

# Graph theoretical approach for vehicular broadcast communications

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## Background

- ▶ 3GPP recently introduced V2V *mode-3*.
- ▶ V2V *mode-3* is mainly aimed at supporting broadcast communications between vehicles.
- ▶ It consists of two stages:
  - ▷ The eNodeB assigns subchannels to vehicles.
  - ▷ Vehicles engage in direct communications.

**Important: Vehicles in the same cluster must be allotted orthogonal subchannels in time domain**

## Objective

- ▶ Propose an approach that:
  - (1) maximizes the system sum-capacity
  - (2) guarantees a conflict-free subchannel allocation for V2V *mode-3*.

## System Model

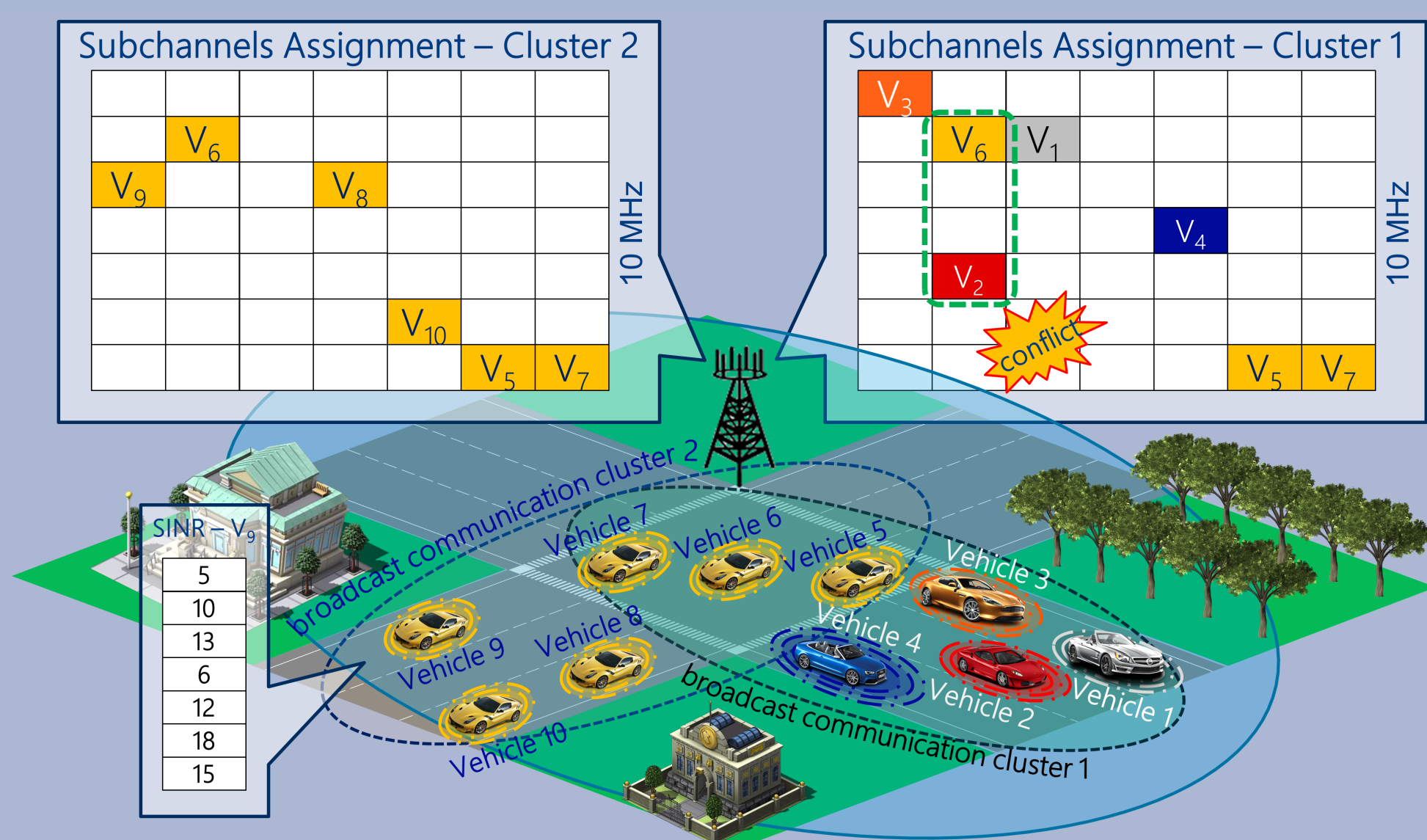


Figure 1: Broadcast communications via sidelink V2V *mode-3*

## Sidelink Subchannel Grid

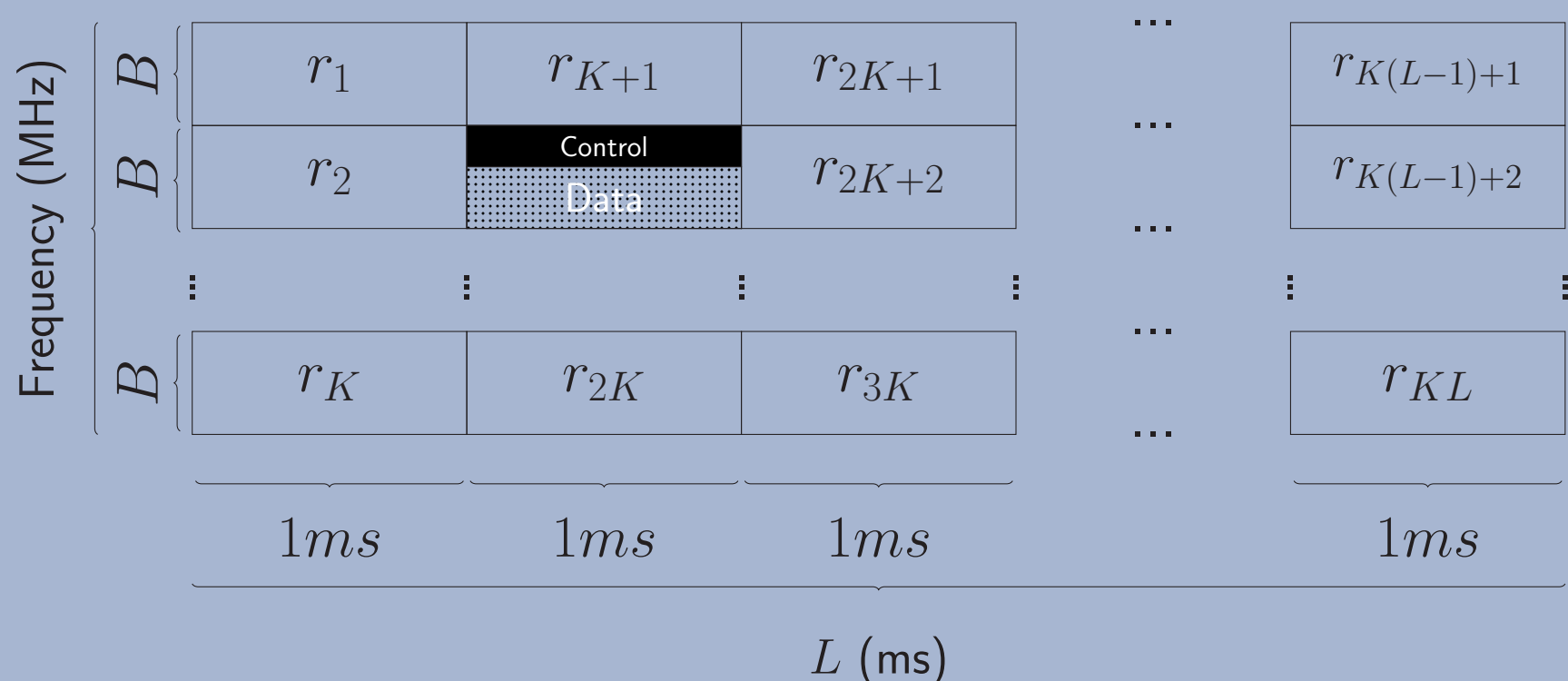


Figure 2: Channelization of sidelink resource blocks (RBs)

$B$ : subchannel bandwidth.  $L$ : number of subframes.  
 $K$ : number of subchannels per subframe.

## Subchannel Allocation Problem Representation

- ▶ Solve for each cluster  $\mathcal{V}^{(j)}$

$$\begin{aligned} & \max \mathbf{c}_j^T \mathbf{x}_j \\ & \text{subject to } \underbrace{\begin{bmatrix} \mathbf{I}_{N_j \times N_j} \otimes \mathbf{1}_{1 \times L} \\ \mathbf{1}_{1 \times N_j} \otimes \mathbf{I}_{L \times L} \end{bmatrix}}_{\mathbf{A}} \otimes \mathbf{1}_{1 \times K} \mathbf{x}_j = \mathbf{1} \\ & \mathbf{c} \in \mathbb{R}^M, \mathbf{x} \in \mathbb{B}^M, \mathbf{A} \in \mathbb{B}^{2L \times M}, M = KL^2. \end{aligned}$$

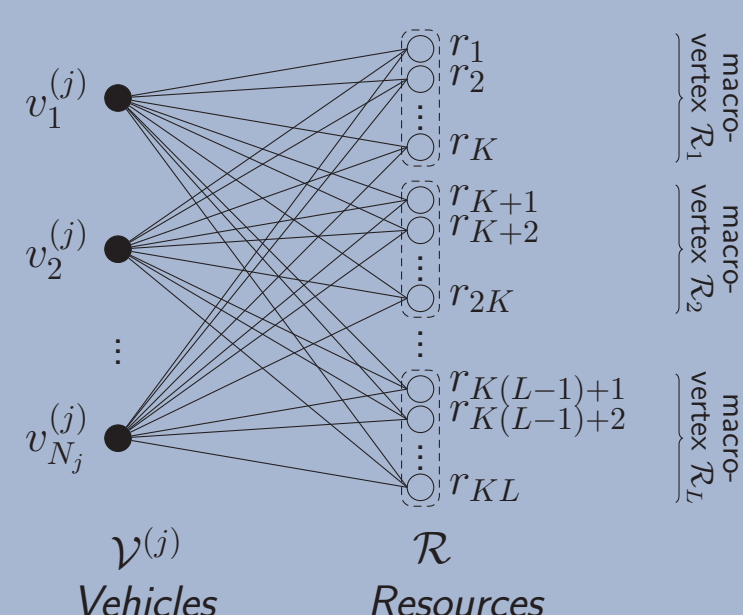


Figure 3: Resource allocation example

- ▶ Equivalent Problem

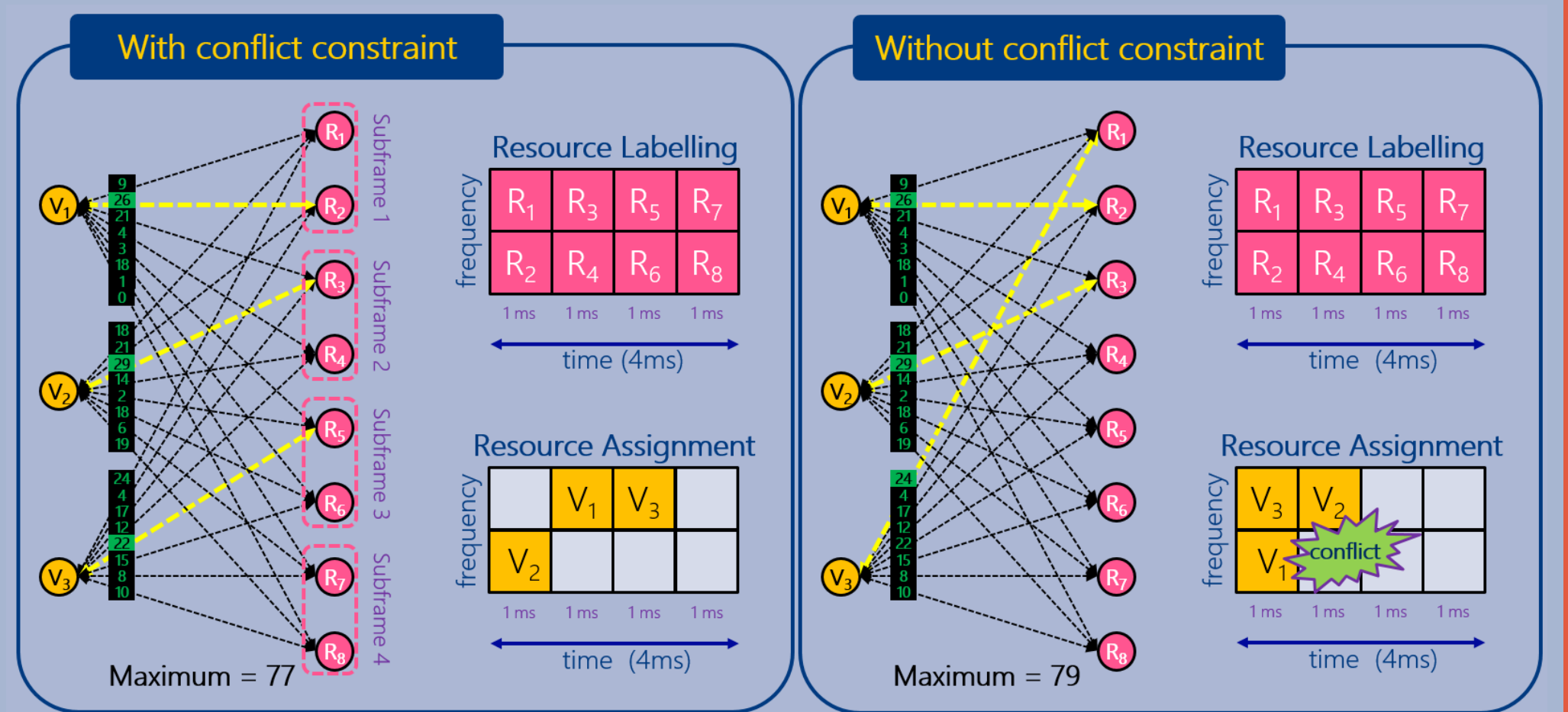
$$\begin{aligned} & \max \mathbf{d}_j^T \mathbf{y}_j \\ & \text{subject to } \begin{bmatrix} \mathbf{I}_{L \times L} \otimes \mathbf{1}_{1 \times L} \\ \mathbf{1}_{1 \times L} \otimes \mathbf{I}_{L \times L} \end{bmatrix} \mathbf{y}_j = \mathbf{1}. \end{aligned}$$

$$\begin{aligned} & \mathbf{x} \rightarrow \mathbf{I}_{M \times M} \otimes \mathbf{1}_{1 \times K} \rightarrow \mathbf{y} \\ & \mathbf{c} \rightarrow \text{diag}(\cdot) \rightarrow \mathbf{I}_{M \times M} \otimes \mathbf{1}_{1 \times K} \rightarrow \mathbf{d} \\ & \mathbf{d}_j = \lim_{\beta \rightarrow \infty} \frac{1}{\beta} \log \left\{ (\mathbf{I}_{M \times M} \otimes \mathbf{1}_{1 \times K}) e^{\beta \mathbf{c}_j} \right\} \end{aligned}$$

## Proposed Approach

- A novel sequential subchannel allocation scheme is proposed.
  - ▶ Clusters are hierarchically sorted based on their cardinality.
  - ▶ Subchannel allocation is performed per each cluster.
  - ▶ The assignment of vehicles with subchannels is based on a bipartite graph matching.

## Example: Resource Allocation Conflict



## Simulation Results

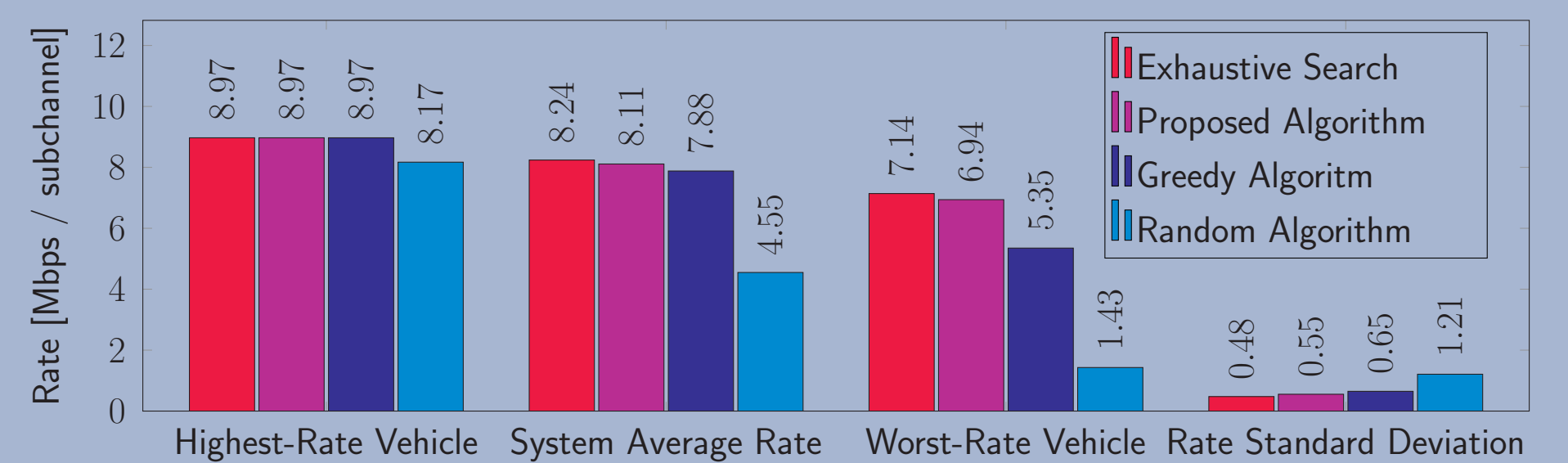


Figure 4: Data rate per vehicle

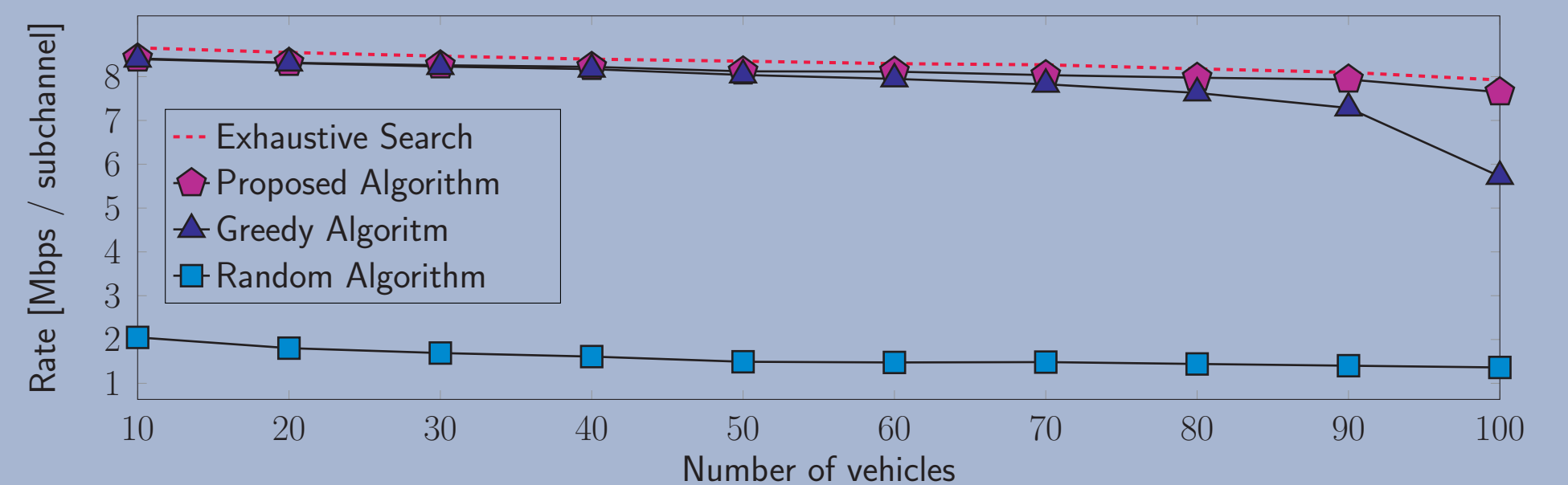


Figure 5: Worst-rate vehicle

## Conclusions

- ▶ Subchannel allocation conflicts were prevented from occurring
- ▶ However, there is a degree of suboptimality incurred due to successive allocation.
- ▶ In exchange, the complexity of the process was reduced if compared to exhaustive search
- ▶ The obtained solutions are near-optimal.

**Remark:** Mobility models were not considered.

## References

- [1] "3GPP TS 36.213; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures; (Release 14) v14.2.0," March 2017.
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- [4] J. Munkres, "Algorithms for the Assignment and Transportation Problems", Journal of the Society for Industrial and Applied Mathematics, Vol. 5, No. 1, pp. 32-38, 1957.