# Shortest Path Queries for Indoor Venues with Temporal Variations


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## 1. Introduction

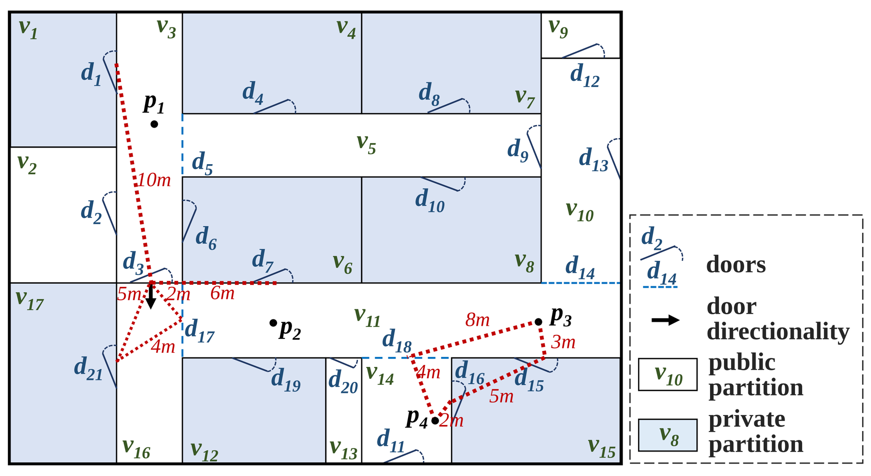
- **Background.**
  - Indoor location-based services are becoming increasingly popular.
  - Shortest path/distance queries are fundamental in many indoor location-based services.
  - Some temporal variations could change the indoor topology.
- **Challenges of handling indoor temporal-variation aware shortest path query (ITSPQ).**
  - The existing graphs used to model the indoor space do not consider temporal variations.
  - The pre-computed and materialized door-to-door distances become invalid when one or more doors open or close at certain times.
- **Contributions.**
  - A new type of query called Indoor Temporal-variation aware Shortest Path Query (ITSPQ) is defined.
  - A graph structure (IT-Graph) that captures indoor temporal variations is designed.
  - We design two algorithms that check a door's accessibility synchronously and asynchronously, respectively.
  - We experimentally evaluate the proposed techniques using synthetic data. The results show that our methods are efficient.

## 2. Problem Formulation

- **Active Time Interval (ATI).** We use [open-time, close-time) to denote an active time interval (ATI) of a door.
- **Indoor Temporal-variation Aware Shortest Path Query (ITSPQ).** Given a start point $p_s$, a target point $p_t$, and a current timestamp $t$, an *indoor temporal-variation aware shortest path query* ITSPQ($p_s$, $p_t$, $t$) returns the valid shortest path from $p_s$ to $p_t$ that meets:
  1) Each door $d_i$ in the path should be open at $t + \Delta t$, where $\Delta t$ is the walking time from $p_s$ to $d_i$ and it is computed based on human's average walking speed — $5km/h$;
  2) The path should not go through any private partition except the private partitions that contain $p_s$ and/or $p_t$.

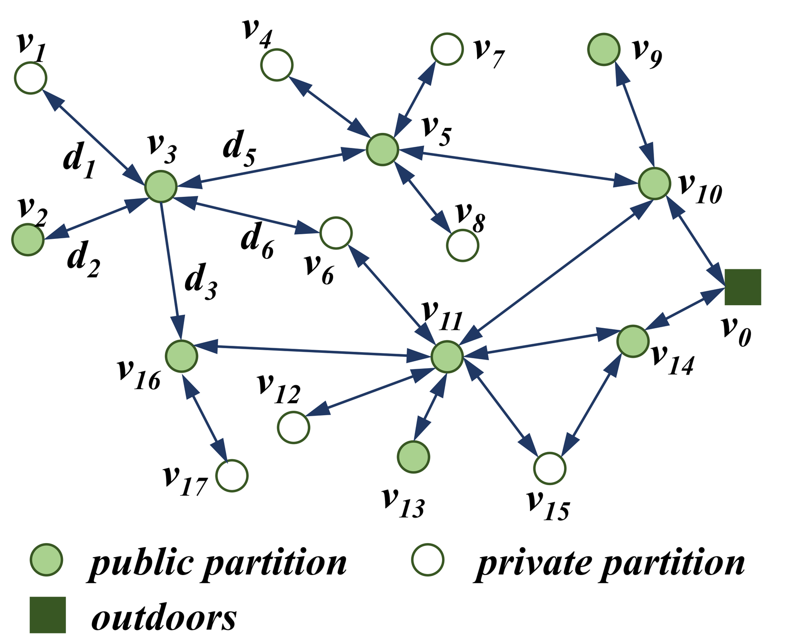
Active Time Intervals (ATIs) of Doors

| Door, ATIs | Door, ATIs |
|---|---|
| $d_1$, ⟨[5:00, 23:00)⟩ | $d_2$, ⟨[8:00, 16:00)⟩ |
| $d_3$, ⟨[6:00, 23:00)⟩ | $d_4$, ⟨[9:00, 18:00)⟩ |
| $d_5$, ⟨[6:30, 23:00)⟩ | $d_6$, ⟨[8:00, 16:00)⟩ |
| $d_7$, ⟨[6:00, 23:30)⟩ | $d_8$, ⟨[9:00, 18:00)⟩ |
| $d_9$, ⟨[0:00, 6:00), [6:30, 23:00)⟩ | $d_{10}$, ⟨[8:00, 16:00)⟩ |
| $d_{11}$, ⟨[5:00, 23:00)⟩ | $d_{12}$, ⟨[5:00, 23:00)⟩ |
| $d_{13}$, ⟨[5:00, 17:00), [18:00, 23:00)⟩ | $d_{14}$, ⟨[0:00, 24:00)⟩ |
| $d_{15}$, ⟨[8:00, 16:00)⟩ | $d_{16}$, ⟨[8:00, 17:00)⟩ |
| $d_{17}$, ⟨[0:00, 24:00)⟩ | $d_{18}$, ⟨[0:00, 23:00)⟩ |
| $d_{19}$, ⟨[8:00, 16:00)⟩ | $d_{20}$, ⟨[5:00, 23:00)⟩ |
| $d_{21}$, ⟨[8:00, 16:00)⟩ | |




## 3. ITSPQ Processing

- **Indoor temporal-variation graph** (IT-Graph) $G_{IT}$ ($V$, $E$, $L_V$, $L_E$):
  1) $V$ is the set of vertices such that each vertex $v \in V$ is an indoor partition.
  2) $E$ is the set of directed edges such that each edge $(v_i, v_j, d_k) \in E$ means one can reach $v_j$ from $v_i$ through a door $d_k$.
  3) $L_V$ is the set of vertex labels, each being a 3-tuple($ID_v$, $p$-$type$, $DM$).
  4) $L_E$ is the set of edge labels, each being a 3-tuple ($ID_d$, $d$-$type$, $ATIs$).



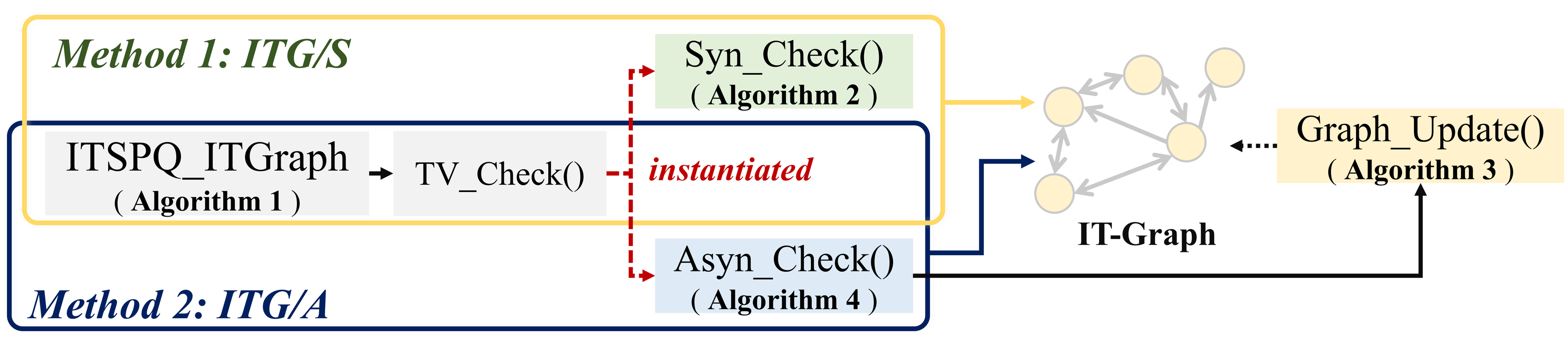

Door Table

| $ID_d$ | d-type | ATIs |
|---|---|---|
| $d_7$ | PRD | ⟨[6:00, 23:30)⟩ |
| $d_3$ | PBD | ⟨[6:00, 23:00)⟩ |
| ... | ... | ... |

Partition Table

| $ID_v$ | p-type | DM |
|---|---|---|
| $v_1$ | PRP | [[($d_1$, $d_1$), 0]] |
| $v_{16}$ | PBP | [[($d_3$, $d_{17}$), 2], [($d_3$, $d_{21}$), 4], [($d_{17}$, $d_{21}$), 5]] |
| ... | ... | ... |

- **Different Methods for ITSPQ Processing**




1) **Synchronous Check.** Look up a door $d$'s $ATIs$ and compare it to the arrival time when one just leaves for $d$.
2) **Asynchronous Check.** Directly refer to a time-dependent IT-Graph that only keeps all currently open doors. The information of IT-Graph only needs to be updated asynchronously at the next checkpoint.

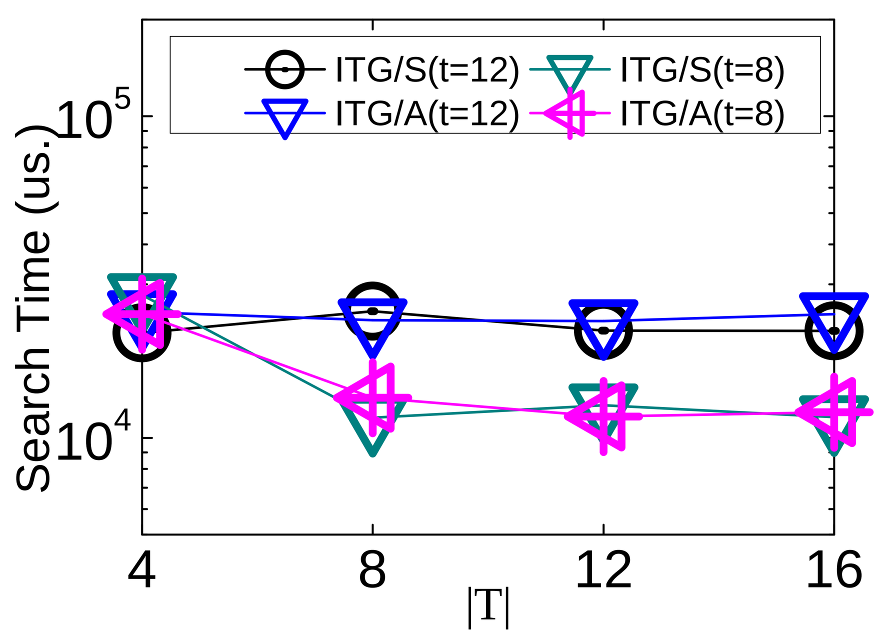
## 4. Experimental Results

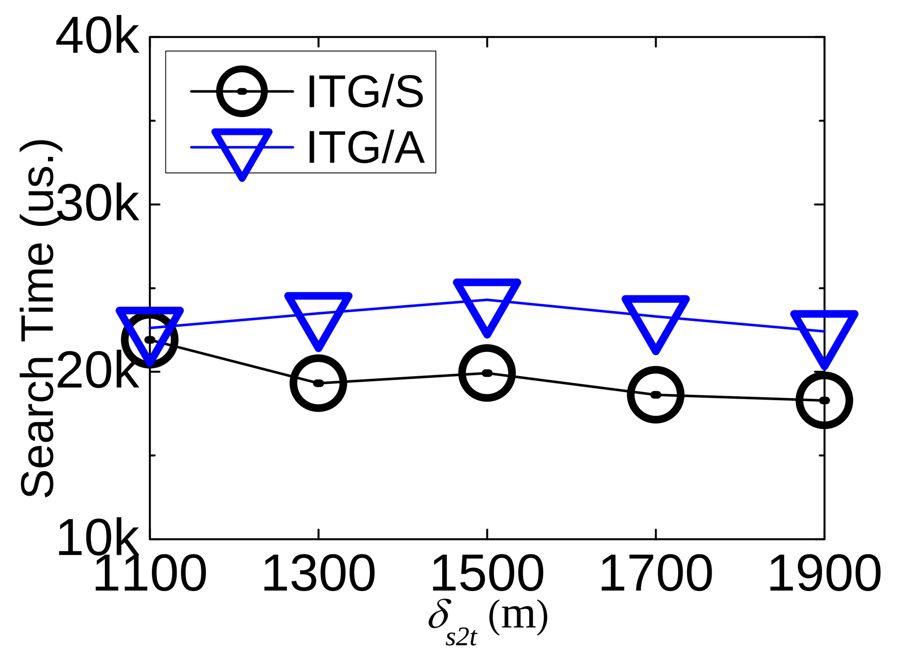
- **Indoor Space Settings.** A 5-floor indoor space with 705 partitions and 1120 doors.
- **Temporal Variations.** We select random pairs of open time and close time to form the checkpoint set $T$ in size of 4, **8**, 12, or 16.

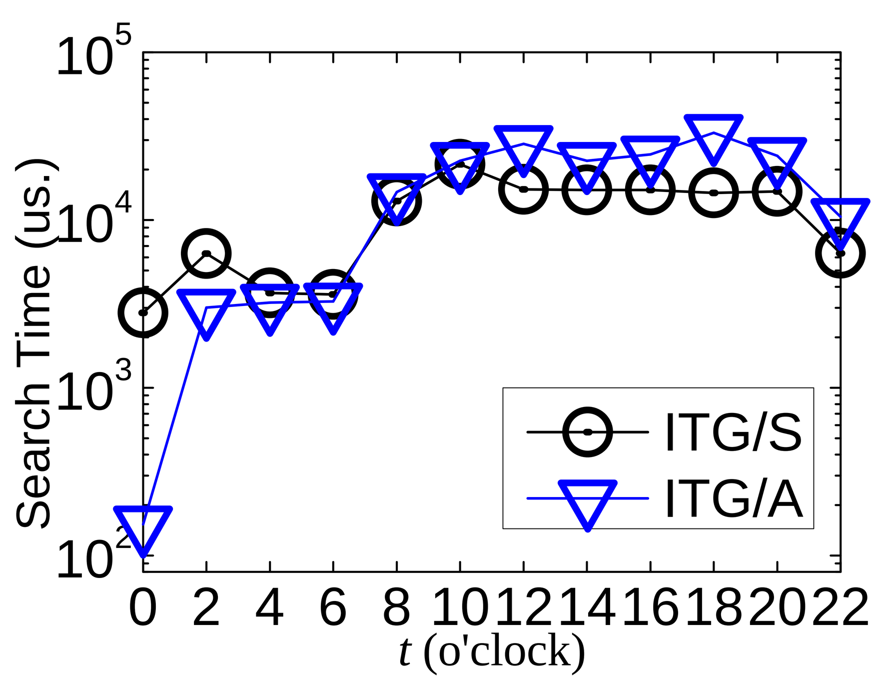
Parameter Settings for Synthetic Data

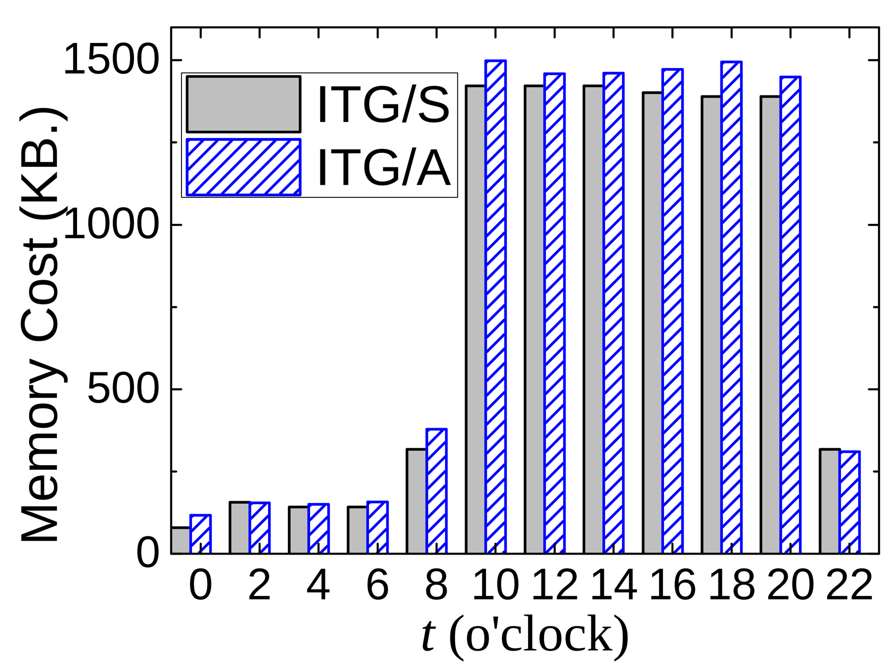
| Parameters | Settings |
|---|---|
| $\|T\|$ | 4, **8**, 12, 16 |
| $\delta_{s2t}$ (m) | 1100, 1300, **1500**, 1700, 1900 |
| $t$ | 0:00, 2:00, . . . , **12:00**, . . . , 22:00 |

- **Query Instances.** For each setting of $\delta_{s2t}$, we generate five pairs of $p_s$ and $p_t$ to form the query instances. In each query instance, time $t$ is fixed to **12:00** to make a fair comparison.
- **Performance Metrics.** We run each query instance ten times, and measure the *average* running time and memory cost.
- **Results.**





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