# Radio Resource Allocation for Cellular V2X Communication

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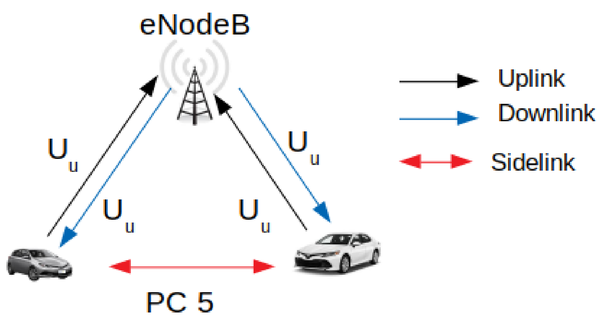
## Problem Statement

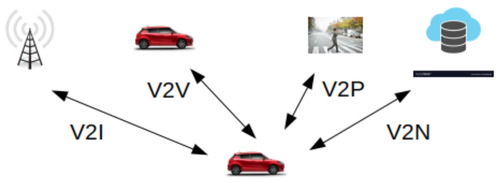
The exchange of safety critical information among vehicles (V2V), with pedestrians (V2P) and with the infrastructure (V2I) requires the communication system to support heterogeneous traffic types in a dynamically changing environment. This poses tremendous challenges on the allocation of radio resources in terms of latency and reliability of the data transmission. This work focuses on development of analytical approaches to seamlessly switch between the two resource allocation modes for Cellular-V2X: in-coverage and out-of-coverage mode by optimizing the radio link parameters such as signal strength and traffic load.

## Cellular-V2X

The cellular interface $U_u$ is responsible for V2N communication and the PC5 interface handles V2V,V2P and V2I (road side unit) sidelink communication.

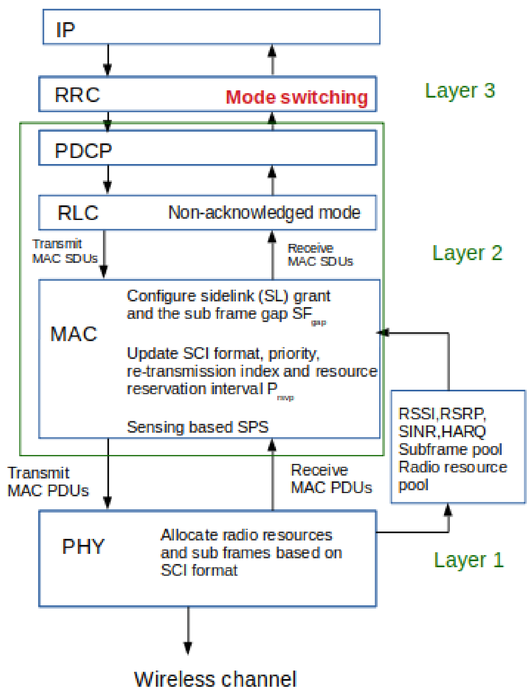



V2X application scenarios




## Protocol Stack

**Simulation Framework OMNET++**




## Evaluation Parameters

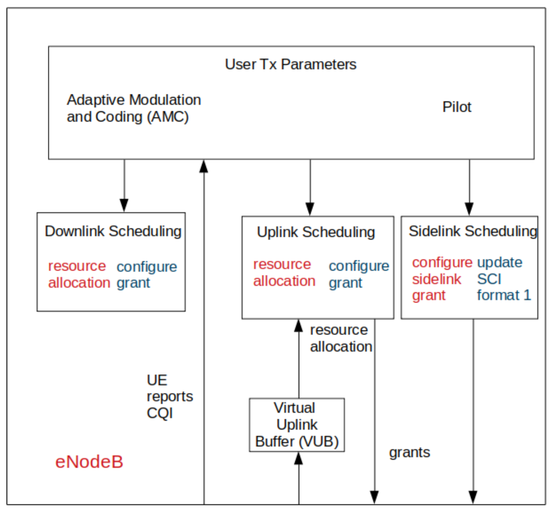
The impact of the key performance indicators (KPIs) to be evaluated by simulations are listed below.

- Mode switch latency
- Synchronization latency
- End-to-end delay
- System throughput
- Packet success ratio
- Packet inter-arrival time
- Node miss ratio

## Resource Allocation Modes for Sidelink Communication

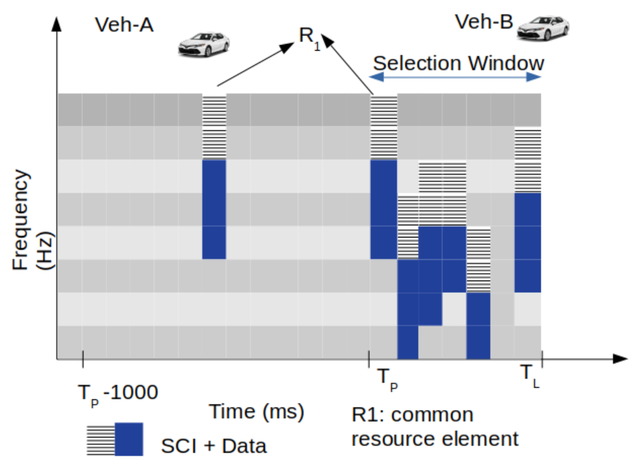
### 1. In-Coverage Mode (Mode 3)

- Existence of cellular coverage
- Centralized scheduling




### 2. Out-of-Coverage Mode (Mode 4)

- Complete absence of network coverage
- Sensing-based semi persistent scheduling (SPS)



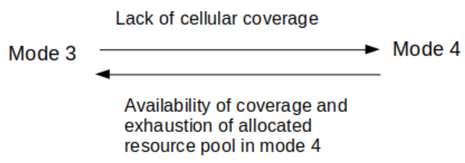

## Analytical Models: Mode Switching Strategies

Defining a transmitter-receiver pair $(i, j)$, the cost function for a chosen resource-allocation mode $n$ at time $t$ can be described as,

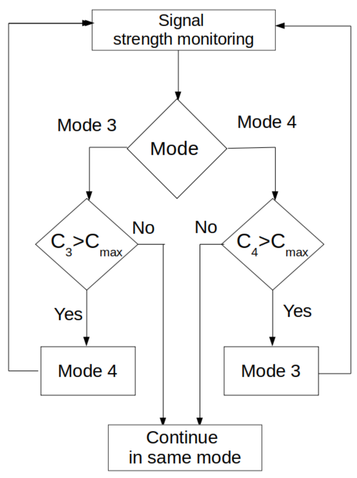
$$C_{i,j,n}(t) = \sum_{\forall i,j,n} w_{i,j,n} Q_{i,j,n}(t)$$

where $w_{i,j,n}$ is the weight co-efficient and $Q_{i,j,n}(t)$ is the radio link parameter chosen for optimization.

### 1. Forced switching




### 2. Signal strength based switching



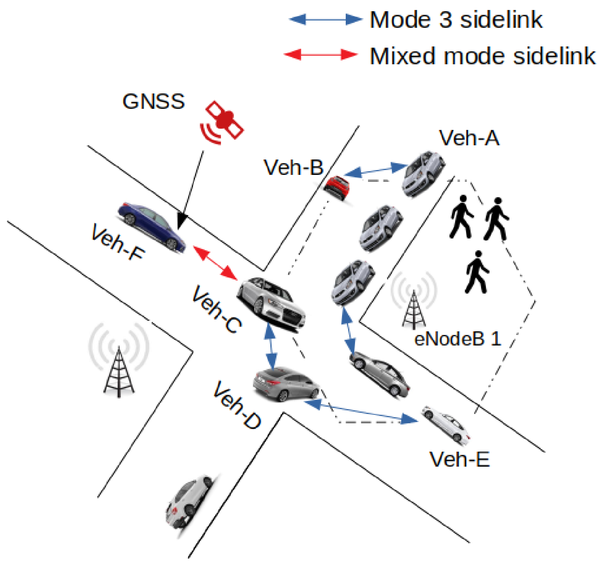

The weighted cost function $C_n(t)$ for the chosen mode $n$ based on the Signal-to-Interference Noise Ratio (SINR) contributions is given by,

$$C_n(t) = min \sum_a w_{a,n} I_{a,n}(t)$$

$I_{a,n}$: total interference resulting from inter-symbol interference (ISI), inter-carrier interference (ICI), adjacent channel interference (ACI) and additive white gaussian noise (AWGN).

### 3. Load based switching

**Scenario**: Veh-F (mode 4) wants to communicate with Veh-C (mode 3) which has not yet been synchronized by eNodeB 1.




A load based cost function $L_{i,n}$ for optimal distribution of traffic between the two modes can be formulated as,

$$L_{i,n} = min \left\{ \sum_{\forall i} w(i) \frac{\rho_{i,n}}{z_{i,n}} \right\}$$

subject to $\rho_{i,n} \leq z_{i,n}$

The index of eNodeB or GNSS source is denoted by $i$. The traffic load is given by $\rho_{i,n}$ and $z_i$ is the total available bandwidth depending on the resource allocation mode $n$.