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Artificial Intelligence Principles

6G7V0011 - 1CWK100

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Outline

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The Six Degree Separation

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Six Degrees of Kevin Bacon

'Six Degrees of Kevin Bacon or Bacon's Law is a parlor game where players challenge each other to arbitrarily choose an actor and then connect them to another actor via a film that both actors have appeared in together, repeating this process to try and find the shortest path that ultimately leads to prolific American actor Kevin Bacon. It rests on the assumption that anyone involved in the Hollywood film industry can be linked through their film roles to Bacon within six steps. The game's name is a reference to "six degrees of separation", a concept which posits that any two people on Earth are six or fewer acquaintance links apart.' **From Wikipedia**

In General

'The well-known six degrees of separation theory is a rule for the interconnected, globalized age we live in. It states that everyone is connected to each other through others they know by, at most, six rounds of introductions'. Credits

Facebook Network

Figure 1: The Facebook social network. Credits

From Six to Four Degree

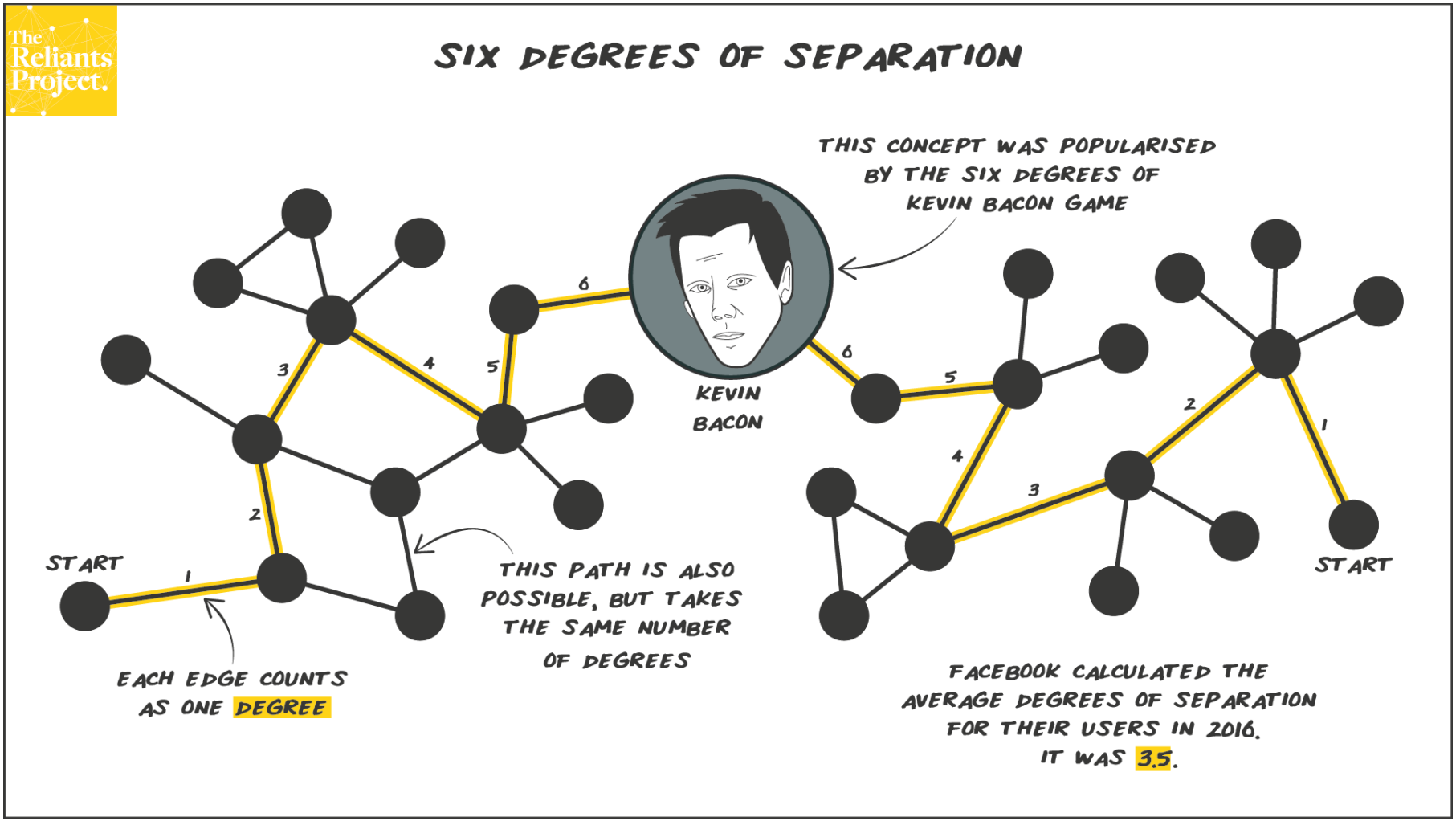

Figure 2: From six to four. Credits

Other Graph Examples?

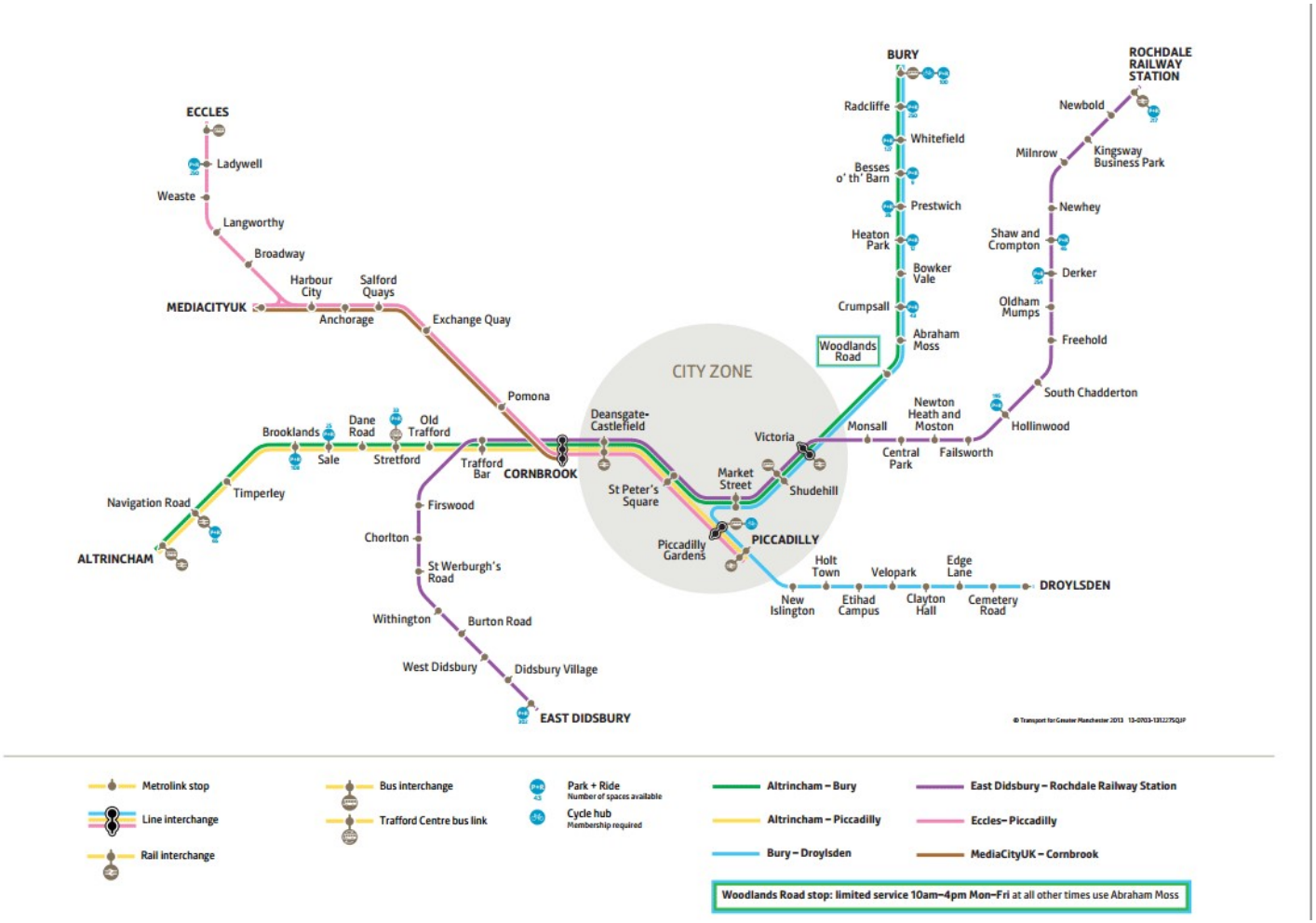

Figure 3: Manchester Tram Network

Other Graph Examples?

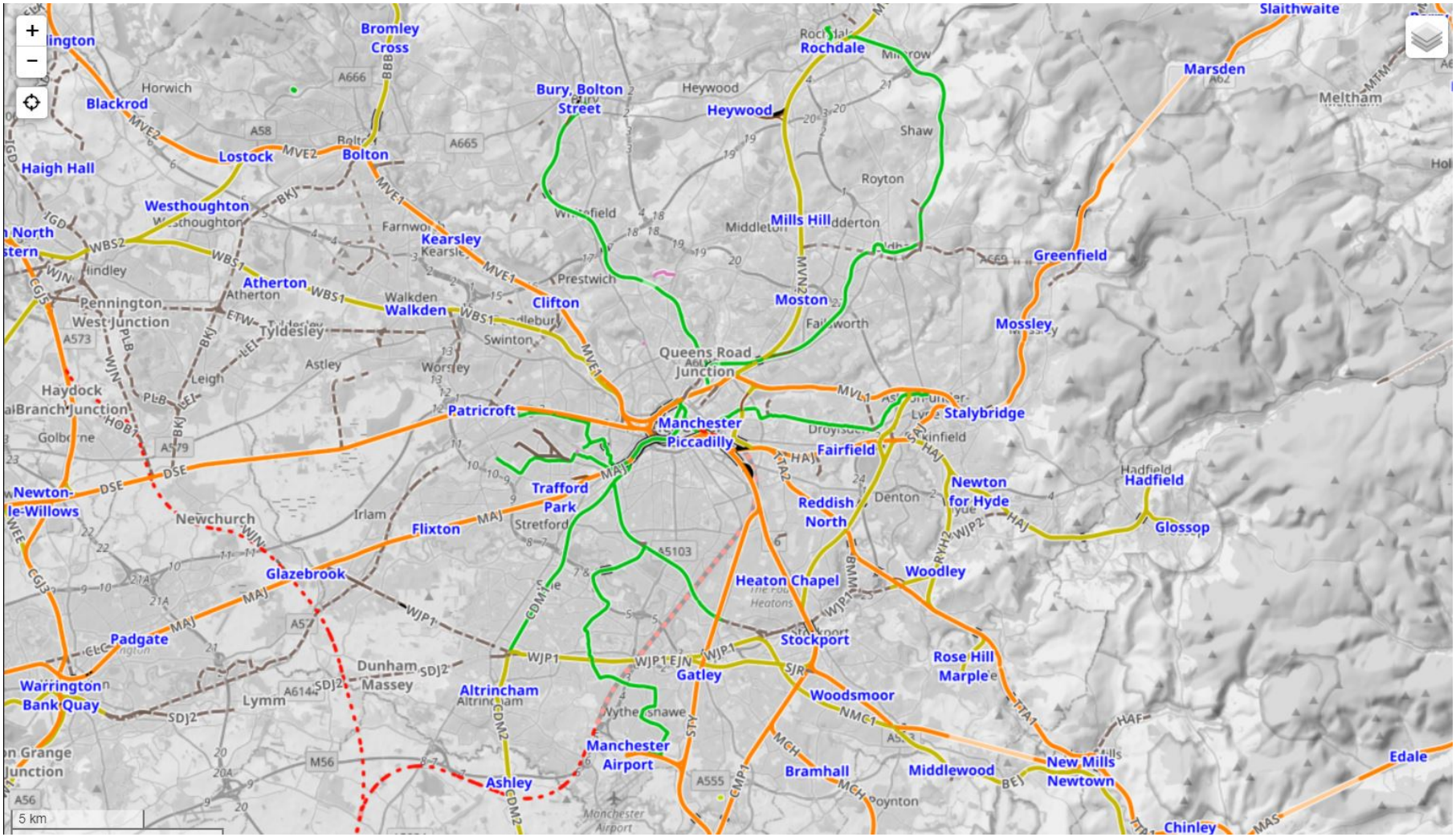

Figure 4: Railway system around Manchester

Other Graph Examples?

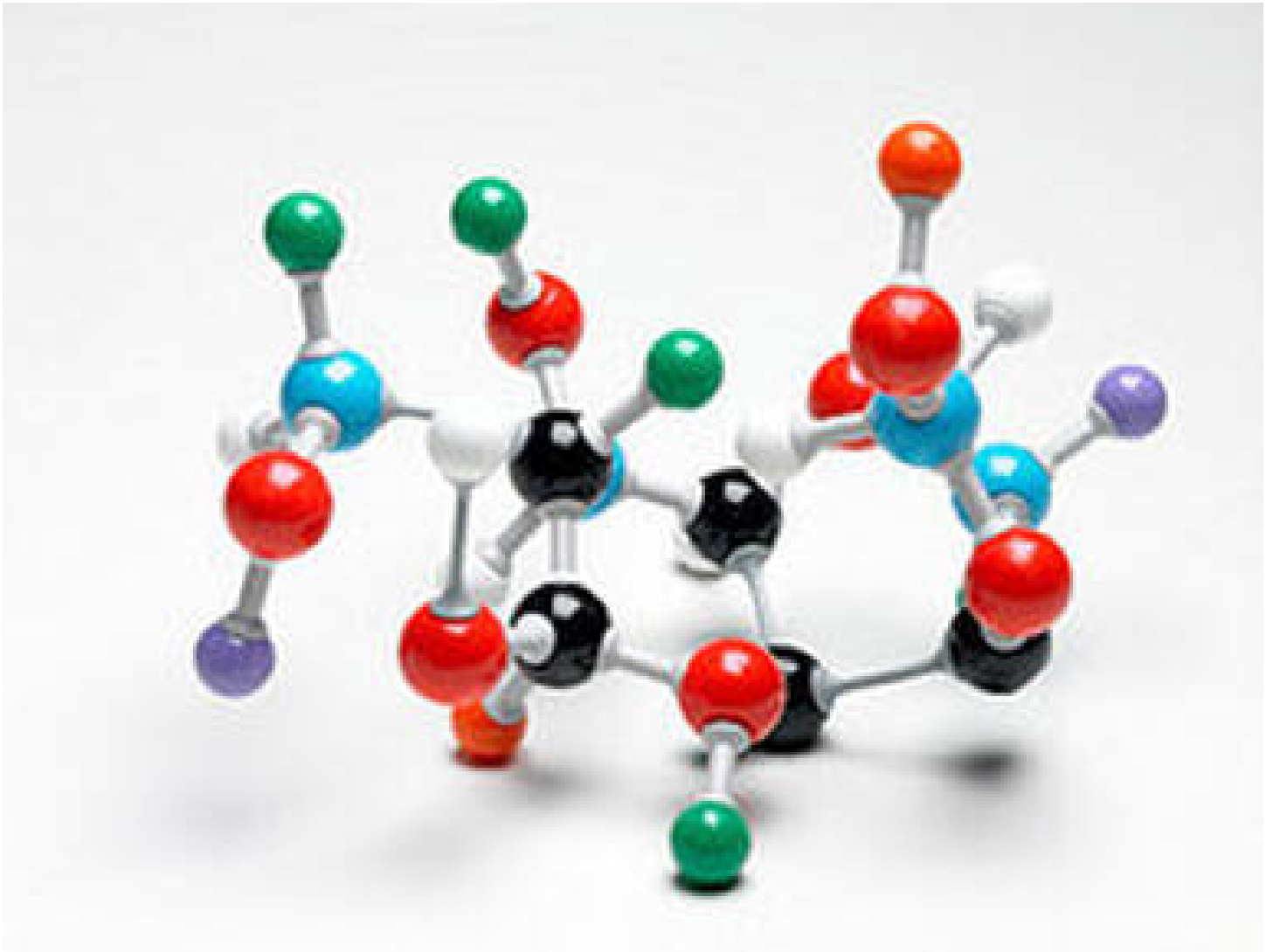

Figure 5: Chemical bonds as graph

Definition and Formulations

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Graph

A graph is a mathematical structure for representing relationships. It consists of a set of nodes connected by edges.

Representations

Graph $G = (V, E)$ consists **a set** of vertices denoted by V, or by $V(G)$ and **a set** of edges E, or $E(G)$

For a graph with n nodes

- $V = \{v_0, v_1, \cdots, v_{n-1}\}$
- $E = \{(v_0, v_1), (v_i, v_j), \cdots\}$

where $0 \leq i, j \leq n - 1$.

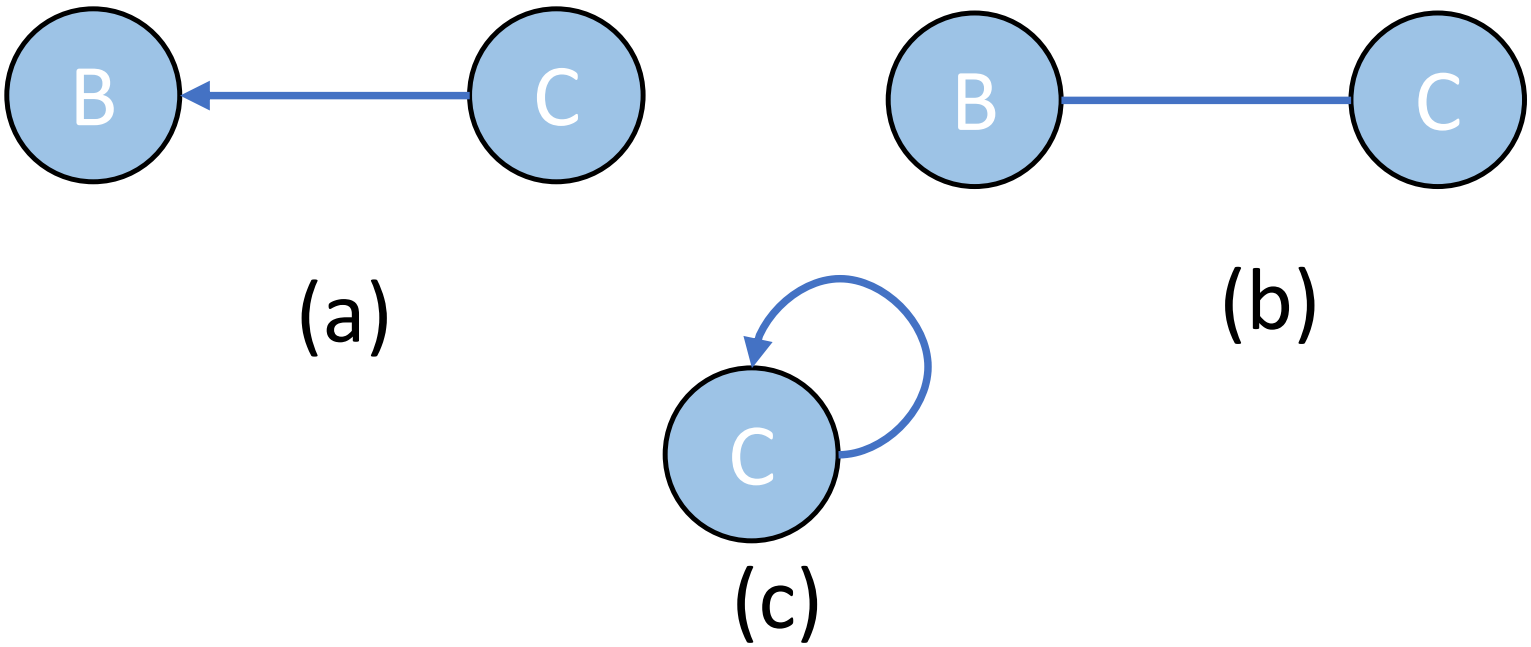
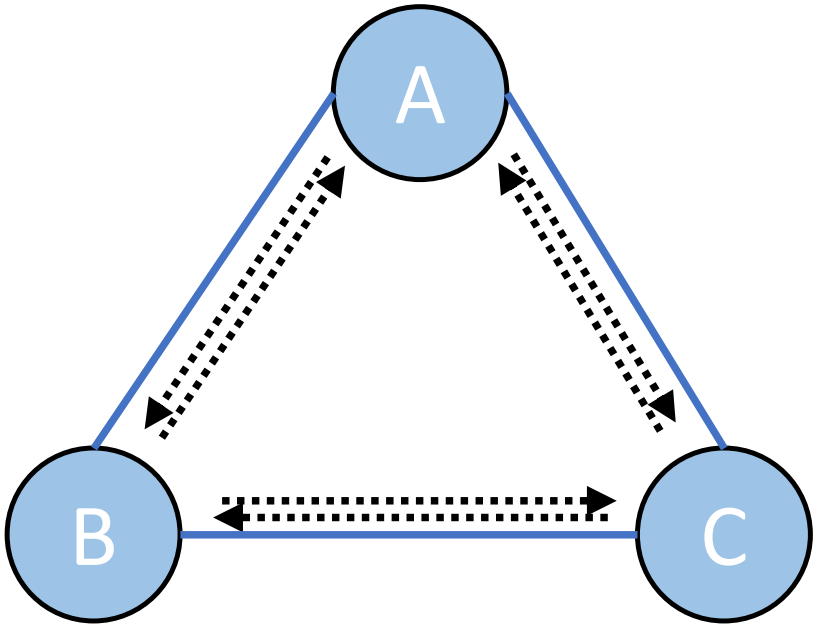


Figure 6: Edge type: (a) directed; (b) undirected; (c) loop

- Directed: An ordered pair of vertices, from node C to node B
- Undirected: An unordered pair of vertices, from node C to node B and vice versa
- Loop: from node C to itself

Undirected Graph



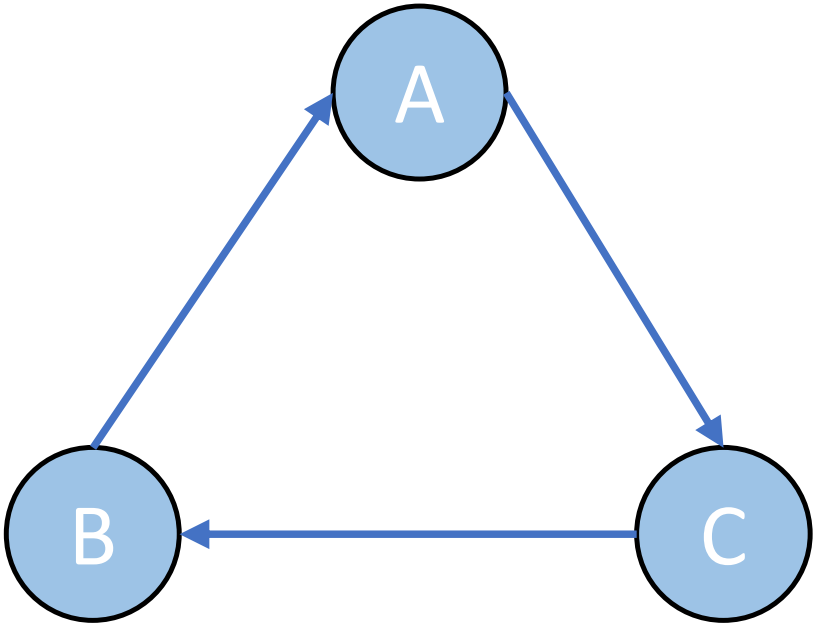
	A	B	C
A	0	1	1
B	1	0	1
C	1	1	0

Figure 7: An exemplar directed graph

Undirected (Simple) Graph

$G(V, E)$, consists of V, a nonempty set of vertices, and E, a set of unordered pairs of distinct elements of V called edges (undirected)
Representation Example:
$G(V, E), V = \{A, B, C\}, E = \{(A, B), (A, C), (B, C)\}$

Directed Graph



	A	B	C
A	0	0	1
B	1	0	0
C	0	1	0

Figure 8: An exemplar directed graph

Directed Graph

$G(V, E)$, a set of vertices V, and a set of Edges E, that are ordered pair of elements of V (directed edges)
Representation Example:
$G(V, E), V = \{A, B, C\}, E = \{(A, C), (C, B), (B, A)\}$

Adjacency Matrix

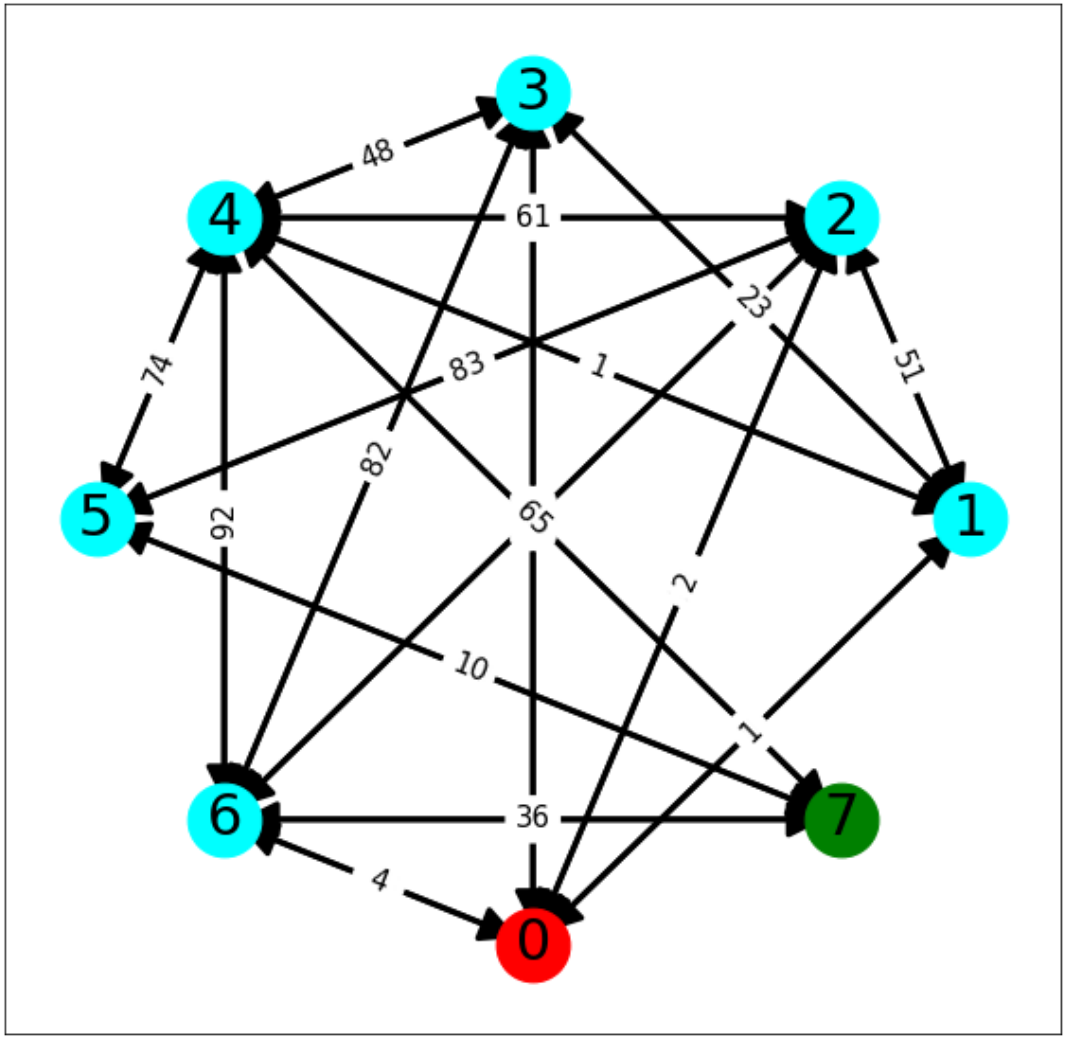


Figure 9: A directed matrix

Adjacency Matrix - continued

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	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	0	1	1	1	0	0	1	0
1	1	0	1	1	1	0	0	0
2	1	1	0	0	1	1	1	0
3	1	1	0	0	1	0	1	0
4	0	1	1	1	0	1	1	1
5	0	0	1	0	1	0	0	1
6	1	0	1	1	1	0	0	1
7	0	0	0	0	1	1	1	0

Table 1: Adjacency matrix

Adjacency Matrix

In graph theory and computer science, an adjacency matrix is a square matrix used to represent a finite graph. The elements of the matrix indicate whether pairs of vertices are adjacent or not in the graph. Normally, 1 for adjacent, 0 for otherwise.

Adjacency Matrix - continued

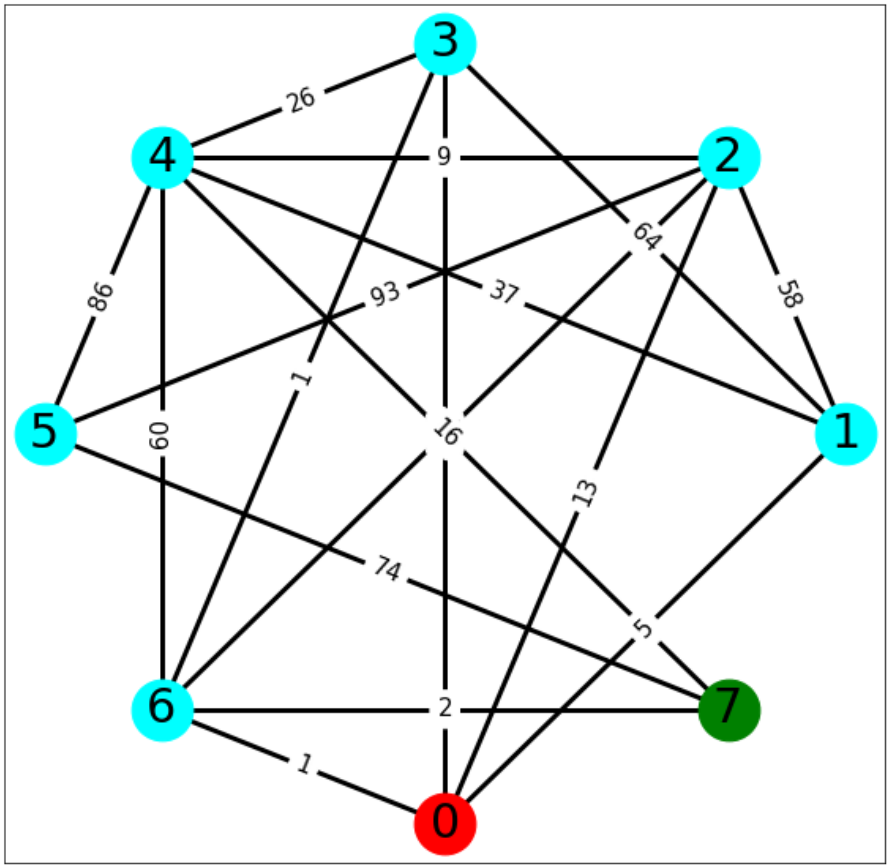

Figure 10: A directed matrix

What's the adjacency matrix of this graph? Replace 1 with weights!

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Trees

1. In computer science, a tree is a widely used abstract data type that represents a hierarchical tree structure with a set of connected nodes.
2. Each node in the tree can be connected to many children (depending on the type of tree), but must be connected to exactly one parent, except for the root node, which has no parent.
3. No cycles or "loops" (no node can be its own ancestor), and also that each child can be treated like the root node of its own subtree, making recursion a useful technique for tree traversal.
4. **Binary trees** are a commonly used type, which constrain the number of children for each parent to exactly two. When

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Trees

A connected acyclic graph is called a tree. In other words, a connected graph with no cycles is called a tree.

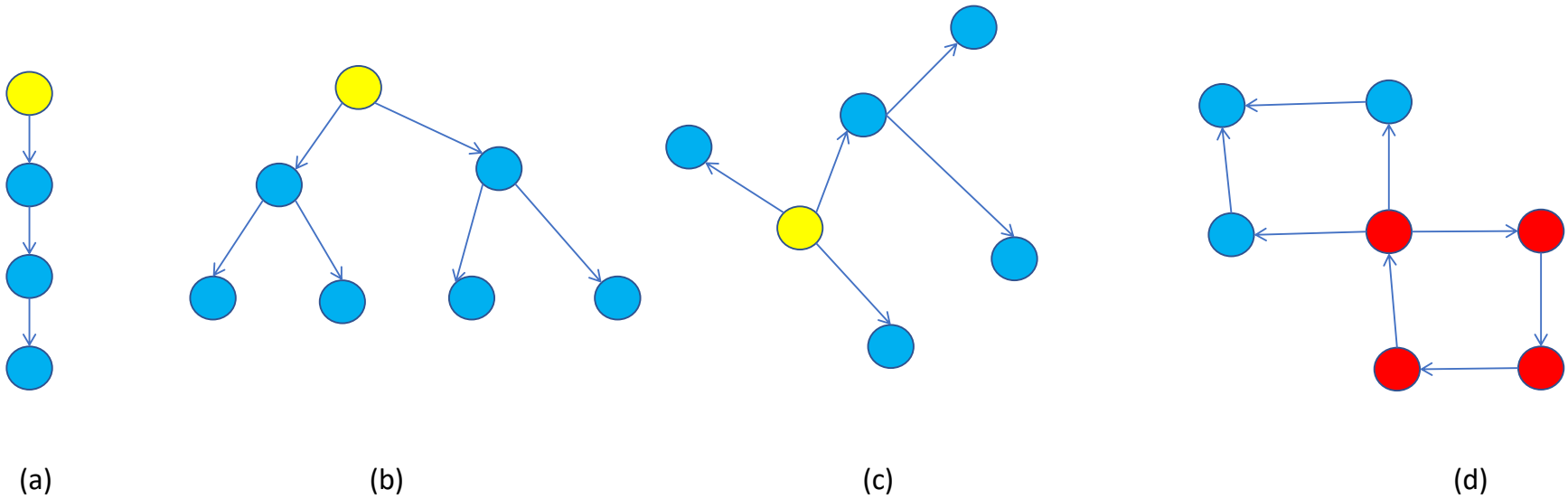
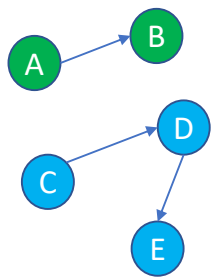
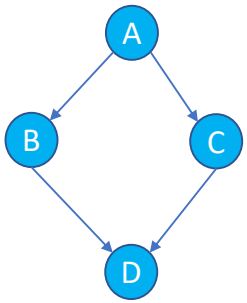
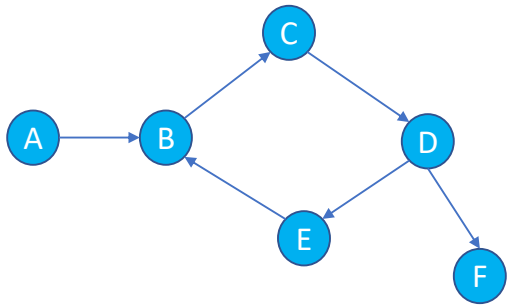
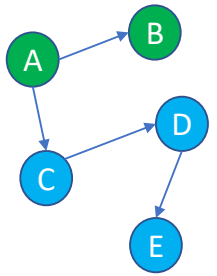


Figure 11: Examples of trees (a) - (c), and is graph but not tree (d)

Note: Yellow nodes are usually called 'root' nodes. (b) is a 'good' tree, i.e., binary tree (each node has at most two children).

Graphs vs Trees

Not a tree, more than one root (A, C)	Not a tree, an undirected circle. D has more than two parents	Not a tree, a directed circle. B has more than two parents	Not a tree, A is the root and also a child	Is a tree
				
A tree has only one root	Circles are not allowed in trees, whether it is directed or undirected. Circles will lead to nodes with more than on parent		The root of a tree cannot be a child	

Note: They are all graphs. Directed Acyclic Graph (DAG) is a directed graph with no directed cycles.

Comparison of trees and graphs I

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Table 2: Comparison of Trees and Graphs

Concepts	Trees	Graphs
Path	Tree is special form of graph i.e. minimally connected graph and having only one path between any two vertices.	In graph there can be more than one path i.e. graph can have uni-directional or bi-directional paths (edges) between nodes
Loops	Tree is a special case of graph having no loops, no circuits and no self-loops.	Graph can have loops, circuits as well as can have self-loops.
Root Node	In tree there is exactly one root node and every child have only one parent.	In graph there is no such concept of root node.

Comparison of trees and graphs II

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Parent Child Relationship	In trees, there is parent child relationship so flow can be there with direction top to bottom or vice versa.	In Graph there is no such parent child relationship.
Complexity	Trees are less complex than graphs as having no cycles, no self-loops and still connected.	Graphs are more complex in compare to trees as it can have cycles, loops etc.
Types of Traversal	Tree traversal is a kind of special case of traversal of graph. Tree is traversed in Pre-Order, In-Order and Post-Order (all three in DFS or in BFS algorithm)	Graph is traversed by Depth First Search (DFS) and in Breadth First Search (BFS) algorithm

Comparison of trees and graphs III

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Connection Rules	In trees, there are many rules / restrictions for making connections between nodes through edges.	In graphs no such rules/ restrictions are there for connecting the nodes through edges.
DAG	Trees come in the category of DAG : Directed Acyclic Graphs is a kind of directed graph that have no cycles.	Graph can be Cyclic or Acyclic.
Different Types	Different types of trees are : Binary Tree , Binary Search Tree, AVL tree, Heaps.	There are mainly two types of Graphs : Directed and Undirected graphs.
Applications	Tree applications: sorting and searching like Tree Traversal & Binary Search.	Graph applications: Coloring of maps, in OR (PERT & CPM), algorithms, Graph coloring, job scheduling, etc.

Comparison of trees and graphs IV

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No. of edges	Tree always has n-1 edges.	In Graph, no. of edges depend on the graph.
Model	Tree is a hierarchical model.	Graph is a network model.

Networkx

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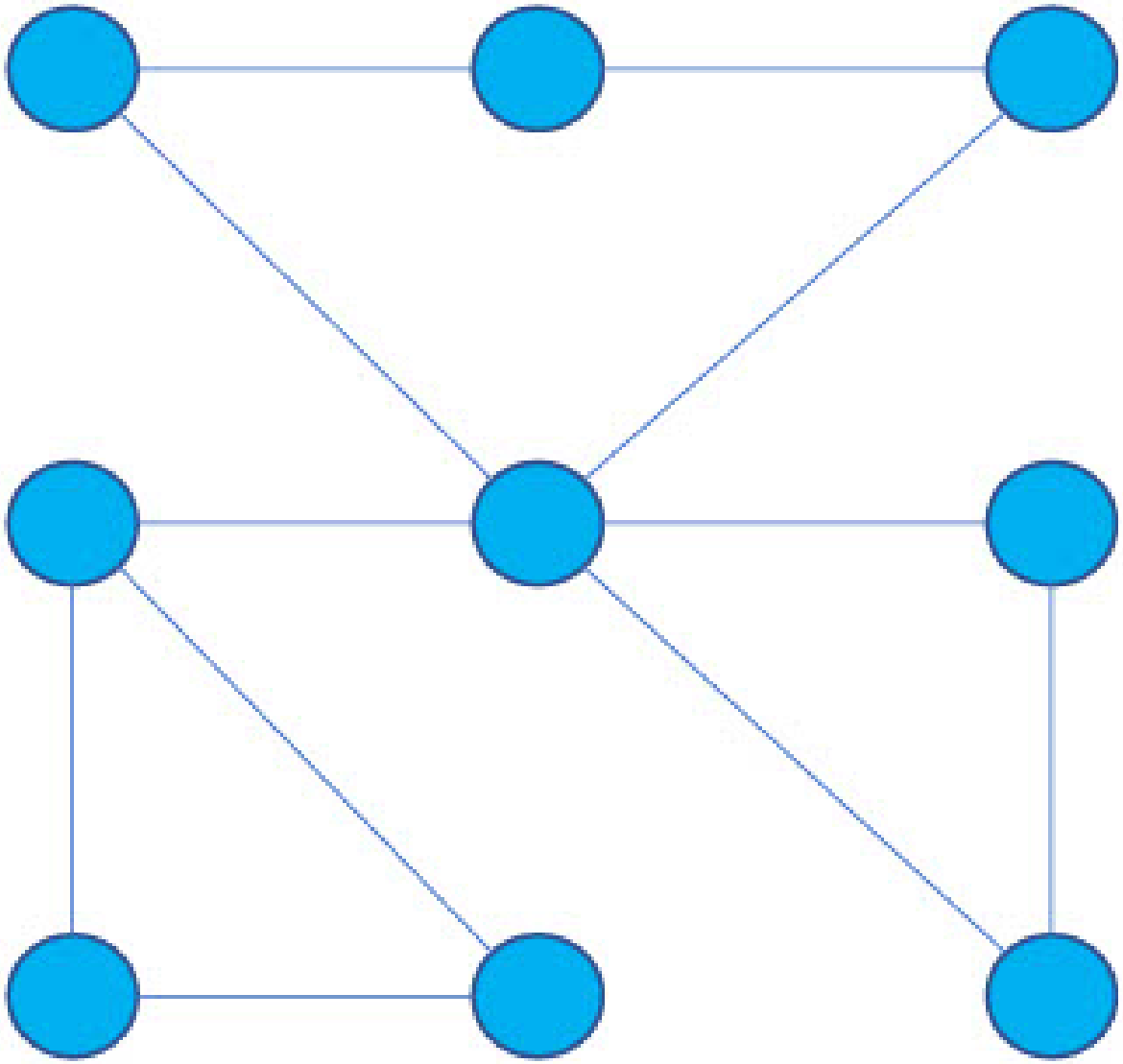
Using Networkx to generate and visualise graphs/trees

- The 'networkx_graph.ipynb' tutorial
- Visualisation
- Tutorial
- More reading
- More on Adjacency Matrix
- DFS with Adjacency Matrix

Graph Search Trees



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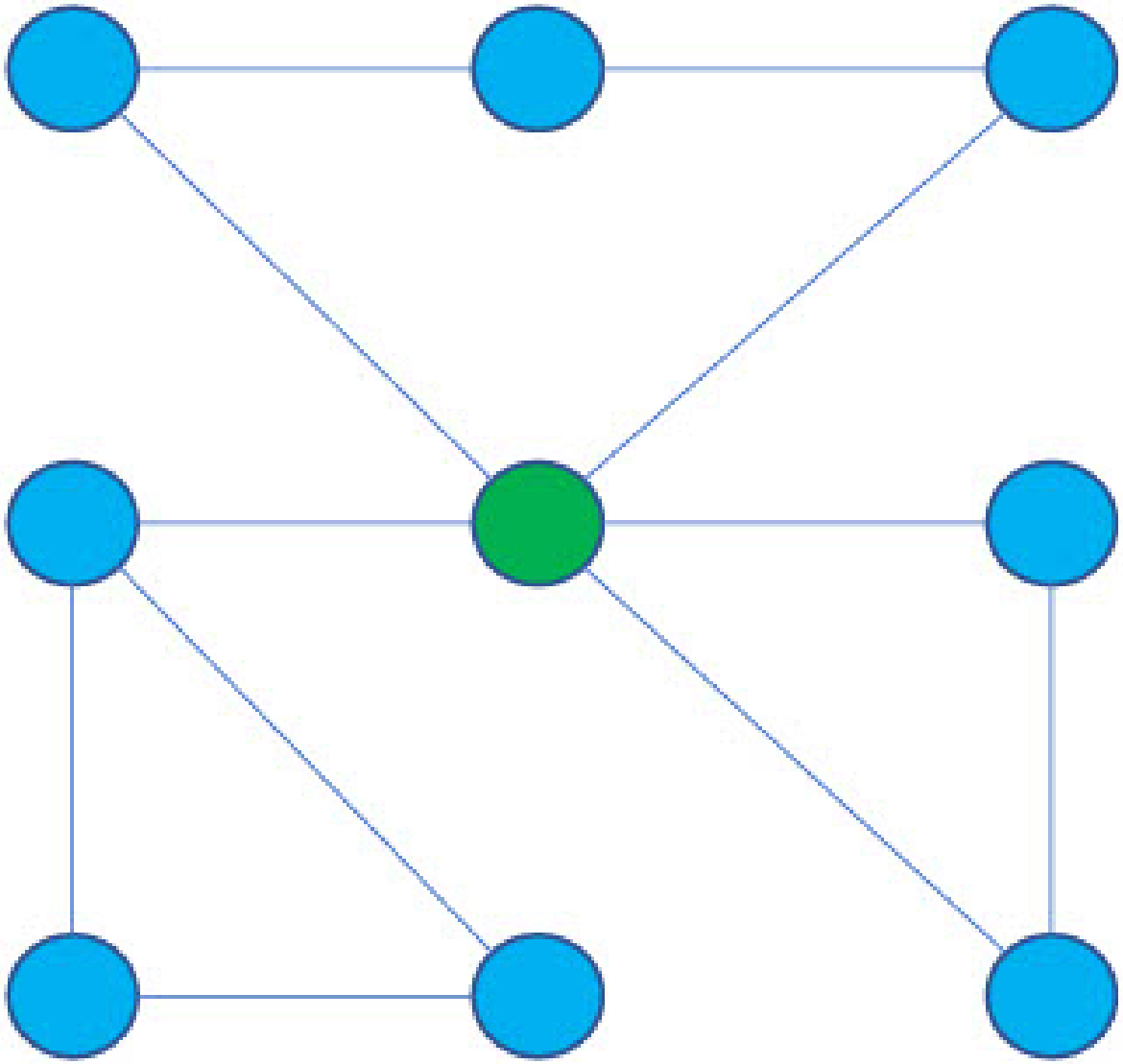

Graph Search Trees

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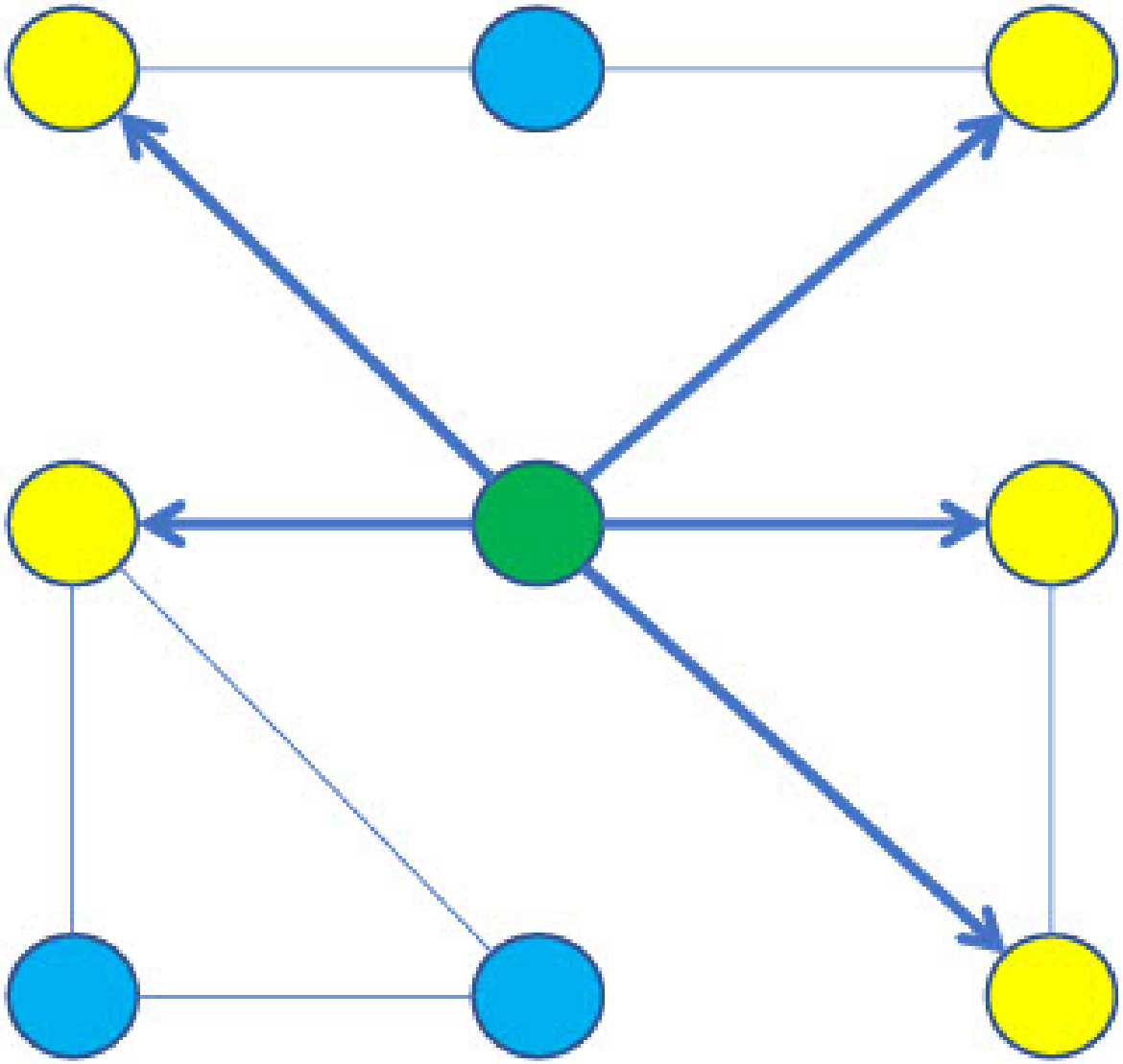

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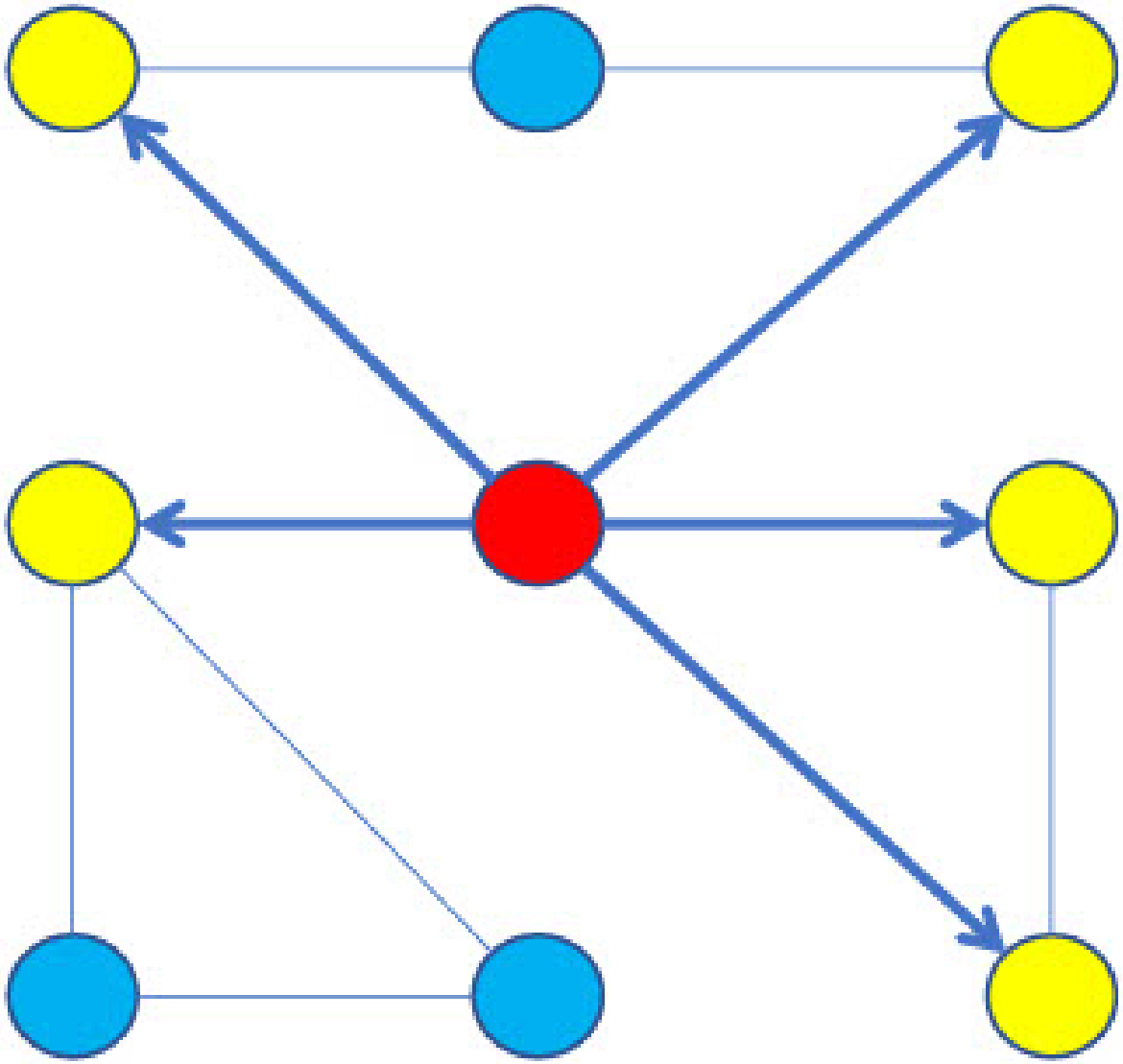

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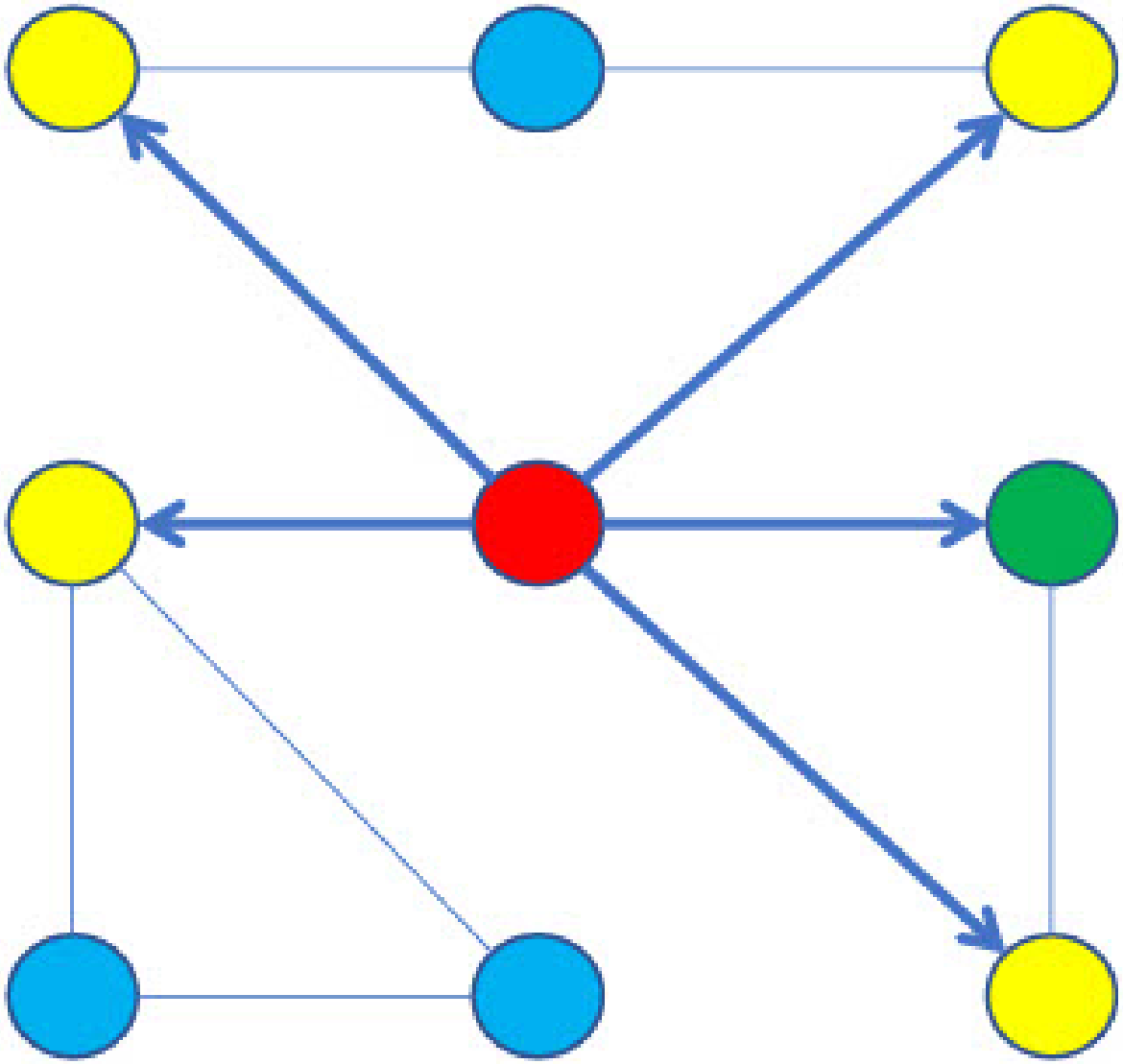

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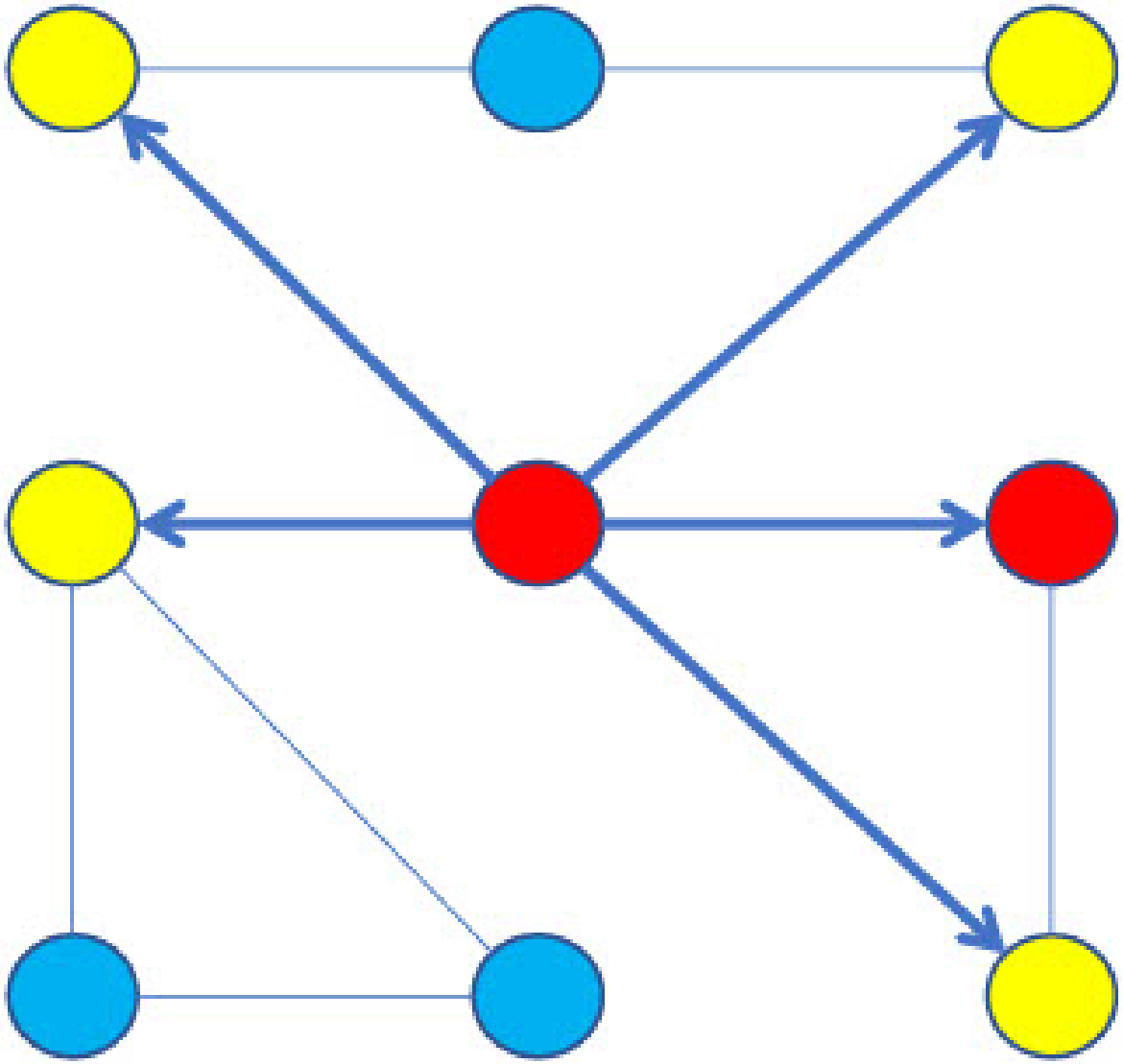

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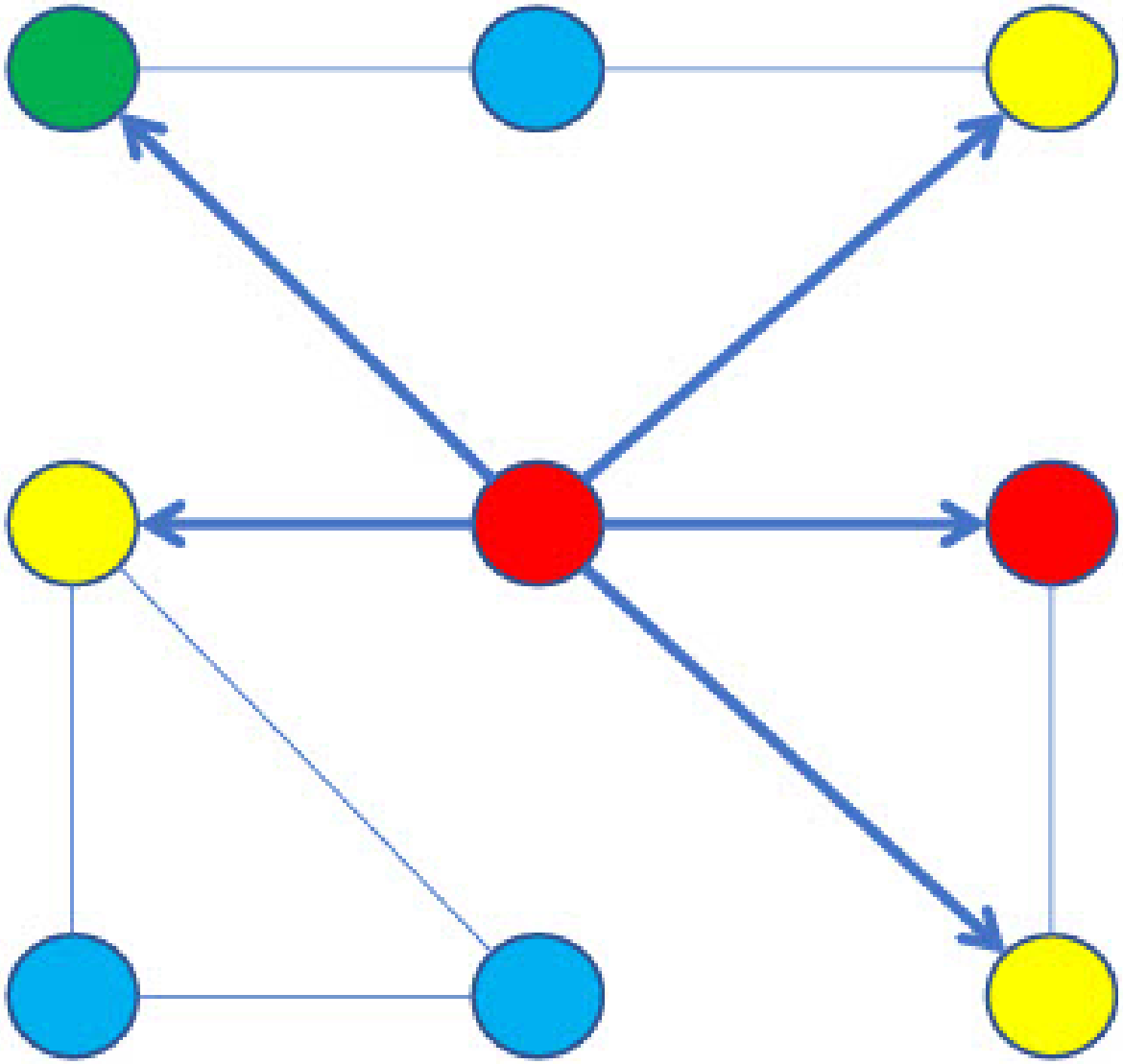

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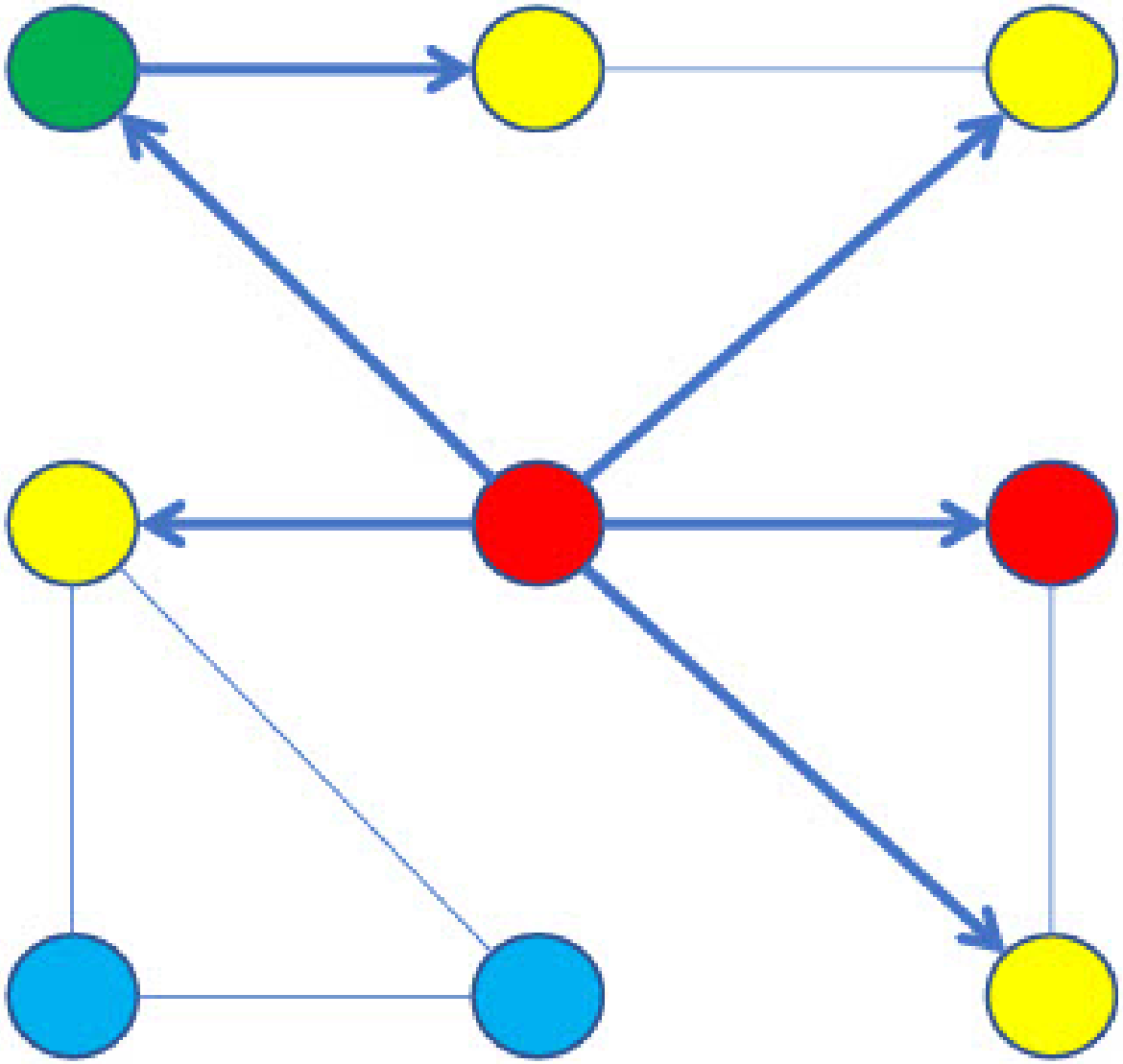

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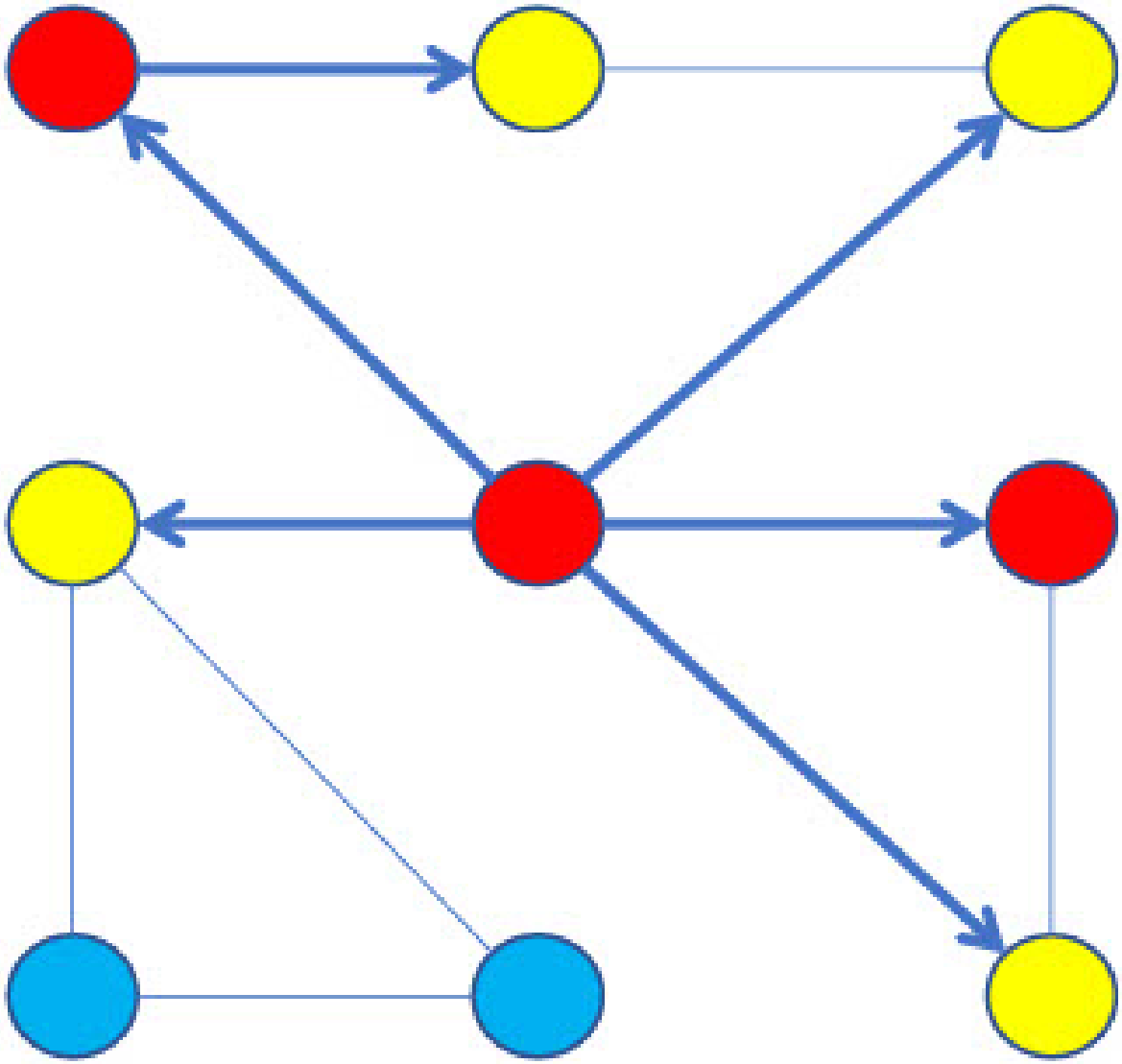

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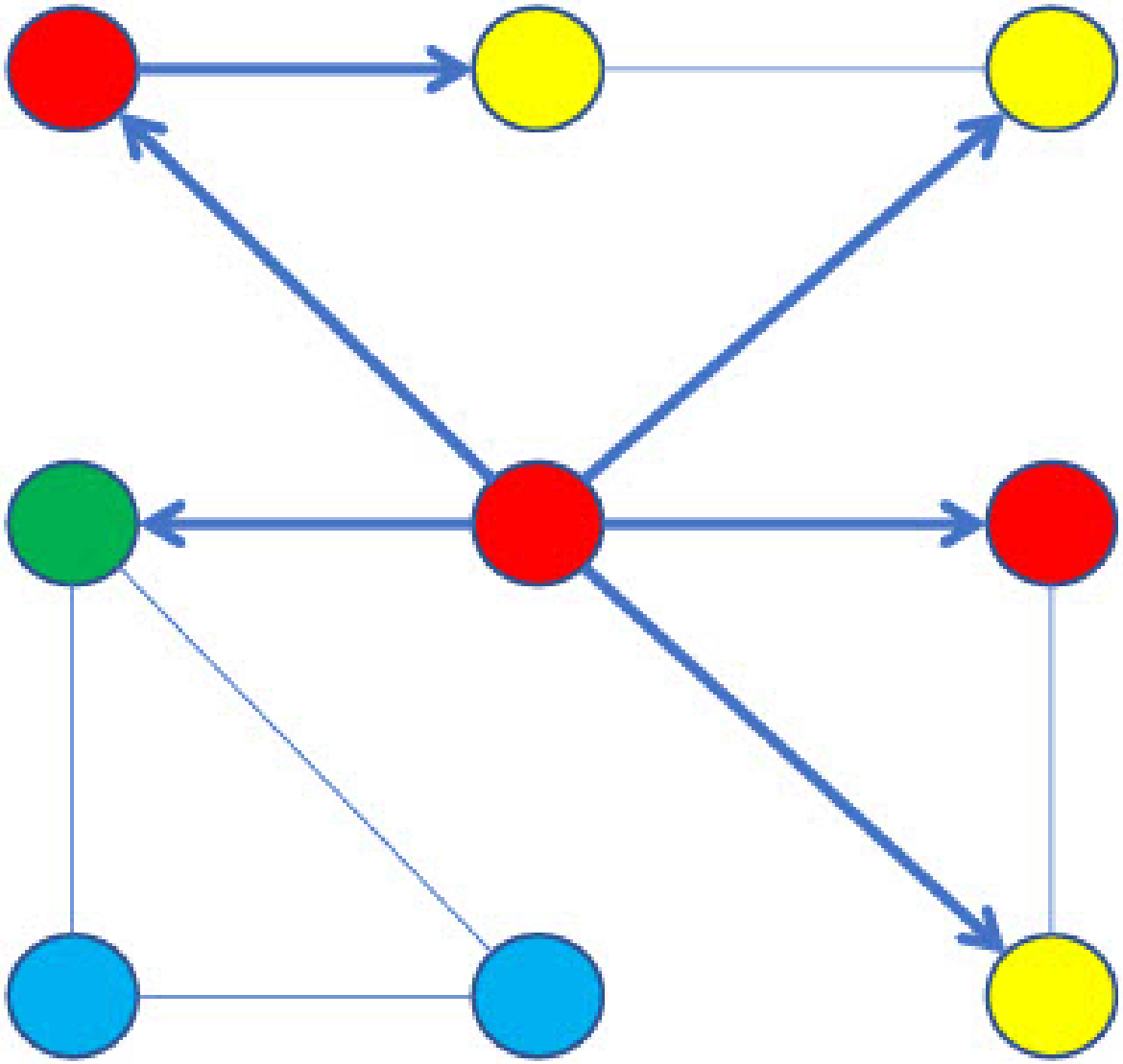

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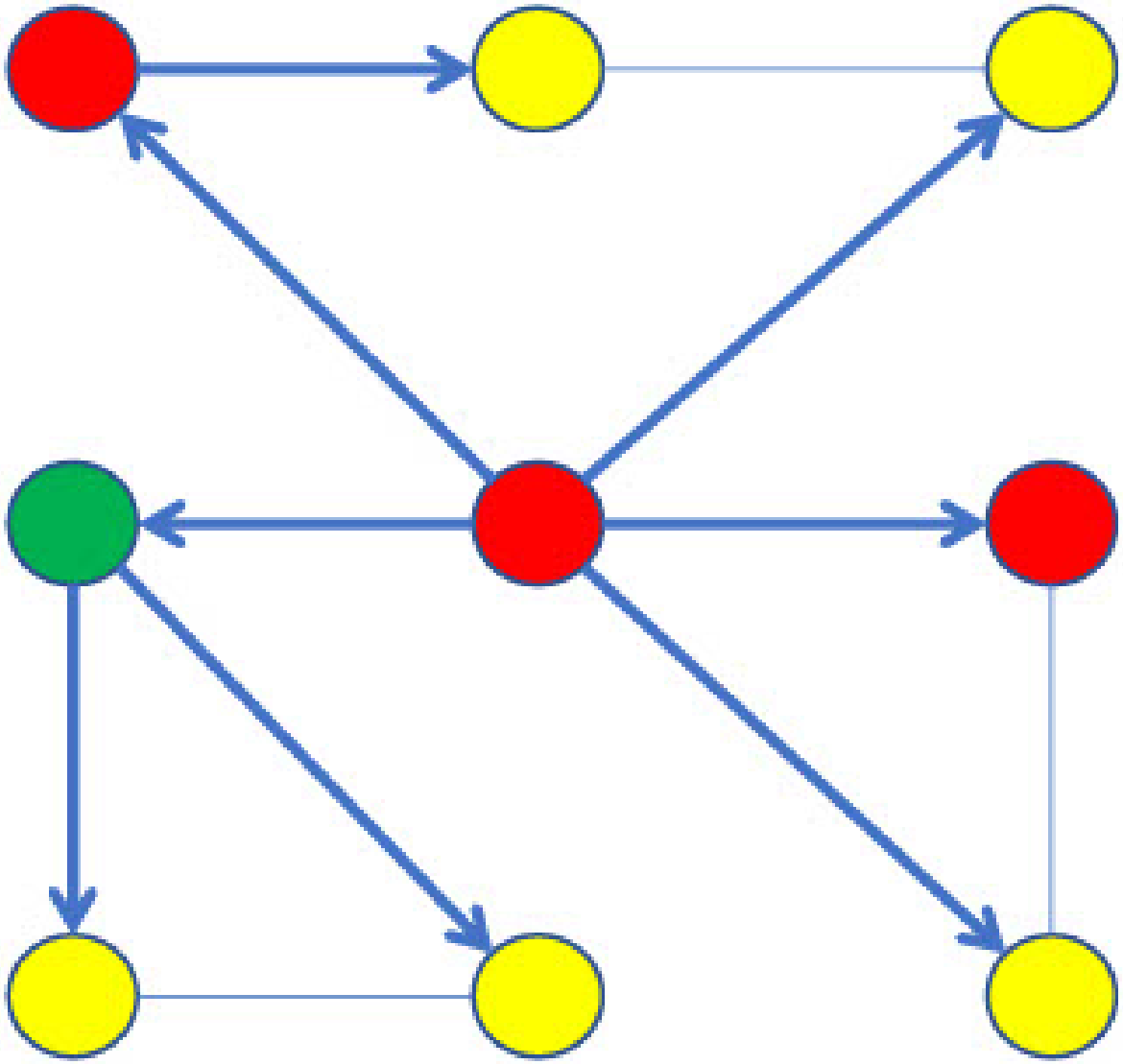

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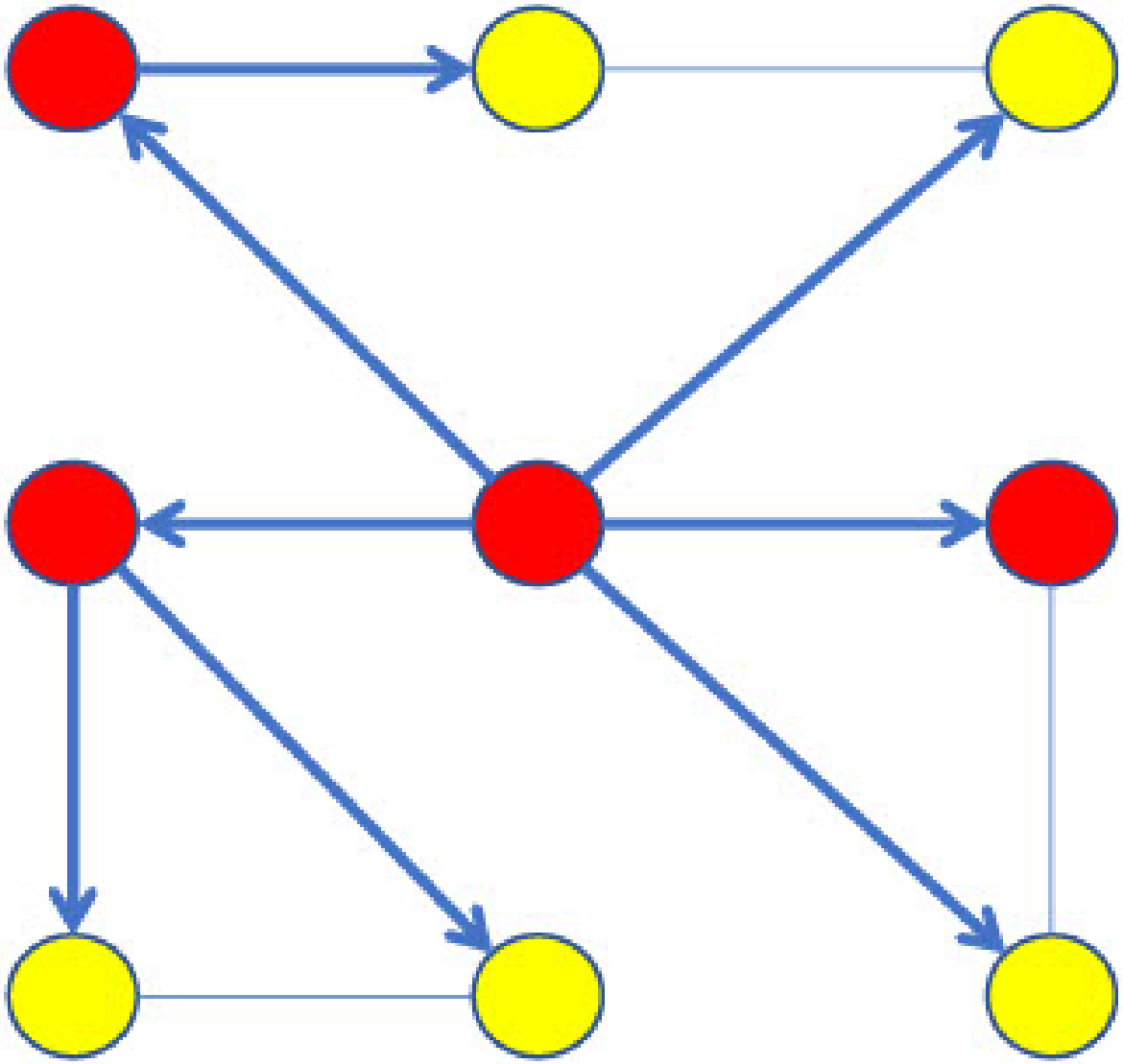

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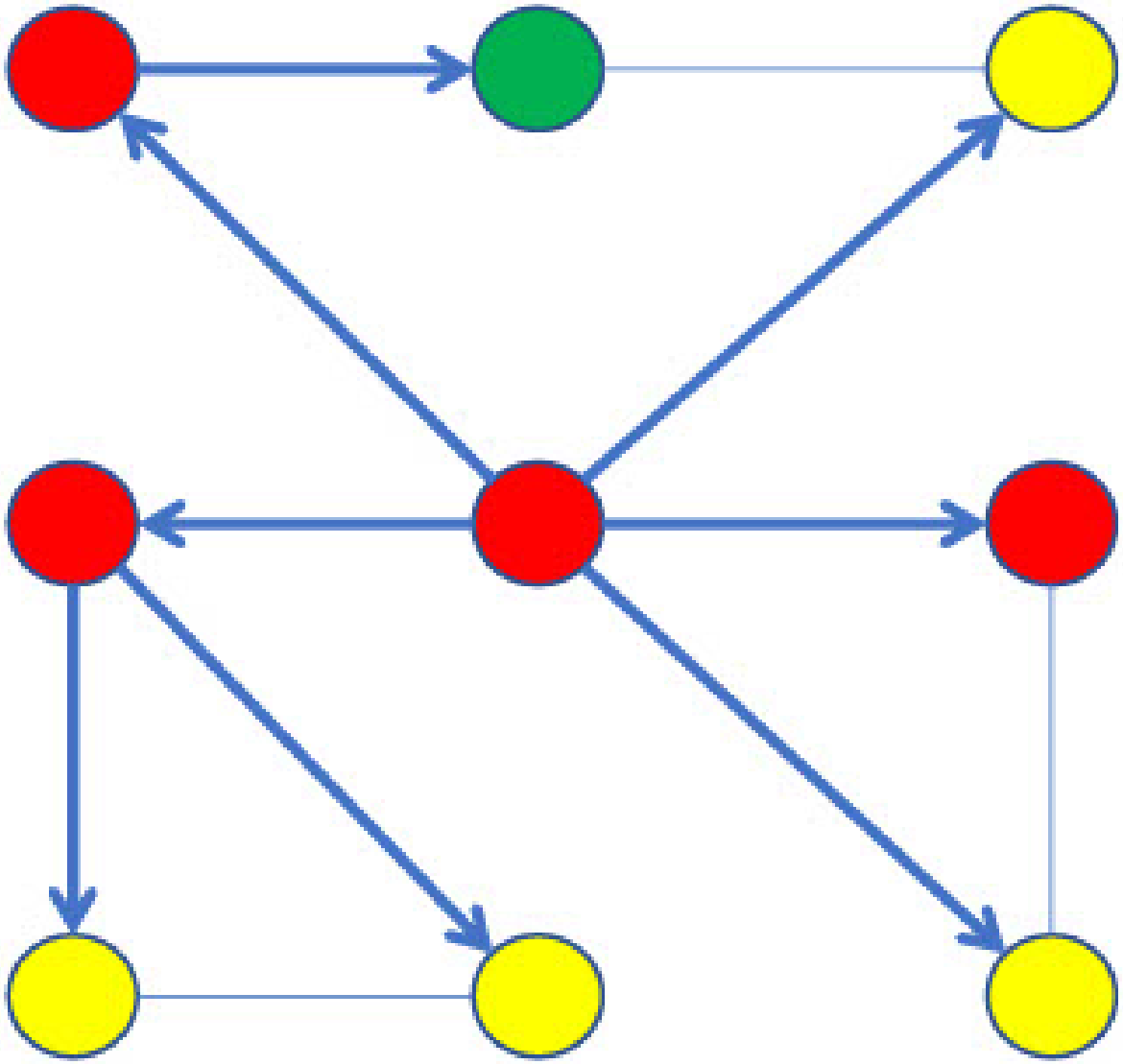

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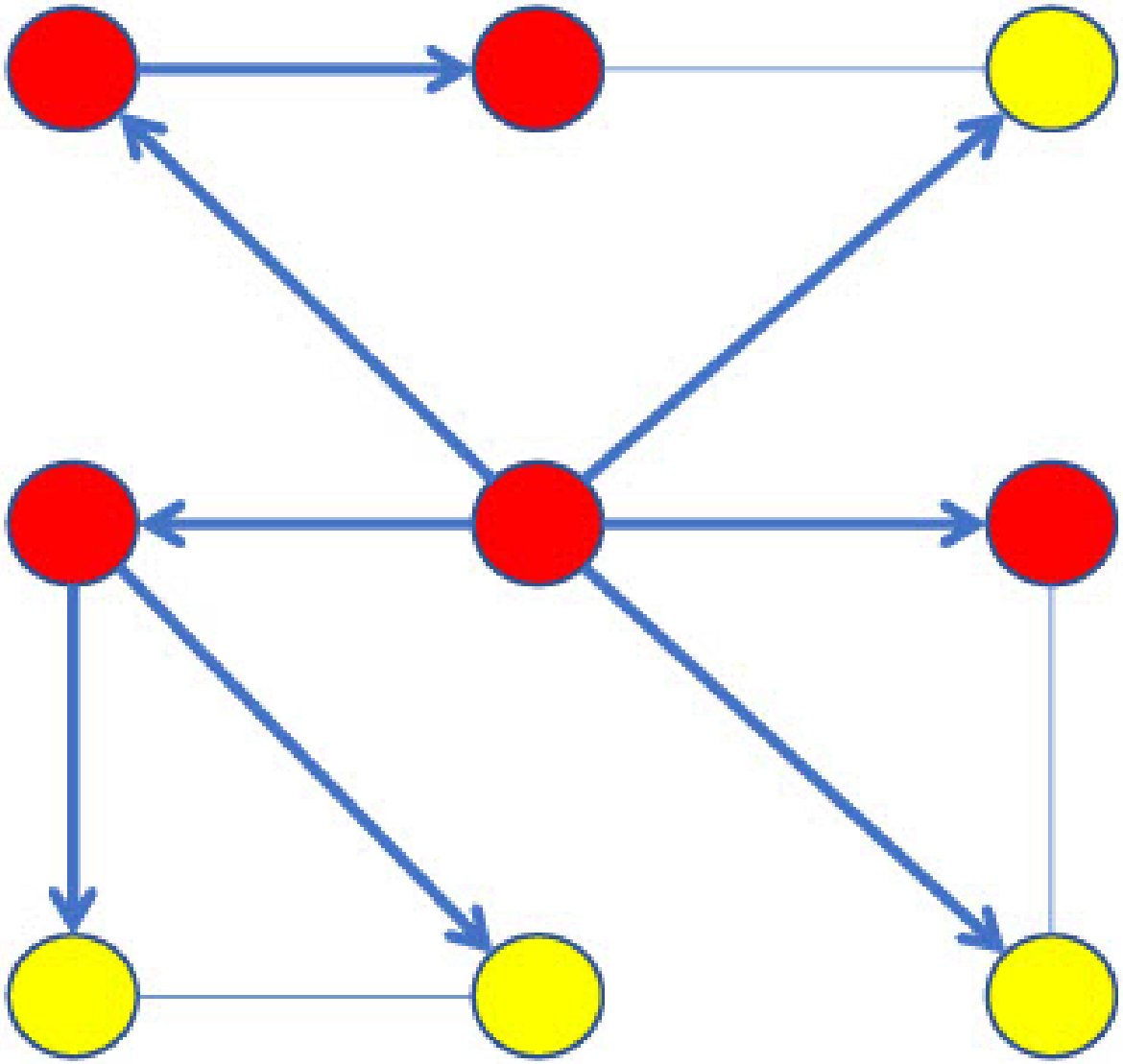

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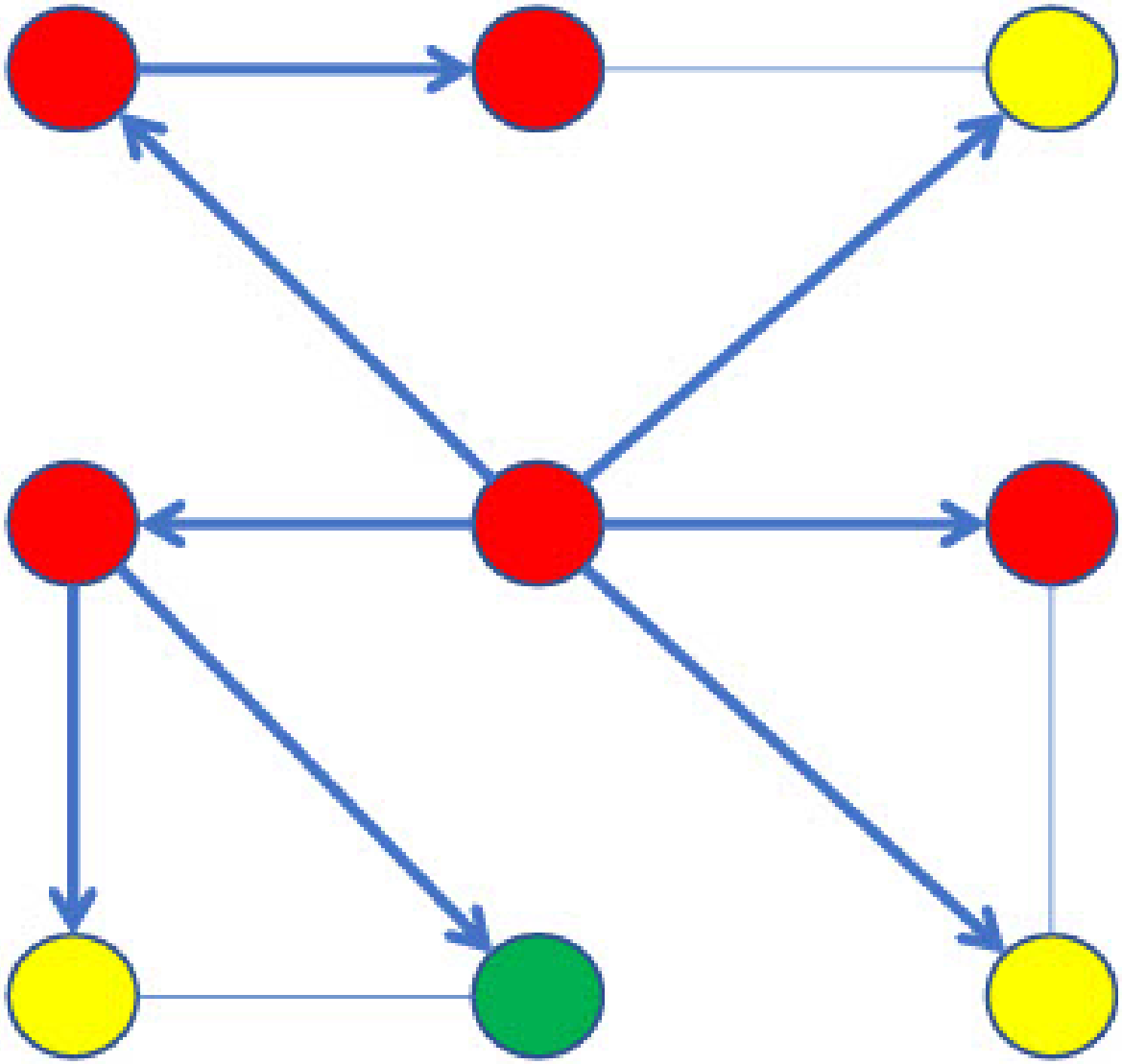

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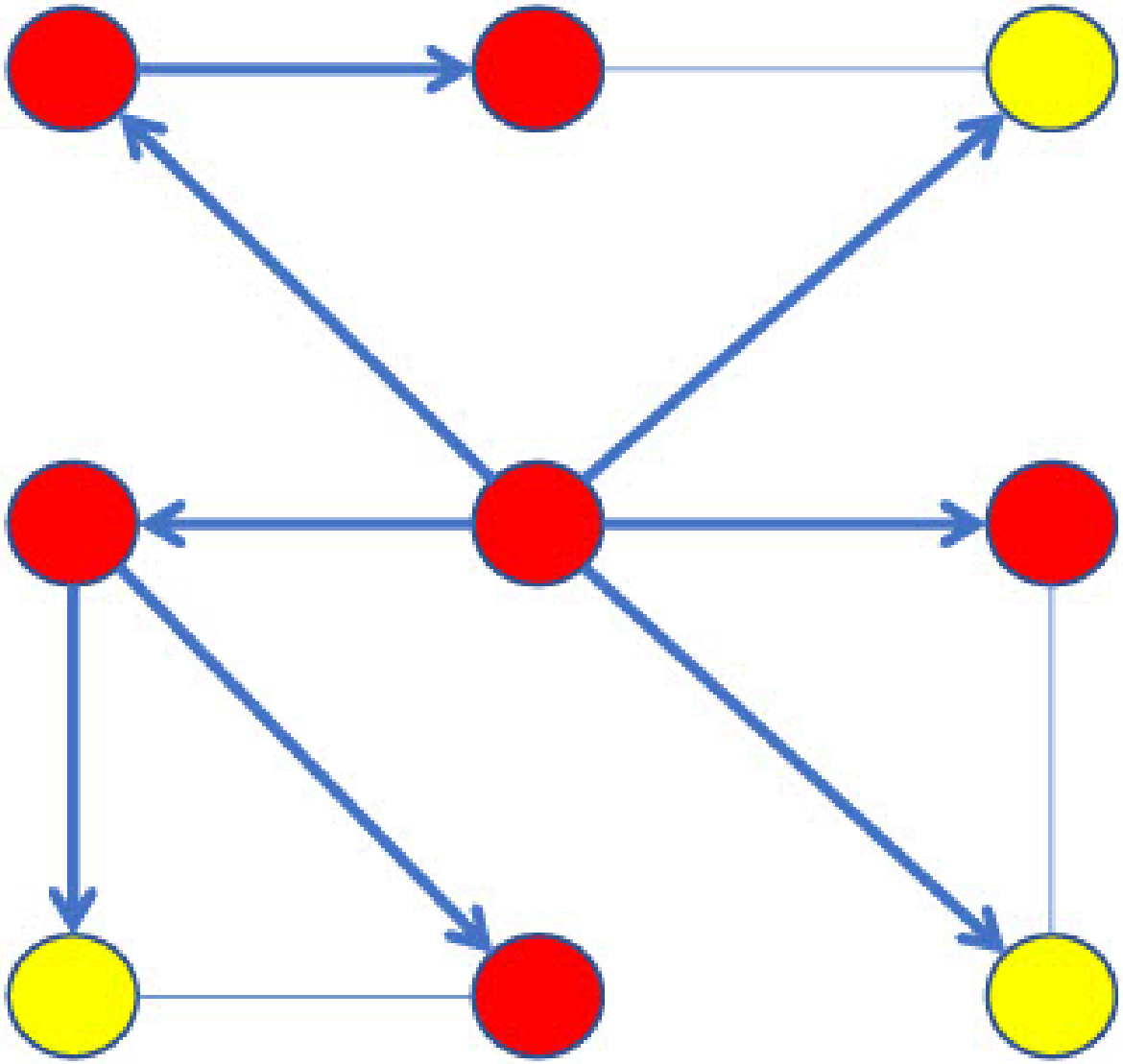

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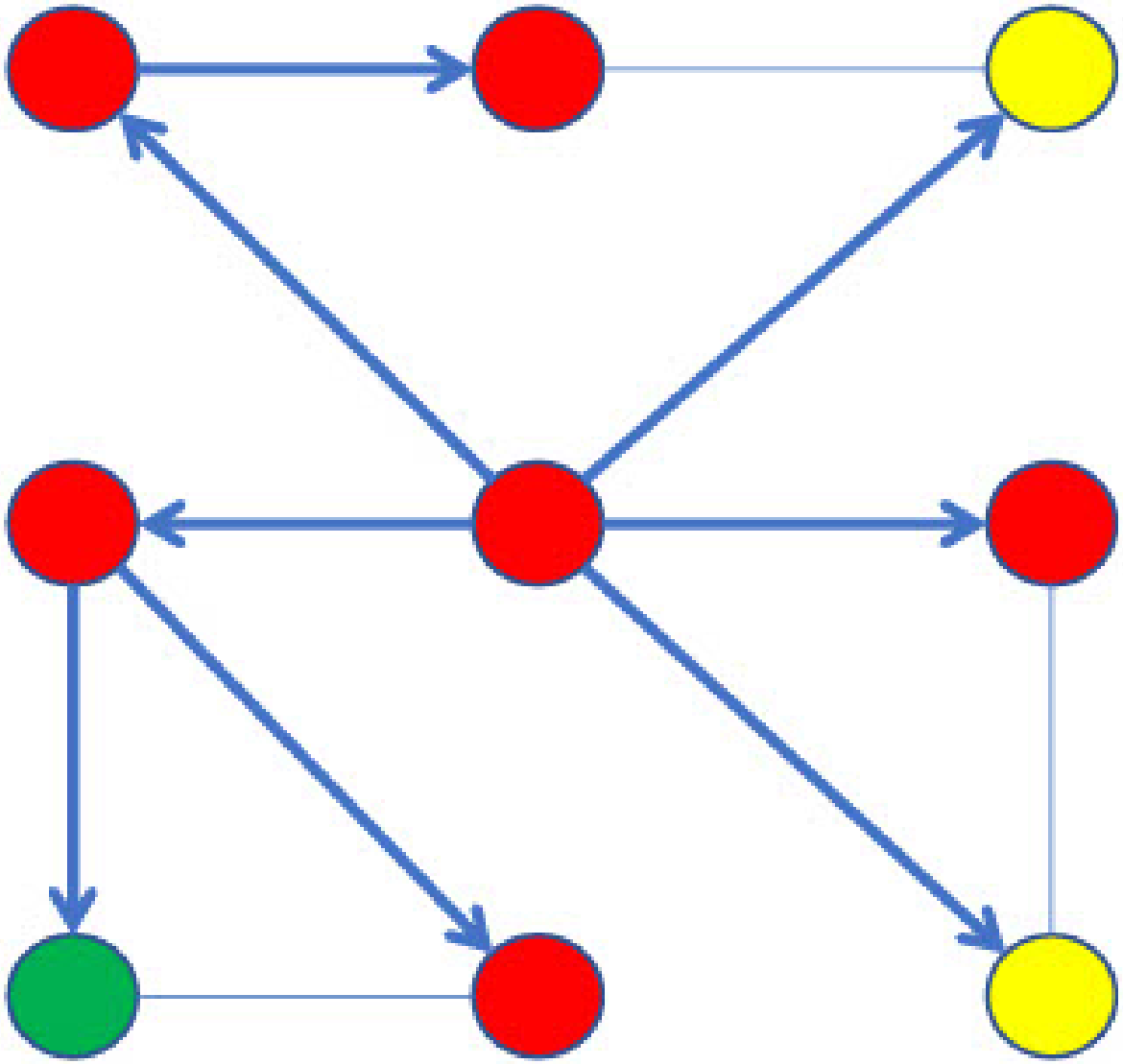

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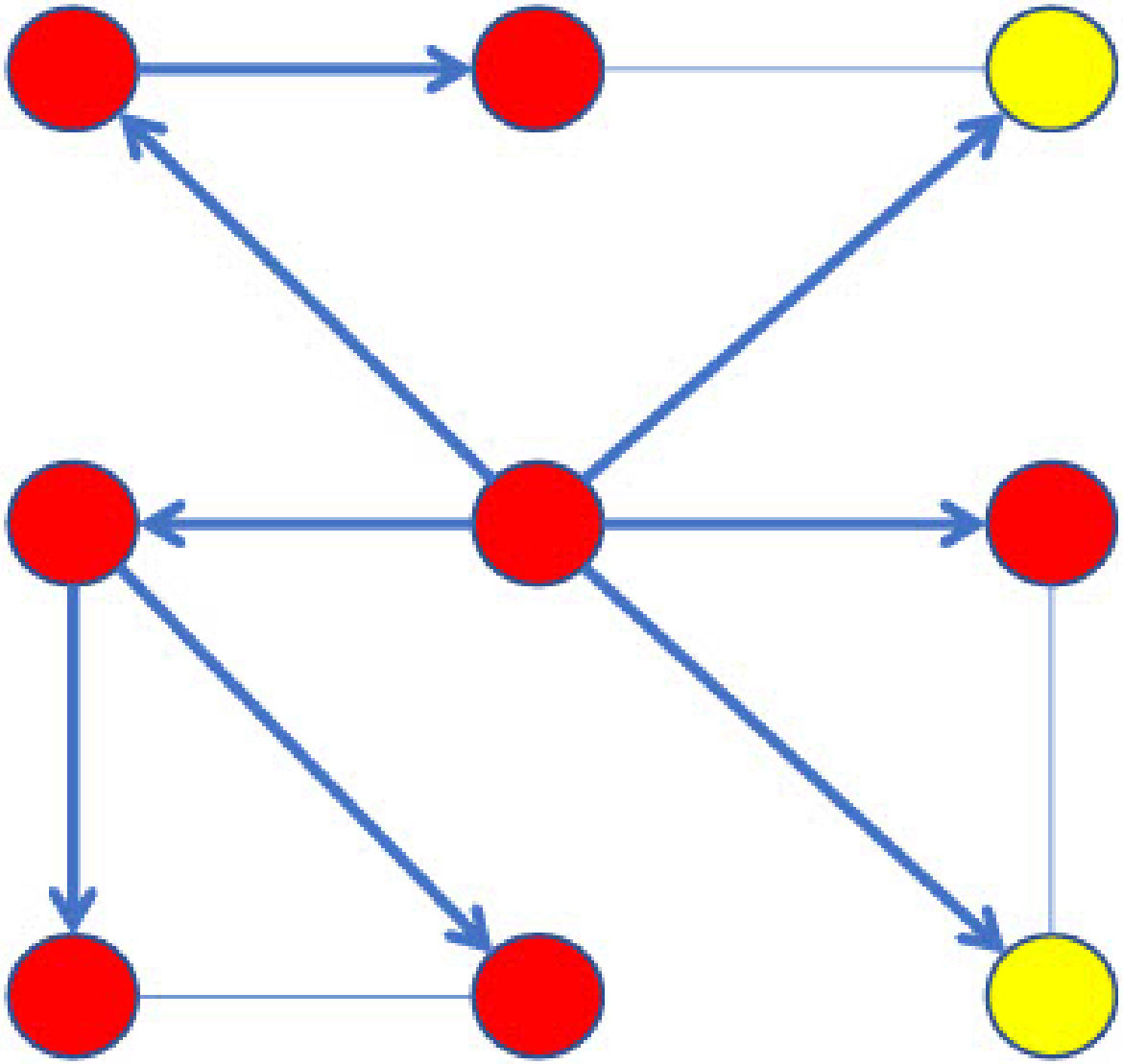

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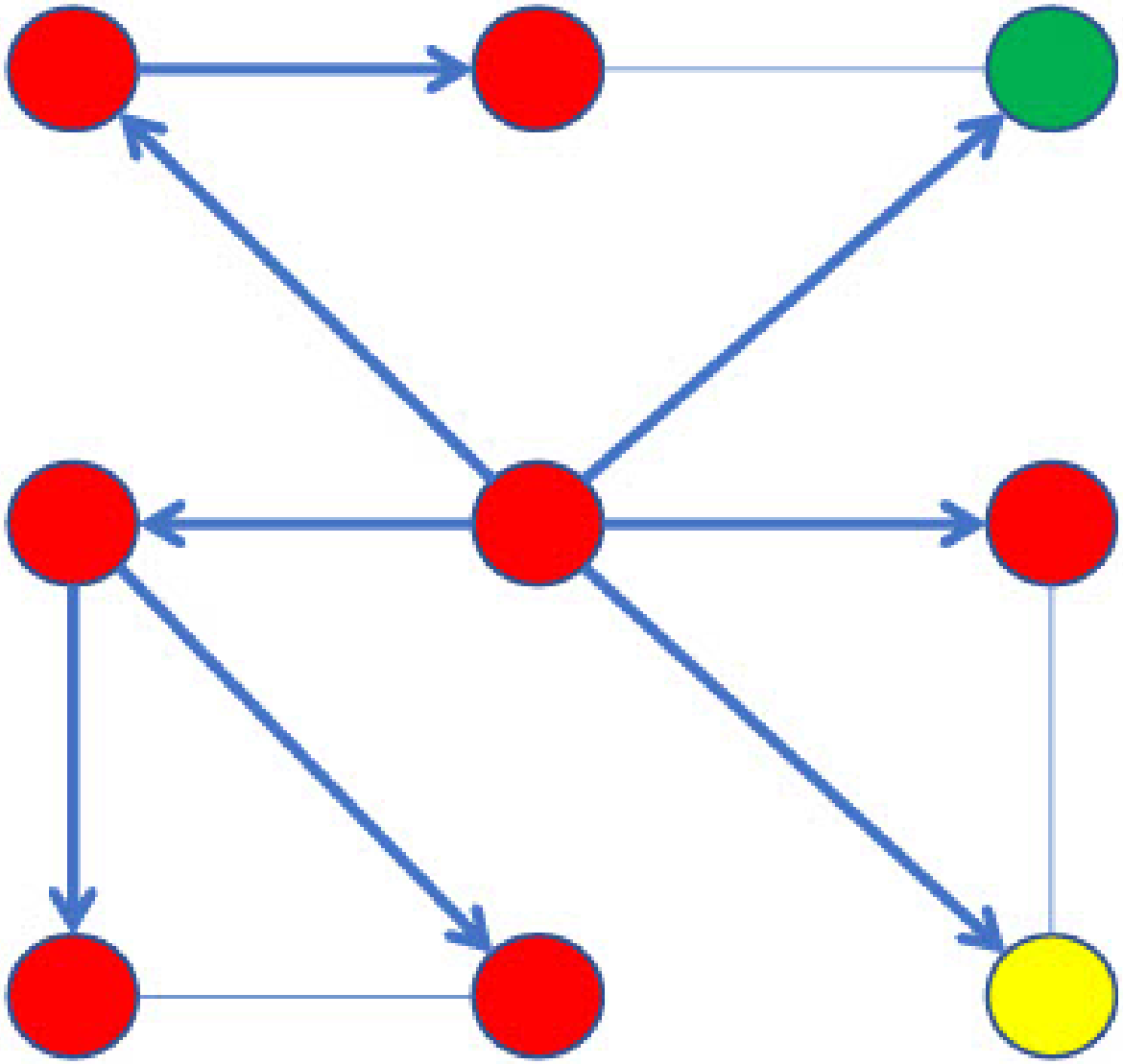

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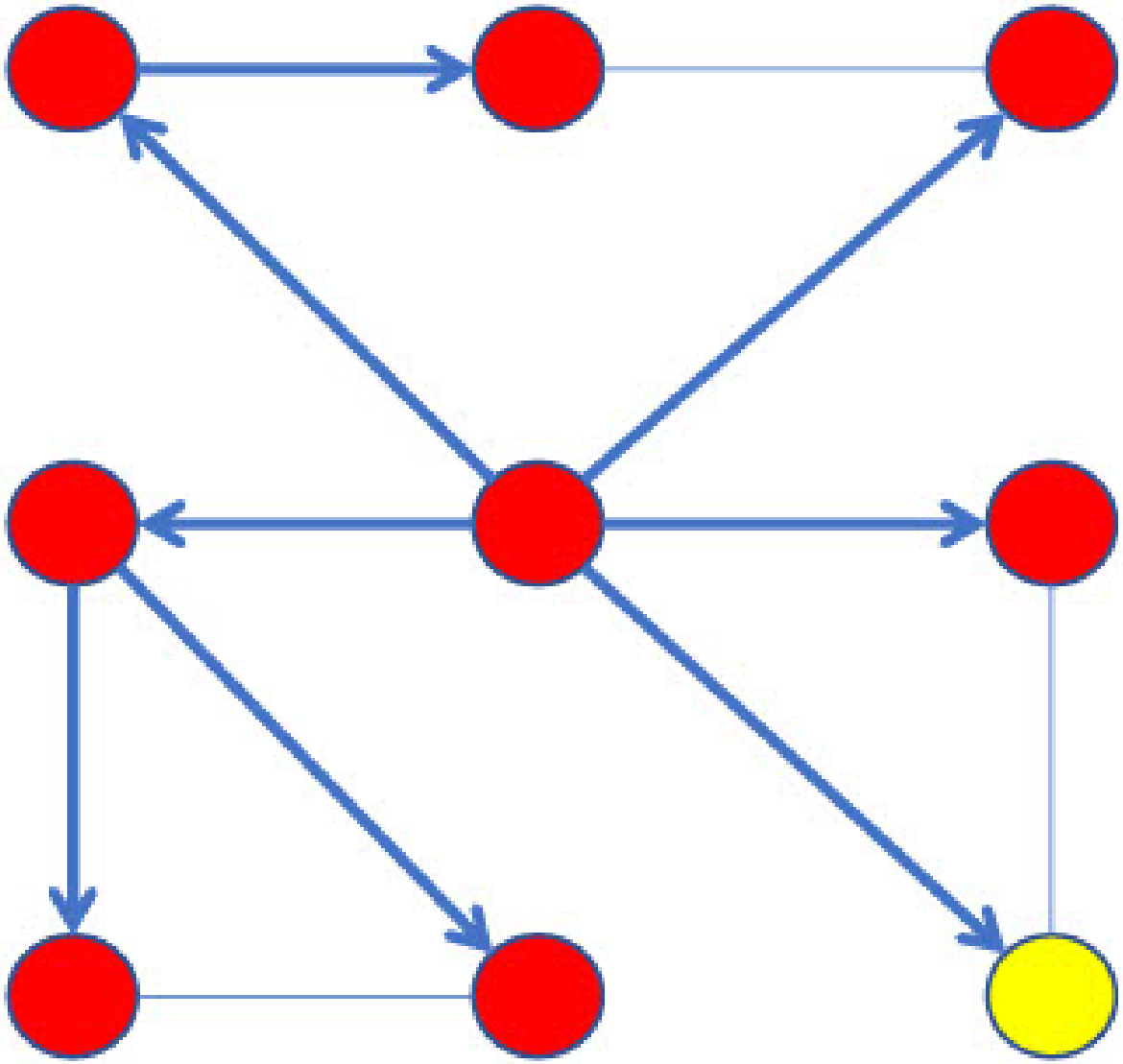

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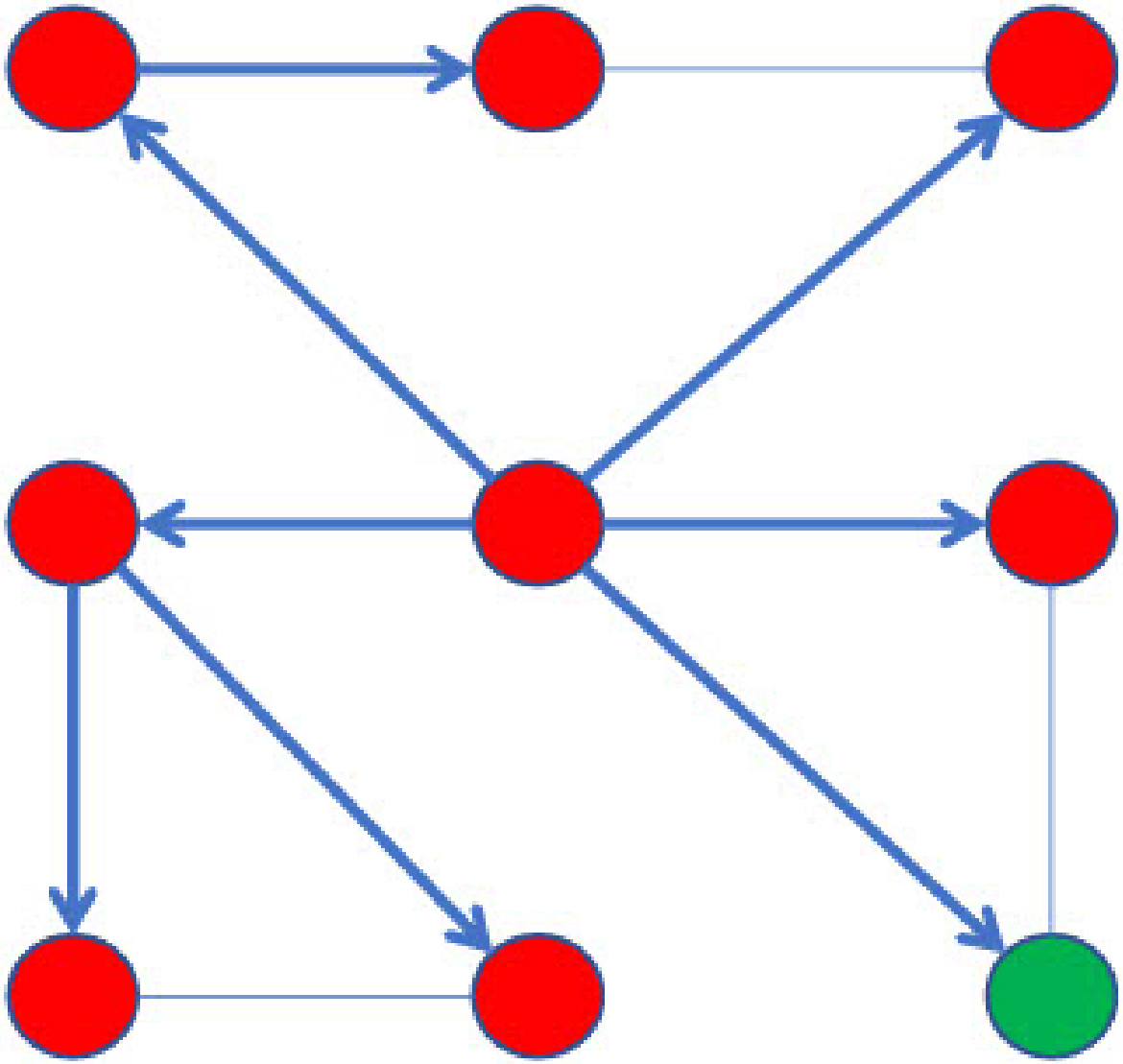

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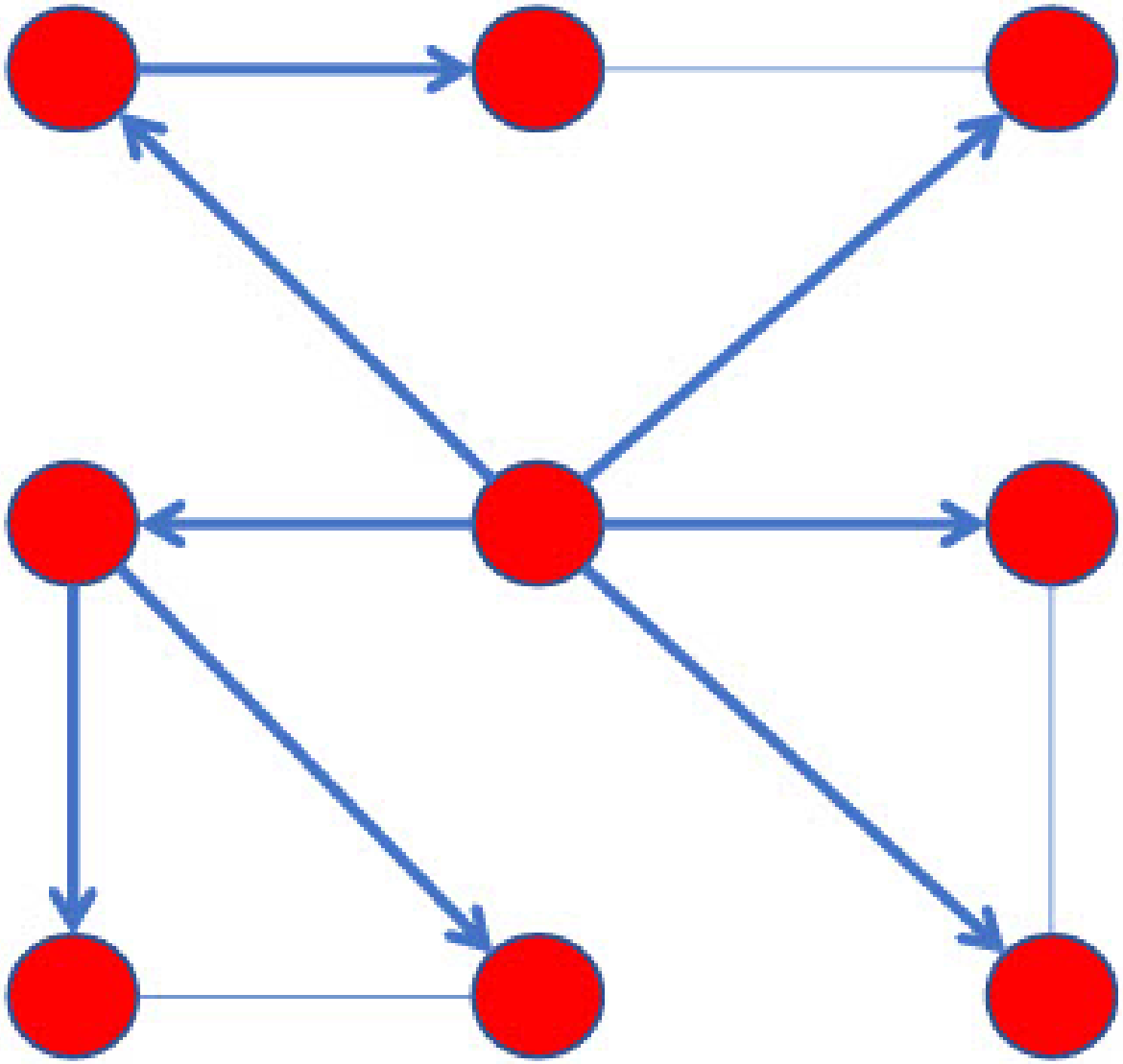

First In First Out Iterating

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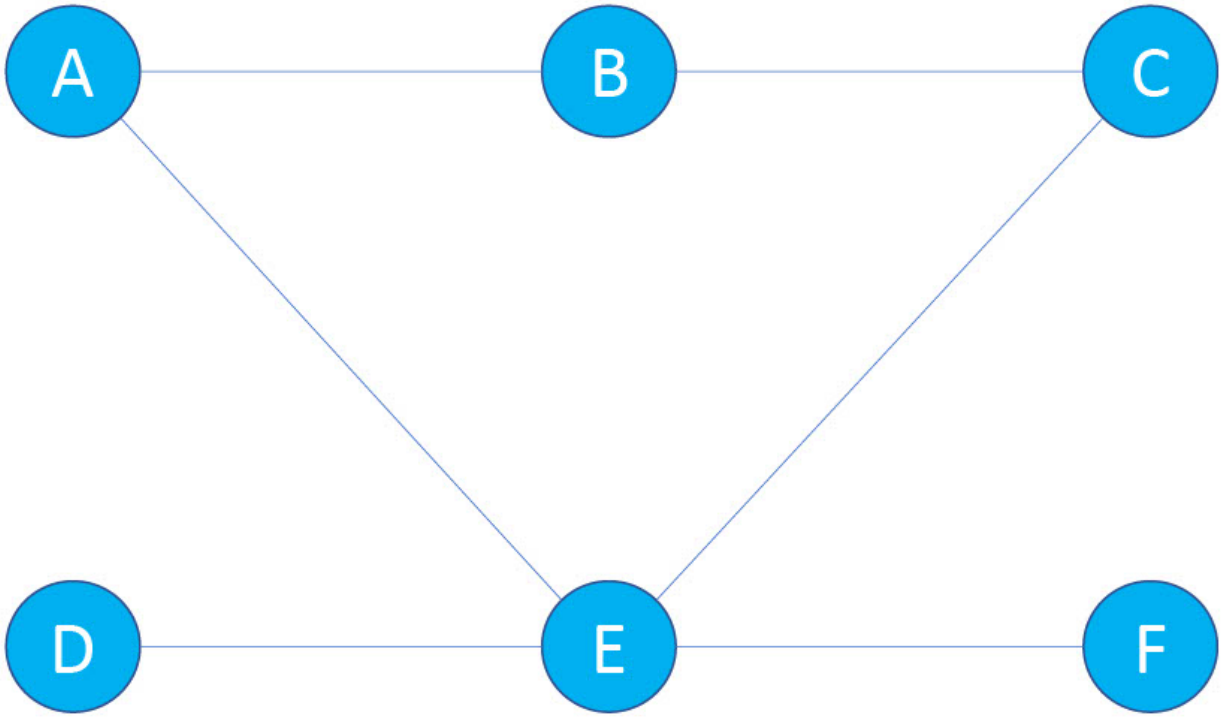

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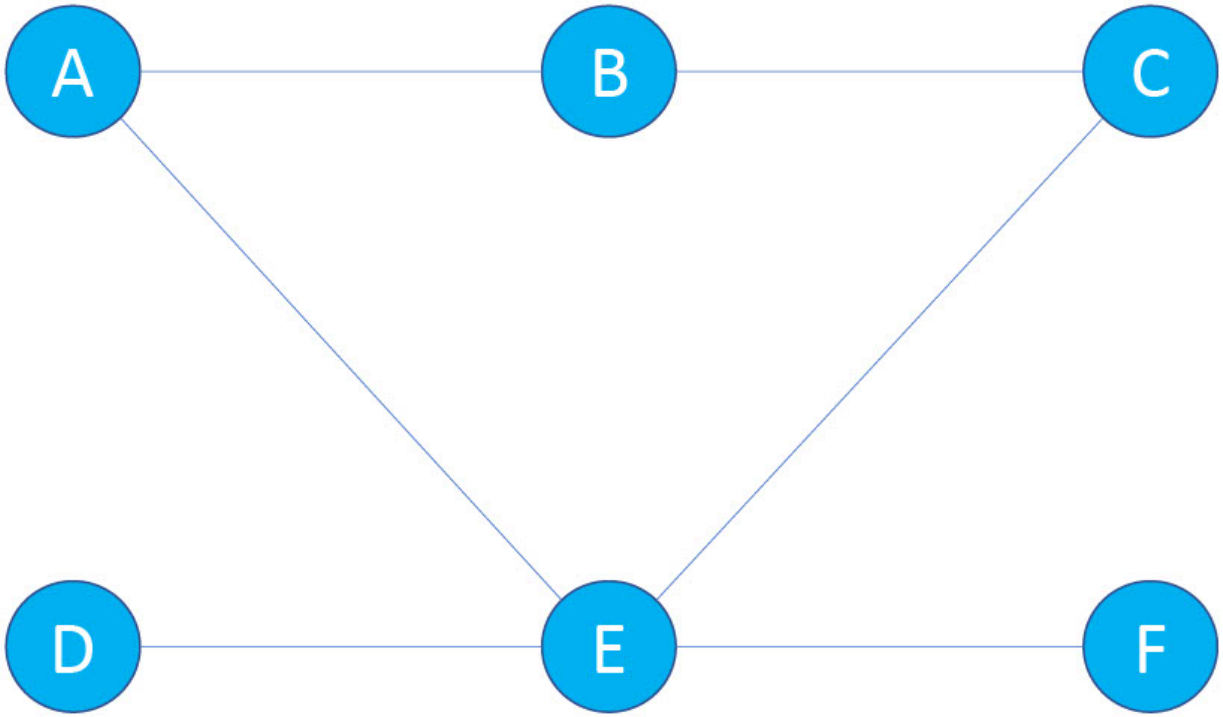

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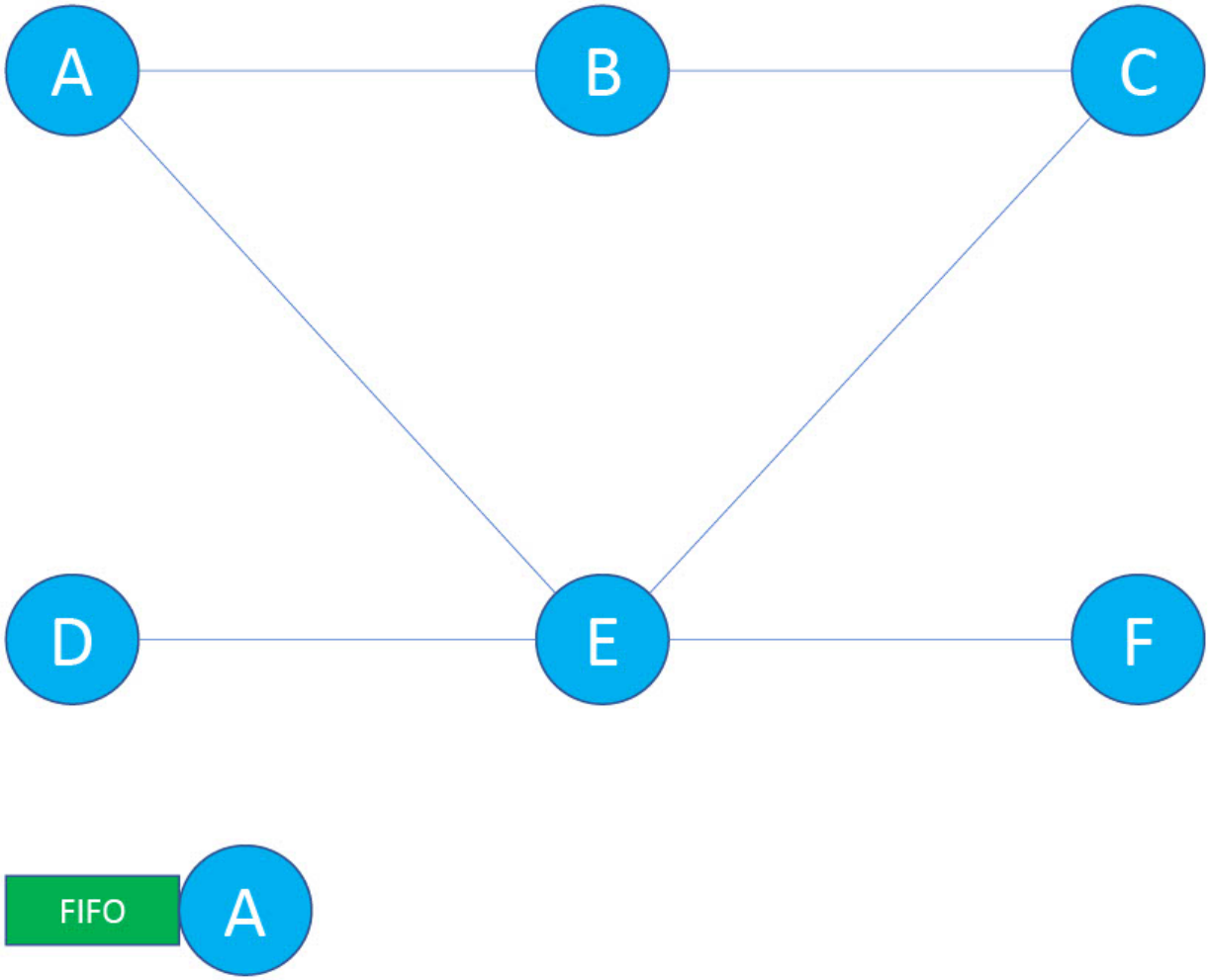

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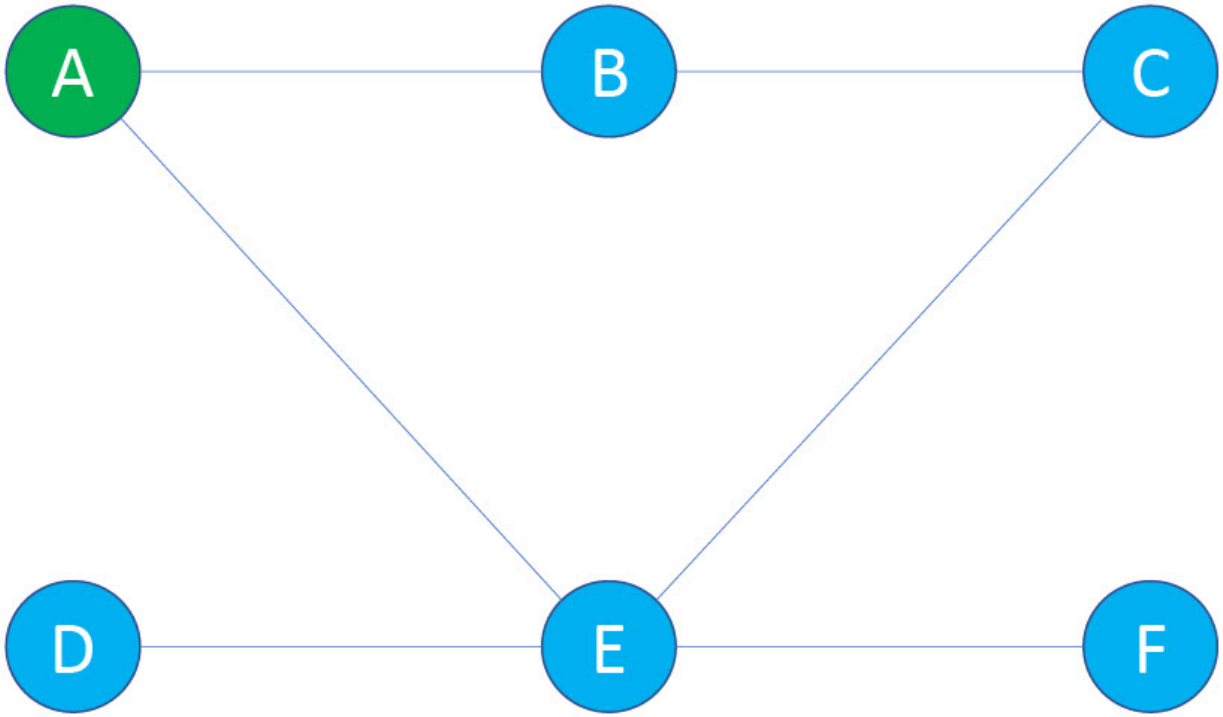

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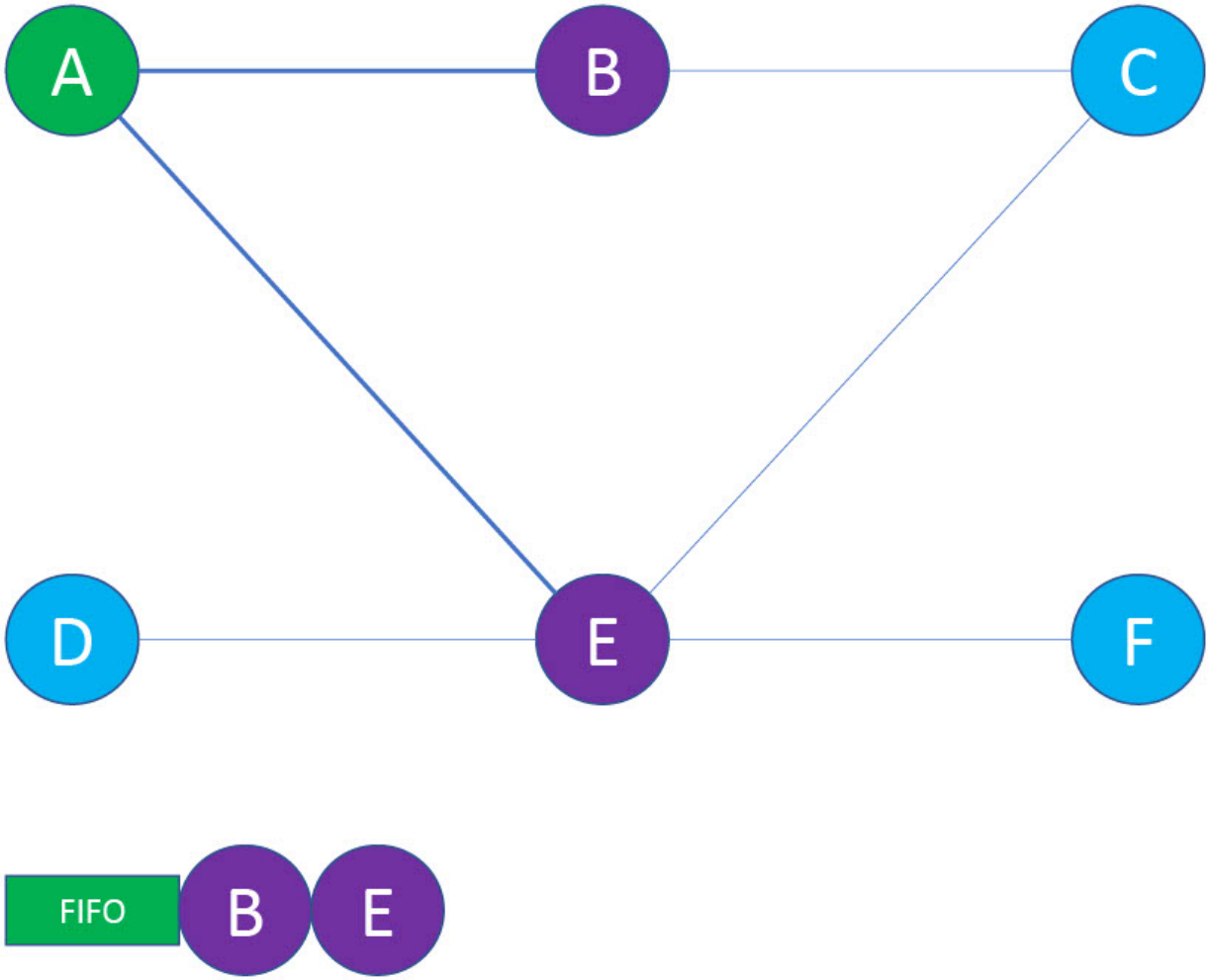

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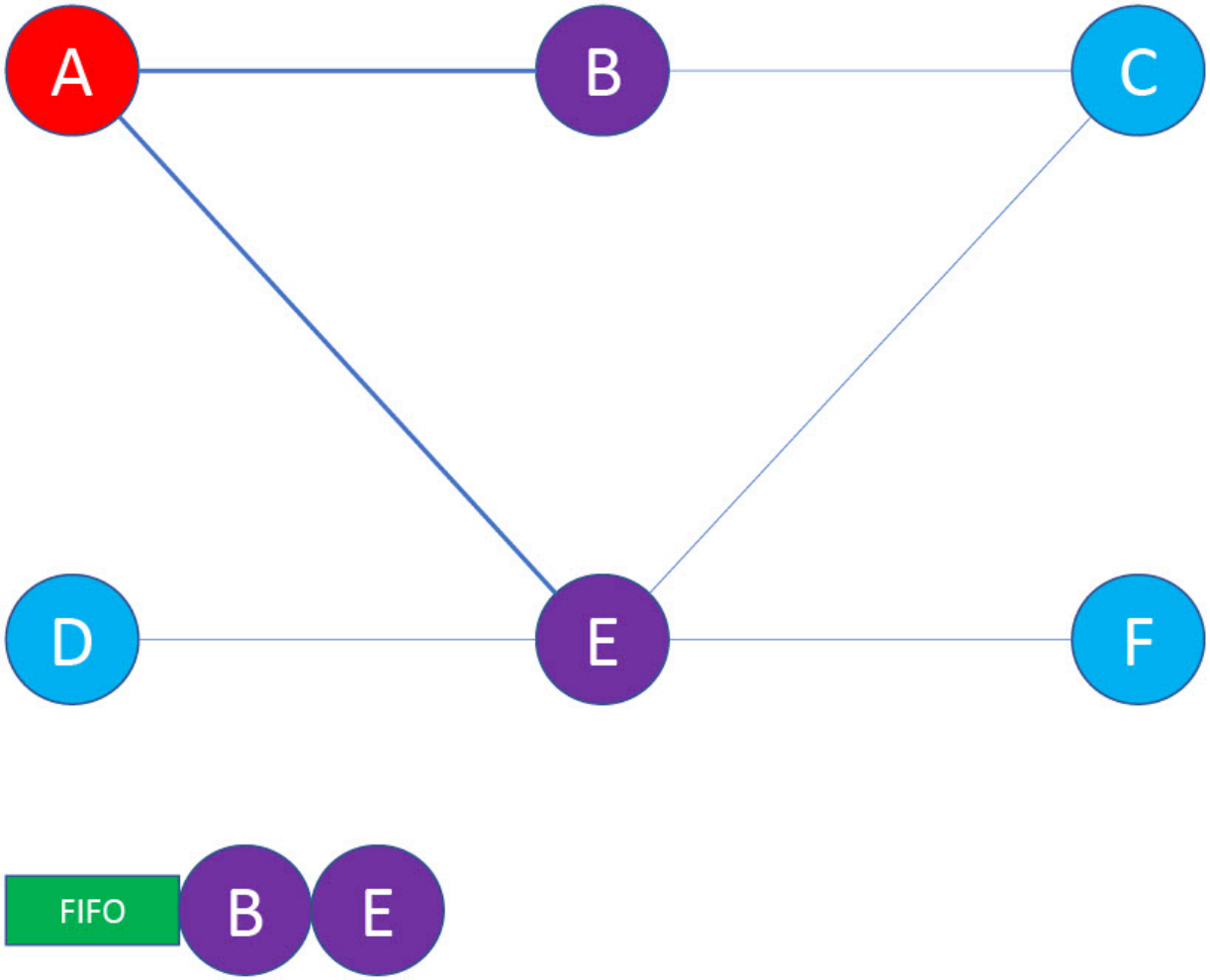

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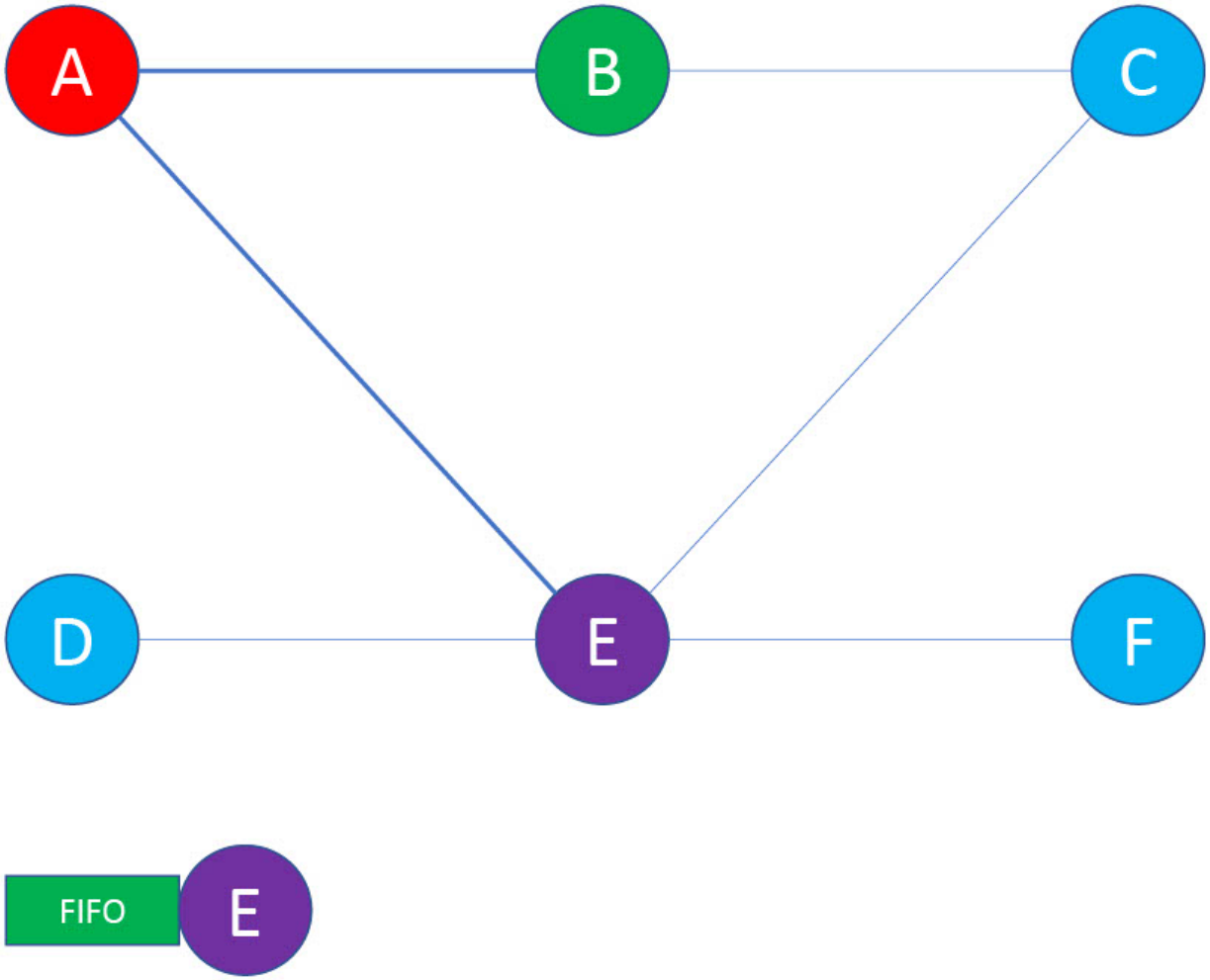
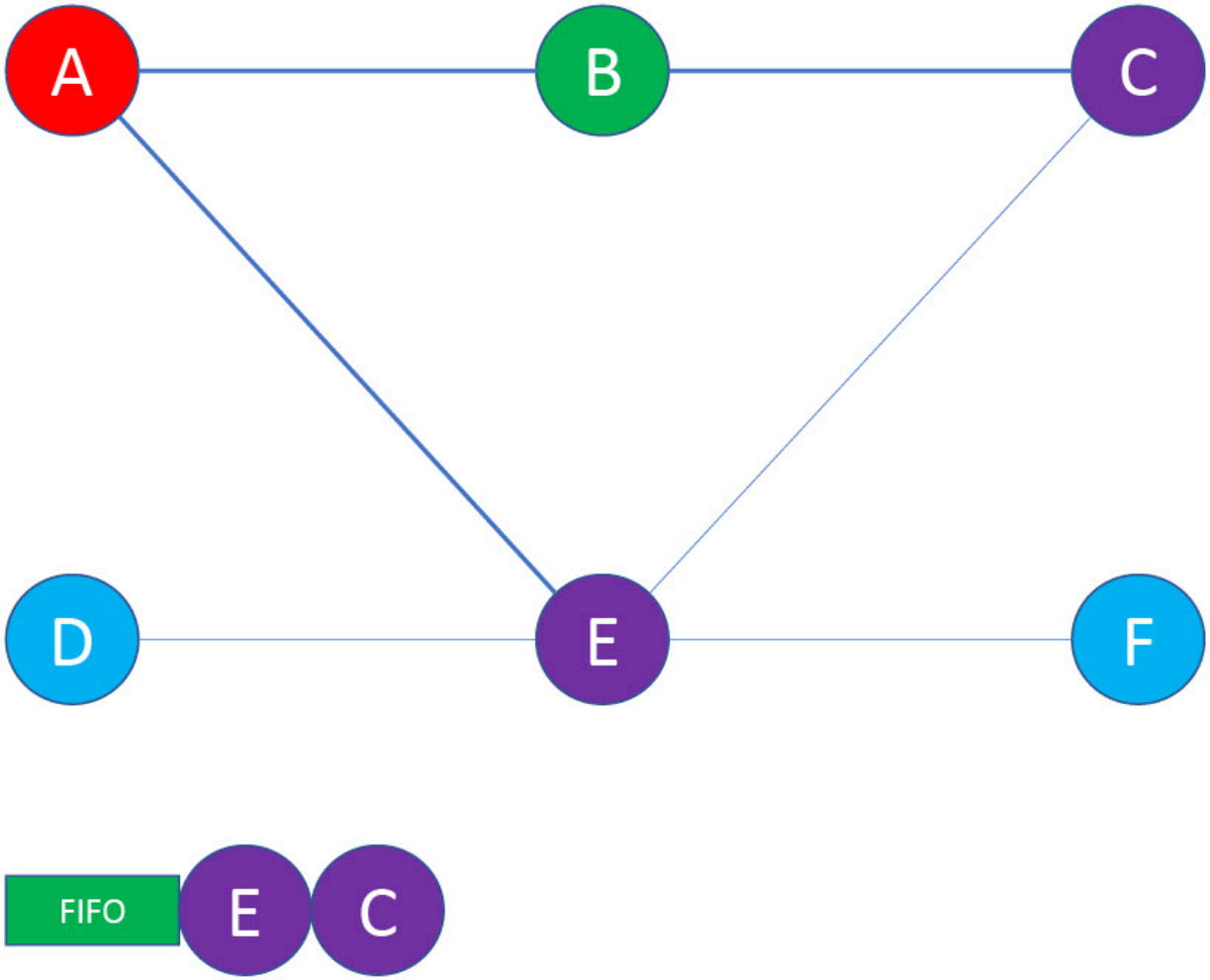


First In First Out Iterating



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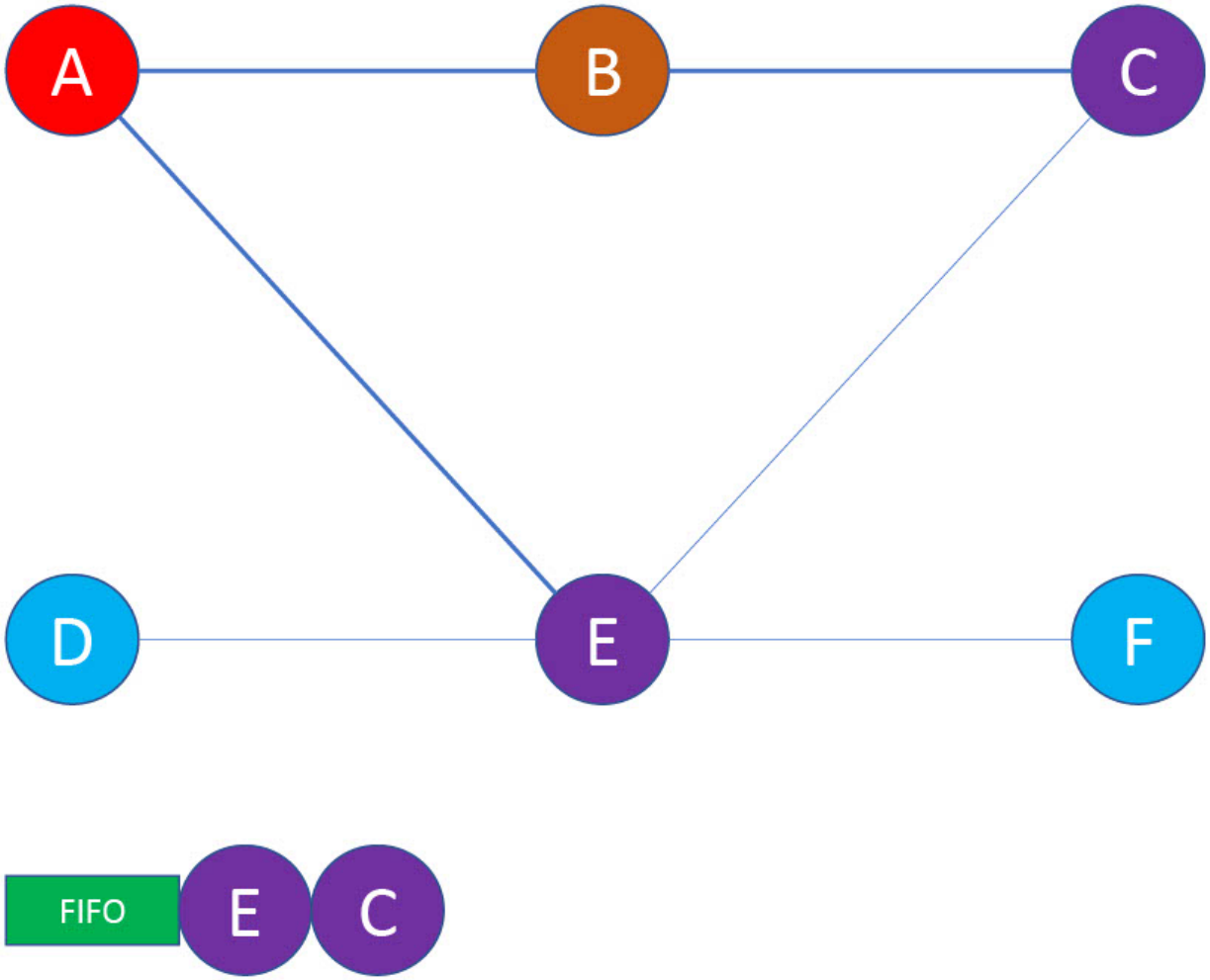

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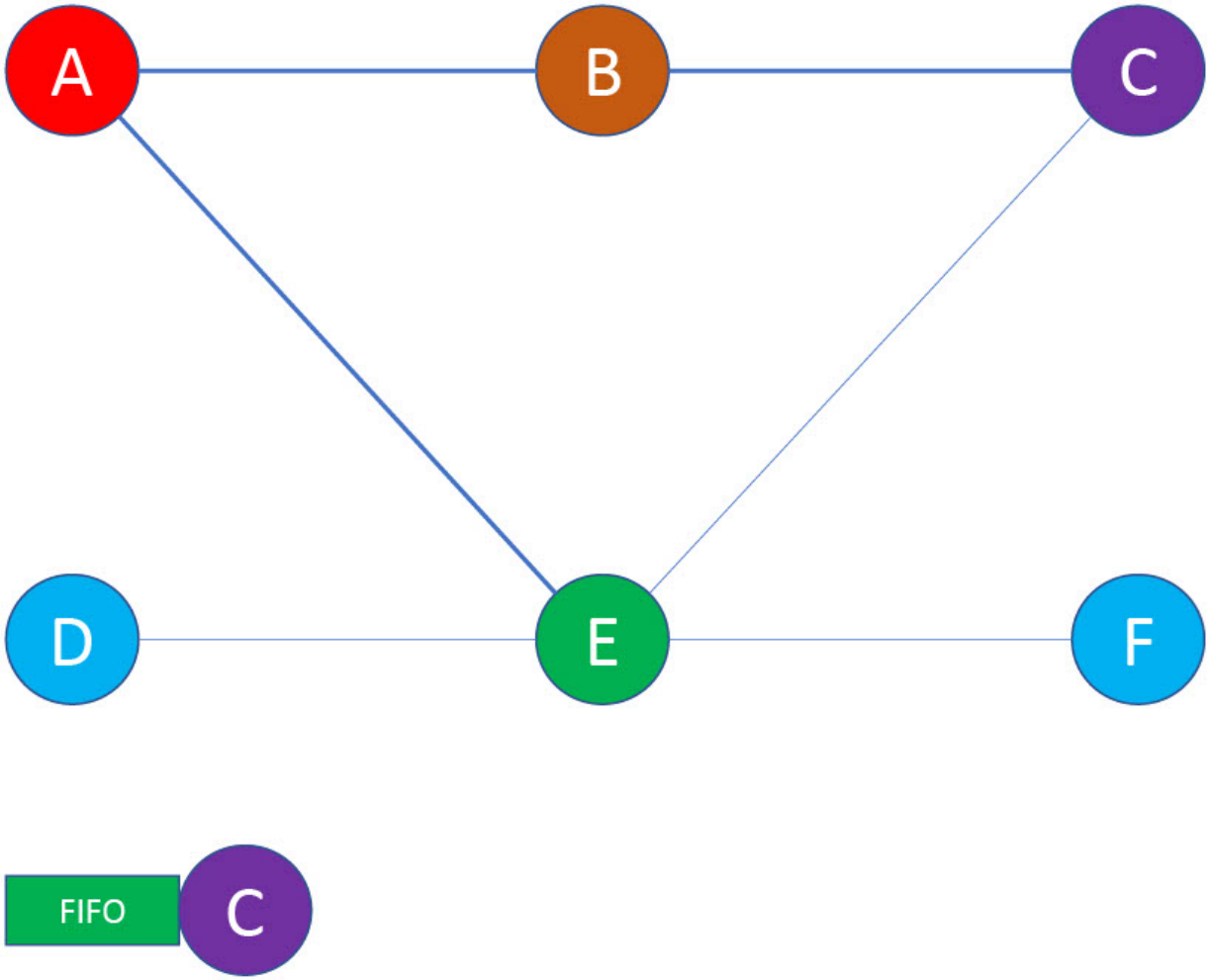

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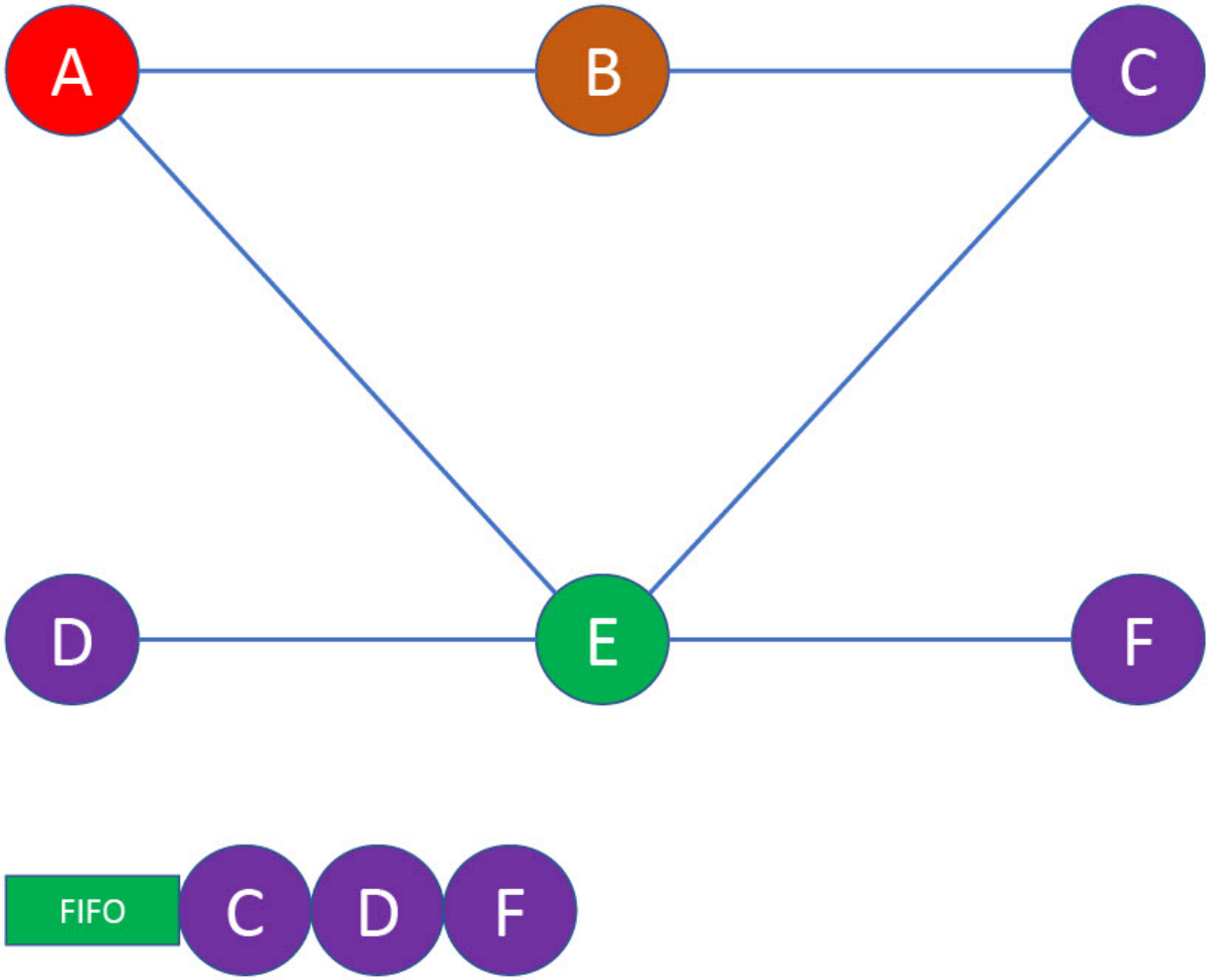

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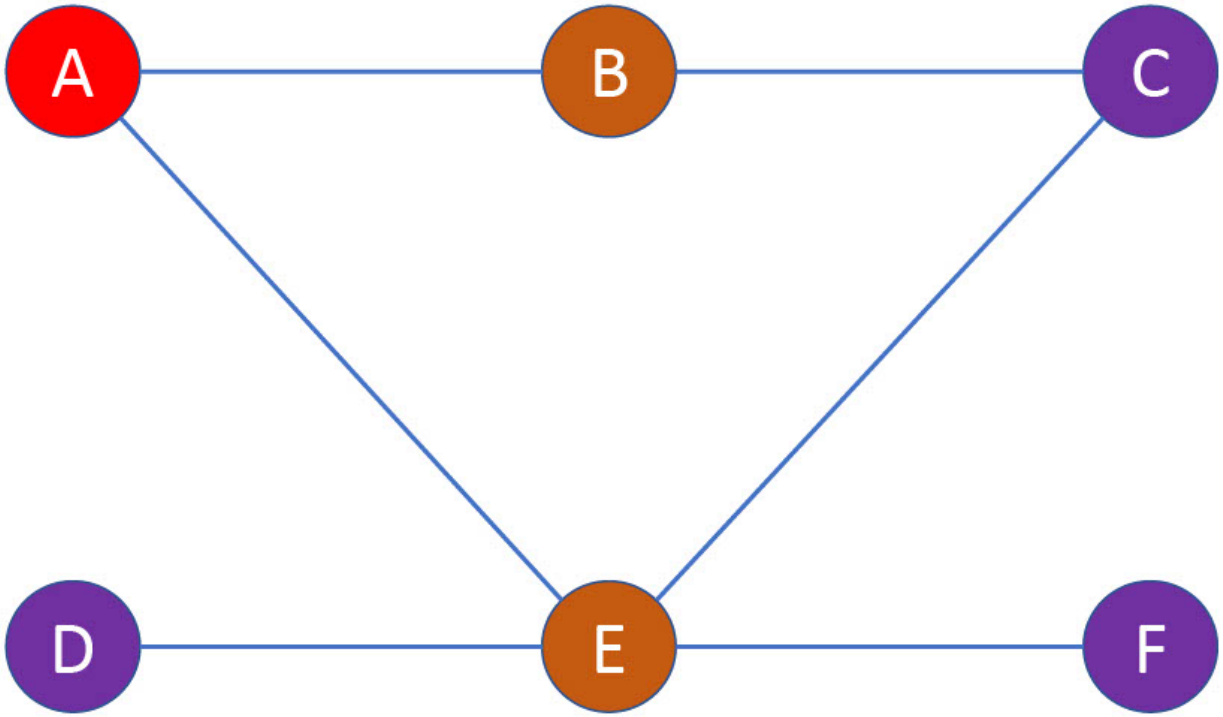

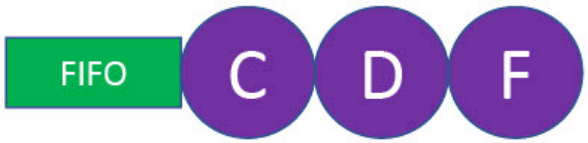

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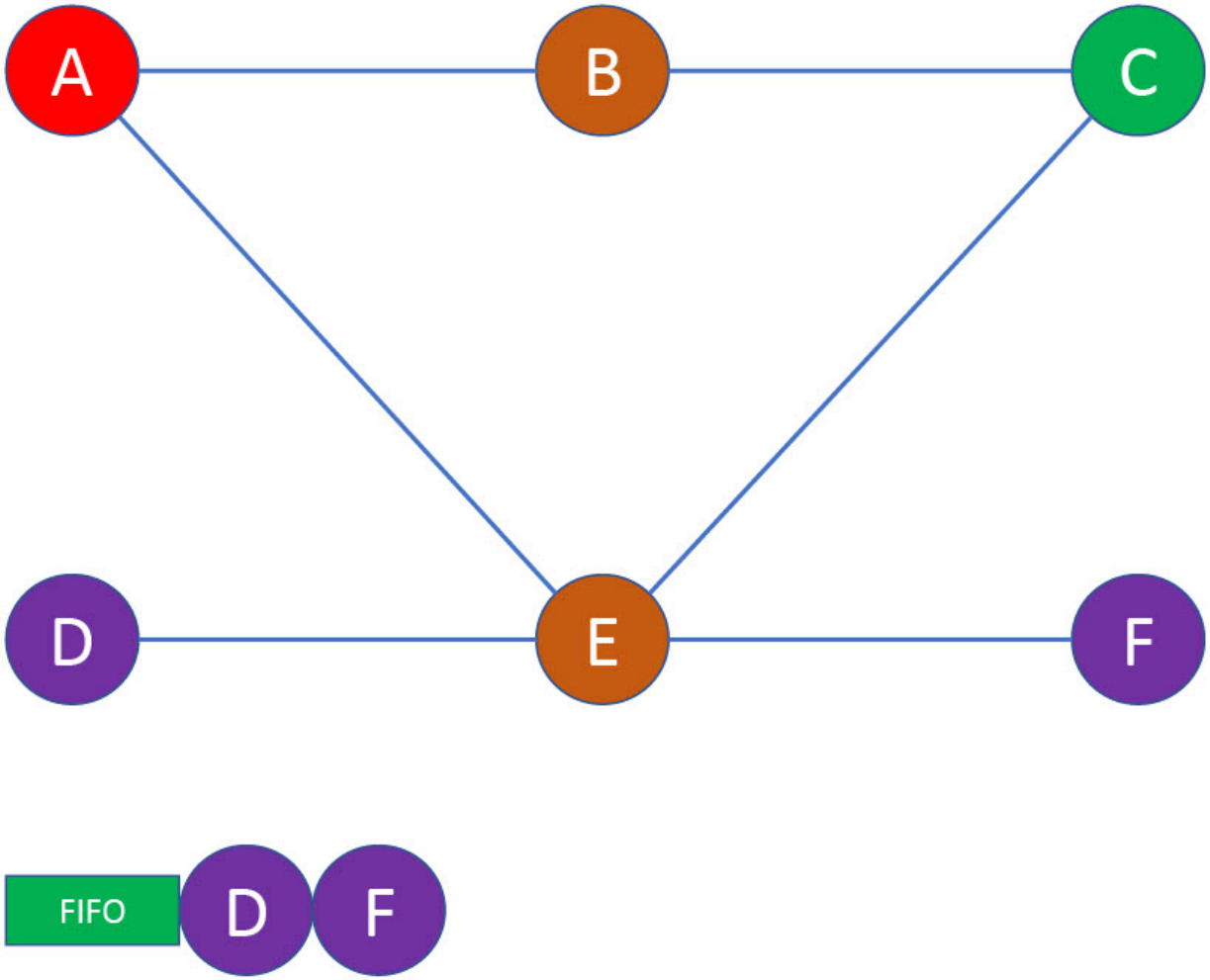

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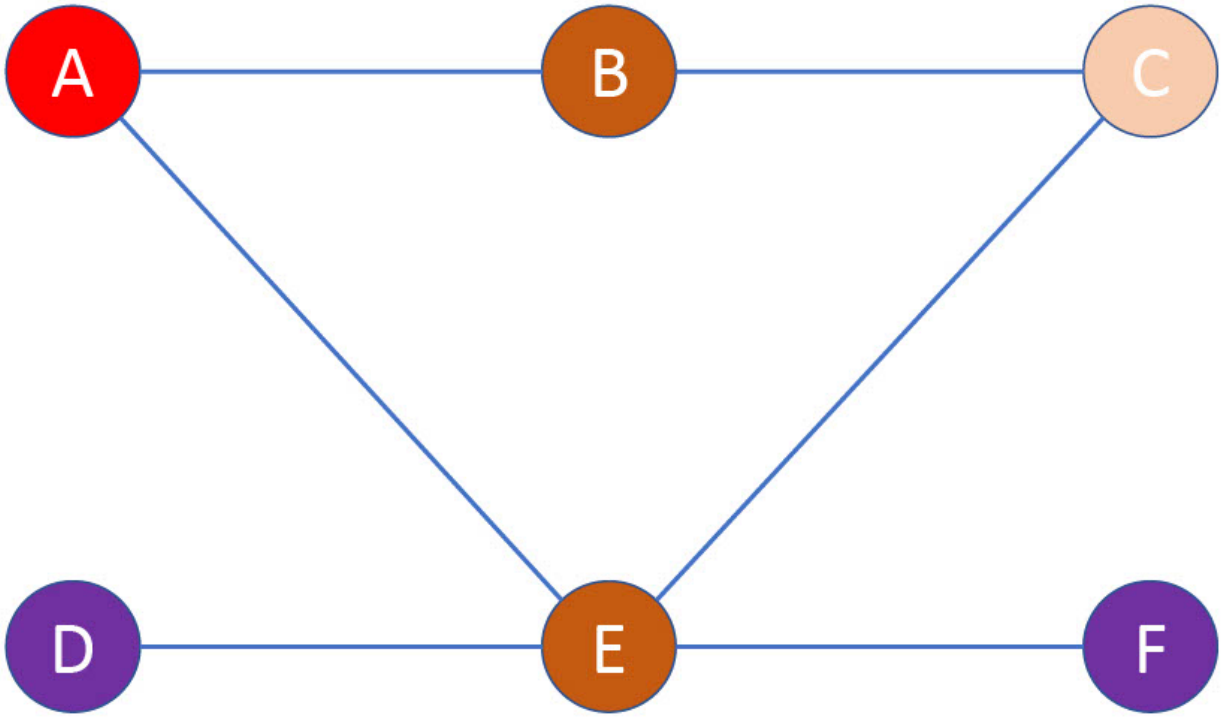

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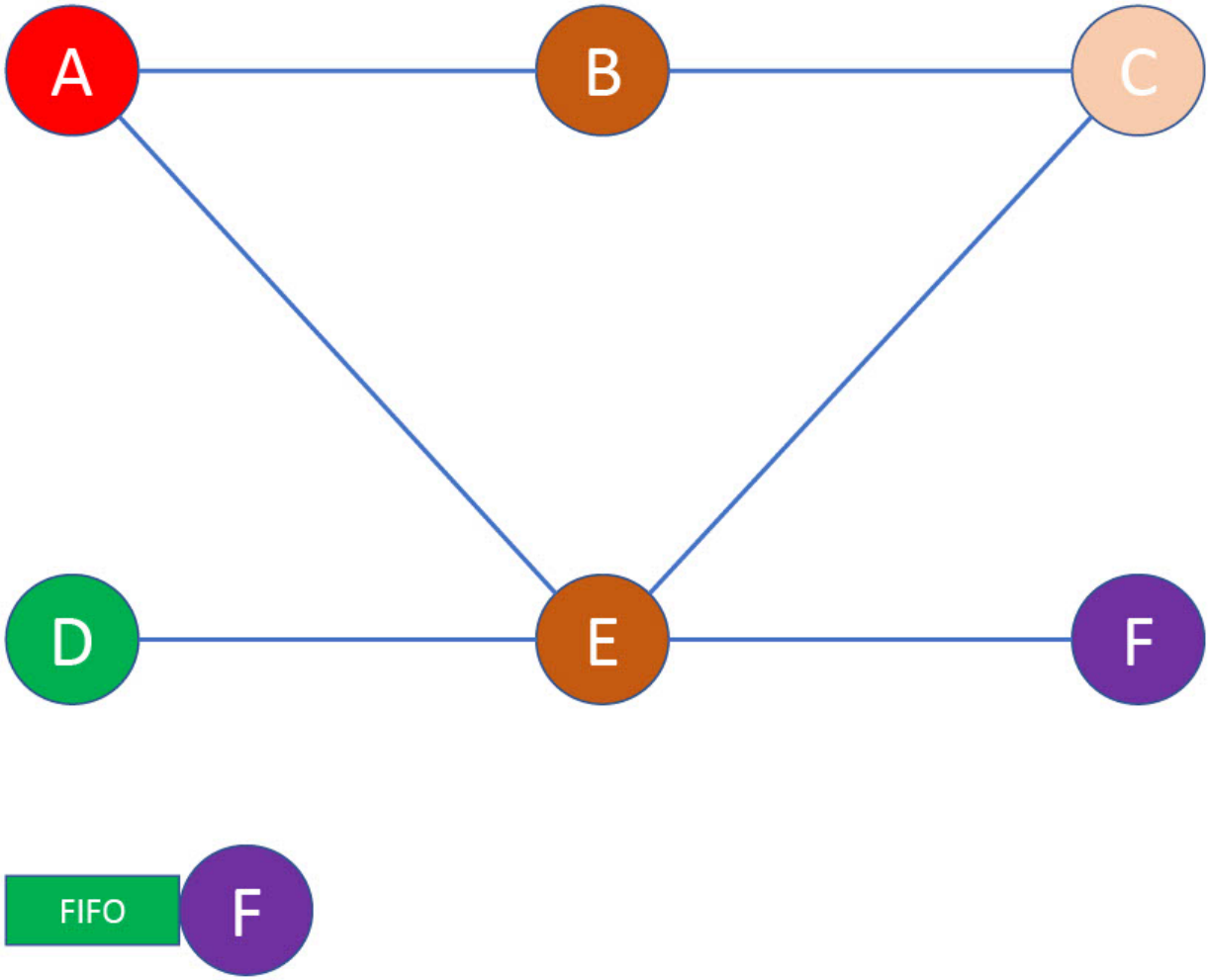
Manchester Metropolitan University



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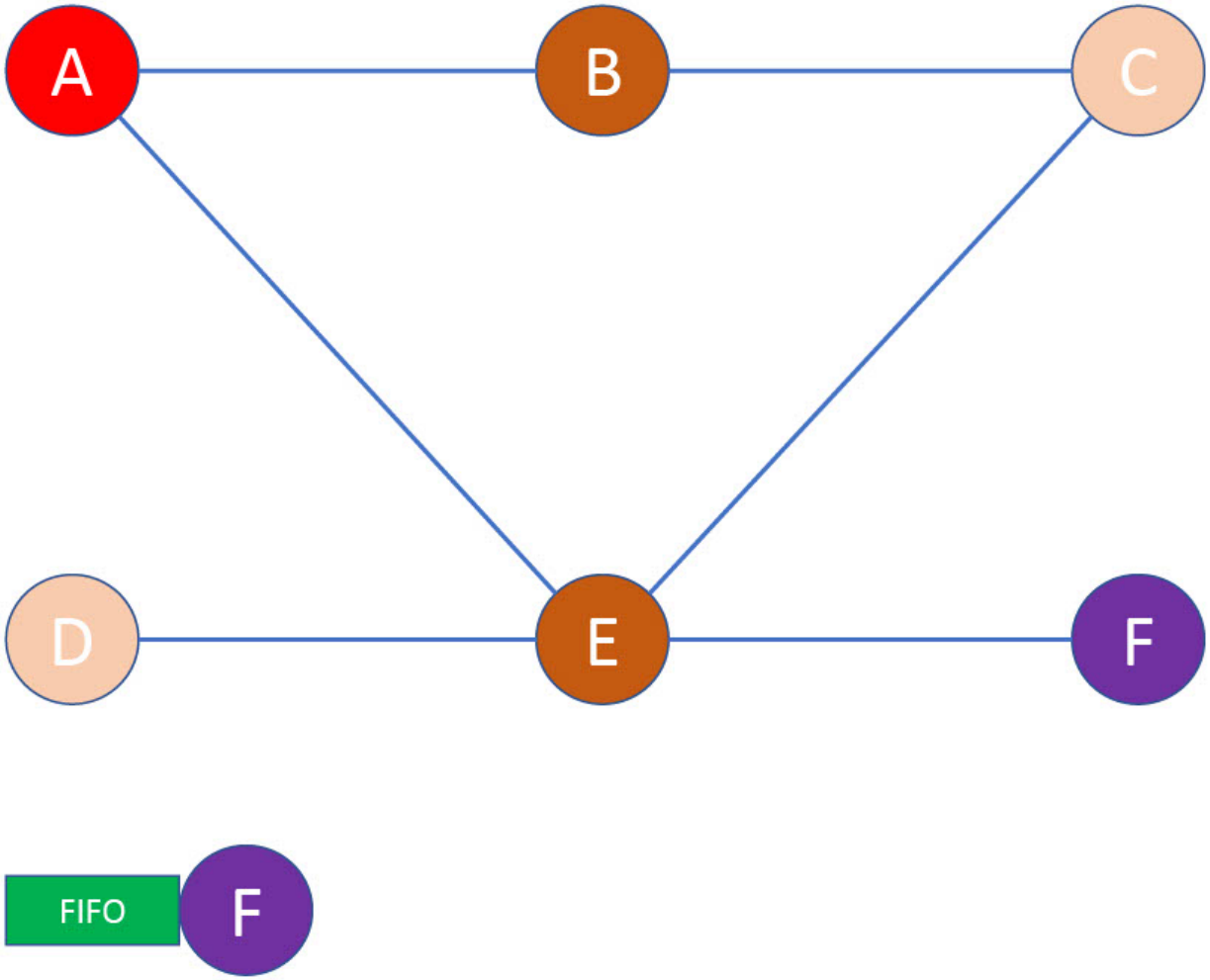

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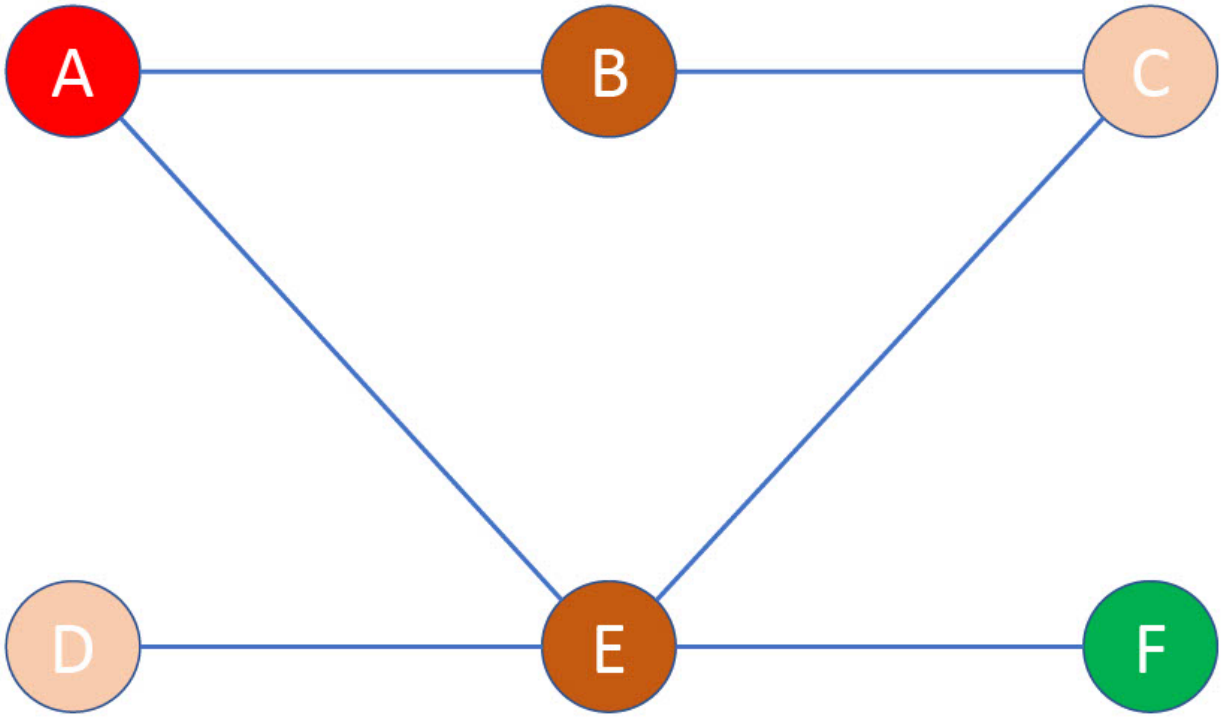

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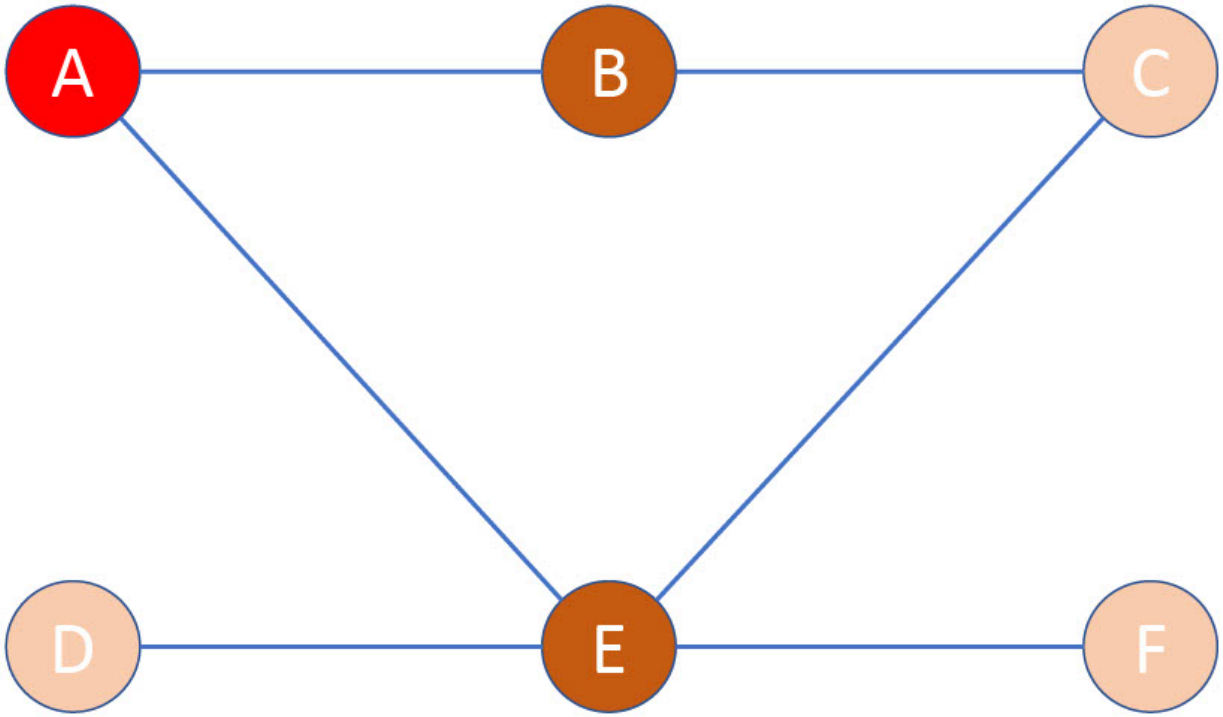

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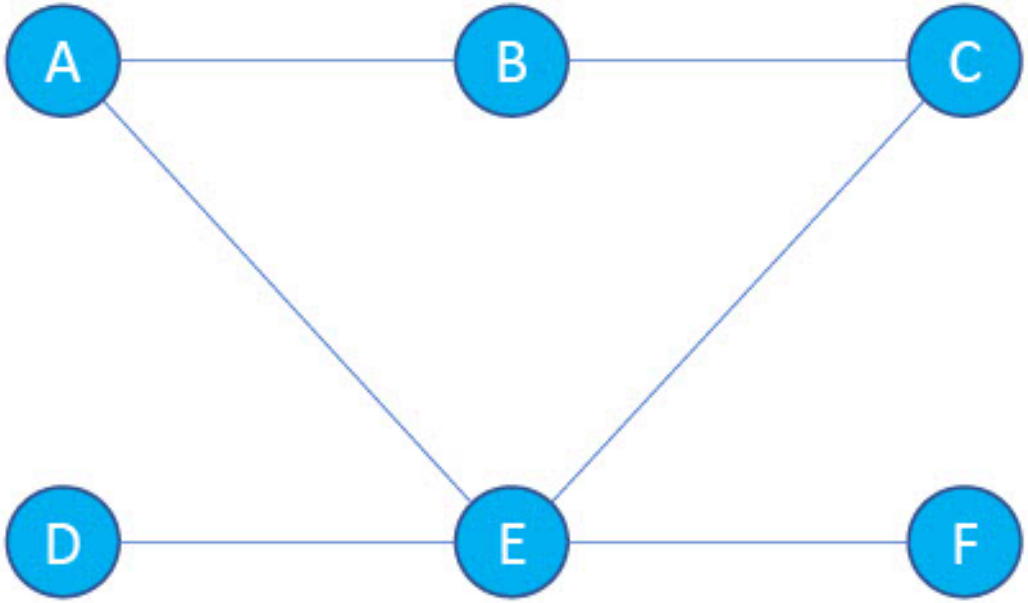

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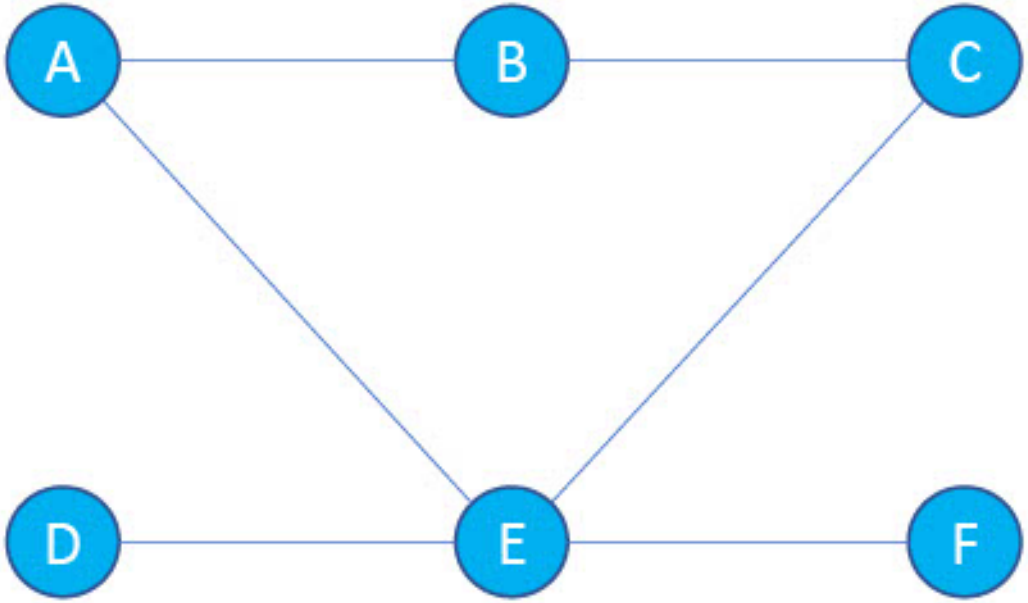

LIFO

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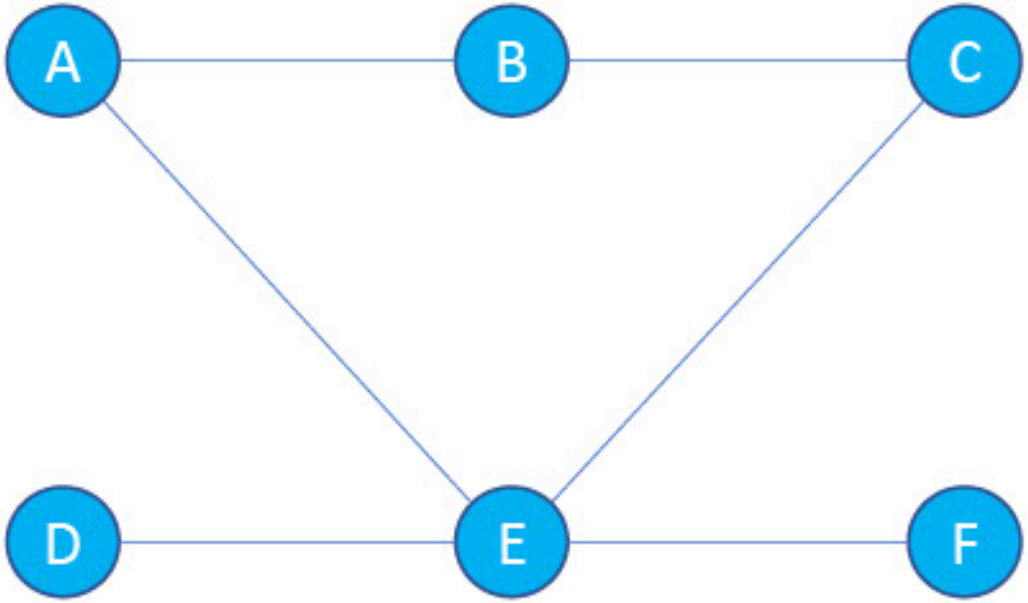

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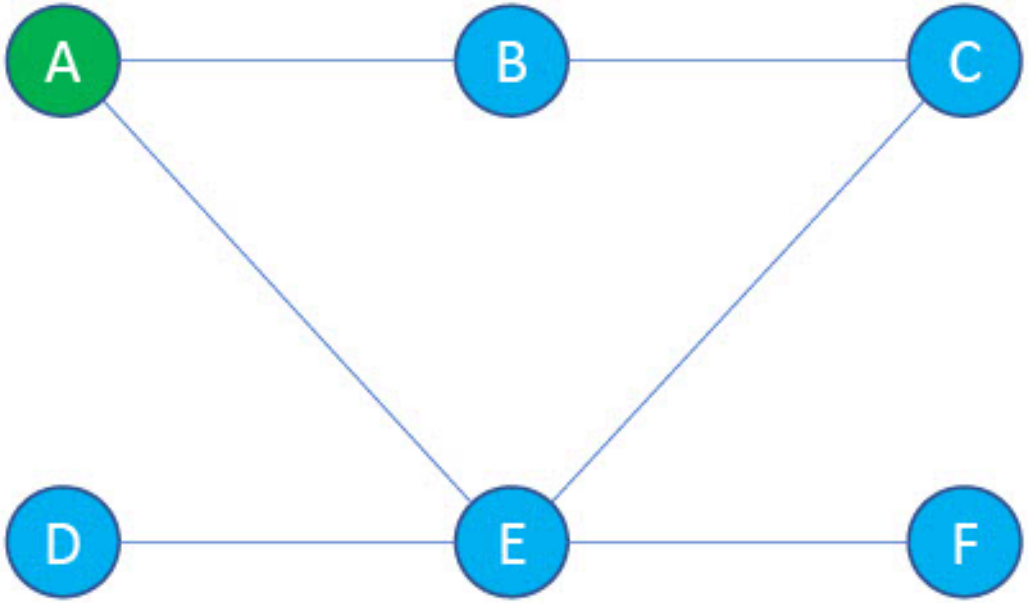

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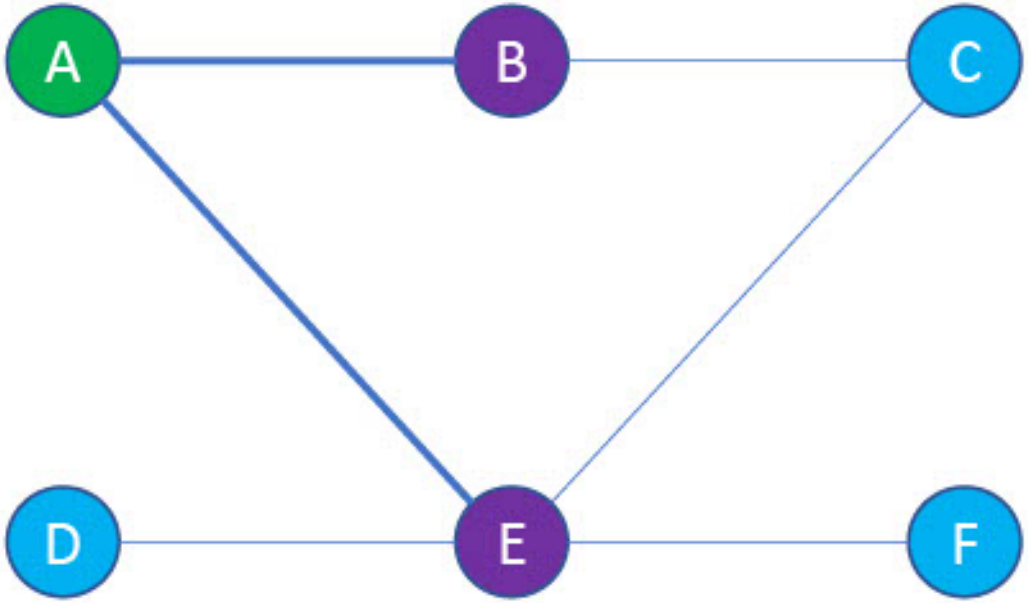

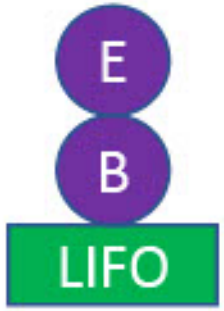

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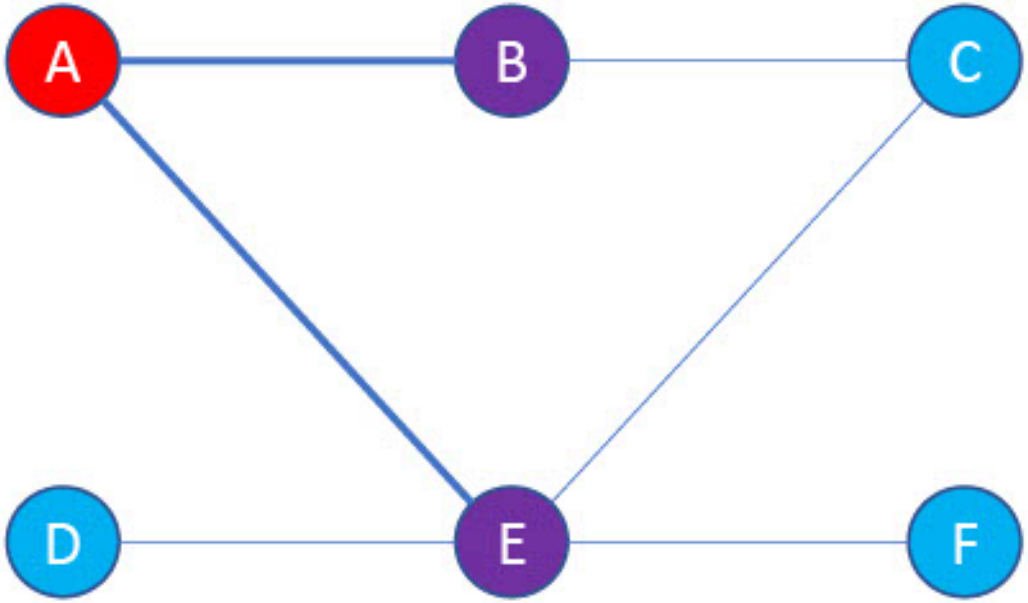

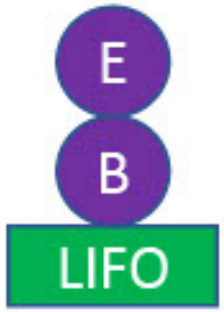

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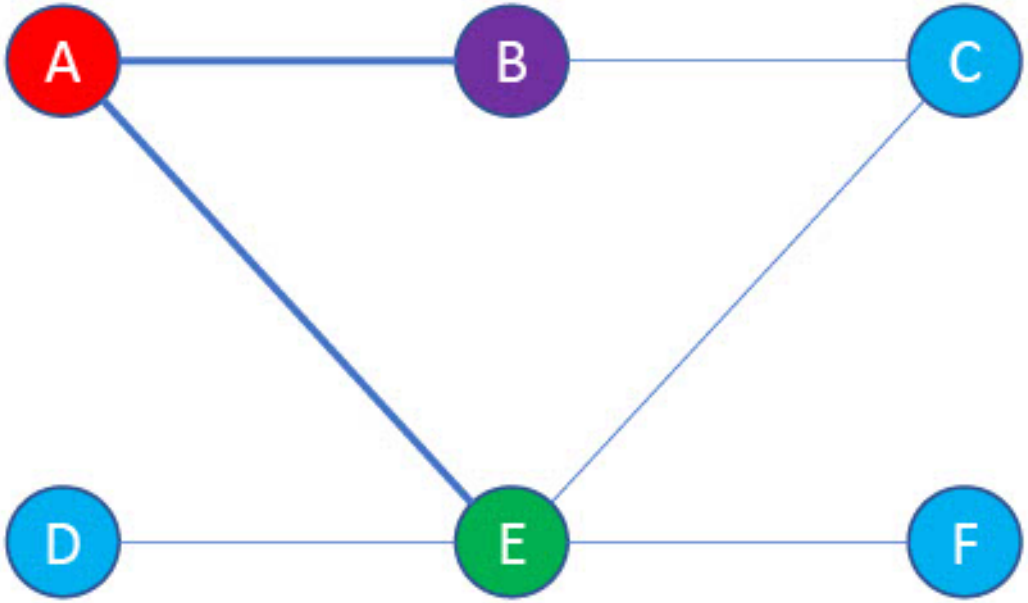

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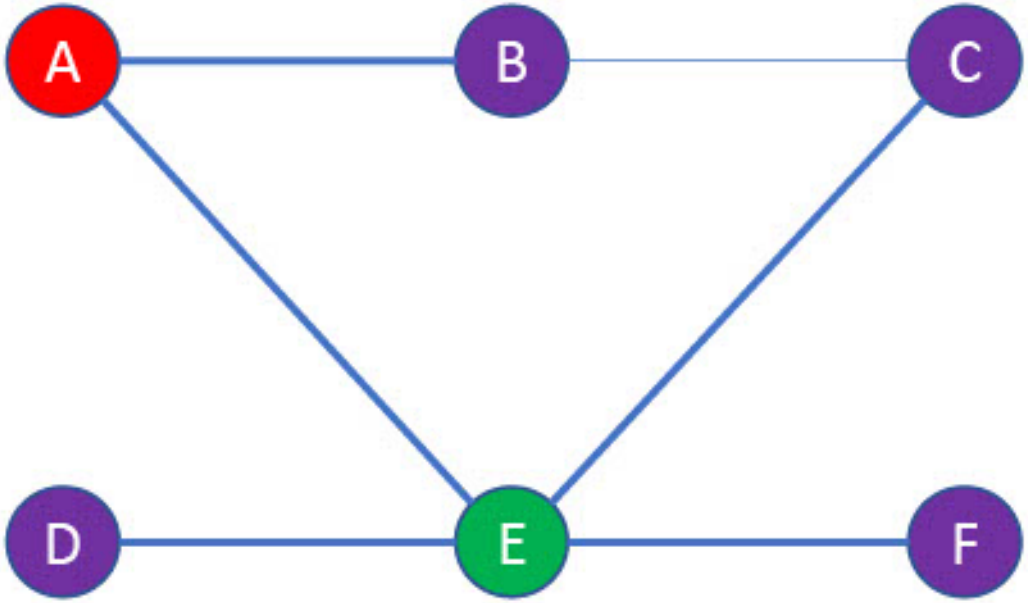

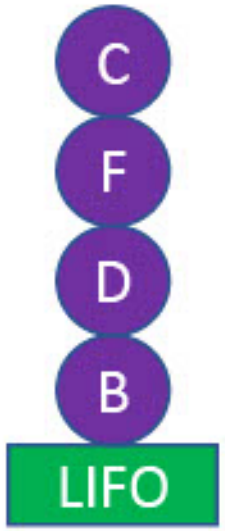

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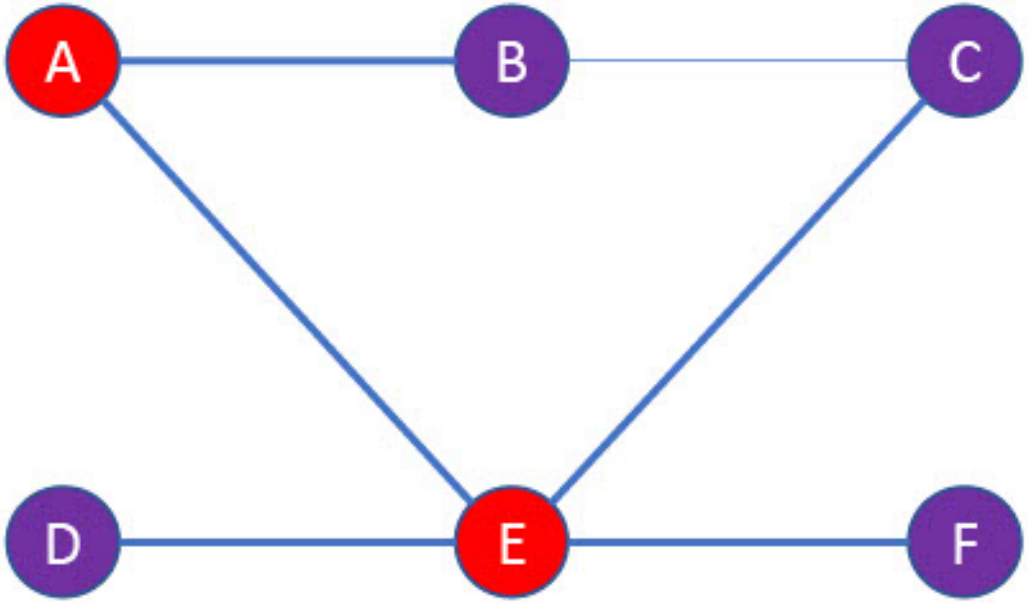

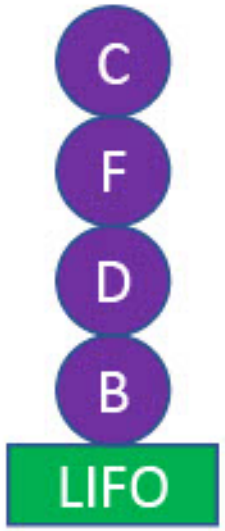

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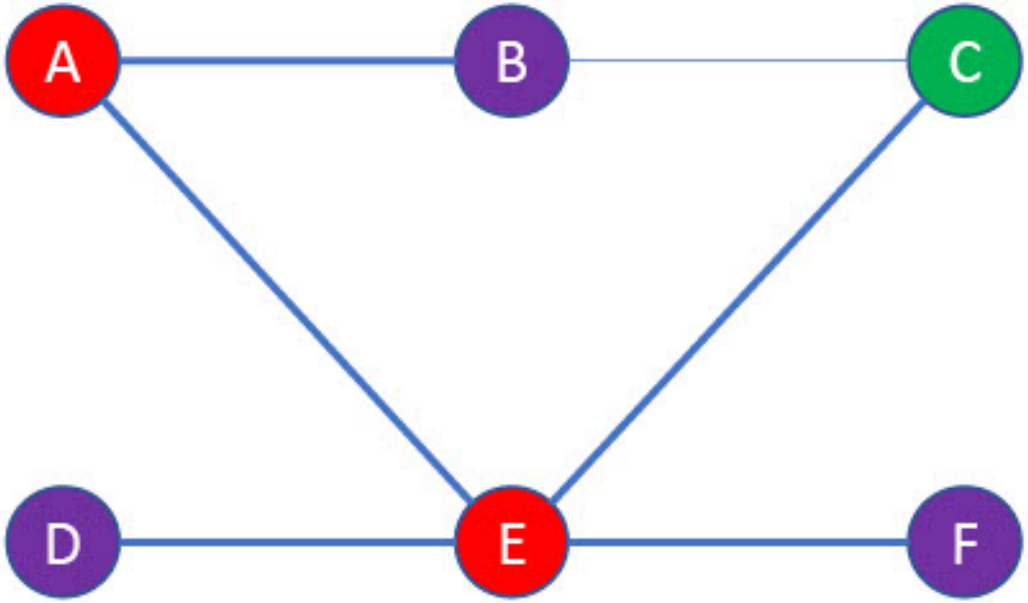

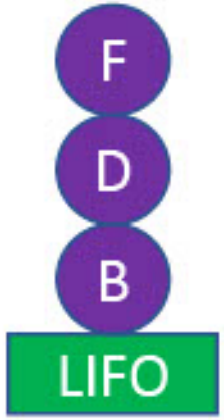

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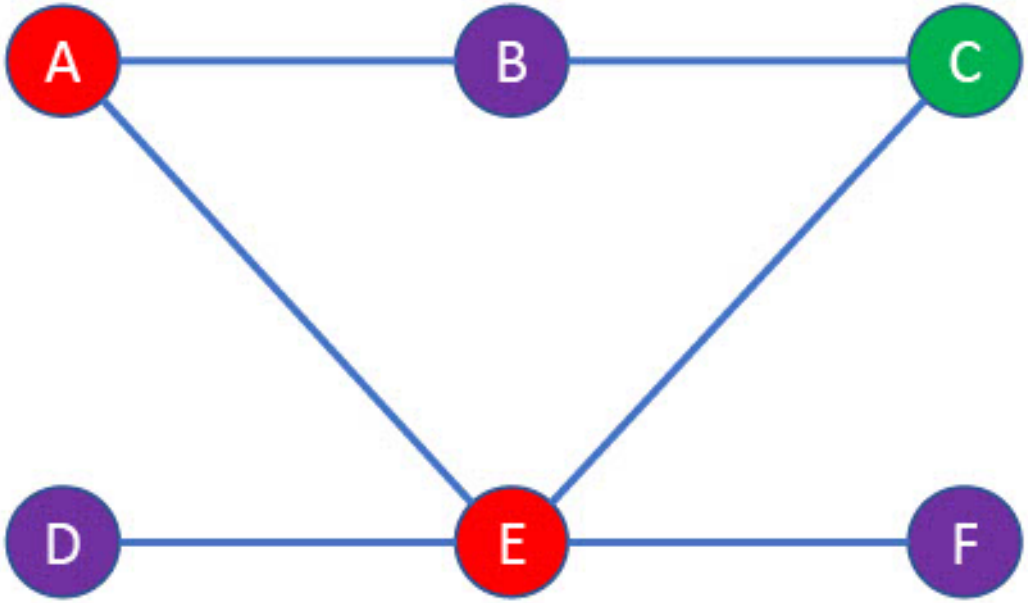

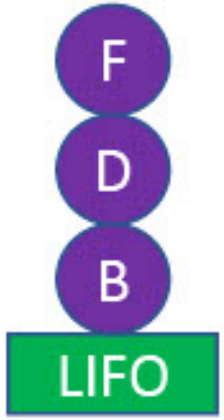

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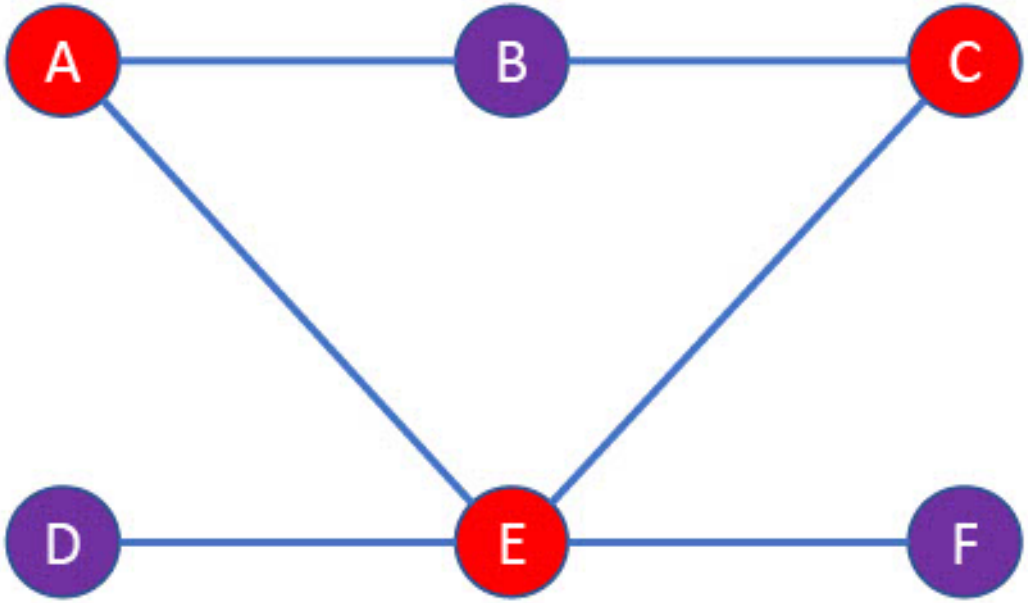

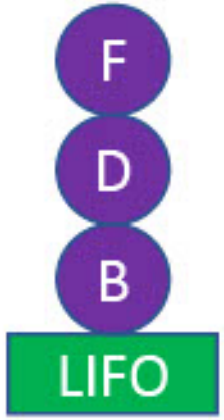

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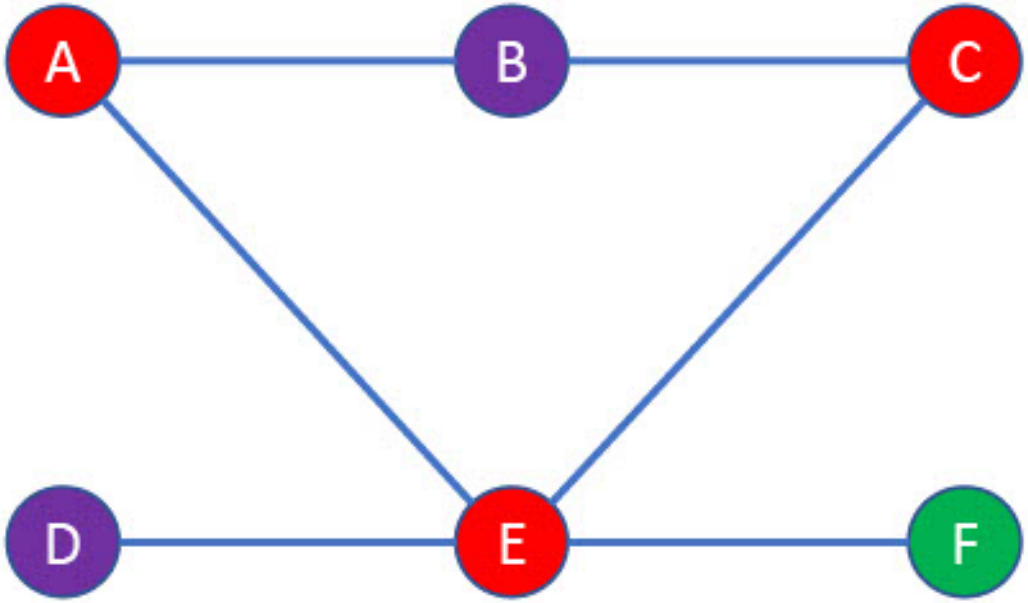

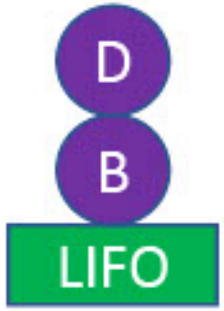

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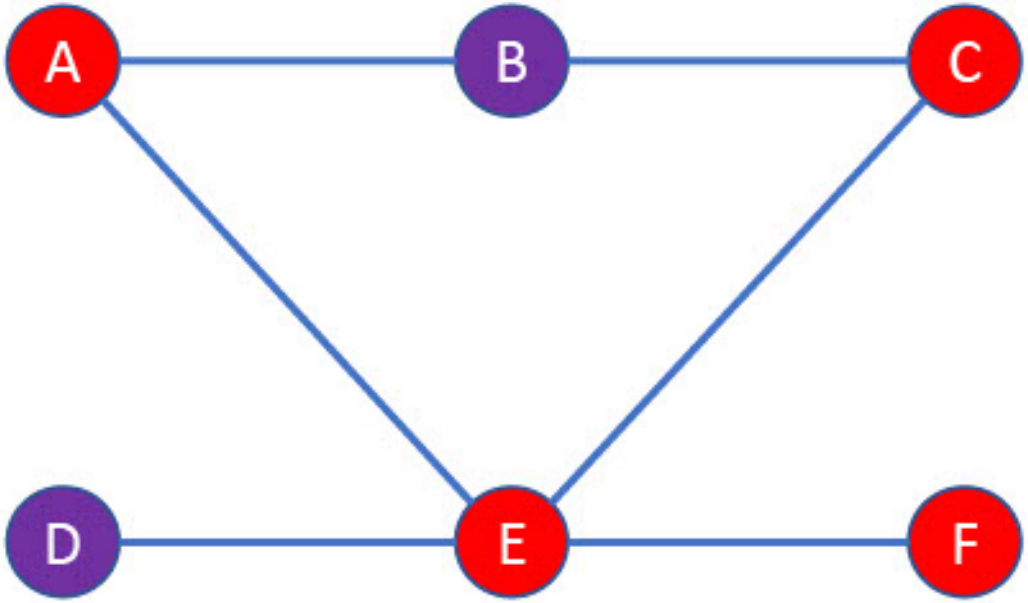

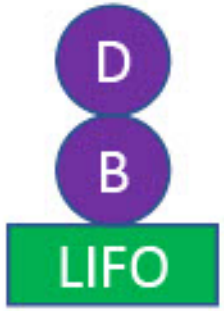

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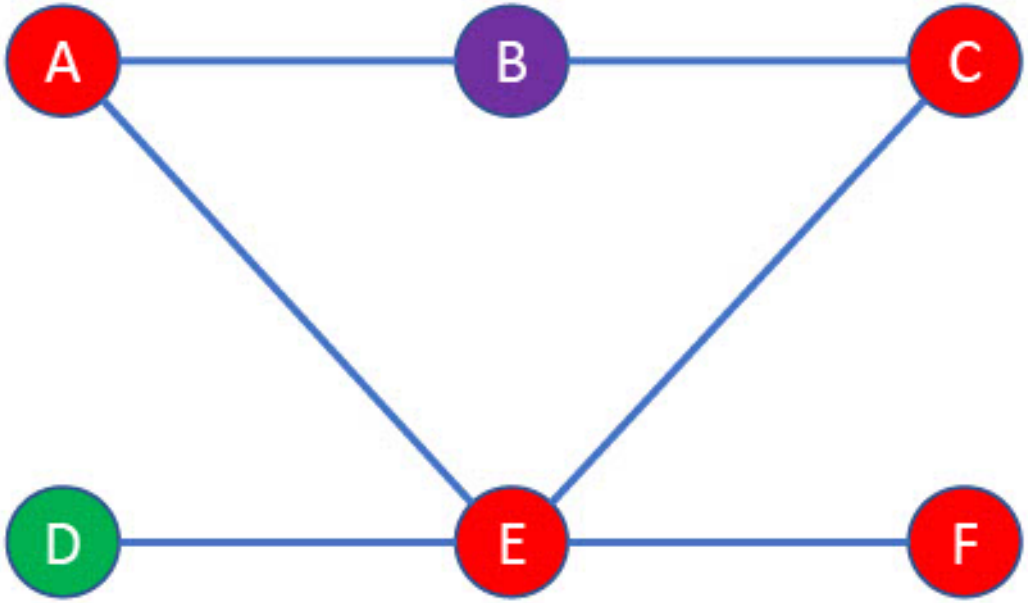

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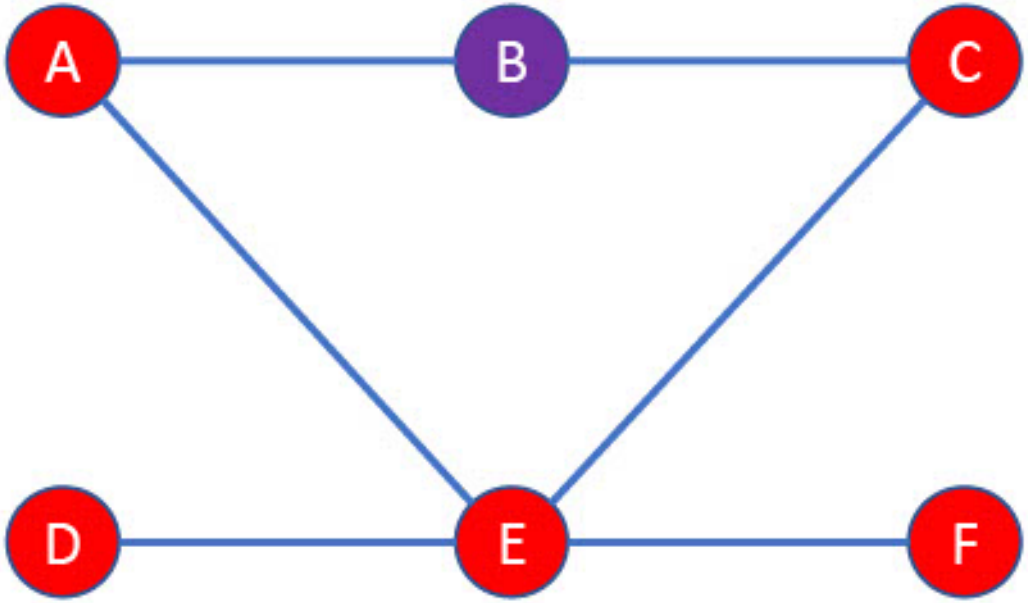

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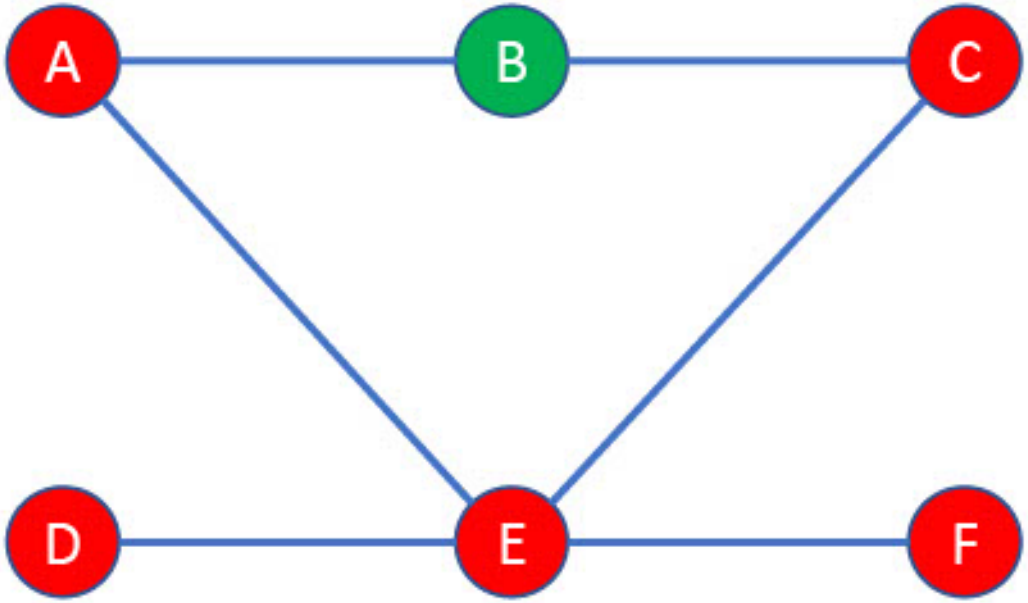

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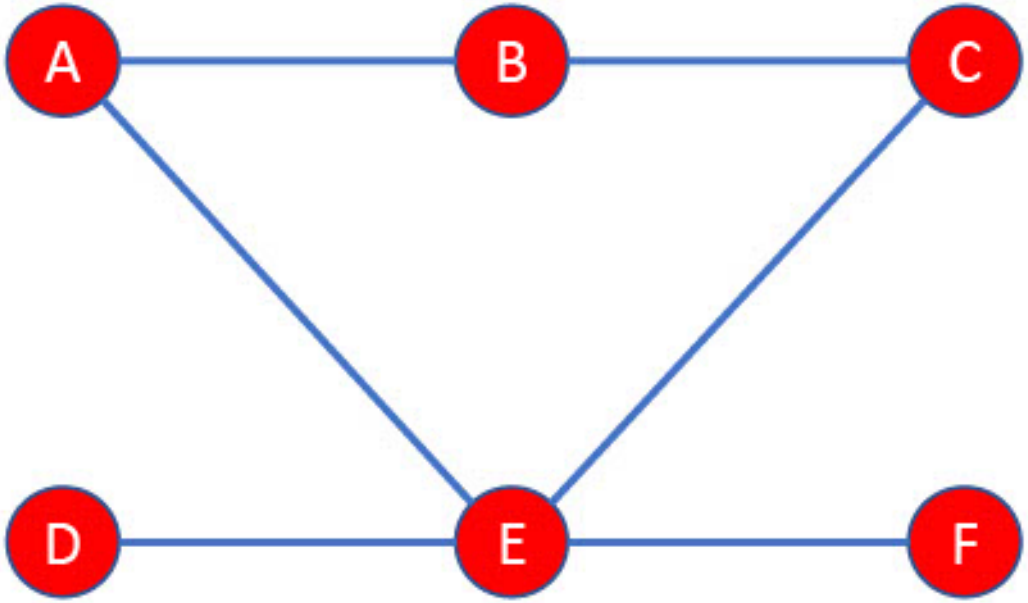

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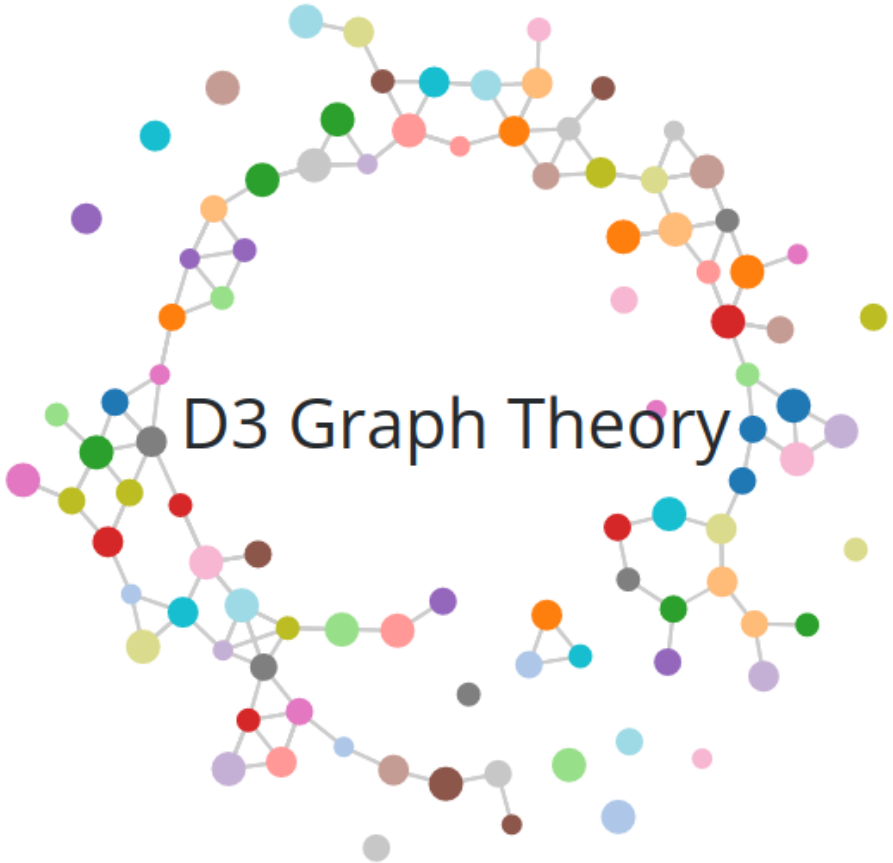

Figure 12: **D3 Graphy Theory**

Credits and Learning Materials

Figure 13: **Graphy Theory - Go Hero**