Řízení provozu na světelné křižovatce

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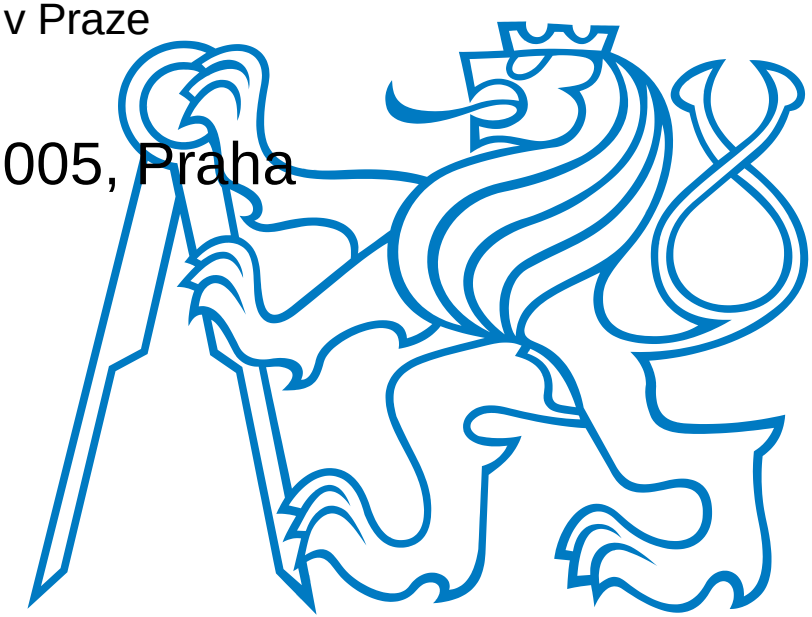
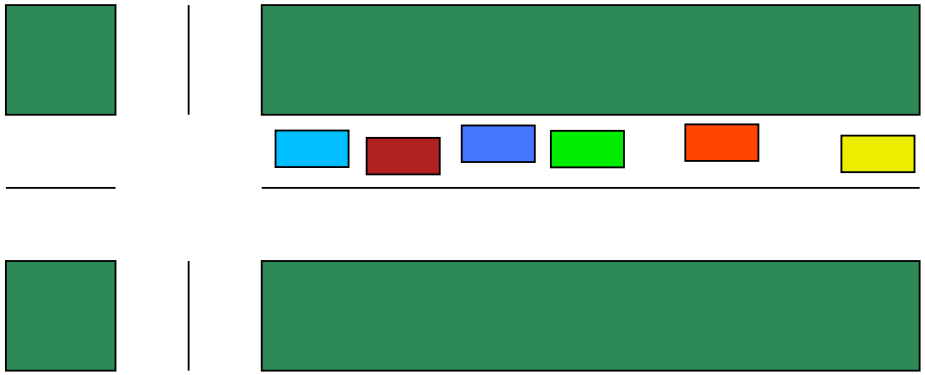


Outline

Queue Modeling

- Commonly used queue model:
  - Only the queue length is used

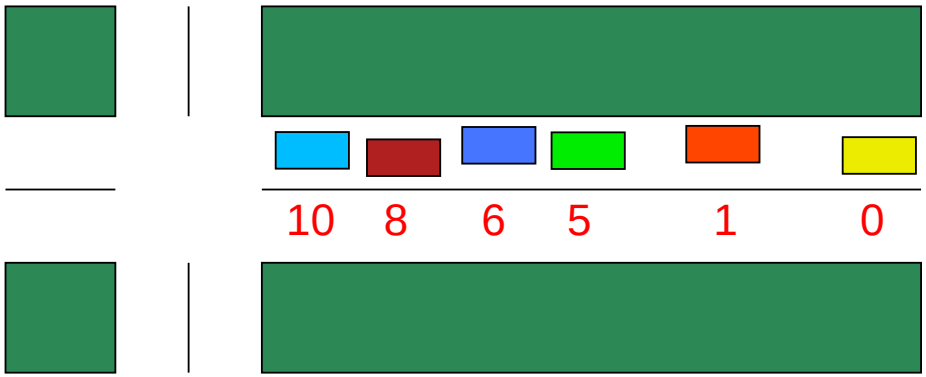


Queue length = 6

  - Model does not include information about the queue dynamics

Queue Modeling

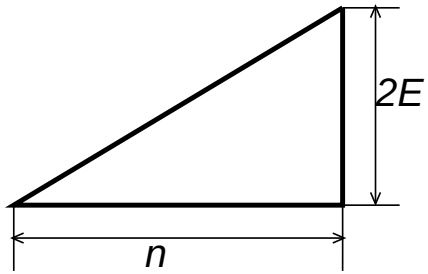
- Commonly used queue model:
  - Only the queue length is used



  - Model does not include information about the queue dynamics
- New model with dynamics information:
  - Waiting time for all cars
  - Theoretically infinite state space
  - Necessary to use queue estimation
  - Basic dynamic model is also used by *(Homolová J., Nagy, I., 2005)*

New Queue Modeling

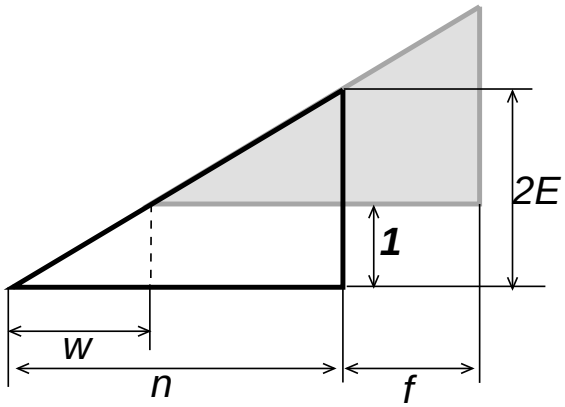
- Flow model:



E - mean value of waiting time
n - queue length

New Queue Modeling

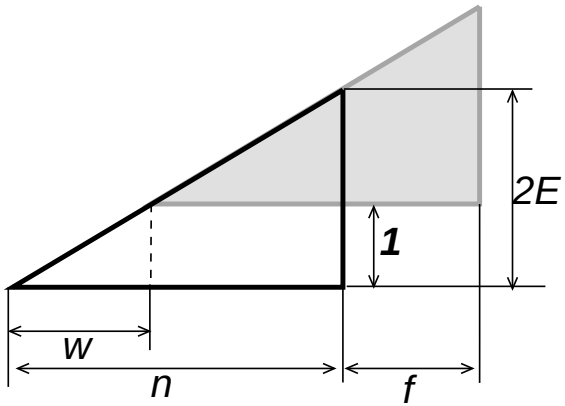
- Flow model:



E	-	mean value of waiting time
n	-	queue length
w	-	incoming traffic
f	-	outgoing flow

New Queue Modeling

- Flow model:



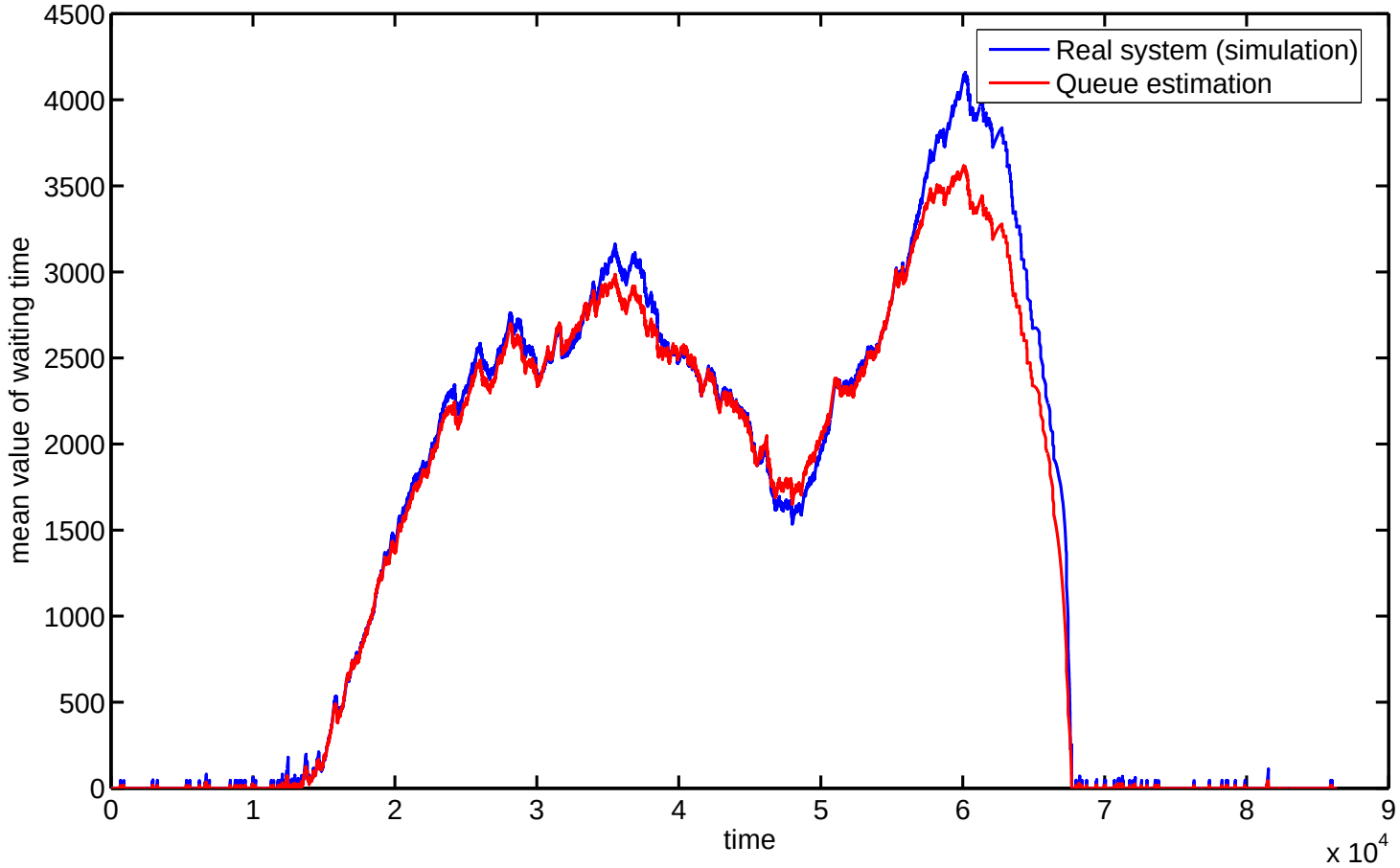
E	-	mean value of waiting time
n	-	queue length
w	-	incoming traffic
f	-	outgoing flow

$$n(k+1) = n(k) + w(k) - f(k)$$

$$E(k+1) = \frac{\frac{E(k)(n(k)-f(k))^2}{n(k)} + n(k) - f(k) + \frac{w(k)}{2}}{n(k) - f(k) + w(k)}$$

- Inspiration from: *(Henriksson, D., Abdelzaher, T., Lu, Y., 2004)*

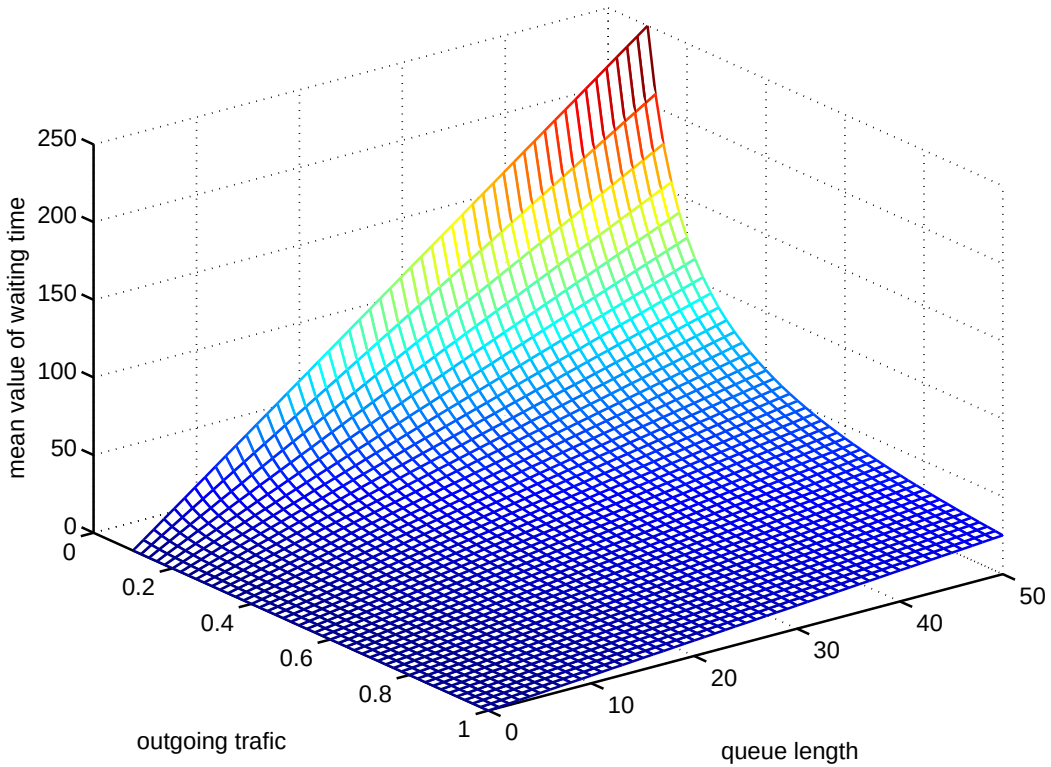
New Queue Model Verification



Equilibrium

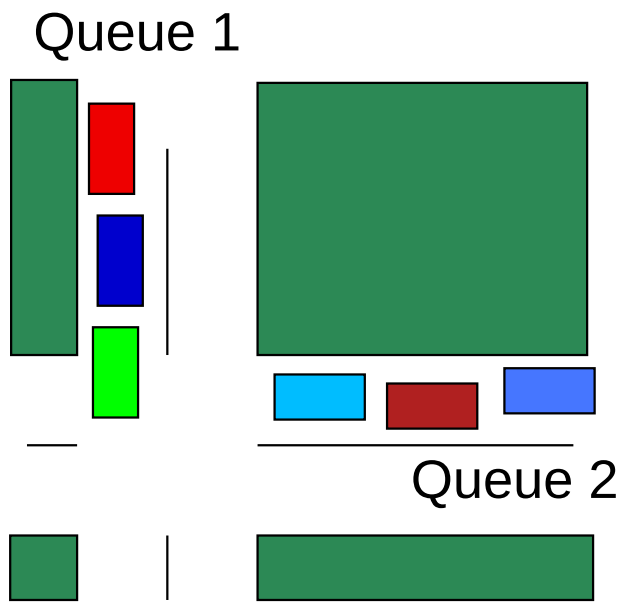
Equilibrium condition:

1. $f^\circ = w^\circ$
2. $E^\circ = 1/2 \dfrac{(2n^\circ - f^\circ)n^\circ}{2f^\circ n^\circ - f^{\circ 2}}$



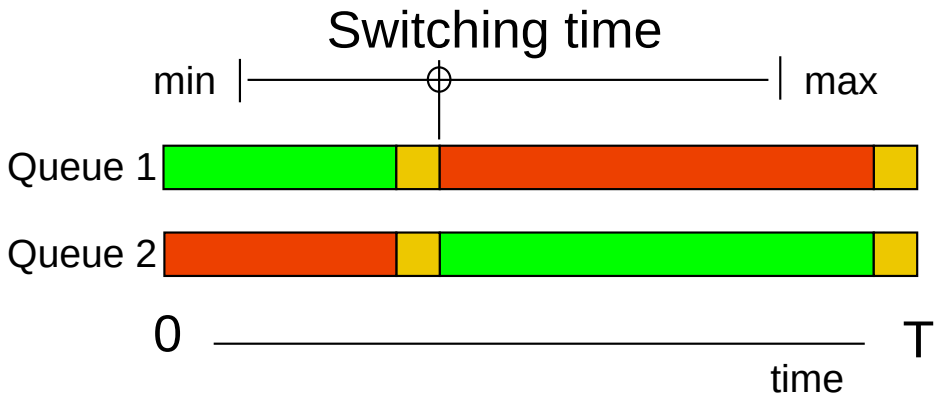
Intersection Model

- Crossroad model with two queues
- Parallel interconnection of queues
- Multiple input system
- Prepared for hybrid controller with safety time



Anti-collision Queue Control

- One period on the crossroad:
  - Safe time (orange box) = 0
  - Min = 0; Max = T



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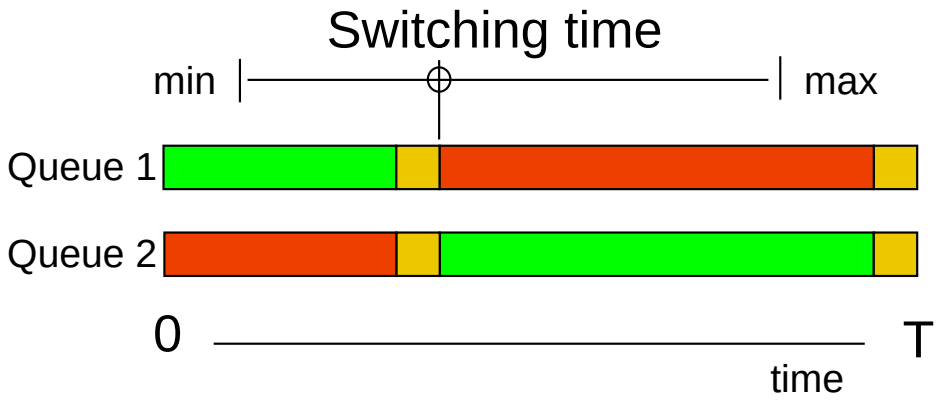
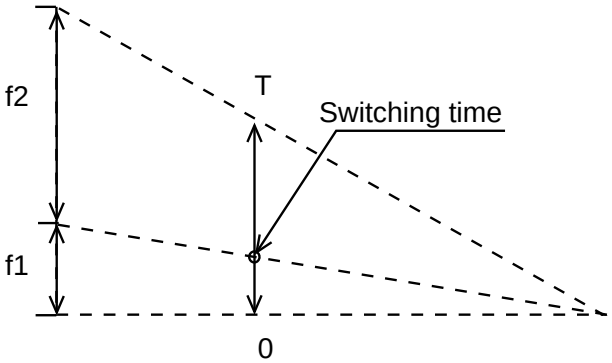


- Switching time computing:



- f1 - required outgoing flow for 1. queue
- f2 - required outgoing flow for 2. queue

State Space and Linearization

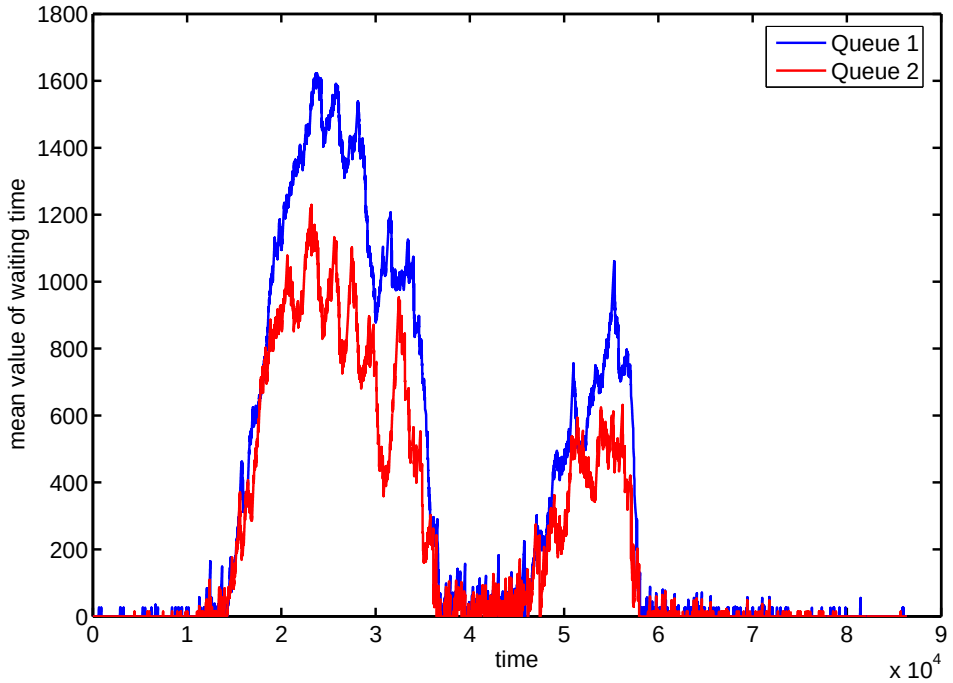
- State vector: $\mathbf{x} = (n_1, E_1, n_2, E_2)'$
- Input vector: $\mathbf{u} = (u_1, u_2)'$
- Input disturbance vector: $\mathbf{w} = (w_1, w_1)'$
- State variables:

$$\mathbf{A} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.050 & 0.997 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0.020 & 0.998 \end{bmatrix} \mathbf{B} = \begin{bmatrix} -1 & 0 \\ -17 & 0 \\ 0 & -1 \\ 0 & -11 \end{bmatrix} \mathbf{B_w} = \begin{bmatrix} 1 & 0 \\ -17 & 0 \\ 0 & 1 \\ 0 & -11 \end{bmatrix}$$

- Linearization at point:
  - $f_1^\circ\ (w_1^\circ) = 0.03; f_2^\circ\ (w_1^\circ) = 0.045$
  - $n_1^\circ\ = 20; n_2^\circ\ = 50;$
  - $E_1^\circ\ = 333; E_2^\circ\ = 555$

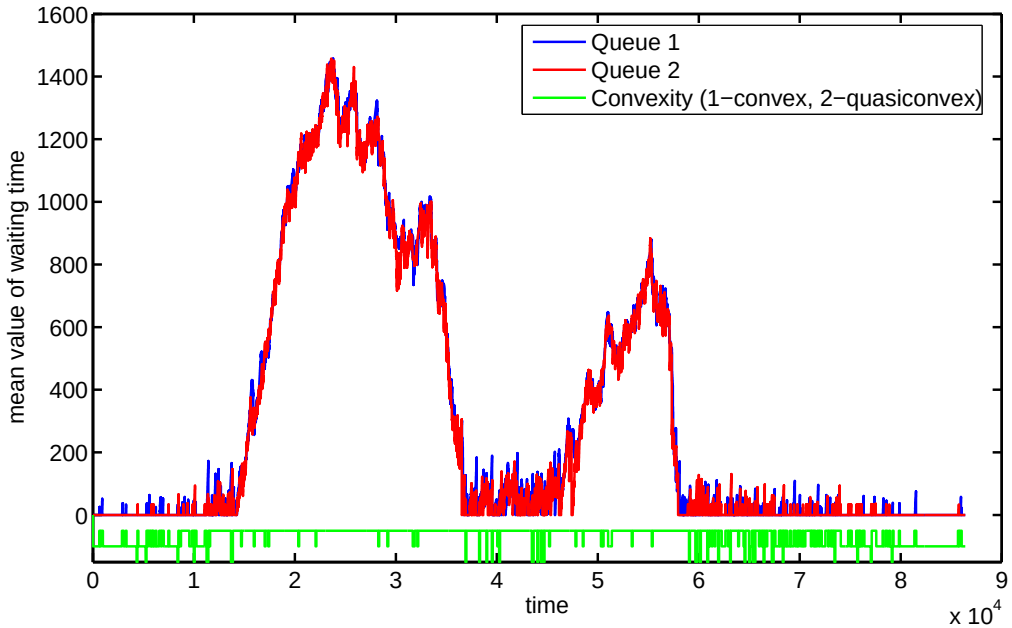
LQ Controller

- Minimization function $J = (E_1 - E_2)^2$
- Matrix $\mathbf{Q} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 \end{bmatrix}$
- Control law $\mathbf{u} = \kappa(\mathbf{x})$ is received as solution of the Riccati equation: $\kappa = \begin{bmatrix} -0.001 & -0.020 & 0.000 & -0.012 \\ 0.001 & 0.016 & -0.001 & -0.062 \end{bmatrix}$



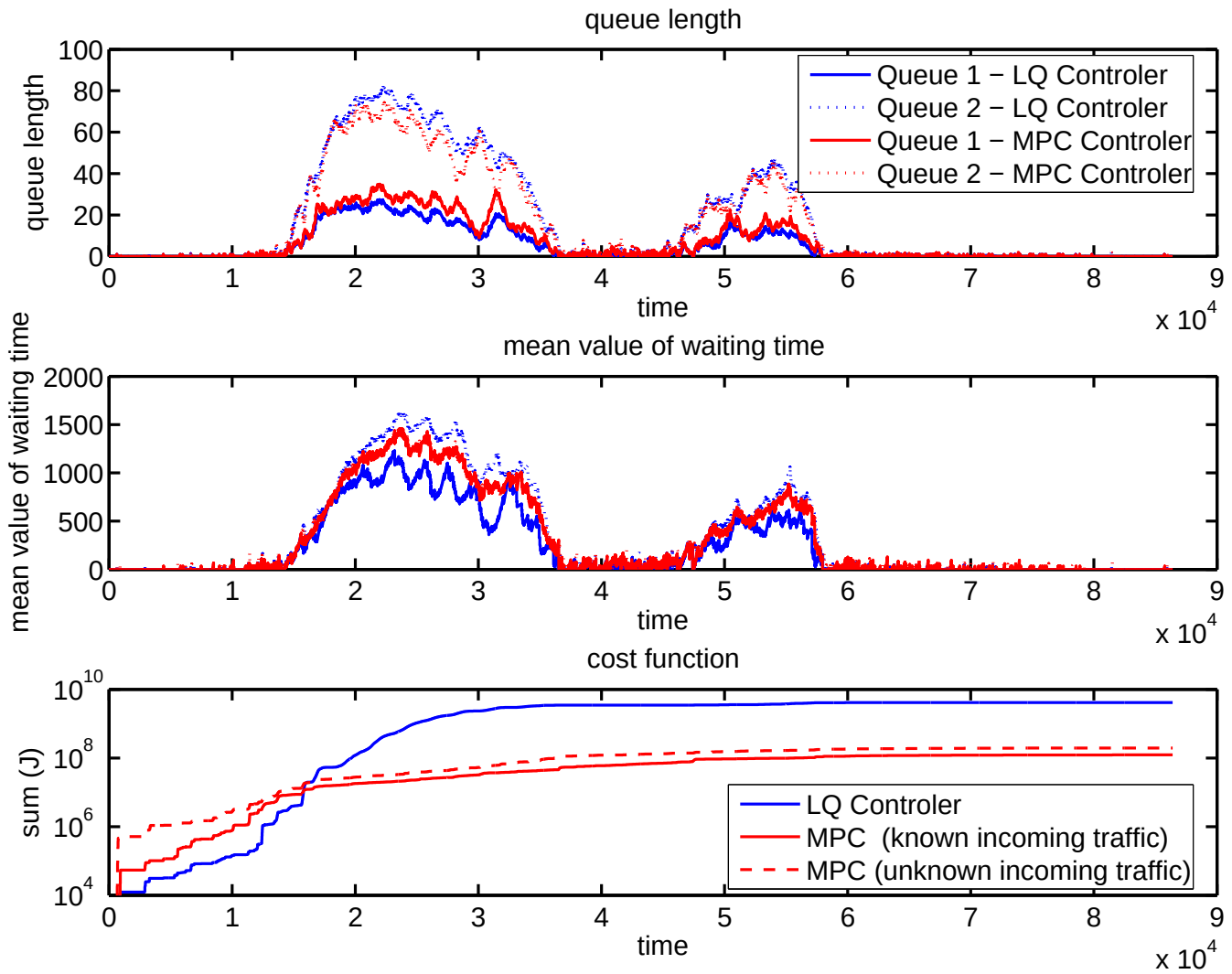
NMPC Controller

- Minimization function $J = (E_1 - E_2)^2$
- Predictive and control horizon 90 s

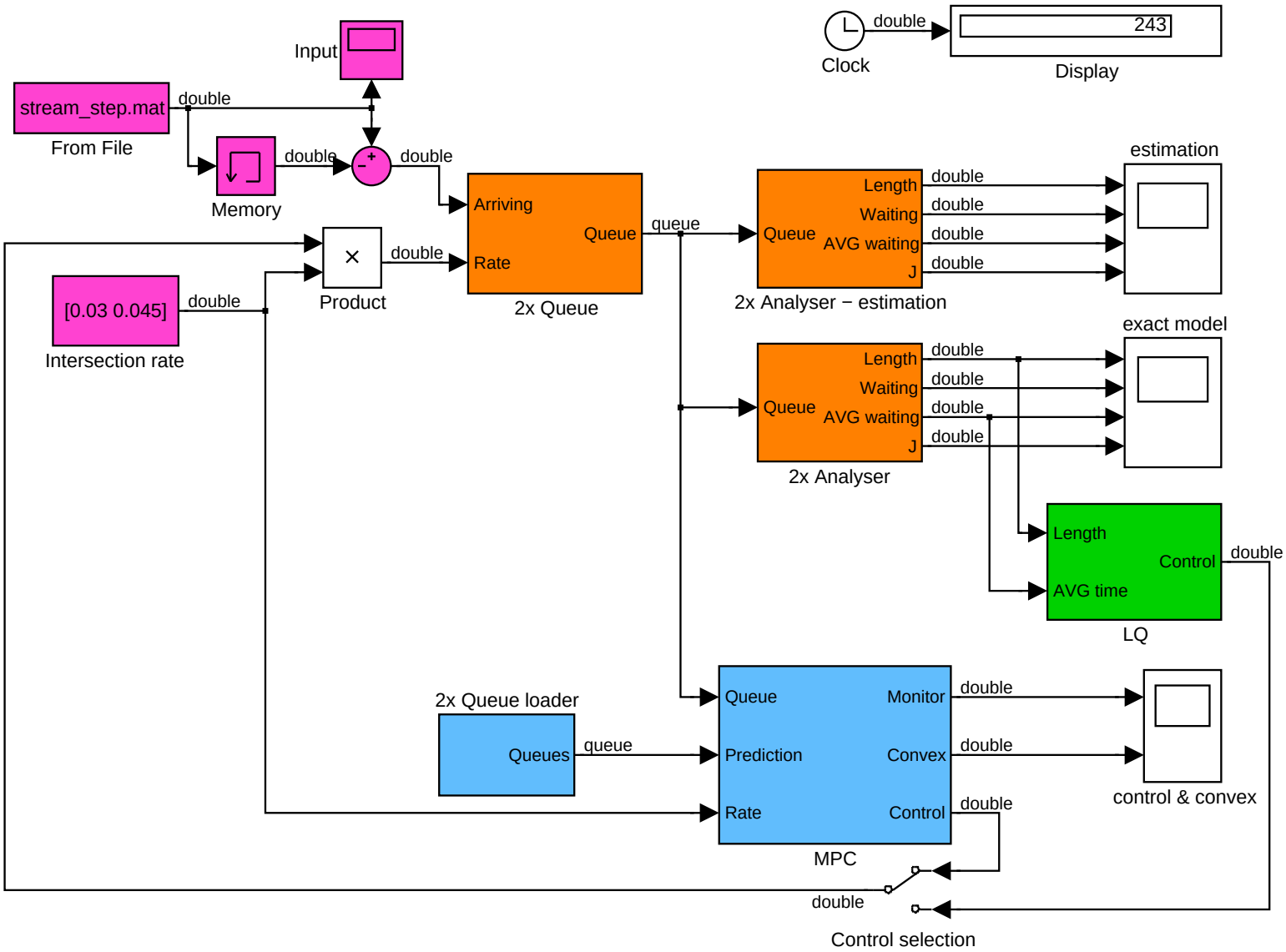


- Notices:
  - Unknown incoming traffic $\sum J = 19,6 \cdot 10^7$
  - Known incoming traffic $\sum J = 12,3 \cdot 10^7$
  - Minimization problem (convex function?)

MPC versus LQ Controller



Simulation Model



Future Work

- Verification by Petri-nets
- Algorithm for minimum cost function search
- Stability for NMPC controller
  (Magni, L., Nicolao, G., Scattolini, R., Allgöwer, F., 2003)
- Multiple intersections connection *(Lei, J., Ozguner, U., 2001)*

Thank You ...

- Questions?