

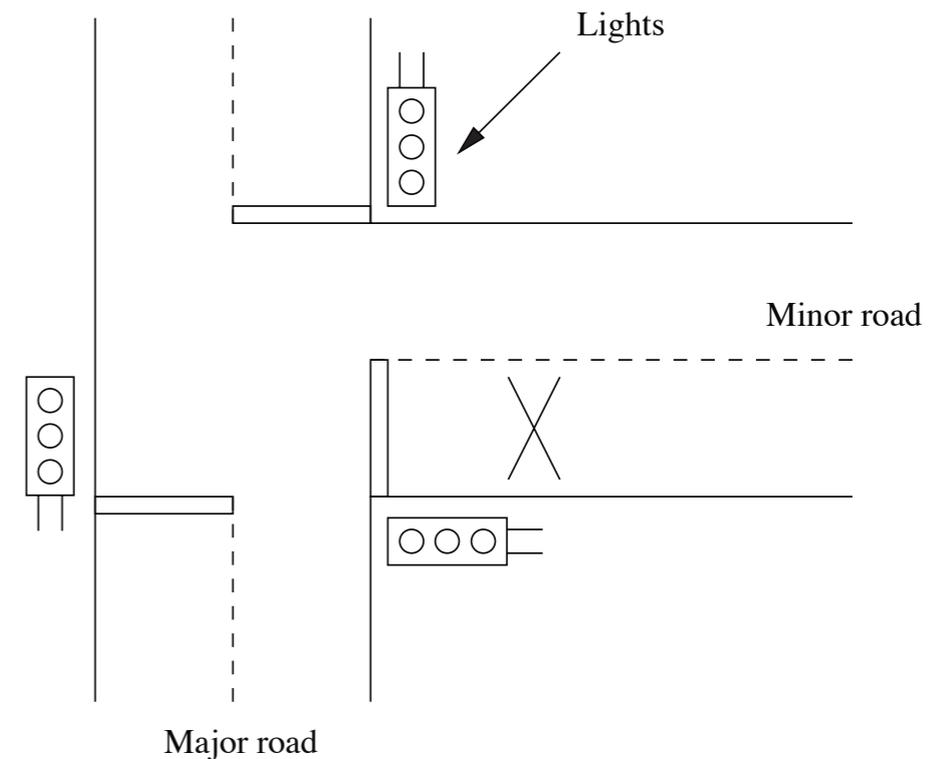
Uppaal Demo

Arquitectura e Cálculo
2019

Traffic Lights Intersection

Behavioural constraints:

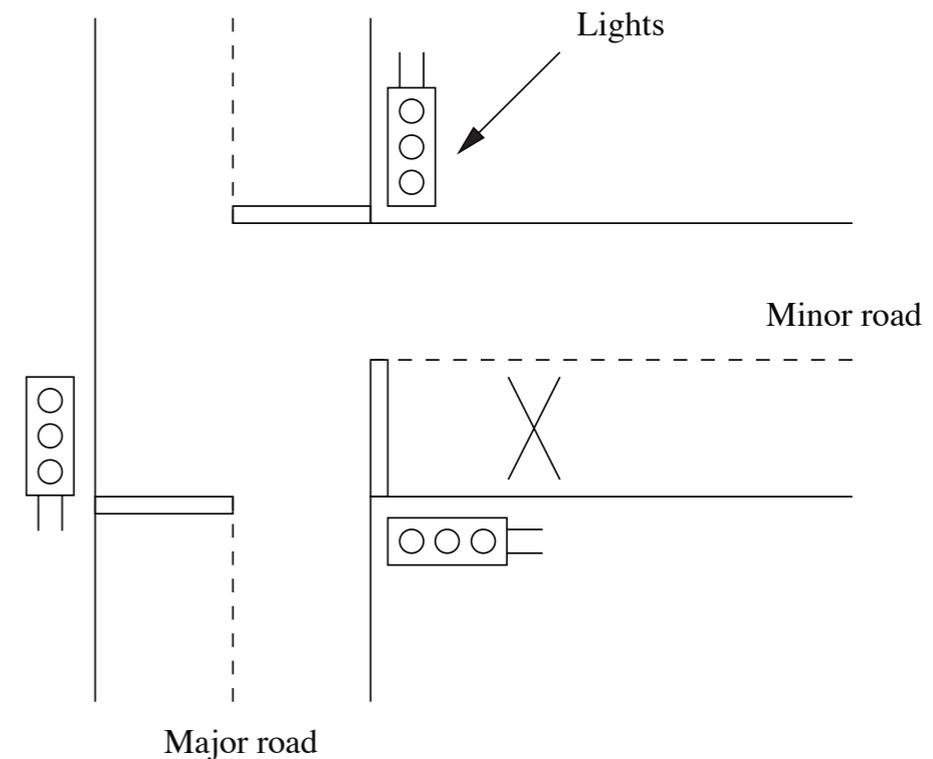
- A control system must ensure the safe and correct functioning of a set of traffic lights at a T-junction between a major and a minor road.
- The lights will be set on green on the major road and red on the minor road unless a vehicle is detected by a sensor in the road just before the lights on the minor road.
- In this case the lights will be switchable in the standard manner and allow traffic to leave the minor road.
- After a suitable interval the lights will revert to their default position to allow traffic to flow on the major road again.
- Once a vehicle is detected the sensor will be disabled until the minor-road lights are set to red again.



Traffic Lights Intersection

Temporal constraints:

- Minor road light stays on green for 30s
- Interim lights stay on for 5s
- 1s delay between switching one light off and the other on
- Major road light must be green for at least 30s in each cycle...
- ... but must respond to the sensor immediately after that



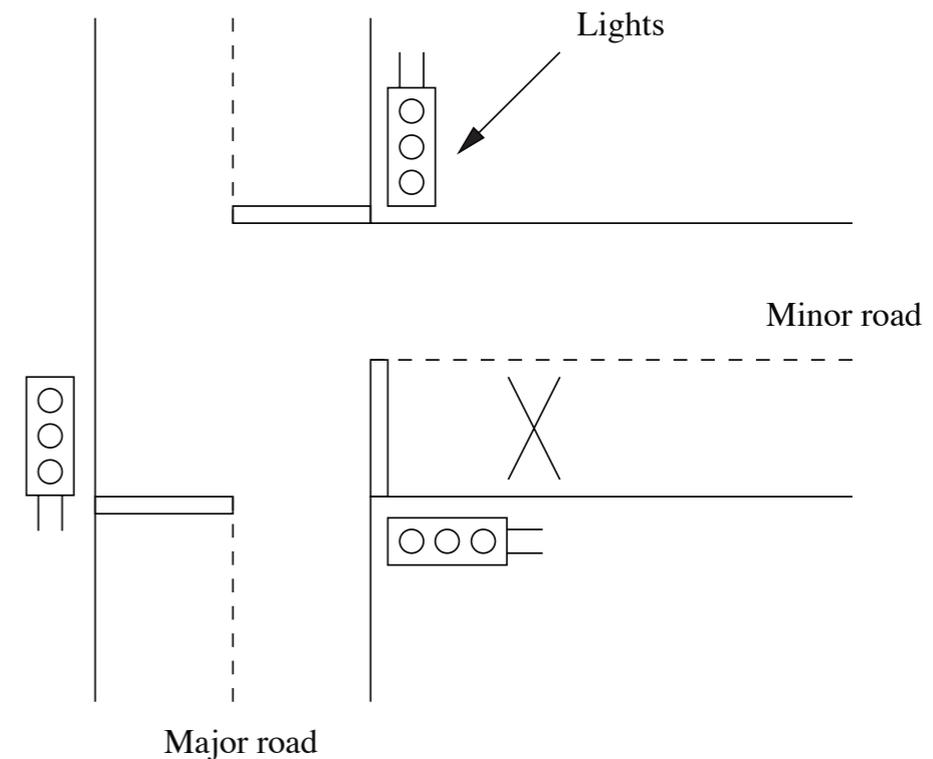
Traffic Lights Intersection

Behavioural constraints:

- Major road is always green until there are cars at the minor road:
 - major road light switches to red, then minor road light switches to green for a while, then back to normal state
 - Sensor is disabled until minor road light switches to red

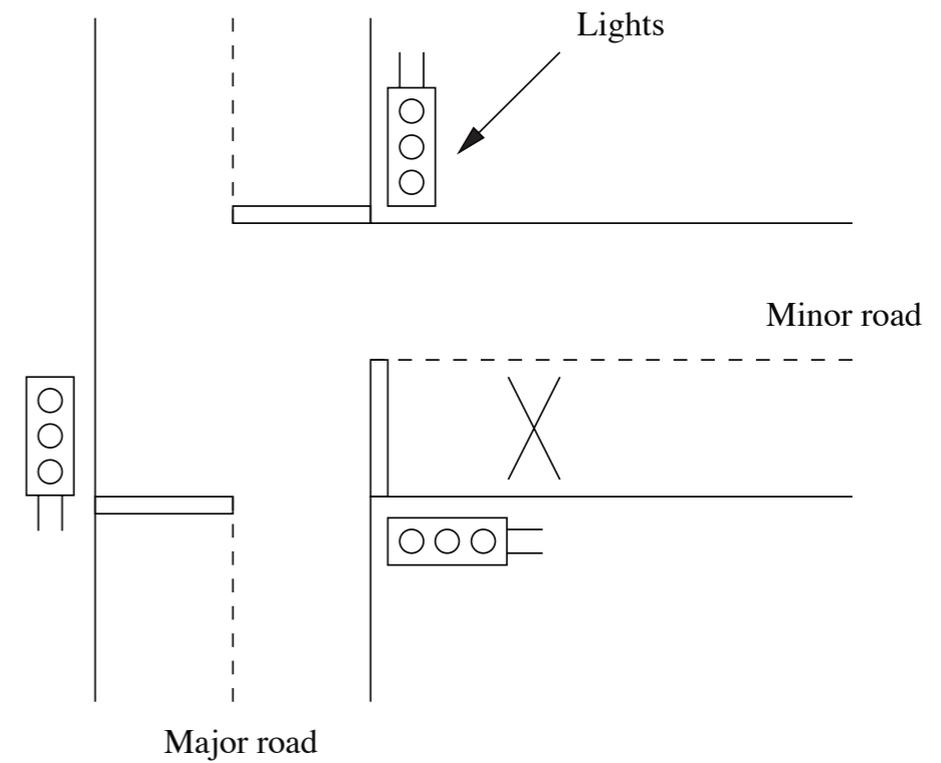
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Traffic Lights Intersection

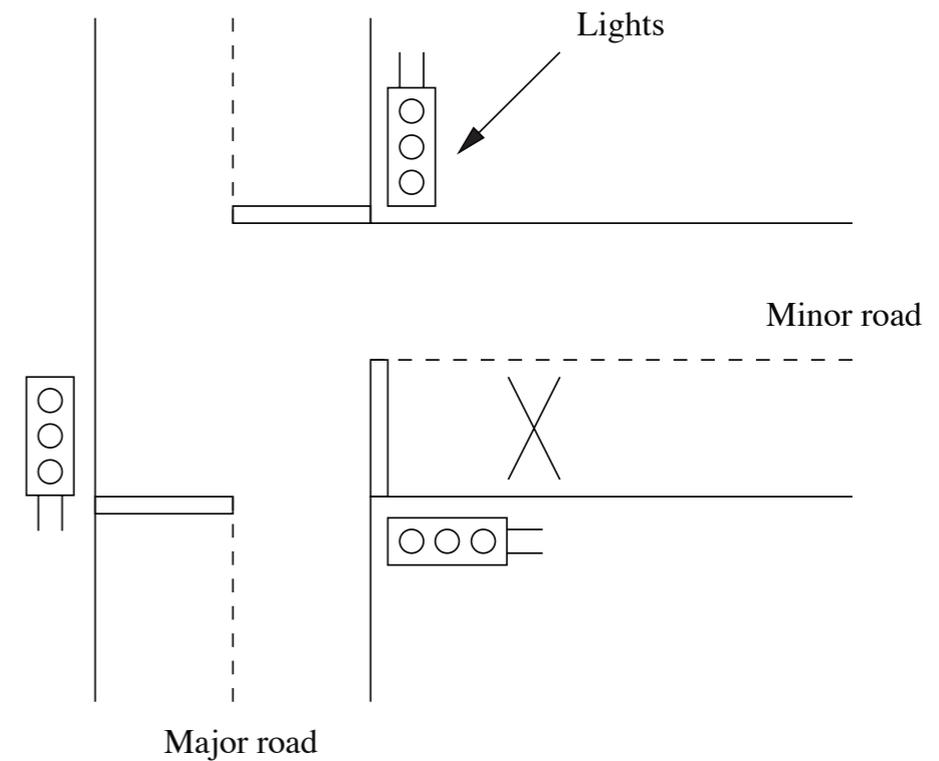
Main actors:



Traffic Lights Intersection

Main actors:

- Major road traffic light
- Minor road traffic light
- Sensor



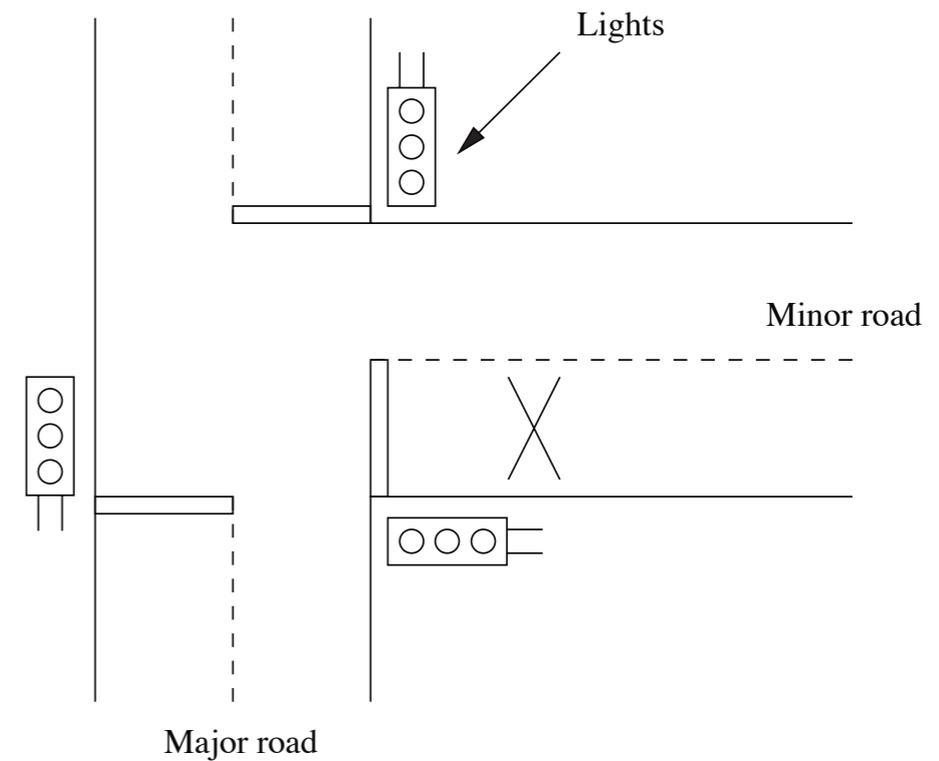
Traffic Lights Intersection

Verification:

Reachability properties

Safety properties

Liveness properties



Traffic Lights Intersection

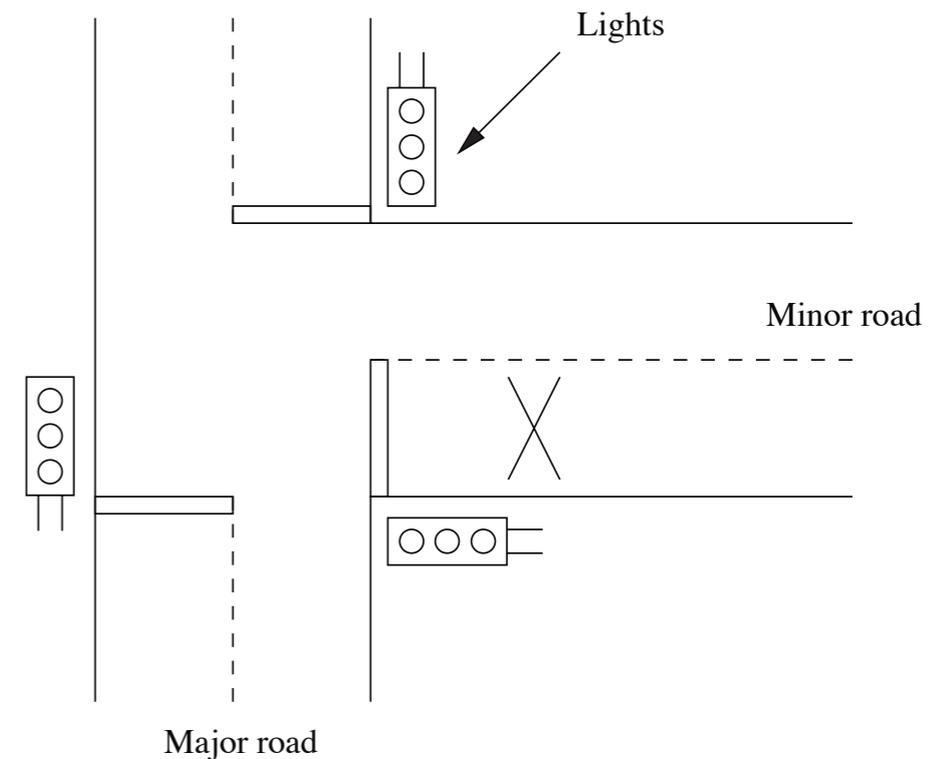
Verification:

Reachability properties

- Minor road light can go green
- Major road light can go red
- ...

Safety properties

Liveness properties



Traffic Lights Intersection

Verification:

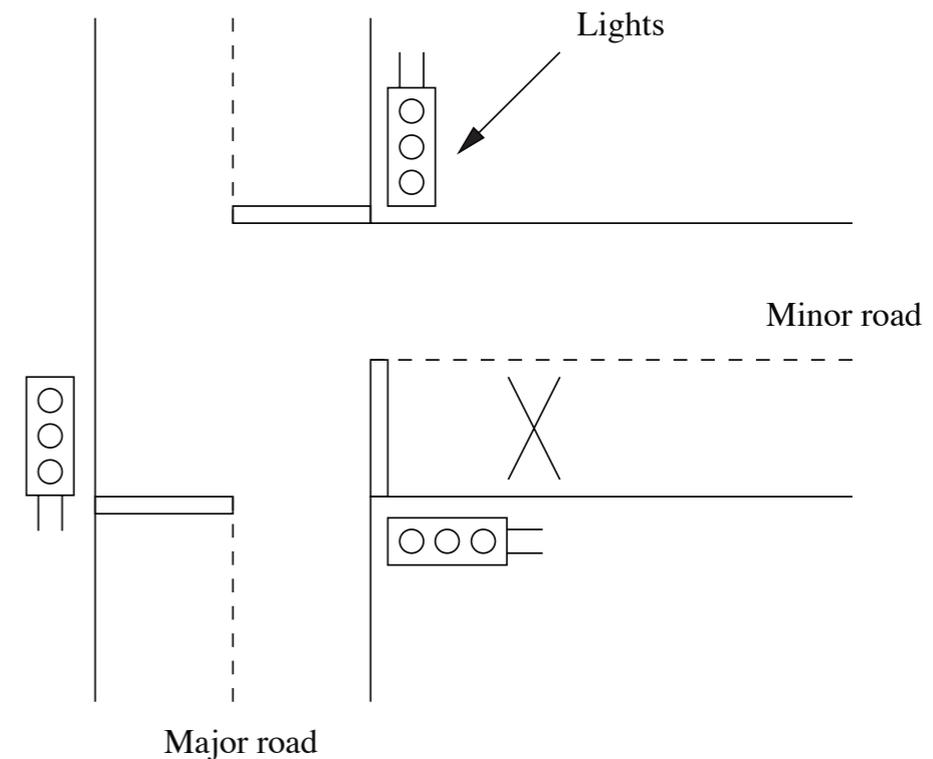
Reachability properties

- Minor road light can go green
- Major road light can go red
- ...

Safety properties

- No deadlock
- Not green at the same time
- ...

Liveness properties



Traffic Lights Intersection

Verification:

Reachability properties

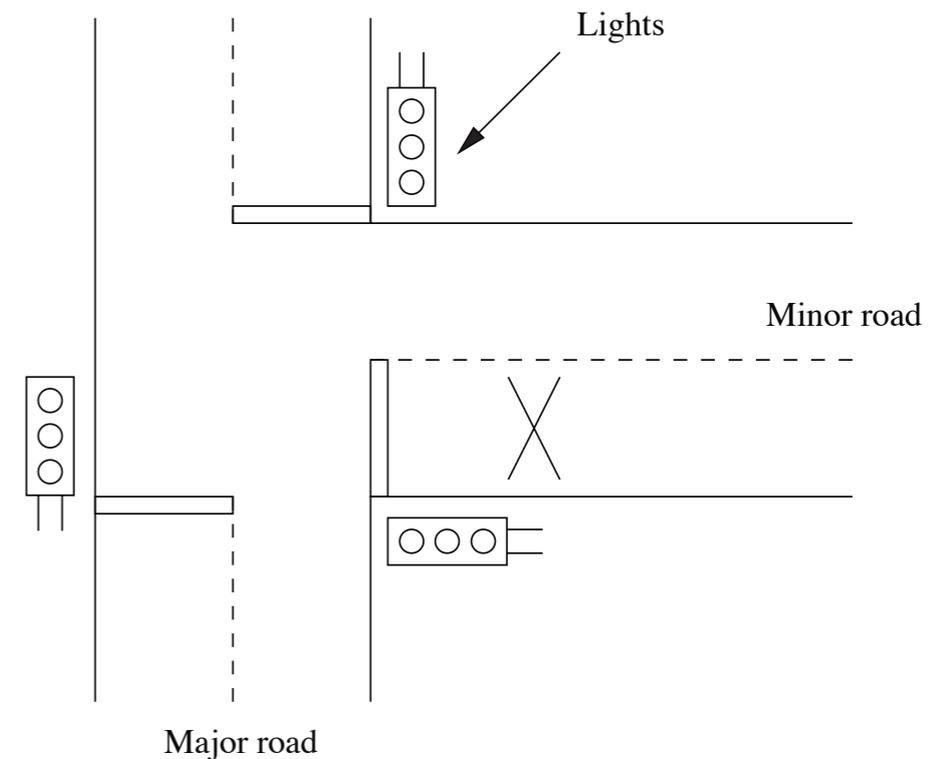
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Liveness properties

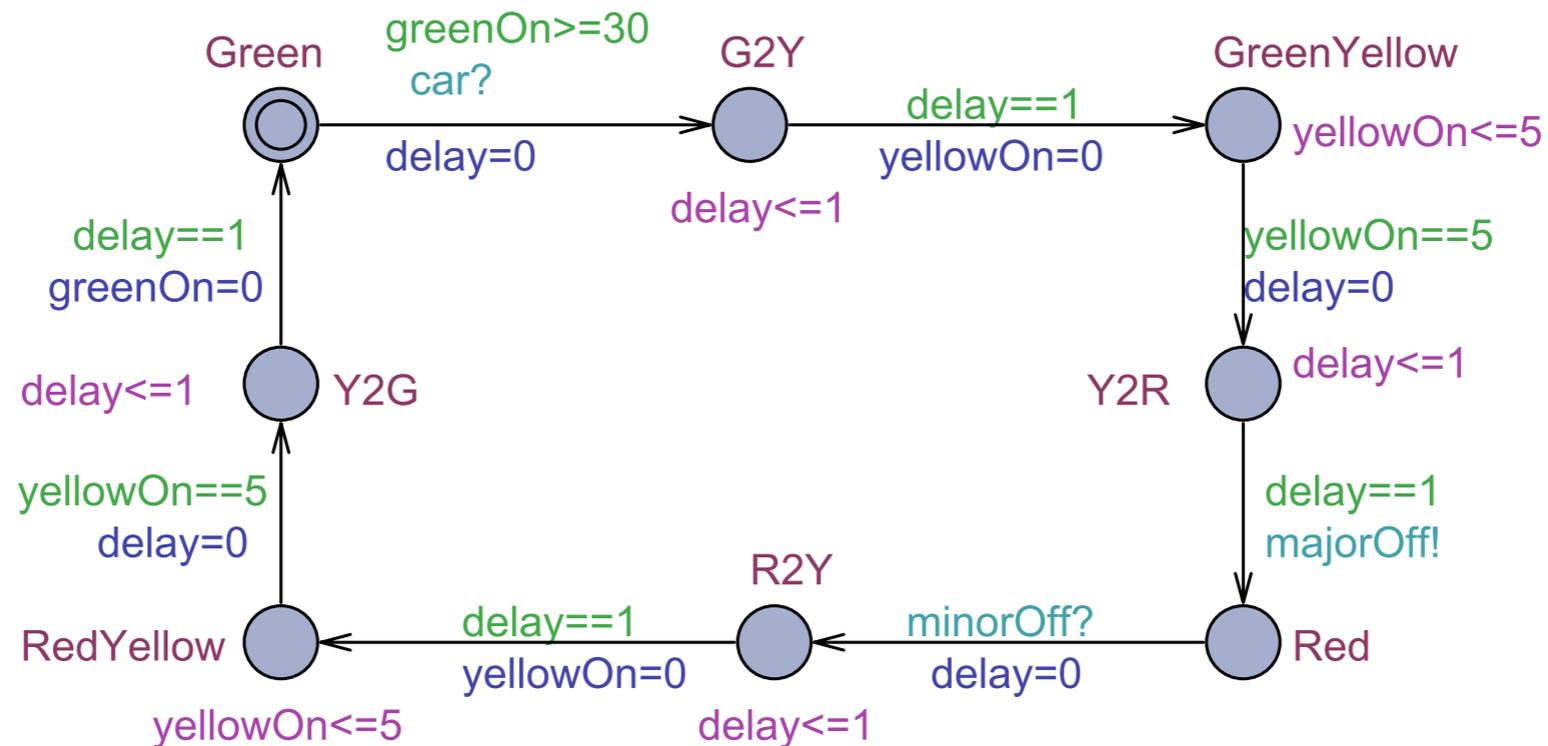
- If there are cars waiting they should get green light
- A car will not wait forever
- ...



Major Road Traffic Light

Local clocks:

- **greenOn** - time elapsed in green light mode
- **delay** - time elapsed between changing lights
- **yellowOn** - time elapsed in yellow light mode



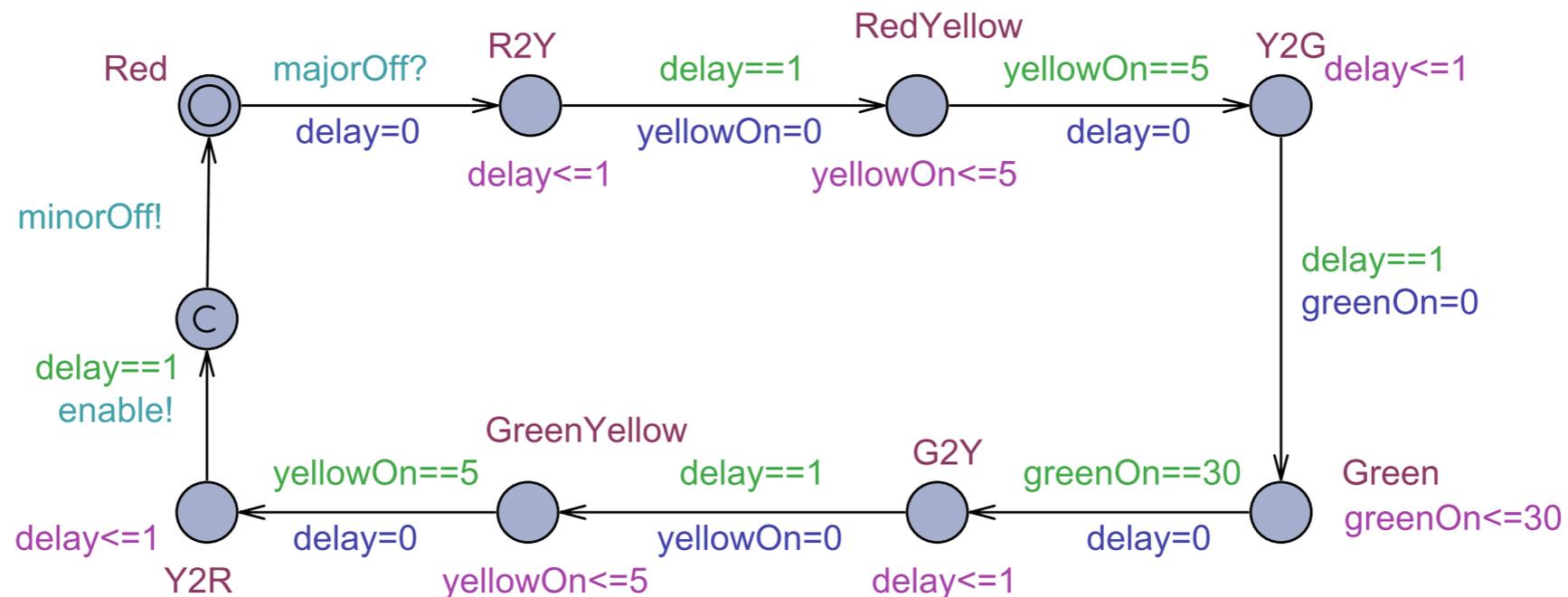
Synchronisation actions:

- **car** - syncs with sensor when a car appears
- **majorOff** - syncs with minor light to notify major is now in red light
- **minorOff** - syncs with minor light when the latter is back to red

Minor Road Traffic Light

Local clocks:

- **greenOn** - time elapsed in green light mode
- **delay** - time elapsed between changing lights
- **yellowOn** - time elapsed in yellow light mode



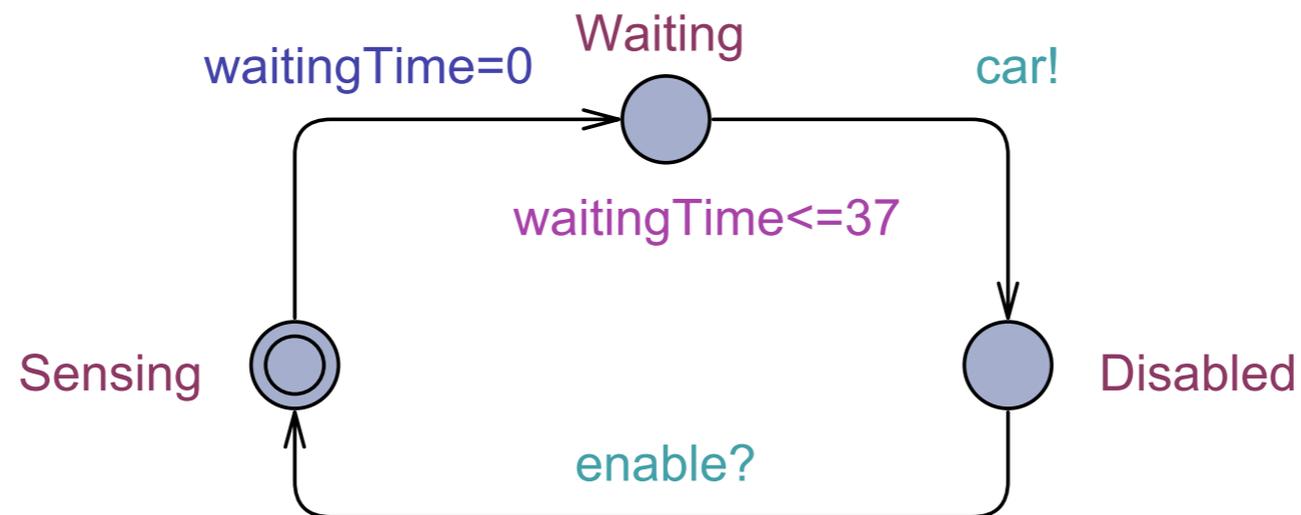
Synchronisation actions:

- **majorOff** - syncs with major light when major is in red light
- **minorOff** - syncs with major light to notify minor light is now back to red light
- **enable** - syncs with sensor to active it again when going back to red light

Sensor

Local clocks:

- **greenOn** - time elapsed in green light mode
- **delay** - time elapsed between changing lights
- **yellowOn** - time elapsed in yellow light mode



Synchronisation actions:

- **car** - syncs with major light to notify there is a car waiting
- **enable** - syncs minor light when it goes red again

Verifying some properties

Reachability

- `E<> Minor.Green // minor can go green`
- `E<> Major.Red // major can go red`

Liveness

- `Minor.Green -> Major.Green // if minor is green, always eventually major will be green again`
- `Sensor.Waiting -> Minor.Green // if there is a car waiting, always eventually minor will go green`

Deadlock freedom

- `A[] not deadlock`

Verifying some properties

Safety

- `A[] Sensor.Waiting imply Sensor.waitingTime<=37 // if a car is waiting it will do so for at most 37s before the lights start changing`
- `A[] Minor.Green imply Sensor.Disabled // whenever minor is green the sensor will be disabled`
- `A[] not (Minor.Red and Major.Red) // both lights can not be red at the same time`
- `A[] not (Minor.Green and Major.Green) // both lights can not be green at the same time`

To have in mind...

- We can model systems in different ways...
- ...for example, we could have assumed that traffic lights are managed by a centralised controller, and used the same template for both lights (different instantiations)

Useful Links

- **Uppaal:**
 - <http://www.uppaal.org/>
- **Uppaal Tutorial:**
 - <http://www.it.uu.se/research/group/darts/papers/texts/new-tutorial.pdf>
- **Some bibliography on TA:**
 - *A theory of timed automata* - Rajeev Alur and David L.Dill
 - *Principles of Model Checking* - Christel Baier and Joost-Pieter Katoen
 - *Timed Automata: Semantics, Algorithms and Tools* - Johan Bengtsson and Wang Yi

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