Queuing under perimeter control: analysis and control strategy

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Perimeter control

What is it?
Perimeter control

What is it?
Perimeter control

What is new? What has changed?
NFD-based Perimeter Control

A new opportunity
Perimeter Control

What is wrong with that?
Feedback NFD-based Perimeter Control

Feedback regulator

\[ q_g(k) = q_g(k - 1) - K_P [TTS(k) - TTS(k - 1)] + K_I [\hat{TTS} - TTS(k)] \]
Feedback NFD-based Perimeter Control

Flow distribution

\[ \sum_{i=1}^{n} q_i = q_g \quad q_{\text{min},i} \leq q_i \leq q_{\text{max},i} \]
Queue management

The queue model

\[ N_i(k + 1) = N_i(k) + T[d_i(k) - q_i(k)] \]

or

\[ N_i(k + 1) = A_i(k) - B_i(k)q_i(k) \]

with

\[ A_i(k) = N_i(k) + Td_i(k) \] and \[ B_i(k) = T \]
Queue management

Queue balancing

\[
\min \sum_{i=1}^{n} \left( \frac{A_i(k) - B_i(k)q_i(k)}{N_{\text{max},i}} \right)^2
\]

s.t.:

\[
\sum_{i=1}^{n} q_i = q_g
\]

\[
q_{\text{min},i} \leq q_i \leq q_{\text{max},i}
\]
Simulation results
City center of Chania, Greece
Simulation results

Protected network and gated links

≈ 80 junctions — 27 with traffic lights and 165 links.
Simulation results

Scenarios

NPC - *no-perimeter-control*
Fixed-time traffic control

PC - *perimeter control without queue balancing*
Feedback perimeter traffic flow control with the flow distribution based on links’ saturation flows

PCQ - *perimeter control with queue balancing*
Feedback perimeter traffic flow control with the flow distribution from the solution of the relative queue balancing problem
Simulation results

Simulation and control setup

\[
\hat{TTS} = 600 \text{ veh} \cdot \text{h/h}, \ K_P = 20 \text{ h}^{-1} \text{ and } K_I = 5 \text{ h}^{-1}, \ T = 90 \text{ s}
\]
Simulation results

Network performance

![Box plot showing delay (s/km) for different scenarios: NPC, PC, PCQ. The box plot compares the performance of these scenarios with PCQ performing the best.](image-url)
Simulation results

Analysis of the NFDs
Simulation results

Analysis of relative queues

NPC

PC

PCQ

- PC does not necessarily lead to larger queues than in the NPC case
- Throughput is higher with PC!
Simulation results
Analysis of relative queues (PCQ)

All links
Gated link 3
Gated link 7
Simulation results

Analysis of delays

![Graph showing simulation results with delays in s/km against time in hours. The graph includes multiple lines representing different scenarios or simulations labeled as 1 to 8. The y-axis is labeled 'Delay (s/km)' and the x-axis is labeled 'Time (h)' with values ranging from 0 to 4 hours. There is a legend indicating the lines correspond to different scenarios or simulations. The graph is labeled as 'PCQ'.]
Final remarks

- Higher throughput with PC and PCQ: smaller queues than with NPC
  - Less interference at upstream junctions

- Unbalanced queues caused by localized congestion
  - Avoid localized congestion within the PN by the use of traffic control
  - PCQ + adaptive traffic control!

- Unbalanced delays (fairness)
  - Delay balancing
Acknowledgement
THANK YOU!

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