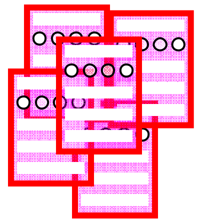
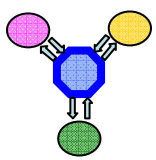
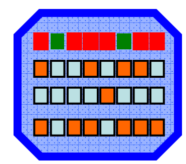


Signal Control
Concepts and software design





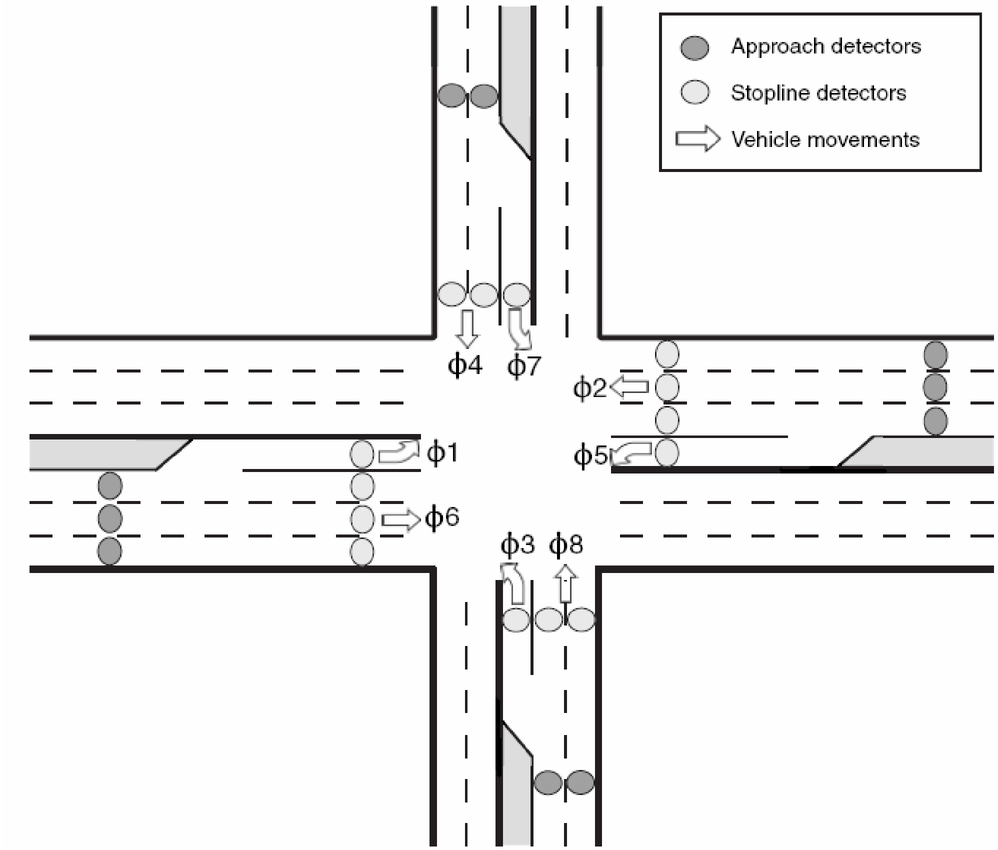
Overview

1. Terminology

2. Control algorithms
    - Pretimed
    - Actuated
    - Coordinated actuated
    - Traffic responsive
    - Adaptive

3. Software design
    - Signal Manager
    - Detector stations
    - Phases
    - Controllers

Terminology – Phases and detectors



Each ***vehicle movement*** has an associated ***phase number***

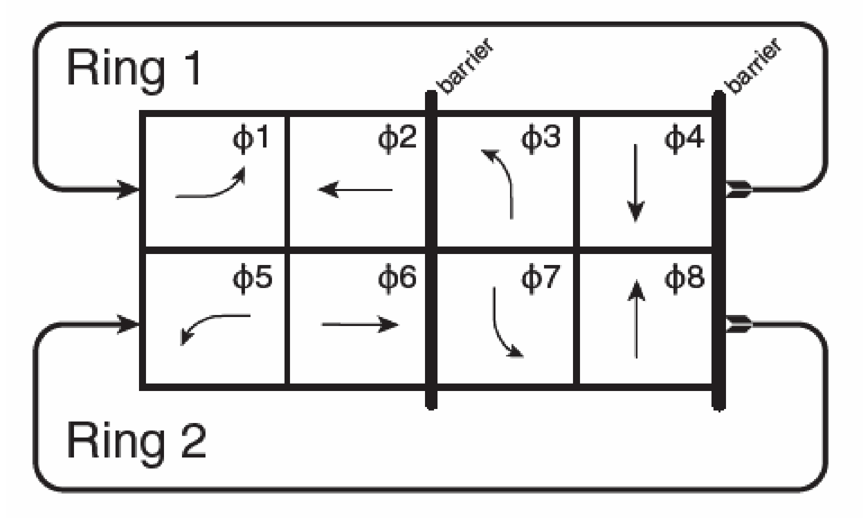
Left turns have ***odd phase numbers***

Through movements have even phase numbers ***even phase numbers***

Phases have ***approach detectors*** and/or ***stopline detectors***

Terminology – Compatible phases

The ***dual ring controller :***



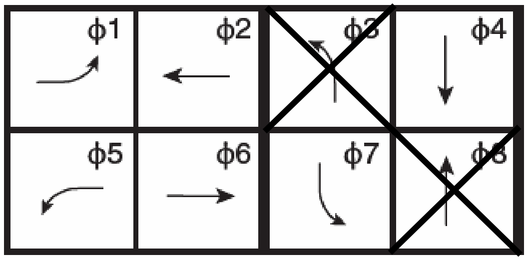
A pair of ***compatible*** phases, ***one from each ring,*** must be active at all times.

Compatible phases are on the same side of the barriers.

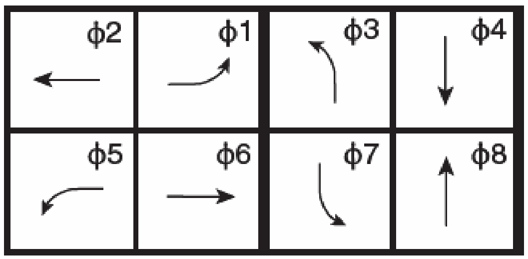
⇩

The two rings must cross the barriers simultaneously

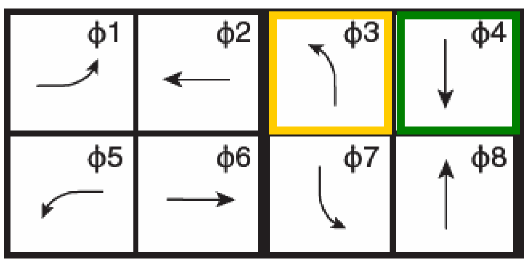
More Terminology



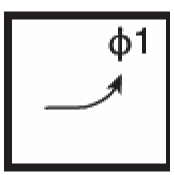
Phases 3 and 7 are not ***protected***



Phases 1 is a ***lagging left turn***



Phases 3 a ***permissive left turn***
if it can proceed when phase 4 is green



Each phase has timing parameters

Minimum green time
Maximum green time
Yellow time
Red clearance time

- Phases durations are preset
- Phases may be coordinated among intersections using ***offsets***
- Offsets usually optimized to maximize ***progression bands.***

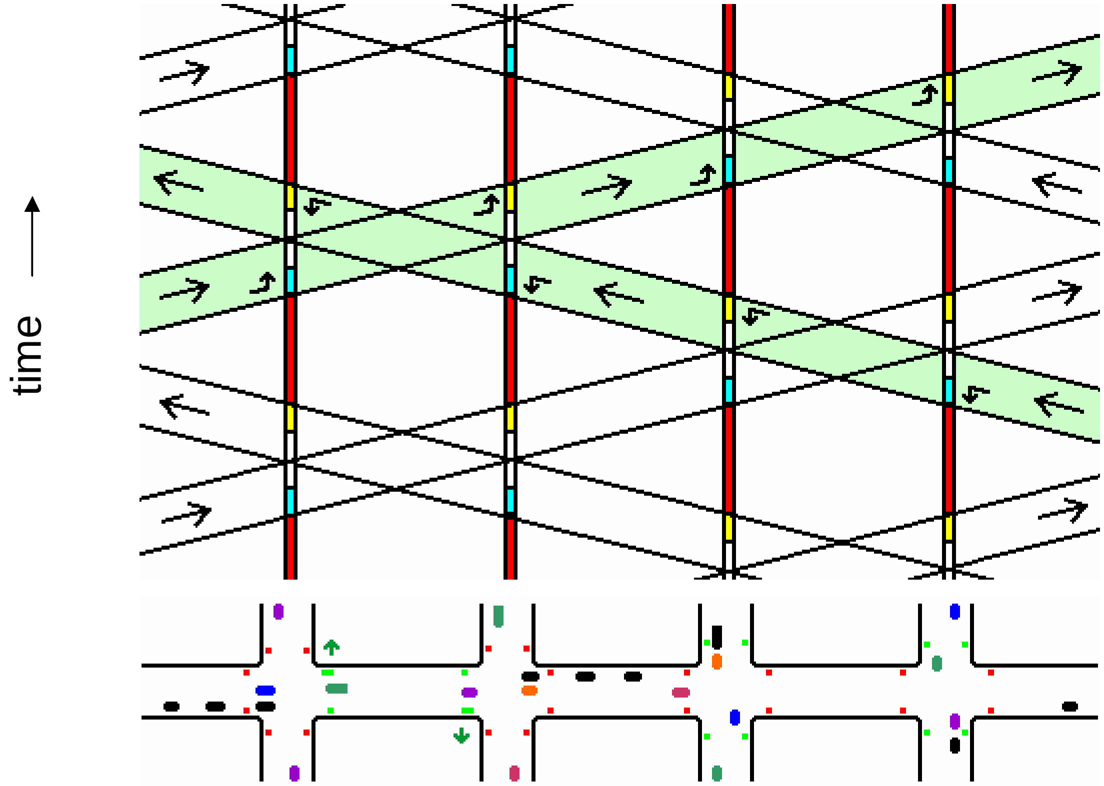
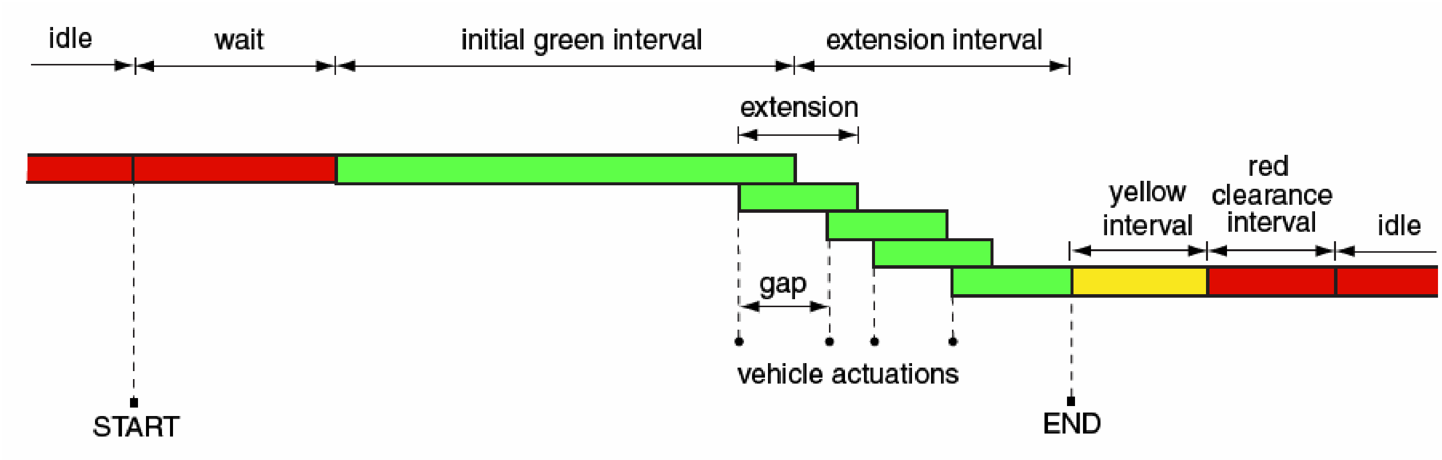


Image taken from http://www.geocities.com/midimagic@sbcglobal.net/progreso.htm

Actuated



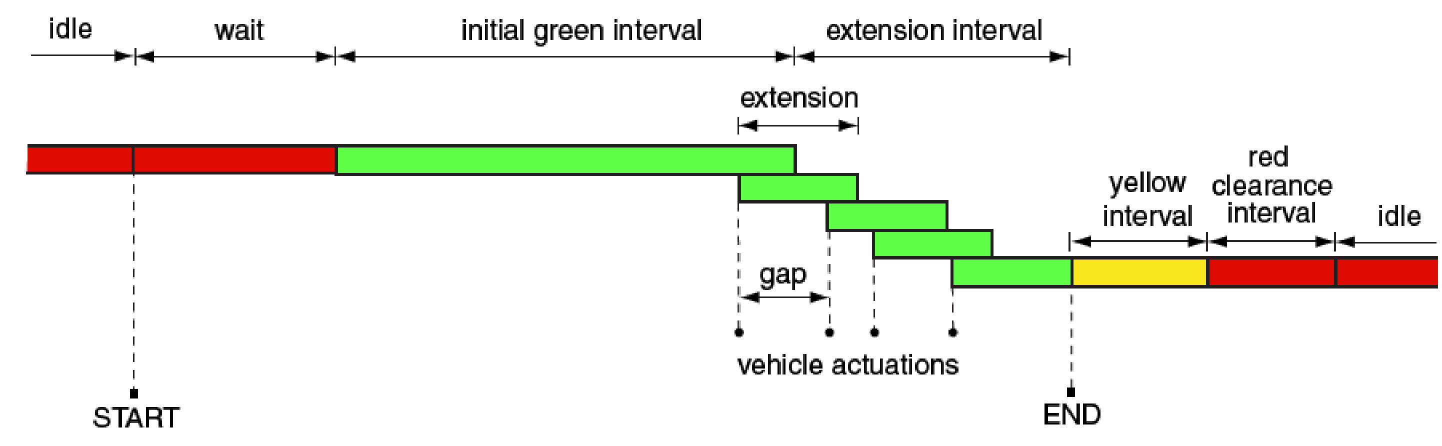
The duration of each phase can be modified based on traffic.

Initial green: An initial green time is calculated based on the number of vehicles waiting in the queue.

$$\text{initial green} = \min\left\{ \max\left\{ (\text{largest count}) \times \texttt{addpervehicle}, \texttt{mingreen} \right\}, \texttt{maxinitial} \right\}$$

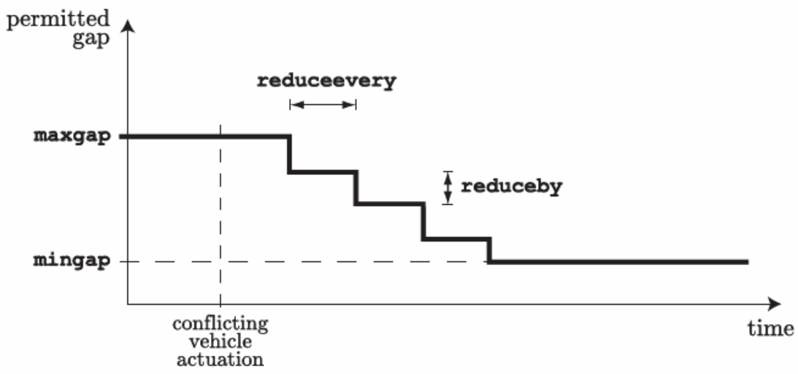
… on approach detectors since last green interval

parameters



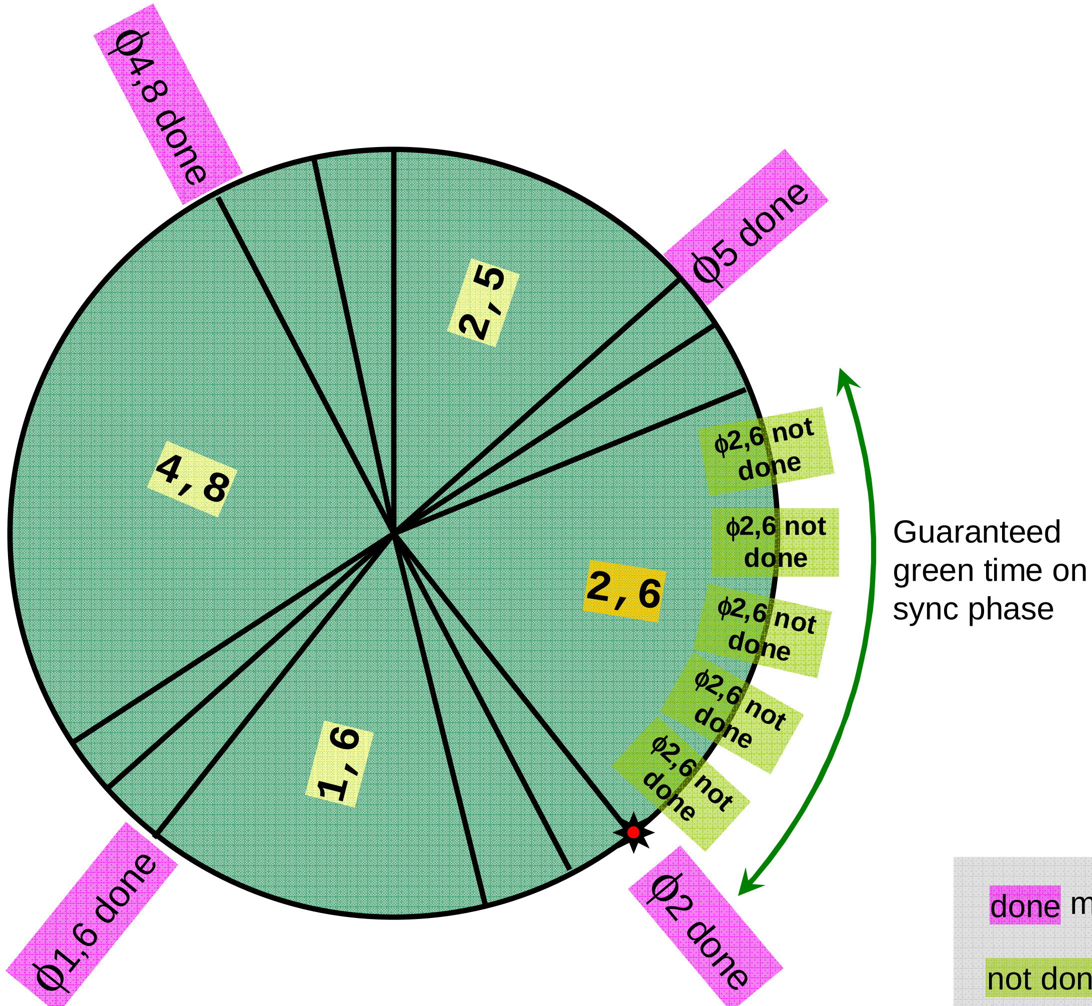
The duration of each phase can be modified depending on traffic.

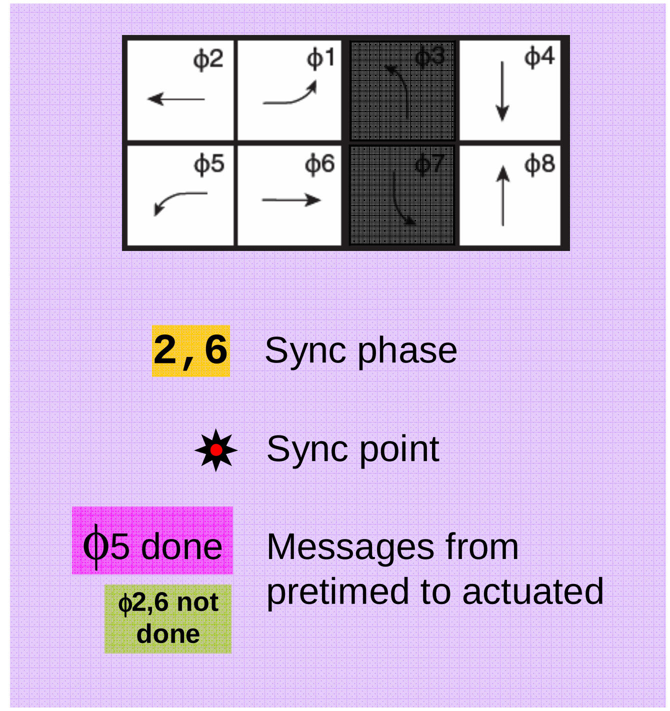
Extension: Extend green time by *extension* for each vehicle actuation on approach detectors, until the gap between vehicles exceeds the permitted gap, or the maximum green time is reached



Coordinated actuated

Combines ***pretimed*** and ***actuated*** control.





done messages are delivered at fixed times.

not done messages are delivered whenever sync phase is active, up to the sync point.

- The controller contains a library of ***pretimed plans.***

- Each plan p has a ***vpko signature:*** $\overline{\text{vpko}}(p,l) \qquad \forall \text{ loops } l$

- "vpko" is the loop "volume plus k times occupancy":

$$\text{vpko}(l) \;=\; \text{vol}^s(l) \;+\; \text{K} \times \text{occ}^s(l)$$

- The plan with whose signature is closest to the measured vpko is selected:

$$\Delta(p) \;=\; \sum_l \text{W}(l) \left| \text{vpko}(l) - \overline{\text{vpko}}(p,l) \right|$$

- To avoid excessive switching, the plan is only changed if the error of the current plan exceeds a threshold and the error of the prospective plan is less than another threshold.

Traffic responsive with Critical Intersection Control

- CIC is an add-on for traffic responsive control
- It is used at individual "critical intersections"
- Critical intersections must have approach detectors on all stages.

1. Compute the ***green demand*** for each loop.

ATSAC: $$\mathrm{gd}(l) \;=\; A\left(\mathrm{vol}^s(l)\right)^B \;+\; C\left(\mathrm{occ}^s(l)\right)^D$$

UTCS: $$\mathrm{gd}(l) \;=\; K_1\,\mathrm{occ}^s(l) \;+\; K_2\,\mathrm{vol}^s(l) \;+\; K_3\,\mathrm{vol}^s(l)\,\mathrm{occ}^s(l)$$

2. Compute the ***excess green demand*** for each stage.

$$\mathrm{gd}_e(s) \;=\; \max\left\{\;\max_l\left\{\,\mathrm{gd}(l)\,\right\} - \mathtt{mingreen}(s)\;;\;0\;\right\}$$

3. Apportion the ***available excess green*** to the stages

$$\mathrm{g}(s) \;=\; \frac{\mathrm{gd}_e(s)}{\sum \mathrm{gd}_e(s)} \times \mathrm{G}_e \;+\; \mathtt{mingreen}(s)$$

with $$\mathrm{G}_e \;=\; \mathtt{cyclelength} - \sum_s\left(\mathtt{mingreen}(s) + \mathtt{yellowtime}(s) + \mathtt{redcleartime}(s)\right)$$

Adaptive

- Adaptive signal control is a class of algorithms that are more sophisticated than others:

   1. They often involve internal models and optimization.
   2. They can adjust all of the timing parameters, including cycle lengths, split times, and stage sequences.

- Examples include

   - RHODES
   - ACS-Lite
   - TUC
   - SCOOT
   - SCATS
   - OPAC

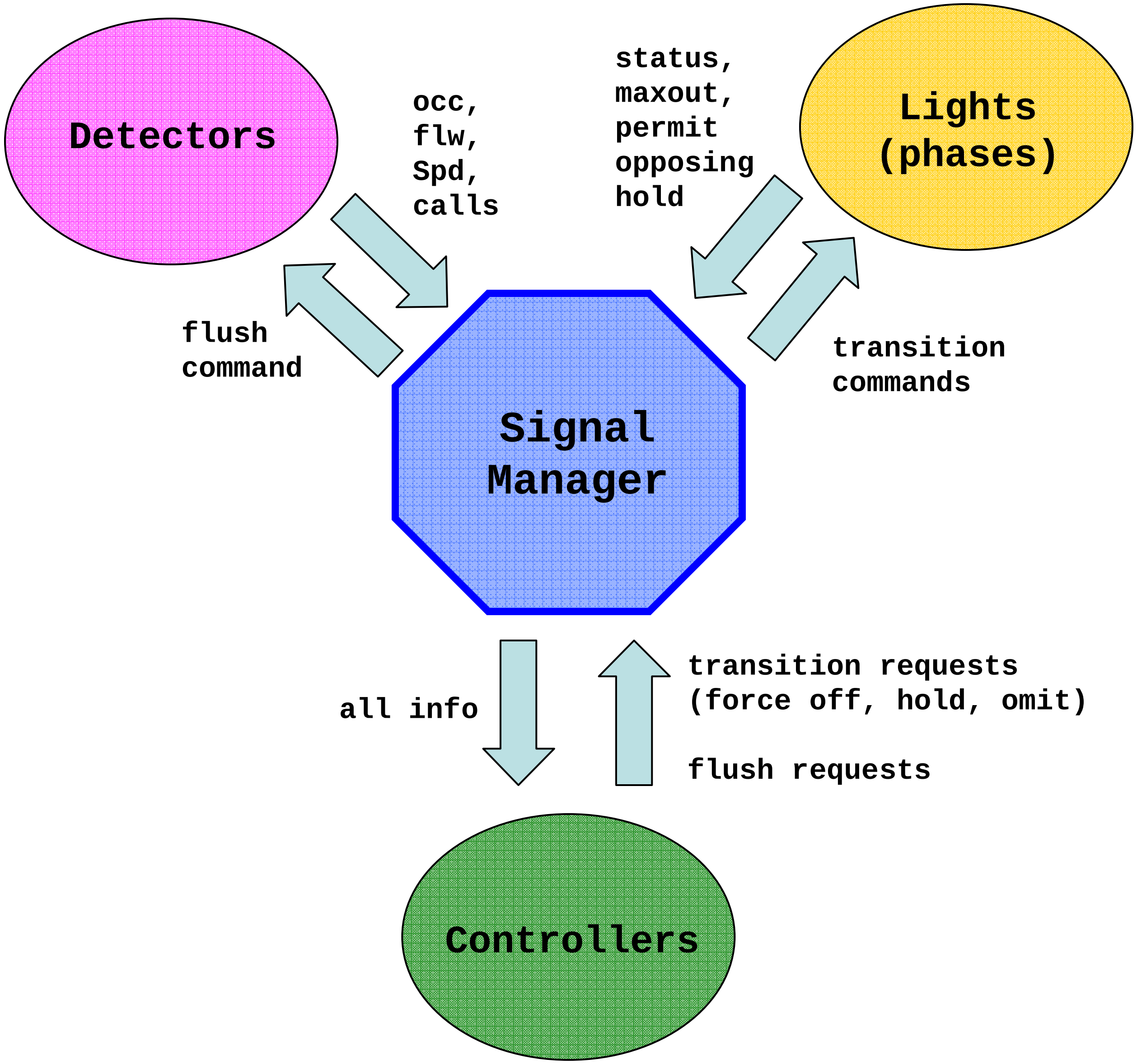
- Replicate the operation of an actual NEMA 170 or 2070 controller.
  - Signal control algorithms do not directly manipulate the signals.
  - They request status changes by issuing "force off", "hold", and "omit" messages.

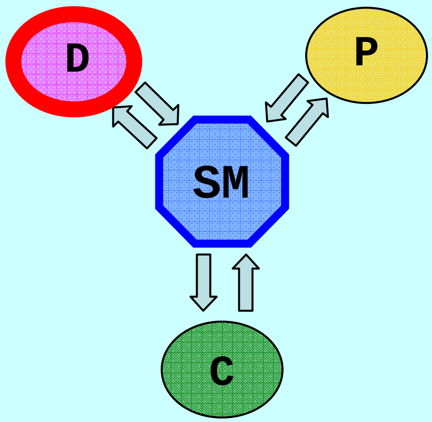
"Force off phase X" : terminate phase X as soon as possible and proceed to the next phase in the sequence.

"Hold phase X" : do not terminate phase X during the current time step.

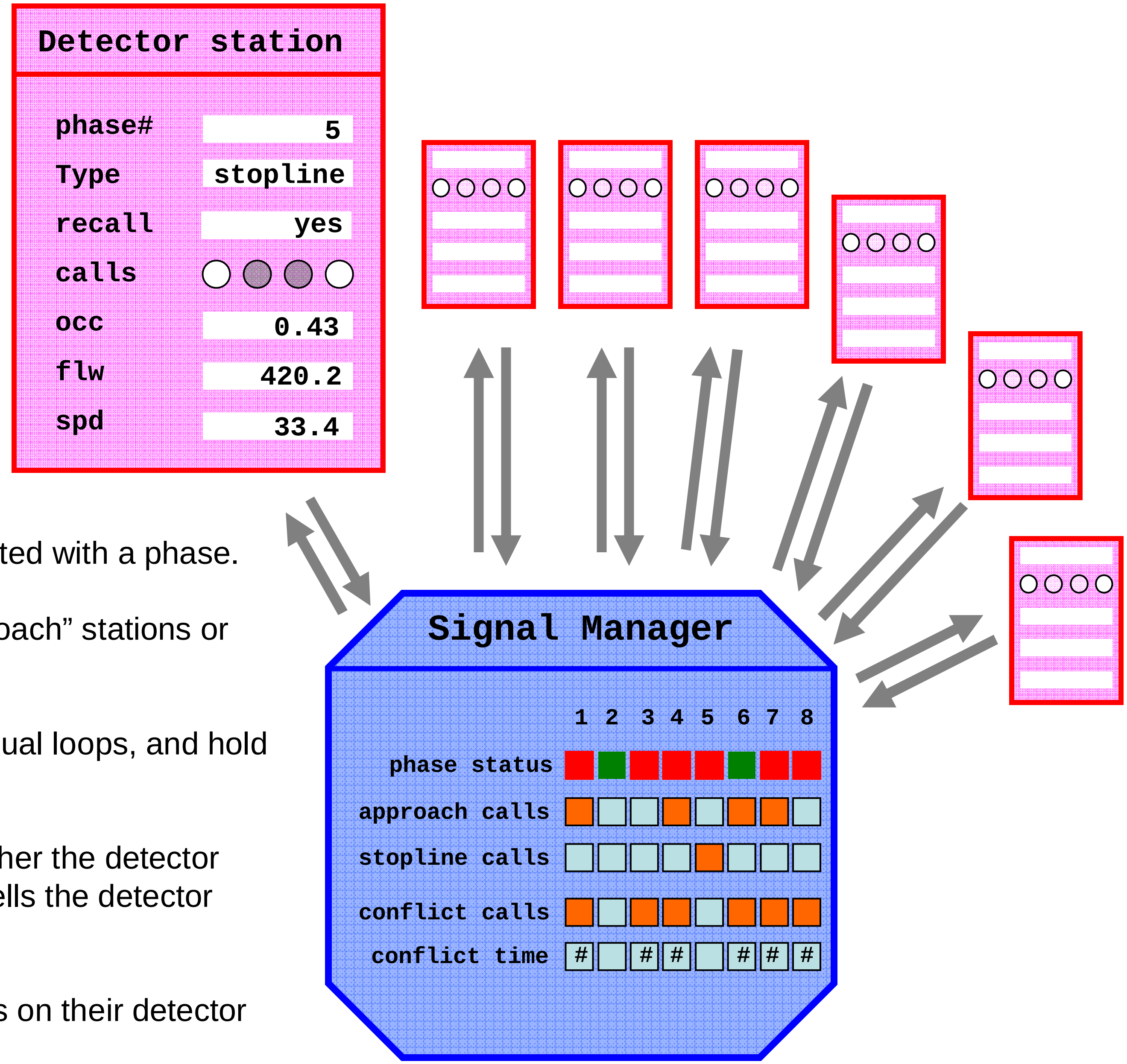
"Omit phase X" : Do not perform any transitions to X during the current time step. If a transition is due, then skip to the following phase, or if that is not possible, hold the current phase.

Software design – Signal Manager





Software design – Signal Manager - Detectors



Each detector station is associated with a phase.

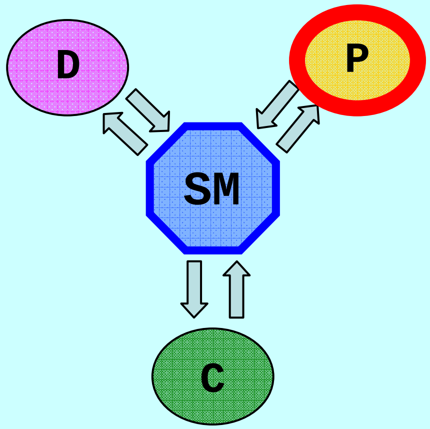
Detectors stations can be “approach” stations or “stopline” stations.

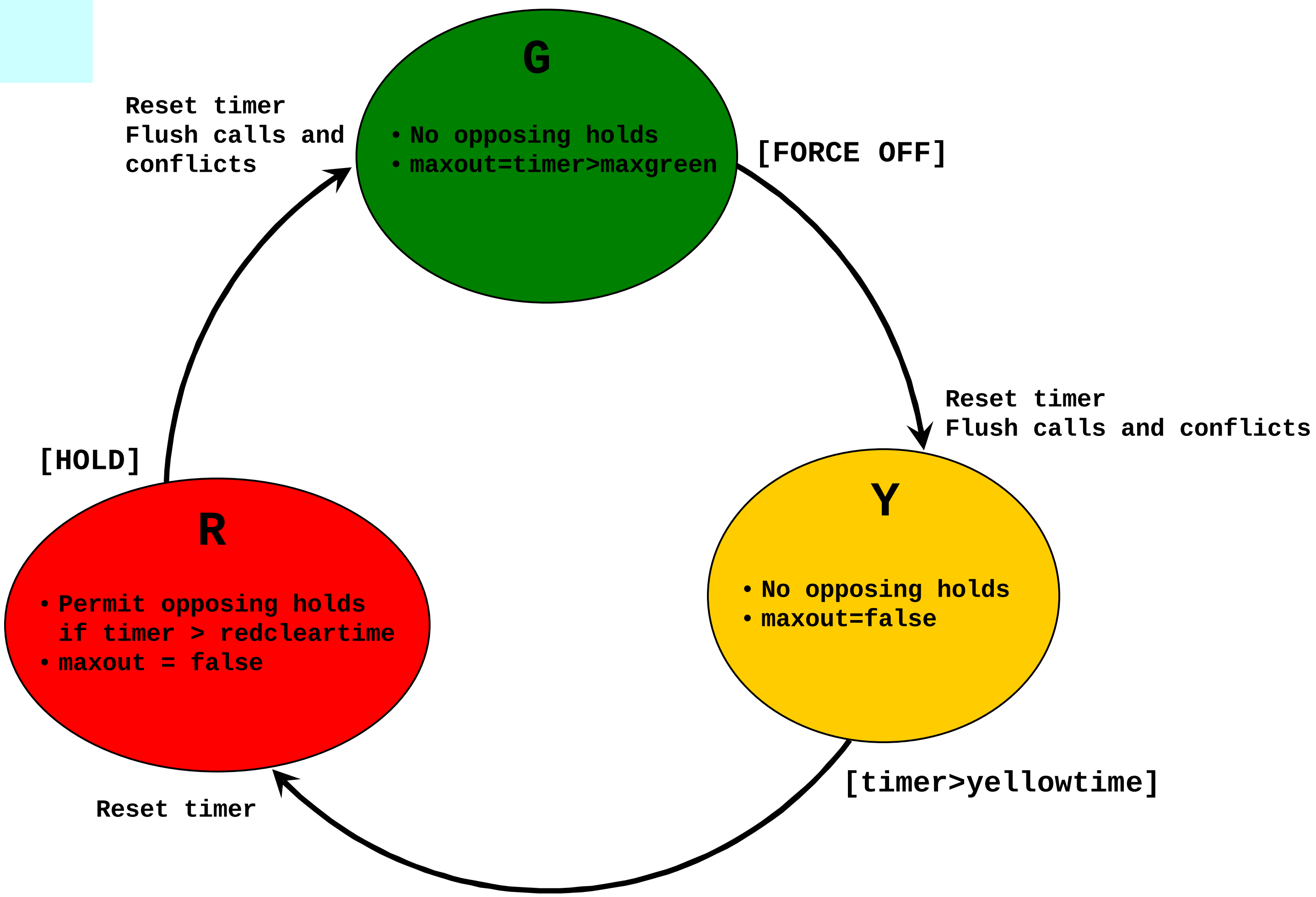
Detector stations contain individual loops, and hold aggregate measurements.

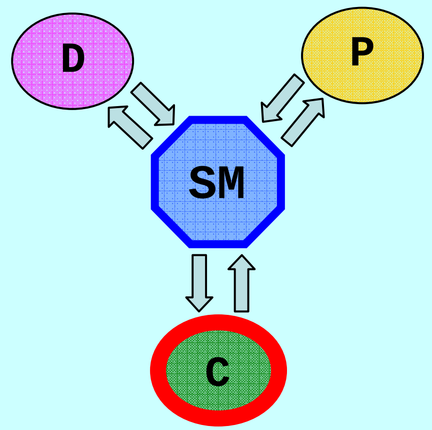
The signal manager reads whether the detector station has any calls, and tells the detector station to *flush* its calls.

Recall phases always have calls on their detector station.

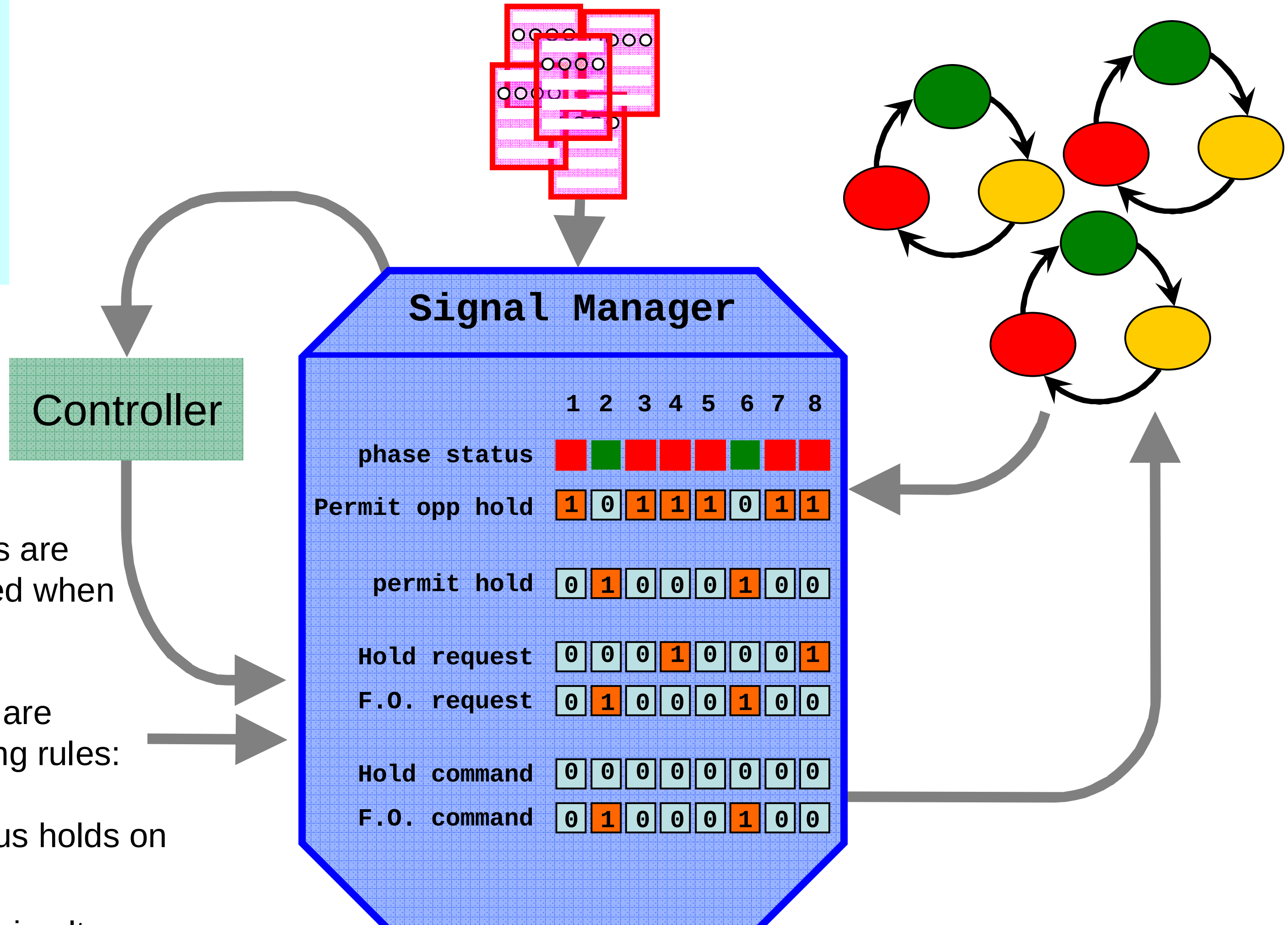
Software design – Signal Manager - Phases







Software design – Signal Manager - Controllers



Hold and force off requests are persistent. They are cleared when serviced by the phase.

Hold and force off request are processed with the following rules:

- Throw away simultaneous holds on conflicting phases.
- Throw away force off in simultaneous hold/force off pair.
- Do not relay unpermitted holds.
- Do not relay force off when timer< mingreen.

Conclusions

- Signal control for intersections is more complex than for freeway onramps.
- Signal control algorithms range in complexity from pretimed to black-box adaptive controllers.
- A simulation plugin for a blackbox controller (e.g. RHODES) must replicate the interface it expects.
- To my knowledge, the basic interface of the 170 and 2070 controllers is that of force-off, hold, and omit message passing.