Graph theoretical approach for vehicular broadcast communications

Graph Theoretical Approach for Vehicular Broadcast Communications

Luis F. Abanto-Leon[1], Arie Koppelaar[2], Sonia Heemstra de Groot[1]

[1]Eindhoven University of Technology, Department of Electrical Engineering, [2]NXP Semiconductors, Eindhoven

TU/e Technische Universiteit Eindhoven University of Technology

Background

- 3GGP 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 alloted 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

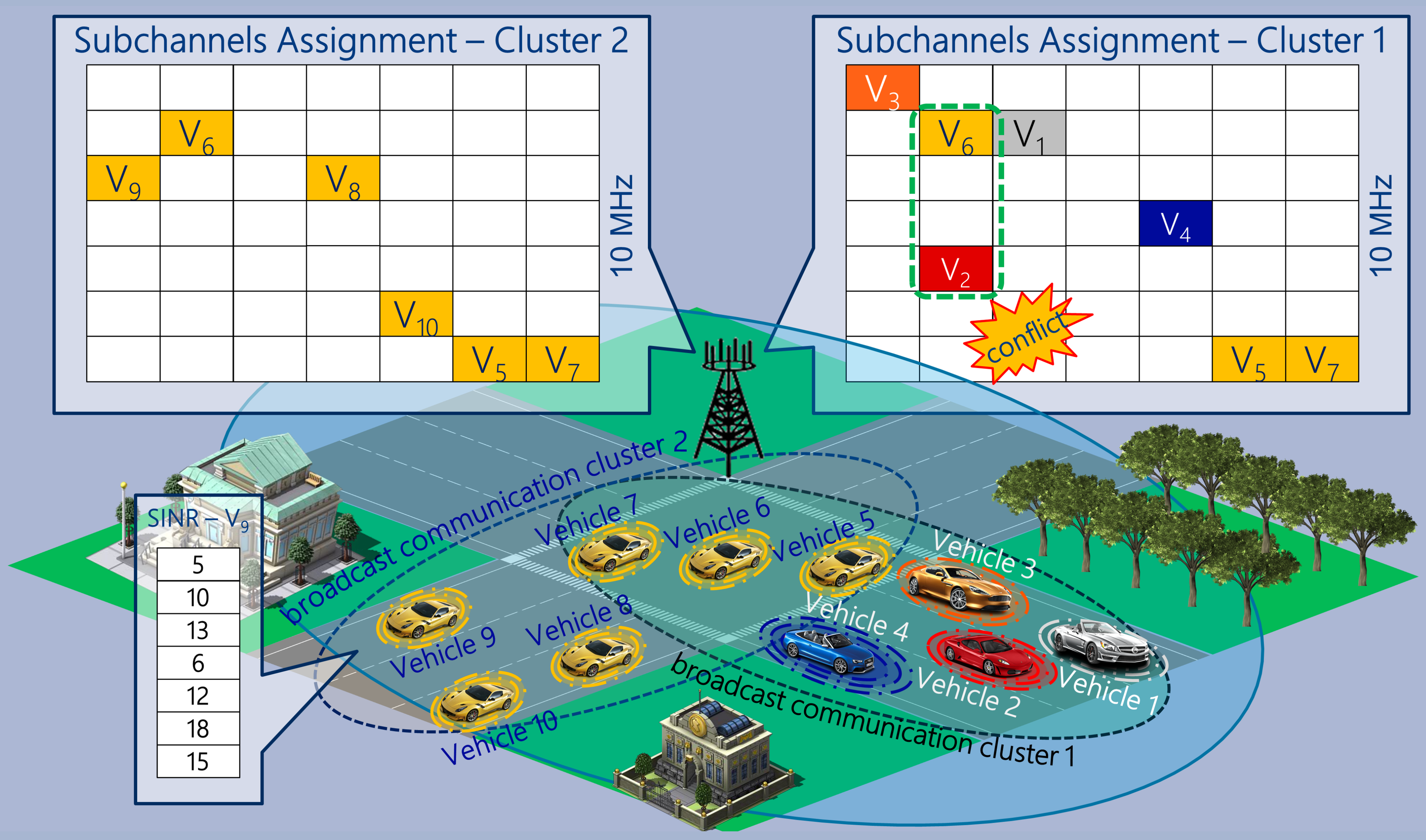


Figure 1: Broadcast communications via sidelink V2V *mode-3*

Sidelink Subchannel Grid

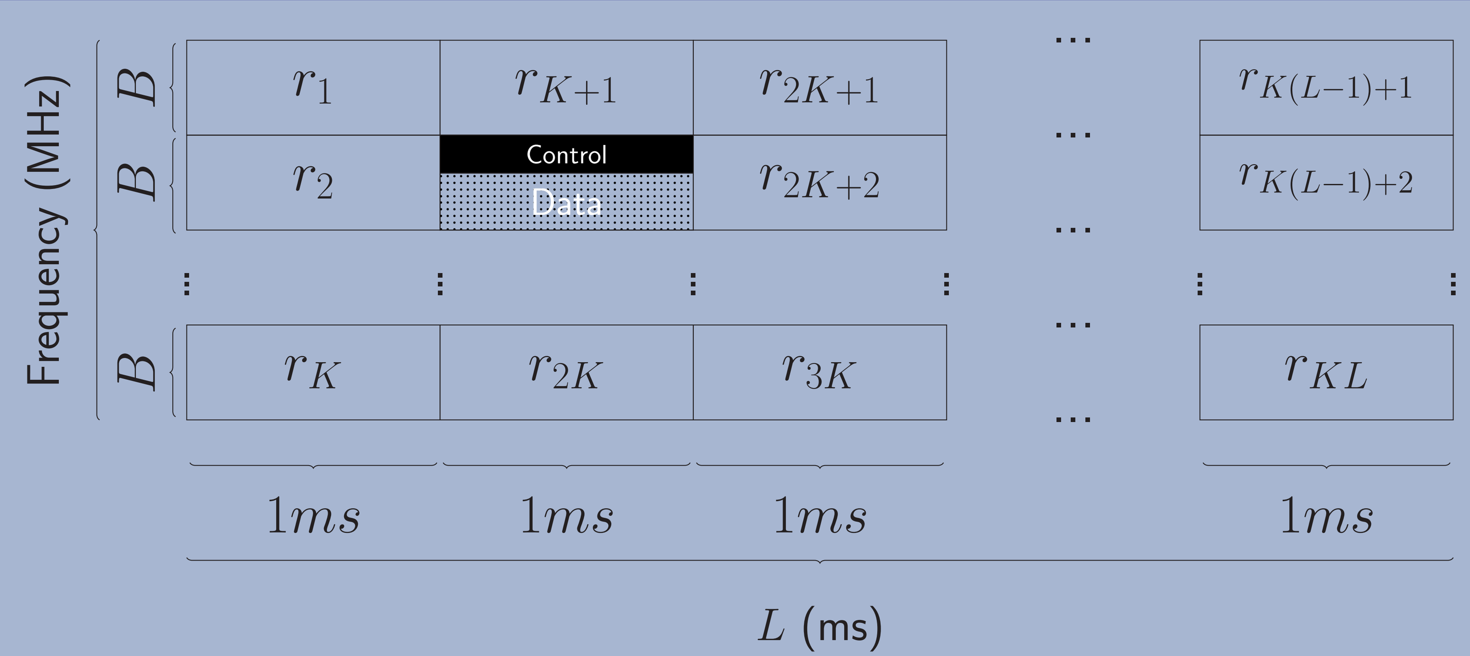


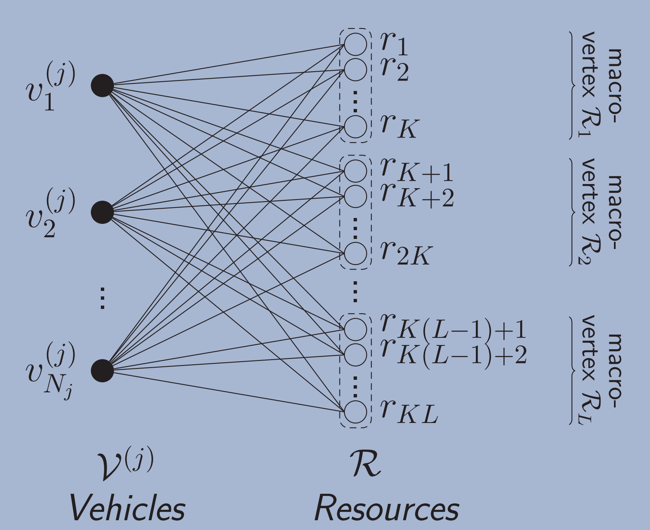
Figure 2: Channelization of sidelink resource blocks (RBs)

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

Subchannel Allocation Problem Representation

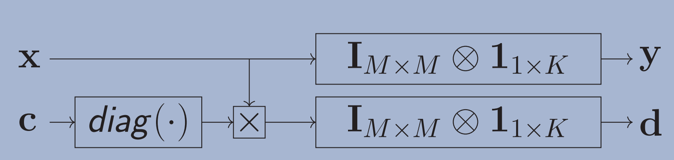
- Solve for each cluster $\mathcal{V}^{(j)}$

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



- Equivalent Problem

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



$$\mathbf{d}_j = \lim_{\beta\to\infty} \frac{1}{\beta} \overset{\circ}{\log}\left\{(\mathbf{I}_{M\times M} \otimes \mathbf{1}_{1\times K}) e^{\circ \beta \mathbf{c}_j}\right\}$$

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

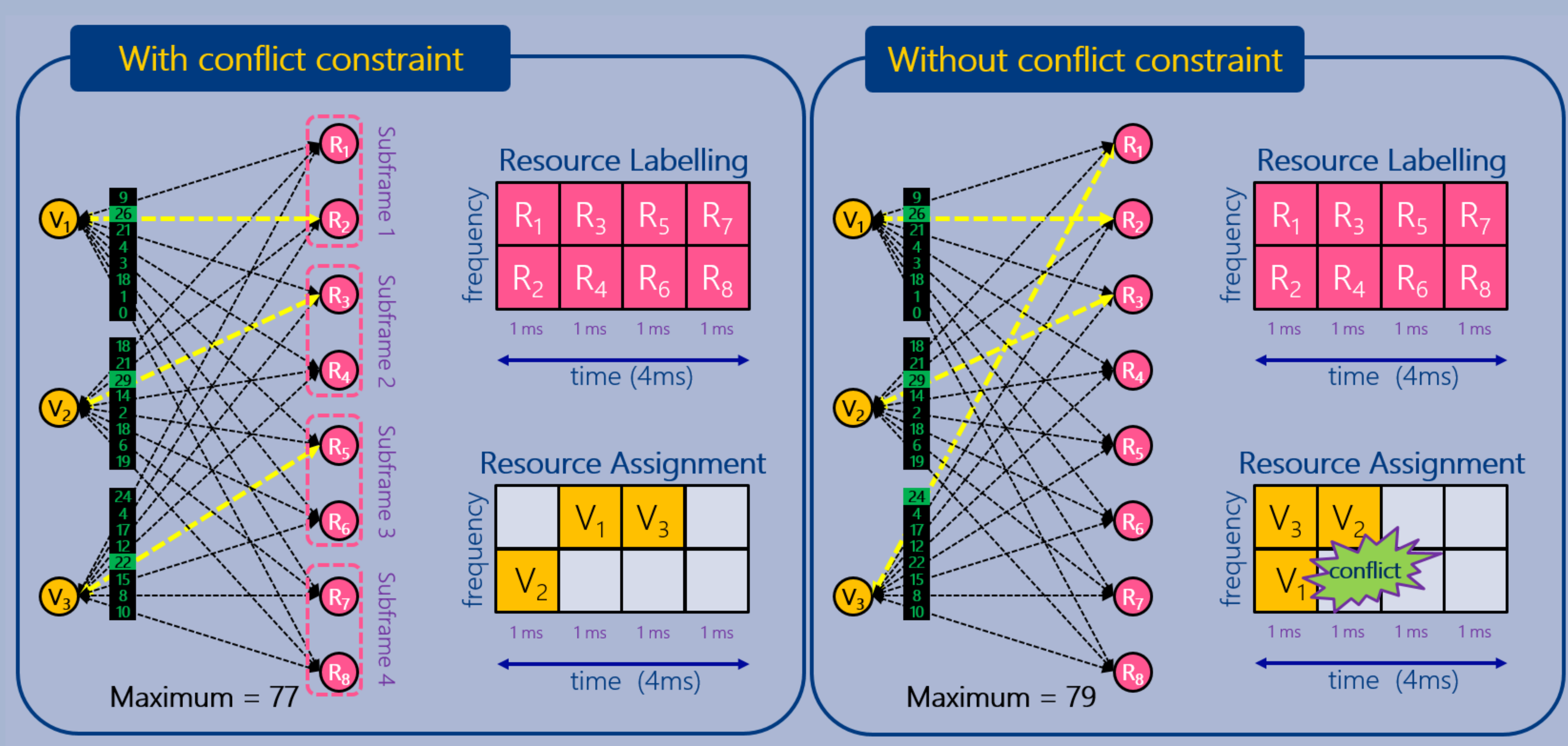


Figure 3: Resource allocation example

Simulation Results

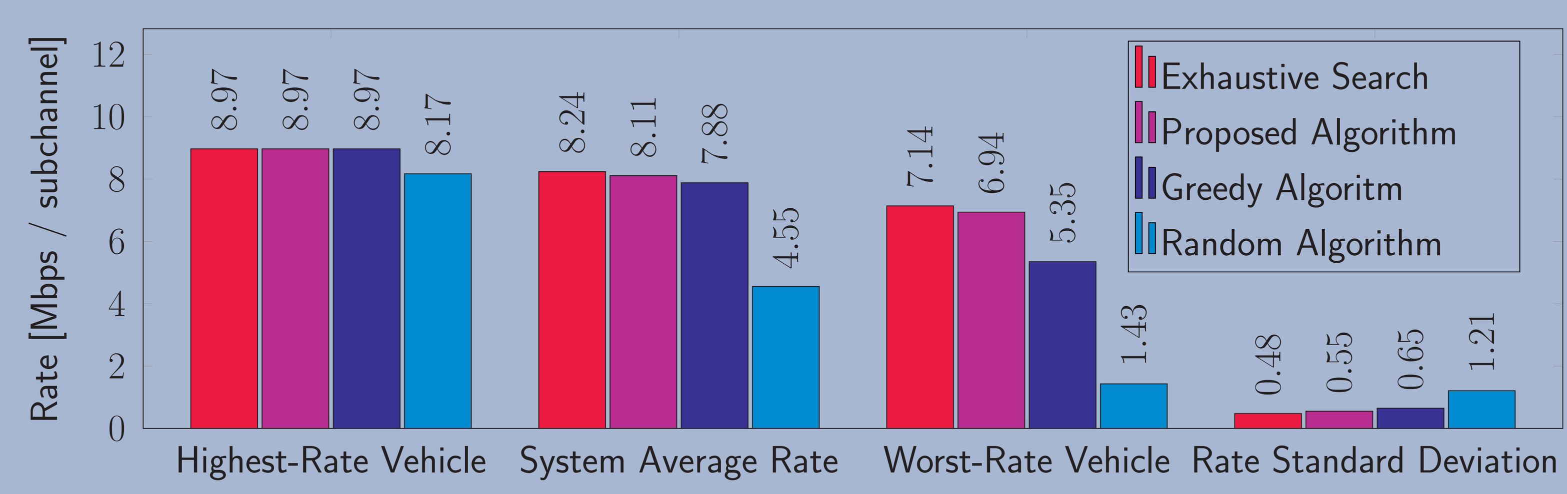


Figure 4: Data rate per vehicle

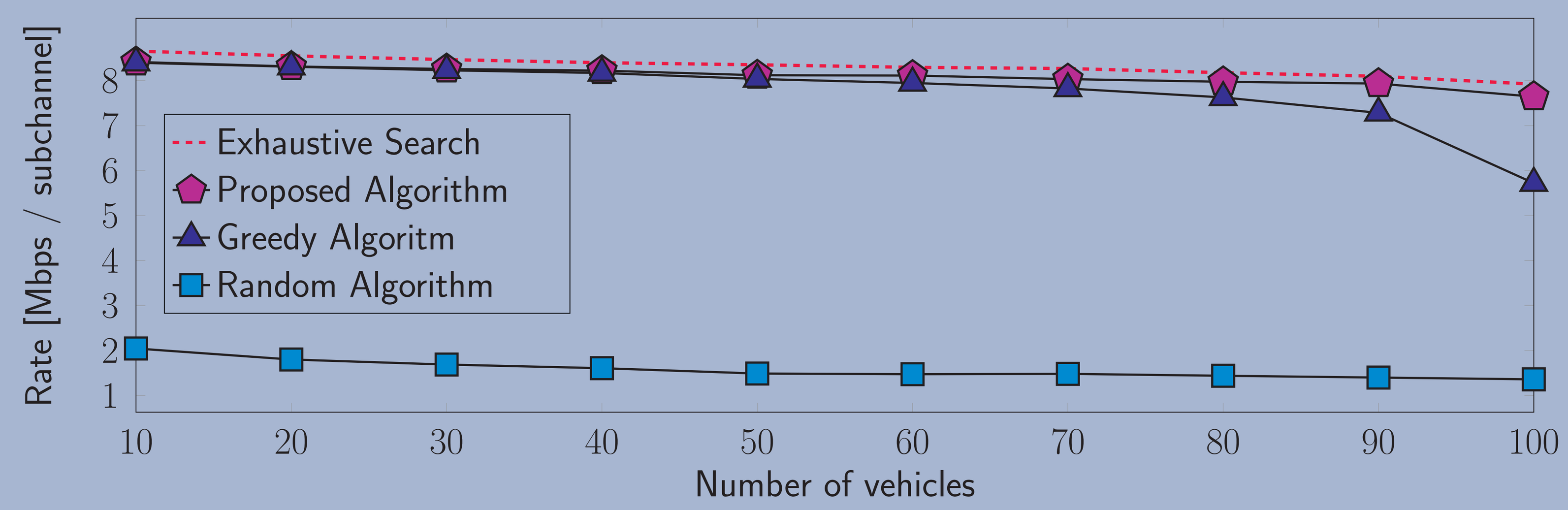


Figure 5: Worst-rate vehicle

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.
[2] "3GPP TR 36.885; Technical Specification Group Radio Access Network; Study on LTE-based V2X Services; (Release 14) v14.0.0," June 2016.
[3] L. F. Abanto-Leon, A. Koppelaar, and S. M. Heemstra de Groot, "Graph-based resource allocation with conflict avoidance for V2V broadcast communications", In Proc. of IEEE PIMRC 2017, Montreal, October 2017.
[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.