In [1]:

```
import networkx as nx
import matplotlib.pyplot as plt
from itertools import combinations
# Function to calculate Jaccard similarity
def jaccard_similarity(set1, set2):
    intersection = len(set1.intersection(set2))
    union = len(set1.union(set2))
    return intersection / union if union > 0 else 0

# Define the Topics dictionary
topics = {
    'A2': ['resource', 'environmental', 'human', 'concept', 'allocation', 'security', 'closed', 'natural', 'recyclable'],
    'A4': ['adaptation', 'climate', 'disaster', 'change', 'assessment', 'risk', 'hazard', 'local', 'natural'],
    'A6': ['land', 'rice', 'model', 'change', 'production', 'paddy', 'map', 'scenario', 'future'],
    'A3': ['program', 'education', 'course', 'student', 'sustainability', 'curriculum', 'master', 'university', 'science'],
    'A8': ['reduction', 'emission', 'target', 'greenhouse', 'lowcarbon', 'company', 'country', 'global', 'society'],
    'A13': ['urban', 'city', 'environmental', 'transformation', 'ruralurban', 'sustainable', 'transition', 'economic', 'strate
    'A9': ['soil', 'carbon', 'organic', 'emission', 'management', 'sequestration', 'agriculture', 'ecosystem', 'greenhouse'],
    'A11': ['drought', 'region', 'intensity', 'index', 'impact', 'extreme', 'systemic', 'dynamic', 'west'],
    'A10': ['coastal', 'rise', 'sealevel', 'vulnerability', 'change', 'climate', 'century', 'coast', 'assessment'],
    'A14': ['innovation', 'transition', 'technology', 'design', 'society', 'industrial', 'system', 'pathway', 'sustainable'],
    'A7': ['water', 'lake', 'quality', 'pollution', 'forest', 'loss', 'fertilizer', 'nitrogen', 'sustainability'],
    'A5': ['desertification', 'livelihood', 'pressure', 'drylands', 'alternative', 'poverty', 'ecosystem', 'land', 'marginal']
    'A1': ['sustainability', 'science', 'network', 'research', 'issue', 'society', 'cluster', 'paper', 'conference'],
    'A12': ['engineering', 'industrial', 'ecology', 'sustainable', 'education', 'competence', 'cultural', 'system', 'state'],
    'B1': ['sustainability', 'science', 'research', 'field', 'education', 'knowledge', 'collaboration', 'challenge', 'contribu
    'B3': ['adaptation', 'change', 'island', 'climate', 'community', 'risk', 'impact', 'beach', 'measure'],
    'B6': ['emission', 'cost', 'reduction', 'mitigation', 'power', 'curve', 'abatement', 'potential', 'country'],
    'B4': ['landscape', 'food', 'place', 'approach', 'relation', 'community', 'system', 'biodiversity', 'production'],
    'B9': ['vulnerability', 'hazard', 'assessment', 'risk', 'component', 'livelihood', 'exposure', 'method', 'change'],
    'B2': ['transdisciplinarity', 'process', 'project', 'type', 'knowledge', 'practice', 'mode', 'research', 'problem'],
    'B10': ['assessment', 'sustainability', 'system', 'impact', 'analysis', 'method', 'tool', 'discourse', 'decision'],
    'B15': ['energy', 'transition', 'degrowth', 'growth', 'cluster', 'intensity', 'consumption', 'electricity', 'initiative'],
    'B12': ['ecosystem', 'service', 'biodiversity', 'conservation', 'system', 'garden', 'area', 'activity', 'forest'],
    'B8': ['resilience', 'system', 'transformation', 'threshold', 'community', 'perturbation', 'management', 'concept', 'gover
    'B5': ['water', 'river', 'approach', 'resource', 'wastewater', 'flow', 'management', 'landuse', 'demand'],
    'B14': ['reuse', 'good', 'sale', 'model', 'market', 'book', 'wastewater', 'equipment', 'waste'],
    'B13': ['governance', 'dimension', 'sustainability', 'urbanization', 'integration', 'multiactor', 'risk', 'framework', 're
    'B7': ['rice', 'date', 'rate', 'yield', 'indicator', 'month', 'fertilization', 'district', 'planting'],
```

```
'B11': ['city', 'region', 'consumption', 'farmer', 'production', 'adoption', 'government', 'policy', 'factor'],
'C2': ['research', 'transdisciplinary', 'project', 'knowledge', 'stakeholder', 'process', 'researcher', 'collaboration', '
'C4': ['climate', 'adaptation', 'change', 'risk', 'uncertainty', 'assessment', 'model', 'sensitivity', 'vulnerability'],
'C14': ['value', 'social', 'relational', 'valuation', 'intrinsic', 'individual', 'concept', 'economics', 'people'],
'C6': ['scenario', 'future', 'model', 'positive', 'population', 'alternative', 'land', 'ecosystem', 'change'],
'C15': ['sdgs', 'development', 'goal', 'sustainable', 'indicator', 'target', 'progress', 'national', 'implementation'],
'C1': ['sustainability', 'science', 'system', 'transition', 'digital', 'discipline', 'society', 'research', 'concept'],
'C7': ['water', 'governance', 'nexus', 'supply', 'management', 'resource', 'demand', 'system', 'decision'],
'C5': ['landscape', 'agroforestry', 'management', 'tree', 'conservation', 'system', 'mediterranean', 'land', 'policy'],
'C12': ['service', 'ecosystem', 'forest', 'capital', 'natural', 'assessment', 'biodiversity', 'payment', 'ecological'],
'C17': ['blue', 'growth', 'economy', 'fishery', 'degrowth', 'marine', 'coastal', 'smallscale', 'economic'],
'C20': ['place', 'meaning', 'sense', 'transformative', 'attachment', 'stewardship', 'transformation', 'narrative', 'transi
'C19': ['cultural', 'selection', 'multilevel', 'evolution', 'evolutionary', 'group', 'institution', 'grouplevel', 'resourc
'C18': ['indigenous', 'knowledge', 'science', 'local', 'community', 'western', 'river', 'traditional', 'protocol'],
'C8': ['food', 'household', 'security', 'consumption', 'production', 'crop', 'healthy', 'health', 'sustainable'],
'C9': ['delta', 'vulnerability', 'region', 'amazon', 'coastal', 'population', 'change', 'risk', 'flood'],
'C13': ['conflict', 'environmental', 'justice', 'movement', 'social', 'distribution', 'injustice', 'violence', 'metabolism
'C10': ['resilience', 'community', 'capital', 'social', 'natural', 'adaptive', 'disturbance', 'capacity', 'framework'],
'C11': ['urban', 'city', 'myth', 'public', 'citizen', 'data', 'governance', 'vision', 'experiment'],
'C3': ['education', 'future', 'program', 'competency', 'educational', 'student', 'curriculum', 'sustainable', 'practice'],
'C16': ['trap', 'human', 'socialecological', 'policy', 'system', 'response', 'dynamic', 'ecological', 'model'],
'D13': ['environmental', 'sustainability', 'impact', 'principle', 'sustainable', 'transition', 'social', 'consumption', 'p
'D9': ['food', 'diet', 'land', 'system', 'landuse', 'agricultural', 'pathway', 'biodiversity', 'emission'],
'D19': ['system', 'transformation', 'leverage', 'point', 'sustainability', 'inner', 'change', 'transformative', 'deep'],
'D2': ['knowledge', 'research', 'indigenous', 'coproduction', 'project', 'transdisciplinary', 'partnership', 'process', 'm
'D17': ['sdgs', 'goal', 'sustainable', 'target', 'tradeoff', 'synergy', 'indicator', 'interlinkages', 'data'],
'D5': ['forest', 'ecosystem', 'service', 'landscape', 'carbon', 'deforestation', 'plan', 'medium', 'enterprise'],
'D4': ['climate', 'change', 'adaptation', 'risk', 'resilience', 'response', 'impact', 'transformative', 'flood'],
'D14': ['governance', 'network', 'action', 'situation', 'power', 'actor', 'institutional', 'analysis', 'social'],
'D7': ['water', 'river', 'basin', 'irrigation', 'management', 'scarcity', 'economic', 'agricultural', 'resource'],
'D15': ['bioeconomy', 'discourse', 'transformation', 'growth', 'strategy', 'decolonial', 'economy', 'socioecological', 'al
'D6': ['scenario', 'future', 'land', 'basin', 'assessment', 'river', 'invasion', 'model', 'landuse'],
'D12': ['urban', 'city', 'expansion', 'community', 'land', 'different', 'smart', 'population', 'laboratory'],
'D10': ['community', 'capital', 'resilience', 'social', 'natural', 'disaster', 'local', 'human', 'resource'],
'D8': ['emission', 'carbon', 'energy', 'mitigation', 'cost', 'industry', 'reduction', 'sector', 'netzero'],
'D16': ['value', 'landscape', 'nature', 'relational', 'people', 'contribution', 'conservation', 'nonmaterial', 'life'],
'D11': ['nexus', 'peace', 'governance', 'resource', 'approach', 'scale', 'solution', 'challenge', 'indicator'],
'D3': ['competency', 'education', 'program', 'student', 'sustainability', 'university', 'learning', 'interdisciplinary', '
'D1': ['science', 'sustainability', 'research', 'researcher', 'problem', 'scientific', 'field', 'tension', 'method'],
'D18': ['crisis', 'covid19', 'pandemic', 'global', 'research', 'transformation', 'challenge', 'response', 'opportunity'],
```

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    'D20': ['generation', 'future', 'narrative', 'intergenerational', 'imaginary', 'intervention', 'participatory', 'participa
}
```

In [2]:

```
# Calculate Jaccard similarity between all topic pairs
topic_combinations = list(combinations(topics.keys(), 2))
similarity_scores = []
# Set a threshold to identify overlapping topics (adjust as needed)
threshold = 0.1

for topic1, topic2 in topic_combinations:
    # Check if the topics start with the same letter or are the same topic
    if topic1[0] != topic2[0] and topic1 != topic2:
        words1 = set(topics[topic1])
        words2 = set(topics[topic2])
        similarity = jaccard_similarity(words1, words2)
        if similarity > threshold:
            similarity_scores.append((topic1, topic2, similarity))

# Print similarity scores above the threshold
print("Similarity scores above the threshold:")
for topic1, topic2, similarity in similarity_scores:
    print(f"Jaccard similarity between {topic1} and {topic2}: {similarity:.4f}")
```

```
Similarity scores above the threshold:
Jaccard similarity between A2 and D10: 0.2000
Jaccard similarity between A4 and B3: 0.2857
Jaccard similarity between A4 and B9: 0.2857
Jaccard similarity between A4 and C4: 0.3846
Jaccard similarity between A4 and C12: 0.1250
Jaccard similarity between A4 and C9: 0.1250
Jaccard similarity between A4 and D4: 0.2857
Jaccard similarity between A4 and D10: 0.2000
Jaccard similarity between A6 and C4: 0.1250
Jaccard similarity between A6 and C6: 0.3846
Jaccard similarity between A6 and D6: 0.2857
Jaccard similarity between A3 and B1: 0.2000
Jaccard similarity between A3 and C1: 0.1250
Jaccard similarity between A3 and C3: 0.2857
Jaccard similarity between A3 and D3: 0.3846
Jaccard similarity between A3 and D1: 0.1250
Jaccard similarity between A8 and B6: 0.2000
Jaccard similarity between A8 and D8: 0.1250
Jaccard similarity between A13 and C20: 0.1250
Jaccard similarity between A13 and C11: 0.1250
Jaccard similarity between A13 and D13: 0.2000
Jaccard similarity between A13 and D15: 0.1250
Jaccard similarity between A13 and D12: 0.1250
Jaccard similarity between A9 and D5: 0.1250
Jaccard similarity between A9 and D8: 0.1250
Jaccard similarity between A10 and B3: 0.1250
Jaccard similarity between A10 and B9: 0.2000
Jaccard similarity between A10 and C4: 0.2857
Jaccard similarity between A10 and C9: 0.2000
Jaccard similarity between A10 and D4: 0.1250
Jaccard similarity between A14 and C1: 0.2000
Jaccard similarity between A14 and D13: 0.1250
Jaccard similarity between A14 and D9: 0.1250
Jaccard similarity between A5 and C6: 0.2000
Jaccard similarity between A1 and B1: 0.2000
Jaccard similarity between A1 and C1: 0.2857
Jaccard similarity between A1 and D1: 0.2000
Jaccard similarity between A12 and C3: 0.1250
Jaccard similarity between B1 and C2: 0.2000
Jaccard similarity between B1 and C1: 0.2000
```

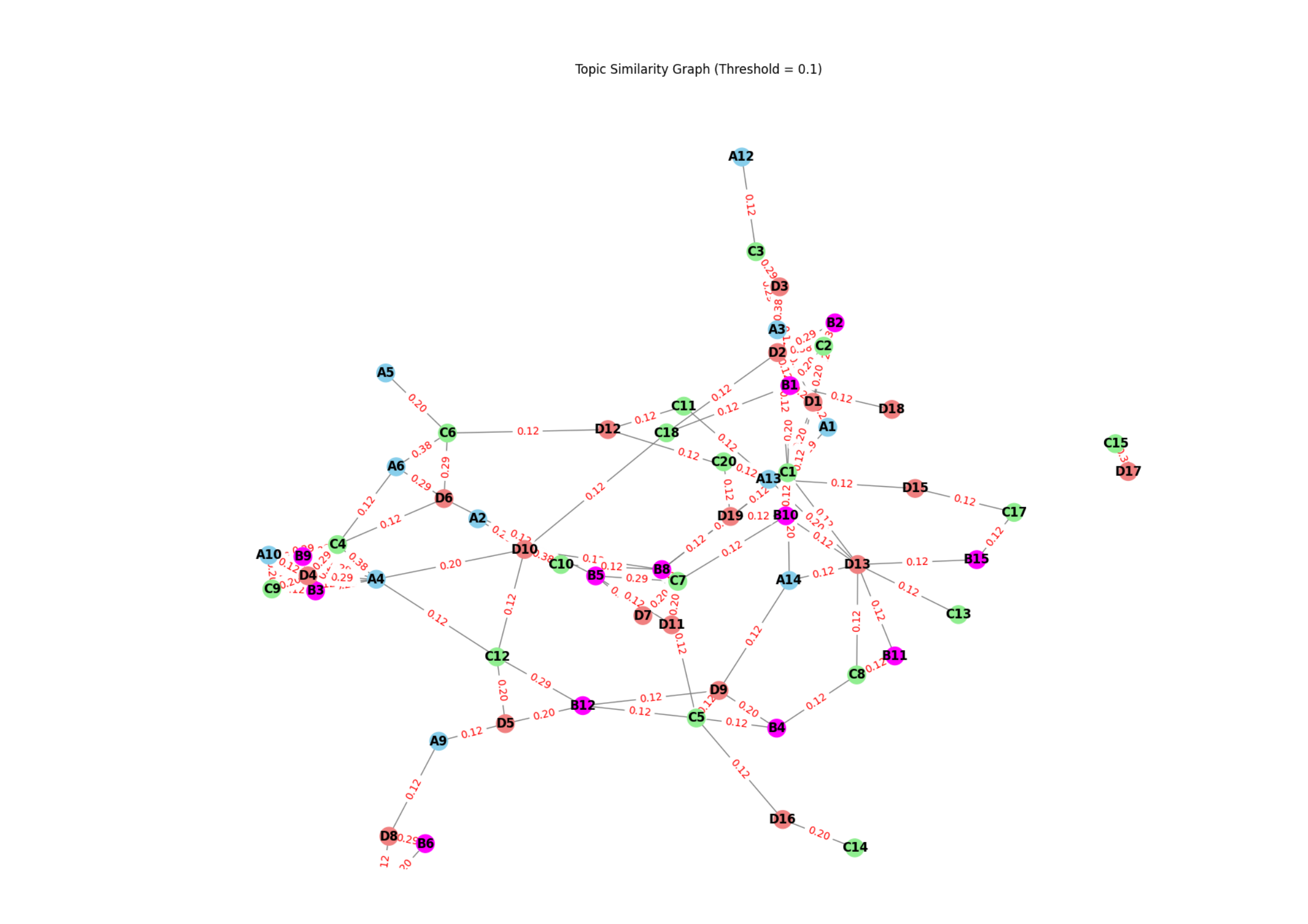
```
Jaccard similarity between B1 and C18: 0.1250
Jaccard similarity between B1 and D2: 0.1250
Jaccard similarity between B1 and D3: 0.1250
Jaccard similarity between B1 and D1: 0.2857
Jaccard similarity between B1 and D18: 0.1250
Jaccard similarity between B3 and C4: 0.2857
Jaccard similarity between B3 and C9: 0.1250
Jaccard similarity between B3 and D4: 0.3846
Jaccard similarity between B6 and D8: 0.2857
Jaccard similarity between B4 and C5: 0.1250
Jaccard similarity between B4 and C8: 0.1250
Jaccard similarity between B4 and D9: 0.2000
Jaccard similarity between B9 and C4: 0.2857
Jaccard similarity between B9 and C9: 0.2000
Jaccard similarity between B9 and D4: 0.1250
Jaccard similarity between B2 and C2: 0.3846
Jaccard similarity between B2 and D2: 0.2857
Jaccard similarity between B2 and D1: 0.1250
Jaccard similarity between B10 and C1: 0.1250
Jaccard similarity between B10 and C7: 0.1250
Jaccard similarity between B10 and D13: 0.1250
Jaccard similarity between B10 and D19: 0.1250
Jaccard similarity between B10 and D1: 0.1250
Jaccard similarity between B15 and C17: 0.1250
Jaccard similarity between B15 and D13: 0.1250
Jaccard similarity between B12 and C5: 0.1250
Jaccard similarity between B12 and C12: 0.2857
Jaccard similarity between B12 and D9: 0.1250
Jaccard similarity between B12 and D5: 0.2000
Jaccard similarity between B8 and C1: 0.1250
Jaccard similarity between B8 and C7: 0.2000
Jaccard similarity between B8 and C5: 0.1250
Jaccard similarity between B8 and C10: 0.1250
Jaccard similarity between B8 and D19: 0.1250
Jaccard similarity between B8 and D10: 0.1250
Jaccard similarity between B5 and C7: 0.2857
Jaccard similarity between B5 and D7: 0.2857
Jaccard similarity between B5 and D6: 0.1250
Jaccard similarity between B5 and D11: 0.1250
Jaccard similarity between B11 and C8: 0.1250
Jaccard similarity between B11 and D13: 0.1250
```

```
Jaccard similarity between C2 and D2: 0.3846
Jaccard similarity between C2 and D1: 0.2000
Jaccard similarity between C4 and D4: 0.2857
Jaccard similarity between C4 and D6: 0.1250
Jaccard similarity between C14 and D16: 0.2000
Jaccard similarity between C6 and D6: 0.2857
Jaccard similarity between C6 and D12: 0.1250
Jaccard similarity between C15 and D17: 0.3846
Jaccard similarity between C1 and D13: 0.1250
Jaccard similarity between C1 and D19: 0.1250
Jaccard similarity between C1 and D1: 0.2000
Jaccard similarity between C7 and D7: 0.2000
Jaccard similarity between C7 and D11: 0.2000
Jaccard similarity between C5 and D9: 0.1250
Jaccard similarity between C5 and D16: 0.1250
Jaccard similarity between C12 and D5: 0.2000
Jaccard similarity between C12 and D10: 0.1250
Jaccard similarity between C17 and D15: 0.1250
Jaccard similarity between C20 and D19: 0.1250
Jaccard similarity between C18 and D2: 0.1250
Jaccard similarity between C18 and D10: 0.1250
Jaccard similarity between C8 and D13: 0.1250
Jaccard similarity between C9 and D4: 0.2000
Jaccard similarity between C13 and D13: 0.1250
Jaccard similarity between C10 and D10: 0.3846
Jaccard similarity between C11 and D12: 0.1250
Jaccard similarity between C3 and D3: 0.2857
```

In [3]:

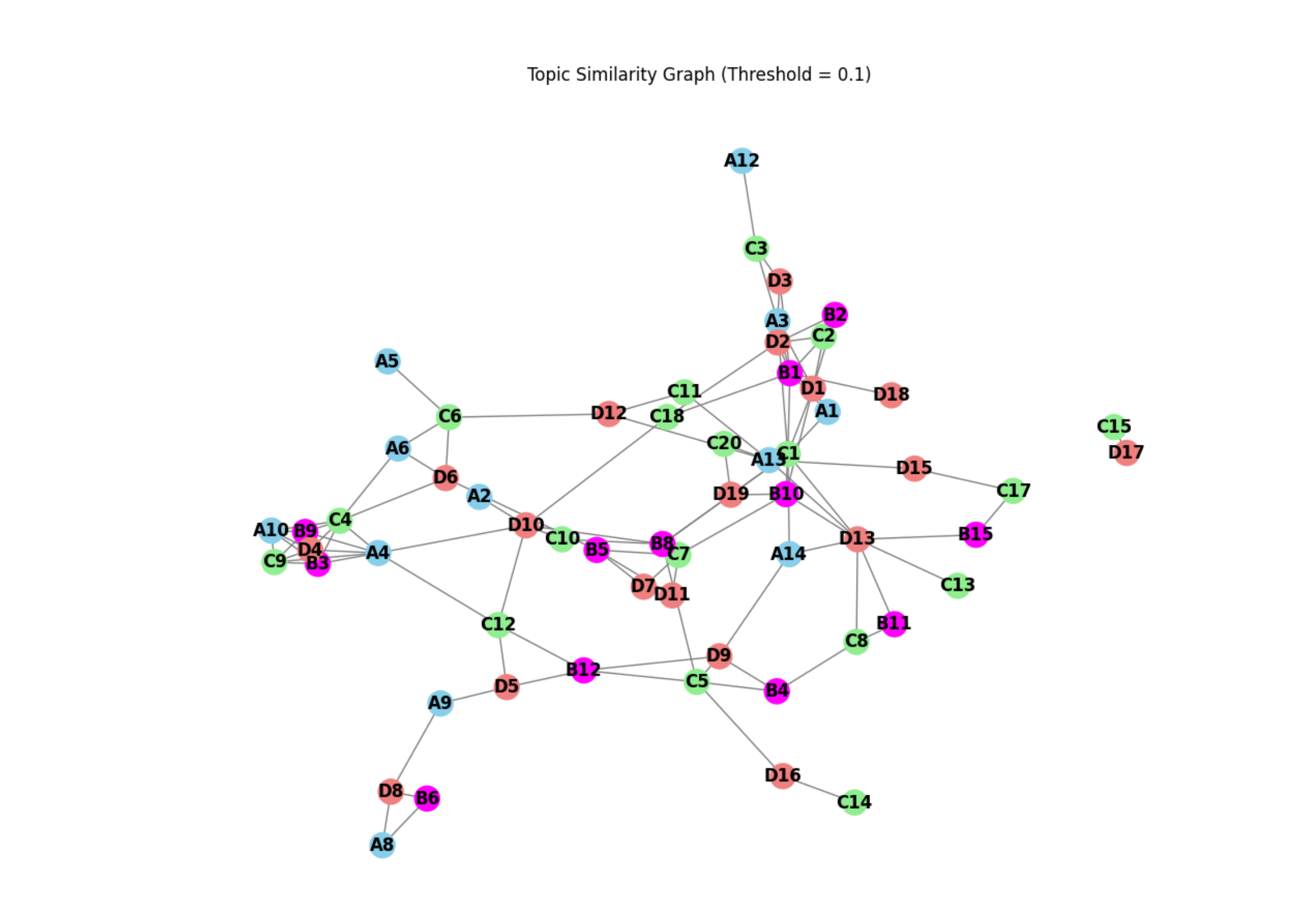
```python
# Calculate Jaccard similarity between all topic pairs and obtain unique similarity scores
topic_combinations = list(combinations(topics.keys(), 2))
similarity_scores = []
threshold = 0.1

for topic1, topic2 in topic_combinations:
    if topic1[0] != topic2[0]:  # Exclude pairs with the same first letter
        words1 = set(topics[topic1])
        words2 = set(topics[topic2])
        similarity = jaccard_similarity(words1, words2)
        if similarity > threshold:
            similarity_scores.append((topic1, topic2, similarity))
```

```
# Remove duplicate pairs
unique_similarity_scores = []
for score in similarity_scores:
    if (score[1], score[0], score[2]) not in unique_similarity_scores:  # Check reverse pair as well
        unique_similarity_scores.append(score)

# Create a graph
G = nx.Graph()
for topic1, topic2, similarity in unique_similarity_scores:
    G.add_edge(topic1, topic2, weight=similarity)

# Draw the graph
pos = nx.spring_layout(G, seed=42)
edge_labels = {(u, v): f"{d['weight']:.2f}" for u, v, d in G.edges(data=True)}

node_colors = {'A': 'skyblue', 'B': 'magenta', 'C': 'lightgreen', 'D': 'lightcoral'}
colors = [node_colors[node[0]] for node in G.nodes()]

plt.figure(figsize=(14, 12))

nx.draw(G, pos, with_labels=True, font_weight='bold', node_color=colors, edge_color='gray')
nx.draw_networkx_edge_labels(G, pos, edge_labels=edge_labels, font_color='red')

plt.title("Topic Similarity Graph (Threshold = {})".format(threshold))
plt.show()
```


Topic Similarity Graph (Threshold = 0.1)
A12
C3
D3
A3
B2
D2
C2
A5
B1
D1
D18
C11
C6
D12
C18
A1
C15
D17
A6
C20
C1
A13
D15
C17
D6
D19
B10
A2
C4
D10
A10
B9
C10
B8
D13
B15
D4
A4
B5
C7
A14
C9
B3
D7
D11
C13
C12
B11
C8
D9
B12
C5
B4
D5
A9
D16
D8
B6
C14

In [4]:

```python
# Create a graph
G = nx.Graph()
for topic1, topic2, similarity in similarity_scores:
    G.add_edge(topic1, topic2, weight=similarity)

# Draw the graph
pos = nx.spring_layout(G, seed=42)  # Position nodes using the Fruchterman-Reingold force-directed algorithm
edge_labels = {(u, v): f"{d['weight']:.2f}" for u, v, d in G.edges(data=True)}

# Assign different node colors based on the first letter of topic codes
node_colors = {'A': 'skyblue', 'B': 'magenta', 'C': 'lightgreen', 'D': 'lightcoral'}
colors = [node_colors[node[0]] for node in G.nodes()]

# Increase the figure size
plt.figure(figsize=(10, 8))

nx.draw(G, pos, with_labels=True, font_weight='bold', node_color=colors, edge_color='gray')
# Uncomment the line below if you want to add edge labels
# nx.draw_networkx_edge_labels(G, pos, edge_labels=edge_labels, font_color='red')

plt.title("Topic Similarity Graph (Threshold = {})".format(threshold))
plt.show()
```


Topic Similarity Graph (Threshold = 0.1)
A12
C3
D3
A3
B2
D2
C2
A5
B1
D1
D18
C11
D12
C18
A1
C6
C15
D17
C20
A6
A15
C1
D15
D6
A2
D19
B10
C17
C4
D10
A10
B9
C10
B8
D13
B15
D4
B5
C7
A14
A4
C9
B3
D7
D11
C13
C12
B11
C8
D9
B12
C5
D5
B4
A9
D16
D8
B6
C14
A8

In [1]:

```
import plotly.graph_objects as go
import pandas as pd
# Sample data (replace this with your actual data)
data = [
    {'Source': 'A1 (Advancing sustainable science research) ', 'Target': 'B1 (Advancing sustainable science research) ', 'Valu
    {'Source': 'A1 (Advancing sustainable science research) ', 'Target': 'C1 (Advancing sustainable science research) ', 'Valu
    {'Source': 'A1 (Advancing sustainable science research) ', 'Target': ' D1 (Advancing sustainable science research)', 'Valu
    {'Source': 'A2 (Coupled human and natural systems)', 'Target': 'D10 (Social-ecological resilience) ', 'Value': 0.2000},
    {'Source': 'A3 (Sustainability education and competency) ', 'Target': 'B1 (Advancing sustainable science research) ', 'Val
    {'Source': 'A3 (Sustainability education and competency) ', 'Target': ' C1 (Advancing sustainable science research) ', 'Va
    {'Source': 'A3 (Sustainability education and competency) ', 'Target': 'C3 (Sustainability education and competency) ', 'Va
    {'Source': 'A3 (Sustainability education and competency) ', 'Target': 'D3 (Sustainability education and competency) ', 'Va
    {'Source': 'A3 (Sustainability education and competency) ', 'Target': ' D1 (Advancing sustainable science research) ', 'Va
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'B3 (Climate change adaption) ', 'Value': 0.2857},
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'B9 (Disaster risk assessment) ', 'Value': 0.2857},
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'C12 (Biodiversity and ecosystem services assessment) ', 'Value':
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'C4 (Climate change adaption and mitigation) ', 'Value': 0.3846},
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'C9 (Social-ecological resilience) ', 'Value': 0.1250},
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'D10 (Social-ecological resilience) ', 'Value': 0.2000},
    {'Source': 'A4 (Climate change assessment) ', 'Target': 'D4 (Transformative responses to climate change) ', 'Value': 0.285
    {'Source': 'A5 (Sustainable landscape management) ', 'Target': 'C6 (Future land use scenarios and planning) ', 'Value': 0.
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    {'Source': 'A6 (Future land use scenarios and planning)  ', 'Target': 'C6 (Future land use scenarios and planning) ', 'Val
    {'Source': 'A6 (Future land use scenarios and planning)  ', 'Target': 'D6 (Future land use scenarios and planning) ', 'Val
    {'Source': 'A8 (Reducing GHG emissions) ', 'Target': 'B6 (Solutions for emission reduction) ', 'Value': 0.2000},
    {'Source': 'A8 (Reducing GHG emissions) ', 'Target': 'D12 (Sustainable urban transitions) ', 'Value': 0.1250},
    {'Source': 'A8 (Reducing GHG emissions) ', 'Target': 'D8 (Low carbon energy transitions) ', 'Value': 0.1250},
    {'Source': 'A9 (Agroecosystems emissions management) ', 'Target': 'D5 (Sustainable landscape management) ', 'Value': 0.125
    {'Source': 'A9 (Agroecosystems emissions management) ', 'Target': 'D8 (Low carbon energy transitions) ', 'Value': 0.1250},
    {'Source': 'A10 (Coastal vulnerability assessment) ', 'Target': 'B3 (Climate change adaption) ', 'Value': 0.1250},
    {'Source': 'A10 (Coastal vulnerability assessment) ', 'Target': 'B9 (Disaster risk assessment) ', 'Value': 0.2000},
    {'Source': 'A10 (Coastal vulnerability assessment) ', 'Target': 'C4 (Climate change adaption and mitigation) ', 'Value': 0
    {'Source': 'A10 (Coastal vulnerability assessment) ', 'Target': 'C9 (Social-ecological resilience) ', 'Value': 0.2000},
    {'Source': 'A10 (Coastal vulnerability assessment) ', 'Target': 'D4 (Transformative responses to climate change) ', 'Value
    {'Source': 'A12 (Sustainable industrial systems)', 'Target': 'C3 (Sustainability education and competency) ', 'Value': 0.1
    {'Source': 'A13 (Sustainable urban transitions)', 'Target': 'C20 (Placed-based sustainability transformations)', 'Value':
```

```
{'Source': 'A13 (Sustainable urban transitions) ', 'Target': 'C11 (Sustainable urban transitions) ', 'Value': 0.1250},
{'Source': 'A13 (Sustainable urban transitions) ', 'Target': 'D13 (Sustainable social transitions) ', 'Value': 0.2000},
{'Source': 'A13 (Sustainable urban transitions) ', 'Target': 'D15 (Sustainable bioeconomy transitions) ', 'Value': 0.1250}
{'Source': 'A14 (Sustainable societal transitions) ', 'Target': ' C1 (Advancing sustainable science research) ', 'Value':
{'Source': 'A14 (Sustainable societal transitions) ', 'Target': 'D13 (Sustainable social transitions) ', 'Value': 0.1250},
{'Source': 'A14 (Sustainable societal transitions) ', 'Target': 'D9 (Sustainable land use and food systems) ', 'Value': 0.
{'Source': 'B1 (Advancing sustainable science research) ', 'Target': 'C2 (Transdisciplinary knowledge development) ', 'Val
{'Source': 'B1 (Advancing sustainable science research) ', 'Target': 'C1 (Advancing sustainable science research) ', 'Valu
{'Source': 'B1 (Advancing sustainable science research) ', 'Target': 'C18 (Indigenous and traditional knowledge) ', 'Value
{'Source': 'B1 (Advancing sustainable science research) ', 'Target': 'D2 (Transdisciplinary knowledge development) ', 'Val
{'Source': 'B1 (Advancing sustainable science research) ', 'Target': 'D3 (Sustainability education and competency) ', 'Val
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]

# Clean the 'Source' and 'Target' values by stripping spaces
for item in data:
    item['Source'] = item['Source'].strip()
    item['Target'] = item['Target'].strip()
```

```python
# Define a default value for all links as a list
default_value = [0.1] * len(data)

# Define time periods and their positions
time_periods = {
    '2006-2010': ["A1 (Advancing sustainable science research)", "A2 (Coupled human and natural systems)", "A3 (Sustainability
    '2011-2015': ["B1 (Advancing sustainable science research)", "B2 (Transdisciplinary knowledge development)", "B3 (Climate
    '2016-2020': ["C1 (Advancing sustainable science research)", "C2 (Transdisciplinary knowledge development)", "C3 (Sustaina
    '2021-2023': ["D1 (Advancing sustainable science research)", "D2 (Transdisciplinary knowledge development)", "D3 (Sustaina
}

# Create a DataFrame from the data
df = pd.DataFrame(data)

# Create nodes for all topics with custom font size and color
node_labels = []
node_dict = {}
node_colors = []

for topics in time_periods.values():
    node_labels.extend(topics)

for node_label in node_labels:
    node_dict[node_label] = len(node_dict)

    # Determine the node color based on the starting letter
    starting_letter = node_label[0]
    if starting_letter == 'A':
        node_colors.append('grey')
    elif starting_letter == 'B':
        node_colors.append('green')
    elif starting_letter == 'C':
        node_colors.append('purple')
    elif starting_letter == 'D':
        node_colors.append('red')

# Define x-locations based on the initial letter of the source
x_locations = {
    'A': 0,  # Set 'A' to x-location 0
    'B': 1,  # Set 'B' to x-location 1
```

```
    'C': 2,  # Set 'C' to x-location 2
    'D': 3,  # Set 'D' to x-location 3
}

# Modify the x-values for each node based on the initial letter of the source
x_values = [x_locations[node_label[0]] if node_label.strip() else -1 for node_label in node_labels]


# Create a color mapping dictionary based on the initial letter
color_mapping = {
    'A': 'Lavender',
    'B': 'Tan',
    'C': 'cyan',
    'D': 'cyan',
}

# Assign colors to the links based on the initial letter of the source node
link_colors = [color_mapping[node_label[0]] for node_label in df['Source']]

# Create a Sankey diagram with Plotly
fig = go.Figure(go.Sankey(
    node=dict(
        pad=25,
        thickness=30,
        line=dict(color="black", width=0.5),
        label=node_labels,
        x=x_values,
        color=node_colors,
    ),
    link=dict(
        source=[node_dict[item['Source']] for item in data],
        target=[node_dict[item['Target']] for item in data],
        value=default_value,  # Use the updated default_value list
        color=link_colors  # Use the corrected link_colors list
    )
))

# Set the node label size to 18, color to blue, and make it bold
fig.update_traces(
    textfont=dict(size=12, color="#00001C"),
)
```

```
# Customize the appearance of the Sankey diagram
fig.update_layout(
    title_text="Topic Evolution Sankey Diagram",
    xaxis=dict(
        title="Time Periods",
    ),
    height=1500,  # Adjust the height as needed
)

# Show the Sankey diagram
fig.show()
```