Assignment of Dynamic Transmission Range Based on Estimation of Vehicle Density

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VANET 2005

Motivation

- Network topologies of VANET vary widely over time and space
  - Connectivity map
- In order to maintain a full connectivity for any vehicle, i.e., any vehicle can reach any other vehicle in a group in the context of V2V communication, ...
  - The definition of the group is not clear yet

Motivation

- A group of vehicles?
  - On a highway without congestion:
  - On a highway with congestion:
  - Around an intersection in a city:
  - Maybe more to come later:
- Radio transmission range
  - Fixed: free-flow, congestion, intersection?
  - Dynamic: ???

Objectives

- Dynamic control of the radio transmission power
  - Max. transmission power for sparse networks
  - Min. or reduced power for dense networks
  - Constraints: full connectivity for each node
  - Pros and cons?
- How to know network conditions (dense or sparse)?

Objectives

- Without having a clear definition of the “group”
  - One surest way to figure out the network condition is to ask vehicles around until a consensus is reached
    - What to ask: signal strengths, how many immediate neighbors?, etc, ..
    - How many vehicles need to be probed?
    - Each one does the same job?
    - How frequently?
    - Maybe a good research problem, but ...

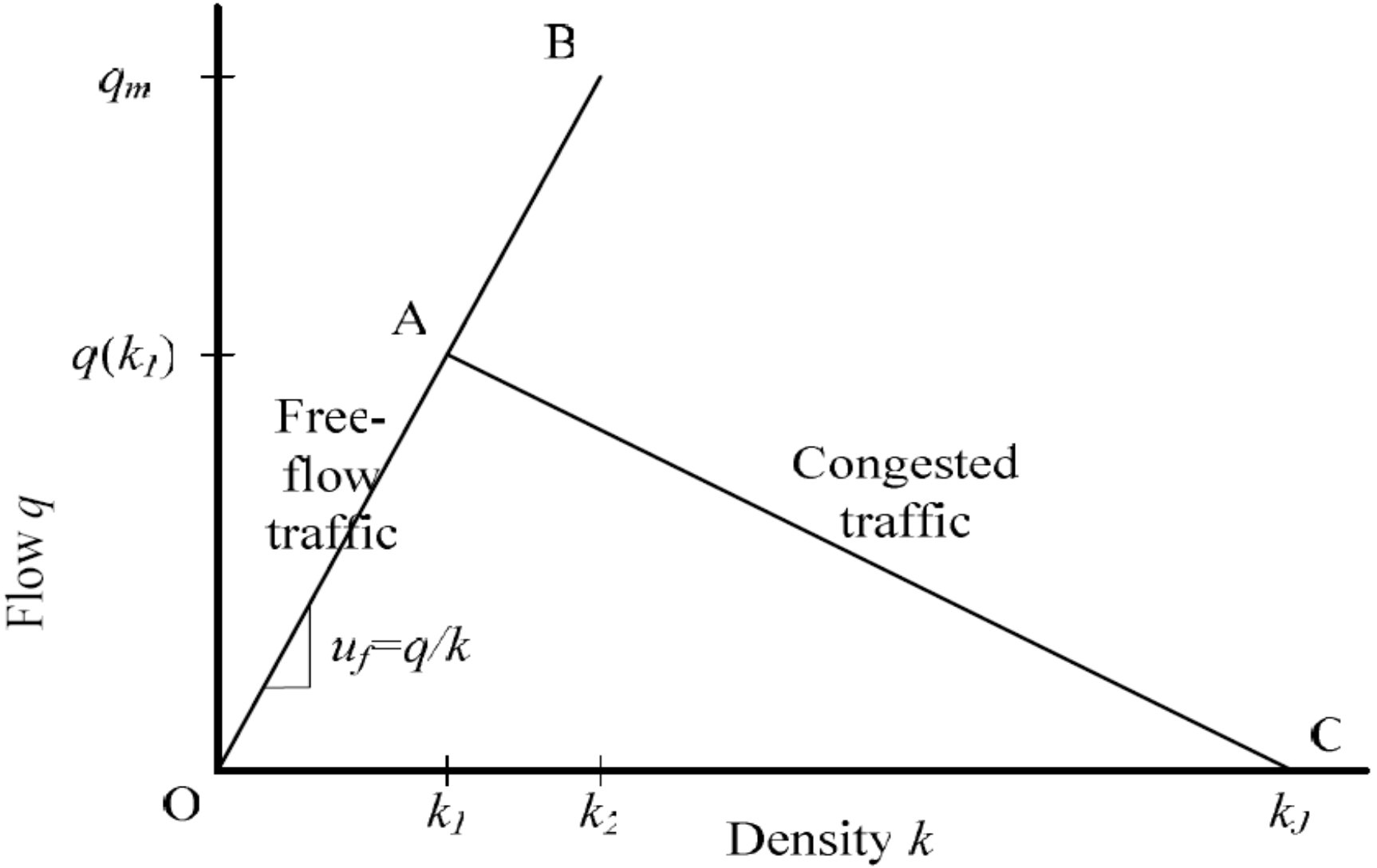
Objectives

- What about estimating the network condition without bothering neighbors?
- If there is such a method, what would it be?
- Road traffic theories may help us find such a method!

Traffic theory

- Flow: the number of vehicles that pass an observer per unit time: q
- Density: the number of vehicles per unit distance: k
- Speed: the distance a vehicle travels per unit time: u
- Free-flow traffic speed: uf

Traffic theory

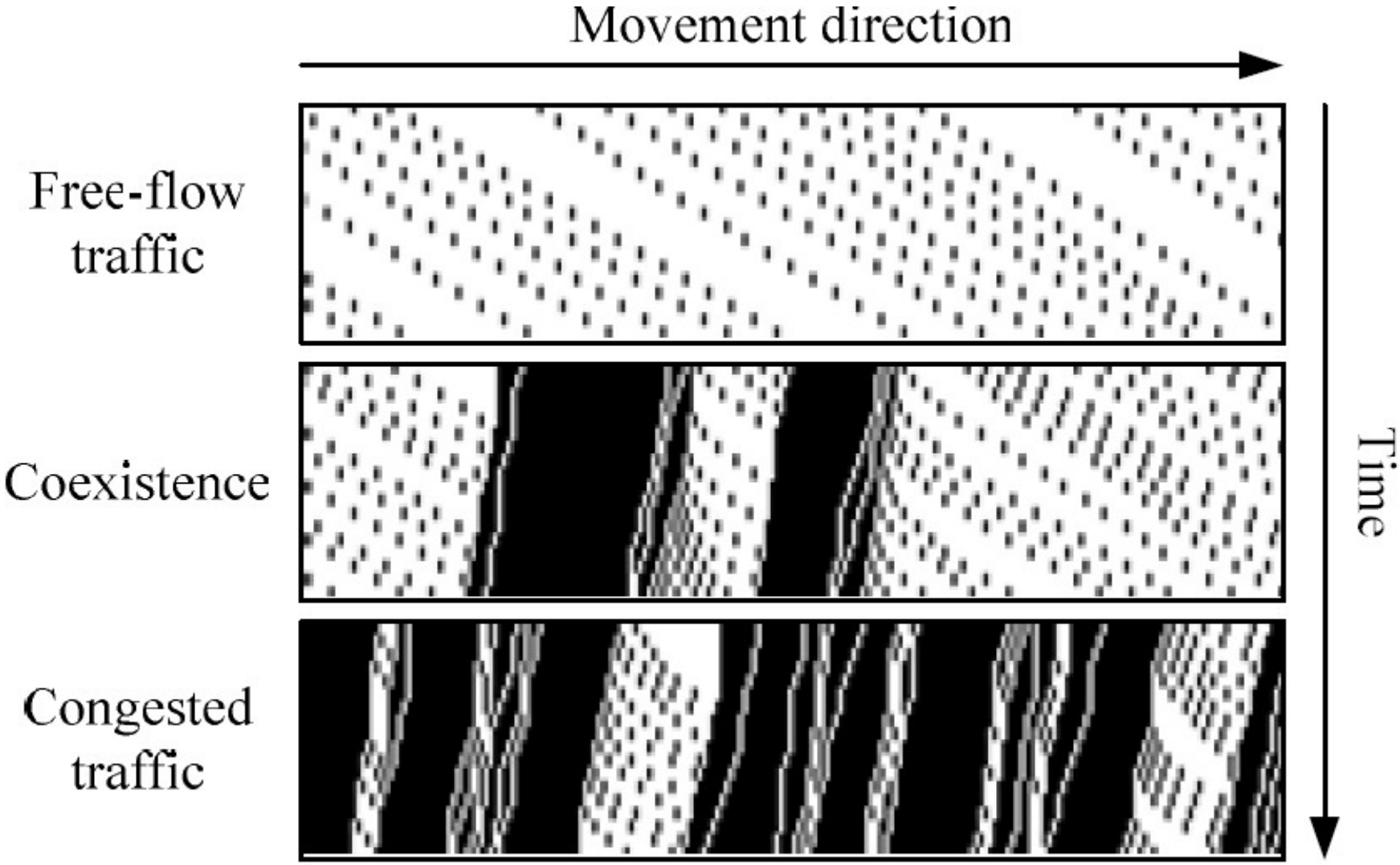


Speed-Density Relationship

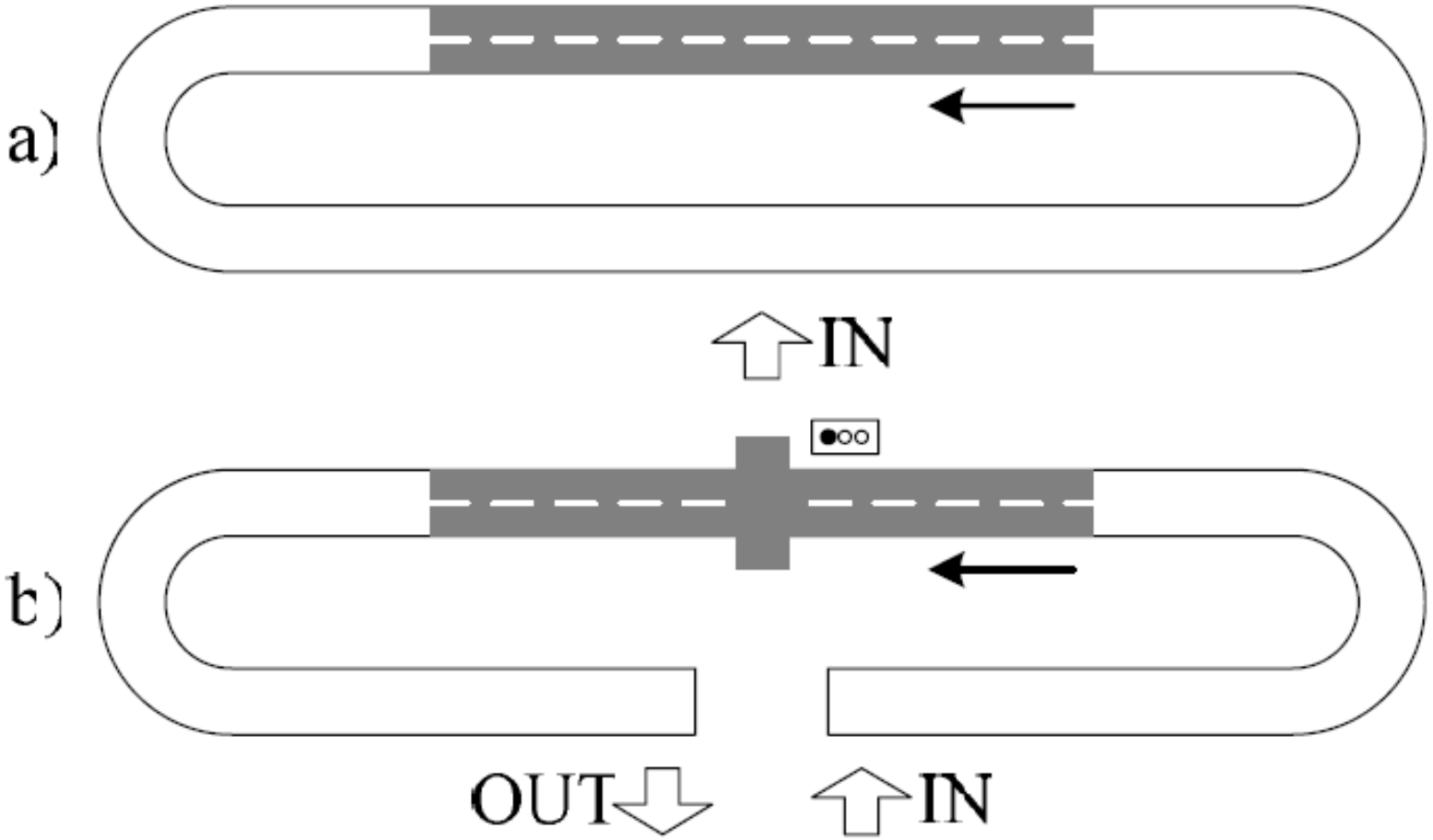
- Sensitivity of the vehicle interaction: lambda
- Max. vehicle density: Kj
-

$$u = \lambda\left(\frac{1}{k} - \frac{1}{k_J}\right)$$

Traffic jams and phase transition



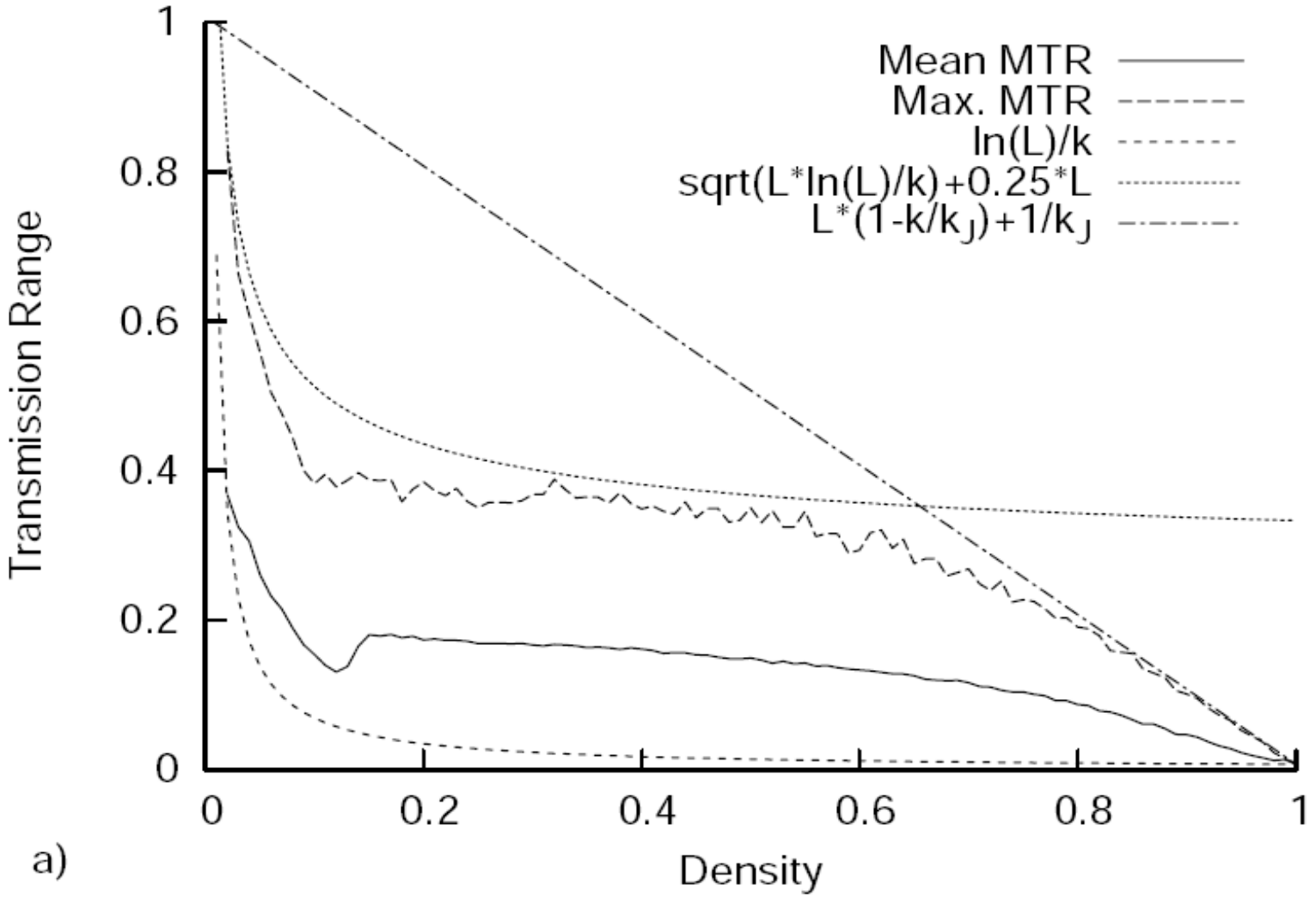
Vehicle Network Simulation



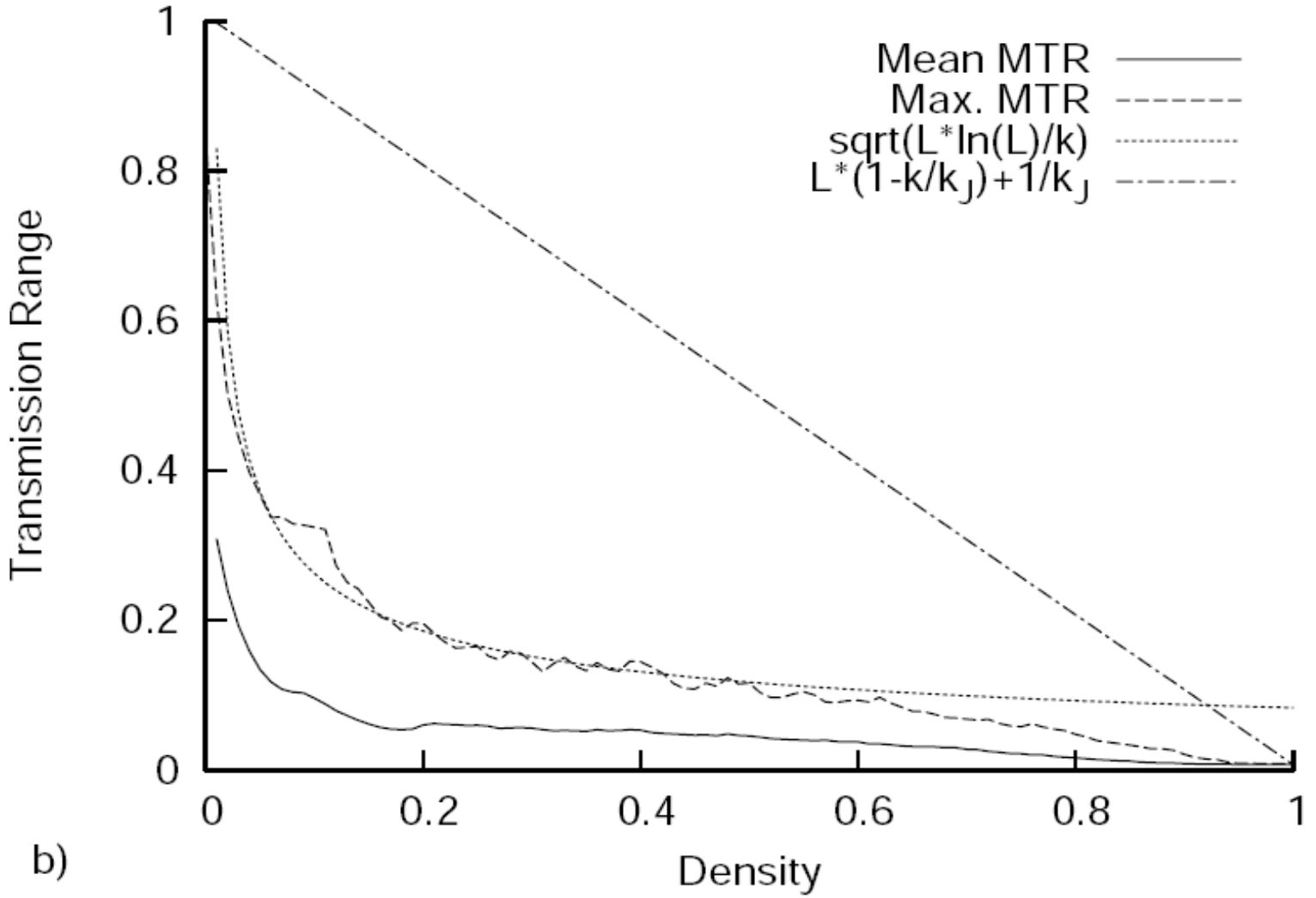
Metrics

- MTR: Minimum transmission range to provide each vehicle with a full connectivity
- MTR is measured at each simulation time
-

Simulation results, 1 lane

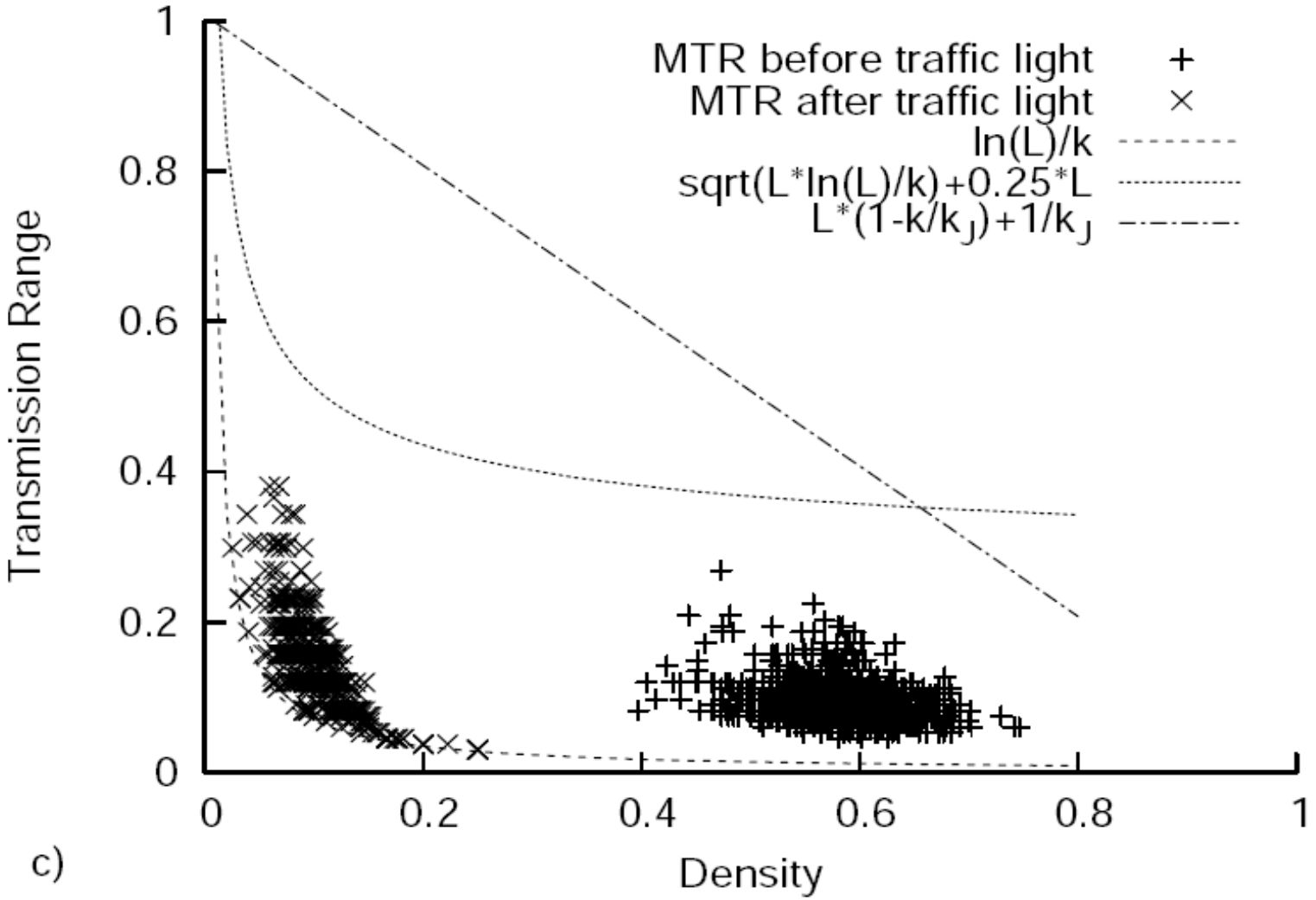


Simulation results, 3 lanes



b)

Simulation results, traffic light



Density estimation

$$u = f(k)$$

$$u = u_f (1 - f_s)^{n+1}$$

$$f_s = T_s / T$$

$$k' = \left[u' / \lambda' + 1 \right]^{-1}$$

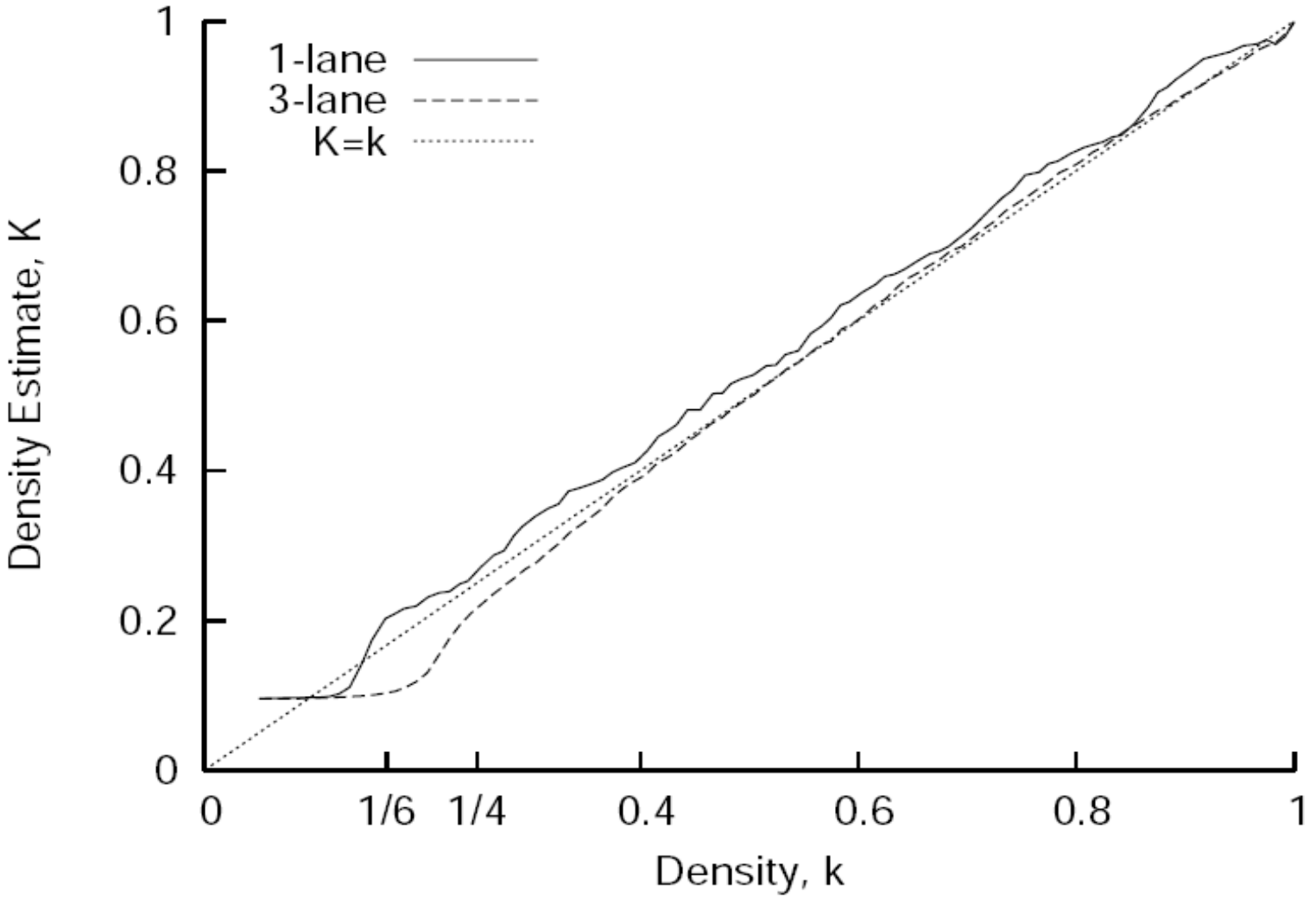
where $k' = k / k_J$, $u' = u / u_f$ and $\lambda' = \lambda / (u_f k_J)$.

Density estimation

$$u' = (1 - T_s / T)^{n+1}$$

$$K = \left[(1 - T_s / T)^{n+1} / \lambda' + 1\right]^{-1}$$

Evaluation


1-lane
3-lane
K=k
Density Estimate, K
Density, k
0
0.2
0.4
0.6
0.8
1
0
1/6
1/4
0.4
0.6
0.8
1

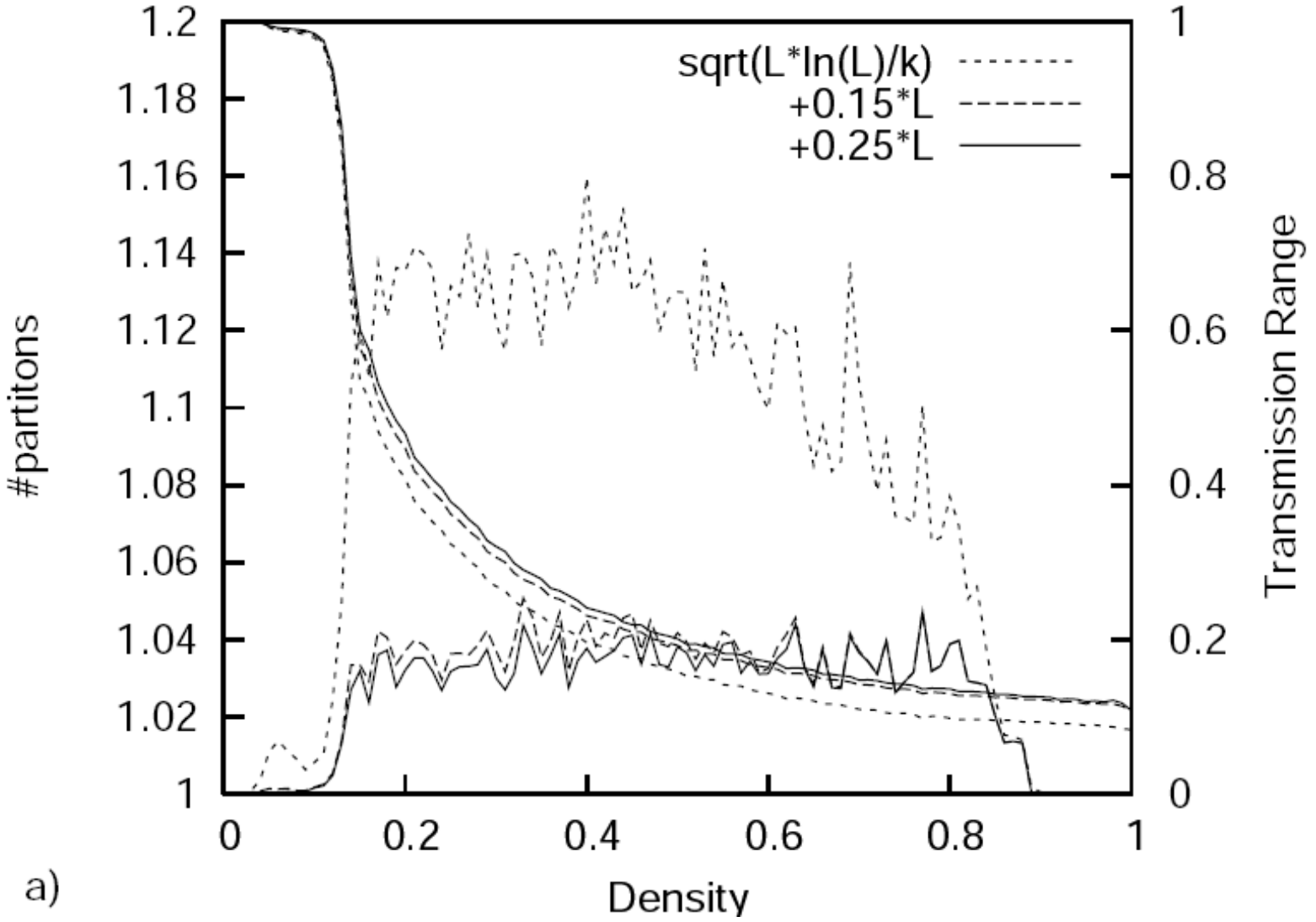
Dynamic Transmission Range Algorithm

- a is a constant
- MR is the maximum transmission range

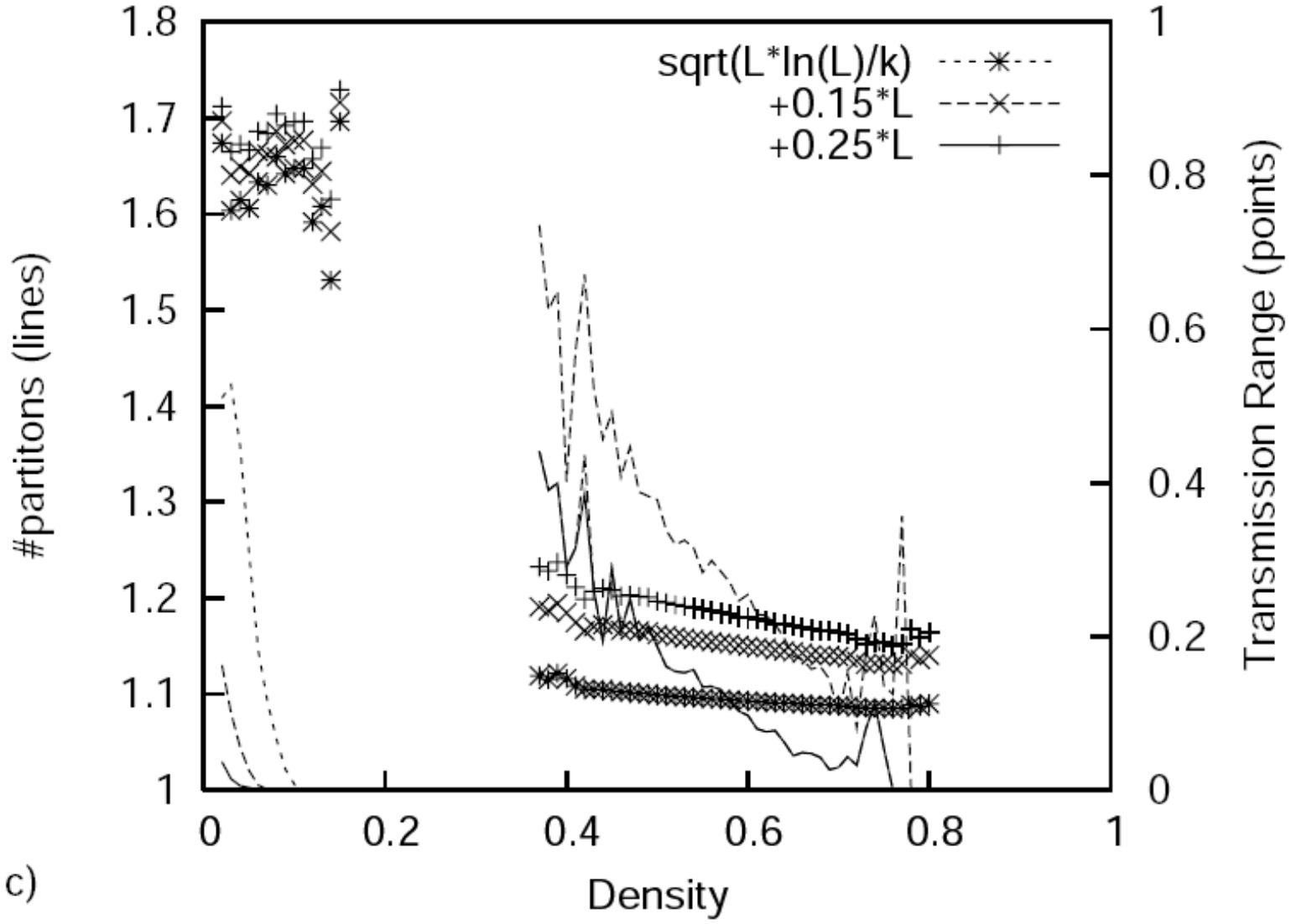
INPUT: fraction time stopped, Ts/T
OUTPUT: transmission range, TR

K=estimte_K(Ts/T)
if Ts/T==0 then
    $TR = MR$
else
    $TR = \min(MR*(1-K), \text{sqrt}(MR*\ln(MR)/K+a*MR)$
end

Performance evaluation, 1 lane



Performance evaluation, 3 lanes



c)