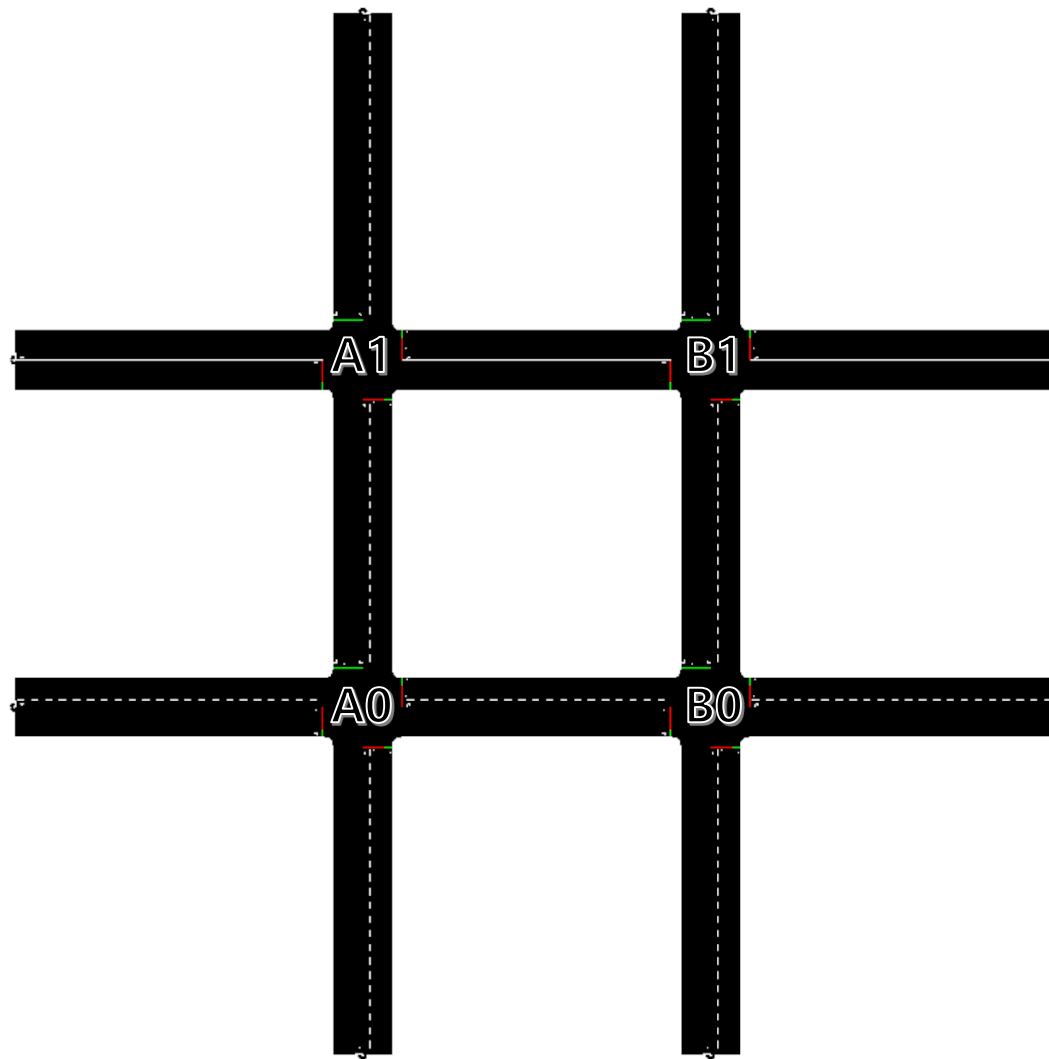
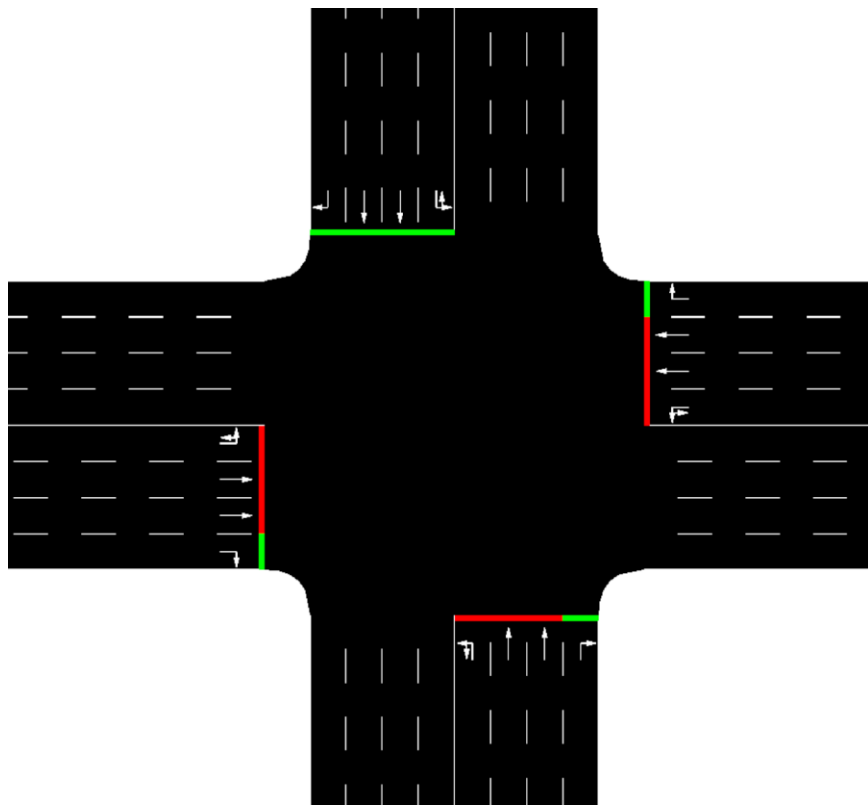


# 강화학습 기반 다중교차로 신호 최적화

2020/07/15

피민규

# 교차로(2x2)



# Agent design

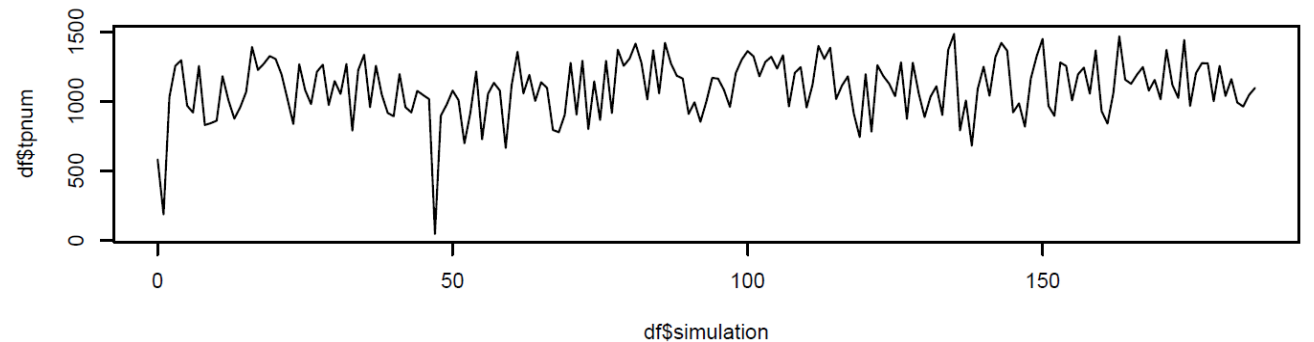
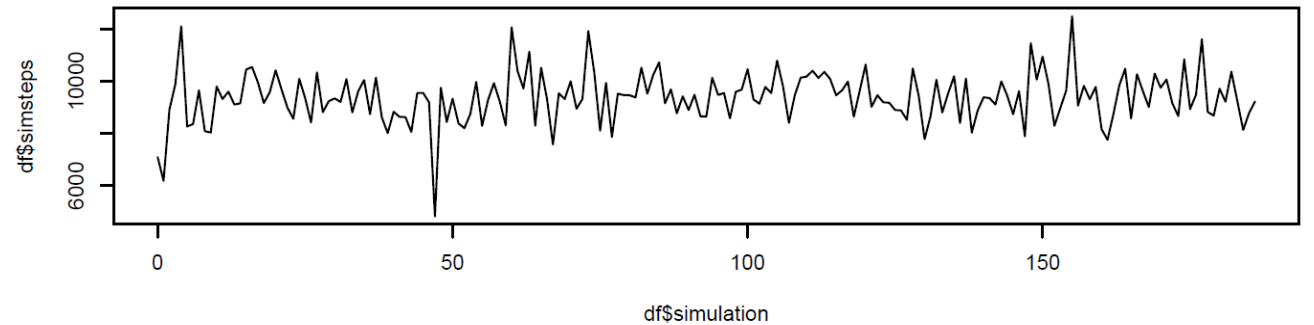
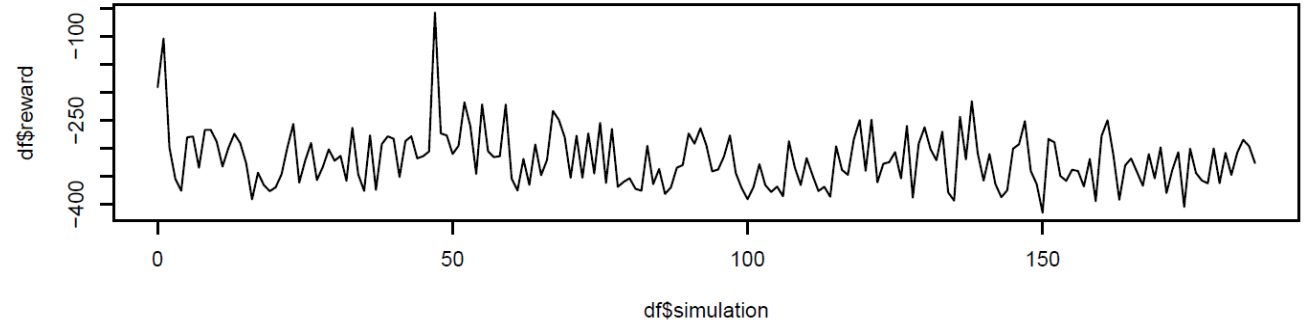
- Single-Agent
- State: 레인의 차량 수( $16 \times 4$ ), 대기 중인 차량 수( $16 \times 4$ ), 현재 신호( $8 \times 4$ )
- Reward: -(4개의 교차로에 들어오는 차선의 대기열 합)

- Action: 16

```
['0000',  
'0001',  
'0010',  
'0011',  
'0100',  
'0101',  
'0110',  
'0111',  
'1000',  
'1001',  
'1010',  
'1011',  
'1100',  
'1101',  
'1110',  
'1111']
```

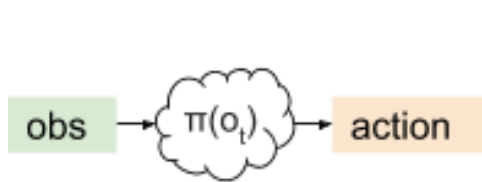
# result

- 186 simulation
- Reward: 증가하지 않음
- Simsteps: 종료 step
  - 0-3600 랜덤 수요
  - 고정신호로 실행했을 때 3700 전후
- Tpnnum: 텔레포트 한 차량 수
  - SUMO에서 너무 오래 기다리면 자동으로 텔레포트 시킴
  - 학습 초기에 텔레포트 하는 차량 수가 많았다가 0으로 수렴하는게 정상

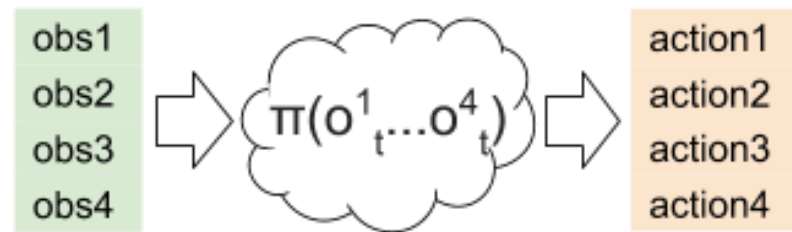


# Agent design

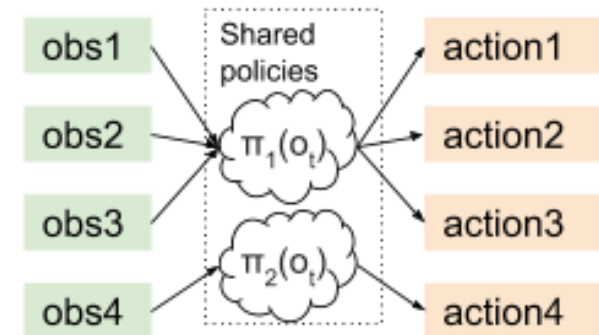
- Single-Agent(super-agent)
- $State_i$ : 교차로  $i$ 의 레인별 차량 수, 대기중인 차량 수, 현재 신호
- $Action_i$ : 0,1(교차로  $i$ 의 현재신호 유지, 황색신호 후 다음 신호로 변경)
- $Reward_i$ : 교차로  $i$ 로 진입하는 차선의 대기열 합



(a) Single-agent

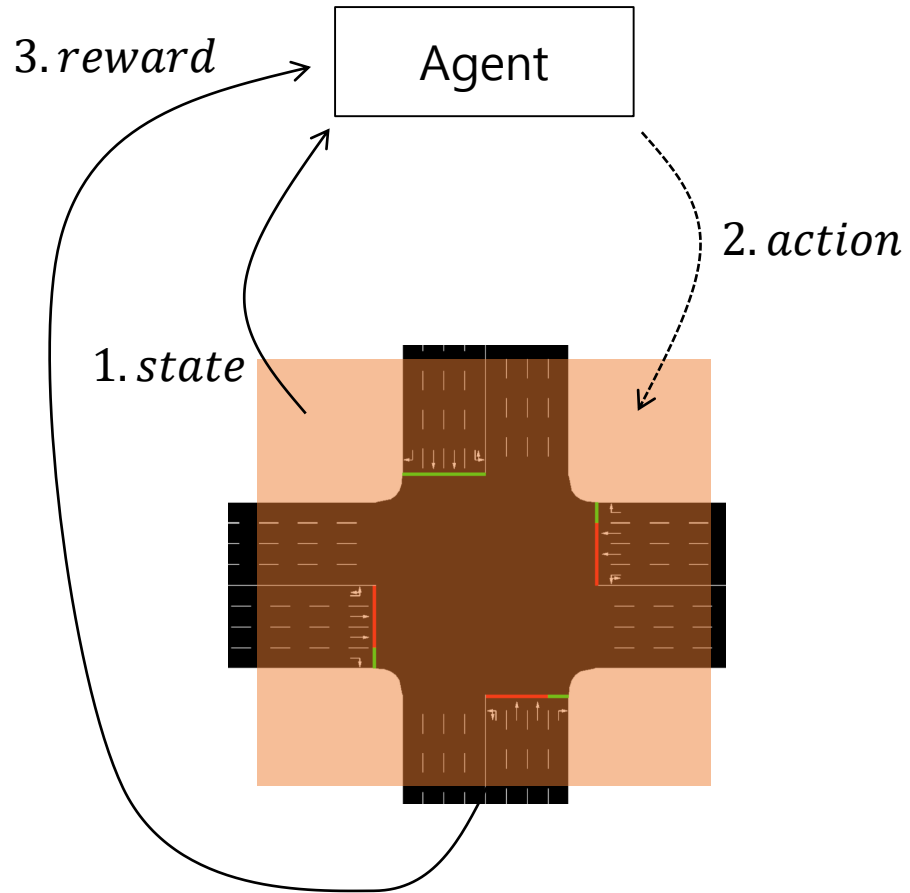


(b) Multiple logical entities, single "super-agent"

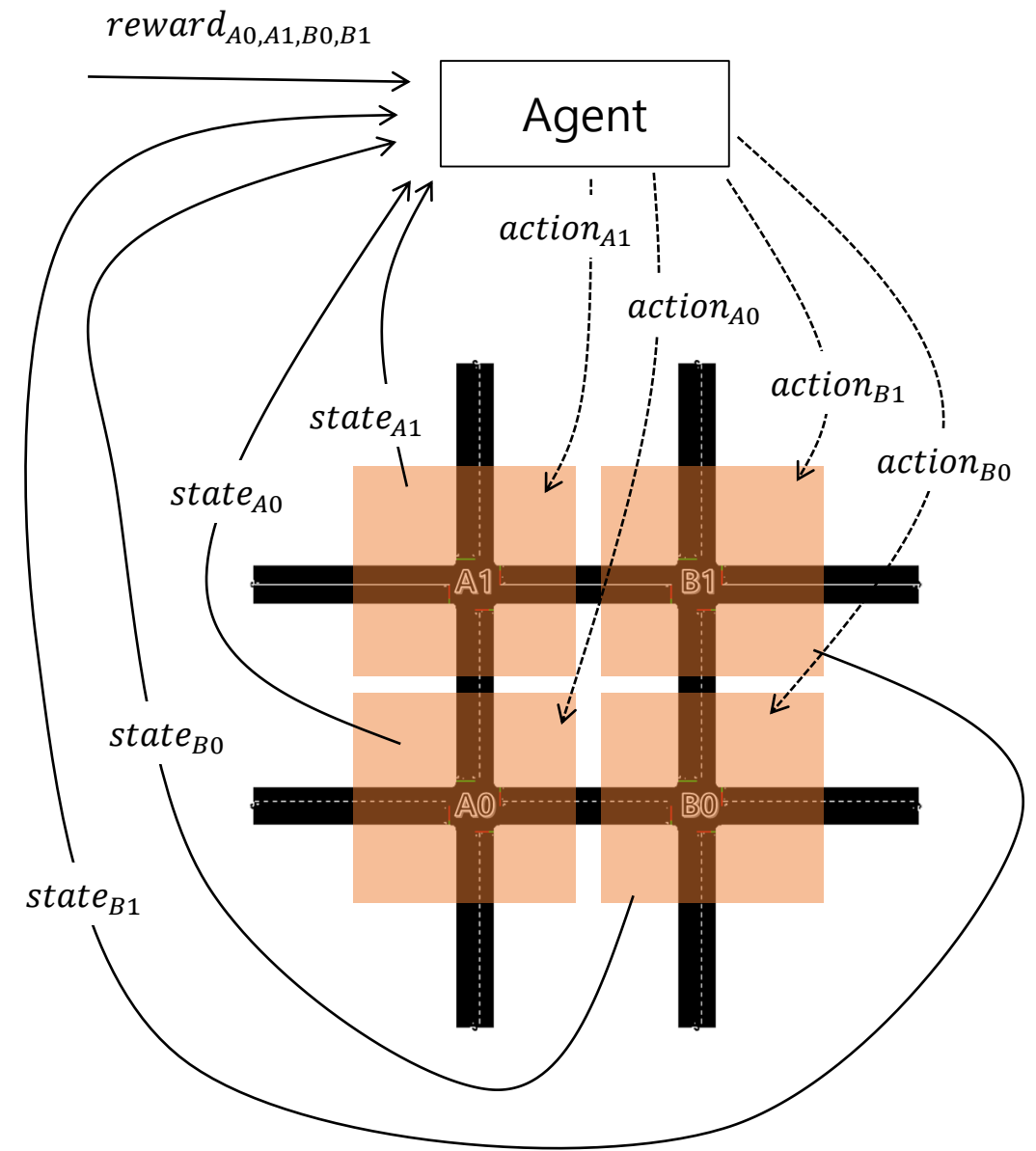


(c) Multi-agent

# Agent design



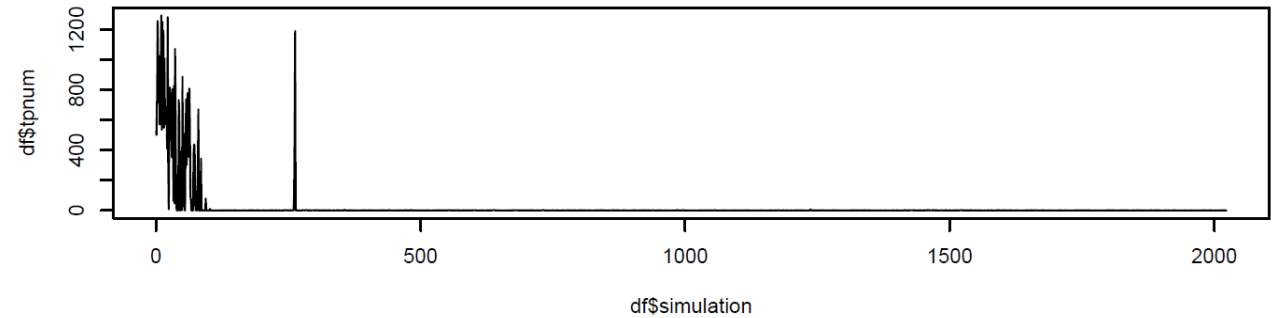
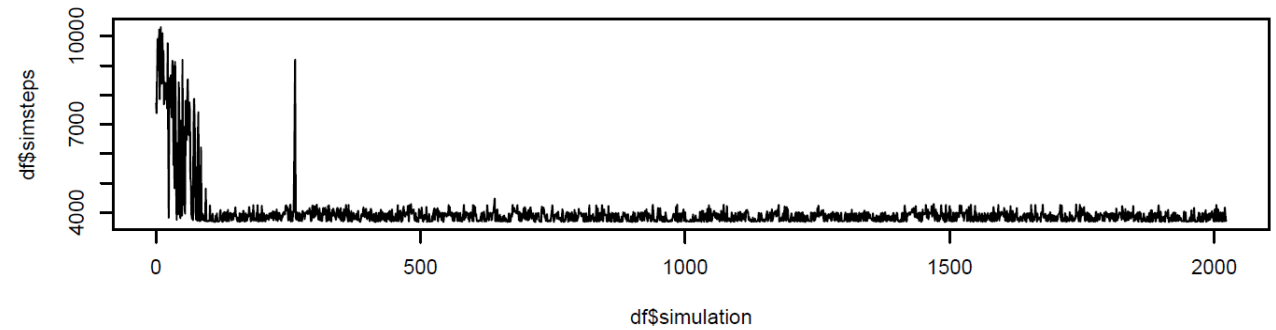
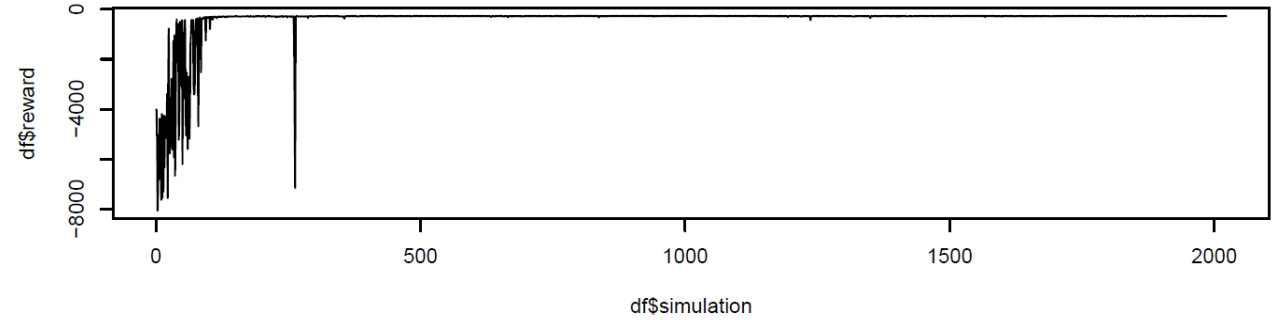
**Single-Agent**



**Super-Agent**

# result

- 2000 simulation
- 약 100번째 시뮬레이션에서 수렴함
  - Reward 증가
  - Simsteps, tpnum 감소



# 고정신호

The screenshot displays the SUMO 1.6.0 software interface. On the left, the 'network: Parameters' window is open, showing a list of simulation parameters. The main window shows a 2x2 grid of intersection configurations. The status bar at the bottom indicates the simulation is ready to start.

| Name                              | Value  | Dynamic |
|-----------------------------------|--------|---------|
| loaded vehicles [#]               | 2      |         |
| insertion-backlogged vehicles [#] | 0      |         |
| departed vehicles [#]             | 0      |         |
| running vehicles [#]              | 0      |         |
| arrived vehicles [#]              | 0      |         |
| discarded vehicles [#]            | 0      |         |
| collisions [#]                    | 0      |         |
| teleports [#]                     | 0      |         |
| halting [#]                       | 0      |         |
| avg. speed [m/s]                  | -1.00  |         |
| avg. relative speed               | -1.00  |         |
| end time [s]                      | 3600   |         |
| begin time [s]                    | 0      |         |
| step duration [ms]                | 0      |         |
| FPS                               | 142.86 |         |
| simulation duration [ms]          | 0      |         |
| idle duration [ms]                | 0      |         |
| duration factor                   | -1.00  |         |
| updates per second                | -1.00  |         |
| avg. updates per second           | -1.00  |         |
| nodes [#]                         | 12     |         |
| edges [#]                         | 24     |         |
| total edge length [km]            | 3.06   |         |
| total lane length [km]            | 12.25  |         |
| network version                   | 1.60   |         |

0 100m

Loading net-file from 'C:\Users\USER\traffic-signal\sumo\env\small-grid\small-grid.net.xml' ... done (8ms).  
Loading additional-files from 'C:\Users\USER\traffic-signal\sumo\env\small-grid\small-grid\output-config.xml' ... done (12ms).  
Loading done.  
Start the loaded simulation.

x:-122.59, y:456.43 x:-122.59, y:456.43



# Super-Agent

The screenshot displays the SUMO 1.6.0 software interface. On the left, a 'network: Parameter' window is open, showing a table of simulation parameters. The main window shows a 4x4 grid of road segments, each with a dashed white center line. The interface includes a menu bar (File, Edit, Settings, Locate, Simulation, Windows, Help), a toolbar, and a status bar at the bottom.

| Name                              | Value   | Dynamic |
|-----------------------------------|---------|---------|
| loaded vehicles [#]               | 169     |         |
| insertion-backlogged vehicles [#] | 0       |         |
| departed vehicles [#]             | 3       |         |
| running vehicles [#]              | 3       |         |
| arrived vehicles [#]              | 0       |         |
| discarded vehicles [#]            | 0       |         |
| collisions [#]                    | 0       |         |
| teleports [#]                     | 0       |         |
| halting [#]                       | 1       |         |
| avg. speed [m/s]                  | 2.13    |         |
| avg. relative speed               | 0.15    |         |
| end time [s]                      | 3600    | ✗       |
| begin time [s]                    | 0       | ✗       |
| step duration [ms]                | 188     |         |
| FPS                               | 1000.00 |         |
| simulation duration [ms]          | 1       |         |
| idle duration [ms]                | 187     |         |
| duration factor                   | 1000.00 |         |
| updates per second                | 3000.00 |         |
| avg. updates per second           | 20.41   |         |
| nodes [#]                         | 12      | ✗       |
| edges [#]                         | 24      | ✗       |
| total edge length [km]            | 3.06    | ✗       |
| total lane length [km]            | 12.25   | ✗       |
| network version                   | 1.60    | ✗       |


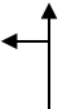
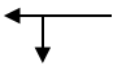

0 100m

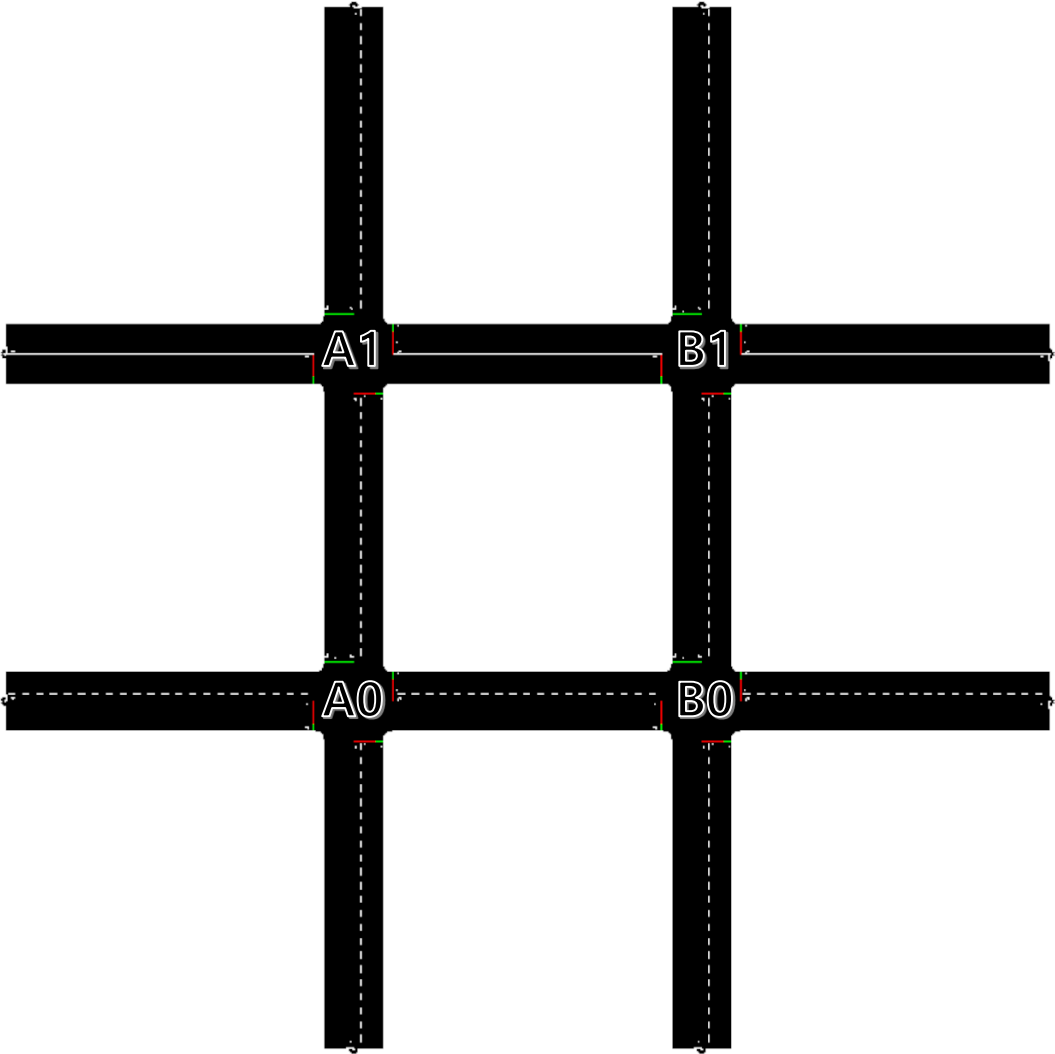
Loading additional-files from 'env/small-grid/./output-config.xml' ... done (11ms).  
Loading done.  
Simulation started with time: 0.00  
'env/small-grid/small-grid.sumocfg' loaded.

3 | x-227.03, y291.95 | x-227.03, y291.95

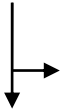
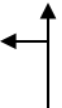
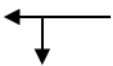

# 기존 교차로는 4개 모두 동일한 신호

42:42:42:42(황색3초, 주기180)



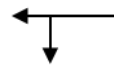

| Φ1   | Φ2  | Φ3  | Φ4  |
|--|---|---|---|
|  |  |  |  |



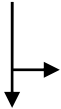

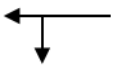

42:42:42:42(황색3초, 주기180)

| Φ1  | Φ2  | Φ3  | Φ4  |
|---|---|---|---|
|  |  |  |  |

42:42:42:42(황색3초, 주기180)

| Φ1   | Φ2  | Φ3  | Φ4  |
|--|---|---|---|
|  |  |  |  |

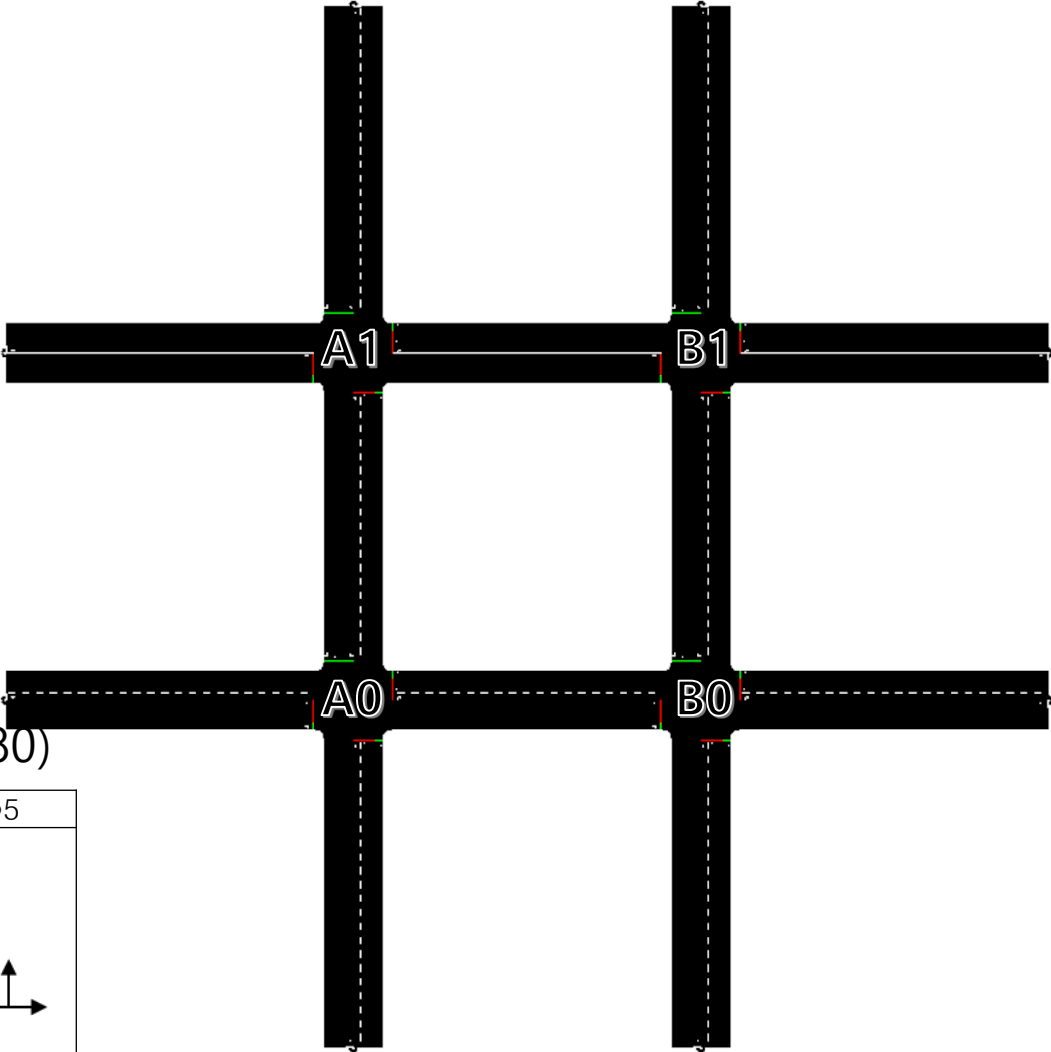
42:42:42:42(황색3초, 주기180)

| Φ1  | Φ2  | Φ3  | Φ4  |
|---|---|---|---|
|  |  |  |  |

# 네 개 모두 다른 신호로 실험

42:42:42:42(황색3초, 주기180)

| Φ1 | Φ2 | Φ3 | Φ4 |
|----|----|----|----|
|    |    |    |    |



42:42:42:42(황색3초, 주기180)

| Φ1 | Φ2 | Φ3 | Φ4 |
|----|----|----|----|
|    |    |    |    |

33:33:33:33:33(황색3초, 주기180)

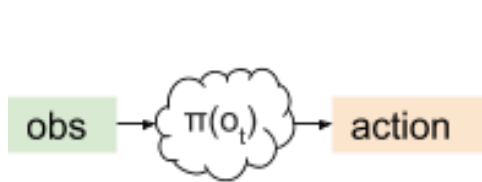
| Φ1 | Φ2 | Φ3 | Φ4 | Φ5 |
|----|----|----|----|----|
|    |    |    |    |    |

42:42:42:42(황색3초, 주기180)

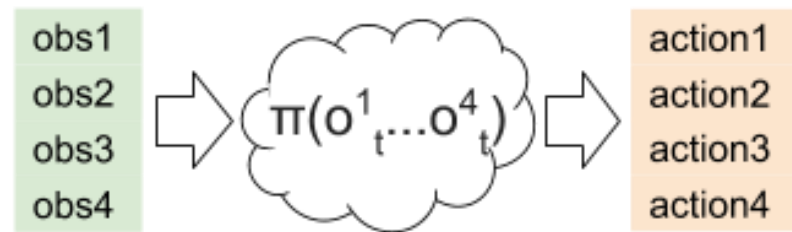
| Φ1 | Φ2 | Φ3 | Φ4 |
|----|----|----|----|
|    |    |    |    |

# Agent design

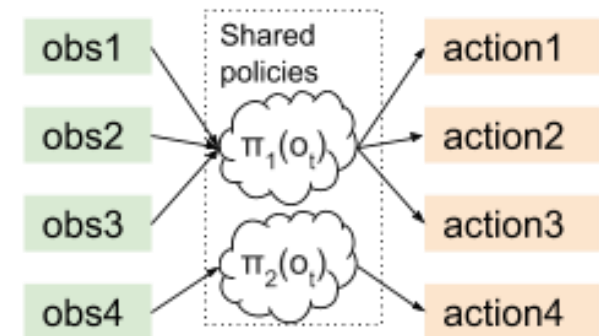
- Single-Agent(super-agent)
- $State_i$ : 교차로  $i$ 의 레인별 차량 수, 대기중인 차량 수, **현재 신호  $\rightarrow$  현재 신호에 갈 수 있는 차선의 방향과 수**
- $Action_i$ : 0,1(교차로  $i$ 의 현재신호 유지, 황색신호 후 다음 신호로 변경)
- $Reward_i$ : 교차로  $i$ 로 진입하는 차선의 대기열 합



(a) Single-agent



(b) Multiple logical entities, single "super-agent"



(c) Multi-agent

33:33:33:33:33(황색3초, 주기180)

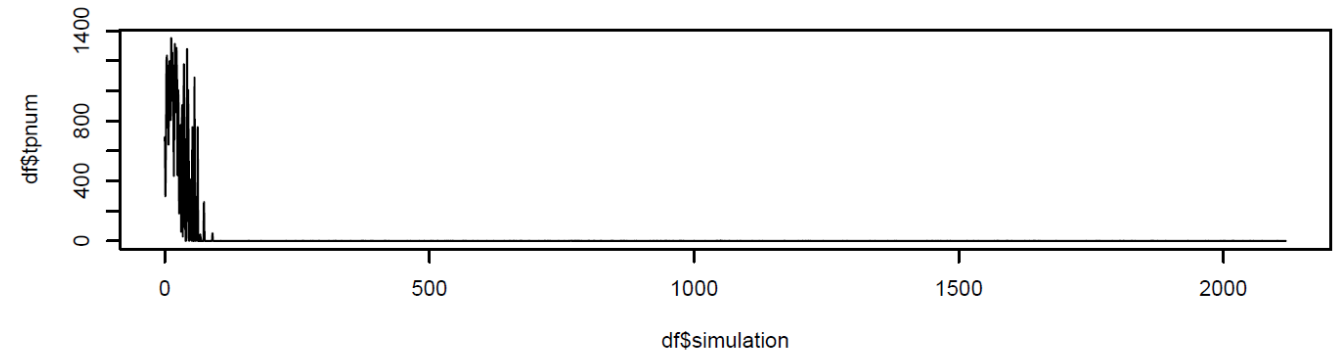
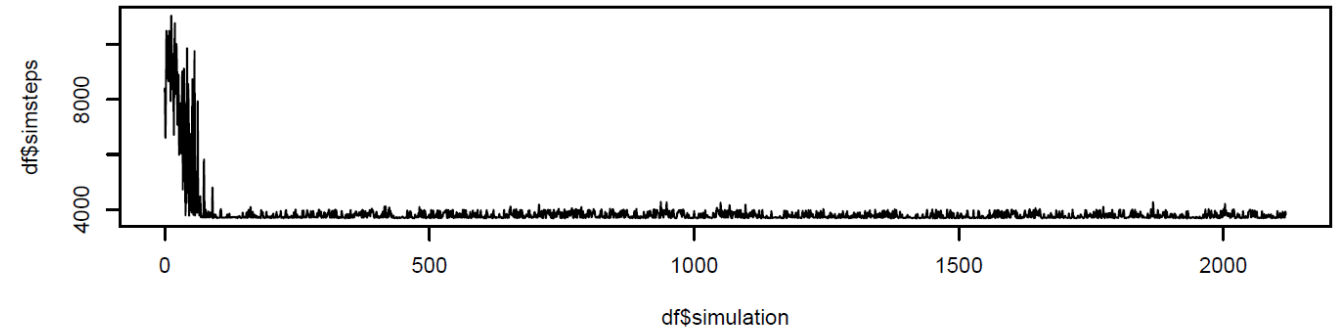
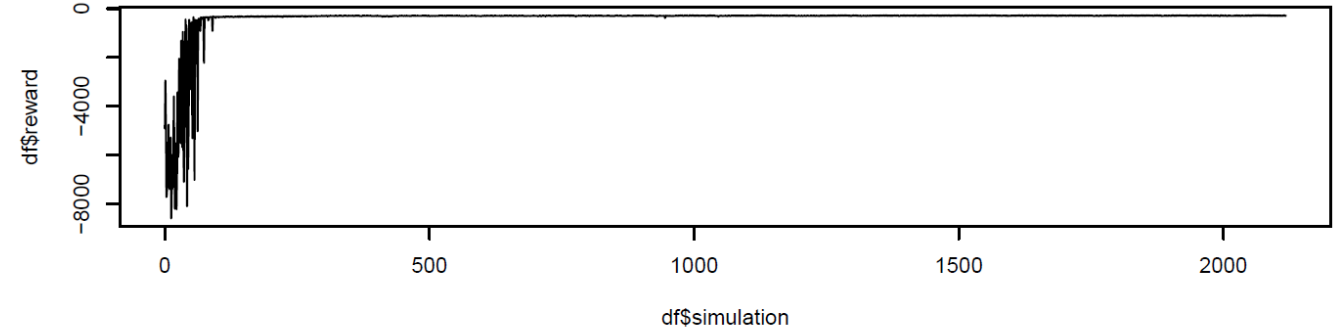
[us, ul, rs, rl, ds, dl, ls, ll]

## 변경

```
<tlLogic id="A0" type="static" programID="0" offset="0">
  <phase duration="33" state="GrrGGGrrrrGrrrrGrrrr"/>
  <phase duration="3" state="GrryyGrrrrGrrrrGrrrr"/>
  <phase duration="33" state="GGGrrGrrrrGGGrrGrrrr"/>
  <phase duration="3" state="GyyrrGrrrrGyyrrGrrrr"/>
  <phase duration="33" state="GrrrrGrrrrGrrGGGrrrr"/>
  <phase duration="3" state="GrrrrGrrrrGrryyGrrrr"/>
  <phase duration="33" state="GrrrrGGGGGGrrrrGrrrr"/>
  <phase duration="3" state="GrrrrGyyyyGrrrrGrrrr"/>
  <phase duration="33" state="GrrrrGrrrrGrrrrGGGGGG"/>
  <phase duration="3" state="GrrrrGrrrrGrrrrGyyyy"/>
</tlLogic>
```

# result

- 2120 simulation
- 약 100번째 시뮬레이션에서 수렴함
  - Reward 증가
  - Simsteps, tpnum 감소



# 고정신호

small-grid2.sumocfg - SUMO 1.6.0

File Edit Settings Locate Simulation Windows Help

Time: [Progress Bar] Delay (ms): 0 Scale Traffic: 1

network: Parameter

| Name                              | Value | Dynamic                             |
|-----------------------------------|-------|-------------------------------------|
| loaded vehicles [#]               | 2     | <input checked="" type="checkbox"/> |
| insertion-backlogged vehicles [#] | 0     | <input checked="" type="checkbox"/> |
| departed vehicles [#]             | 0     | <input checked="" type="checkbox"/> |
| running vehicles [#]              | 0     | <input checked="" type="checkbox"/> |
| arrived vehicles [#]              | 0     | <input checked="" type="checkbox"/> |
| discarded vehicles [#]            | 0     | <input checked="" type="checkbox"/> |
| collisions [#]                    | 0     | <input checked="" type="checkbox"/> |
| teleports [#]                     | 0     | <input checked="" type="checkbox"/> |
| halting [#]                       | 0     | <input checked="" type="checkbox"/> |
| avg. speed [m/s]                  | -1.00 | <input checked="" type="checkbox"/> |
| avg. relative speed               | -1.00 | <input checked="" type="checkbox"/> |
| end time [s]                      | 3600  | <input checked="" type="checkbox"/> |
| begin time [s]                    | 0     | <input checked="" type="checkbox"/> |
| step duration [ms]                | 0     | <input checked="" type="checkbox"/> |
| FPS                               | 26.32 | <input checked="" type="checkbox"/> |
| simulation duration [ms]          | 0     | <input checked="" type="checkbox"/> |
| idle duration [ms]                | 0     | <input checked="" type="checkbox"/> |
| duration factor                   | -1.00 | <input checked="" type="checkbox"/> |
| updates per second                | -1.00 | <input checked="" type="checkbox"/> |
| avg. updates per second           | -1.00 | <input checked="" type="checkbox"/> |
| nodes [#]                         | 12    | <input checked="" type="checkbox"/> |
| edges [#]                         | 24    | <input checked="" type="checkbox"/> |
| total edge length [km]            | 3.06  | <input checked="" type="checkbox"/> |
| total lane length [km]            | 12.25 | <input checked="" type="checkbox"/> |
| network version                   | 1.60  | <input checked="" type="checkbox"/> |

0 100m

Loading net-file from 'C:\Users\WUSER\traffic-signal\sumo\env\small-grid\small-grid2.net.xml' ... done (6ms).  
Loading additional-files from 'C:\Users\WUSER\traffic-signal\sumo\env\small-grid#\output-config.xml' ... done (11ms).  
Loading done.  
Start the loaded simulation.

x-71.95, y:455.60 x-71.95, y:455.60

# Super-Agent

small-grid2.sumocfg - SUMO 1.6.0

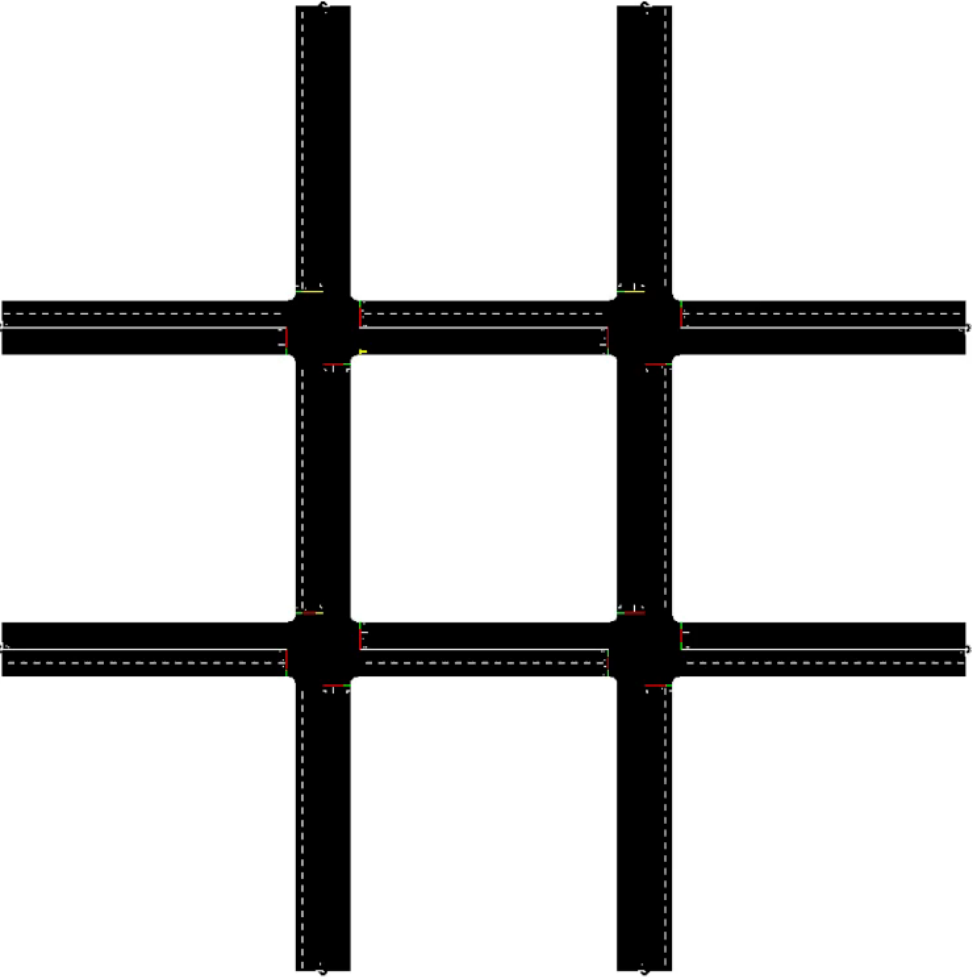
File Edit Settings Locate Simulation Windows Help

Time: 00:00 Delay (ms): 0 Scale Traffic: 1

standard

network: Parameter

| Name                              | Value   | Dynamic |
|-----------------------------------|---------|---------|
| loaded vehicles [#]               | 2       |         |
| insertion-backlogged vehicles [#] | 0       |         |
| departed vehicles [#]             | 1       |         |
| running vehicles [#]              | 1       |         |
| arrived vehicles [#]              | 0       |         |
| discarded vehicles [#]            | 0       |         |
| collisions [#]                    | 0       |         |
| teleports [#]                     | 0       |         |
| halting [#]                       | 1       |         |
| avg. speed [m/s]                  | 0.00    |         |
| avg. relative speed               | 0.00    |         |
| end time [s]                      | 3600    |         |
| begin time [s]                    | 0       |         |
| step duration [ms]                | 311     |         |
| FPS                               | 1000.00 |         |
| simulation duration [ms]          | 311     |         |
| idle duration [ms]                | 0       |         |
| duration factor                   | 3.22    |         |
| updates per second                | 3.22    |         |
| avg. updates per second           | 3.22    |         |
| nodes [#]                         | 12      |         |
| edges [#]                         | 24      |         |
| total edge length [km]            | 3.06    |         |
| total lane length [km]            | 12.25   |         |
| network version                   | 1.60    |         |



0 100m

Loading additional-files from 'env/small-grid/./output-config.xml' ... done (10ms).  
Loading done.  
Simulation started with time: 0.00  
Start the loaded simulation.

1 | x-178.43, y:455.10 | x-178.43, y:455.10