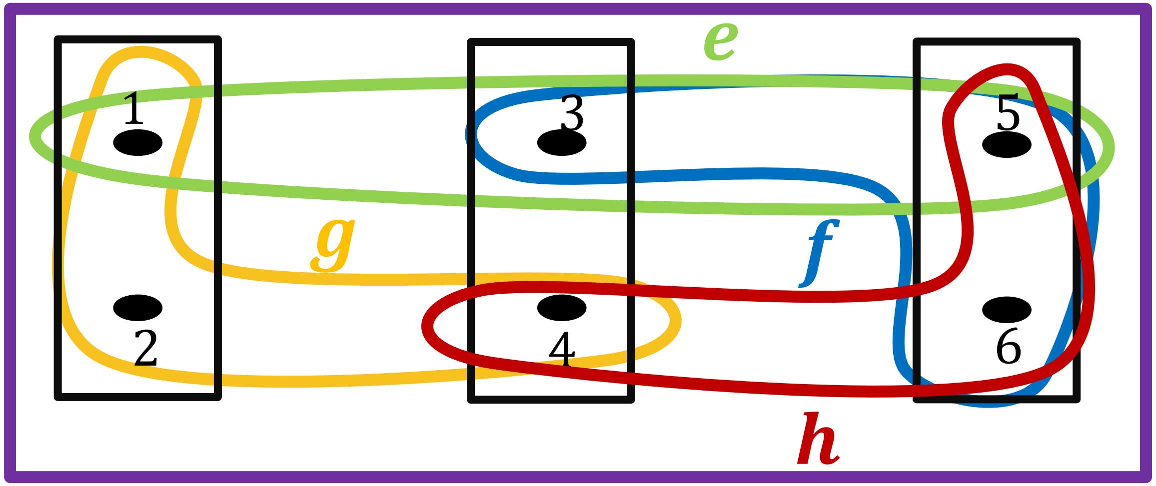
Ye

Example of cycle

Example of cycle

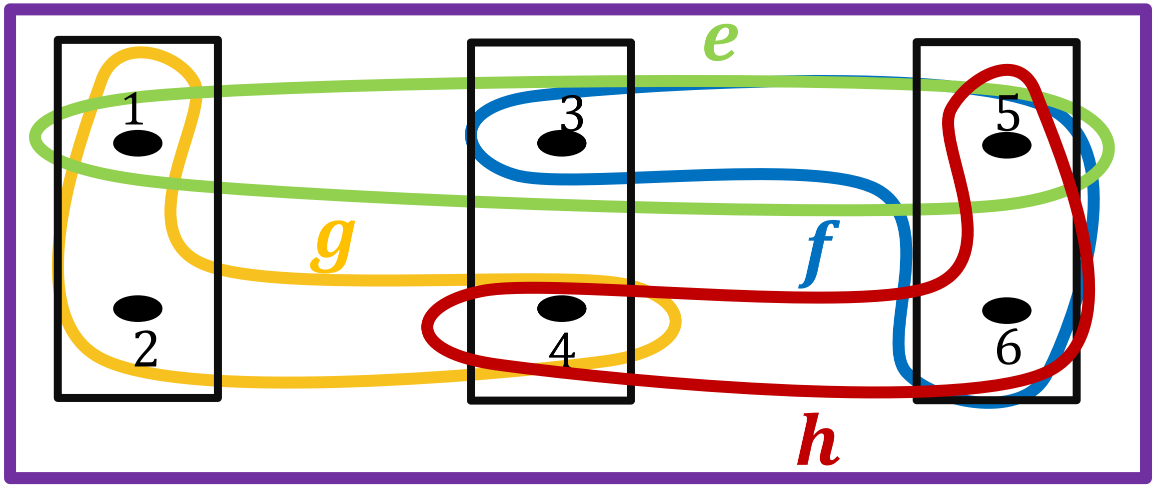


Example of cycle



$C_1 = 5, e, 3, f$

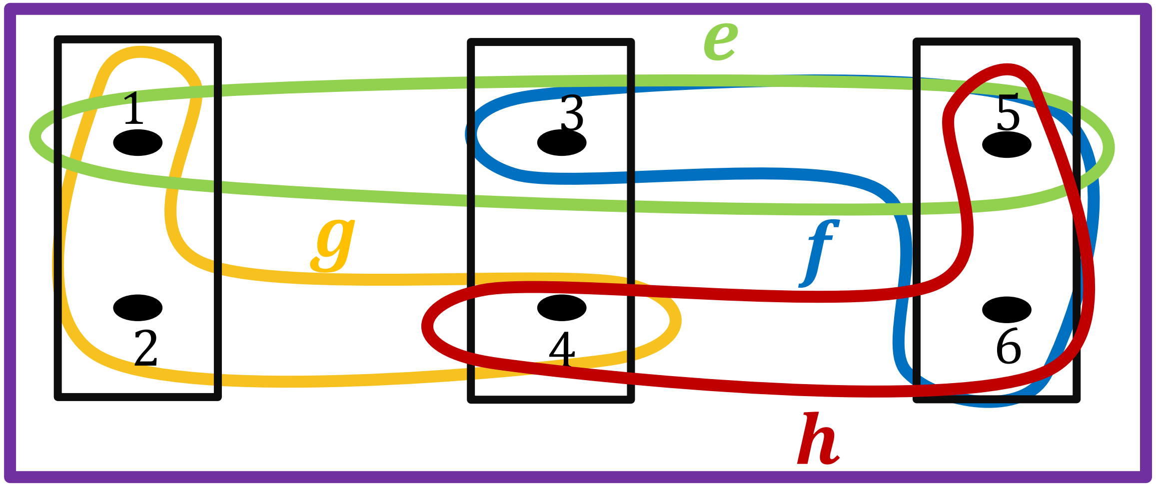
Example of cycle



$C_1 = 5, e, 3, f$

A cycle of length 2

Example of cycle

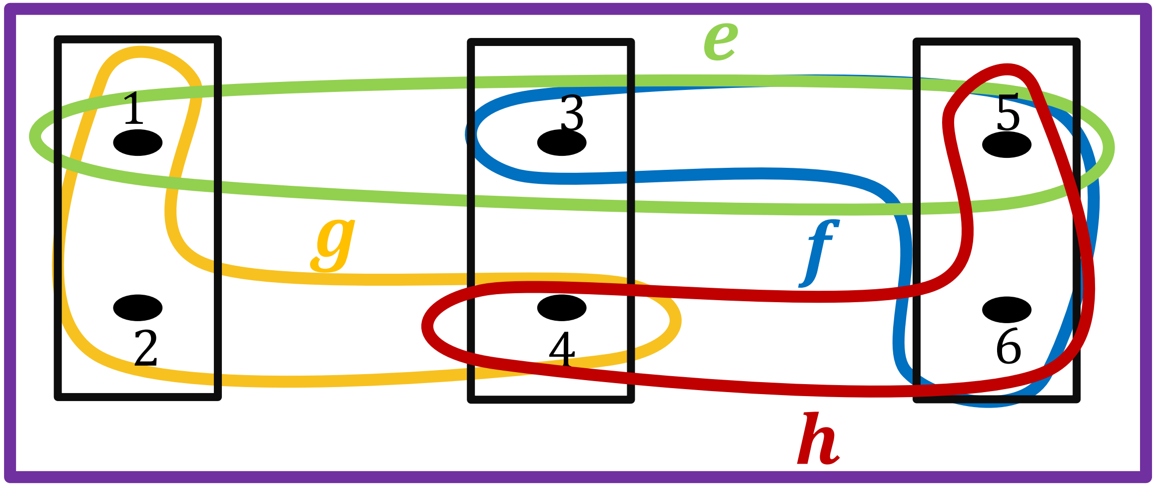


$C_1 = 5, e, 3, f$

A cycle of length 2

$C_2 = 4, h, 6, f, 3, e, 1, g$

Example of cycle



$C_1 = 5, e, 3, f$ → A cycle of length 2

$C_2 = 4, h, 6, f, 3, e, 1, g$ → A cycle of length 4

k-Zero-divisor hypergraphs of a commutative ring R

Chelvam et. al.

$\boldsymbol{k}$-Zero-divisor hypergraphs of a commutative ring $\boldsymbol{R}$

- $V = Z(R, k)$, set of all k-Zero-Divisors

Chelvam et. al.

$\boldsymbol{k}$-Zero-divisor hypergraphs of a commutative ring $\boldsymbol{R}$

- $V = Z(R,k)$, set of all k-Zero-Divisors
- $E = \{a_1, a_2, a_3, \dots, a_k\} \in \mathcal{E}$

- $a_1 a_2 a_3 \cdots a_k = 0$
- the products of elements of any $k-1$ subsets of $\{a_1, a_2, a_3, \dots, a_k\}$ are nonzero

Chelvam et. al.

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- We see that k-Zero-Divisor Hypergraphs is k-uniform hypergraph

Chelvam et. al.

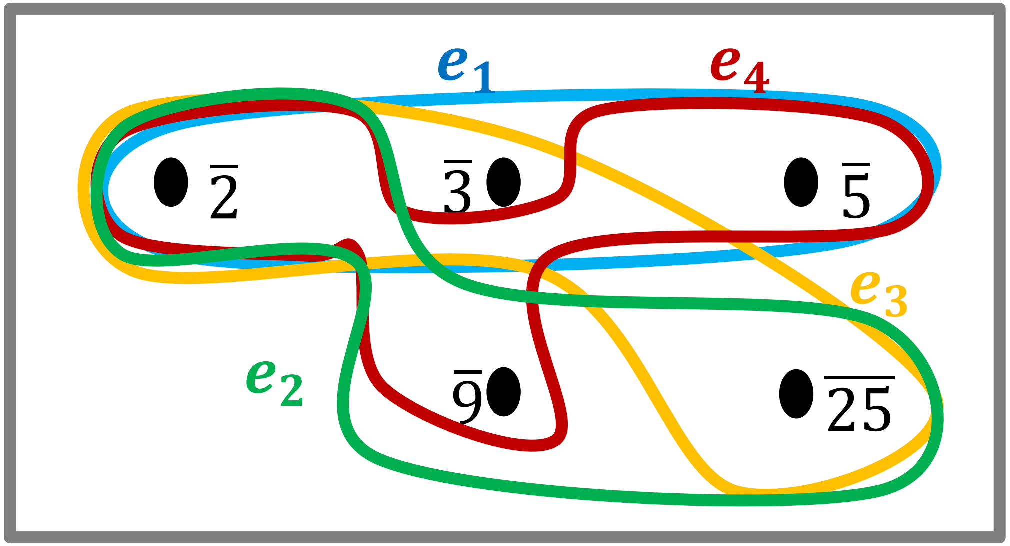
Example of $\mathbf{3}$-zero-divisor hypergraphs of $\mathbb{Z}_{30}$

Example of $\mathbf{3}$-zero-divisor hypergraphs of $\mathbb{Z}_{30}$

$$\boxed{Z(\mathbb{Z}_{30},3)=\{\overline{2},\overline{3},\overline{4},\overline{5},\overline{8},\overline{9},\overline{14},\overline{16},\overline{21},\overline{22},\overline{25},\overline{26},\overline{27},\overline{28}\}}$$

Example of $\mathbf{3}$-zero-divisor hypergraphs of $\mathbb{Z}_{30}$

$$Z(\mathbb{Z}_{30},3)=\{\bar{2},\bar{3},\bar{4},\bar{5},\bar{8},\bar{9},\overline{14},\overline{16},\overline{21},\overline{22},\overline{25},\overline{26},\overline{27},\overline{28}\}$$



$e_1=\{\bar{2},\bar{3},\bar{5}\}$

$e_2=\{\bar{2},\bar{9},\overline{25}\}$

$e_3=\{\bar{2},\bar{3},\overline{25}\}$

$e_4=\{\bar{2},\bar{9},\bar{5}\}$

Complete k-zero-divisor hypergraph

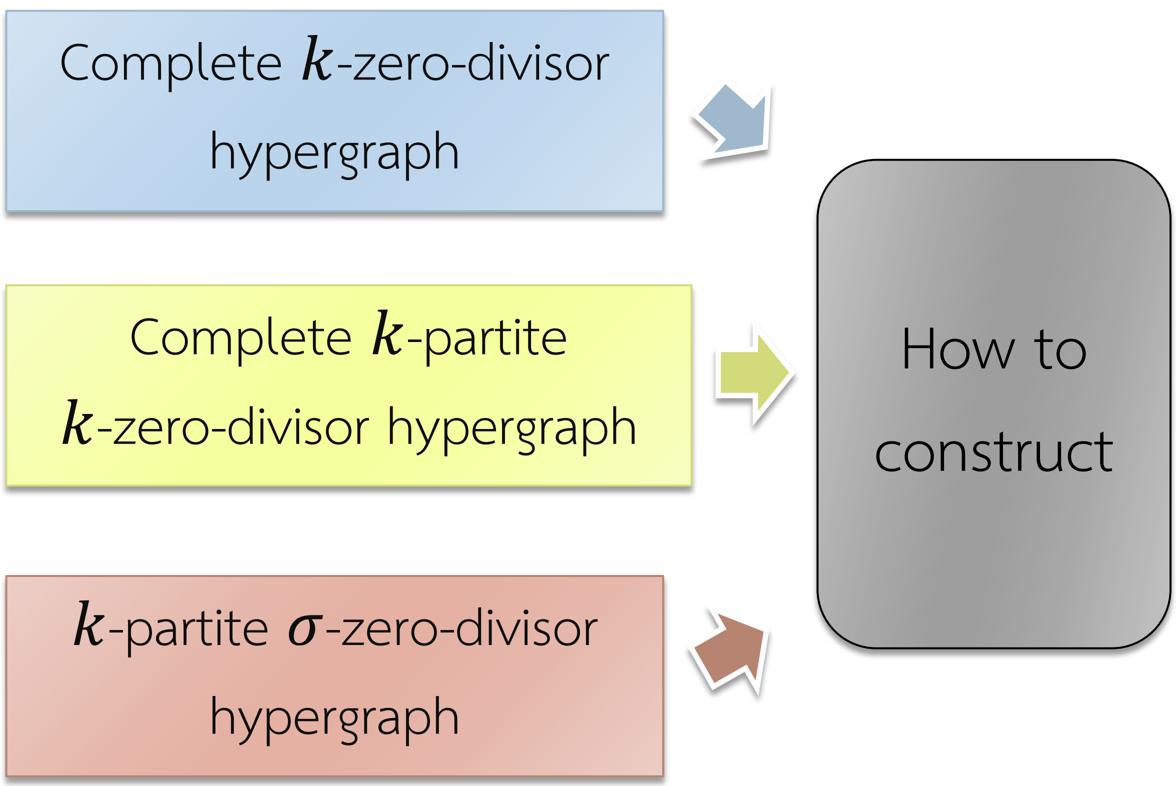
Complete k-zero-divisor hypergraph

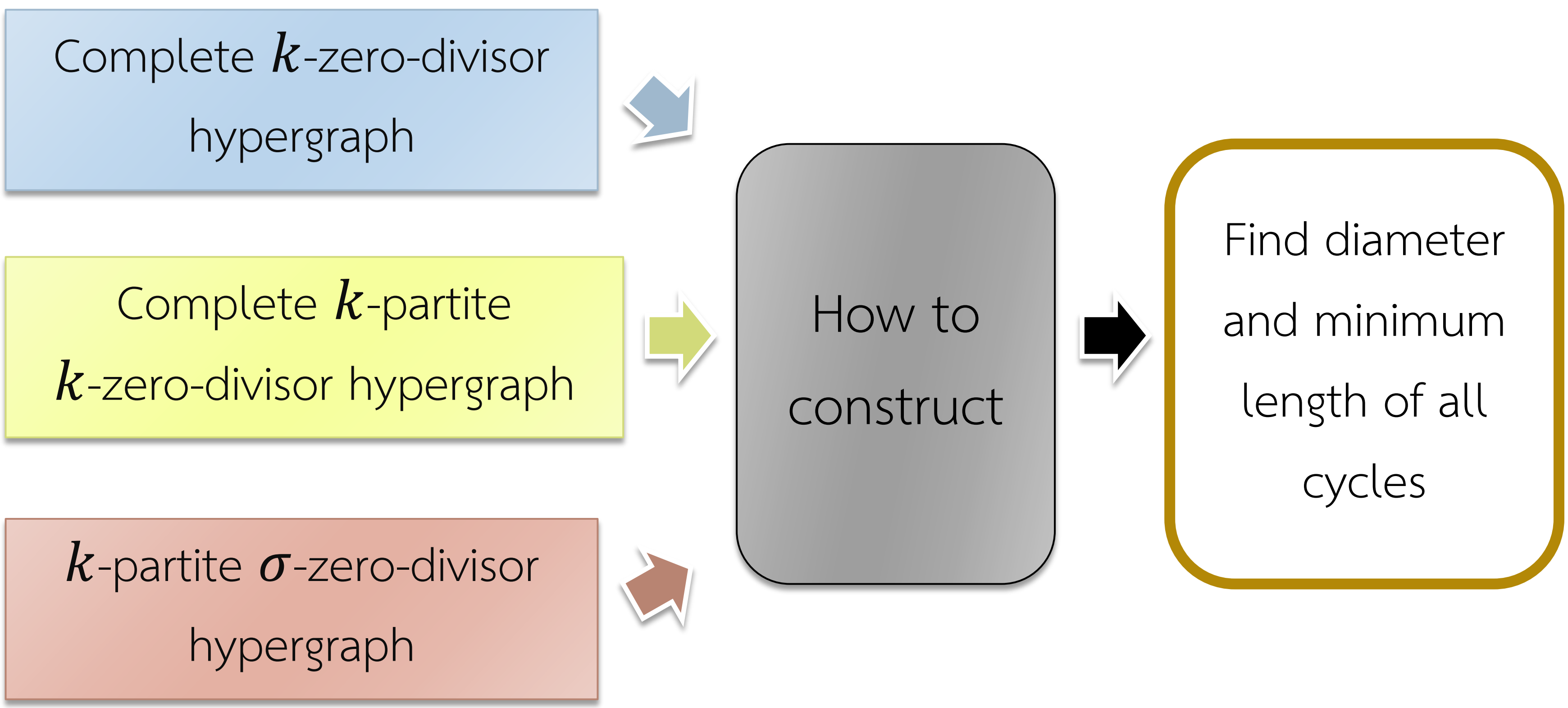
Complete k-partite k-zero-divisor hypergraph

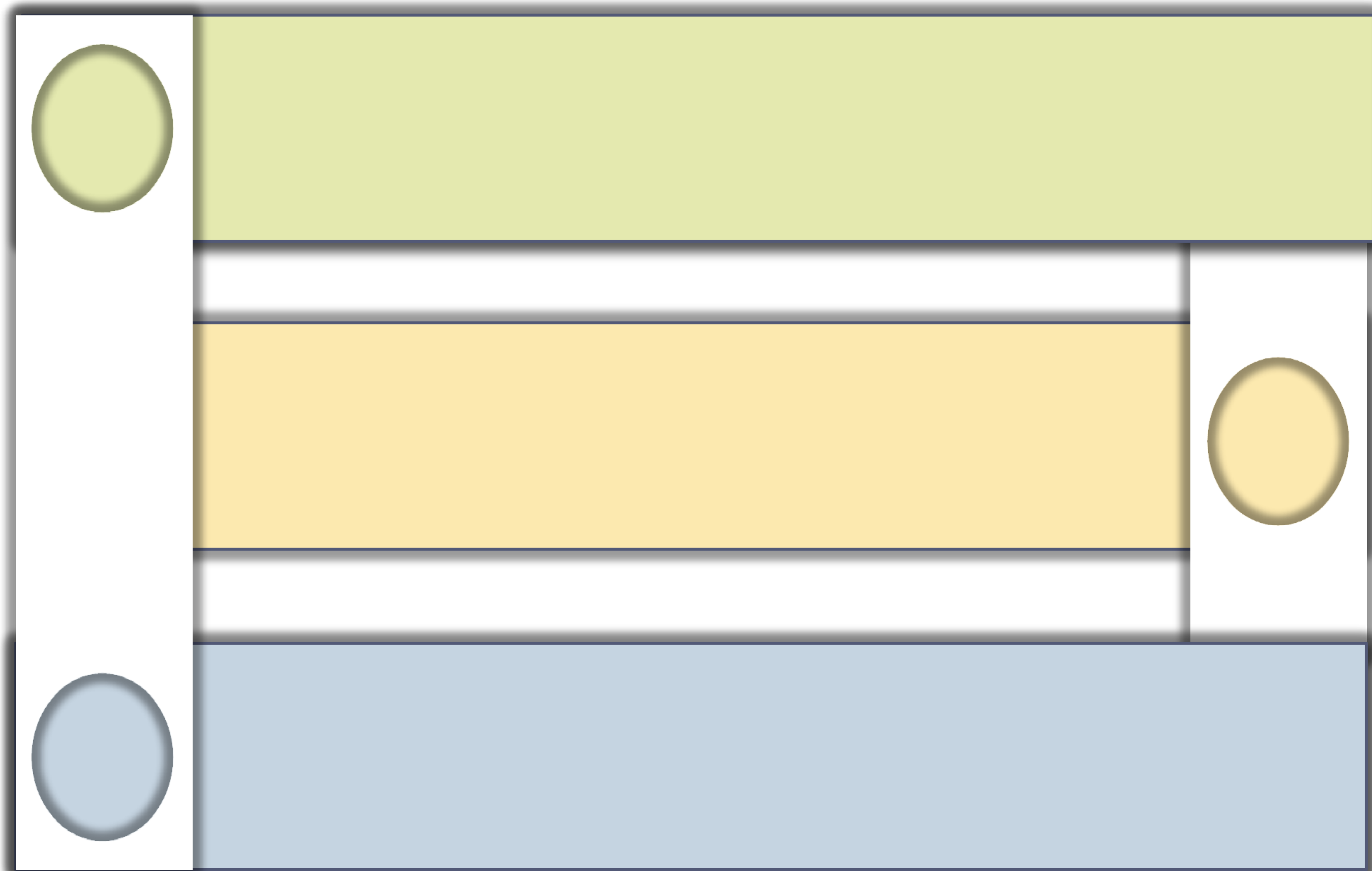
Complete k-zero-divisor hypergraph

Complete k-partite k-zero-divisor hypergraph

k-partite σ-zero-divisor hypergraph


Complete k-zero-divisor hypergraph
Complete k-partite k-zero-divisor hypergraph
k-partite σ-zero-divisor hypergraph
How to construct


Complete k-zero-divisor hypergraph
Complete k-partite k-zero-divisor hypergraph
k-partite σ-zero-divisor hypergraph
How to construct
Find diameter and minimum length of all cycles



Ring R

- Principal ideal domain (PID)
- There exist at least k prime elements $p_1, p_2, p_3, \dots, p_k$

Ring R

- Principal ideal domain (PID)
- There exist at least k prime elements $p_1, p_2, p_3, \dots, p_k$

- Finiteness of a ring R/I

Commutative Ring R/I

Ring R

- Principal ideal domain (PID)
- There exist at least k prime elements $p_1, p_2, p_3, \dots, p_k$

- Finiteness of a ring $R/_I$

Example: $\mathbb{Z}_n \cong \mathbb{Z}/_{n\mathbb{Z}}$

Commutative Ring $R/_I$

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Commutative Ring $^{R}/_{I}$

- Finiteness of a ring $^{R}/_{I}$

Example: $\mathbb{Z}_n \cong {}^{\mathbb{Z}}/_{n\mathbb{Z}}$

Objective

- Find an appropriate ideal so that constructed k-zero-divisor hypergraph has the desired properties

Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: $R/_{Rp^k}$

Appropriate ideal: Rp^k

Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: ${}^{R}/_{Rp^k}$

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Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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Conditions: $\left| {}^{Rp}/_{Rp^k} - {}^{Rp^2}/_{Rp^k} \right| \geq k$

Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: $R/_{Rp^k}$

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⬇

Conditions: $\left|{}^{Rp}/_{Rp^k} - {}^{Rp^2}/_{Rp^k}\right| \geq k$

⬇

Vertex set: $\mathrm{Z}\left({}^{R}/_{Rp^k}, k\right) = {}^{Rp}/_{Rp^k} - {}^{Rp^2}/_{Rp^k}$

Complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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Complete $\boldsymbol{k}$-zero-divisor hypergraph

Example of complete $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Example of complete $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{27} \cong \mathbb{Z}/_{27\mathbb{Z}} \cong \mathbb{Z}/_{3^3\mathbb{Z}}$

Example of complete $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

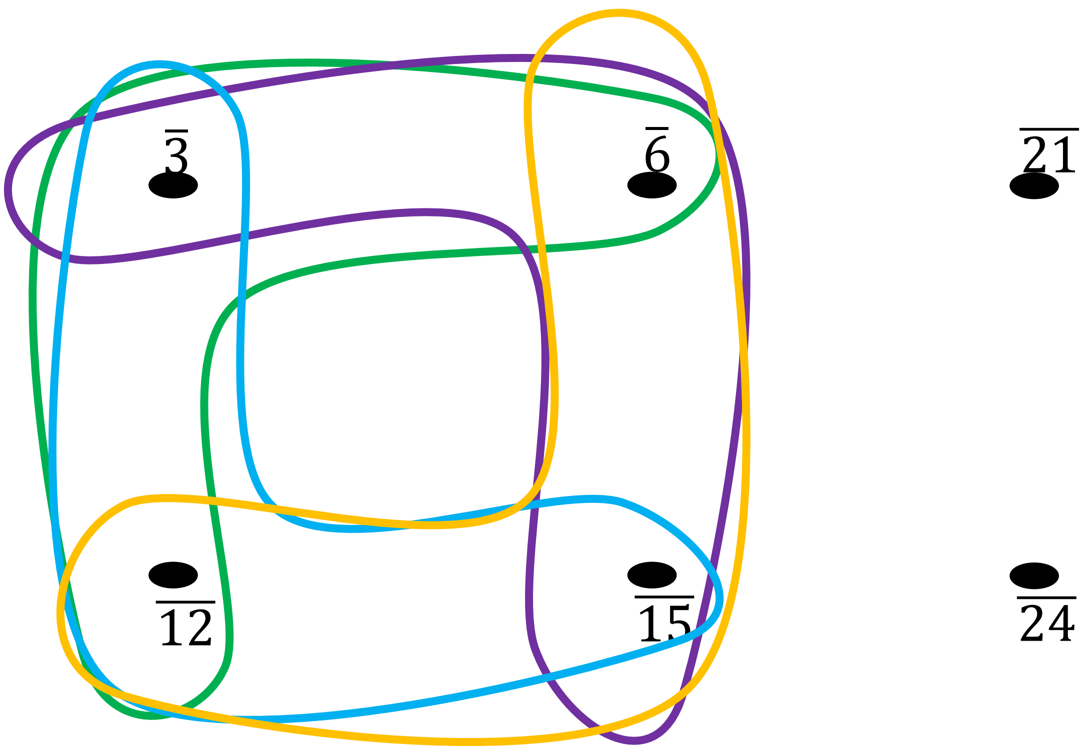
Consider $\mathbb{Z}_{27} \cong \mathbb{Z}/_{27\mathbb{Z}} \cong \mathbb{Z}/_{3^3\mathbb{Z}}$

A vertex set $Z(\mathbb{Z}_{27}, 3) = \{\overline{3}, \overline{6}, \overline{12}, \overline{15}, \overline{21}, \overline{24}\}$

Example of complete $\boldsymbol{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{27} \cong \mathbb{Z}/_{27\mathbb{Z}} \cong \mathbb{Z}/_{3^3\mathbb{Z}}$

A vertex set $Z(\mathbb{Z}_{27}, 3) = \{\overline{3}, \overline{6}, \overline{12}, \overline{15}, \overline{21}, \overline{24}\}$



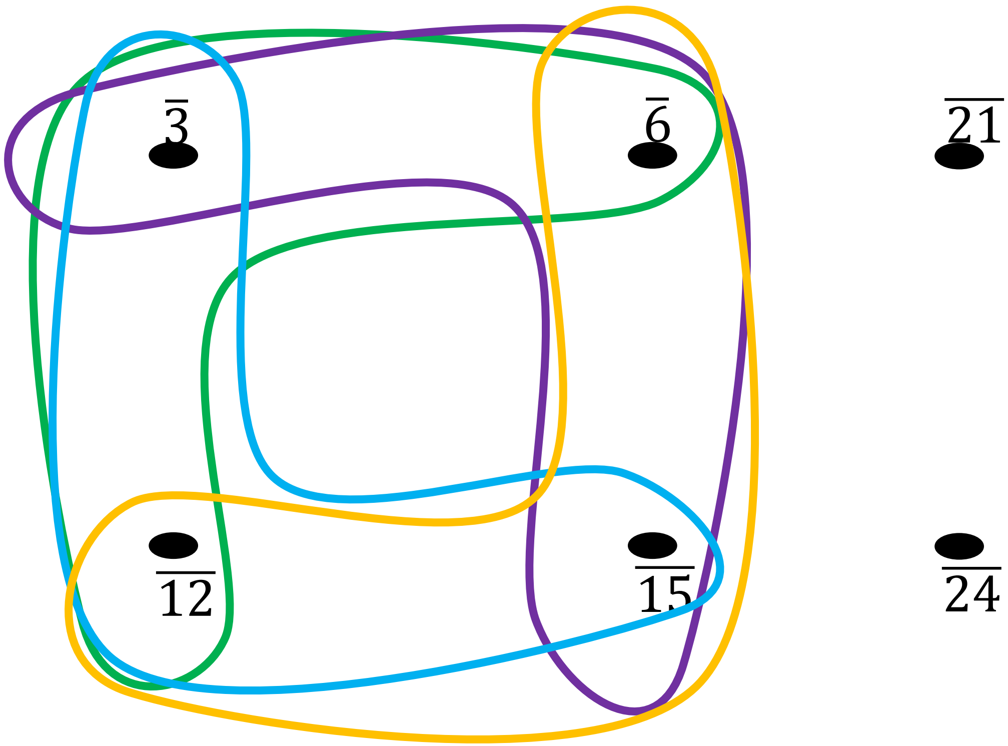
Diameter of complete $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Diameter of complete k-zero-divisor hypergraph of ring R

- Diameter is 1 same as a complete graph

Diameter of complete k-zero-divisor hypergraph of ring R

➢ Diameter is 1 same as a complete graph



The minimum length of all cycles

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- 0 if $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| = k$

The minimum length of all cycles

- 0 if $\left| Z\left({}^{R}/_{Rp^k}, k \right) \right| = k$

Only one edge

The minimum length of all cycles

- 0 if $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| = k$

Only one edge

- 2 if $k \geq 3$ and $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| \geq k + 1$

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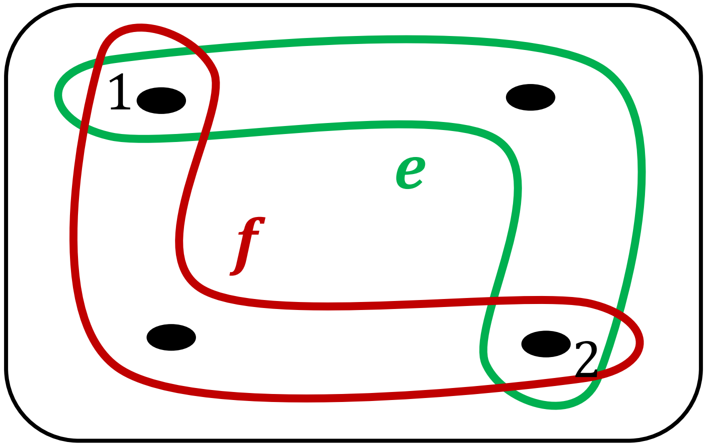

$c = 1, e, 2, f$

The minimum length of all cycles

- 0 if $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| = k$

Only one edge

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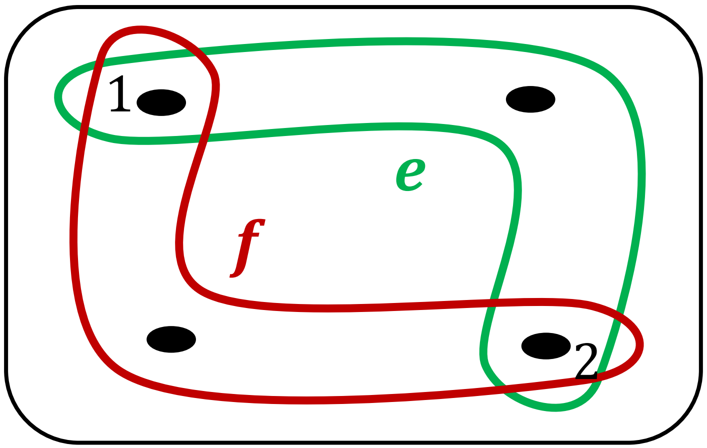


$c = 1, e, 2, f$

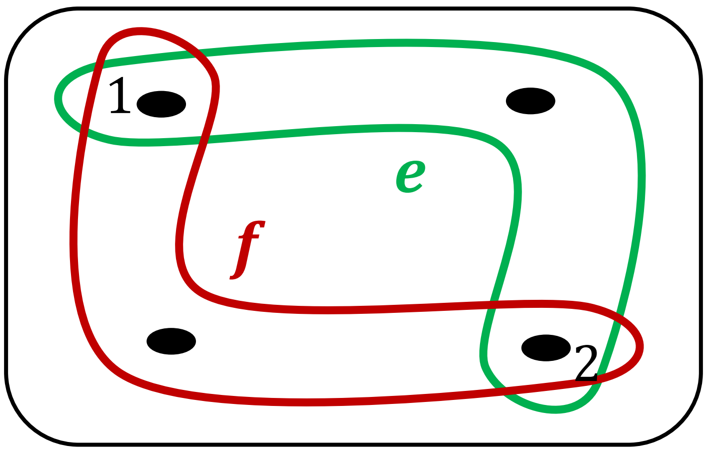
- 3 if $k = 2$ and $\left|Z\left({}^{R}/_{Rp^2}, 2\right)\right| \geq 3$

The minimum length of all cycles

- 0 if $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| = k$

Only one edge

- 2 if $k \geq 3$ and $\left|Z\left({}^{R}/_{Rp^k}, k\right)\right| \geq k + 1$



$c = 1, e, 2, f$

- 3 if $k = 2$ and $\left|Z\left({}^{R}/_{Rp^2}, 2\right)\right| \geq 3$

Same idea as complete graph

Conclusion table

Conclusion table

Hypergraph	Appropriate Ideal	Vertex Set	Diameter	Minimum length of all cycles
Complete k-zero-divisor hypergraph	Rp^k	$Z\left({}^{R}/_{Rp^k}, k\right) = {}^{Rp}/_{Rp^k} - {}^{Rp^2}/_{Rp^k}$	1	$0, 2,$ or 3

Complete $\boldsymbol{k}$-partite $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Complete $\boldsymbol{k}$-partite $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: ${}^{R}\!/_{Rp_1p_2p_3\cdots p_k}$

Appropriate ideal: $Rp_1p_2p_3\cdots p_k$

Condition: R has at least k prime elements

Complete $\boxed{k}$-partite $\boxed{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: $R/_{Rp_1p_2p_3\cdots p_k}$

Appropriate ideal: $R\boxed{p_1p_2p_3\cdots p_k}$

Condition: R has at least k prime elements

Complete $\boxed{k}$-partite $\boxed{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Commutative ring: $R/_{Rp_1p_2p_3\cdots p_k}$

Appropriate ideal: $R\boxed{p_1p_2p_3\cdots p_k}$

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Let $\gamma = p_1p_2p_3\cdots p_k$

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Appropriate ideal: $R\boxed{p_1p_2p_3\cdots p_k}$

Condition: R has at least k prime elements

Let $\gamma = p_1p_2p_3\cdots p_k$

Each partite set V_i: ${}^{Rp_i}/_{R\gamma} - \bigcup_{j\neq i} {}^{Rp_j}/_{R\gamma}$

$$\bigcup_{i=1}^{k} V_i = Z({}^{R}/_{R\gamma}, k)$$

Complete $\boxed{k}$-partite $\boxed{k}$-zero-divisor hypergraph of ring R

Commutative ring: ${}^{R}/_{Rp_1p_2p_3\cdots p_k}$

Appropriate ideal: $R\boxed{p_1p_2p_3\cdots p_k}$

Condition: R has at least k prime elements

$\Downarrow$

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$\Downarrow$

Complete $\boldsymbol{k}$-partite $\boldsymbol{k}$-zero-divisor hypergraph

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{\mathbf{30}} \cong {}^{\mathbb{Z}}/_{\mathbf{30}\mathbb{Z}} \cong {}^{\mathbb{Z}}/_{(\mathbf{2}\cdot\mathbf{3}\cdot\mathbf{5})\mathbb{Z}}$

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{\mathbf{30}} \cong {}^{\mathbb{Z}}/_{30\mathbb{Z}} \cong {}^{\mathbb{Z}}/_{(2\cdot3\cdot5)\mathbb{Z}}$

A vertex set $Z(\mathbb{Z}_{30}, 3) = \{\overline{2}, \overline{3}, \overline{4}, \overline{5}, \overline{8}, \overline{9}, \overline{14}, \overline{16}, \overline{21}, \overline{22}, \overline{25}, \overline{26}, \overline{27}, \overline{28}\}$

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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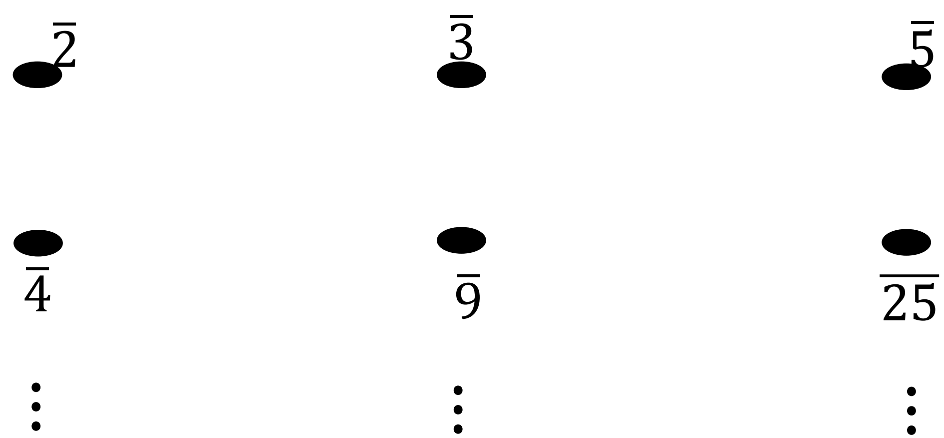

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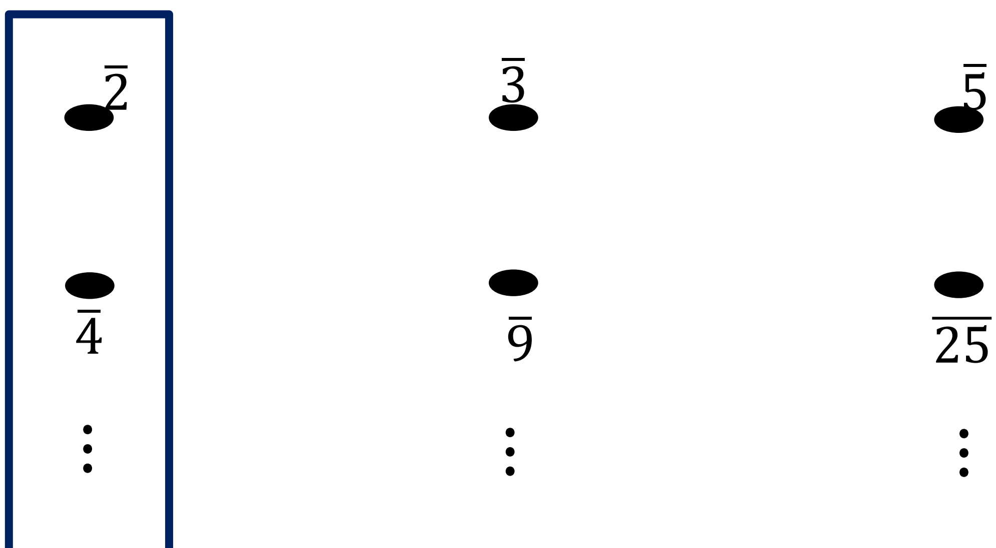
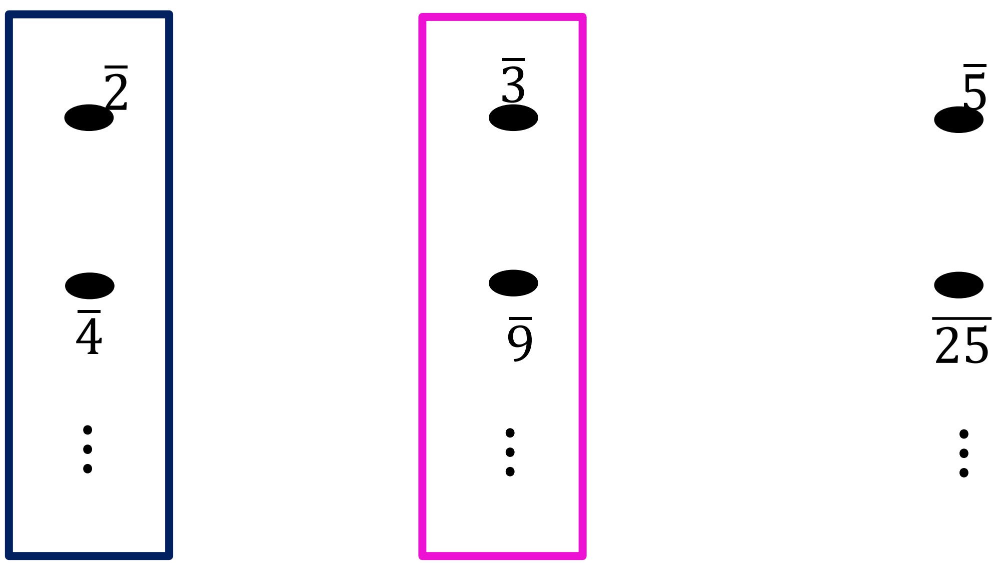


$V_1 = \{\overline{2}, \overline{4}, \overline{8}, \overline{14}, \overline{16}, \overline{22}, \overline{26}, \overline{28}\}$

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{30} \cong \mathbb{Z}/_{30\mathbb{Z}} \cong \mathbb{Z}/_{(2\cdot3\cdot5)\mathbb{Z}}$

A vertex set $Z(\mathbb{Z}_{30},3) = \{\bar{2},\bar{3},\bar{4},\bar{5},\bar{8},\bar{9},\overline{14},\overline{16},\overline{21},\overline{22},\overline{25},\overline{26},\overline{27},\overline{28}\}$



$V_1 = \{\bar{2},\bar{4},\bar{8},\overline{14},\overline{16},\overline{22},\overline{26},\overline{28}\}$

$V_2 = \{\bar{3},\bar{9},\overline{21},\overline{27}\}$

Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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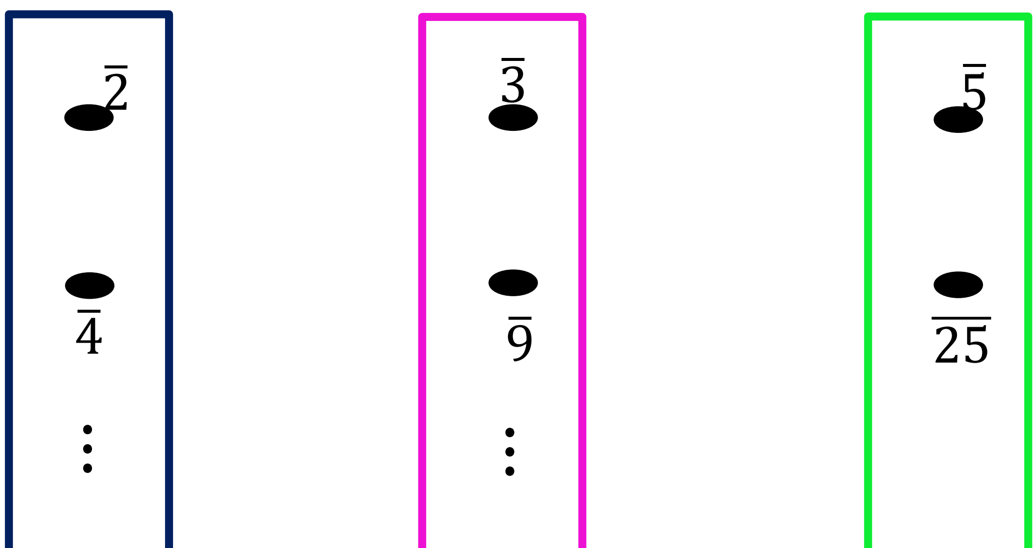

$V_3 = \{\overline{5}, \overline{25}\}$

$V_1 = \{\overline{2}, \overline{4}, \overline{8}, \overline{14}, \overline{16}, \overline{22}, \overline{26}, \overline{28}\}$

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Example of complete $\mathbf{3}$-partite $\mathbf{3}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{30} \cong {}^{\mathbb{Z}}/_{30\mathbb{Z}} \cong {}^{\mathbb{Z}}/_{(2\cdot3\cdot5)\mathbb{Z}}$

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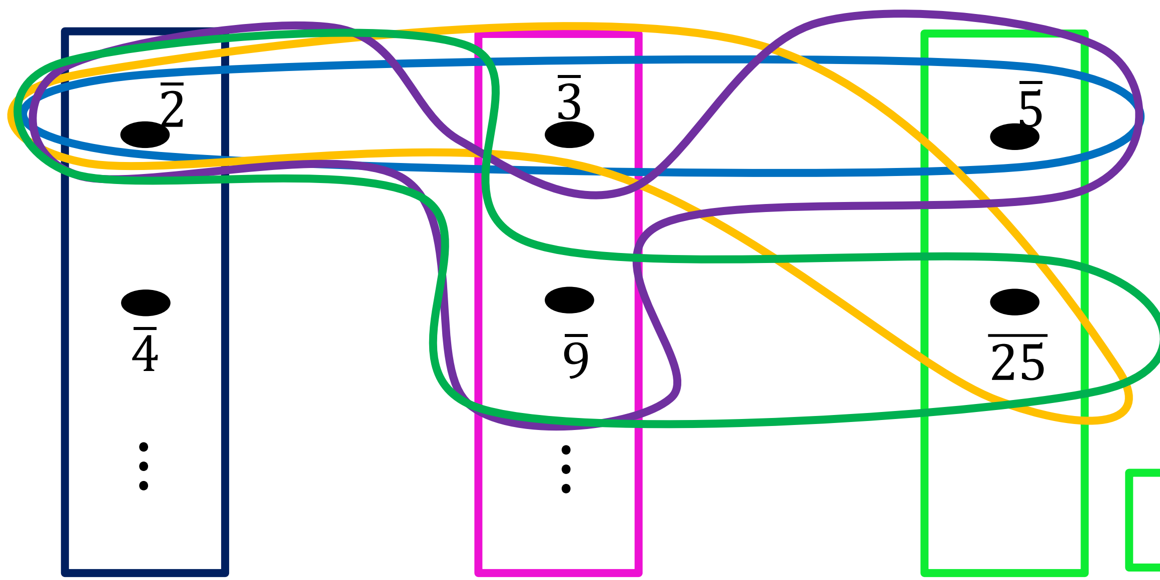


$V_3 = \{\bar{5}, \overline{25}\}$

$V_1 = \{\bar{2}, \bar{4}, \bar{8}, \overline{14}, \overline{16}, \overline{22}, \overline{26}, \overline{28}\}$

$V_2 = \{\bar{3}, \bar{9}, \overline{21}, \overline{27}\}$

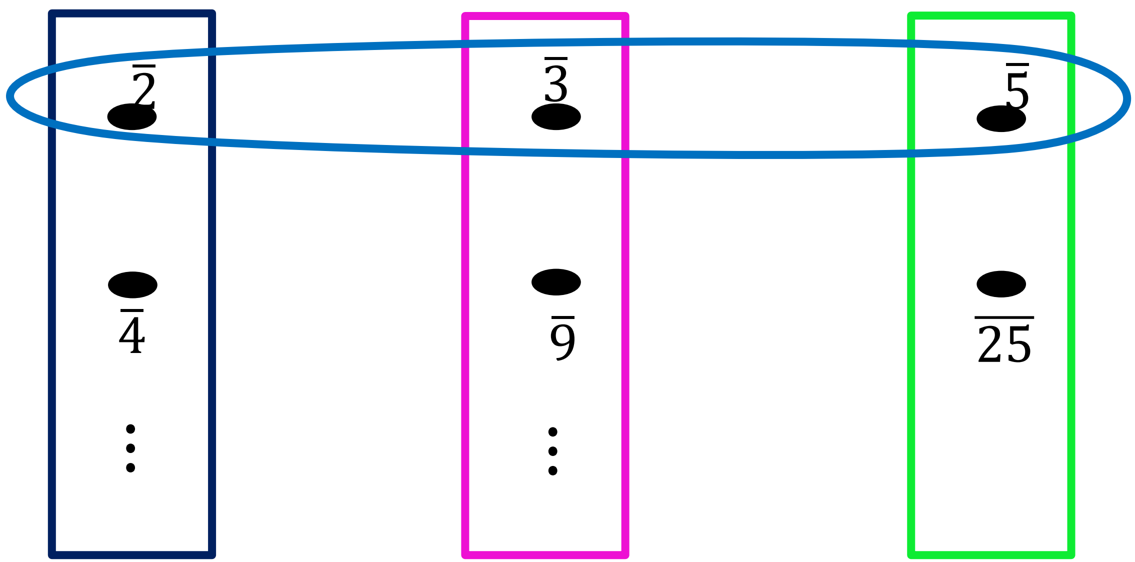
Diameter of complete $\boldsymbol{k}$-partite $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Diameter of complete k-partite k-zero-divisor hypergraph of ring R

➢ Diameter is $\mathbf{2}$

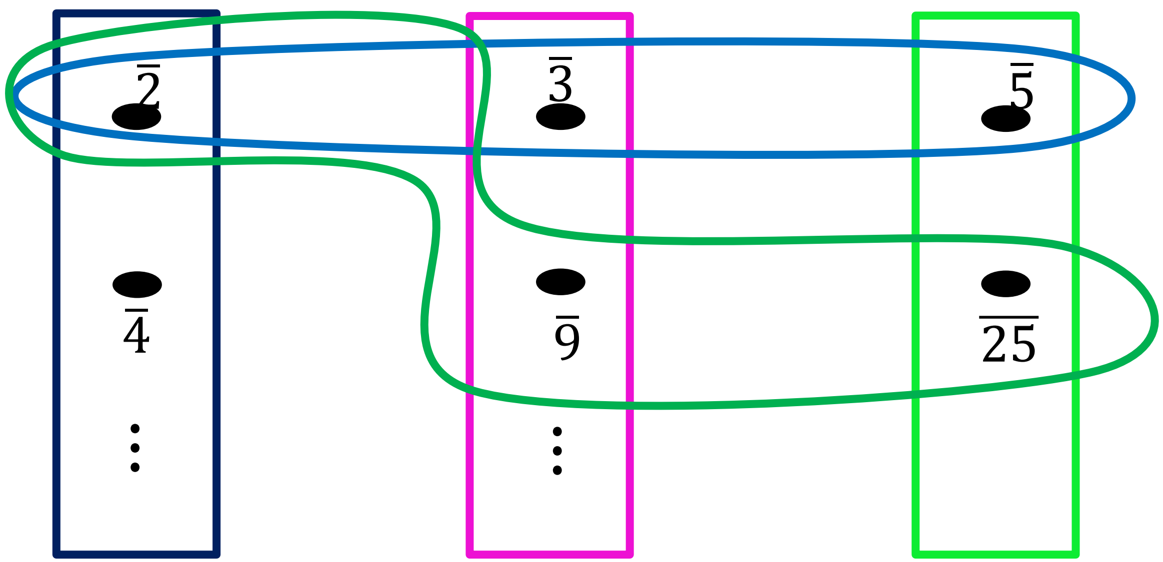
Diameter of complete $\boldsymbol{k}$-partite $\boldsymbol{k}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

> Diameter is 2



Diameter of complete k-partite k-zero-divisor hypergraph of ring R

- Diameter is **2**



The minimum length of all cycles

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- 0 if $\left|Z\left({}^{R}/_{R\gamma}, k\right)\right| = k$

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Only one edge

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- 2 if $k \geq 3$ and $\left|Z\left({}^{R}/_{R\gamma}, k\right)\right| \geq k + 1$

The minimum length of all cycles

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Only one edge

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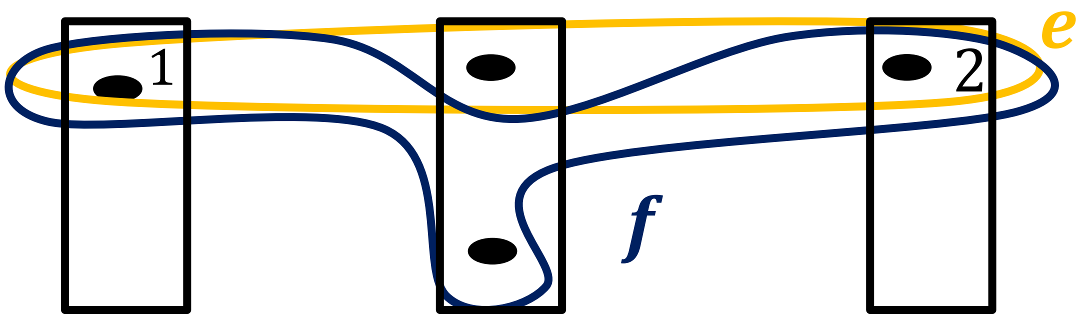

$$c = 1, e, 2, f$$

The minimum length of all cycles

The minimum length of all cycles

- 0 if $k = 2$ and $\left|Z\left({}^{R}/_{R\gamma}, 2\right)\right| \geq 3$ (one of partite sets has only one element)

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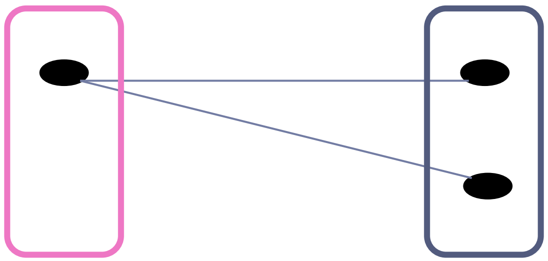

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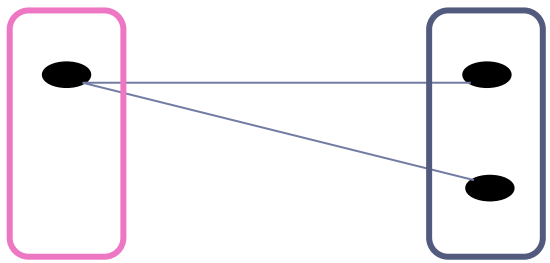

- 4 if $k = 2$ and $\left|Z\left({}^{R}/_{R\gamma}, 2\right)\right| \geq 3$ (each partite set has more than one element)

The minimum length of all cycles

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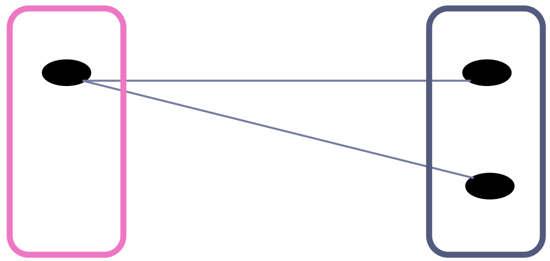


- 4 if $k = 2$ and $\left|Z\left({}^{R}/_{R\gamma}, 2\right)\right| \geq 3$ (each partite set has more than one element)

Same idea as complete bipartite graph

Conclusion table

Conclusion table

Hypergraph	Appropriate Ideal	Vertex Set $(\gamma = p_1p_2p_3\cdots p_k)$	Diameter	Minimum length of all cycles
Complete k-partite k-zero-divisor hypergraph	$Rp_1p_2p_3\cdots p_k$	$V_i = {}^{Rp_i}/_{R\gamma} - \bigcup_{j\neq i} {}^{Rp_j}/_{R\gamma}$ $\bigcup_{i=1}^{k} V_i = Z\left({}^{R}/_{R\gamma}, k\right)$	2	$0,2,$ or 4

$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

How to construct k-partite σ-zero-divisor hypergraph

$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

How to construct k-partite σ-zero-divisor hypergraph

Construct complete k-partite k-zero-divisor hypergraph

$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

How to construct k-partite σ-zero-divisor hypergraph

Construct complete k-partite k-zero-divisor hypergraph

Construct complete l-zero-divisor hypergraph

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

$\boldsymbol{3}$-partite $\boldsymbol{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

3-partite 4-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

$Rp_1^2p_2p_3$

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

$Rp_1^2p_2p_3$

Ring $\mathbb{Z}_{60} \cong \mathbb{Z}/_{(2^2\cdot 3\cdot 5)\mathbb{Z}}$

$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

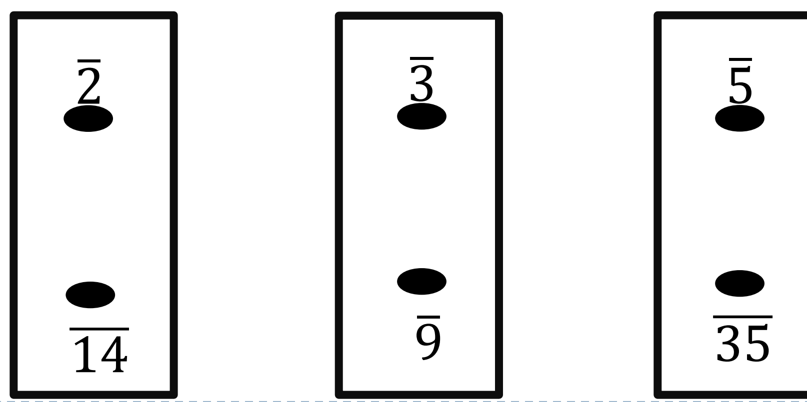
$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

$Rp_1^2p_2p_3$

Ring $\mathbb{Z}_{60} \cong \mathbb{Z}/_{(2^2\cdot 3\cdot 5)\mathbb{Z}}$

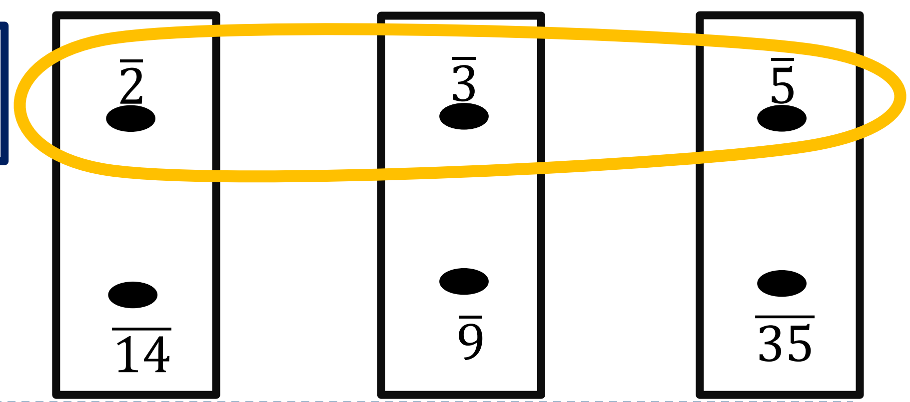


$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

Ring $\mathbb{Z}_{60} \cong \mathbb{Z}/_{(2^2\cdot3\cdot5)\mathbb{Z}}$



$\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

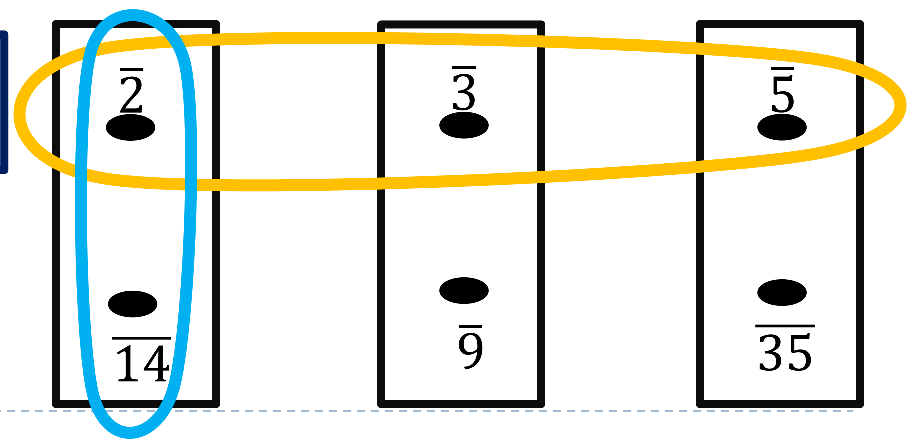
complete 3-partite 3-zero-divisor hypergraph

$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

Ring $\mathbb{Z}_{60} \cong \mathbb{Z}/_{(2^2\cdot 3\cdot 5)\mathbb{Z}}$



3-partite 4-zero-divisor hypergraph of ring $\boldsymbol{R}$

complete 3-partite 3-zero-divisor hypergraph

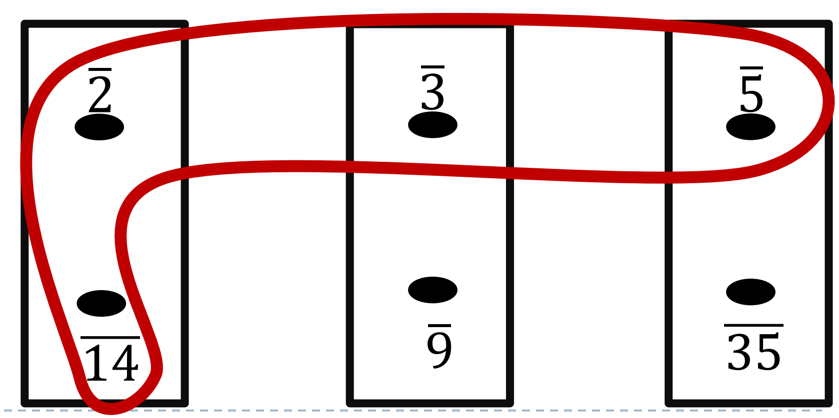
$Rp_1p_2p_3$

complete 2-zero-divisor hypergraph

Rp^2

$Rp_1^2p_2p_3$

Ring $\mathbb{Z}_{60} \cong \mathbb{Z}/_{(2^2\cdot 3\cdot 5)\mathbb{Z}}$



$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

Commutative ring: ${}^{R}\!/_{Rp_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}}$

Appropriate ideal: $Rp_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}$

Condition: R has at least k prime elements

$\boxed{\boldsymbol{k}}$-partite $\boxed{\boldsymbol{\sigma}}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma \geq k}$

$$\sigma = \sum_{m=1}^{k} \alpha_m$$

Commutative ring: ${}^{R}\big/_{Rp_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}}$

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Appropriate ideal: $R\boxed{p_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}}$

Condition: R has at least k prime elements

$\Downarrow$

Let $\pi = p_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}$

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Condition: R has at least k prime elements

Let $\pi = p_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}$

Each partite set V_i:

- ${}^{Rp_i}/_{R\pi} - \bigcup_{j\neq i} {}^{Rp_j}/_{R\pi}$ if $\alpha_i = 1$
- ${}^{Rp_i}/_{R\pi} - \left({}^{Rp_i^2}/_{R\pi} \cup \bigcup_{j\neq i} {}^{Rp_j}/_{R\pi}\right)$ if $\alpha_i \geq 2$

$$\bigcup_{i=1}^{k} V_i = Z\left({}^{R}/_{R\pi}, \sigma\right)$$

$\boxed{\boldsymbol{k}}$-partite $\boxed{\boldsymbol{\sigma}}$-zero-divisor hypergraph of ring $\boldsymbol{R}$ where $\boldsymbol{\sigma} \geq \boldsymbol{k}$

$$\sigma = \sum_{m=1}^{k} \alpha_m$$

Commutative ring: ${}^{R}/_{Rp_1^{\alpha_1}p_2^{\alpha_2}p_3^{\alpha_3}\cdots p_k^{\alpha_k}}$

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$\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph

Example of $\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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Consider $\mathbb{Z}_{\mathbf{60}} \cong \mathbb{Z}/_{60\mathbb{Z}} \cong \mathbb{Z}/_{(2^2\cdot 3\cdot 5)\mathbb{Z}}$

Example of $\mathbf{3}$-partite $\mathbf{4}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

Consider $\mathbb{Z}_{60} \cong {}^{\mathbb{Z}}/_{60\mathbb{Z}} \cong {}^{\mathbb{Z}}/_{(2^2 \cdot 3 \cdot 5)\mathbb{Z}}$

A vertex set

$Z(\mathbb{Z}_{60}, 4) = \{\overline{2}, \overline{3}, \overline{5}, \overline{9}, \overline{14}, \overline{21}, \overline{22}, \overline{25}, \overline{26}, \overline{27}, \overline{33}, \overline{34}, \overline{35}, \overline{38}, \overline{39}, \overline{46}, \overline{51}, \overline{55}, \overline{57}, \overline{58}\}$

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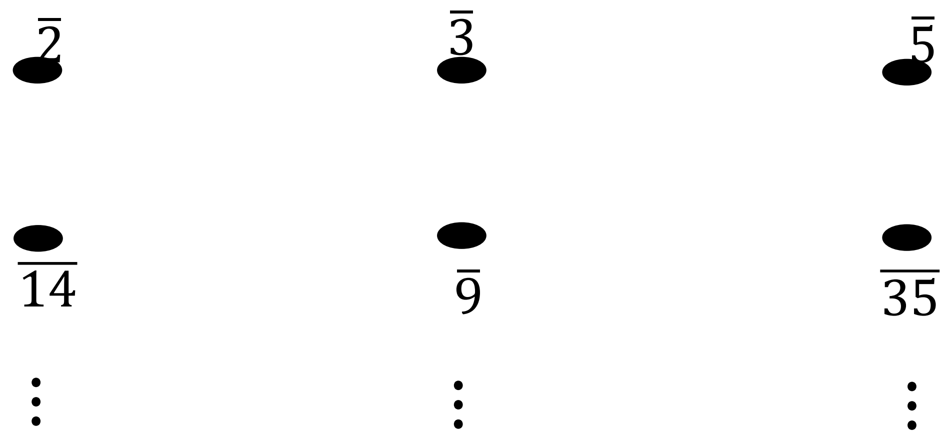

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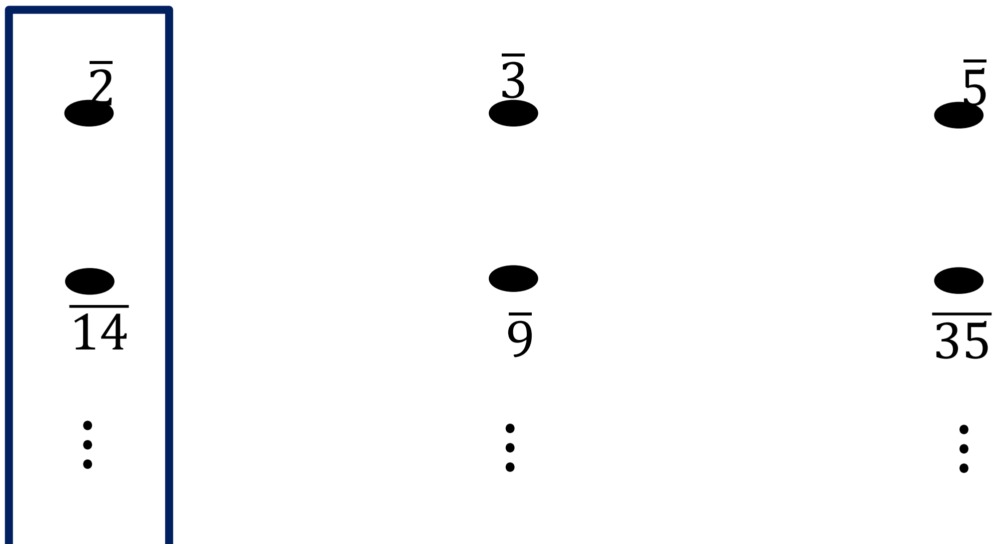

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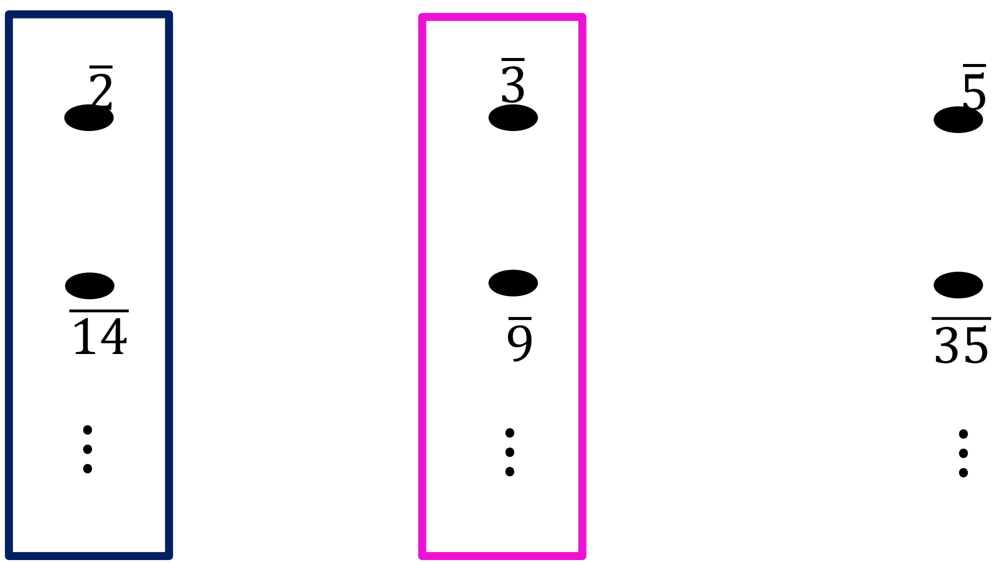

$$V_1 = \{\bar{2},\overline{14},\overline{22},\overline{26},\overline{34},\overline{38},\overline{46},\overline{58}\}$$

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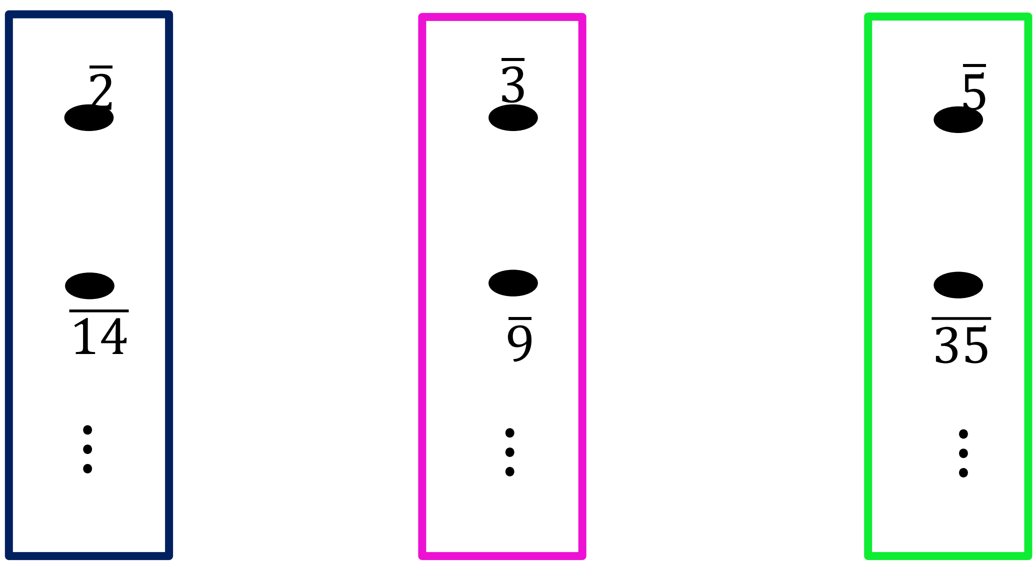

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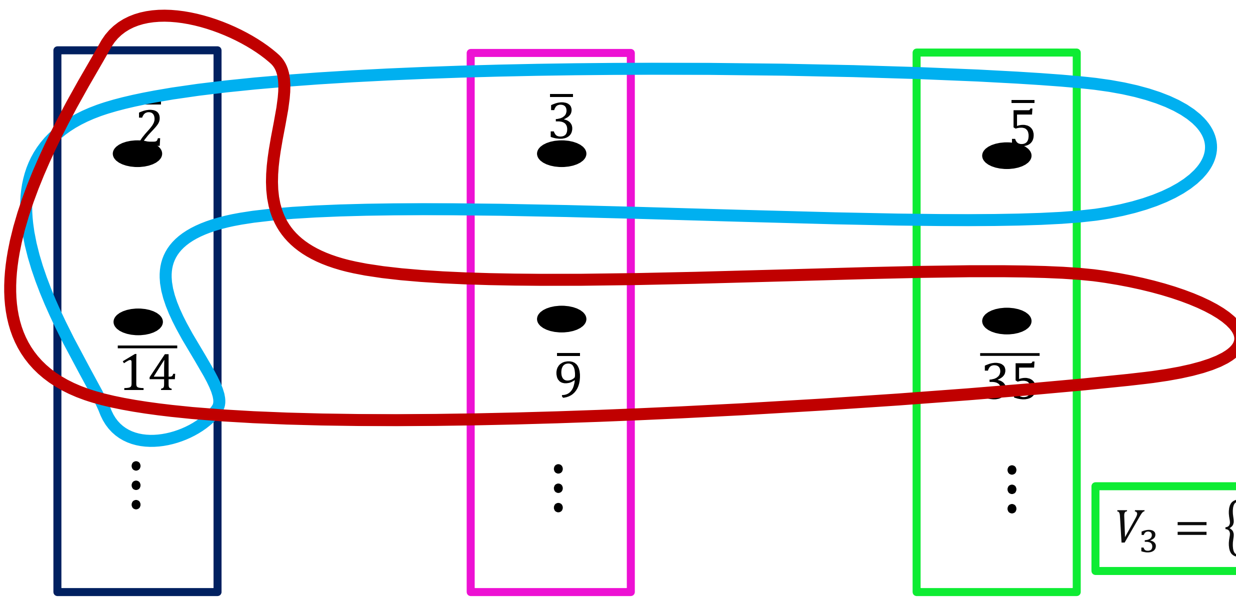

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Diameter of $\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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➢ Diameter is $\mathbf{2}$

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Diameter of $\boldsymbol{k}$-partite $\boldsymbol{\sigma}$-zero-divisor hypergraph of ring $\boldsymbol{R}$

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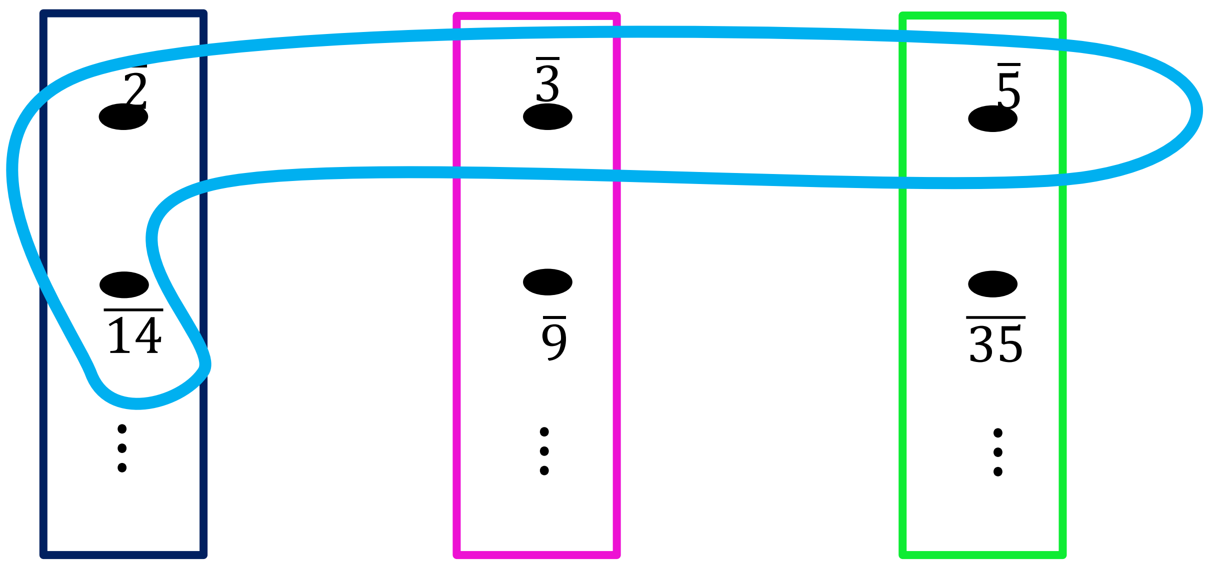
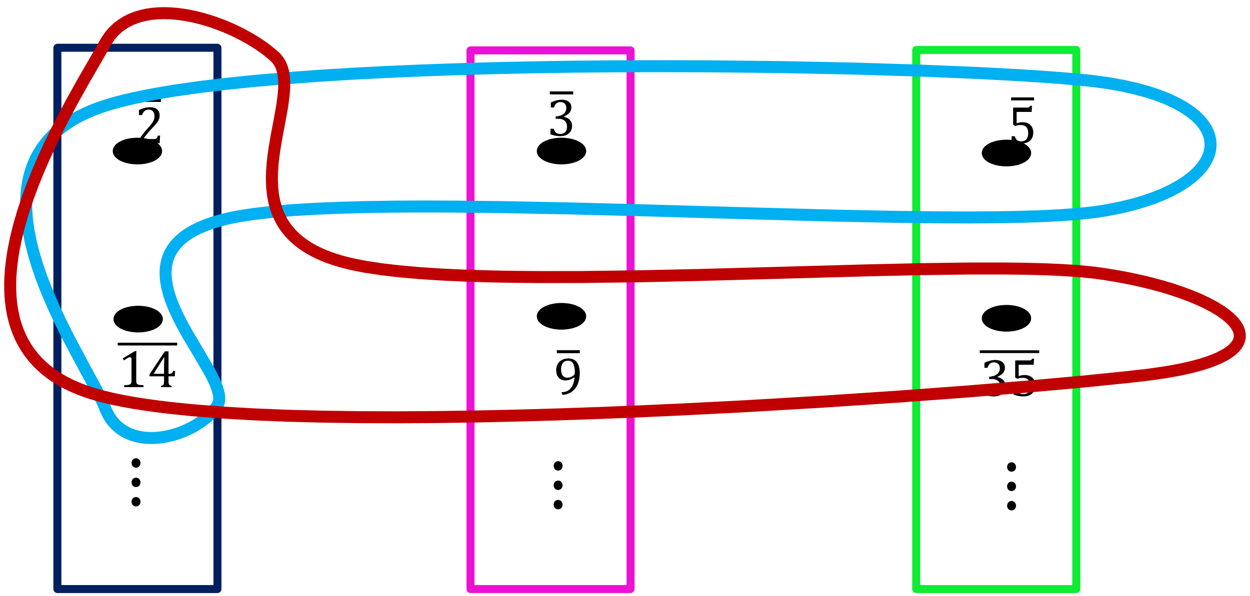


Diameter of k-partite σ-zero-divisor hypergraph of ring R

➤ Diameter is 2

$$\mathbb{Z}_{60} \cong \mathbb{Z}/(2^2 \cdot 3 \cdot 5)\mathbb{Z}$$



The minimum length of all cycles

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- 0 if $|Z({}^{R}/_{R\pi}, \sigma)| = \sigma$

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Only one edge

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Only one edge

- 2 if $k \geq 3$ and $|Z(R/_{R\pi}, \sigma)| \geq \sigma + 1$

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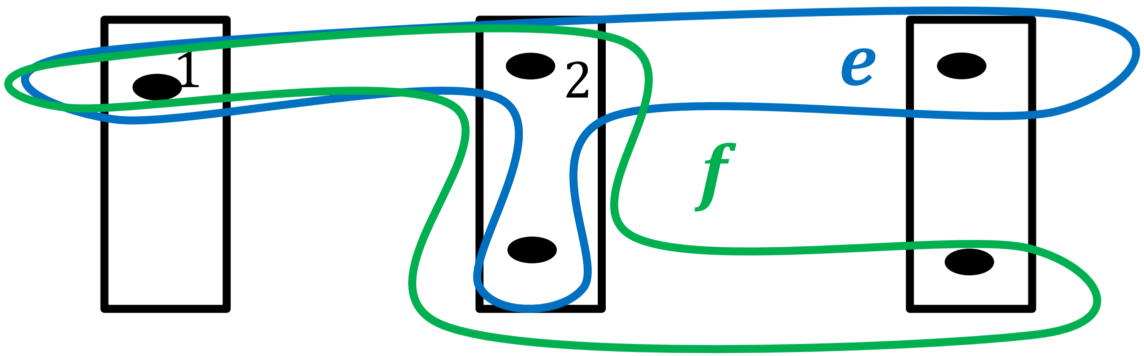

$$c = 1, e, 2, f$$

The minimum length of all cycles

The minimum length of all cycles

- 0 if $k = 2$ and $|Z(R/_{R\pi}, \alpha_1 + \alpha_2)| \geq \alpha_1 + \alpha_2 + 1$ and $|V_1| = 1$ and $\alpha_2 = 1$

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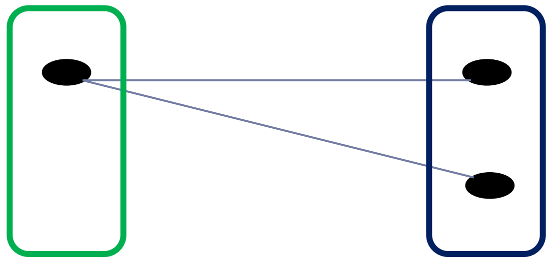

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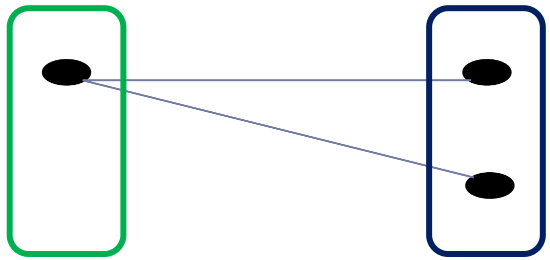

- 2 if $k = 2$ and $|Z({}^{R}/_{R\pi}, \alpha_1 + \alpha_2)| \geq \alpha_1 + \alpha_2 + 1$ and $|V_1| = 1$ and $\alpha_2 \geq 2$

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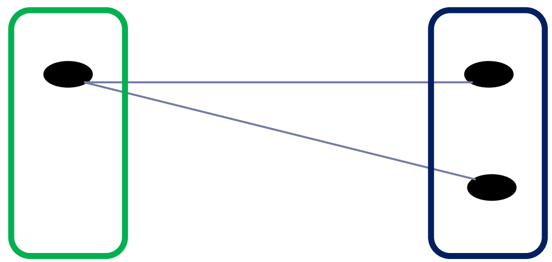

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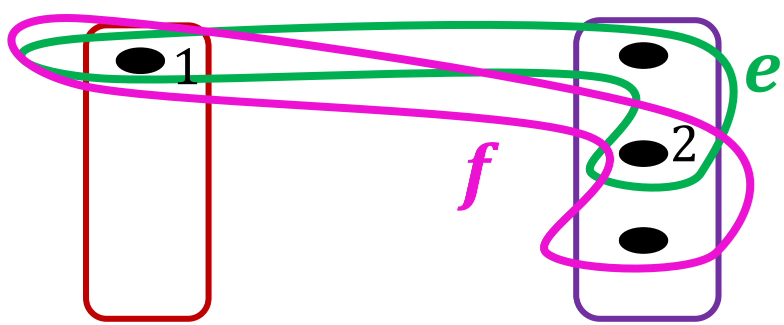

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The minimum length of all cycles

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- 2 if $k = 2$ and $|Z({}^{R}/_{R\pi}, \alpha_1 + \alpha_2)| \geq \alpha_1 + \alpha_2 + 1$ and $|V_i| \geq 2$ for all $1 \leq i \leq 2$ and there exists $1 \leq i \leq 2$ such that $\alpha_i \geq 2$

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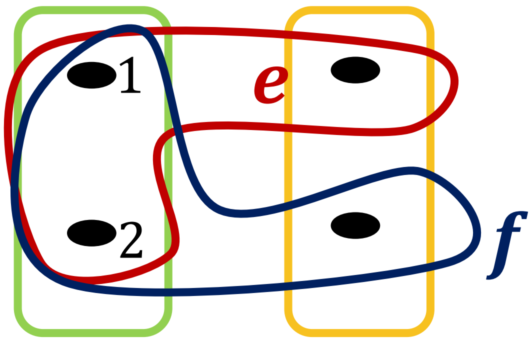

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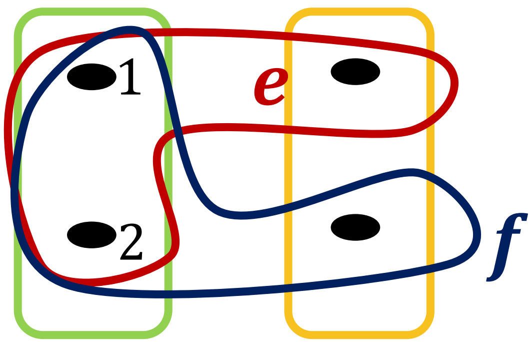

$c = 1, e, 2, f$

- 4 if $k = 2$ and $|Z(^R/_{R\pi}, \alpha_1 + \alpha_2)| \geq \alpha_1 + \alpha_2 + 1$ and $|V_i| \geq 2$ with $\alpha_i = 1$ for all $1 \leq i \leq 2$

The minimum length of all cycles

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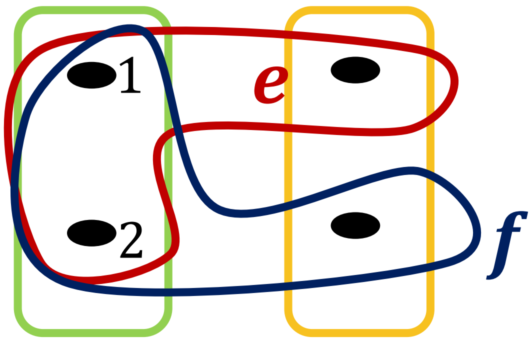

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Same idea as complete bipartite graph

Conclusion table

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Hypergraph	Appropriate Ideal	Vertex Set $(\sigma = \sum_{m=1}^{k} \alpha_m,\ \pi = p_1^{\alpha_1} p_2^{\alpha_2} p_3^{\alpha_3} \cdots p_k^{\alpha_k})$	Diameter	Minimum length of all cycles
k-partite σ-zero-divisor hypergraph	$Rp_1^{\alpha_1} p_2^{\alpha_2} p_3^{\alpha_3} \cdots p_k^{\alpha_k}$	$V_i = {}^{Rp_i}/_{R\pi} - \bigcup_{j \neq i} {}^{Rp_j}/_{R\pi}$ if $\alpha_i = 1$ $V_i = {}^{Rp_i}/_{R\pi} - \left({}^{Rp_i^2}/_{R\pi} \cup \bigcup_{j \neq i} {}^{Rp_j}/_{R\pi}\right)$ if $\alpha_i \geq 2$ $\bigcup_{i=1}^{k} V_i = Z({}^{R}/_{R\pi}, \sigma)$	2	0,2, or 4

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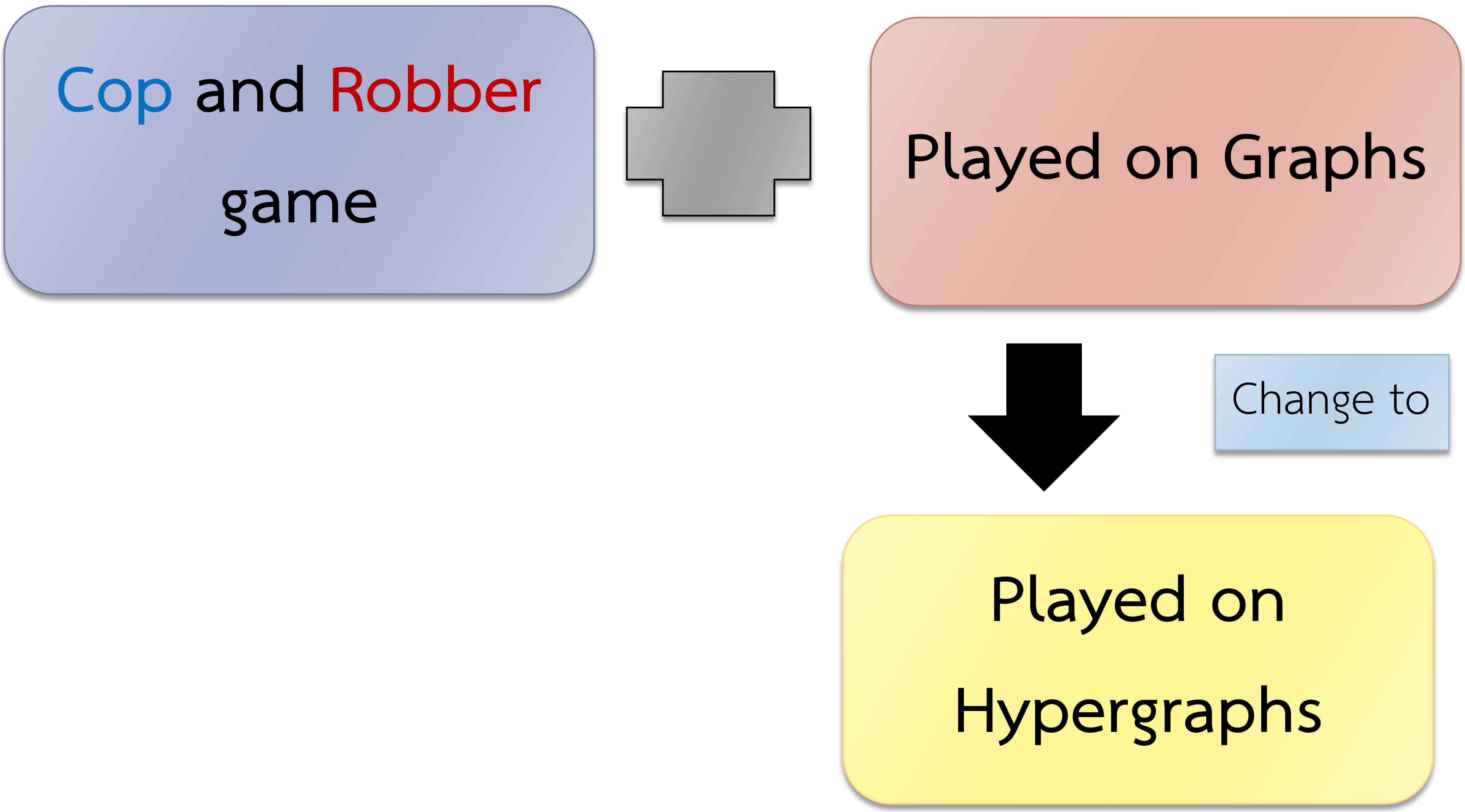

Games played on hypergraphs

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Played on Hypergraphs

Cop and Robber game played on graphs

Nowakowski and Winkler

Cop and Robber game played on graphs

Two players

Nowakowski and Winkler

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Rules of the game played on graphs

Nowakowski and Winkler

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Rules of the game played on graphs

1. The cop choose a beginning vertex and then the robber choose a beginning vertex

Nowakowski and Winkler

Cop and Robber game played on graphs

Two players

Cop

Robber

Rules of the game played on graphs

1. The cop choose a beginning vertex and then the robber choose a beginning vertex

2. In each round, the cop and the robber take alternatively moving from their present vertex to other vertices along edges or staying put.

Nowakowski and Winkler

Cop and Robber game played on graphs

Cop and Robber game played on graphs

How to finish the game

Cop and Robber game played on graphs

How to finish the game

Cop wins if cop can catch robber by occupying the same vertex as the robber after finite number of moves

Cop and Robber game played on graphs

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Cop and Robber game played on graphs

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Robber wins if robber can run away

Cop and Robber game played on graphs

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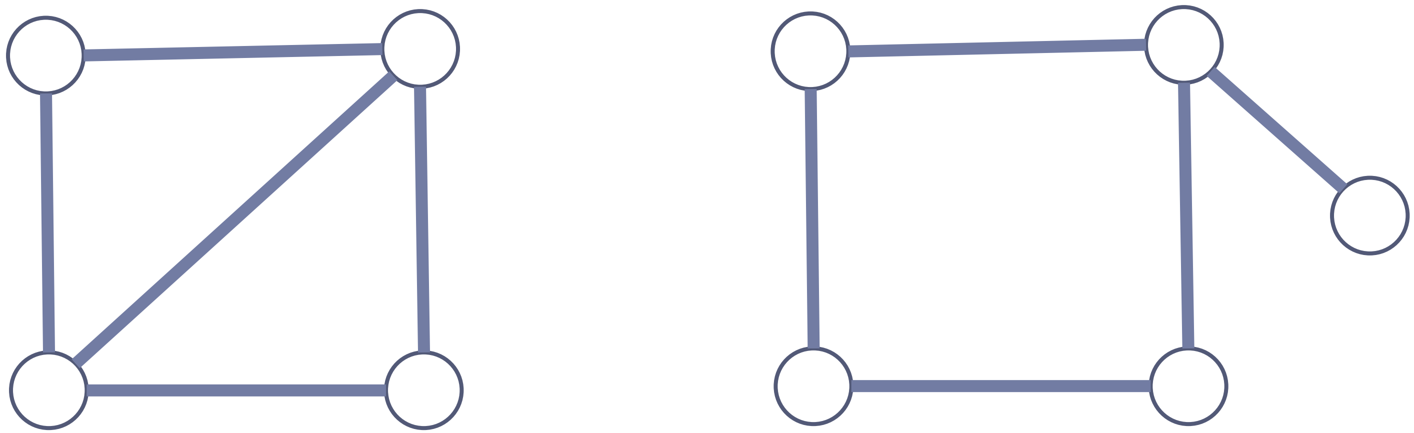
Example of cop wins and robber wins

Example of cop wins and robber wins

Given two graphs, which one that cop wins?



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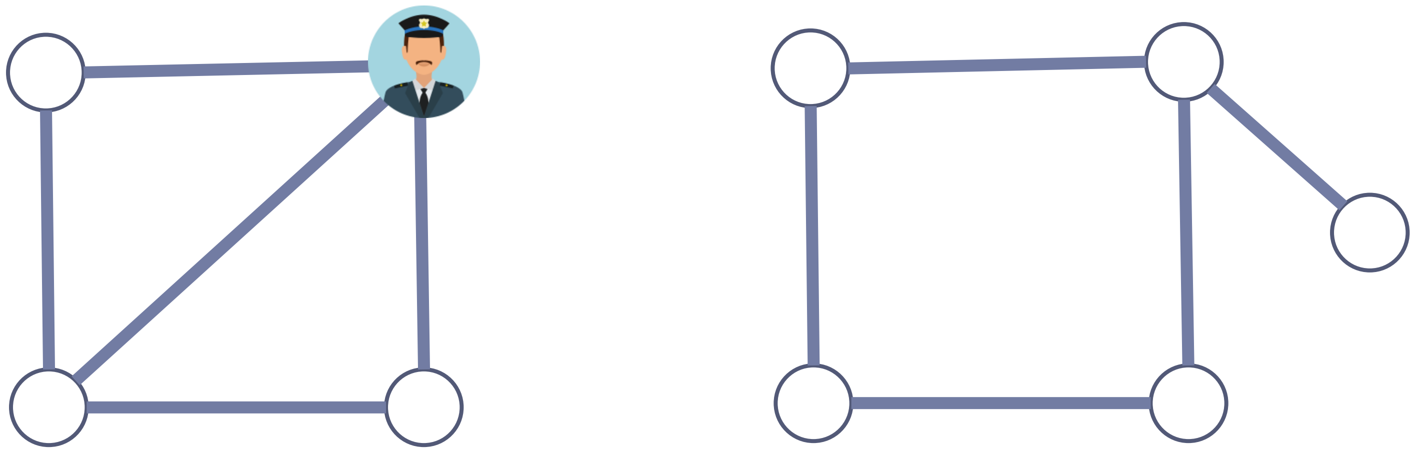

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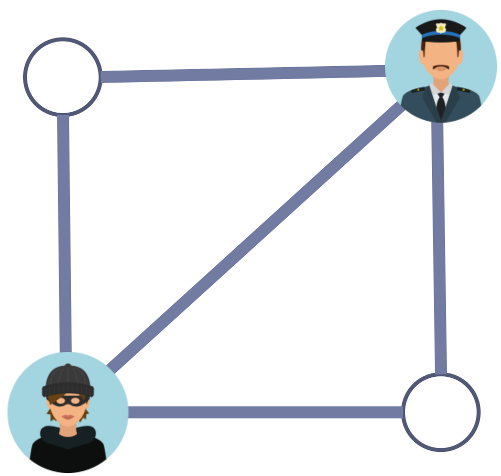

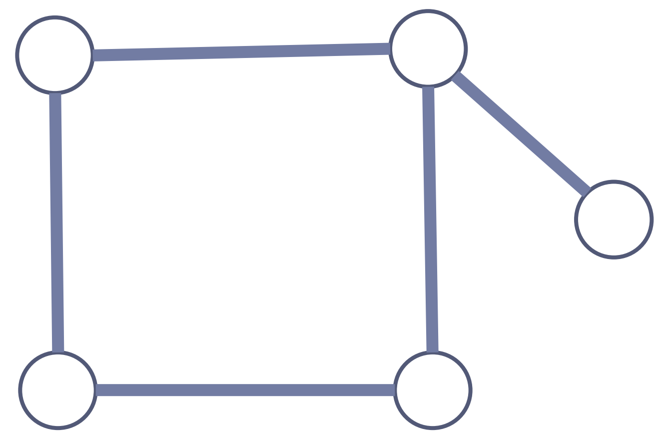

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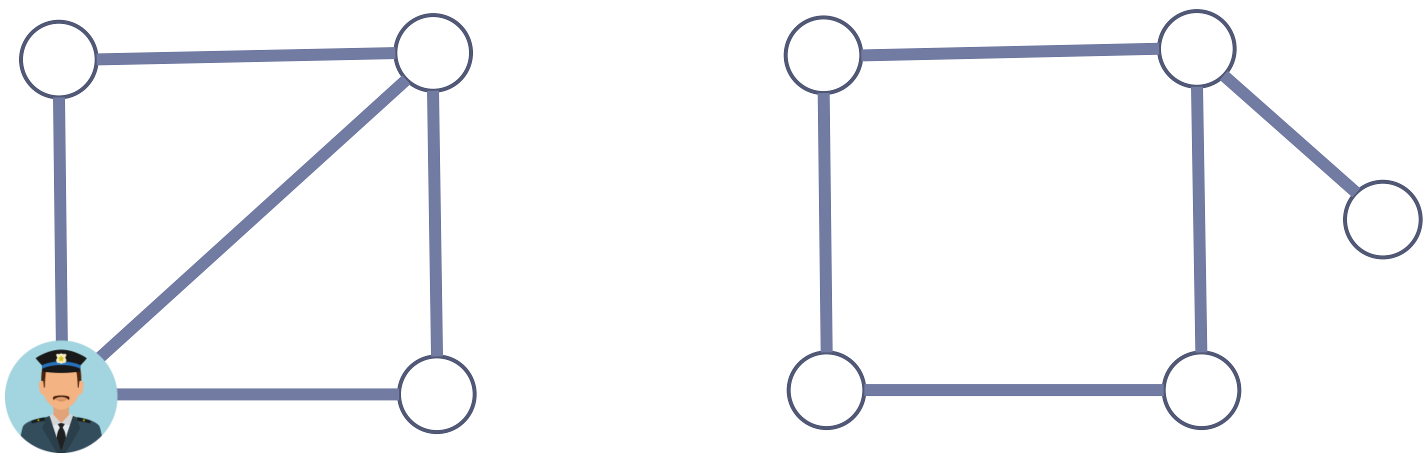

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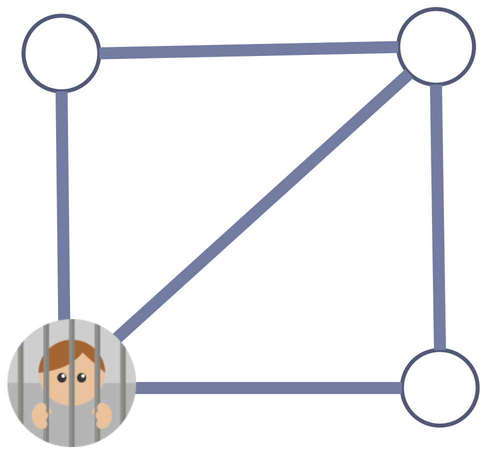

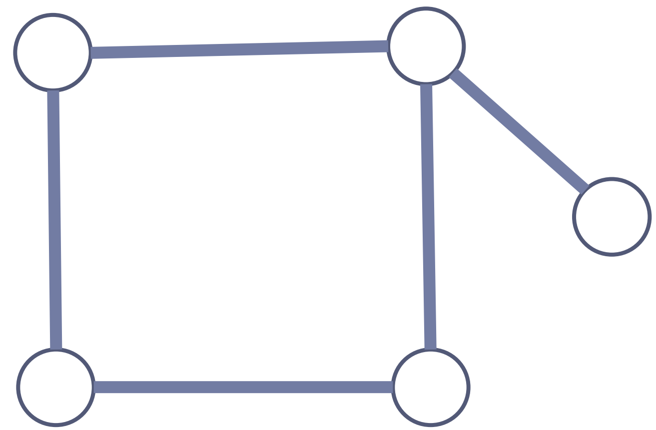

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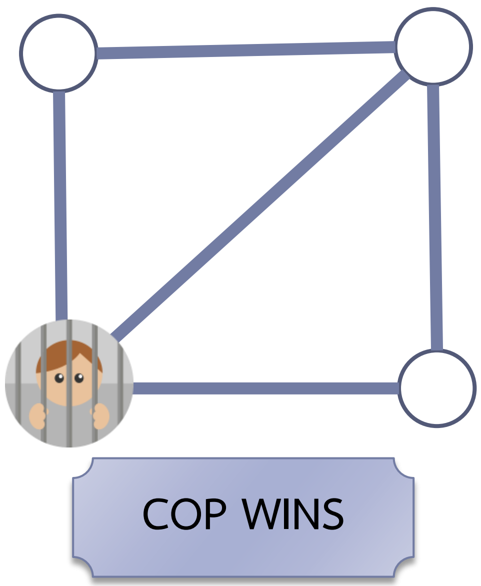

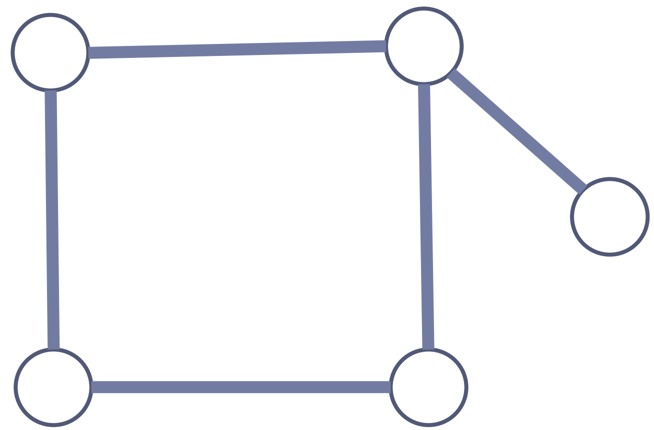

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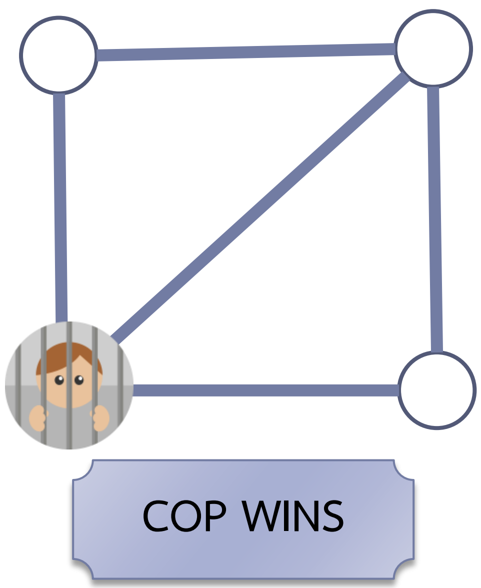

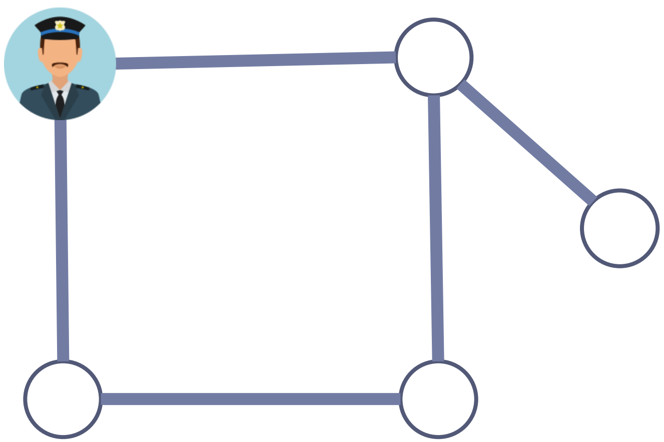

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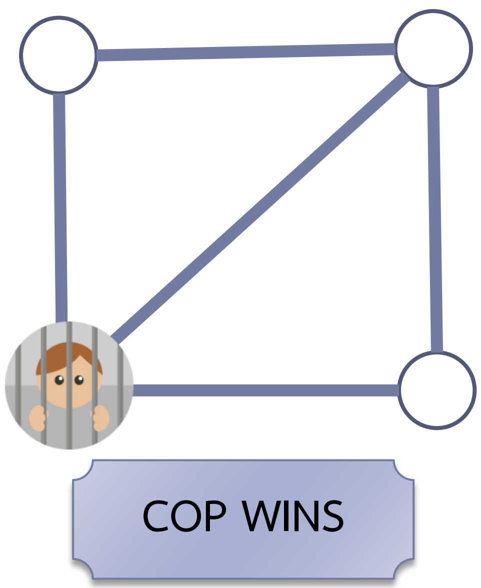

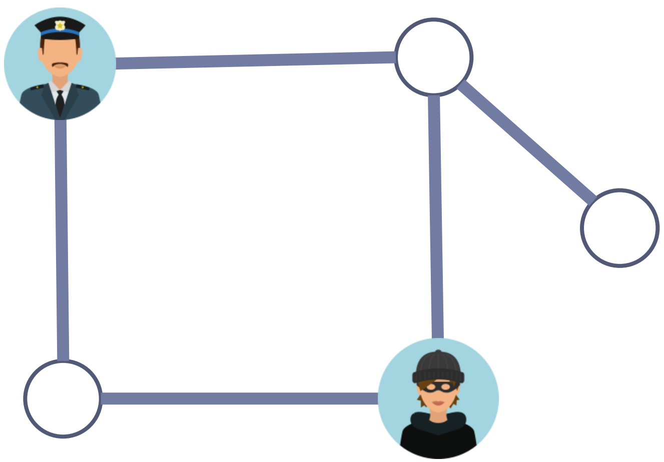

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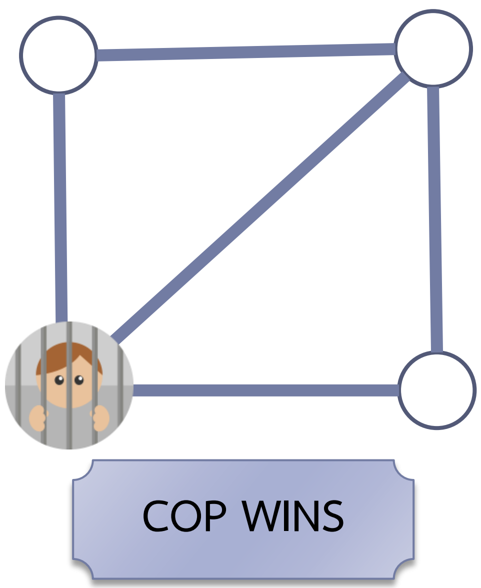

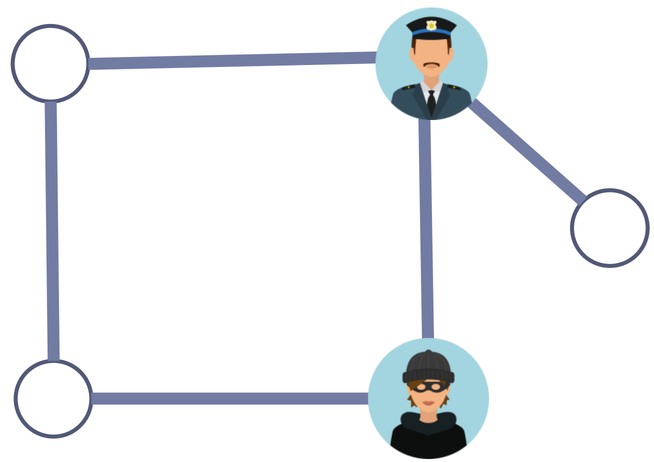

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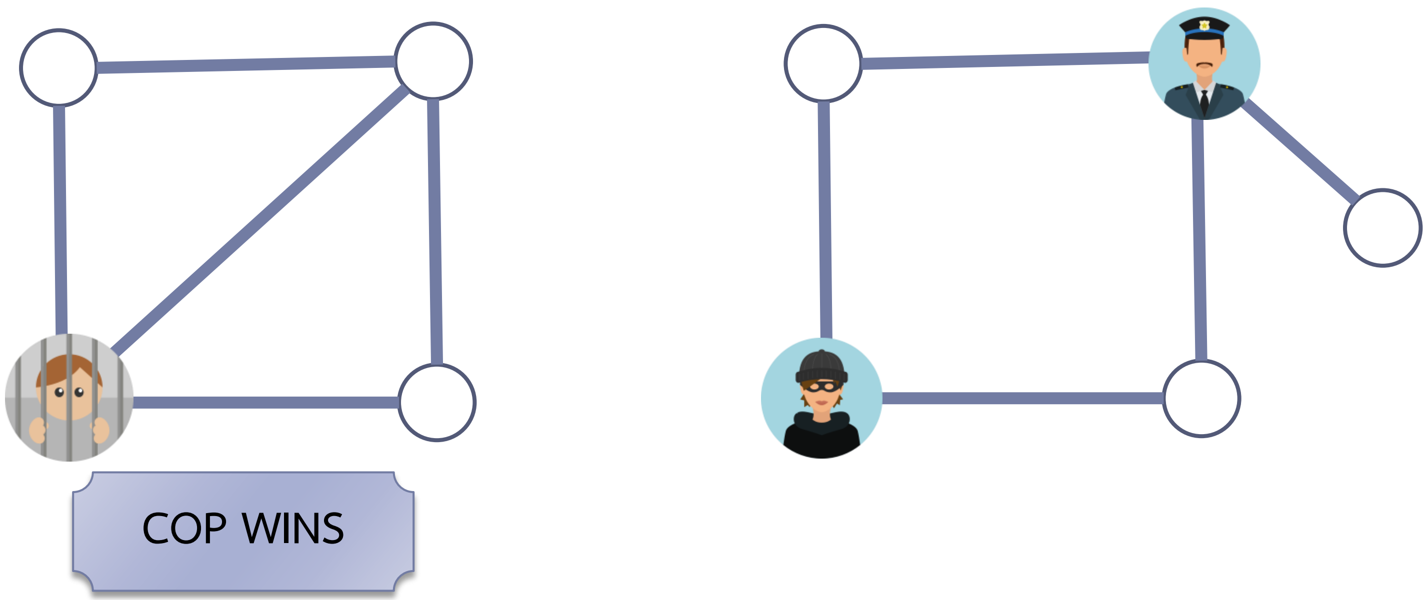

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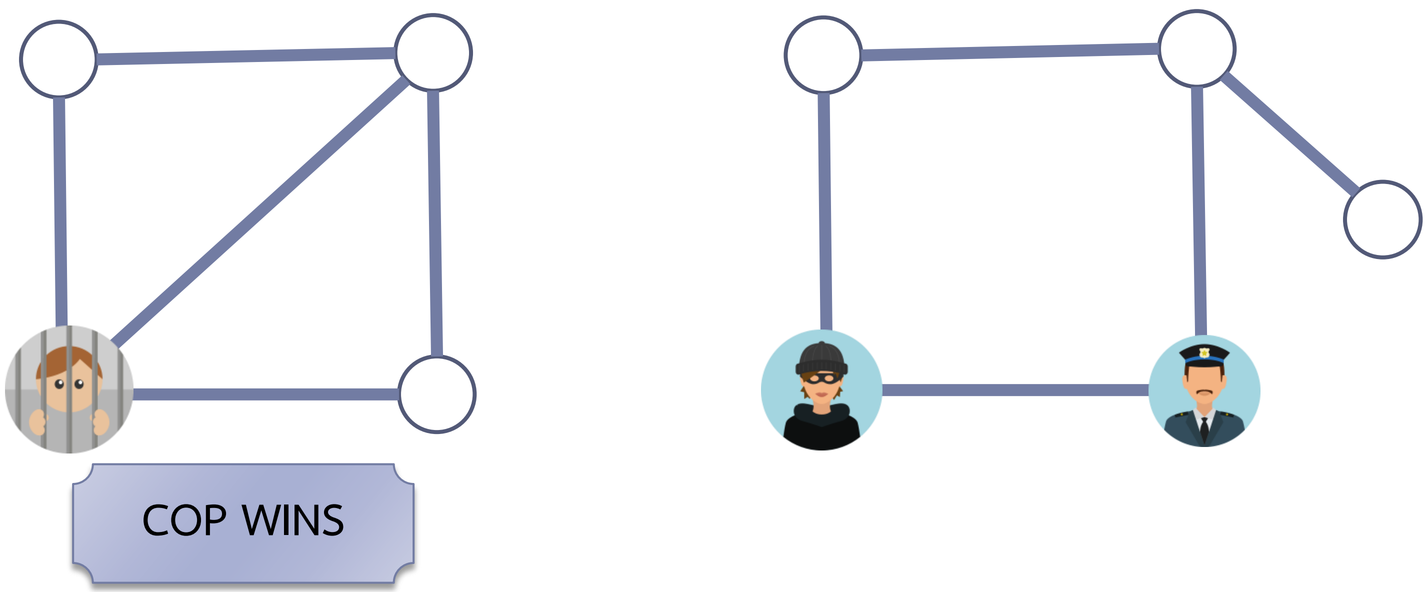

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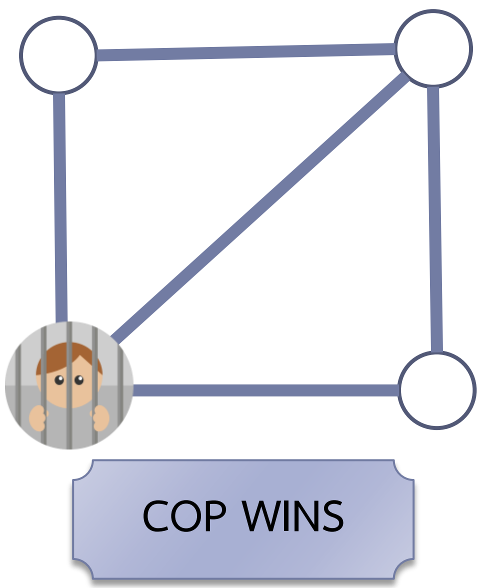

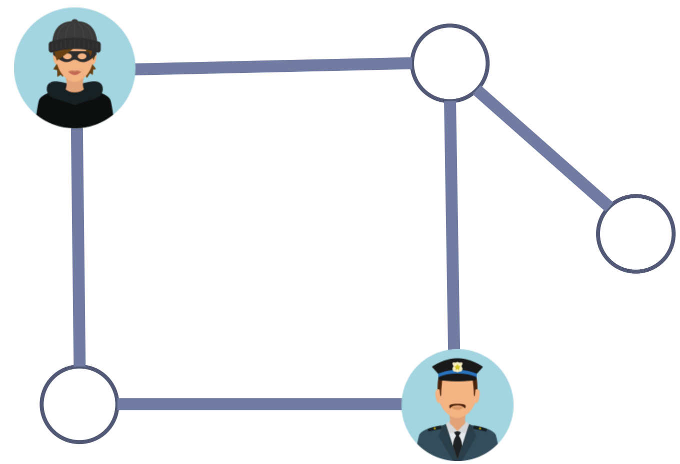

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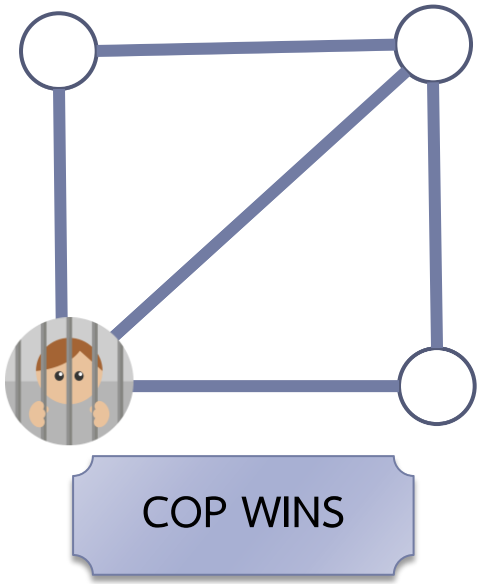

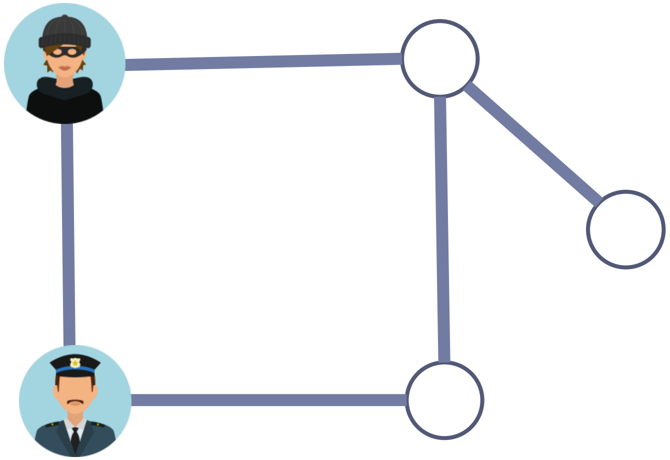

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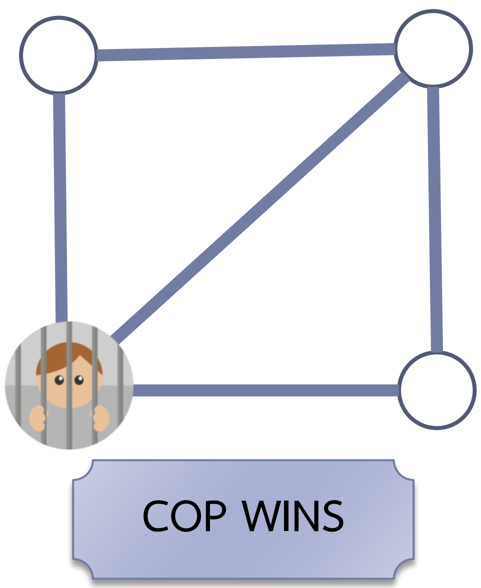

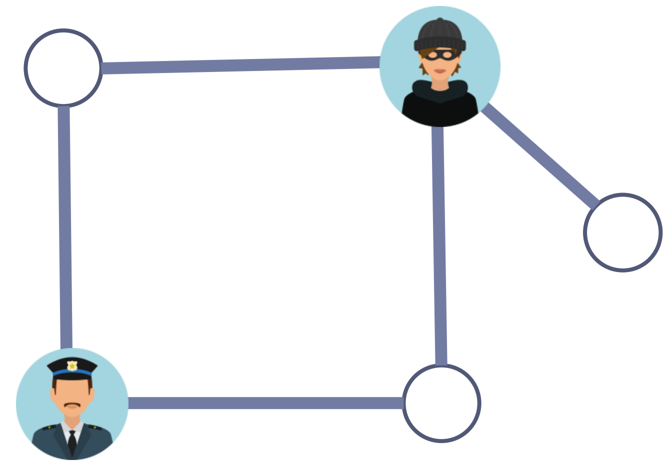

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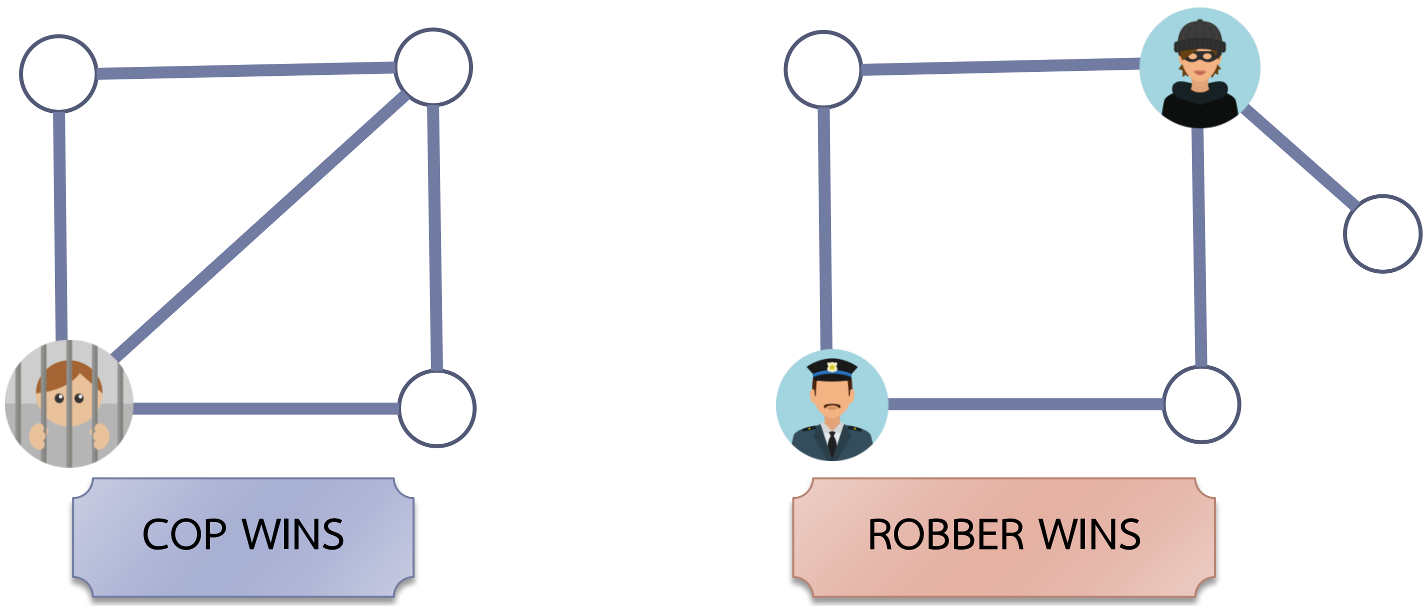

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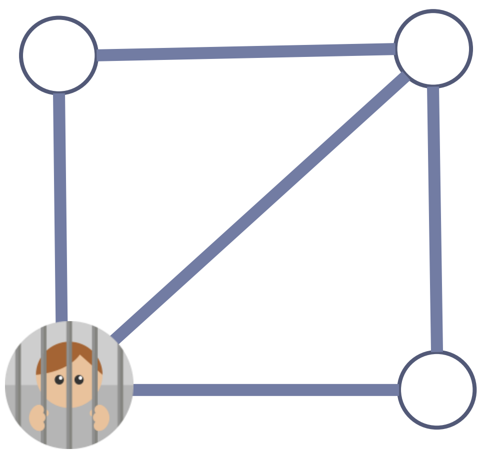
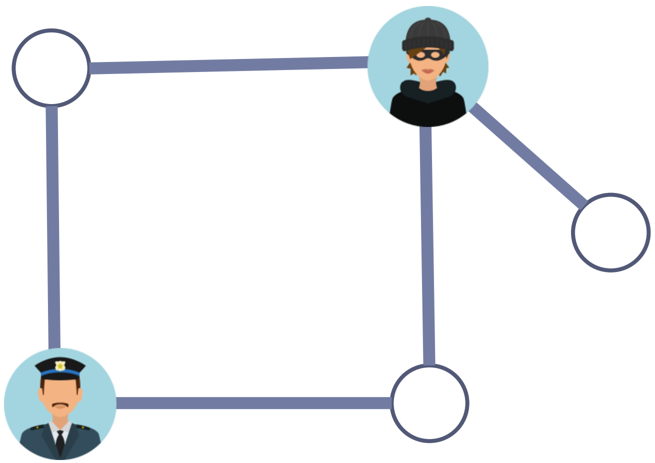


COP WINS



ROBBER WINS

The graph which cop wins is called **a cop-win graph**; otherwise, **a robber-win graph**.

Cop and Robber game played on hypergraphs

Cop and Robber game played on hypergraphs

Two players

Cop

Robber

Cop and Robber game played on hypergraphs

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Rules of the game played on hypergraphs

Cop and Robber game played on hypergraphs

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Rules of the game played on hypergraphs

1. The cop choose a beginning vertex and then the robber choose a beginning vertex

Cop and Robber game played on hypergraphs

Two players

Cop

Robber

Rules of the game played on hypergraphs

1. The cop choose a beginning vertex and then the robber choose a beginning vertex

2. In each round, they take alternatively moving from their present vertex x to any vertex y belonging to the same hyperedge as vertex x or staying put.

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Cop and Robber game played on hypergraphs

Cop and Robber game played on hypergraphs

How to finish the game

Cop and Robber game played on hypergraphs

How to finish the game

Same as playing on graphs

Cop and Robber game played on hypergraphs

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Cop **wins** if cop can catch robber by occupying the same vertex as the robber after finite number of moves. The hypergraph which cop wins is called **a cop-win hypergraph**

Cop and Robber game played on hypergraphs

How to finish the game

Same as playing on graphs

Cop **wins** if cop can catch robber by occupying the same vertex as the robber after finite number of moves. The hypergraph which cop wins is called **a cop-win hypergraph**

Robber **wins** if robber can run away. The hypergraph which robber wins is called **a robber-win hypergraph**

Cop and Robber game played on hypergraphs

Cop and Robber game played on hypergraphs

Baird

A path is a cop-win hypergraph

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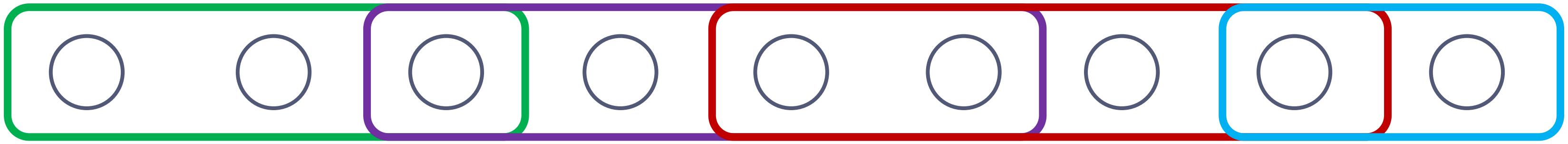

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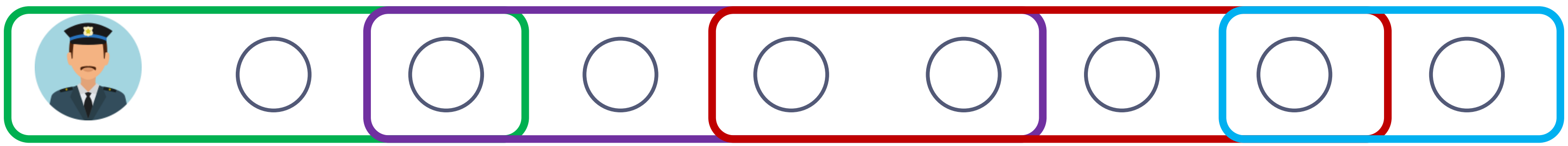

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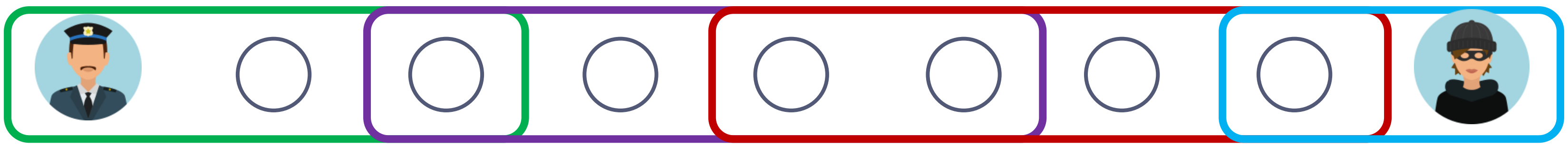

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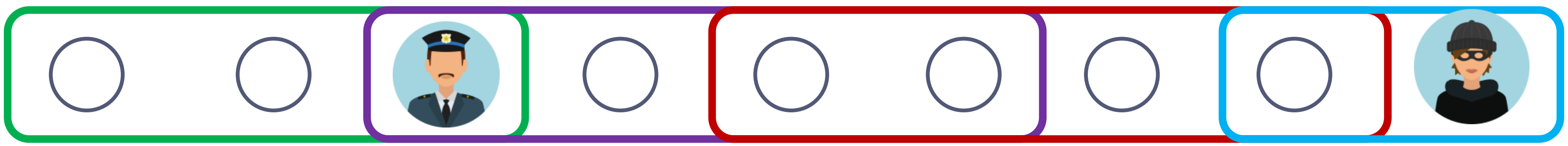

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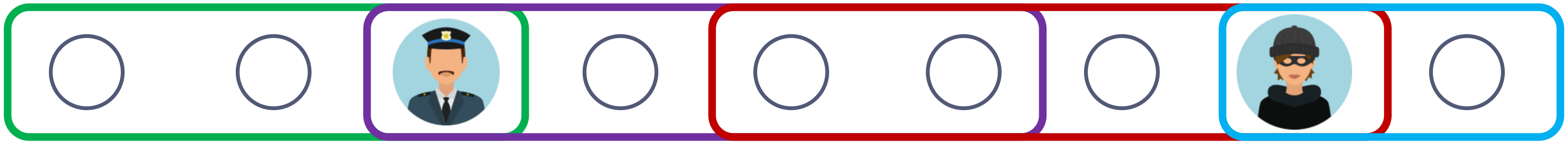

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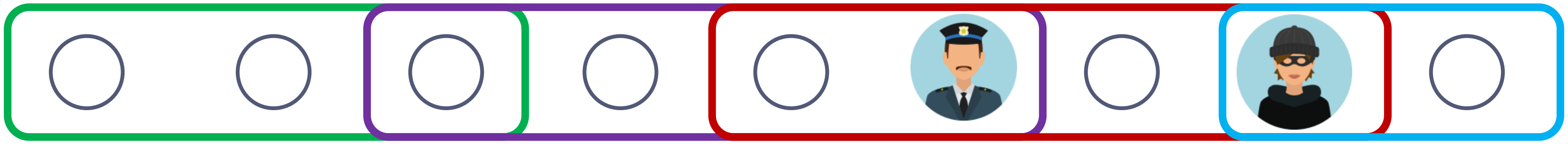

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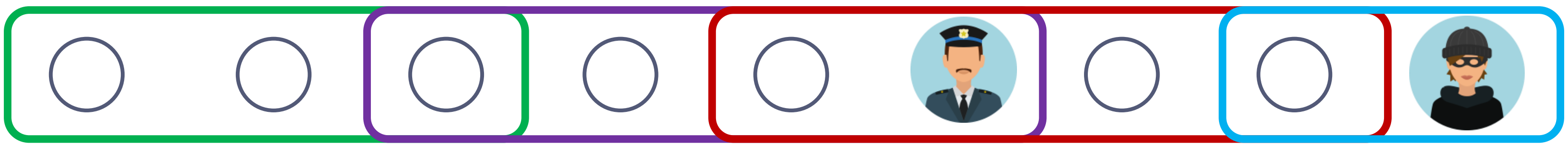

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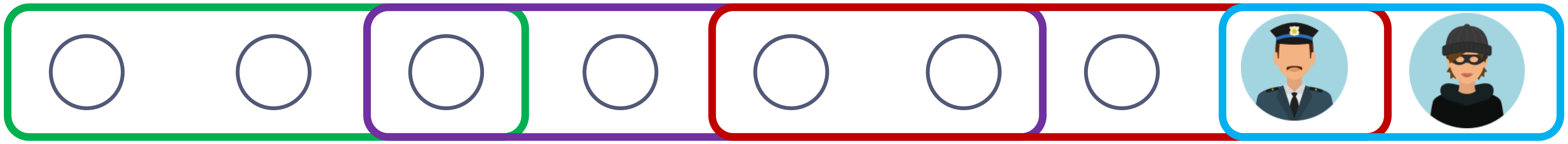

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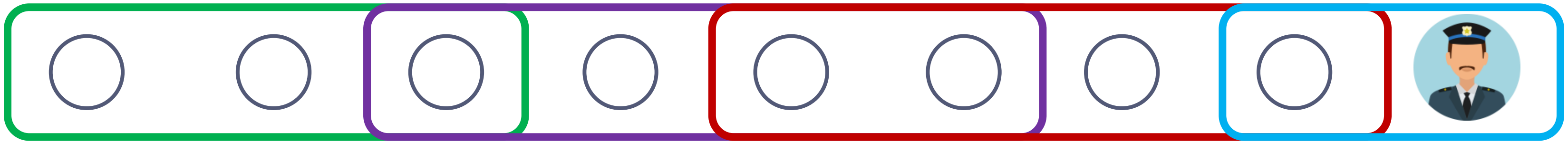

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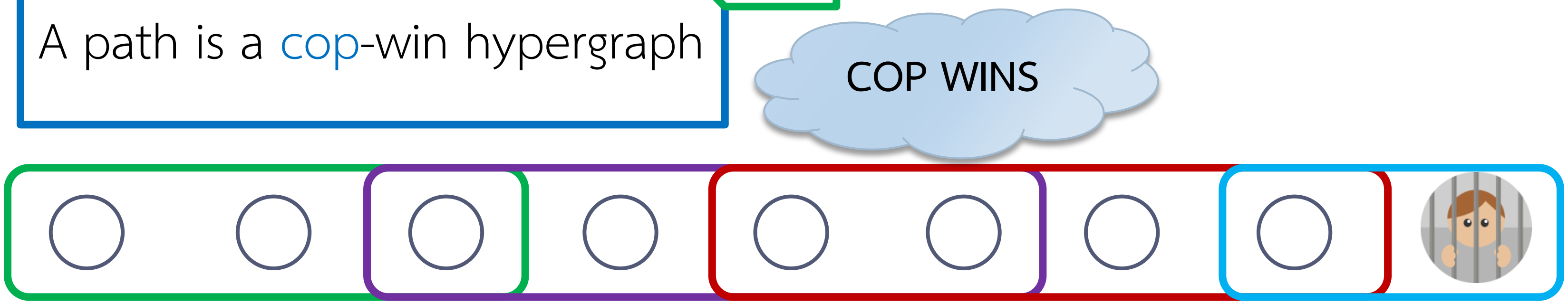

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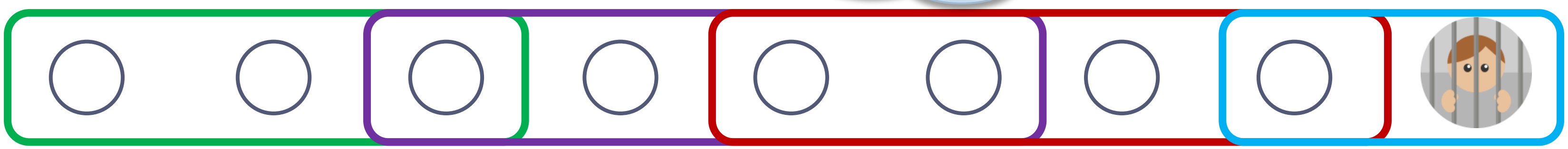
COP WINS



Baird

A cycle of length exceed 4 is a robber-win hypergraph

Cop and Robber game played on hypergraphs

Baird

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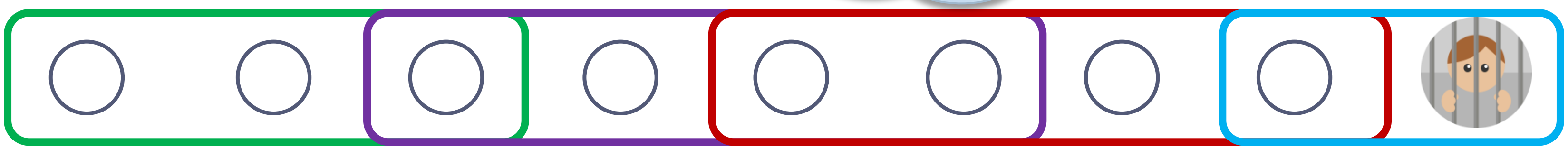

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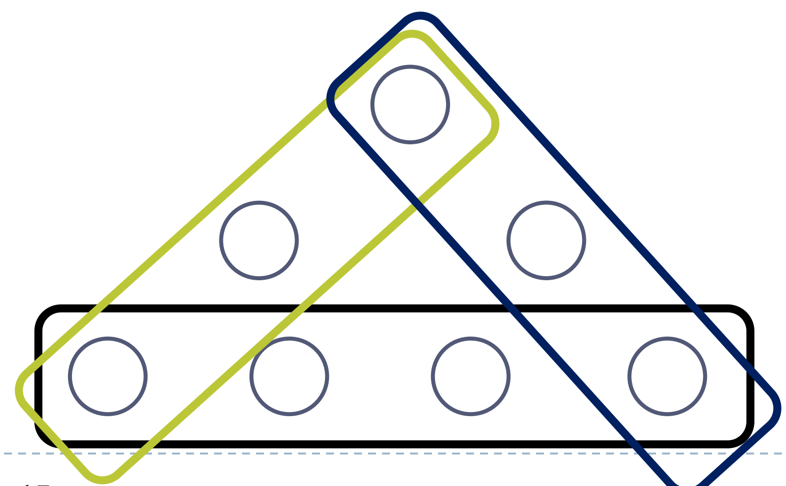

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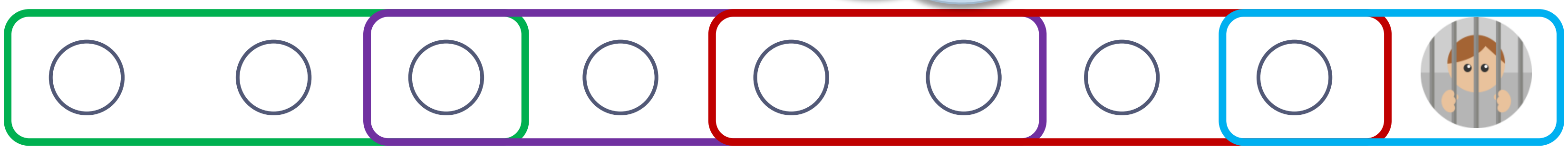

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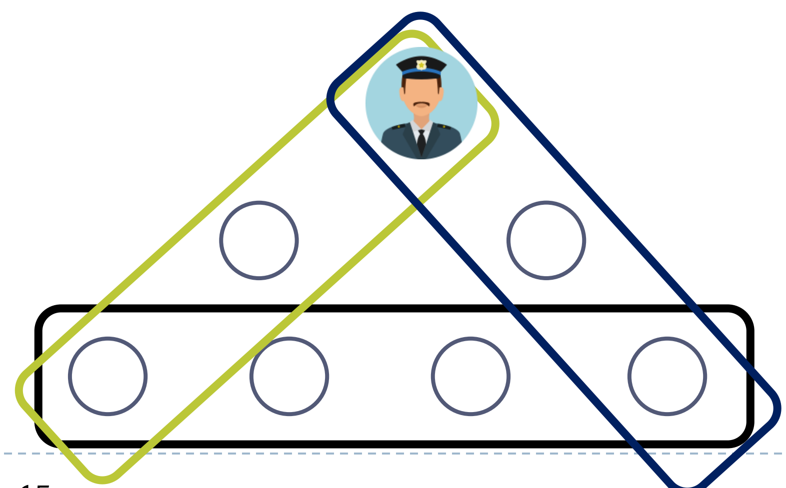

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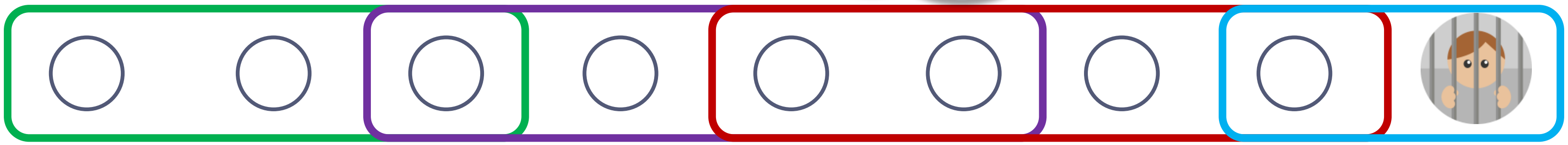

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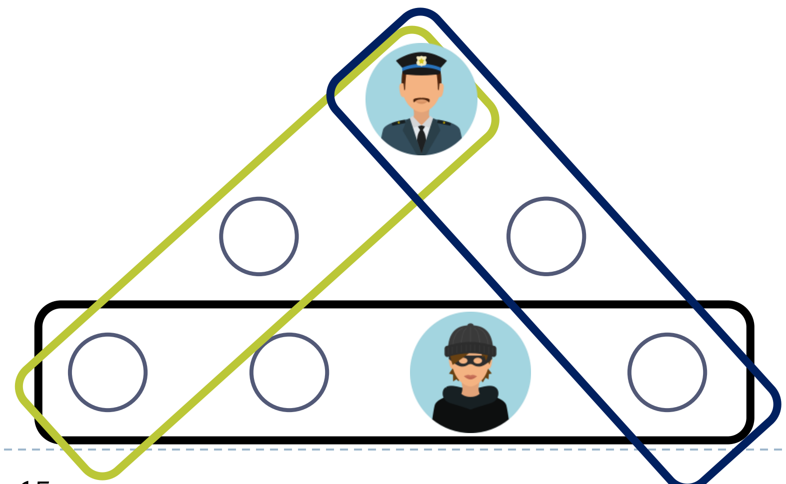

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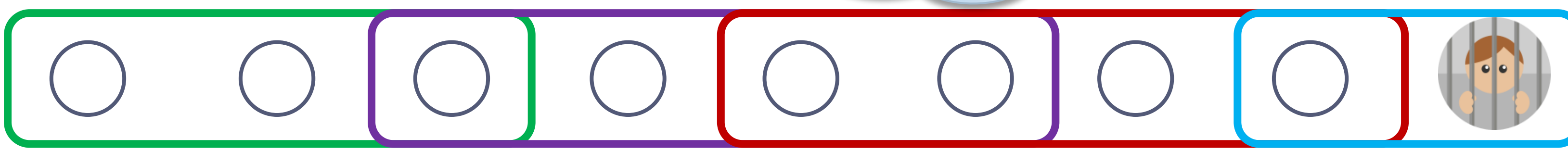

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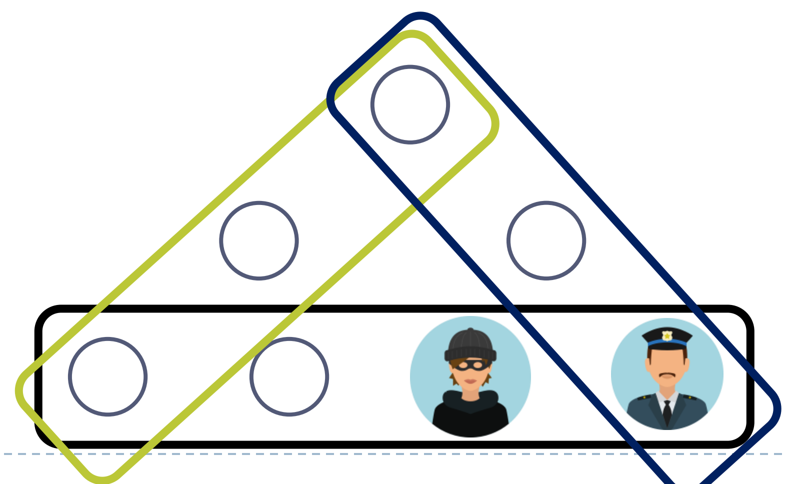

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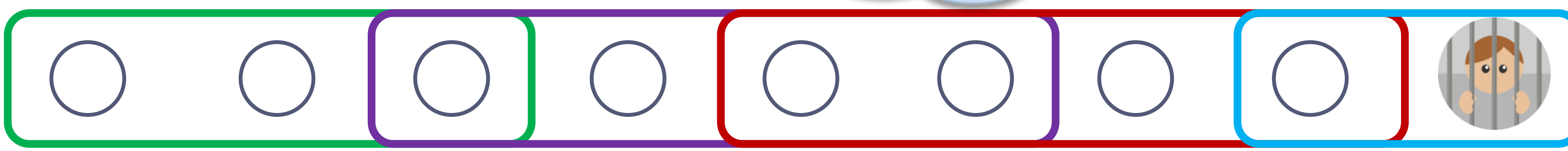

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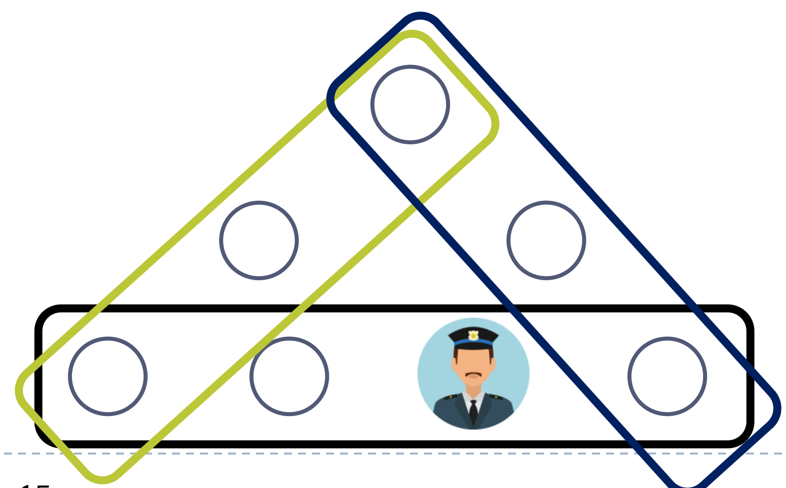

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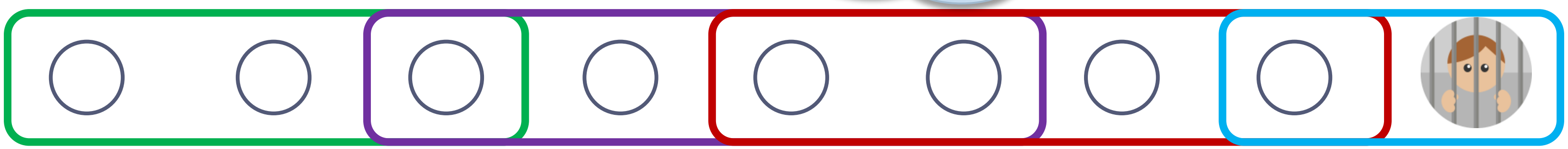

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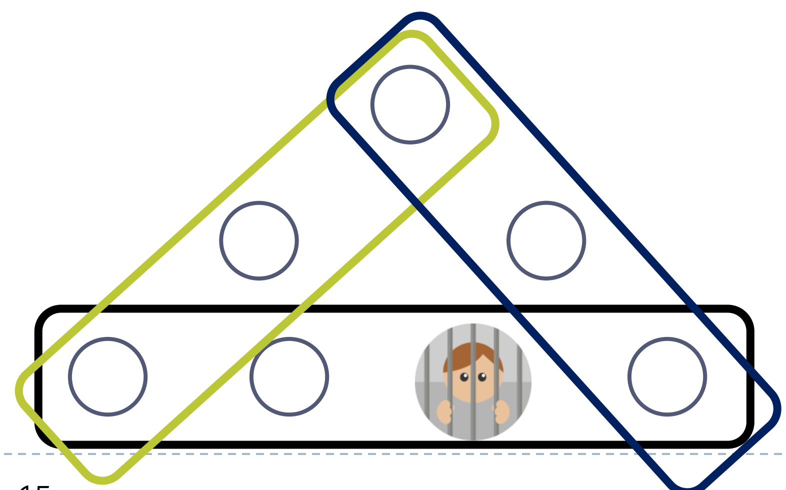

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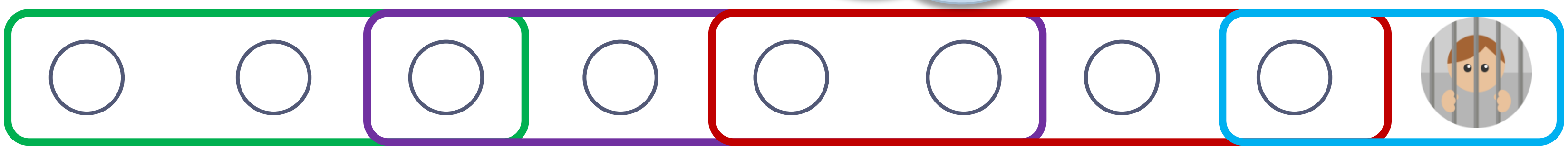

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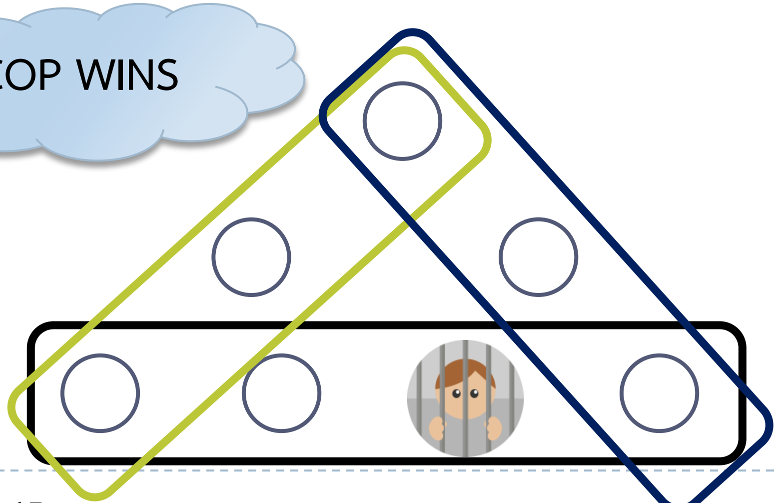

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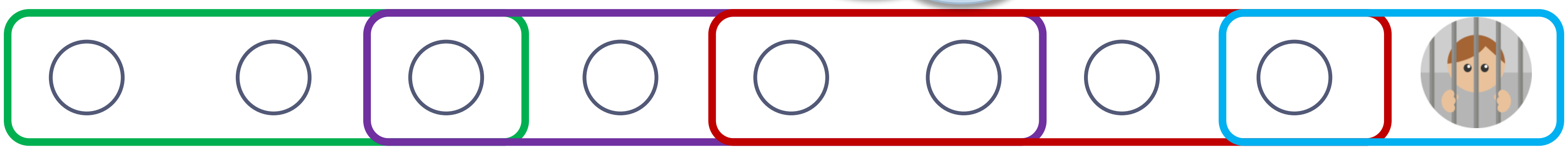

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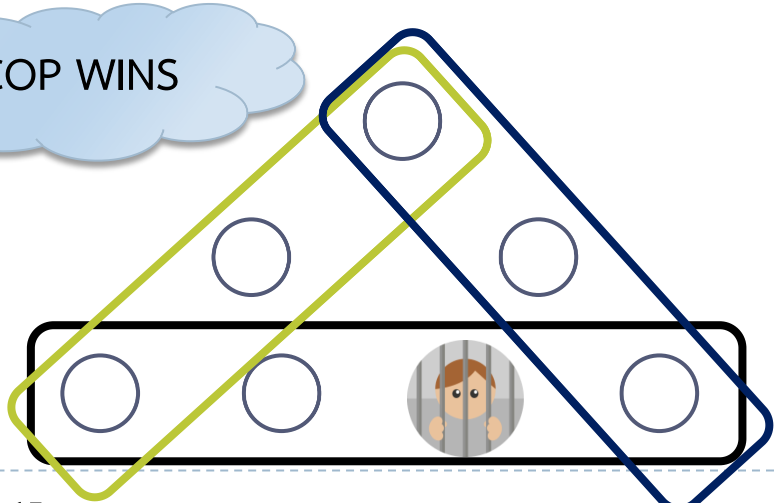

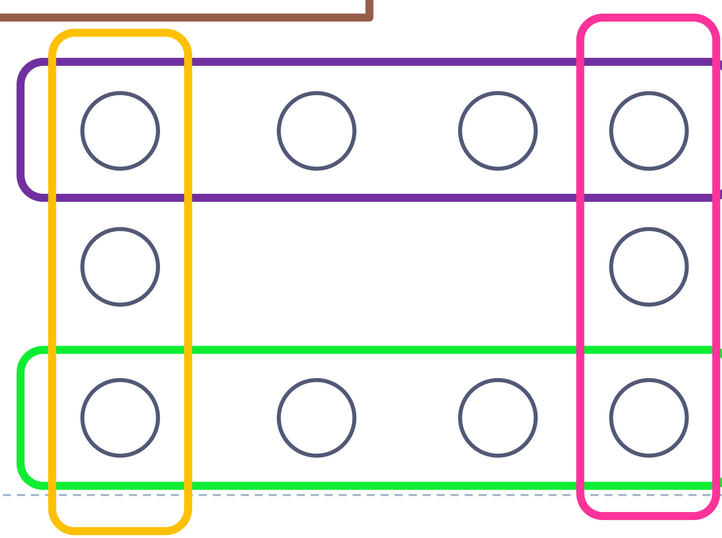

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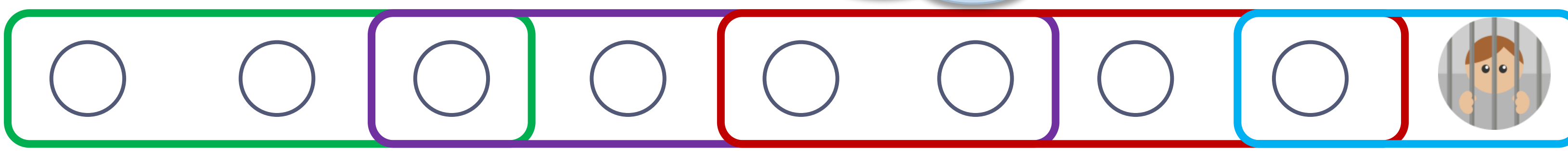

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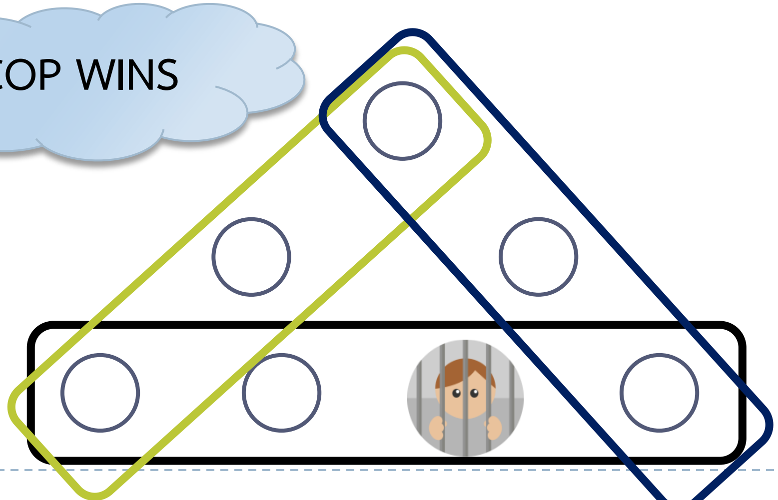

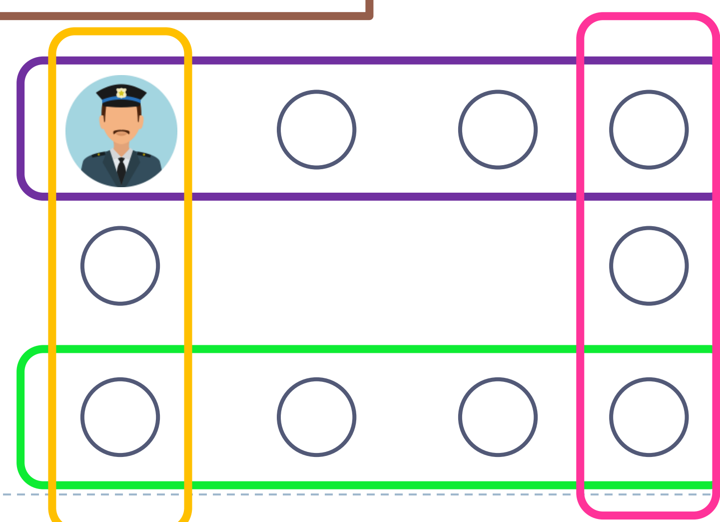

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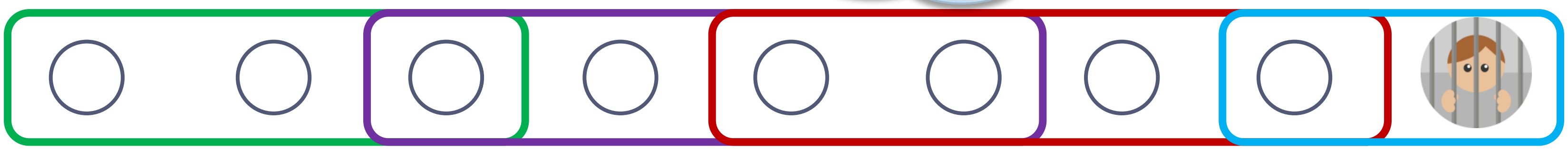

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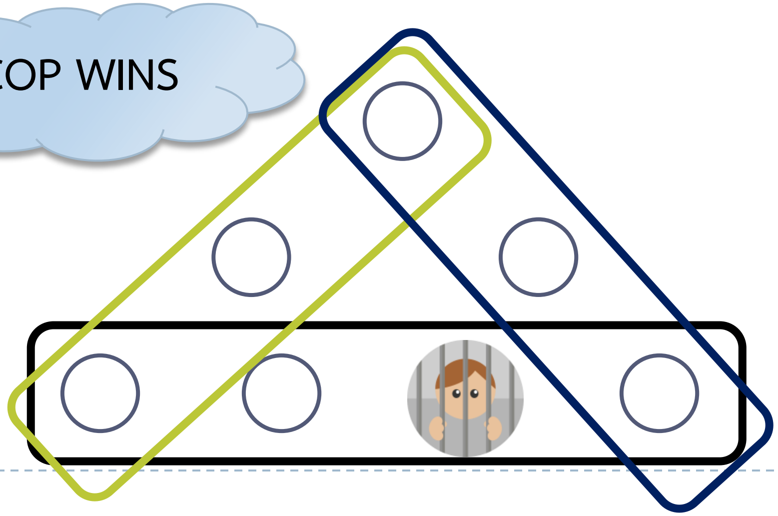

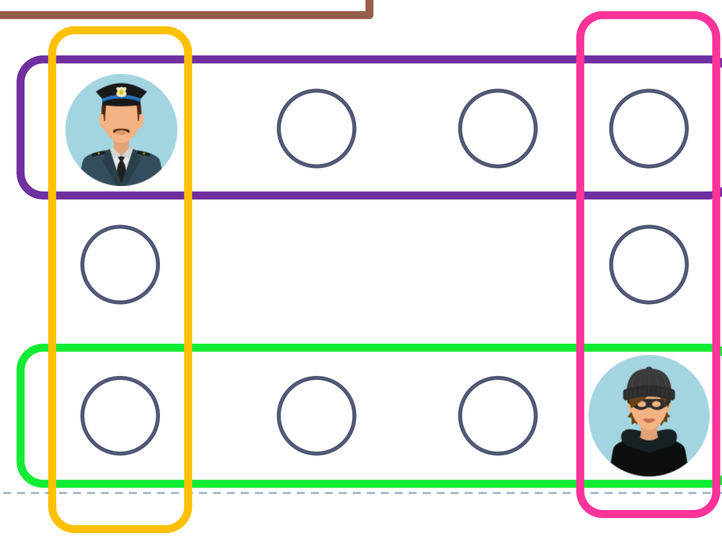

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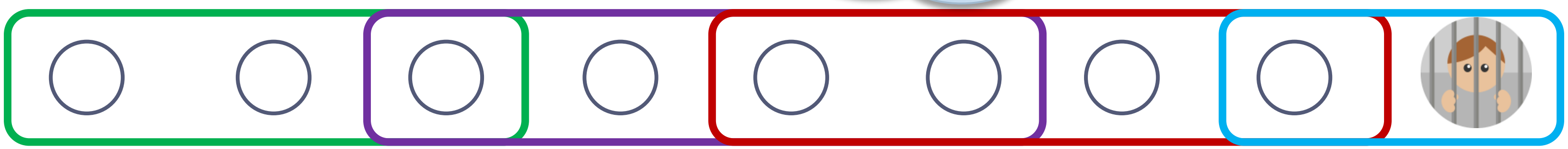

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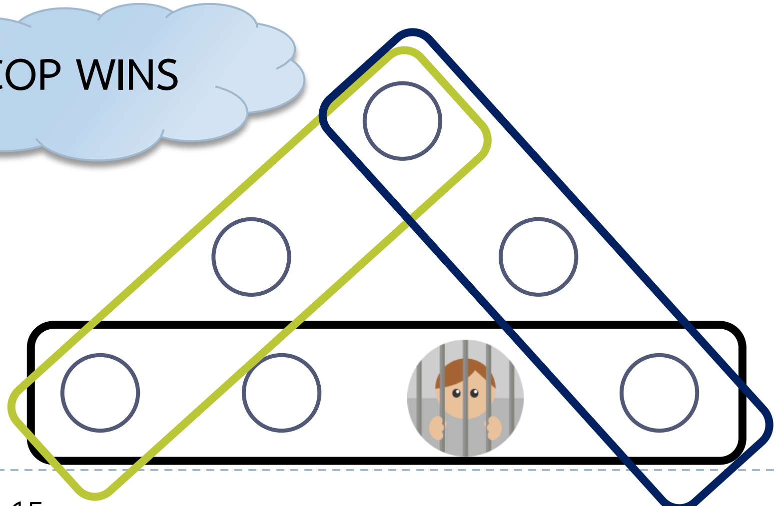

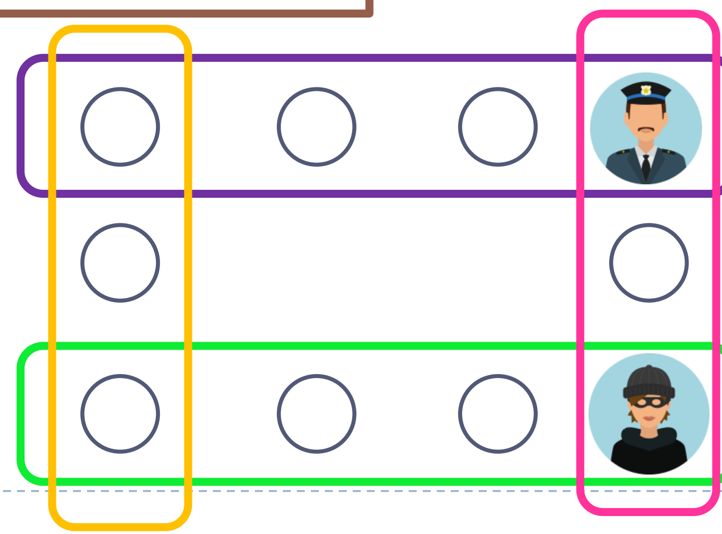

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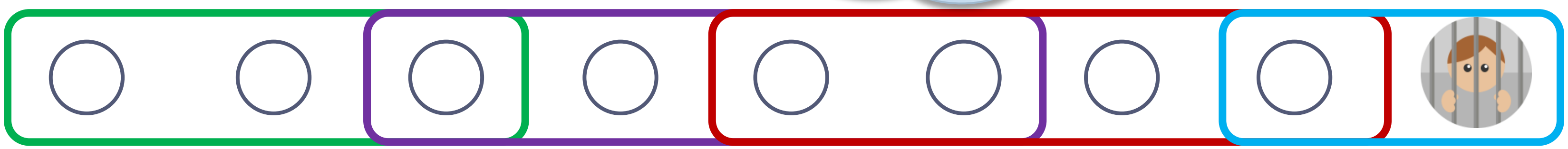

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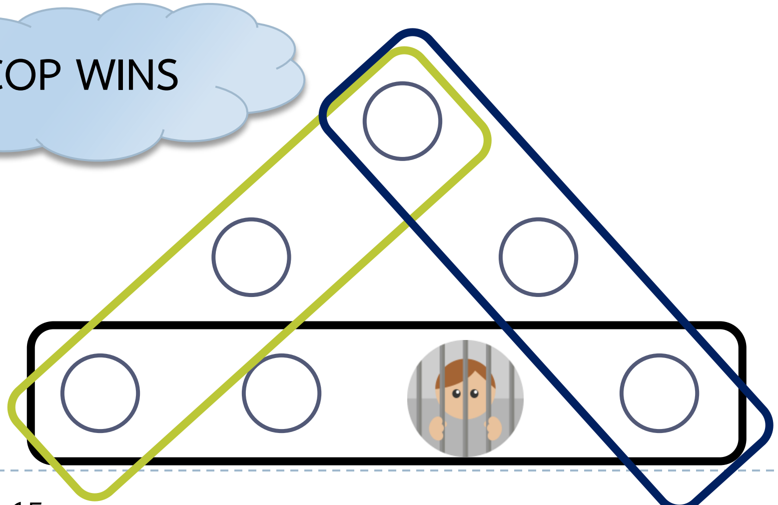

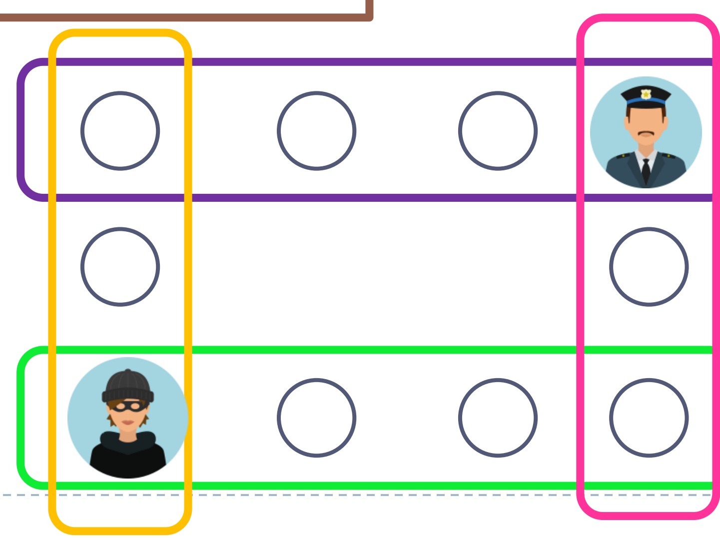

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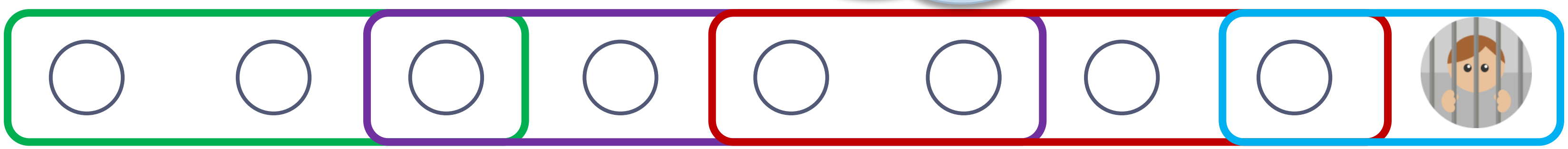

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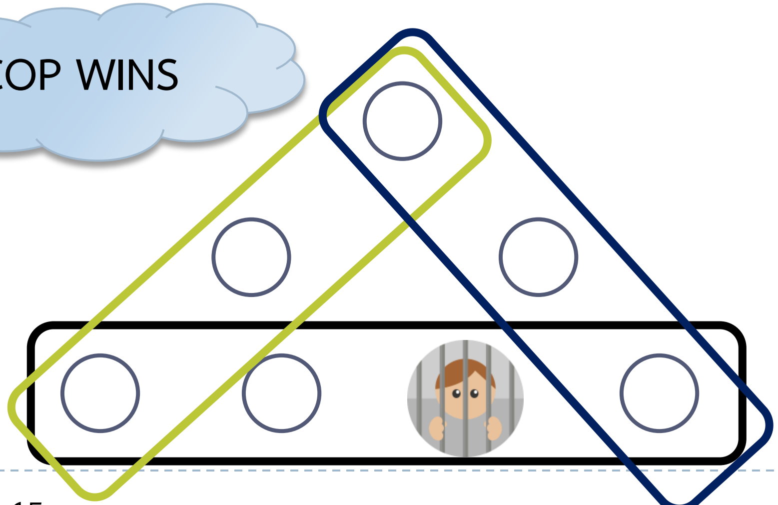

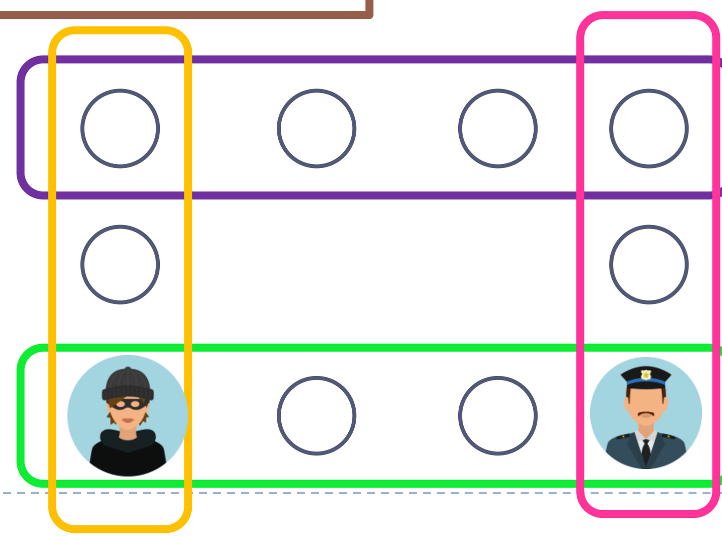

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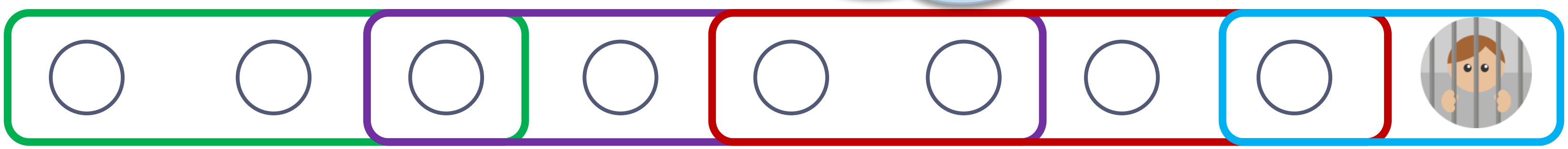

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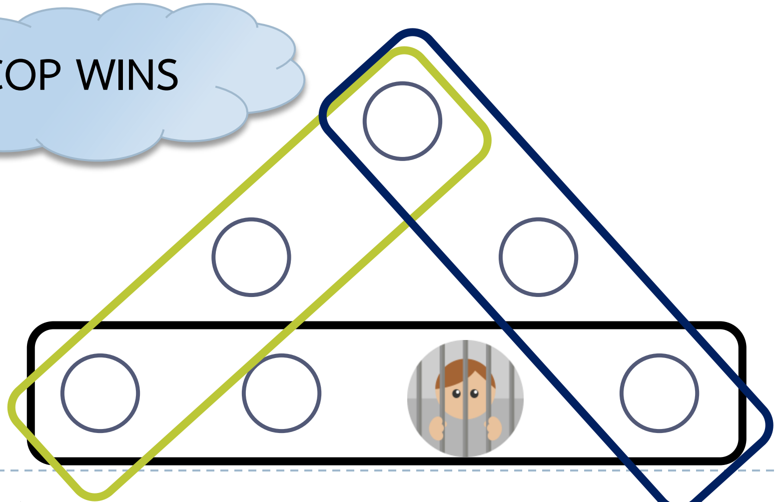

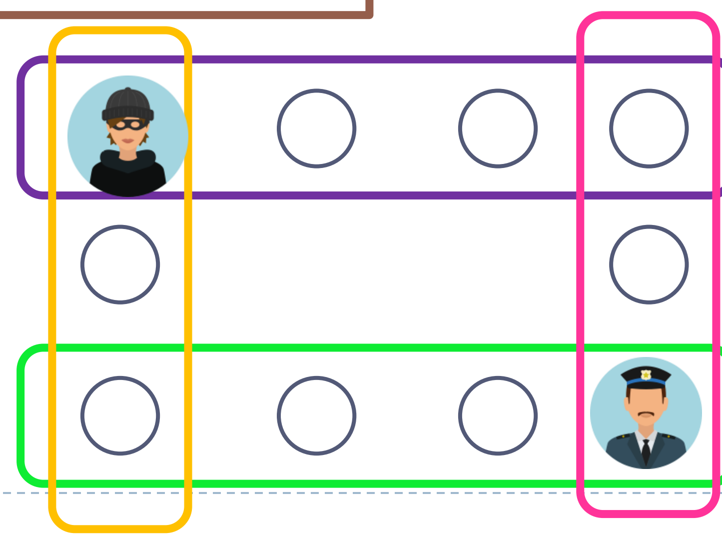

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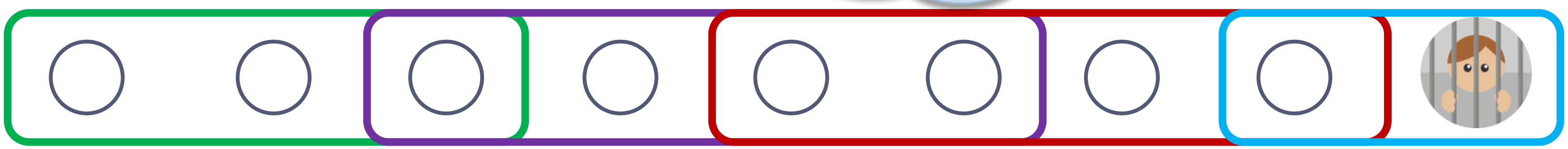

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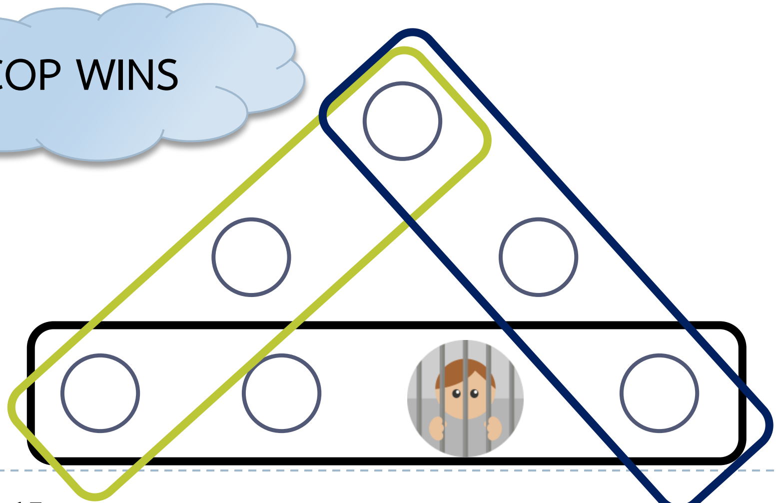
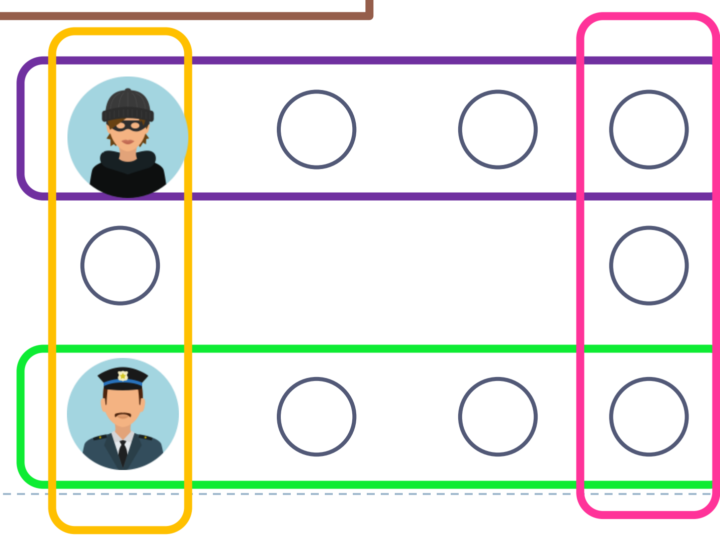
A cycle of length exceed 4 is a robber-win hypergraph

COP WINS



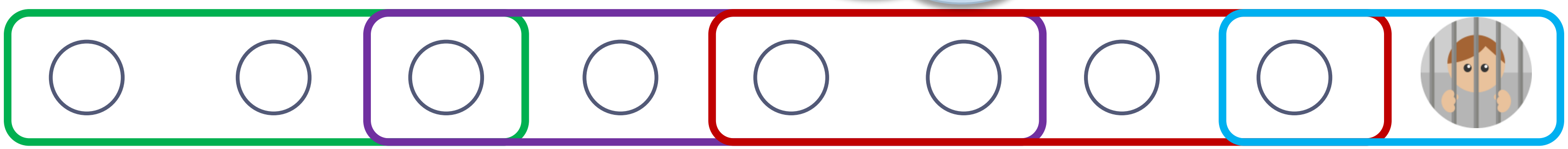


Cop and Robber game played on hypergraphs

Baird

A path is a cop-win hypergraph

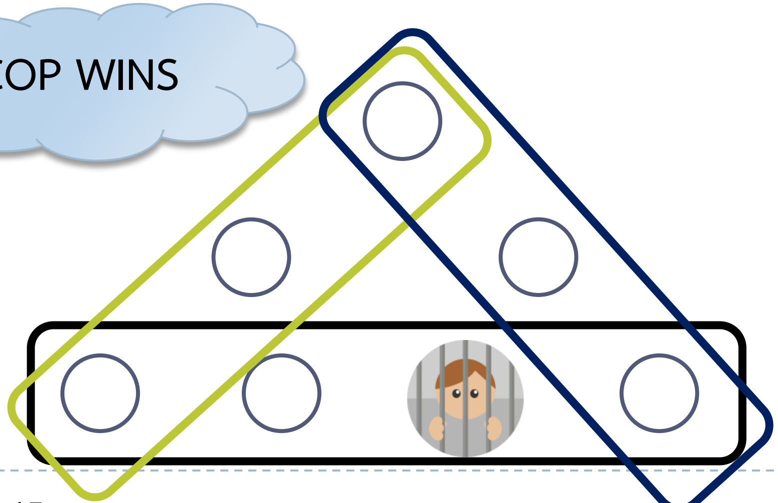
COP WINS

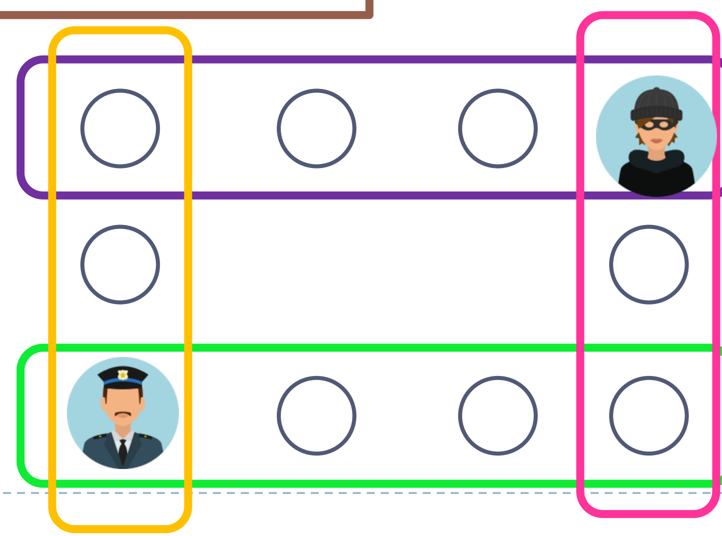


Baird

A cycle of length exceed 4 is a robber-win hypergraph

COP WINS



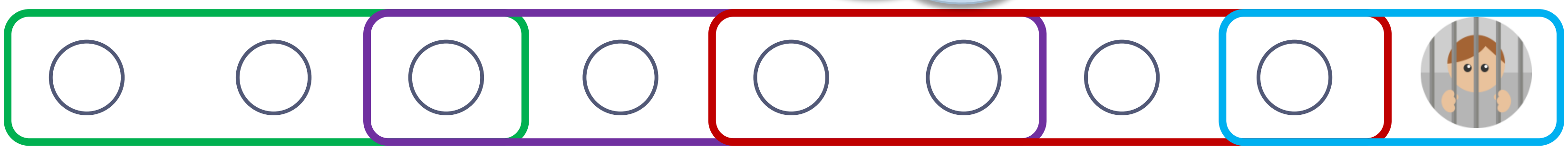


Cop and Robber game played on hypergraphs

Baird

A path is a cop-win hypergraph

COP WINS

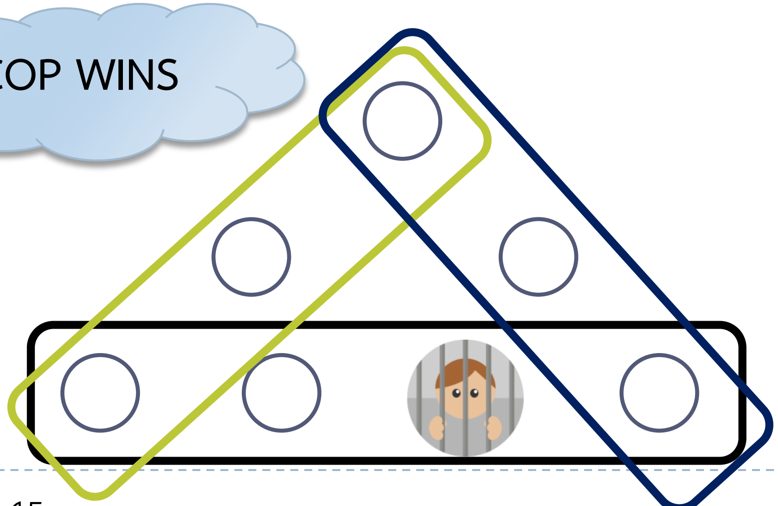


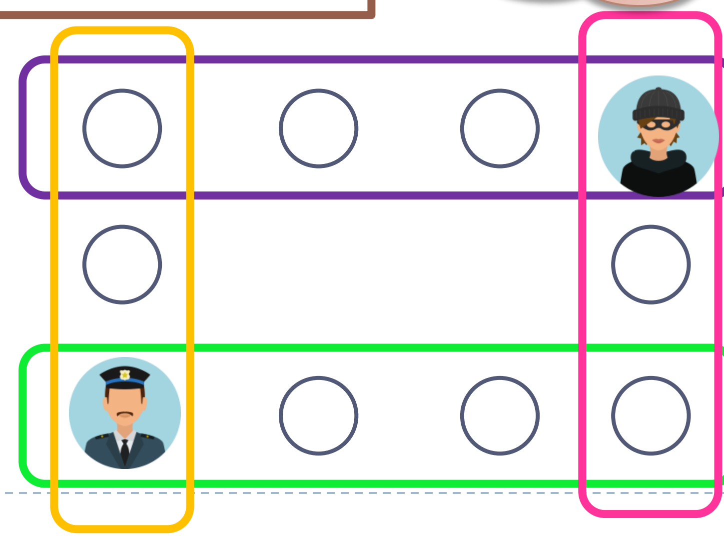
Baird

A cycle of length exceed 4 is a robber-win hypergraph

ROBBER WINS

COP WINS





Cop and Robber game played on <u>hypergraphs</u>

Cop and Robber game played on hypergraphs

Characterize cop-win hypergraphs

Cop and Robber game played on hypergraphs

Characterize cop-win hypergraphs

Generalize some results on graphs to hypergraphs

Cop and Robber game played on hypergraphs

Characterize cop-win hypergraphs

Generalize some results on graphs to hypergraphs

Find the number of cops to catch robber when $\mathcal{H}$ is a robber-win hypergraph

Cop and Robber game played on hypergraphs

Characterize cop-win hypergraphs

Generalize some results on graphs to hypergraphs

Find the number of cops to catch robber when $\mathcal{H}$ is a robber-win hypergraph

Determine the complexity of cop and robber game played on hypergraphs

Catch me! If you can.


SWAG