# Network-assisted resource assignment scheme for V2V broadcast communications

# Network-Assisted Resource Assignment Scheme for V2V Broadcast Communications

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## Problem Formulation

- In V2V broadcast systems, it is critical to assure that vehicles in the same communications cluster transmit in orthogonal time resources to prevent compromising data reliability and thus ultimately guaranteeing safety.
- It is also important to perform adequate management of the spectrum resources in order to leverage the system capacity.

⋆ **How can resource allocation in this scenario be accomplished with affordable computational complexity while satisfying resource conflict avoidance constraints?**

## Objectives

- Approach the scheduling problem with conflict constraints as a weighted bipartite graph.
- Prove that an optimal solution for such a problem exists.
- Examine the suitability of the proposed approach for V2V communications while avoiding resource allocation conflicts.
- Examine the system fairness.

## System Model

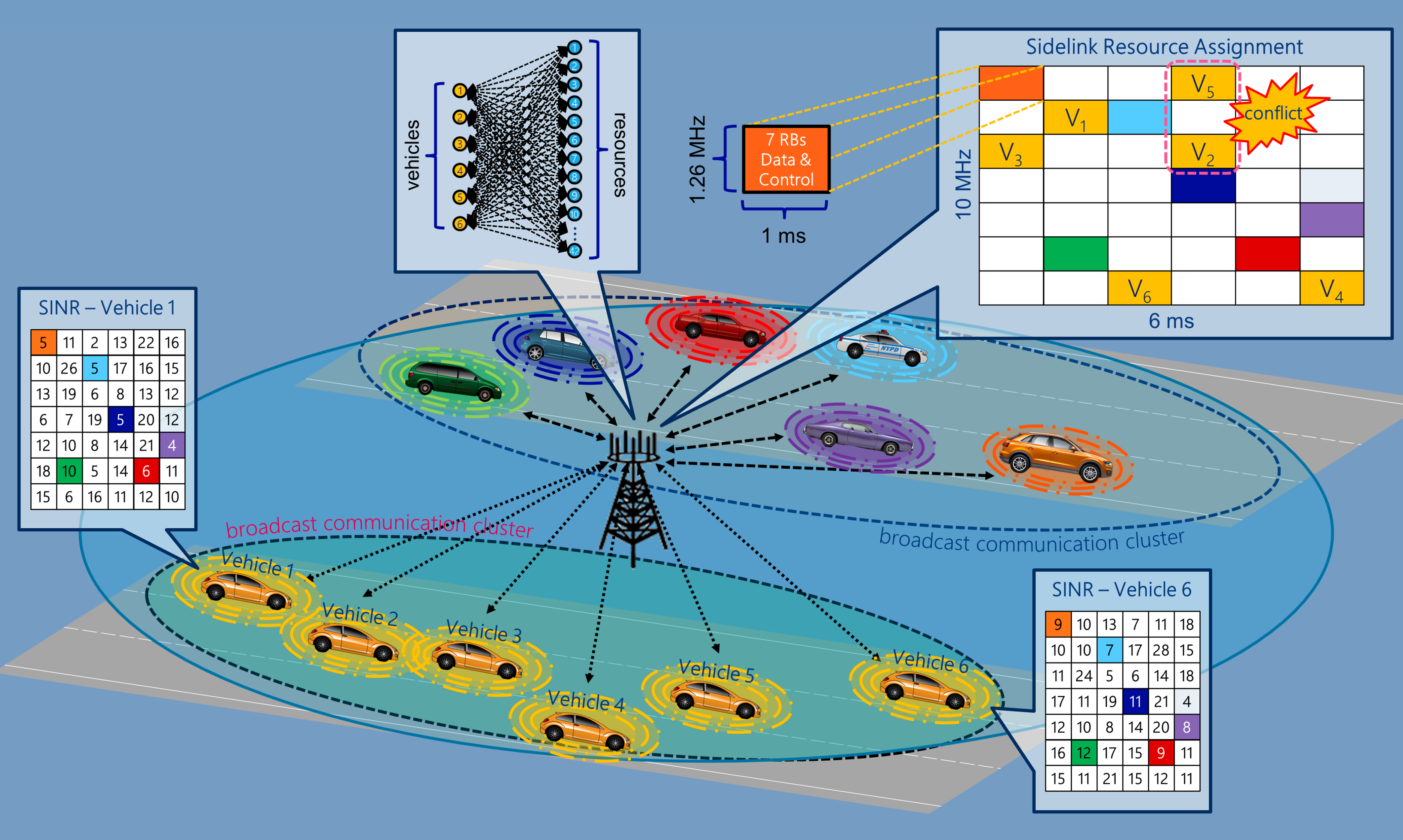


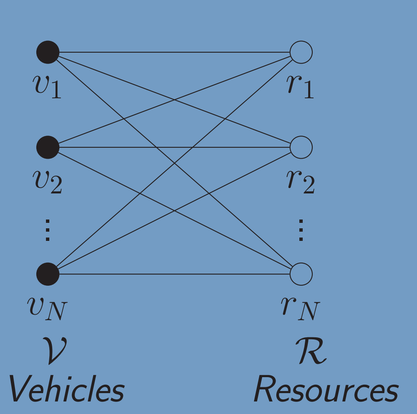

Figure 1: Vehicular Broadcast Communications via Sidelink

## Unconstrained Weighted Graph Matching

- Bipartite graph matching problem

$$\max \ \mathbf{c}^T\mathbf{x} \qquad \mathbf{c} \in \mathbb{R}^M, \mathbf{x} \in \mathbb{B}^M,$$
$$\text{subject to } \mathbf{A}\mathbf{x} = \mathbf{1} \qquad \mathbf{A} \in \mathbb{B}^{2N \times M}, M = N^2.$$

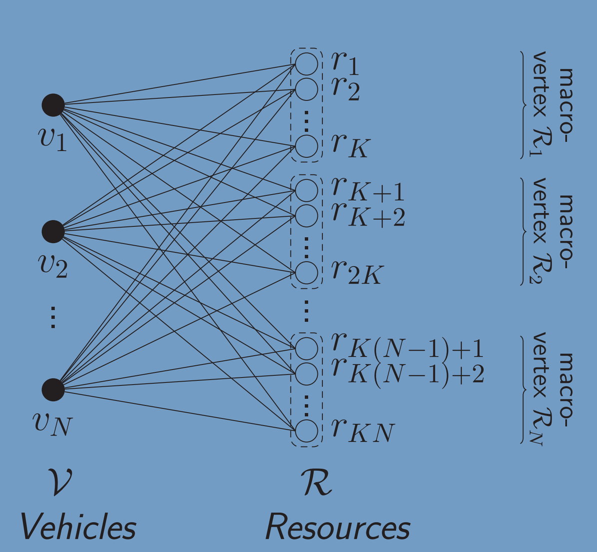
– $\mathbf{x} = [x_{1,1}, \ldots, x_{N,N}]^T$: solution vector
– $\mathbf{c} = [c_{1,1}, \ldots, c_{N,N}]^T$: capacity vector
– $c_{ij} = B \log_2(1 + \mathsf{SINR}_{ij})$: resource capacity




## Proposed Constrained Weighted Graph Matching Solution

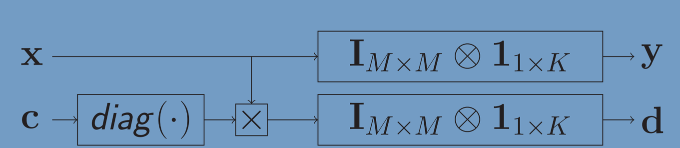
- Bipartite graph matching with conflict constraints

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




- Equivalent Problem

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




$$\mathbf{y} = (\mathbf{I}_{M\times M} \otimes \mathbf{1}_{1\times K})\mathbf{x}$$
$$\mathbf{d} = (\mathbf{I}_{M\times M} \otimes \mathbf{1}_{1\times K}) diag(\mathbf{c})\mathbf{x}$$

## Results

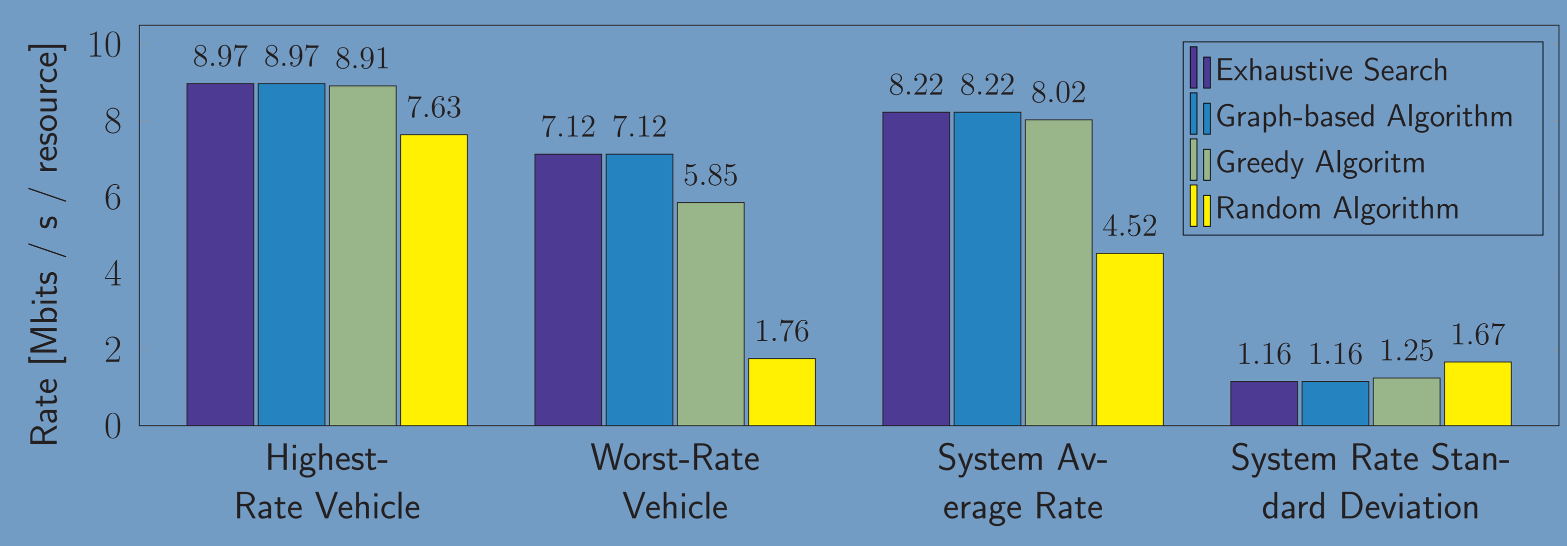



Figure 2: Vehicles Data Rate

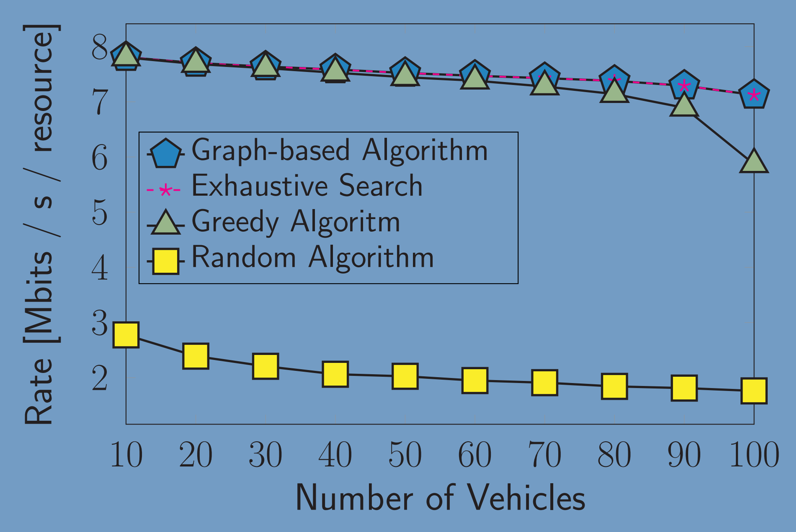



Figure 3: Worst-rate vehicle

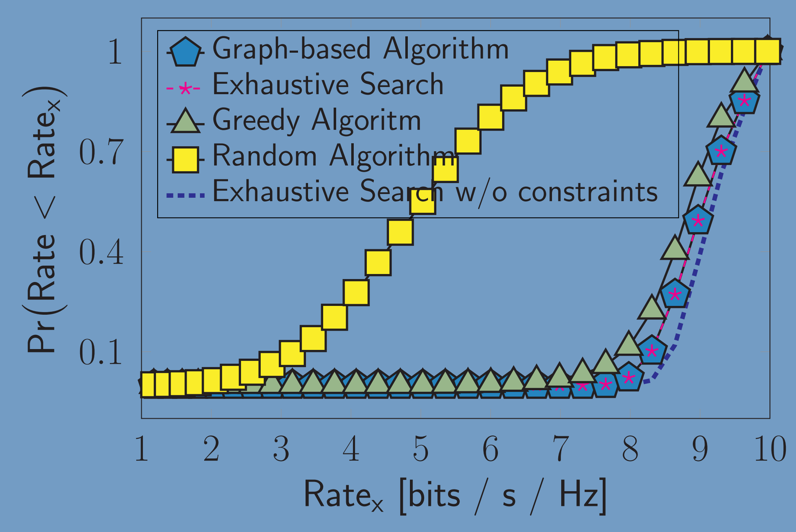



Figure 4: Cumulative Distribution Function

## Example: Resource Allocation Conflict

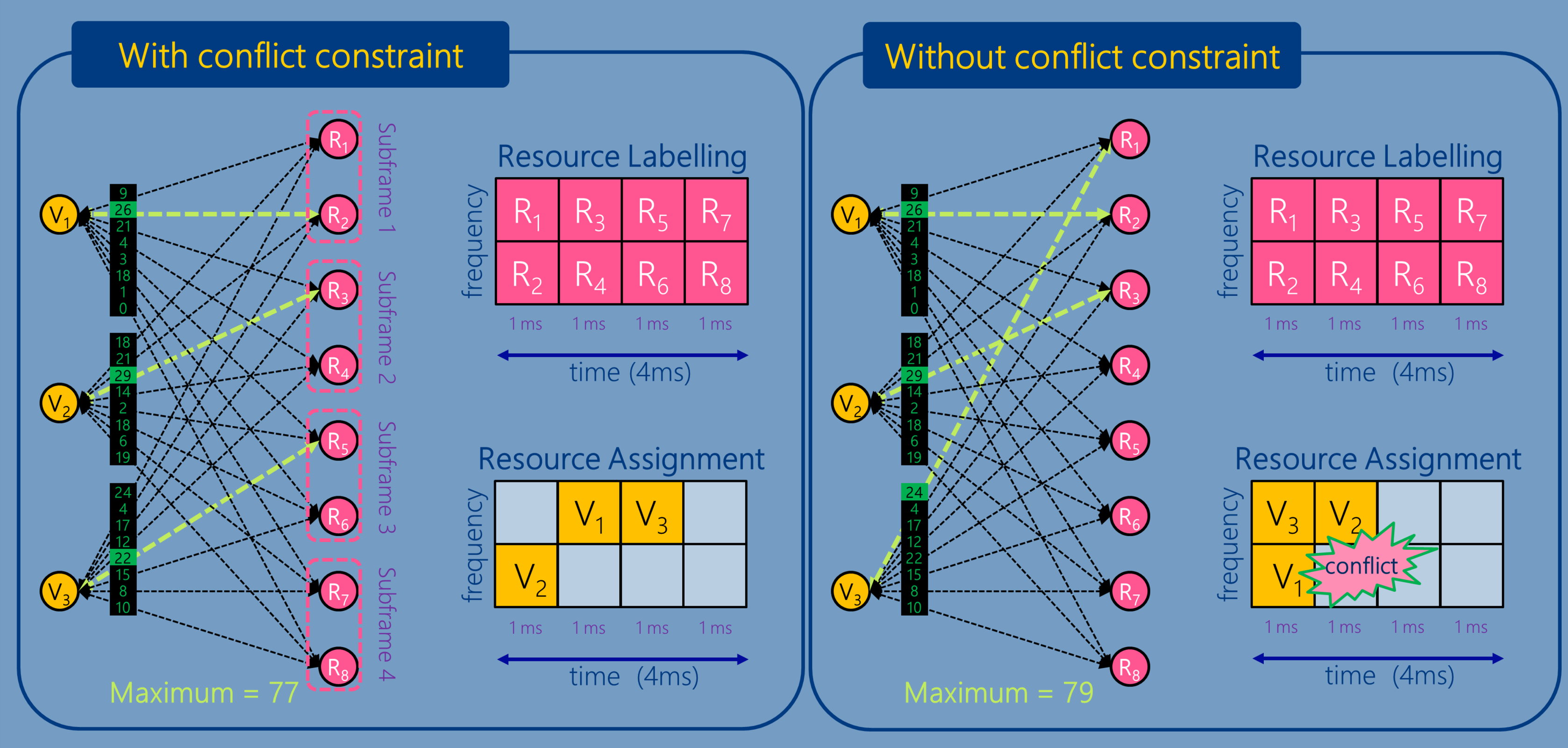



Figure 5: Resource Allocation Example

## Contributions

- Kuhn-Munkres [1] is a computationally efficient method for solving matching problems in bipartite graphs. However, due to additional time orthogonality constraints, the resultant problem is not directly approachable by the aforementioned method. In our solution, vertices conflicting among each other have been aggregated into macro-vertices yielding a resultant graph which is solvable by Kuhn-Munkres.
- Vertex aggregation cuts down the number of effective vertices and consequently narrows the amount of potential solutions without affecting optimality. The envisaged approach can attain an optimal solution at the same computational expense as the unconstrained graph matching.
- We show through simulations that our approach is capable of providing fairness among all vehicles, especially in scenarios with high vehicle density.

## Conclusions

- We have presented a novel resource allocation algorithm for V2V communications considering conflict constraints that must be enforced.
- We were able to transform the original problem into a simplified form by means of two approaches and still we were able to attain optimality.
- In future work, we will consider $(i)$ power control and $(ii)$ the assumption that some vehicles may belong to more than one cluster simultaneously.

## References

[1] 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.