Essential `networkx` Functions for Network Analysis

This guide introduces the key `networkx` functions you'll use to build, analyze, and visualize networks. Each function is explained with details on its role in network analysis, making it a helpful reference as you work with `networkx` to explore the structure and properties of networks.

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1. Creating and Managing Graphs

- **`nx.DiGraph()`**
    - **Purpose**: Creates a directed graph.
    - **Explanation**: A `DiGraph` in `networkx` allows you to work with networks where edges have direction (e.g., flights from Airport A to Airport B).
- **`G.add_node(node, **attr)`**
    - **Purpose**: Adds a node to the graph `G`.
    - **Explanation**: Each node can have attributes like `name`, `latitude`, or `longitude`. For example, `G.add_node("LAX", name="Los Angeles International", latitude=33.9416, longitude=-118.4085)`.
- **`G.add_edge(node1, node2)`**
    - **Purpose**: Adds a directed edge from `node1` to `node2`.
    - **Explanation**: This function connects two nodes with a directed edge (e.g., from Airport A to Airport B).
- **`G.subgraph(nodes)`**
    - **Purpose**: Creates a subgraph containing only the specified nodes and edges between them.
    - **Explanation**: Useful for focusing on a subset of the network, such as top hubs by degree.

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2. Basic Network Properties

- **`G.degree(node)`**
    - **Purpose**: Returns the total degree of a node (sum of in-degree and out-degree).
    - **Explanation**: The degree measures how connected a node is. In a directed graph, `G.degree(node)` considers all edges, both incoming and outgoing.
- **`G.in_degree(node)`**
    - **Purpose**: Returns the in-degree (number of incoming edges) of a node.

    - **Explanation**: In-degree shows how many connections lead to a node (e.g., how many flights arrive at an airport).
- `G.out_degree(node)`
    - **Purpose**: Returns the out-degree (number of outgoing edges) of a node.
    - **Explanation**: Out-degree measures how many connections go out from a node (e.g., how many flights depart from an airport).
- `nx.density(G)`
    - **Purpose**: Computes the density of the graph.
    - **Explanation**: Density is the ratio of actual edges to possible edges, showing how interconnected the network is.
- `nx.reciprocity(G)`
    - **Purpose**: Calculates the proportion of reciprocal edges in the directed graph.
    - **Explanation**: Reciprocity measures the percentage of pairs of nodes that have mutual connections (A → B and B → A).

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3. Connected Components

- `nx.strongly_connected_components(G)`
    - **Purpose**: Returns a list of all strongly connected components in the directed graph.
    - **Explanation**: Each strongly connected component is a subset of nodes where each node can be reached from any other node in the subset by following directed edges.
- `nx.weakly_connected_components(G)`
    - **Purpose**: Returns a list of all weakly connected components in the directed graph.
    - **Explanation**: Weakly connected components are parts of the graph where nodes are connected if edge direction is ignored.

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4. Path Lengths and Diameter

- `nx.shortest_path_length(G, source, target)`
    - **Purpose**: Computes the shortest path length between a `source` node and `target` node.
    - **Explanation**: Measures the minimum number of edges needed to reach one node from another. In directed graphs, it respects edge direction.
- `nx.average_shortest_path_length(G)`
    - **Purpose**: Calculates the average shortest path length within the largest connected component.
    - **Explanation**: Provides insight into how easily nodes can be reached across the network.
- `nx.diameter(G)`

- **Purpose**: Computes the diameter of the largest connected component in the graph.
- **Explanation**: The diameter is the longest shortest path between any two nodes, indicating the maximum "distance" across the network.

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5. Centrality and Hubs

- `sorted(G.in_degree(), key=lambda x: x[1], reverse=True)[:n]`
    - **Purpose**: Finds the top `n` nodes by in-degree (or out-degree if `G.out_degree()` is used).
    - **Explanation**: Identifies the most connected nodes, useful for spotting key hubs in the network.

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6. Clustering and Assortativity

- `nx.transitivity(G)`
    - **Purpose**: Computes the global clustering coefficient of the graph.
    - **Explanation**: In directed graphs, transitivity measures the likelihood that nodes that share a connection are also directly connected.
- `nx.average_neighbor_degree(G, source="in", target="in")`
    - **Purpose**: Calculates the average in-degree of neighbors for each node.
    - **Explanation**: This function helps analyze assortativity by showing whether nodes with a high in-degree are connected to other nodes with a high in-degree.

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7. Visualization Tools

- `nx.draw_networkx_nodes(G, pos, **kwargs)`
    - **Purpose**: Draws the nodes of the graph at positions specified by `pos`.
    - **Explanation**: Customizable with node size, color, transparency, and other visual options.
- `nx.draw_networkx_edges(G, pos, **kwargs)`
    - **Purpose**: Draws the edges of the graph at positions specified by `pos`.
    - **Explanation**: Can be styled with color, transparency, and line width.
- `nx.spring_layout(G)`
    - **Purpose**: Generates a position layout for nodes based on a force-directed algorithm.
    - **Explanation**: Useful for visually analyzing the network structure, as nodes with more connections are positioned closer to each other.
- `nx.draw_networkx_labels(G, pos, labels, **kwargs)`
    - **Purpose**: Adds labels to nodes at specified positions.

- **Explanation**: Helpful for annotating important nodes, like top hubs.