General node models

CE 392D

OUTLINE

1. An overview of general intersections
2. Basic signals
3. Intersections with equal priority
4. Intersections with unequal priority
5. “Smoothed” intersections

GENERAL INTERSECTIONS

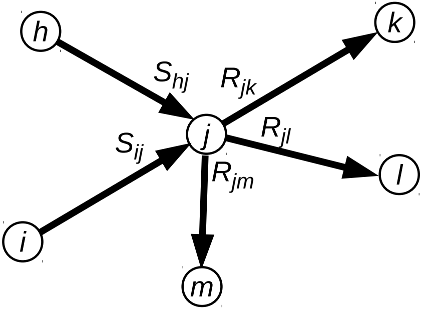
Recall: for two links i and j in series $q_{ij} = \min\{S_i, R_j\}$

What happens for a diverge?

What happens for a merge?

One way to think about congested merge models is “going back for more pizza.” If the receiving flow isn’t used up, unsatisfied approaches with queues get another shot at the remaining receiving flow

General intersection models have some of the flavor of merges, and some of the flavor of diverges.



Like a diverge, the most restricted turning movement from each approach determines the flow to all of its movements. Like a merge, approaches competing for restricted receiving flow divide according to fixed proportions.

There are many approaches to models for general intersections:

- Model signal phases *explicitly* as diverges.
- Model "average delays" and "average capacities"
- Model turn-taking behavior.
- Introduce gap acceptance concepts.

These slides describe a few models for general intersections; there are others too.

BASIC SIGNALS

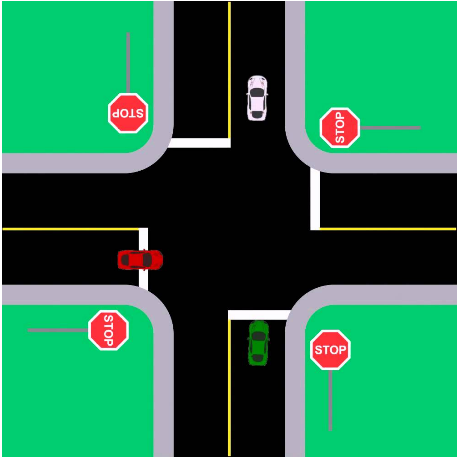
A “basic” signal has the following properties:

- All turns are protected (no simultaneously-allowed movements ever conflict)
- All turning movements from the same approach move simultaneously

Such signals can be treated as a “rotating” diverge. At each time step, whichever approach has a green indication is treated as a diverge, all other flows are set to zero.

EQUAL PRIORITY

Imagine an intersection with an all-way stop. No movement has priority over any other, but they interact with each other and compete for space at the downstream link.



Some additional definitions

The *oriented capacity* of turning movement $[h, i, j]$ is $q_{max}^{hij} = q_{max}^{hi} p_{hij}$. (This will determine the proportions of turning movement flows when receiving flow is limited.)

The *oriented sending flow* of turning movement $[h, i, j]$ is $S_{hij} = S_{hi} p_{hij}$.

Like a merge, for each outgoing link (i, j), we will require

$$\frac{y_{hij}}{y_{h'ij}} = \frac{q_{max}^{hij}}{q_{max}^{h'ij}}$$

for each turning approach whose oriented sending flow is enough to meet this allocation. (Otherwise, think "leftover pizza.")

Like a diverge, for each approach (h, i) we will require

$$\frac{y_{hij}}{y_{hij'}} = \frac{S_{hij}}{S_{hij'}} = \frac{p_{hij}}{p_{hij'}}$$

Each turning movement is either *demand-constrained* (all of its sending flow can move) or *supply-constrained* by a downstream link (whose receiving flow is fully used).

There is an algorithm for determining y values which are consistent with these conditions.

This algorithm makes use of additional variables:

$\tilde{S}_{hij}$ and $\tilde{R}_{ij}$ are the remaining sending flow for $[h, i, j]$ and receiving flow for (i, j). (They start at S_{hij} and R_{ij} and decrease as we assign flow.)

A is the set of active turning movements (once we know whether a turning movement is demand- or supply-constrained, it becomes inactive.)

α_{hij} is the rate at which we will add flow to y_{hij} at a given step of the algorithm. (*For approaches which are "linked" by merge/diverge conditions, these must obey the proportions on the prevoius slide. For "independent" approaches, they can be chosen arbitrarily.*)

Intuition: start with zero flows everywhere; increase flows by α until some movement either becomes demand- or supply-constrained. Make it inactive, calculate new α values, and repeat.

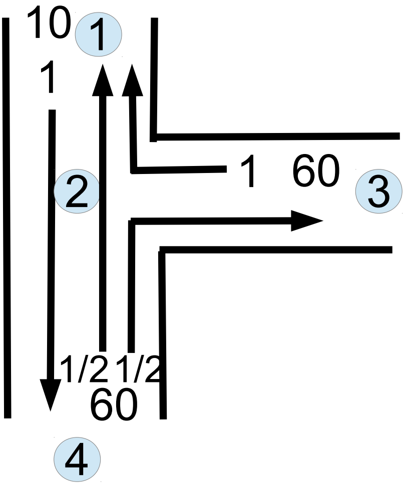
Algorithm

1. Calculate oriented capacity and sending flow; initialize $y_{hij} \leftarrow 0$, $\tilde{S}_{hij} \leftarrow S_{hij}$, $\tilde{R}_{ij} \leftarrow R_{ij}$; put all turning movements with positive sending flow in A.
2. Identify α_{hij} rates consistent with merge/diverge conditions.
3. Identify the total inflow rate for each outgoing link: $\alpha_{ij} = \sum_{[h,i,j] \in A} \alpha_{hij}$.
4. Identify how much flow we can send at this rate:

$$\theta = \min \left\{ \min_{[h,i,j] \in A} \left\{ \frac{\tilde{S}_{hij}}{\alpha_{hij}} \right\}, \min_{(i,j) \in \Gamma(i) : \alpha_{ij} > 0} \left\{ \frac{\tilde{R}_{ij}}{\alpha_{ij}} \right\} \right\}$$

5. Increase flows: $y_{hij} \leftarrow y_{hij} + \theta \alpha_{hij}$, $\tilde{S}_{hij} \leftarrow \tilde{S}_{hij} - \theta \alpha_{hij}$, $\tilde{R}_{ij} - \theta \alpha_{hij}$
6. Remove inactive turning movements from A (those for which $\tilde{S}_{hij} = 0$, or $\tilde{R}_{ij'} = 0$ for *any* used outgoing link (i, j)).
7. If A is empty, stop. Otherwise, return to step 3.

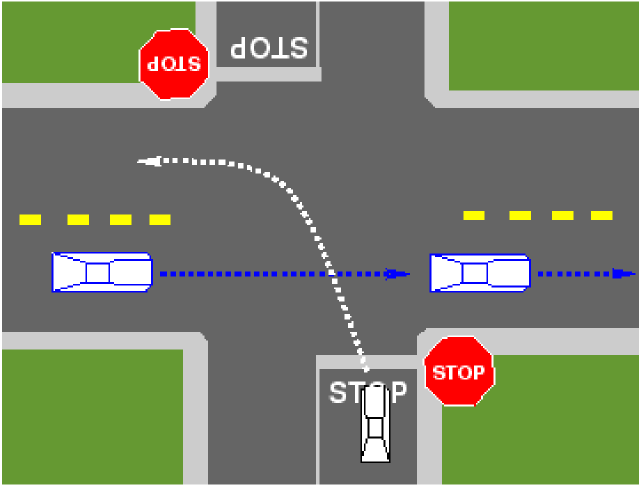
Example



Sending flows and turning proportions shown. All links have a capacity of 60.

UNEQUAL PRIORITY

If there are conflicting movements which can (potentially) move simultaneously, priority rules govern who has to yield to whom.



This introduces additional complications.

For these intersections, define a set of conflict points C.

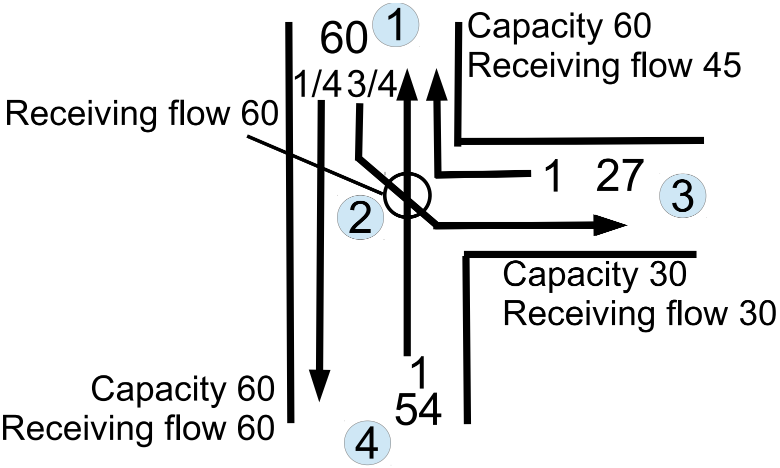
For each conflict point c, let $\Xi(c)$ denote the turning movements which use point c, and R_c the maximum number of vehicles which can pass through the conflict point in one time step.

To define priorities, let β^c_{hij} denote the (relative) priority of movement (h, i, j) at conflict point c. (If R_c is constraining, the "fair share" for the competing approaches follows the ratio of the β values multiplied by S_{hij}, as with oriented capacity.)

The "equal priority" algorithm is modified in the following ways:

- Turning movements can either be demand-constrained, supply-constrained by a downstream link, or supply-constrained by a conflict point.
- Let $\tilde{R}_c$ be the remaining receiving flow for conflict point c.
- The α values must now be chosen to respect $\alpha_{hij}/\alpha_{h'ij'} = \beta_{hij}S_{hij}/\beta_{h'ij'}S_{h'ij'}$
- θ must consider constraints from conflict points (the ratio of $\tilde{R}_c$ and α_c).
- A turning movement becomes inactive if $\tilde{S}_{hij} = 0$, $\tilde{R}_{ij'} = 0$, or if $\tilde{R}_c = 0$ for any conflict point used by a movement from (h, i).

Example



Sending flows and turning proportions shown. Links (2,4) and (2,3) have receiving flow of 60; link (2,1) has receiving flow of 45. $\beta_{421}/\beta 123 = 5$.

SMOOTHED INTERSECTIONS

An alternative approach... instead of trying to simulate the intersection dynamics at each time step, can we replace the node model with formulas representing the "average" impact on vehicles.

- Yperman describes one such approach which only requires calculation of capacities and delays for each turning movement (HCM, ...)
- Vehicles do not make route choices based on short-term node fluctuations, do we need to model nodes with such high detail?