

A Comparison of Traffic Flow Performance of Roundabouts and Signalized Intersections using Simulation

Mohammad AL_Momani

Computer Engineering Department
Faculty of Engineering
Near East University

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- Introduction
- Background
- Methodology
- Implementation
- Test Results and Discussion
- Conclusions and Future Work

- Traffic congestion is a reality in many countries because of increasing number of vehicles and limited capacity of transportation infrastructure.
- Build more infrastructure and use "effective traffic management systems" to handle traffic congestion.
- "Traffic simulation" has been widely used in the evaluation of alternative "traffic management systems."
- This thesis investigates the operational performance of "roundabouts" and "signalized intersections" using simulation.

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- Compare operational performance based on vehicle travel time.
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- A basic method for optimizing split 4-phase traffic signal timing plans.
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Traffic Signals & Roundabouts

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- In roundabouts, traffic enters a one-way stream around a central island, and vehicles in a roundabout have the right-of-way.

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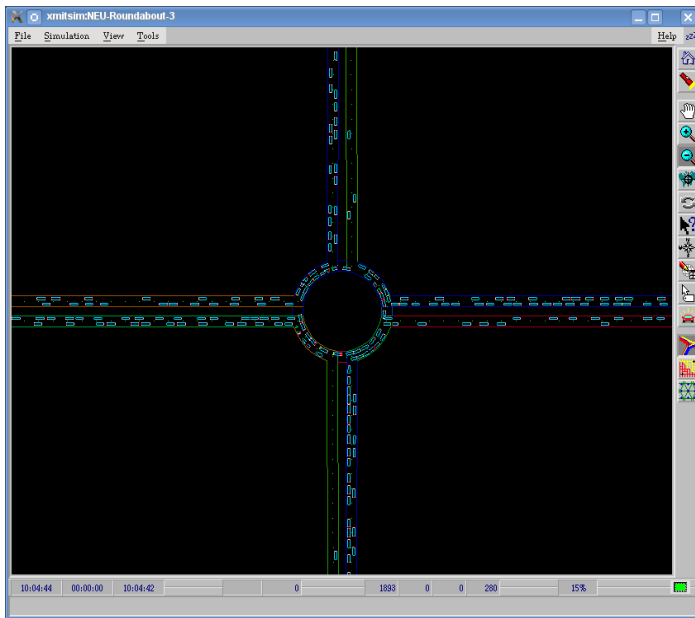
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- Traffic Management Simulator (TMS).
- Graphical User Interface (GUI).

MITSIMLab Components

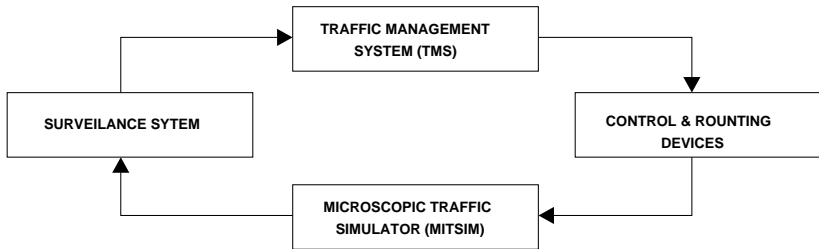
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Graphical User Interface (GUI)



MITSIMLab Simulation Framework



Related Work

- [Thorson et al., 2001] evaluated the performance of four-way stops, roundabouts, and signalized intersection of a single intersection. The evaluation is based on average time delay and fuel consumption. The study showed roundabouts had lowest average time delay and fuel consumption.
- [Isebrands, 2009] evaluated a roundabout between two signalized intersections. The study found that, roundabout had less delay when the system below its capacity, while signalized intersection had slightly less delay when the system approached its full capacity.
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- Vehicle demand.
- Traffic signal optimization.

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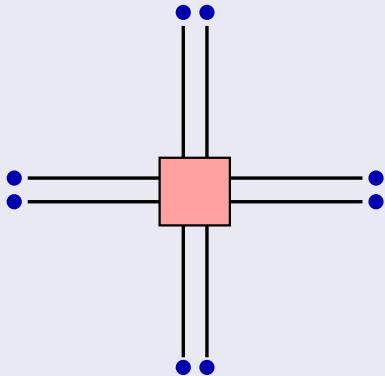
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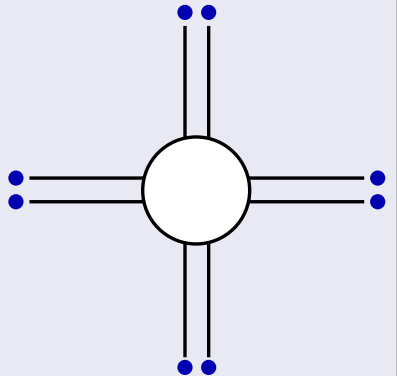
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Network Infrastructure / 1 Junction

An Intersection

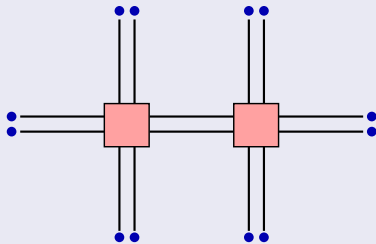


A Roundabout

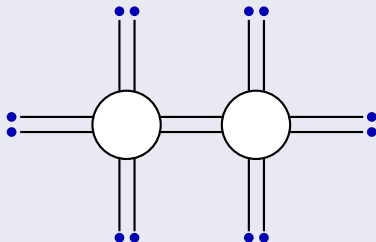


Network Infrastructure / 2 Junctions

2 Intersections

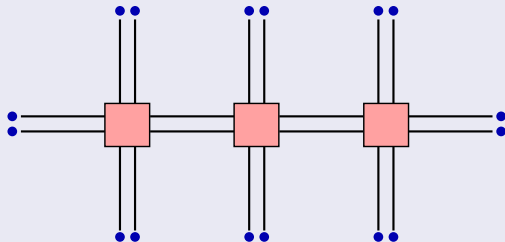


2 Roundabouts

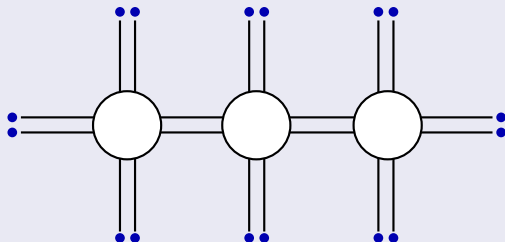


Network Infrastructure / 3 Junctions

3 Intersections

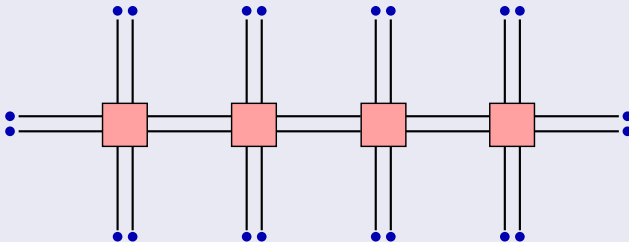


3 Roundabouts

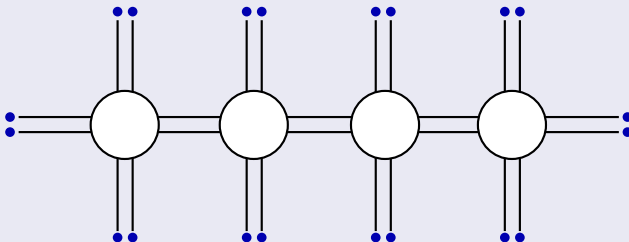


Network Infrastructure / 4 Junctions

4 Intersections



4 Roundabouts



Vehicle Demand

- Identical vehicle demand on each compatible network.
- Identical vehicle demand at source nodes and equal distribution over all destination nodes.
- U-turns are disallowed.
- Simulator generates vehicles using fixed-seed randomization
⇒ Identical vehicle IDs, types, driver types, ODs, and departure times.

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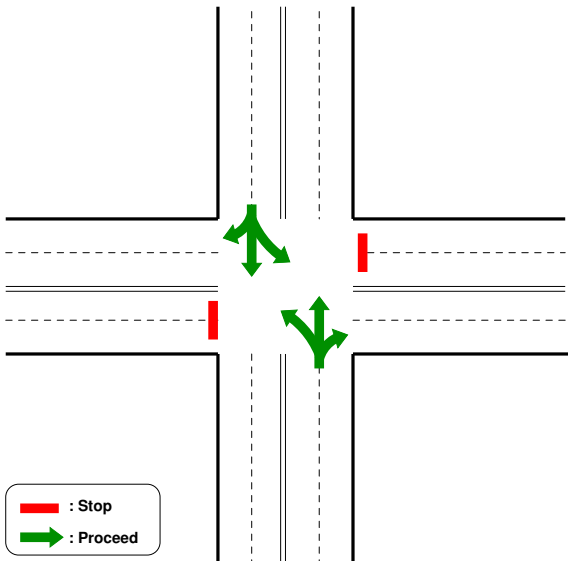
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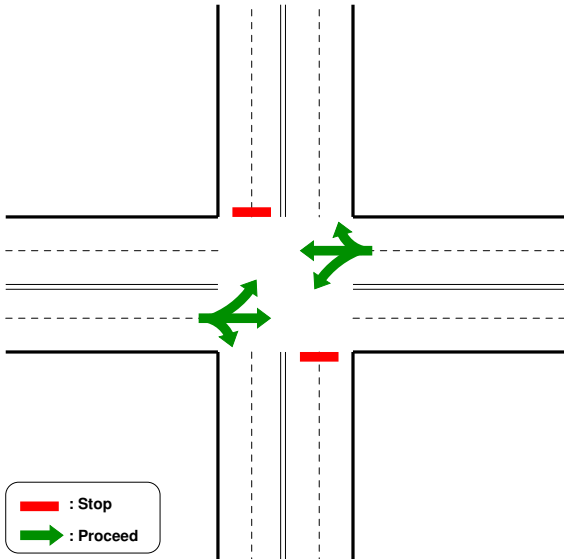
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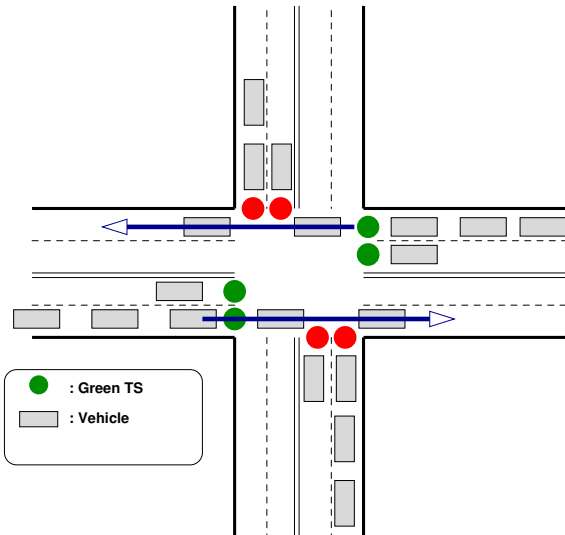
2-Phase Traffic Signals / Phase 1



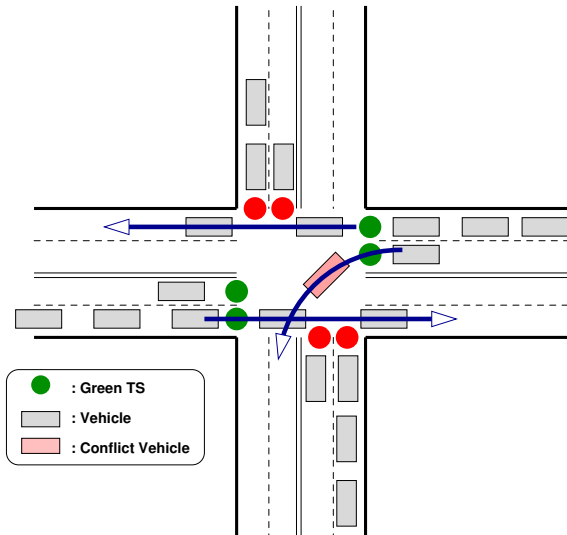
2-Phase Traffic Signal / Phase 2



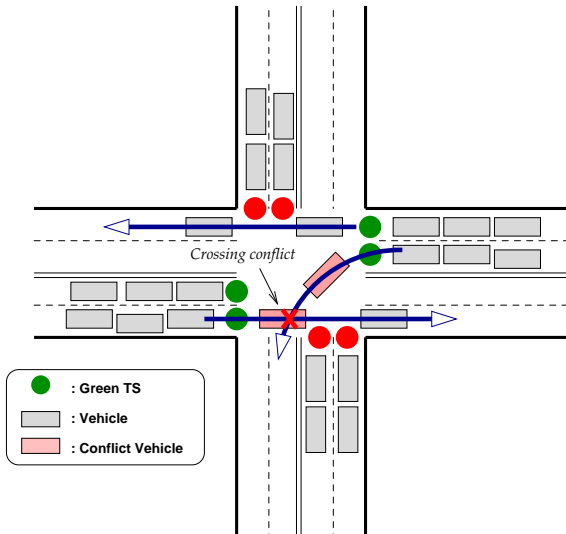
2-Phase Traffic Signal Conflict Movement



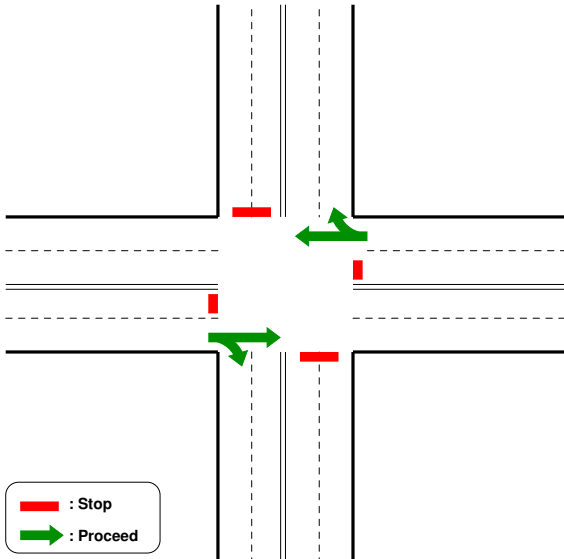
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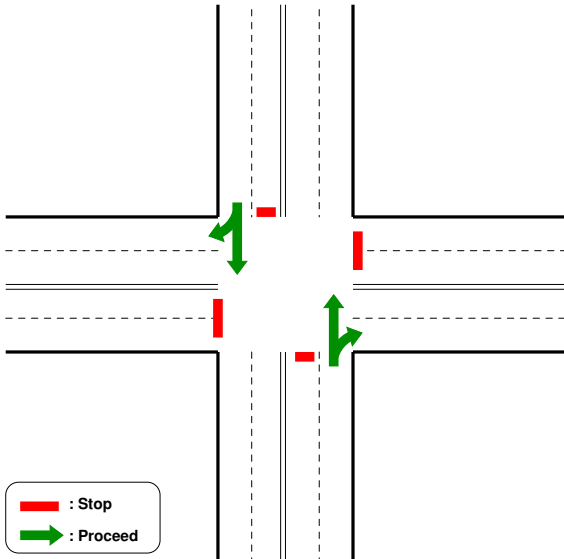
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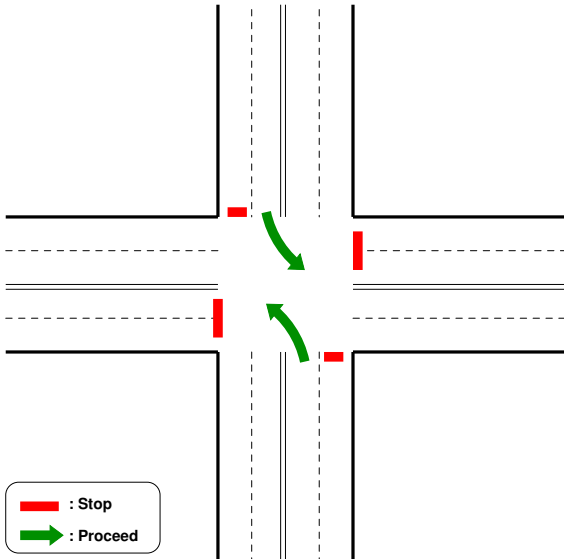
4-Phase Traffic Signal / Phase 1



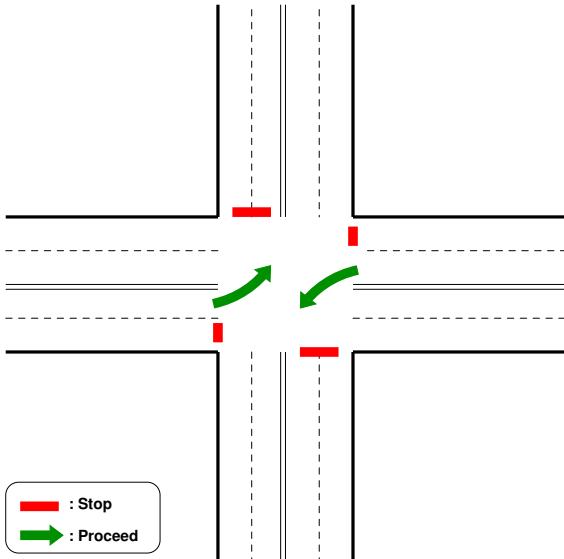
4-Phase Traffic Signal / Phase 2



4-Phase Traffic Signal / Phase 3

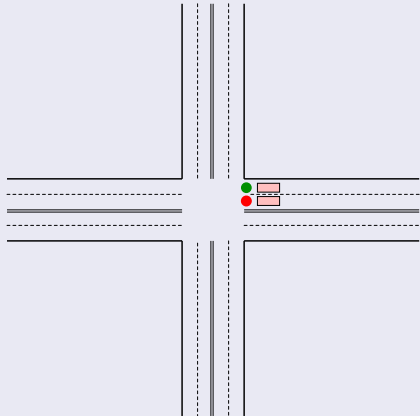


4-Phase Traffic Signal / Phase 4

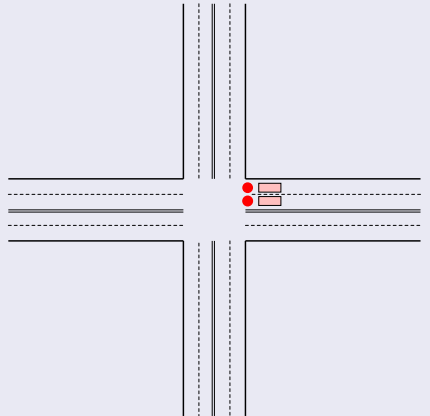


Lane-specific & Link-specific Traffic Signals

Lane-specific traffic signal

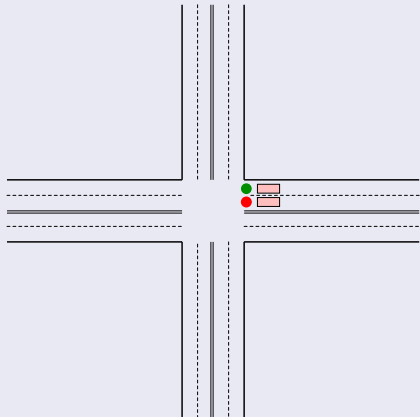


Link-specific traffic signal

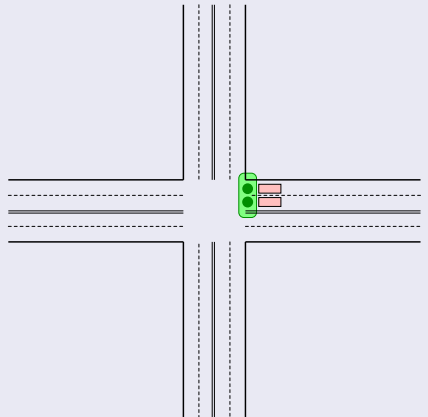


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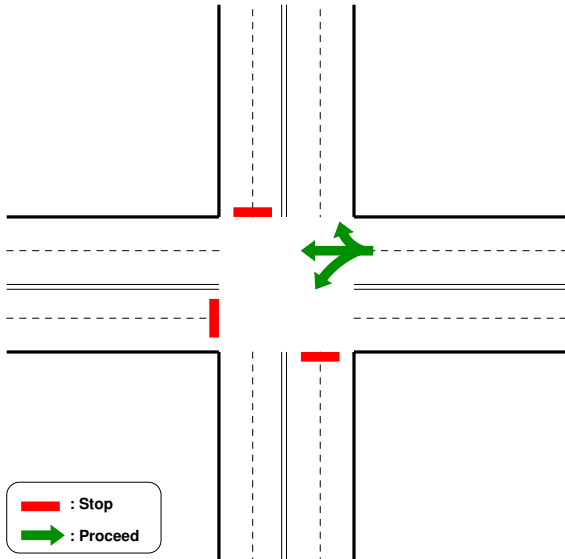
Lane-specific traffic signal



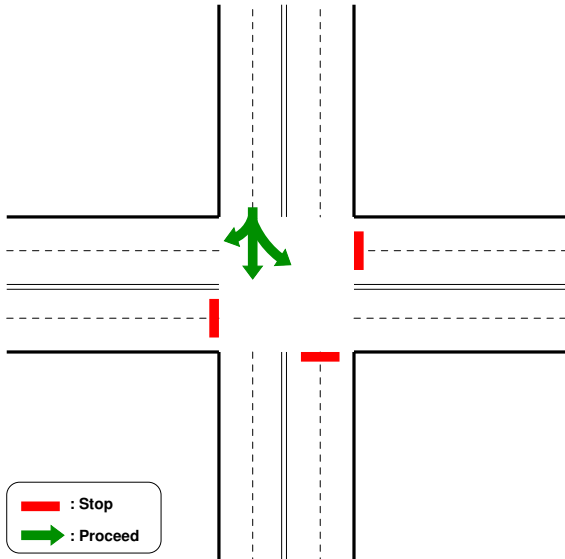
Link-specific traffic signal



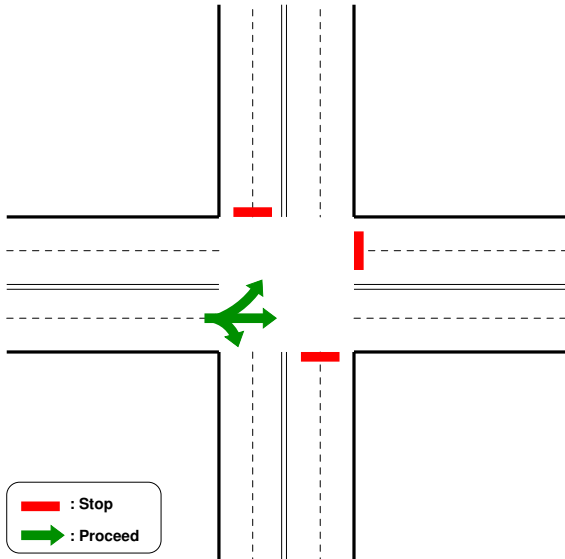
Split 4-Phase Traffic Signal / Phase 1



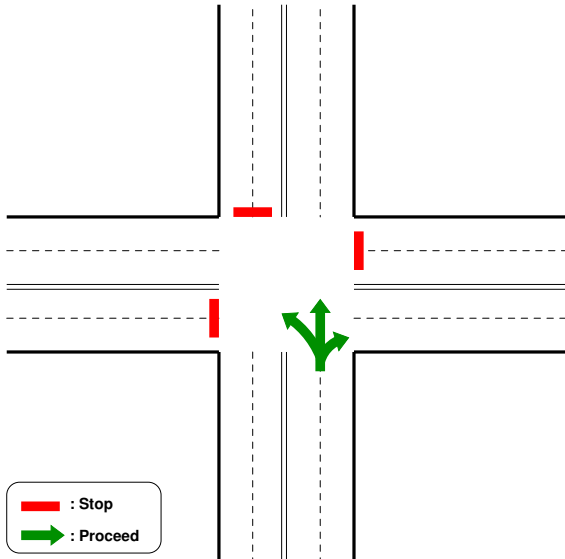
Split 4-Phase Traffic Signal / Phase 2



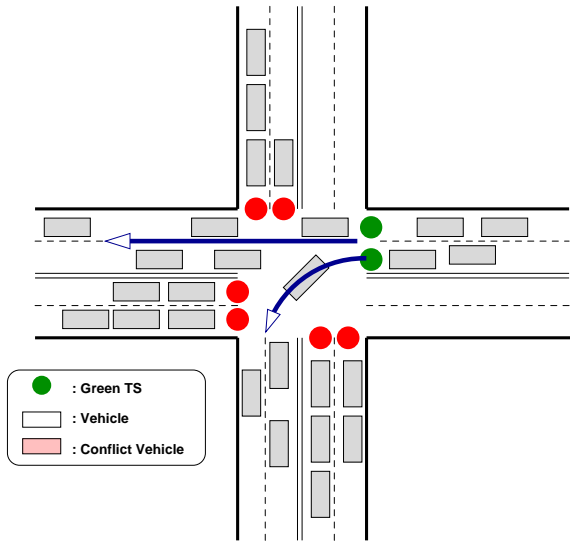
Split 4-Phase Traffic Signal / Phase 3



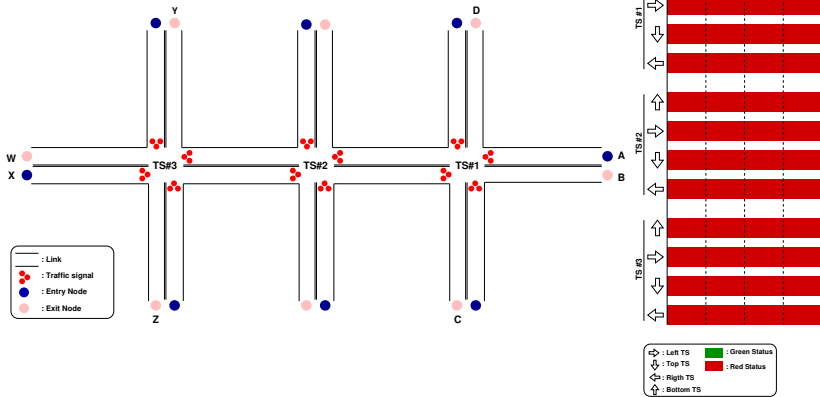
Split 4-Phase Traffic Signal / Phase 4



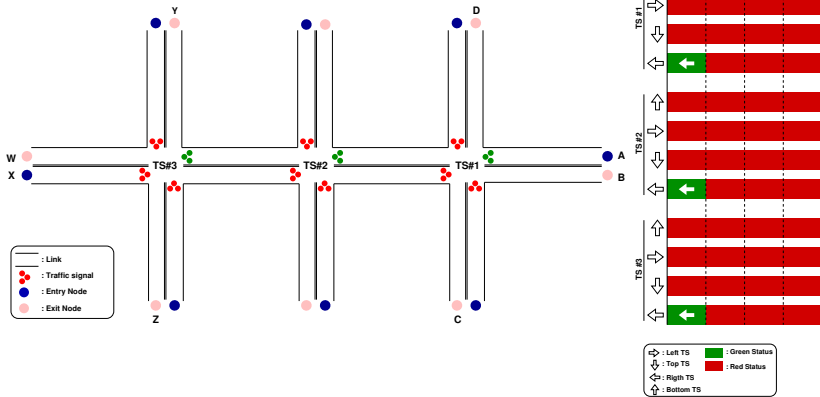
Split 4-Phase Traffic Signal Movement



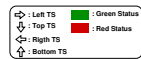
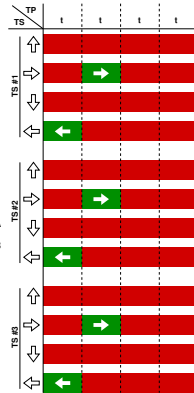
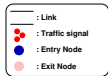
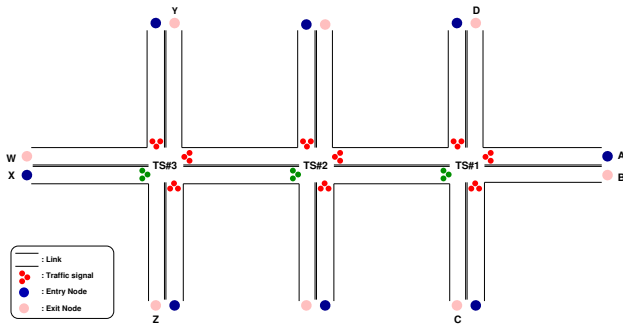
Non-optimized Traffic Signal



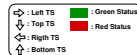
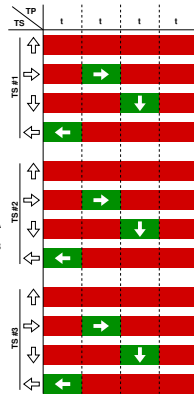
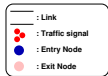
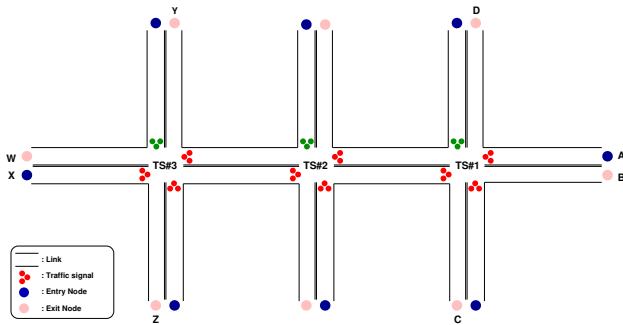
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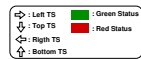
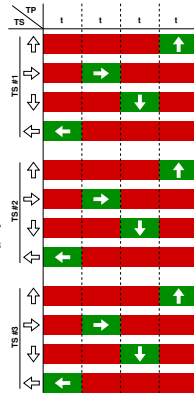
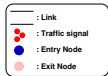
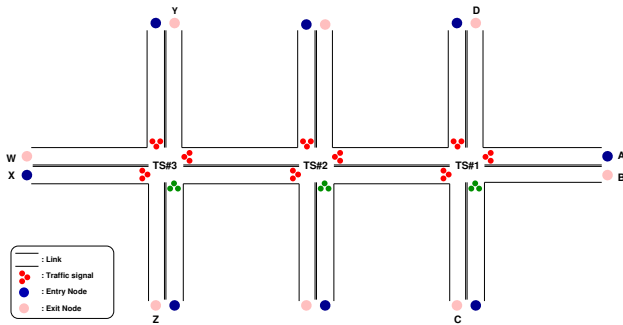
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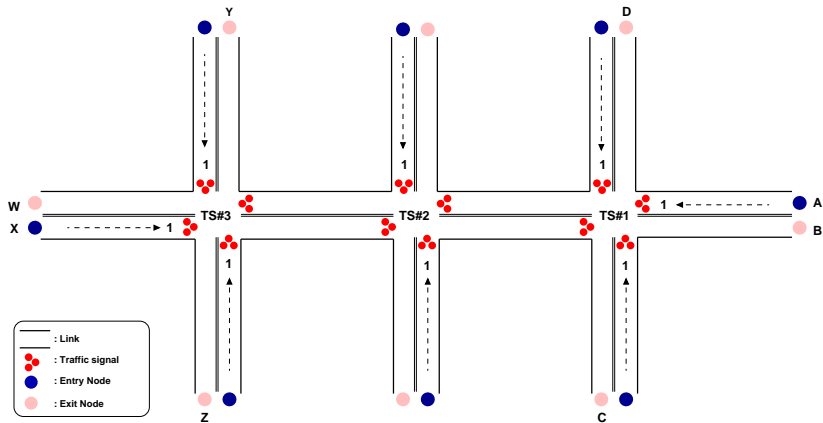
Non-optimized Traffic Signal



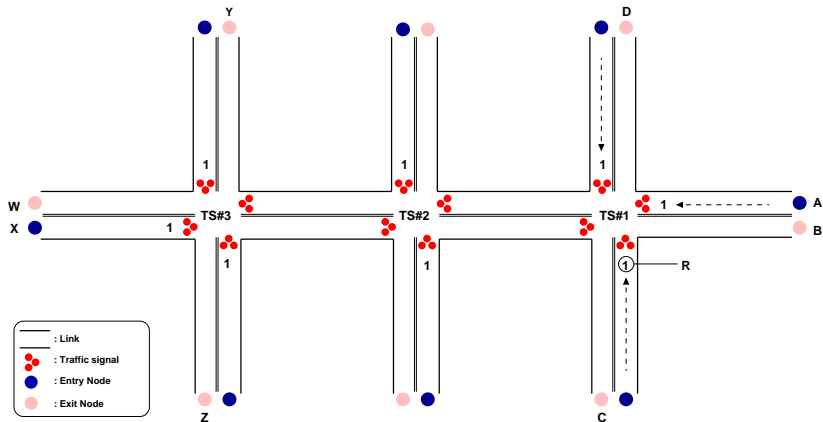
Non-optimized Traffic Signal



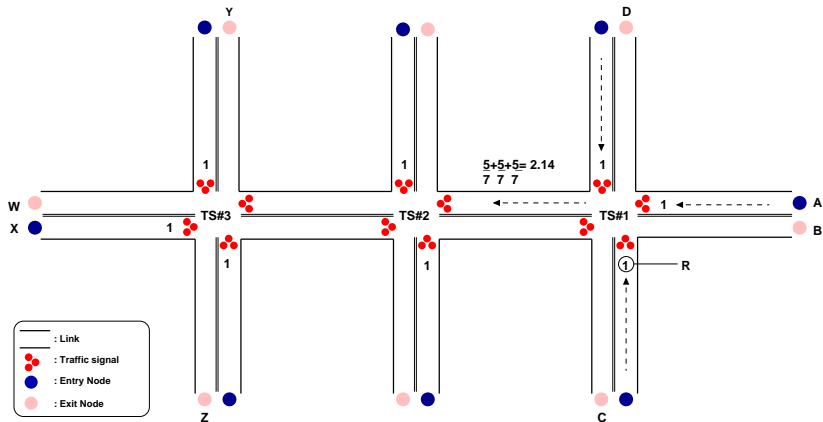
Traffic Signal Optimization 1/2



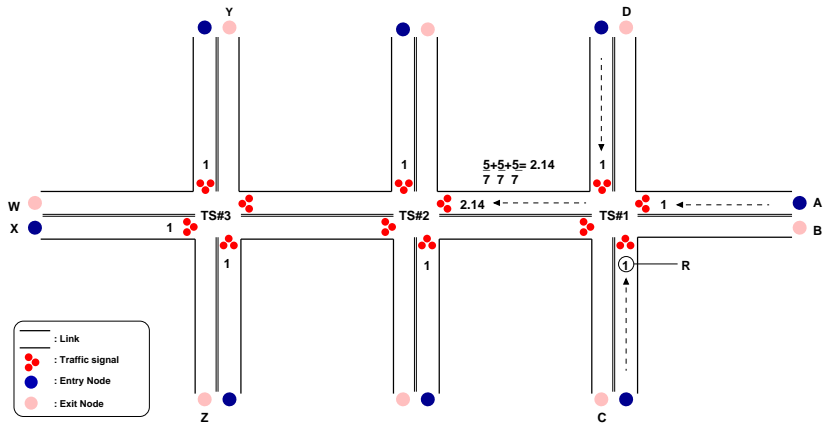
Traffic Signal Optimization 1/2



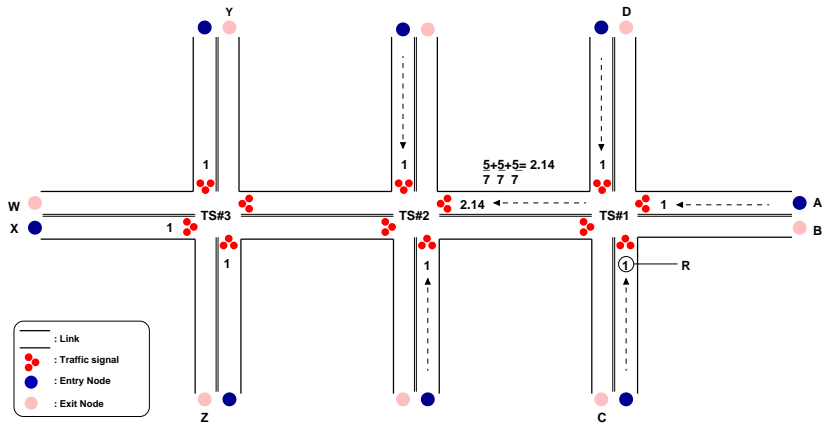
Traffic Signal Optimization 1/2



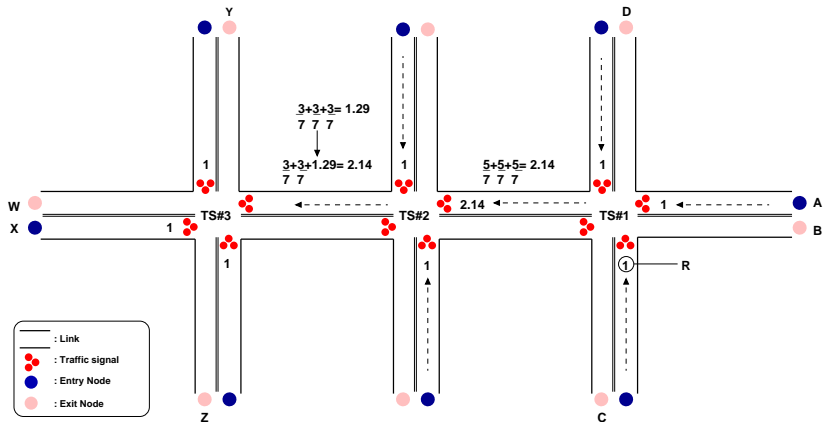
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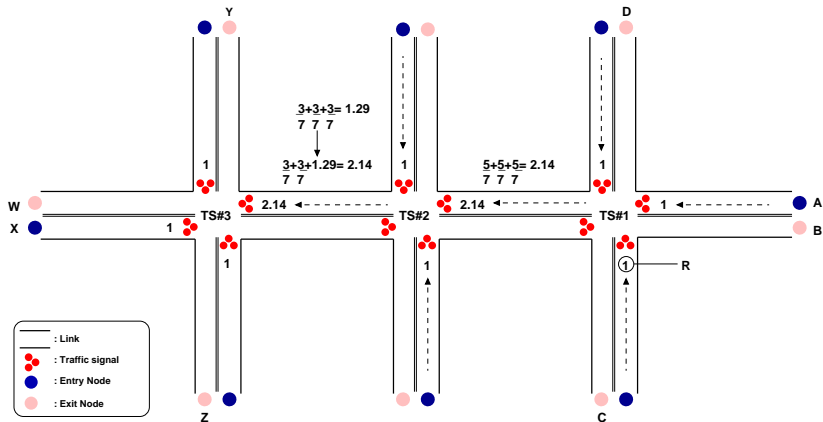
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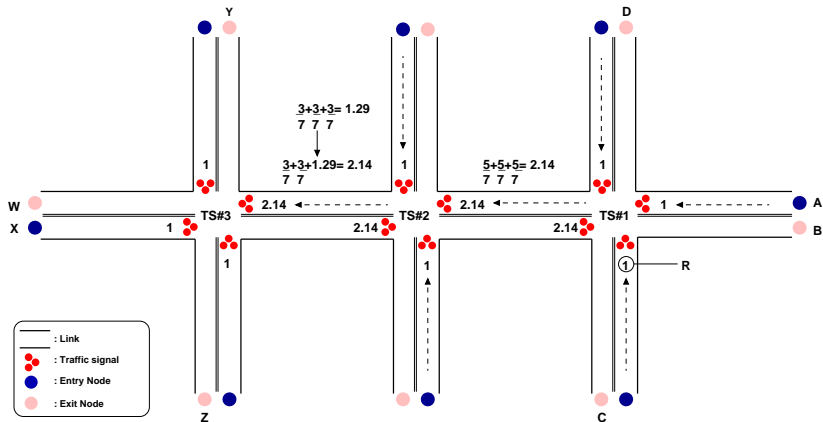
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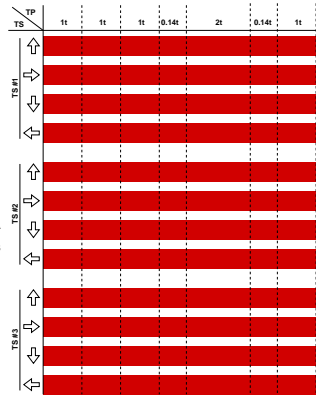
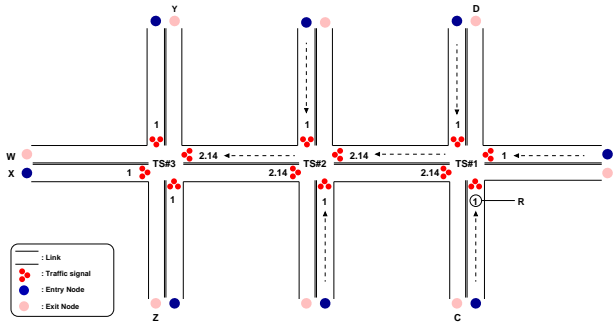
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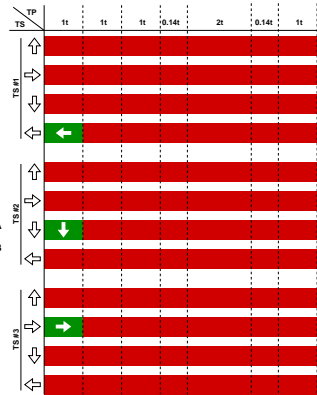
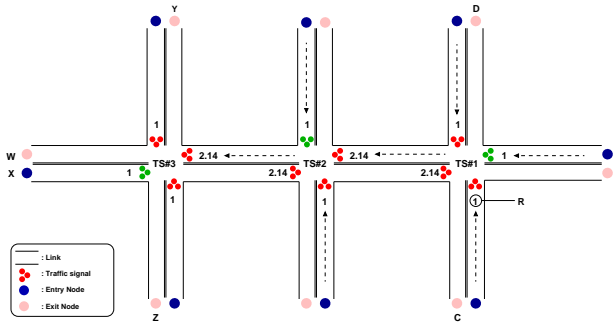
Traffic Signal Optimization 1/2



Traffic Signal Optimization 2/2



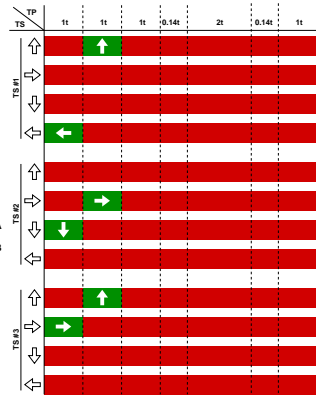
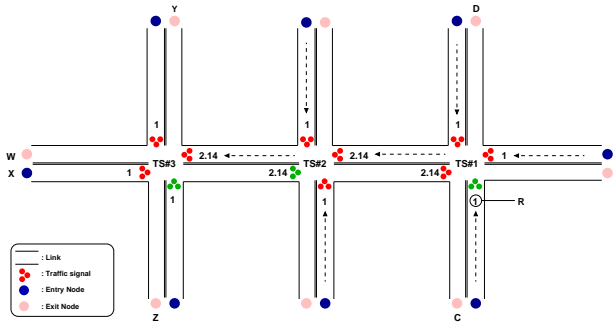
Traffic Signal Optimization 2/2



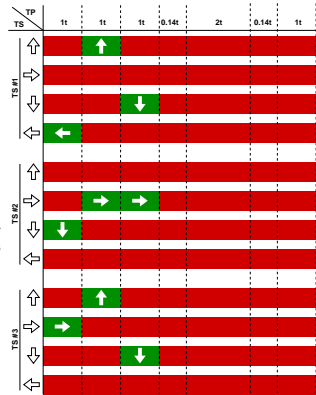
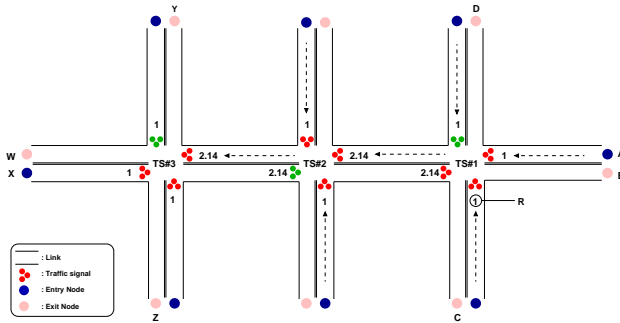
Legend for Signal Status:

- ↔ : Left TS
- ↕ : Top TS
- ↔ : Right TS
- ↕ : Bottom TS
- Green Box : Green Status
- Red Box : Red Status

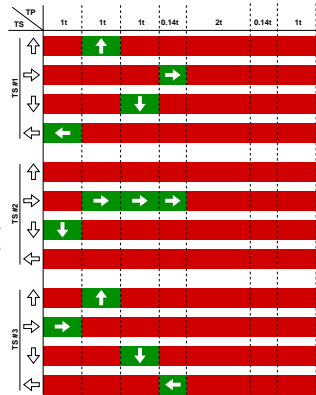
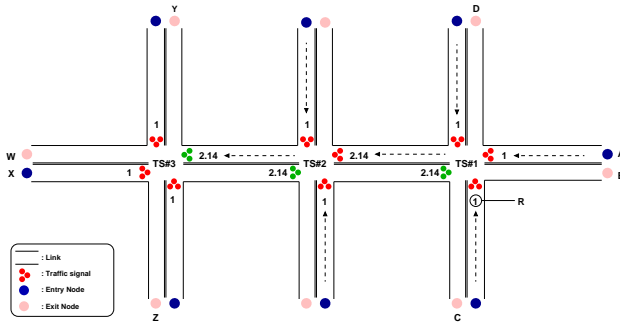
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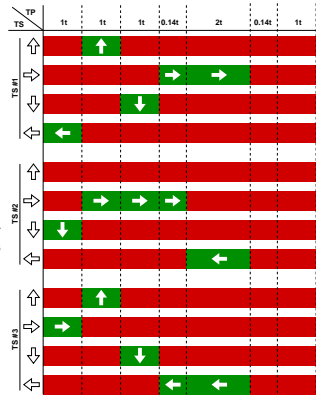
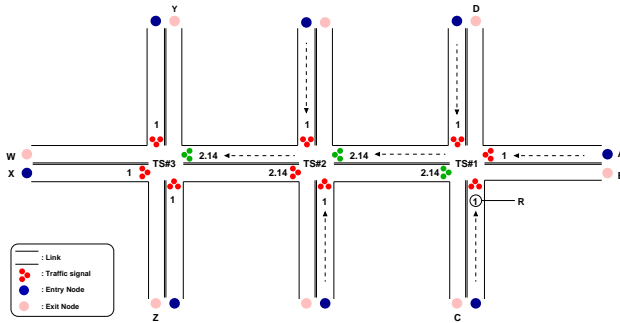
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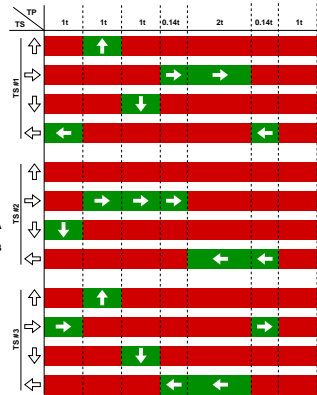
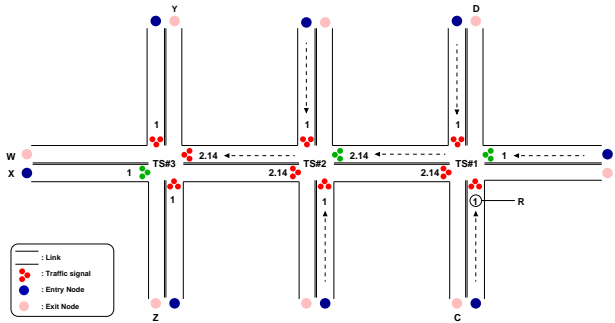
Traffic Signal Optimization 2/2



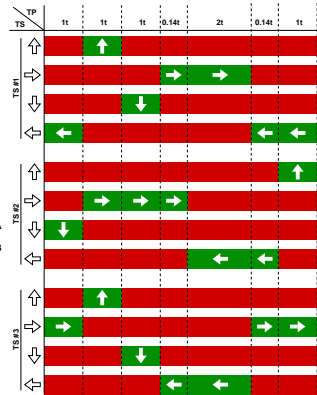
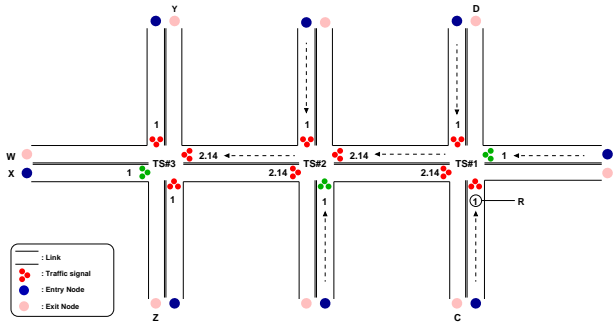
Traffic Signal Optimization 2/2



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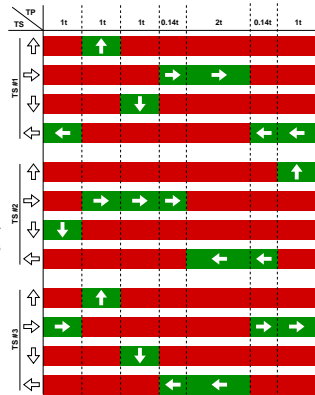
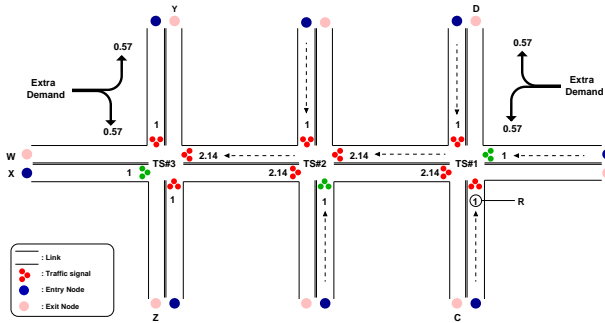


Traffic Signal Optimization 2/2



↕ : Left TS Green Status
 ↔ : Top TS Red Status
 ↕ : Right TS
 ↕ : Bottom TS

Traffic Signal Optimization 2/2



Issues:

- Implementation of roundabouts and signalized intersections.
- Implementation of roundabout right-of-way rules.
- Roundabout speed limits and geometrical design.
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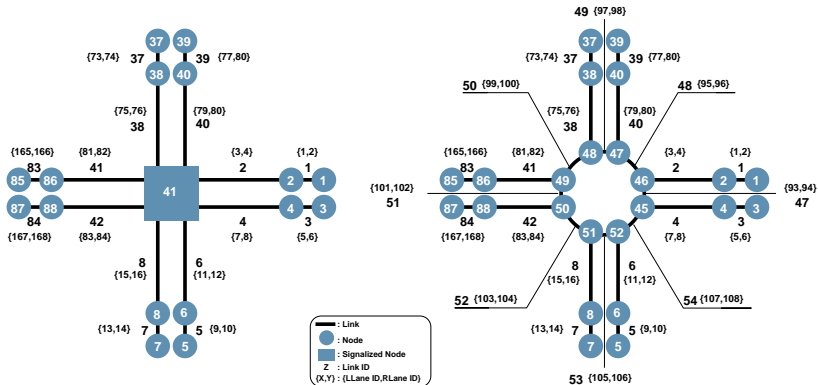
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Implementation of Roundabouts & Signalized Intersections



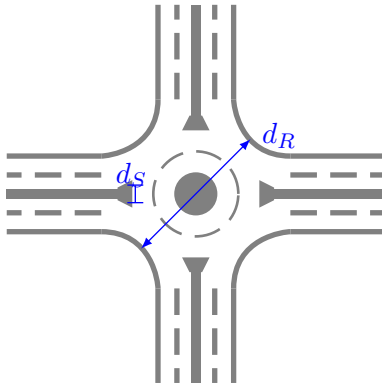
Roundabout Implementation

- Link type.
- Parameters related to nosing, yielding, and headway variance.

Roundabout Implementation

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Roundabout Speed Limits and Geometrical Design



Parameter	Value
d_R	180 ft
d_S	20 ft
#lanes	2
Speed limits	25–30 mph

Updating MITSIMLab

- Update MITSIMLab source code in order to build the executables on latest GNU/Linux systems (openSUSE 11.1).
- Released the modified MITSIMLab source code to MIT Civil Engineering Department researchers, who rebuilt MITSIMLab on Ubuntu 8.04 GNU/Linux operating system.

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Automation of Experiment Generation and Result Analysis

- Two Bash shell scripts that generate roundabout and signalized intersection experiments within a given vehicle demand range and green phase range.
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Highlights:

- Best green phase time.
- Statistical one-to-one comparison of individual vehicle travel times.
- Statistical comparison of average vehicle travel times.
- Total number of completed trips.

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Optimized and Non-optimized Best Green Phase Time

1 Intersection

vd	Non-optimized Average Travel Time	Optimized Average Travel Time
0050	132.15	132.43
0100	133.97	133.64
0150	138.71	137.34
0200	141.74	142.84
0250	150.47	154.41
0300	204.27	204.64
0350	256.71	257.59
0400	312.67	307.69
0450	359.77	349.06

Optimized and Non-optimized Best Green Phase Time

2 Intersections

vd	Non-optimized Average Travel Time	Optimized Average Travel Time
0050	181.66	185.84
0100	238.24	294.01
0150	348.50	407.55
0200	447.07	471.80
0250	511.83	530.88
0300	564.47	582.91
0350	603.80	617.69
0400	644.62	648.32
0450	672.41	676.44

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Optimized and Non-optimized Best Green Phase Time

3 Intersections

vd	Non-optimized Average Travel Time	Optimized Average Travel Time
0050	238.47	249.08
0100	437.65	414.49
0150	565.41	531.07
0200	651.55	616.86
0250	688.27	680.64
0300	744.56	721.11
0350	769.20	751.27
0400	792.35	779.72
0450	816.44	797.19

Optimized and Non-optimized Best Green Phase Time

4 Intersections

vd	Non-optimized Average Travel Time	Optimized Average Travel Time
0050	398.54	382.44
0100	622.37	601.67
0150	719.45	691.33
0200	780.01	765.45
0250	813.53	794.33
0300	853.24	842.16
0350	868.97	859.32
0400	884.41	885.94
0450	898.46	880.70

Statistical Comparison of Optimized & Non-optimized Traffic signal

Two-tailed t-test results

1 Intersection	2 Intersections	3 Intersections	4 Intersections
—	-95%	+99%	+99%

Best Green Phase Time

1 Intersection

vd (#vehicles/hr)	Green Phase Time (sec)
0050	010
0100	010
0150	010
0200	010
0250	010
0300	030
0350	060
0400	050
0450	060

Best Green Phase Time

2 Intersections

vd (#vehicles/hr)	Green Phase Time (sec)
0050	010
0100	020
0150	010
0200	020
0250	020
0300	030
0350	040
0400	060
0450	040

Best Green Phase Time

3 Intersections

vd (#vehicles/hr)	Green Phase Time (sec)
0050	010
0100	010
0150	010
0200	020
0250	020
0300	010
0350	020
0400	020
0450	100

Best Green Phase Time

4 Intersections

vd (#vehicles/hr)	Green Phase Time (sec)
0050	010
0100	010
0150	010
0200	010
0250	010
0300	020
0350	030
0400	010
0450	030

Statistical Comparison of Individual Vehicle Travel Times

Two-tailed t-test results

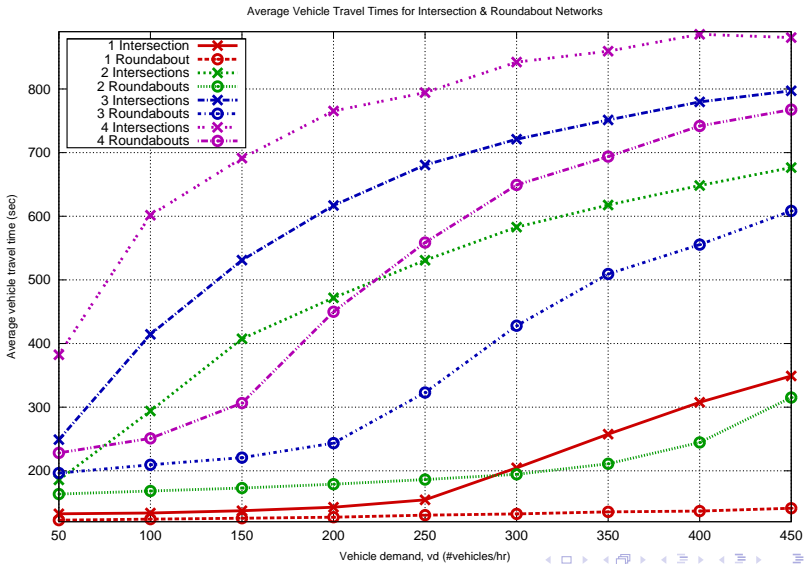
vd	1 Roundabout vs 1 Intersection	2 Roundabouts vs 2 Intersections	3 Roundabouts vs 3 Intersections	4 Roundabouts vs 4 Intersections
050	+99%	+99%	+99%	+99%
100	+99%	+99%	+99%	+99%
150	+99%	+99%	+99%	+99%
200	+99%	+99%	+99%	+99%
250	+99%	+99%	+99%	+99%
300	+99%	+99%	+99%	+99%
350	+99%	+99%	+99%	+99%
400	+99%	+99%	+99%	+99%
450	+99%	+99%	+99%	+99%

Statistical Comparison of Average Vehicle Travel Times

Two-tailed t-test results

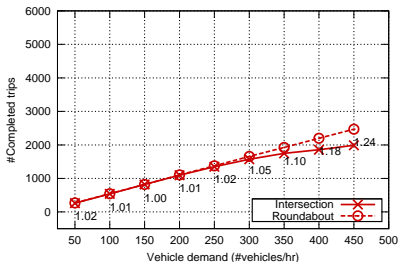
1 Roundabout vs 1 Intersection	2 Roundabouts vs 2 Intersections	3 Roundabouts vs 3 Intersections	4 Roundabouts vs 4 Intersections
+95%	+99%	+99%	+99%

Average Vehicle Travel Times

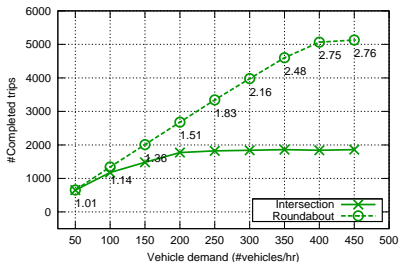


Total Number of Completed Trips

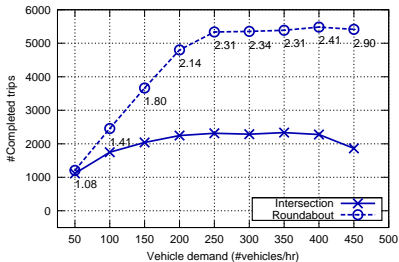
1 Intersection vs 1 Roundabout



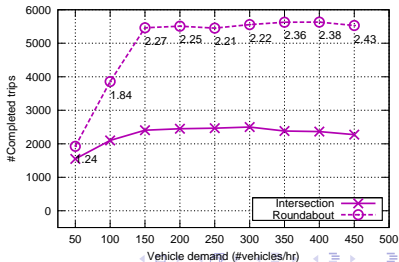
2 Intersections vs 2 Roundabouts



3 Intersections vs 3 Roundabouts



4 Intersections vs 4 Roundabouts



Conclusions

- One-to-one comparison of vehicle travel times
 - Roundabouts are always better than pre-timed signalized intersections for all networks and traffic volumes with a statistical confidence of 99%.
- Comparison of average travel times
 - Roundabouts outperform signalized intersections for all networks and traffic volumes.
 - Single roundabout performs better than a signalized intersection with a statistical confidence of 99%.
- Total number of completed trips
 - Completed trips in roundabout networks always higher than that in signalized intersection networks.
 - Roundabout networks can carry 10% more traffic than signalized networks (per intersection).

Conclusions

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 - Roundabouts are always better than pre-timed signalized intersections for all networks and traffic volumes with a statistical confidence of 99%.
- Comparison of average travel times
 - Roundabouts outperform signalized intersections with a statistical confidence of 99% in 2-, 3- and 4-junction networks.
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- Study a mixture of networks including both roundabouts and signalized intersections within the same traffic stream.
- Modify MITSIMLab to provide explicit high-level right-of-way rules and lane-specific traffic signals.
- Modify MITSIMLab to implement Message Passing Interface (MPI) instead of using Parallel Virtual Machine (PVM).
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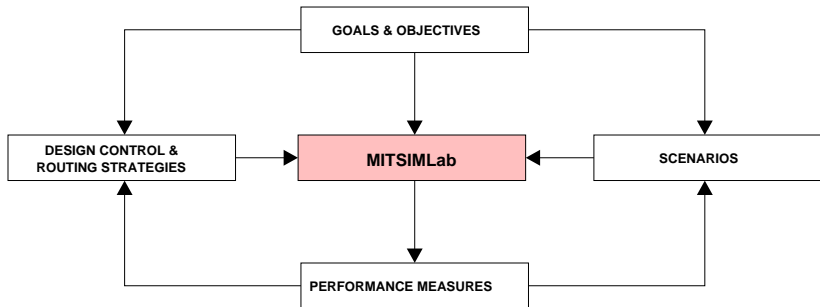
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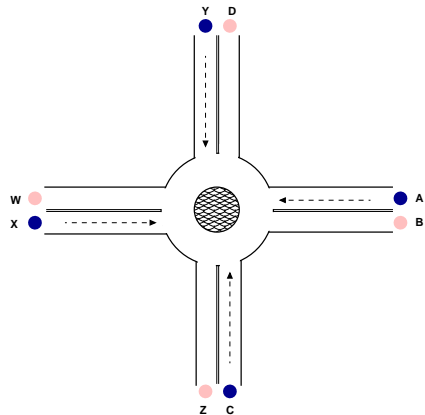
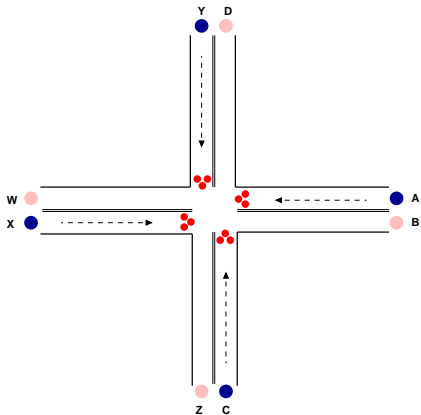
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END

MITSIMLab Evaluation Framework



Vehicle Demand 2/2



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- Statistical comparison of individual vehicle travel times.
- Statistical comparison of average vehicle travel times.
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Statistical Analysis

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