Real Time Routing in Road Networks

Aakriti Gupta

Advisors: Dr. J. Lakshmi, Prof. S. K. Nandy
Cloud Systems Lab, CADL, SERC
Indian Institute of Science

aakriti@cadl.iisc.ernet.in

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- Time Dependent graph: edge weight is a function of current traffic, weather conditions etc.

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- Road junctions as graph vertices
- Connecting road segments as edges
- Static graph: constant edge weight
- Time Dependent graph: edge weight is a function of current traffic, weather conditions etc.
- Now use any shortest path algorithm on this graph, like Dijkstra's search[1].

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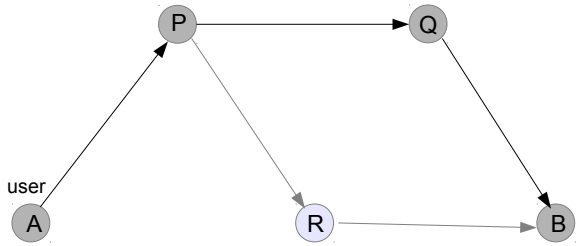
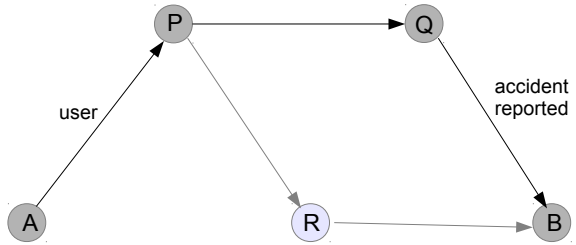
- Most of these approaches haven't shown success in dynamic case[7]
- These algorithms involve 2 steps - preprocessing (slow) and online computation (fast)
- Unrealistic to do the preprocessing step everytime as graph changes. Periodic updates don't use real time information.

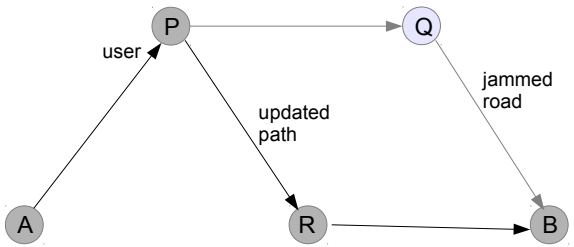
Real-Time processing requirement



(a) t = 0

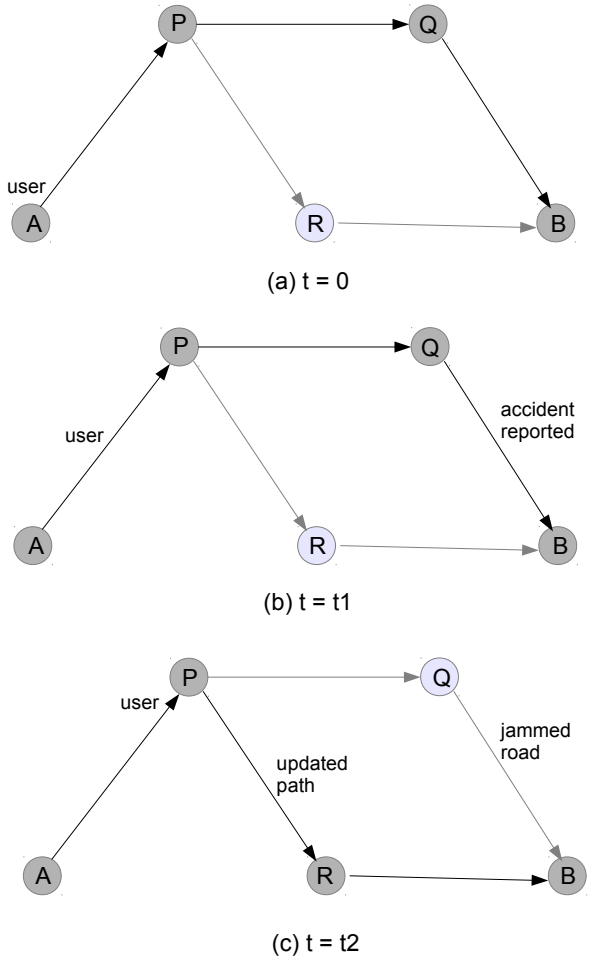


(b) t = t1



(c) t = t2

Real-Time processing requirement



- Real time updates are not fully utilized if revised route not sent to the user
- Need for a proactive system
- Also avoids misdirection! Driver followed satellite navigation instructions in the dark and her car was hit by a train on a rail crossing that was not shown on the system [8].

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The problem with such decentralized approach is

- Prohibitive for thin clients: all mobile devices do not have the capability to handle computations and communication that is required.

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- A graph density based method to choose time optimal algorithm for query dependent route computation.

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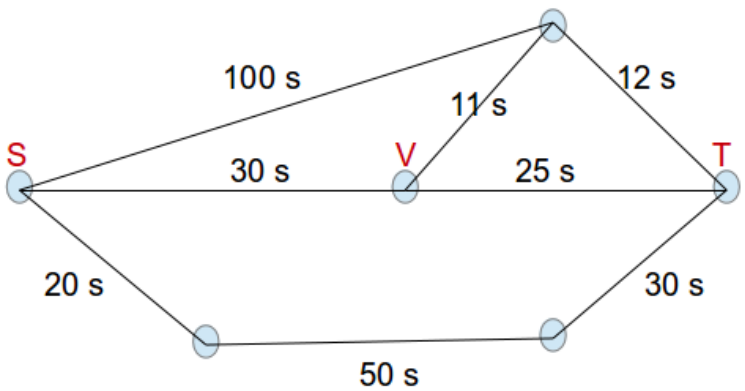

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- Updates (like traffic, weather conditions) on the graph can be analyzed and converted into edge weights [11].
- Edge weight represents the time it would take to travel on that edge at current time.

Types of jobs

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- A new user connecting to the system.
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Redo

- System was late in giving response to the user or user chooses to take a different path.
- Re-computation is required based on current location.

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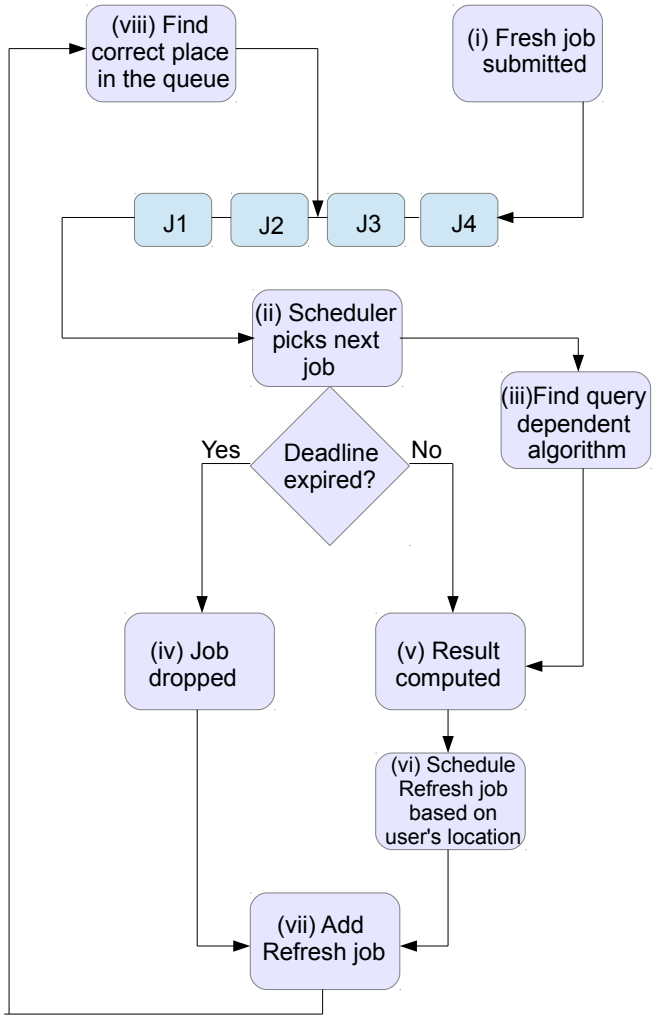
Job scheduling is...

- *Dynamic:* no binding relation between a job and a particular processor.
- *Priority-driven:* scheduling decisions are based on the priorities of the jobs and take place when events such as job completions occur.

Overall System Model



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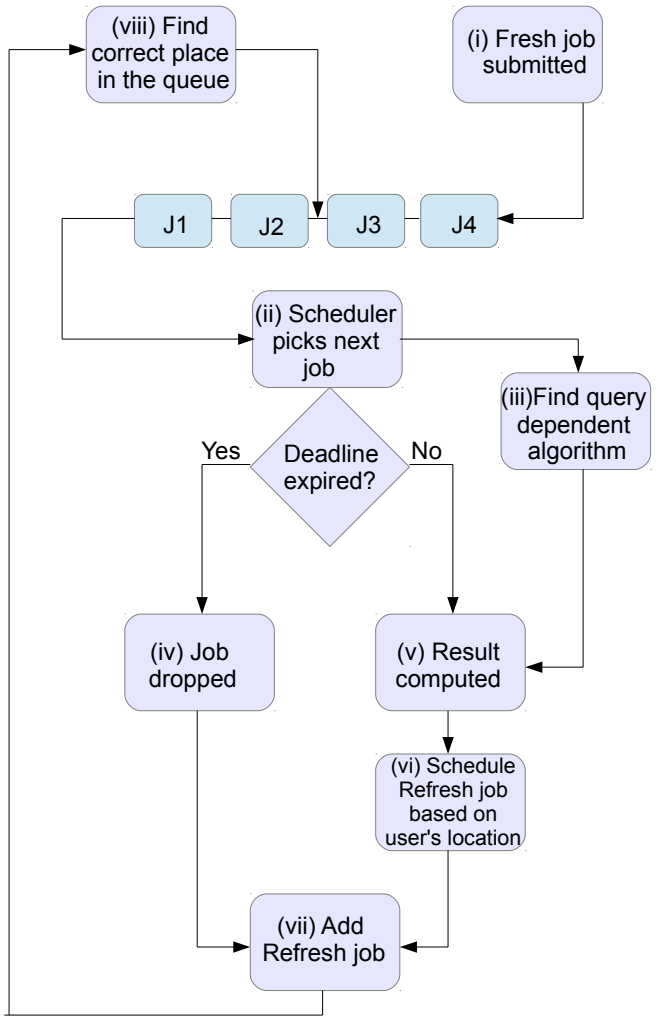

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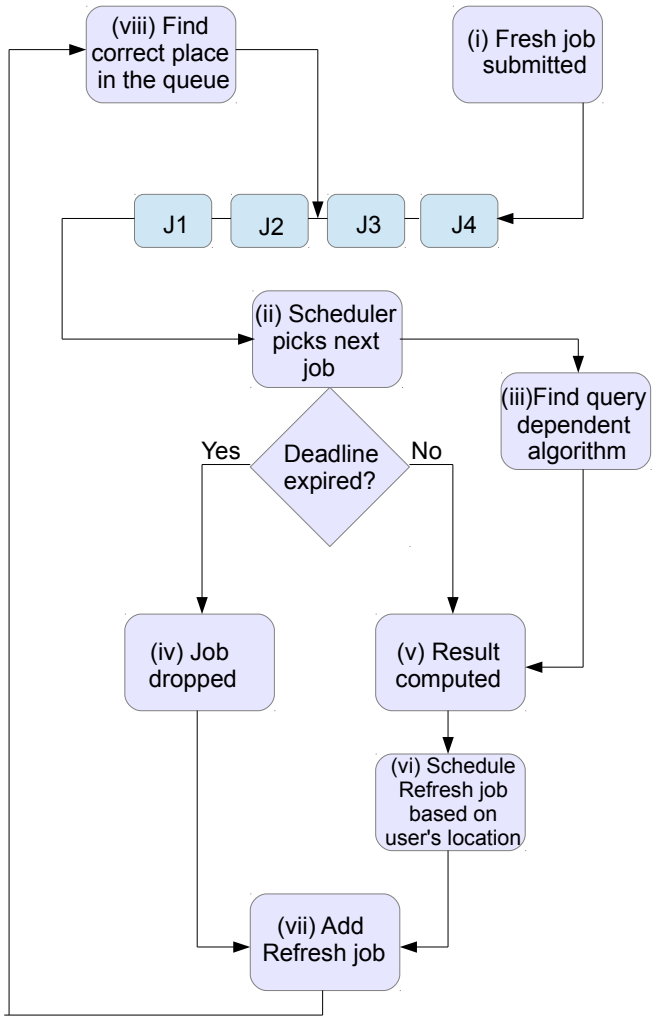

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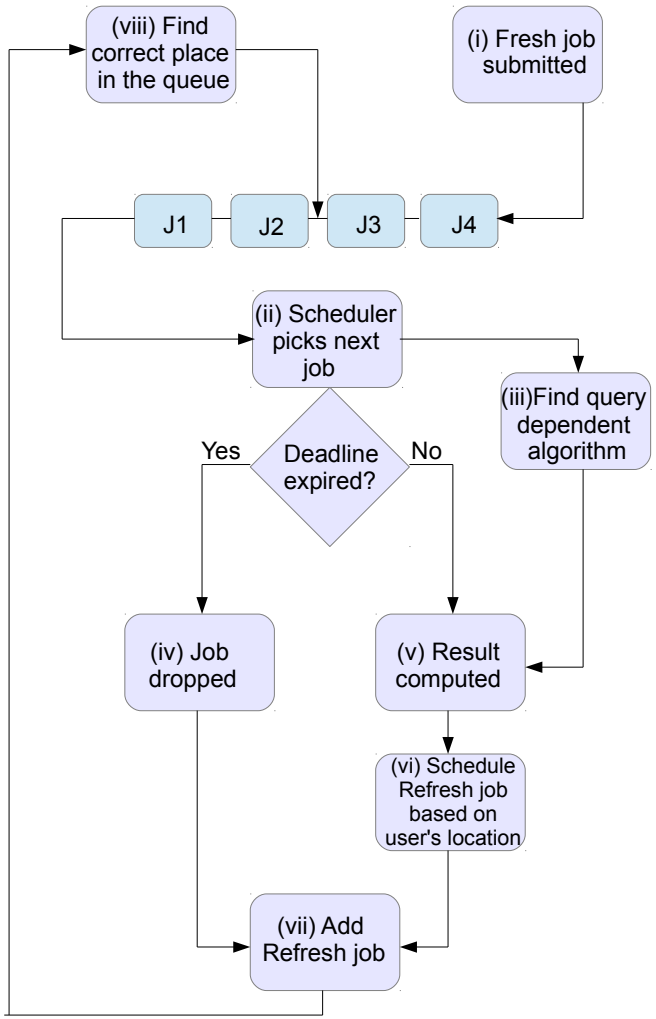

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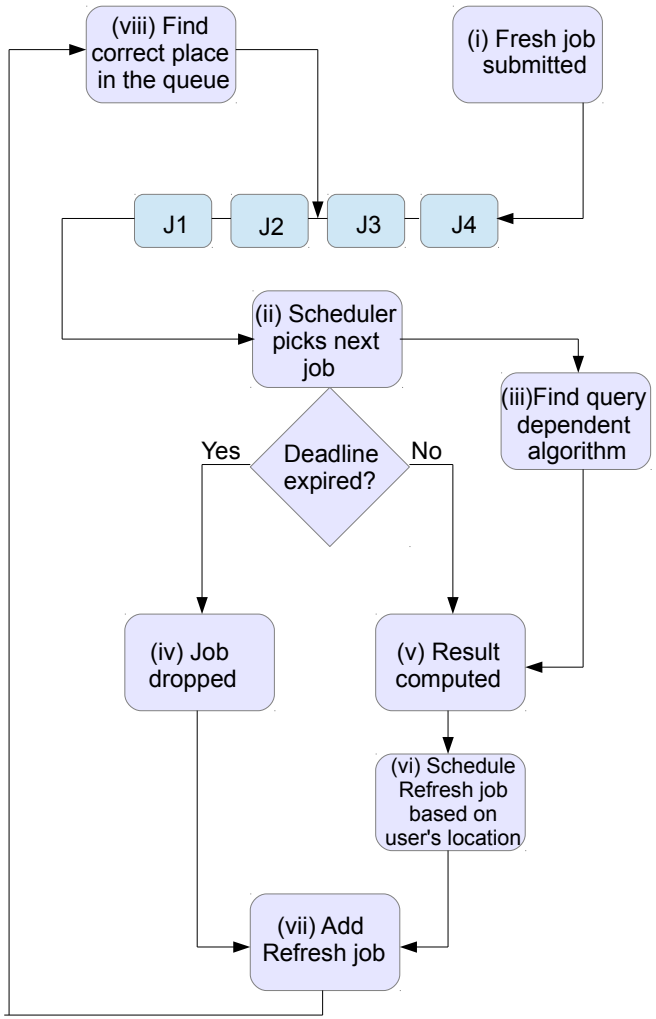

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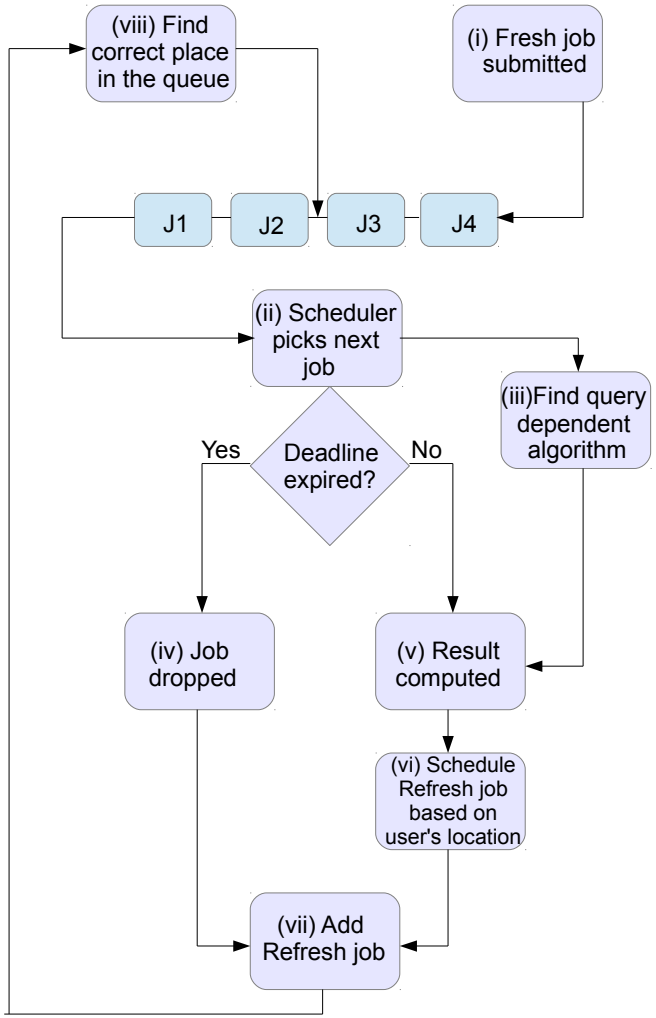

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- Deadline of refresh jobs decides their priority and appropriate place in the job queue.

Computing Job Deadlines

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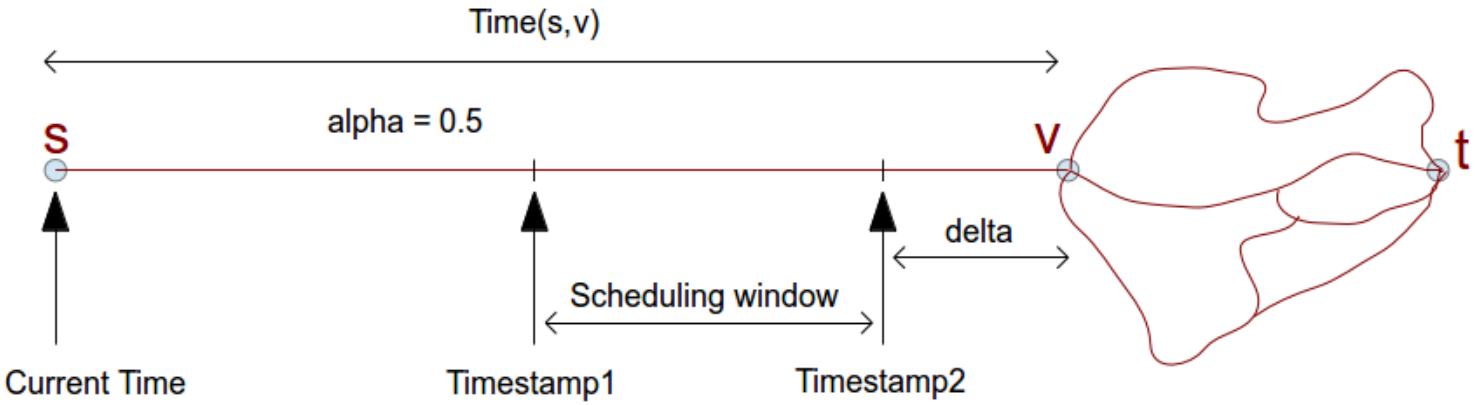
$$Timestamp1 \leq Scheduling\_time \leq Timestamp2 \quad (1)$$

$$Timestamp1 = Current\_time + \alpha * time(s, v) \quad (2)$$

$$Timestamp2 = Current\_time + time(s, v) - \Delta \quad (3)$$

α is any constant ϵ (0,1) and Δ is the estimated upper bound on computation plus communication time.

Illustration

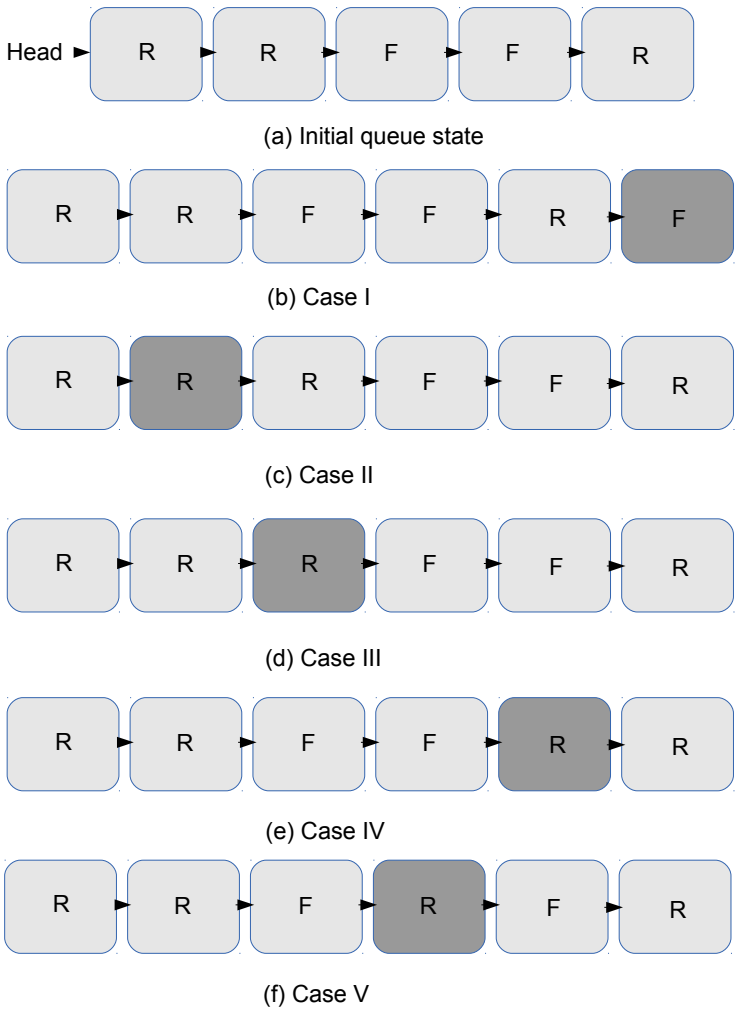


- Route computation before Timestamp1 will not have the lastest information.
- Route computation after Timestamp2 will not be complete before user reaches 'v', hence not useful.

Job Sceduling Algorithm

```
1:  while (1) do
2:      while !(Queue Empty) do
3:          ptr ← queue head
4:          if ptr.jobtype = fresh then
5:              goto compute
6:          else
7:              if ptr.jobtype = refresh & matured(ptr) = true then
8:                  goto compute
9:              else
10:                 if ptr.jobtype = refresh & expired(ptr) = true then
11:                     dropped jobs ++
12:                     goto add
13:                 else
14:                     ptr ← next(ptr)
15:                 end if
16:             end if
17:         end if
18:     end while
19:     compute :
20:       compute shortest path
21:     add :
22:       find next hop
23:       add refresh job
24: end while
```

Job Queue Insertion



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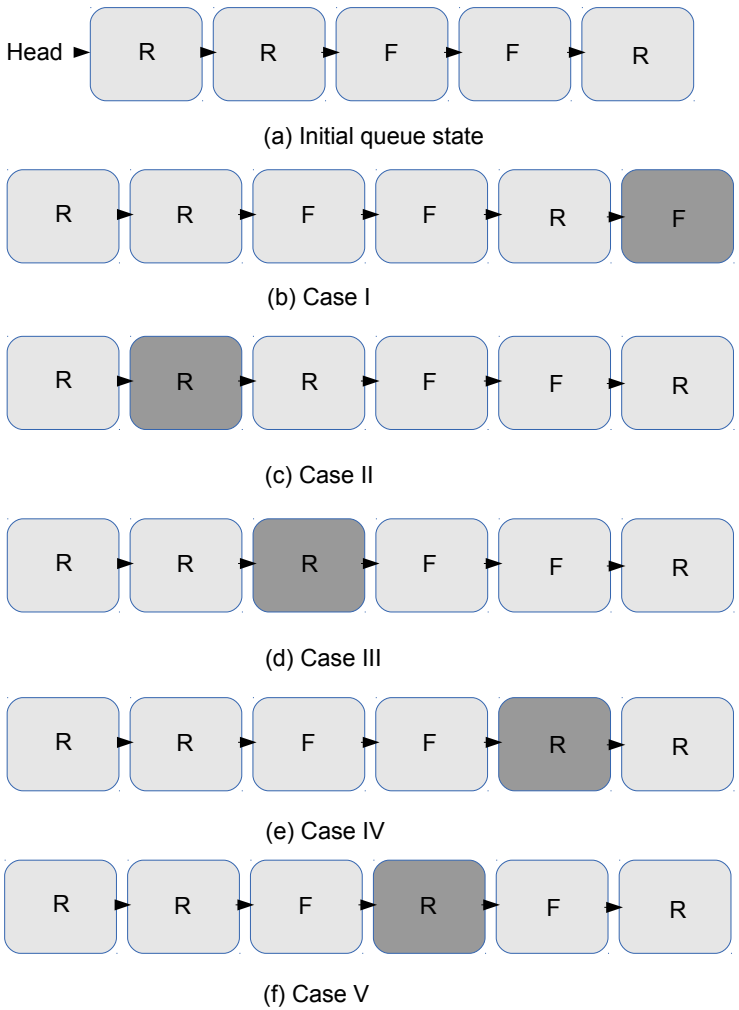

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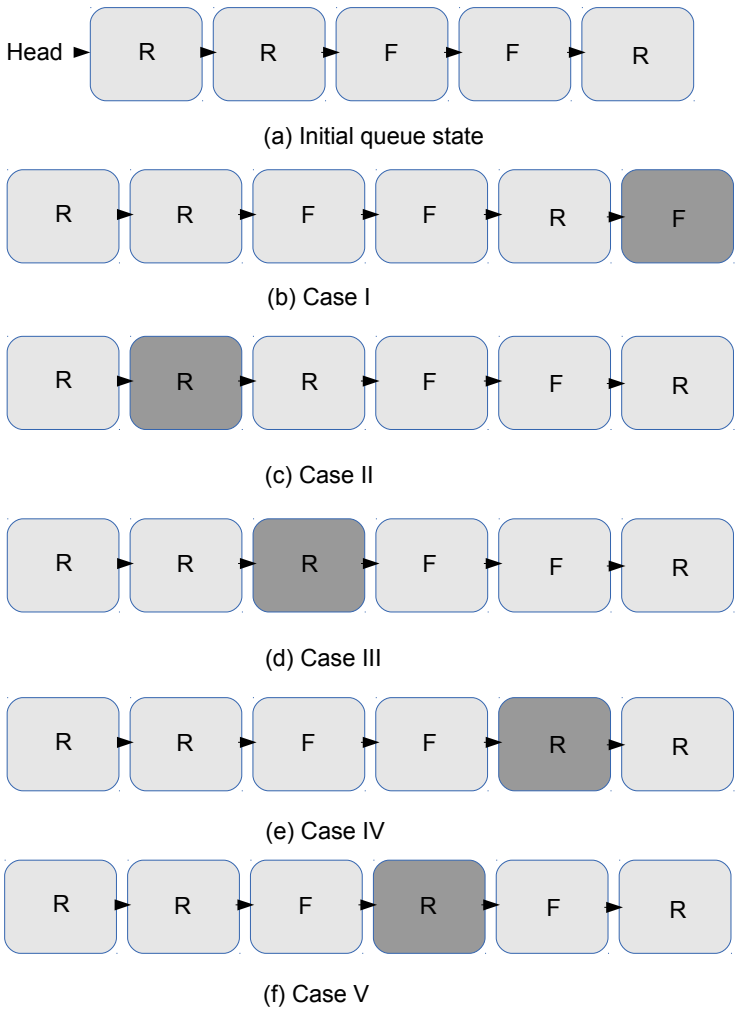

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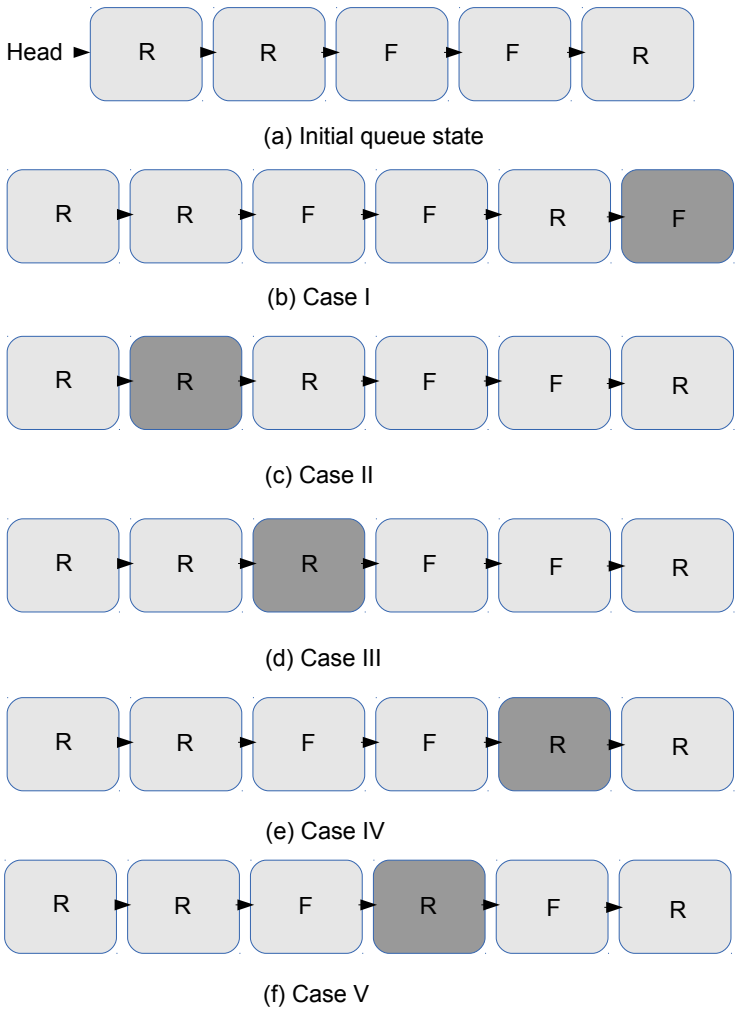

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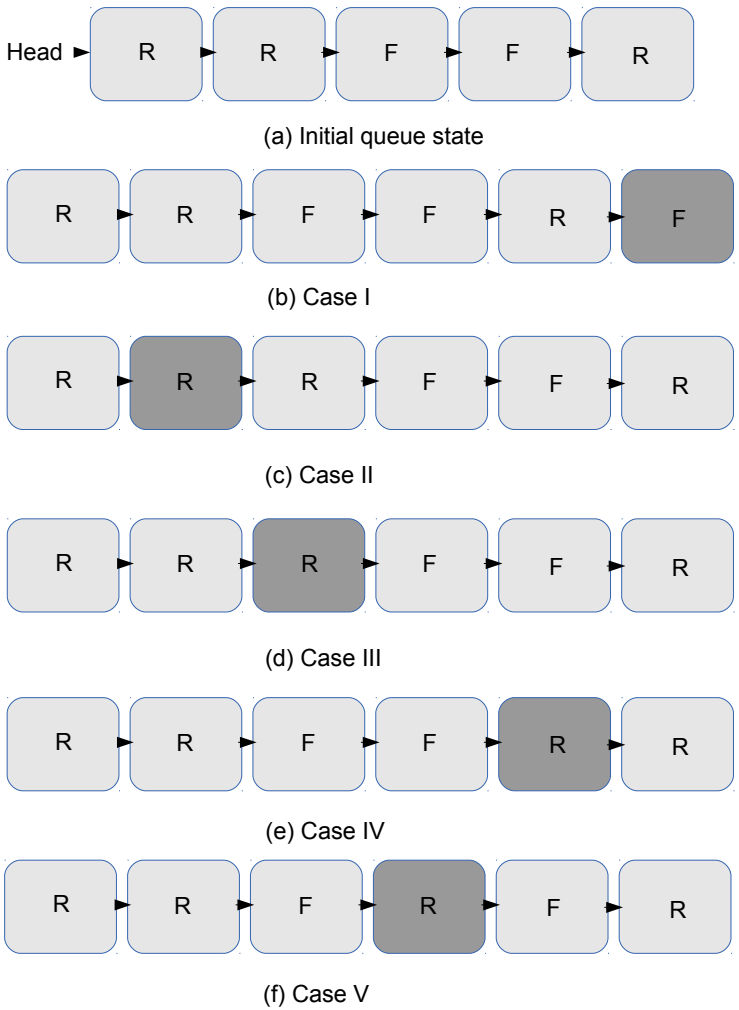

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- Case IV: Fresh job is given higher priority.

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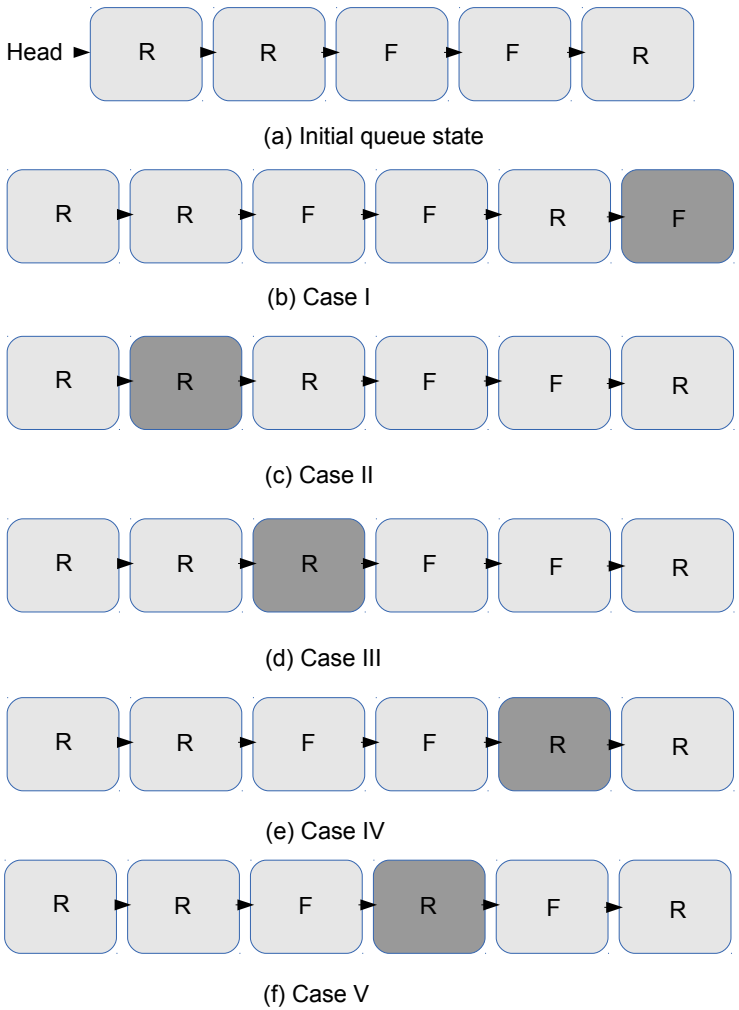

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- Case IV: Fresh job is given higher priority.
- Case V: Relative priorities of fresh jobs and refresh jobs are dynamically computed.

Computing relative priorities for insertion

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If, $Timestamp2(R1) < Timestamp2(R2)$, then:

$$Priority(R1) > Priority(R2) \tag{4}$$

If, $AgingFactor(F) < Threshhold$, then:

$$Priority(R) > Priority(F) \tag{5}$$

If, $AgingFactor(F) \geq Threshhold$, then:

$$Priority(F) > Priority(R) \tag{6}$$

Algorithm for insertion of refresh job

```
1:  if (Queue Empty) then
2:      queue head ← next_refresh_job
3:      return done
4:  end if
5:  ptr ← queue head
6:  while ptr != NULL do
7:      if ptr.jobtype = refresh && ptr.timestamp2 > next_refresh_job.timestamp2
        then
8:          insert next_refresh_job before ptr
9:          return done
10:     end if
11:     if ptr.jobtype = fresh && ptr.age < threshold then
12:         insert next_refresh_job before ptr
13:         temp ← ptr
14:         while temp.jobtype = freshjob do
15:             temp.age++
16:             temp ← next(temp)
17:         end while
18:         return done
19:     end if
20:     ptr ← next(ptr)
21: end while
22: add next_refresh_job at queue end
23: return done
```

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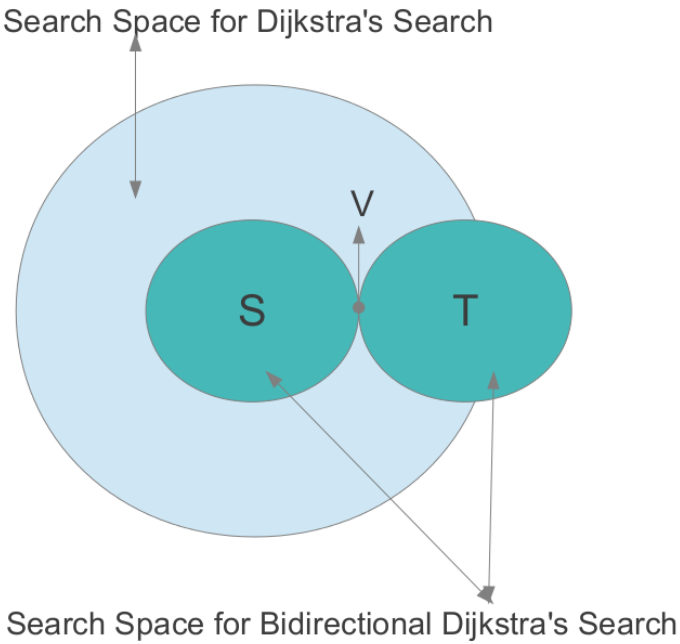
- Most algorithms use Bidirectional search over simple Dijkstra's algorithm because of it's lesser avg. query computation time.
- Possible to select which of the two algorithms would be better for a given query.
- Also reduces the average query computation time.

Search Space and Graph Density



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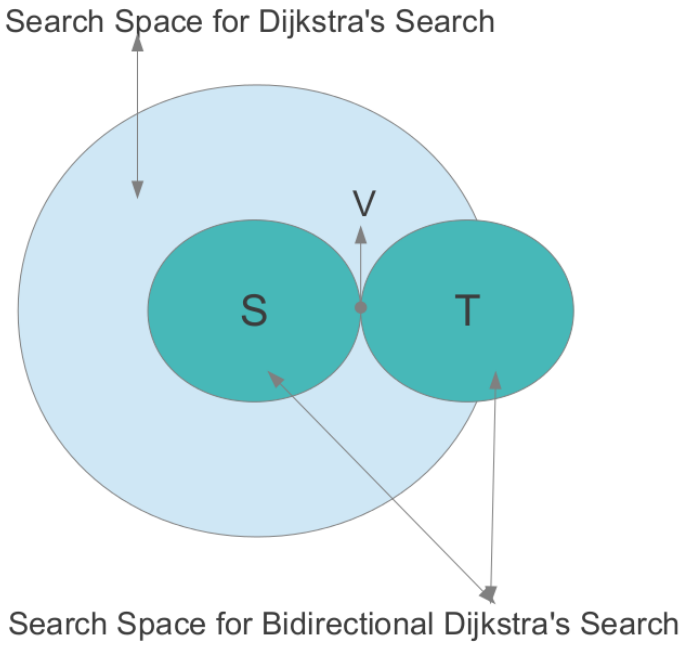
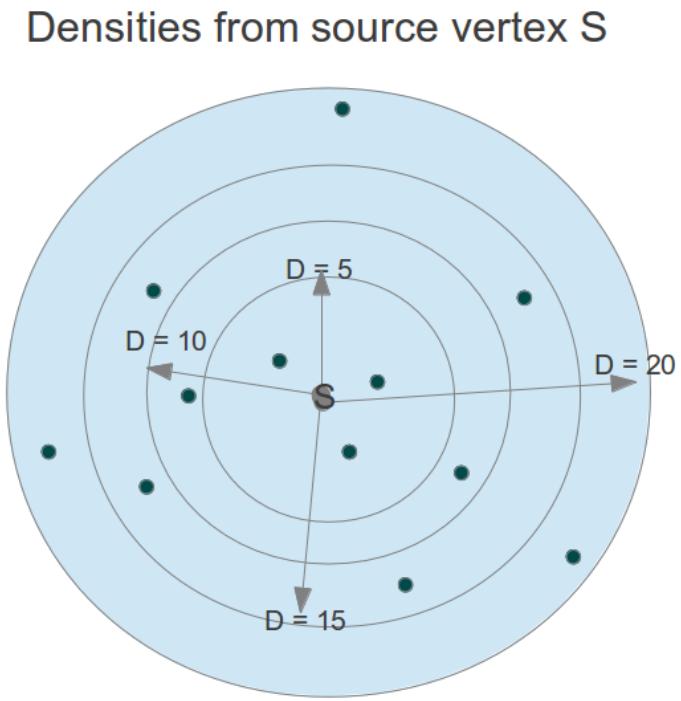




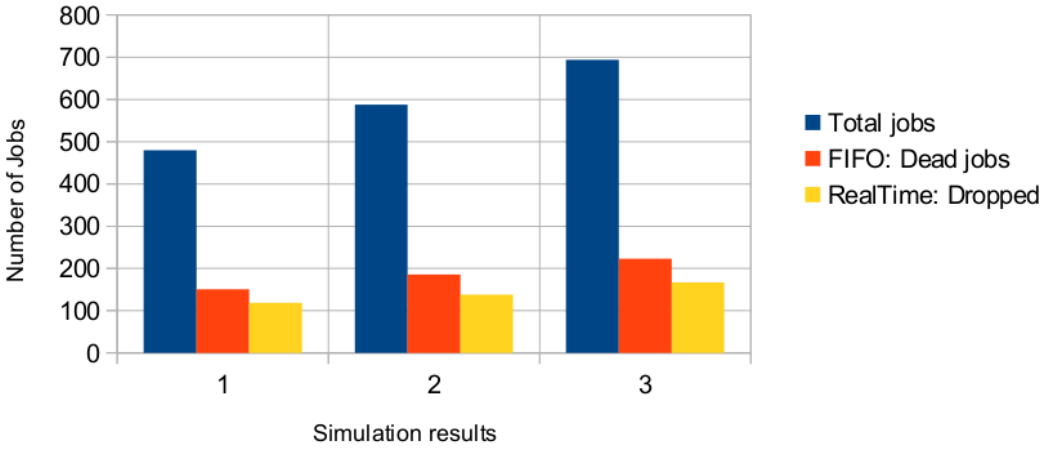
Experimental Setup

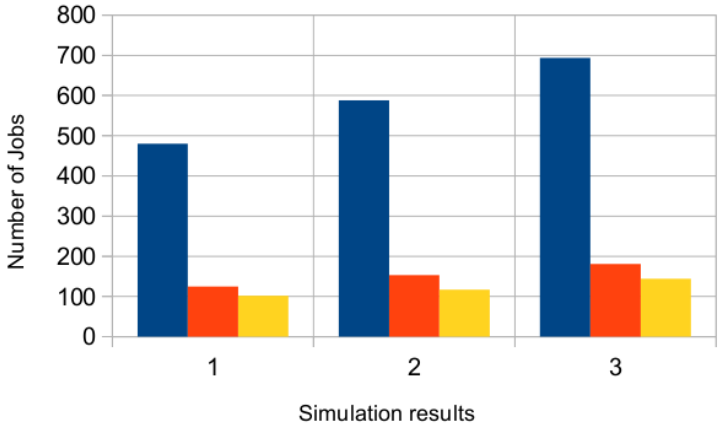
- Road networks were taken from Dimacs Implementation Challenge.

Table: Graph instances used

Graph Name	Number of Vertices	Number of Edges
TG	18263	23874
BAY	174956	223001
SF	321270	800172
COL	435666	1057066
LKS	2758119	6885658

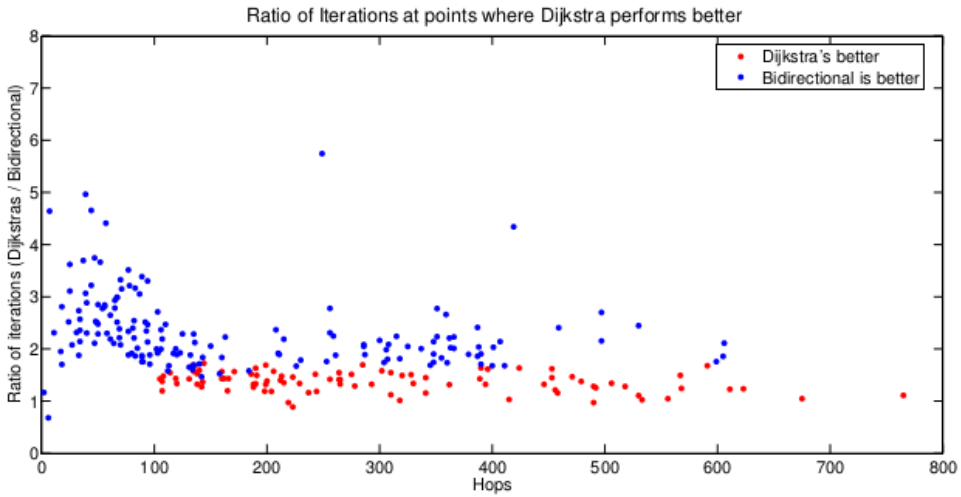
Results for Real Time Routing

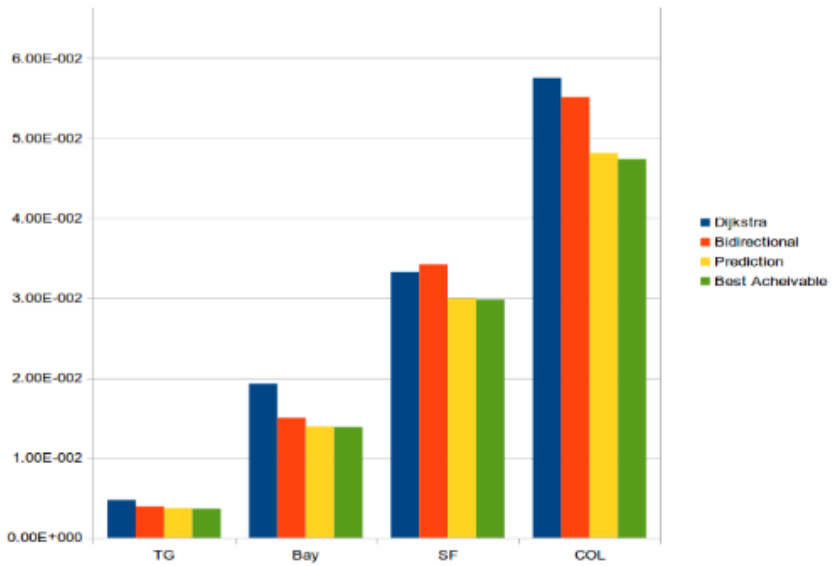




- Showing simulation results with $\alpha = 0.6$ (top) and 0.5 (bottom) and two threads.
- For $\alpha = 0.6$, 31-32% queries are dead in FIFO, 23-24% queries are dropped by our framework.
- With increasing α, scheduling window decreases and more number of queries result into dead/drop computation.
- Our framework processes 7-10% more number of useful queries and takes 10-12% lesser time than FIFO on an average.

Results for Query Dependent Route Computation





Timing results (in seconds) for various road networks

Future Work

- Experimentally coming up with optimal system parameters like α and aging factor.

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Thank you.