Fair Sharing of Bandwidth in VANETs

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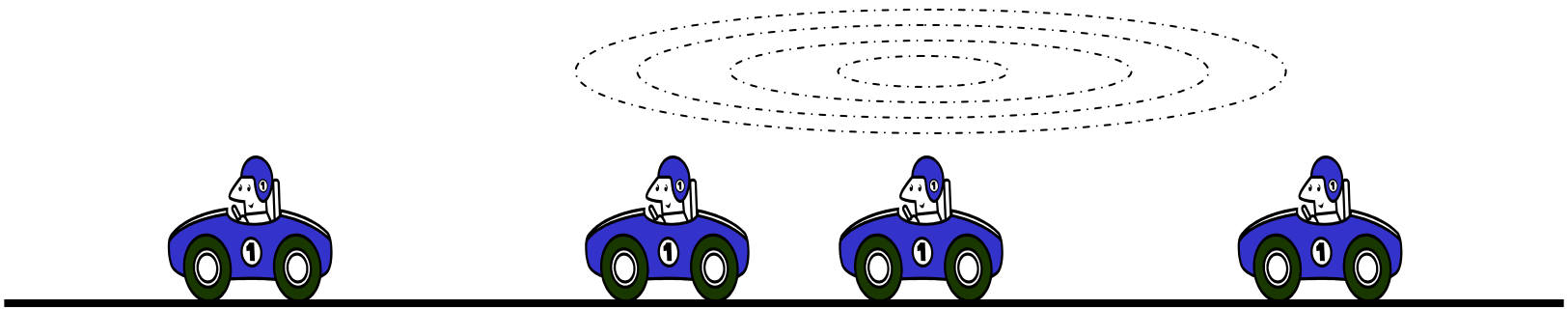
Which Problem are we looking at?

Simple scenario:



Simple question:

- Which transmission power should I use?

Not so simple constraint:

- Safety

Structure of this talk

- Introduction
- Motivation
- The challenge
- Our approach – Fairness
- FPAV Algorithm
- Experiments
- Discussion – Current work
- Summary

Introduction – Context

- In a VANET every vehicle will send/receive into/from shared medium
- In the USA, FCC: 7 channels, 1 control channel
- Control channel: Exchange of safety information
- 2 types of safety related messages:
  - Event driven
  - Periodic
- Periodic messages will essentially contain the state of the vehicle :
  - Position
  - Direction
  - Speed
  - …

Motivation

» **Amount of load resulting from beaconing should be limited**

Why?

- **Leave some bandwidth for unexpected emergency situations**
- **802.11p is a variant of 802.11a with 10MHz channels (half data-rates)**
- **CSMA/CA is an asynchronous approach, not able to manage bandwidth efficiently**
- **Safety messages are mainly broadcast (~Hidden terminal problem)**
- **Potential high node density scenarios**

How?

- **Prioritization – Admission control**
- **Adjusting packet generation rate**
- **Adjusting transmission power**

The Challenge

- **Constraint: The load in the channel must be limited – MBL (Maximum Beaconing Load)**

- **… how do I make sure that the beaconing load is lower than MBL everywhere in a reasonable way?**

- **Options for power level assignments:**
  - **Capacity**
  - **Connectivity**

VANETs main goal is Safety!

How do we achieve safety?

» **… being fair: *Fairness* from the system perspective**

» **How can we adjust transmission power in a fair approach?**

Fair Power Control: All vehicles in a certain (busy) area must restrict their beacons' transmission power by the same ratio

- Maximize the minimum transmission power
- Maximize individual coverage

Our Approach to Fairness – Assumptions

» **Assumptions:**

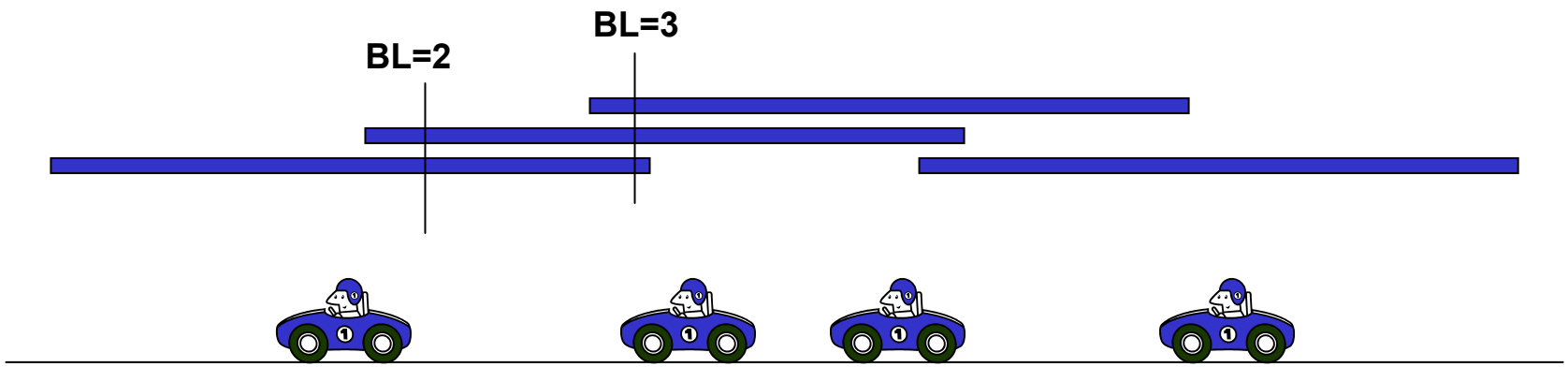
- **The *Carrier Sense Range* is monotonic**

Also in the paper for clarity reasons:

- **All nodes have the same beaconing frequency and packet sizes**
- **All nodes have the same Maximum Transmission Power (P_{max})**

» **In this case, MBL can be counted in:**

- ***bits per second***
- ***# of overlapping Carrier Sense Ranges***

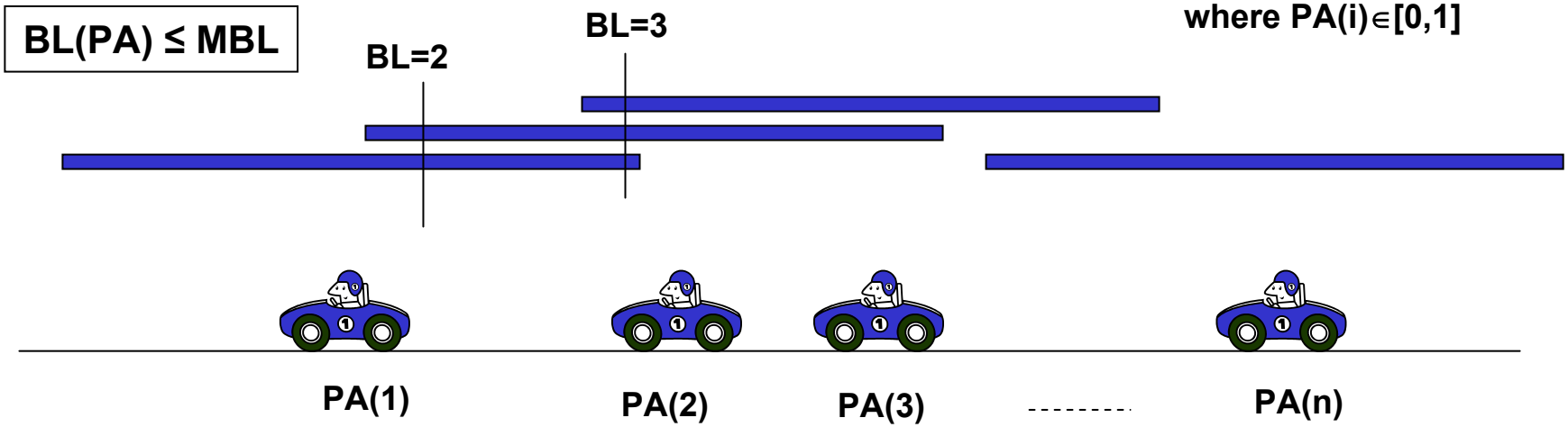


Our Approach to Fairness – Definition

» **Problem Statement:**

- **PA: Power Assignment**
- **PA(i)×Pmax: Transmission Power where PA(i)∈[0,1]**

BL(PA) ≤ MBL



» **Challenge:**

- **Beaconing Max-Min Tx Power**
- **Per node maximal power assignment**

FPAV Algorithm

- **FPAV: Fair Power Adjustment for Vehicular environments**
- **First approach – Optimal Solution:**
  - **Totally centralized**
  - **Global knowledge**
- **Two stages:**
  - **Stage 1: Compute an optimal solution to BMMTxP**
  - **Stage 2: Augment the solution into a per-node maximal power assignment**

FPAV – Stage 1

Input: **a set of nodes** $N = \{u_1, \ldots, u_n\}$

Output: **a power assignment PA which is an ($\varepsilon \times P_{max}$-aproximation of an) optimal solution to BMMTxP**

$$\forall u_i \in N,\ set\ PA(i) = 0$$

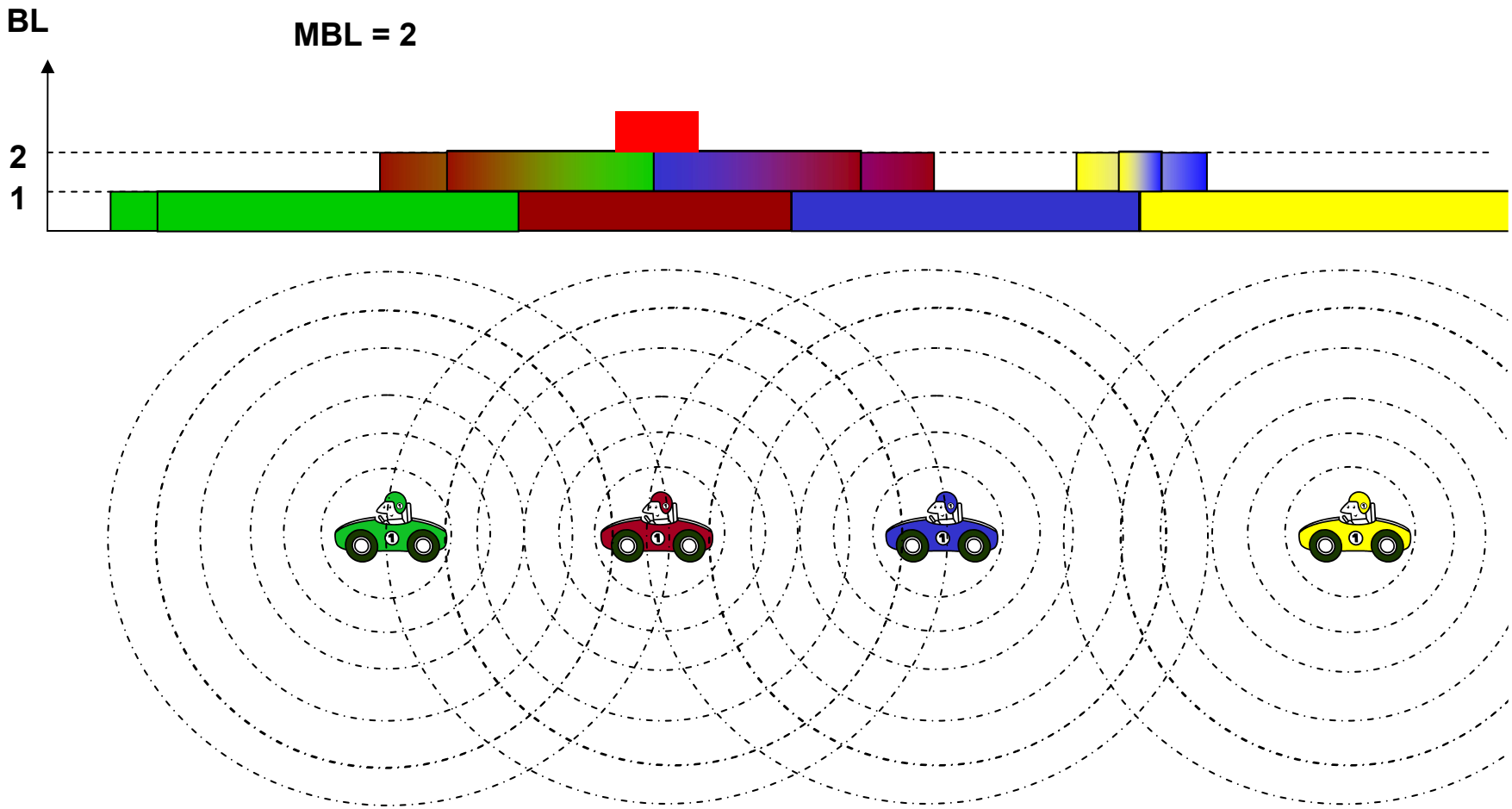
$$\text{while } (BL(PA) \leq MBL) \text{ do}$$

$$\quad \forall u_i \in N,\ PA(i) = PA(i) + \varepsilon$$

$$\text{end while}$$

$$\forall u_i \in N,\ PA(i) = PA(i) - \varepsilon$$

FPAV – Stage 1 – Visualization



FPAV – Stage 2

Input: **an optimal solution to BMMTxP, denoted *PA***

Output: **a power assignment PA which is a (ε×Pmax-aproximation of a) per node maximal power assignment following strict fairness**

$\forall u_i \in N,$ set $ReachedTop(i) = false$

while!($\forall u_i \in N,$ set $ReachedTop = true$) do

  for($i = 1$ *to* n) do

    $PA(i) = PA(i) + \varepsilon$

    if ($BL(PA) > MBL$) then

      $PA(i) = PA(i) - \varepsilon$

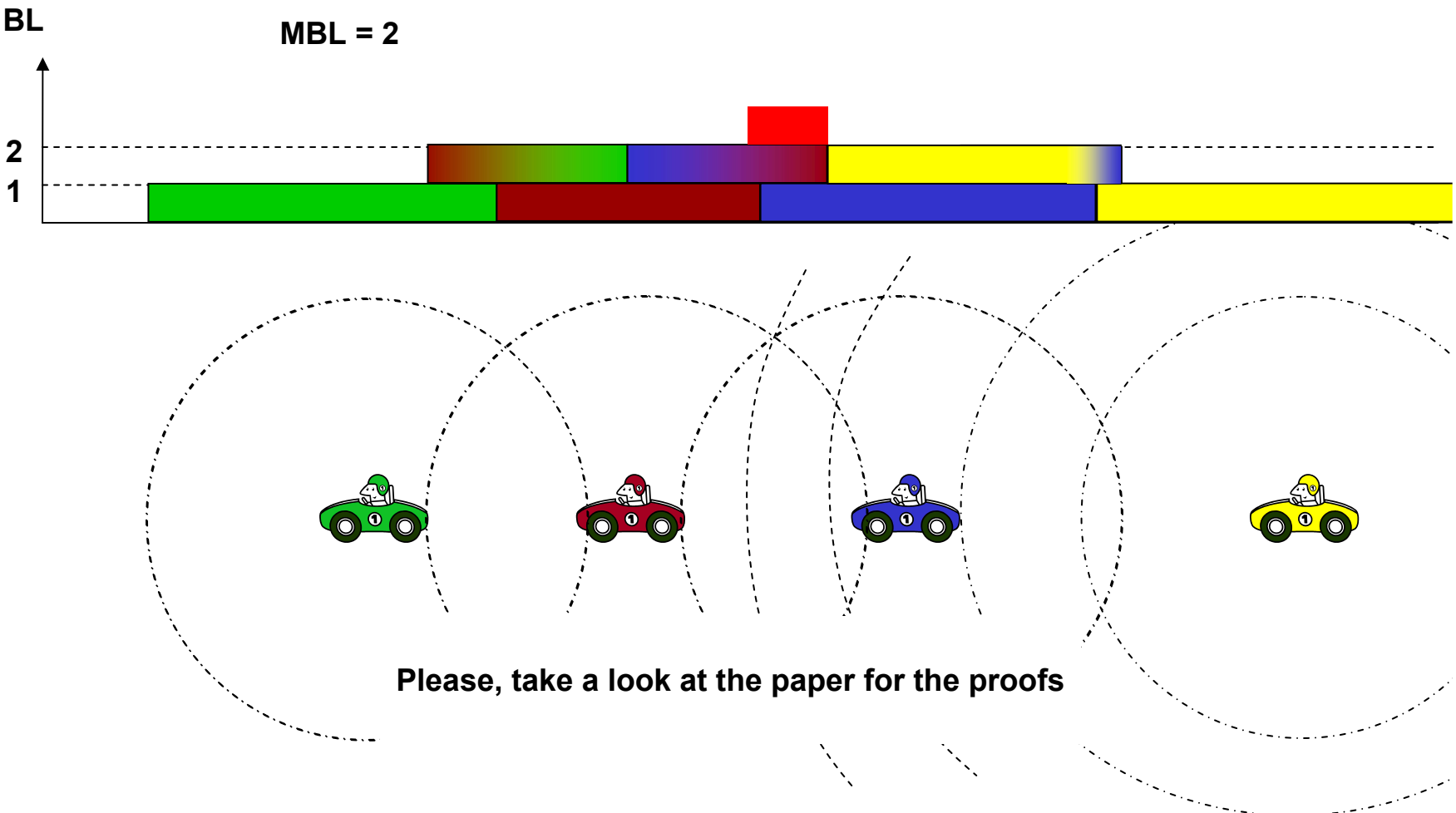
      $ReachedTop(i) = true$

    end if

  end for

end while

FPAV – Stage 2 – Visualization



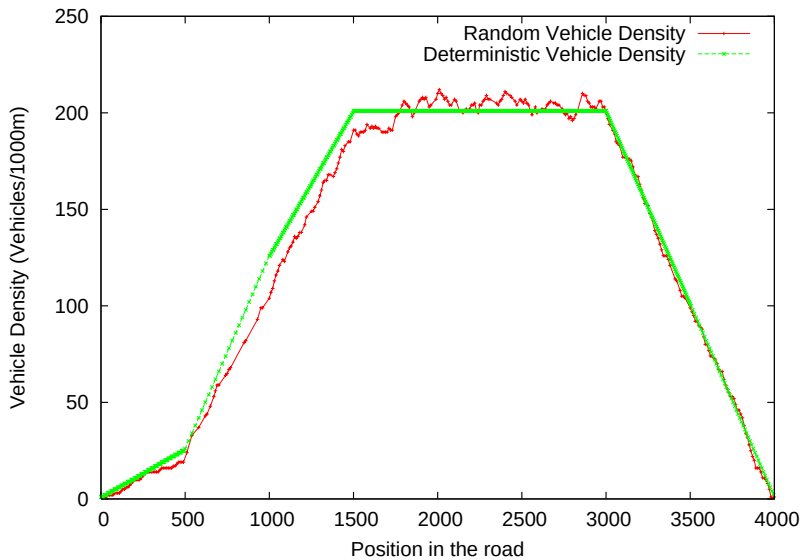
Please, take a look at the paper for the proofs

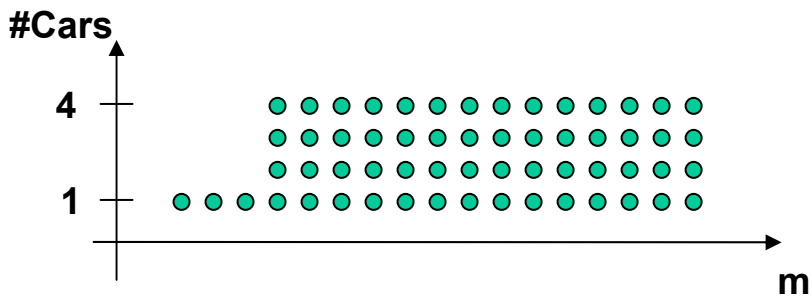
Experiments

Configuration

Packet generation rate	10 pckts/s
Packet size	250B
Loadvehicle	20Kbps
Data Rate	6Mbps
Maximum beaconing load	3Mbps
Communication range	250m
Carrier Sense range	500m
Step size ε	0.01
Vehicle density	20veh./100m

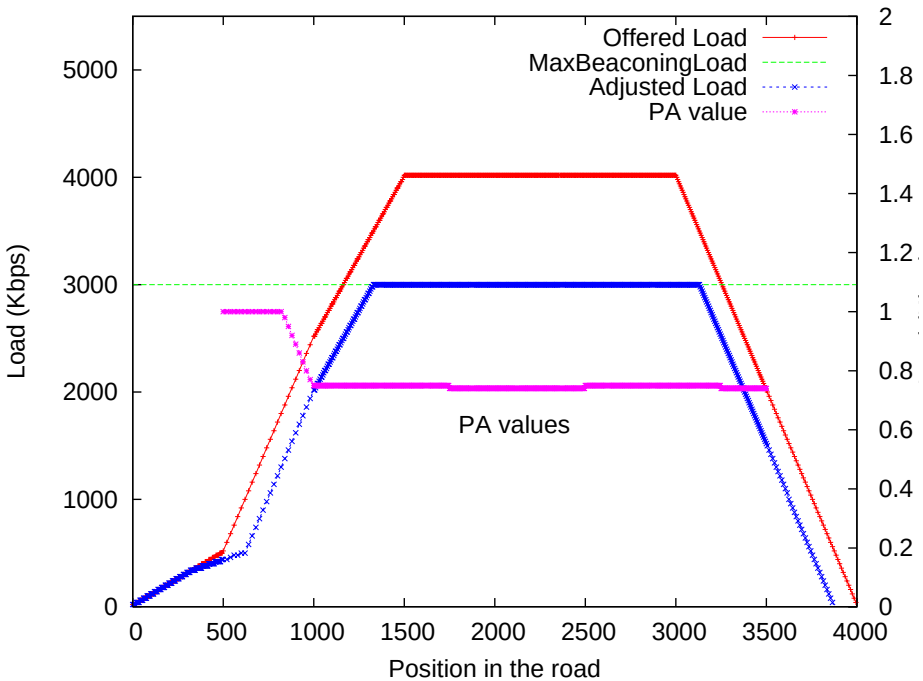
Distribution



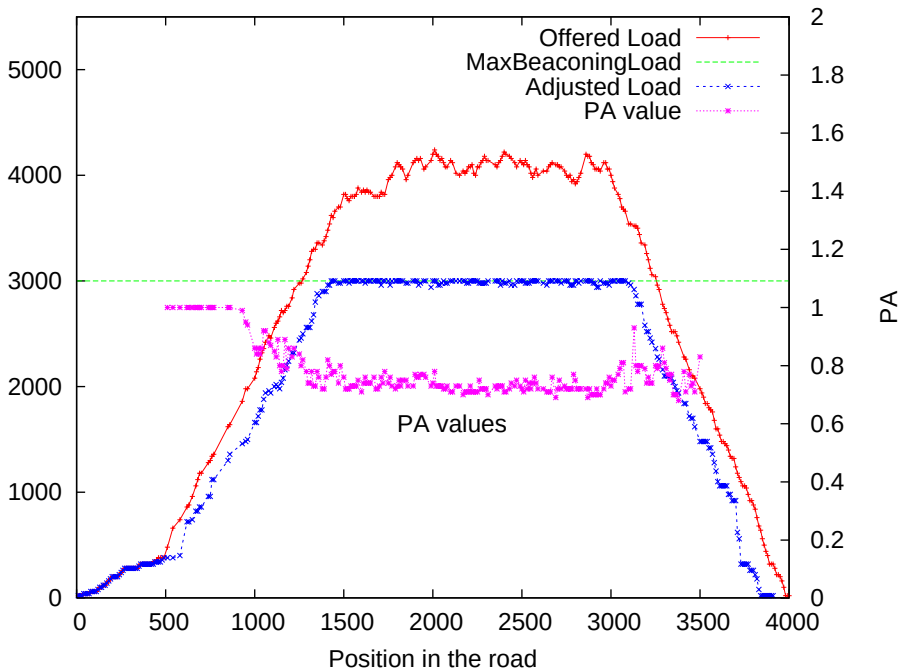


Experiments – Results

Deterministic Distribution



'Random' Distribution



Discussion – Current Work

- Centralized or synchronous approaches are not feasible in VANETs
- Challenge: iterative (feedback) schemes are likely to fail due to high dynamics

Current Work:

- How to implement FPAV in a fully distributed, asynchronous fashion
  - Let each node run FPAV internally with local knowledge
  - How close to centralized FPAV can we get?

Summary

- We addressed the limited channel capacity of VANETs to support safety-related information exchange
- We propose to limit the wireless channel load resulting from periodic messages
- We propose strict *FAIRNESS* due to *SAFETY* nature of VANETs
- Formally defined the challenge in terms of Max-Min optimization problem extending it to obtain per-node maximality
- We proposed a centralized algorithm FPAV and briefly point the issues to bring it into a real scenario
- Our goal is to come up with a fully distributed, localized and asynchronous implementation

Thank you very much for your attention !

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