An Efficient Index for Reachability Queries in Public Transport Networks

Bezaye Tesfaye Nikolaus Augsten Mateusz Pawlik
Michael Böhlen Christian S. Jensen

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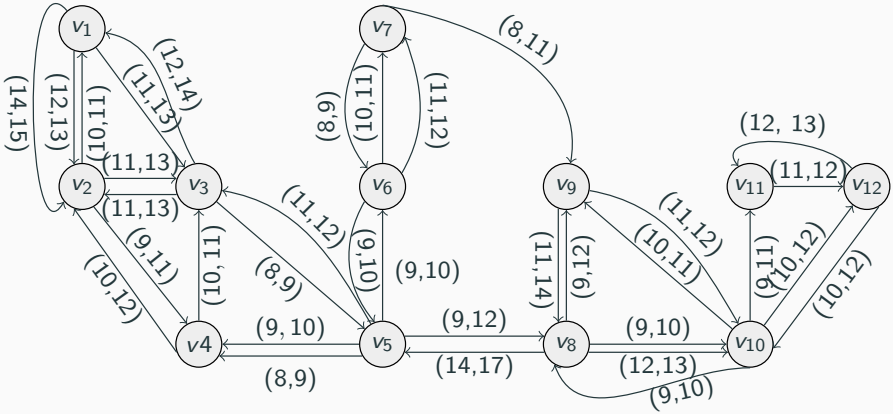
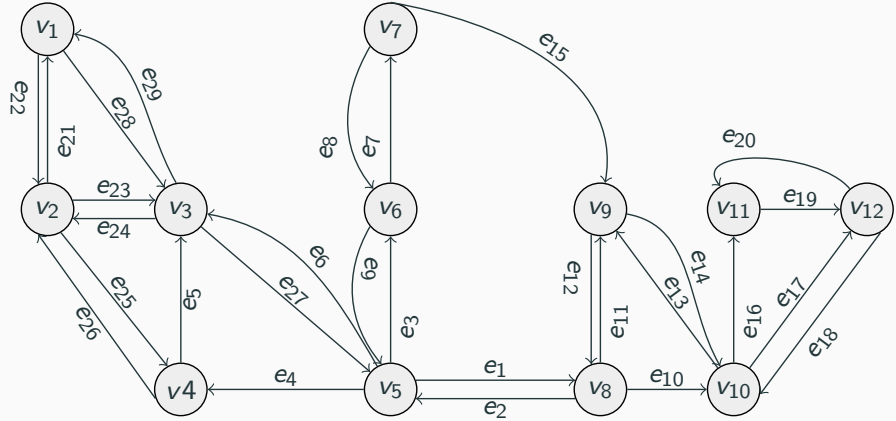
Motivation



Path costs between stations depend on the start time

Motivation

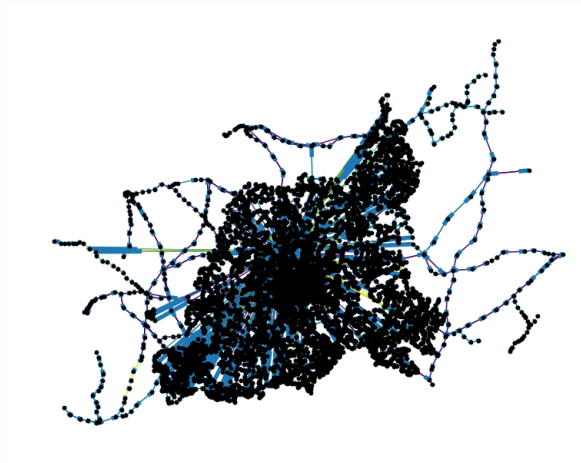


Path costs between nodes depend on the start time

Reachability Query

Reachability query in a temporal graph G**:**

- Which points of interst (POIs) are reachable given:
  - start time
  - start node
  - cost budget
- Application areas:
  - geomarketing
  - recommender systems
  - logistics, ...



Existing Approaches

1. **No-index**: expand edge by edge to find all reachable POIs in the graph
   - does not scale to large networks
2. **Shortest-path index**: issue a shortest path query for each POI
   - expensive index construction
   - does not scale to large numbers of POIs

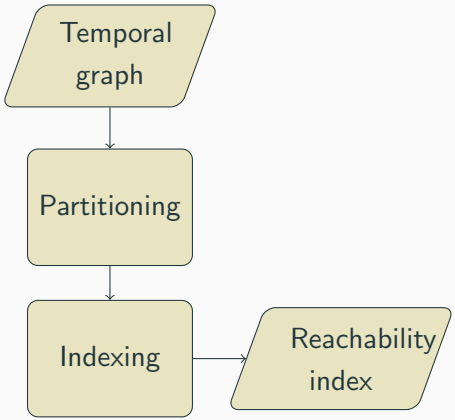
Goal: minimize the query time and the preprocessing time

Our Approach

- Preprocessing:
  - design a reachability index based on graph partitioning
- Query Processing:
  - apply cell by cell expansion using the reachability index

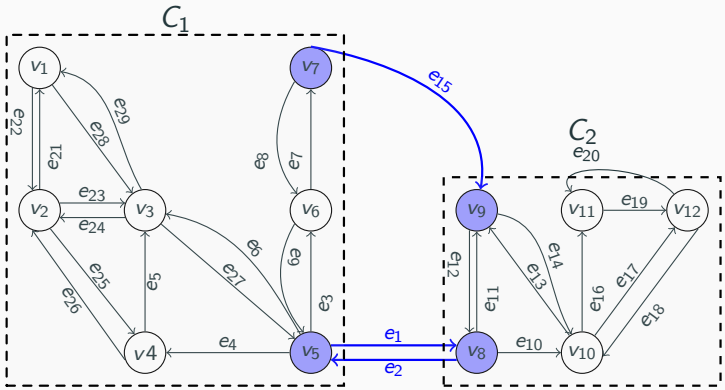
Preprocessing

- Building a reachability index
- Involves:
  - graph partitioning
  - construction of the index core
  - computing index cost function
  - inserting POIs



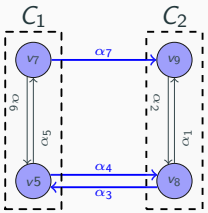
Graph Partitioning

- Given $G = (V, E, c)$, we partition V into a set of disjoint cells
  - **border edges** = edges that connect nodes from different cells
  - **border nodes** = end points of *border edges*

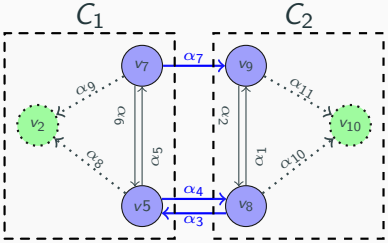


Reachability Index R

- An index core stores:
  - border nodes
  - border edges
  - an edge between each pair of border nodes within a cell
- Reachability index R = index core + POIs:
  - all nodes and edges in the index core
  - a set of POIs
  - an edge from each border node to each POI within a cell



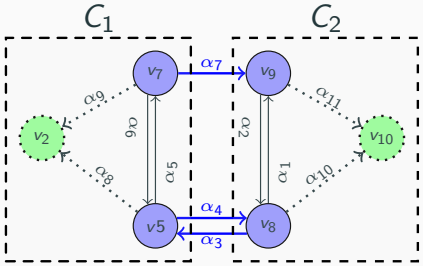
(a) Index core



(b) Reachability index R

Query Processing

- Cell by cell expansion (similar to Dijkstra's algorithm)
- Expand in index R from a query node at a specific start time within a given cost budget



- $RQ(R, v_5, 8, 6) = \{v_2, v_{10}\}$
  - $sp(v_5, v_2, t) = 4$ and $sp(v_5, v_{10}, t) = 5$

Experiments

- GTFS datasets and Synthetic

Dataset	#Nodes	#Edges	#Conn	#Part	#B-nodes		Part. size			#POIs	
					sum	avg	avg	min	max	sum	avg
Zurich	2,508	5,630	555,713	45	315	7.0	55	2	157	99	2.20
Berlin	12,984	34,791	1,348,070	50	1,241	24.8	259	2	921	567	11.34
Synthetic	145,188	433,272	31,042,468	44	1,245	28.3	3,299	831	4,037	7,176	163.00

Comparision with respect to index size and number of expanded edges:

- No-index (NI): expand with temporal Dijkstra in original graph
- Shortest-path (SP): precompute shortest path to all POIs (from each node)
- Reachability query (RQ): our solution

Evaluation

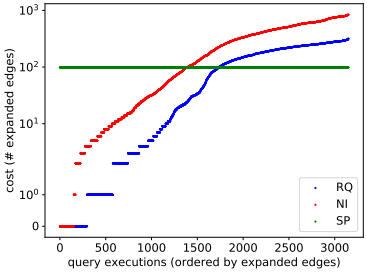
Reachability query = RQ, Shortest-path = SP, No-index = NI

Dataset	Algorithm	#Nodes	#Edges	#Connections
Zurich	*RQ*	414	4,021	421,268
	SP	2,508	248,292	55,015,587
	NI	2,508	5,630	555,713
Berlin	*RQ*	1,808	53,543	2,533,940
	SP	12,984	7,361,928	764,355,690
	NI	12,984	34,791	1,348,070
Synthetic	*RQ*	8,421	212,564	18,018,811
	SP	145,188	1,041,869,088	222,760,750,368
	NI	145,188	433,272	31,042,468

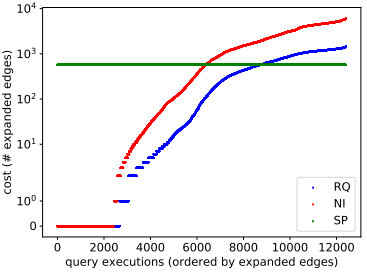
Index size (RQ) $<<$ Index size (SP)

Evaluation

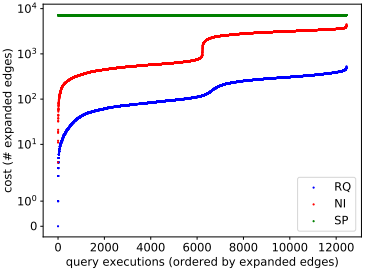
♣ **start times:** $\{8, 12, 16, 18, 22\}$**, cost budgets:** $\{60min, 120min\}$**, POIs: 5% of nodes**



(a) *Zurich*



(b) *Berlin*



(c) *Synthetic*

Summary

- Reachability index requires precomputation from and to border nodes
- Cell by cell expansion scales to large networks
- Network structure may affect the effectiveness of reachability index

Thank you!