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Machine Learning for the Dissemination of CAMs in C-V2X Communications

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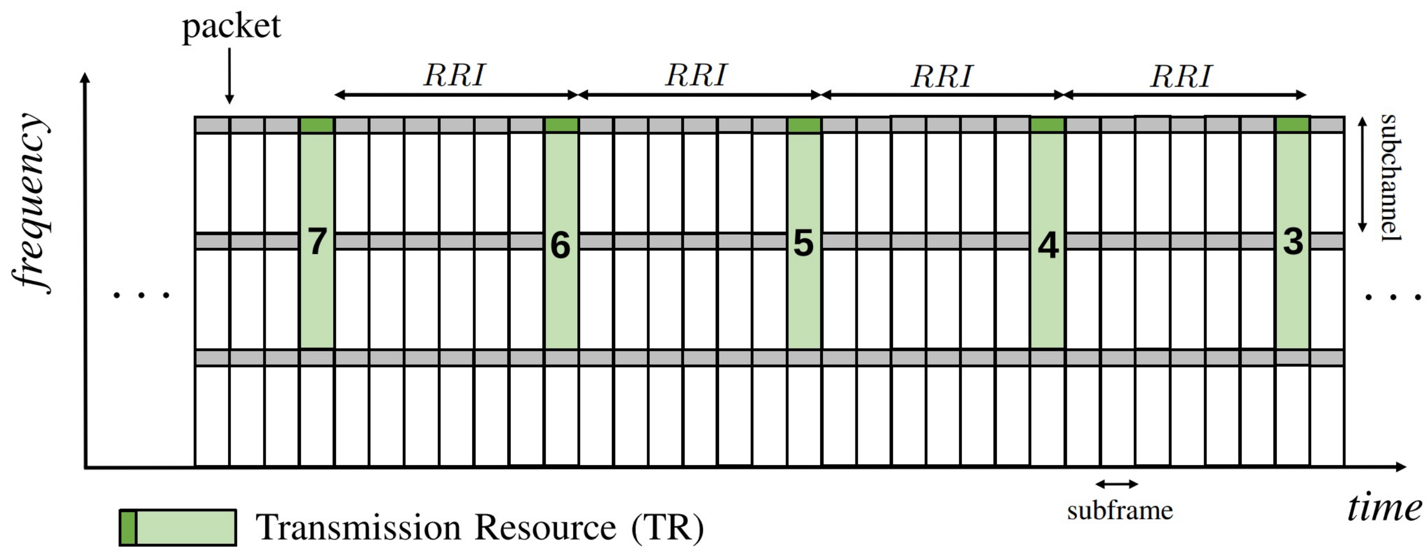
Outline

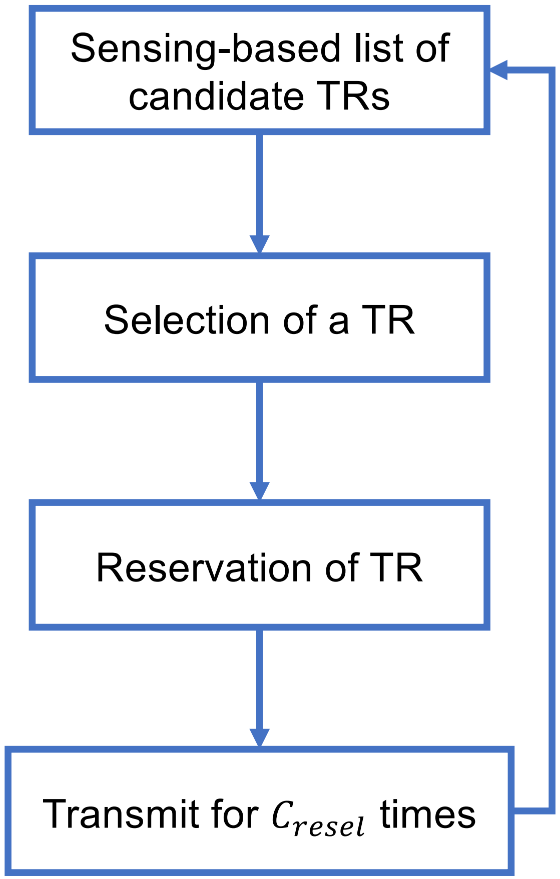
- Overview of LTE-V2X Mode 4
    - Impact of Aperiodic Traffic
- ETSI-generated CAMs
- Machine Learning to predict CAM Traffic
- Numerical Results
- Conclusions

Overview of LTE-V2X Mode 4

- LTE-V2X is the current Cellular Vehicle-to-Everything (C-V2X) communication standard
  - Designed to support safety-oriented applications
  - Includes a distributed resource allocation mode known as **Mode 4**
  - In Mode 4, vehicles *autonomously* select and reserve Transmission Resources (TRs)
    - Contention-based approach



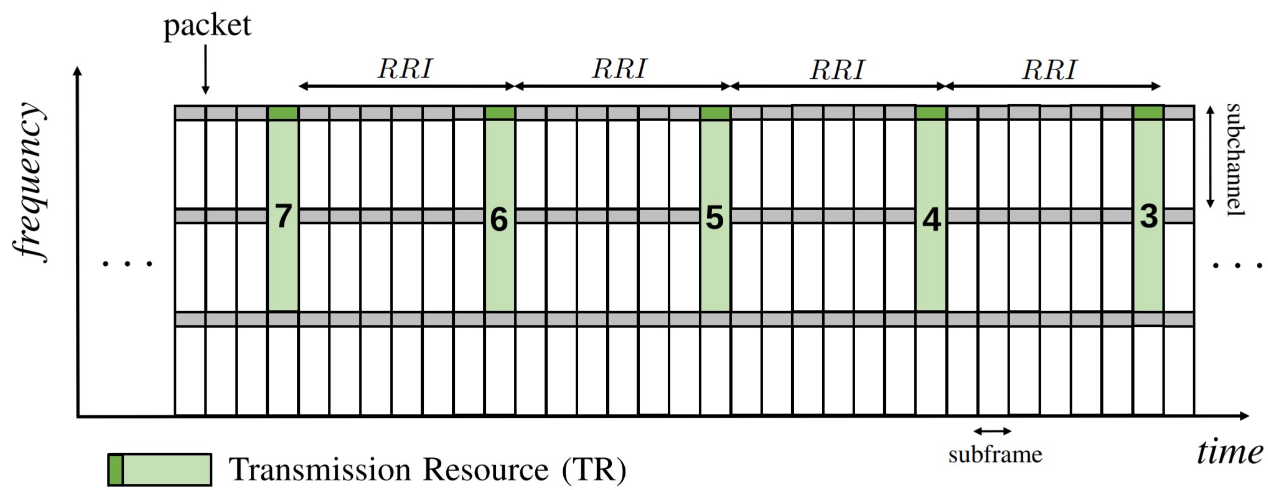
Overview of LTE-V2X Mode 4



- Reservations of Transmission Resources (TRs) are periodic
  - Time between consecutive reservations:

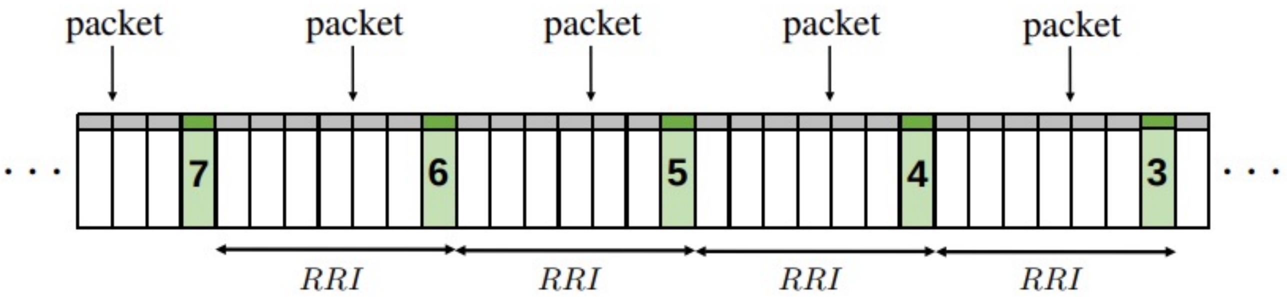
    Resource Reservation Interval (RRI)
  - Total number of reservations:

    Reselection counter (C_{resel})

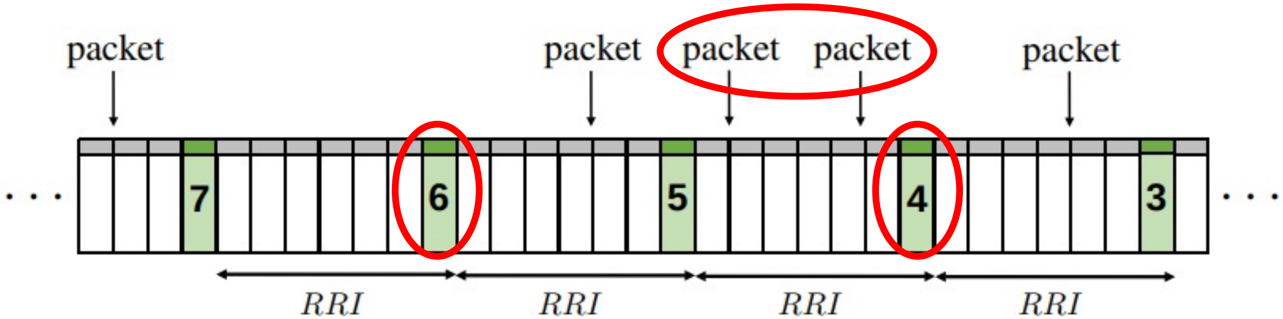


Impact of Aperiodic Traffic

- Periodic traffic:
  - RRI matches traffic periodicity

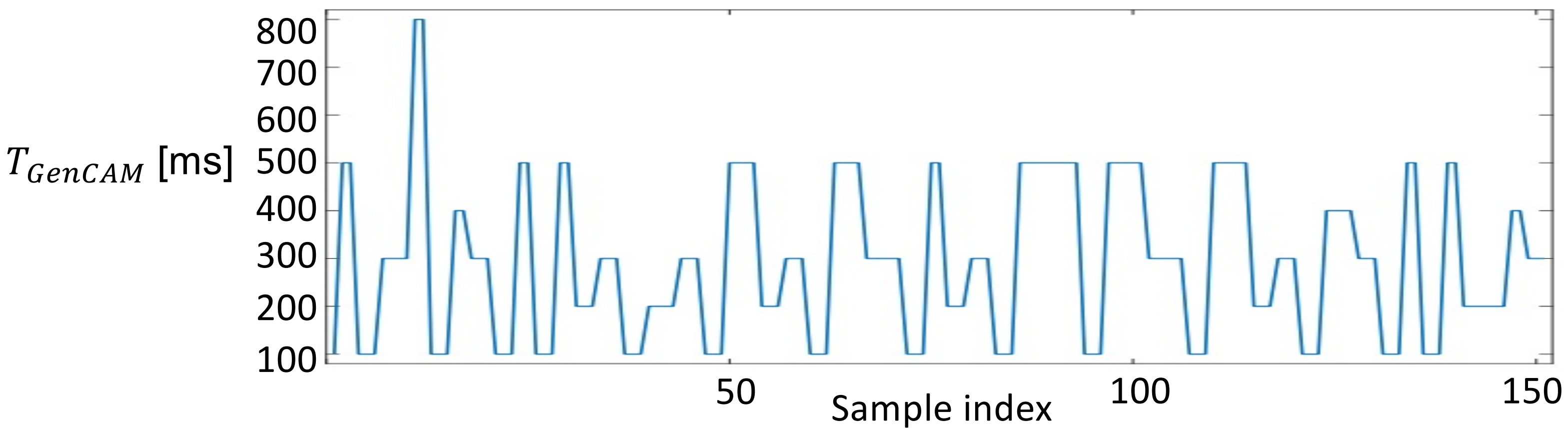


- Aperiodic traffic:
  - Inevitable mismatch between RRI and non-constant packet inter-arrival times
  - Drawbacks:
    1) Unused reservations
    2) Additional reselections



ETSI-generated CAMs

- LTE-V2X Mode 4 is designed to accommodate safety applications traffic
  - Such as Cooperative Awareness (CA) services standardized by ETSI
  - Information about the transmitting vehicle is broadcasted through
    - *Cooperative Awareness Messages (CAMs)*
- Yet, the CAMs inter-arrival time, T_{GenCAM}, depends on the generating **vehicle dynamics**:
  1. Position
  2. Speed
  3. Heading
- As a consequence, the generated traffic is **aperiodic**



Machine Learning to Predict CAM Traffic

- Can we minimize the number of unused reservations and additional reselections?
- **The idea:** dynamically adjust the resource reservation period in Mode 4
- **How:**
  - Use Machine Learning (ML) to predict future T_{GenCAM} values
    - Exploiting the strong correlation with the generating vehicle dynamics
  - Accordingly configure the RRI and C_{resel} parameters

- Model the T_{GenCAM} prediction as a multi-class classification problem
- Use the **K-Nearest Neighbors** (KNN) algorithm
- **Input features:**
  - trajectory, speed and position of the generating vehicle
  - position and speed of the preceding vehicle

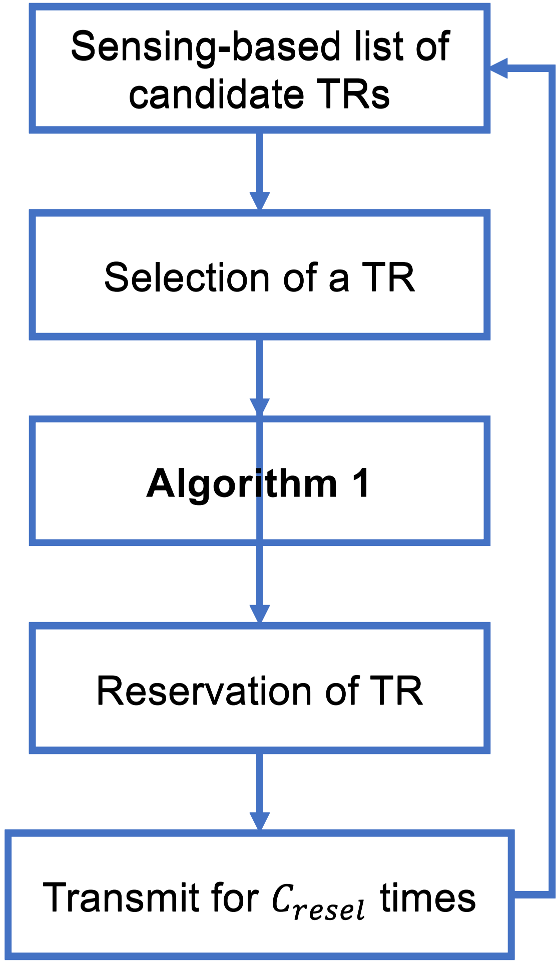
Machine Learning to Predict CAM Traffic

- A dedicated algorithm exploiting ML outputs the RRI and C_{resel} values used in the reservation phase

Algorithm 1: the proposed algorithm

Input : KNN input features
Output: RRI, C_{resel}

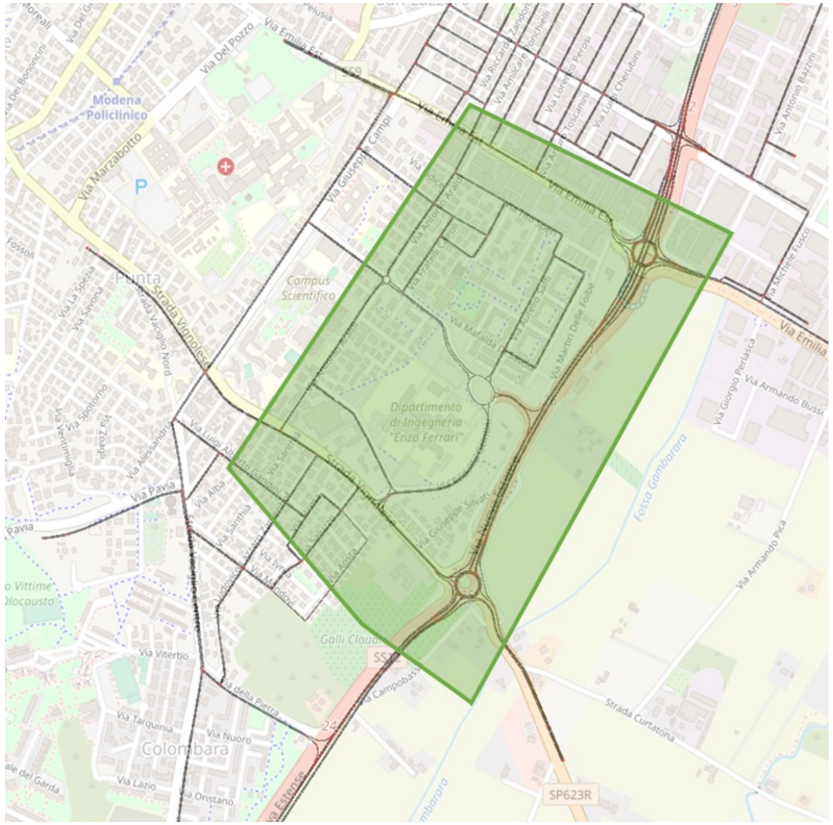
$i = 1$;
T_{GenCAM_i} = `Predict` (Input features, i);
RRI = T_{GenCAM_i};
$C_{resel} = 1$;
while $i \leq N$ **do**
    $i = i + 1$;
    T_{GenCAM_i} = `Predict` (Input features, i);
    if T_{GenCAM_i} = RRI **then**
        $C_{resel} = C_{resel} + 1$;
    else
        break;
    end
end
if $C_{resel} > 3$ **then**
    $C_{resel} = random[3, C_{resel}]$
end



Numerical Results: Simulation Environment

- **Investigated scenario:**
  - Extracted from Open Street Map (OSM) and simulated using SUMO
  - 2.5 km x 3 km area
  - 42 vehicles/km
  - Vehicles' speed ranging from $[50,100]$ km/h
- **LTE-V2X configuration:**

Parameter	Values
Channel bandwidth	10 MHz
Number of subchannels	4
MCS	QPSK 0.7
Packet size	190, 470 bytes
Occupied subchannels	1 (190), 2 (470)

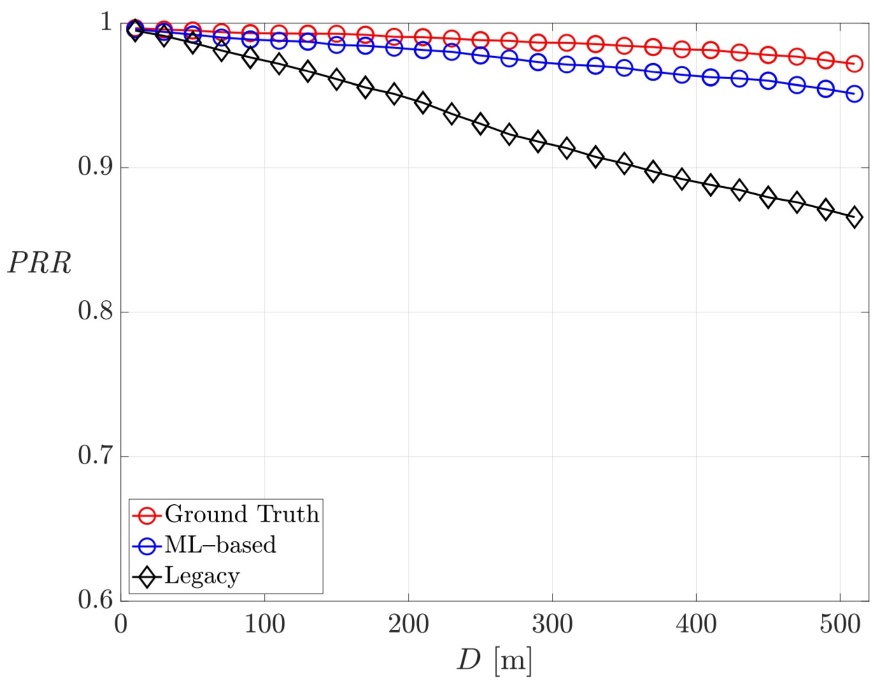


Numerical Results: Outcomes

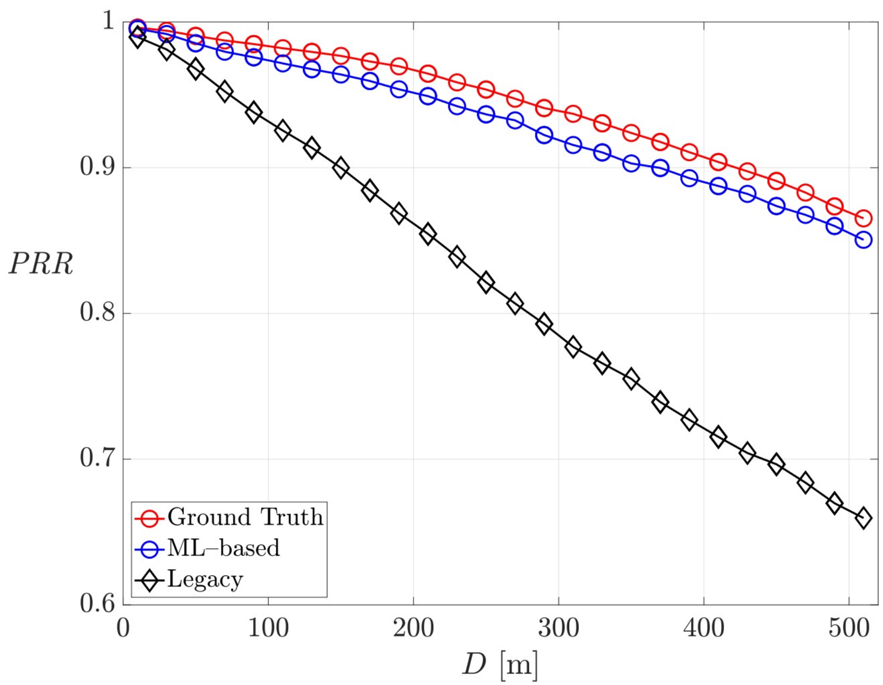
Key Performance Indicator (KPI):

- *Packet Reception Ratio* (PRR): measures the fraction of vehicles successfully receiving a packet over the total number of intended receivers

packet size $= 190$ bytes



packet size $= 470$ bytes



Conclusions

- Presented a ML-based approach to distributed CAMs using LTE-V2X Mode 4
    - Based on a limited number of features
    - Using a simple KNN algorithm
- The ML-based solution outperforms legacy LTE-V2X Mode 4

THANK YOU FOR YOUR ATTENTION