Department Project CP-301

Implementation of O-RAN in Vehicular Networks

- Dr.Brijesh Kumbani sir.

Aremandla Sujesh Gnani 2022EEB1159

Lavudya Shreekar 2022EEB1187

-The Project is done in view of these two research papers :

S.no	IEEE Links	Target achieved
1.	https://ieeexplore.ieee.org/document/8370580/	Traffic flow and vehicle mobility
2.	https://ieeexplore.ieee.org/document/10937198/	Implementation of O-RAN in vehicular Networks

Abstract :

- We built *mobi-**O-RAN***, a smart system combining Open RAN (O-RAN) with Vehicle-to-Everything (V2X) to make car networks better.
- It tackles issues like slow connections and poor resource use in busy traffic.
- Tested in a virtual city, it boosts speed, reliability, and connectivity.
- This could power 5G and future 6G car systems, but more work is needed.

Introduction

- V2X lets cars talk to each other, roads, and networks for safer driving and smoother traffic.
- Old network systems (RANs) aren't flexible enough for V2X's fast-paced needs.
- O-RAN offers a programmable way to control networks, perfect for cars.
- Our project, *mobi-O-RAN*, blends O-RAN with V2X to create a smarter car network.

Objectives

- Design *mobi-O-RAN* to make V2X faster and more reliable.
- Solve four big V2X problems: beam alignment, resource sharing, car-to-car links, and real-time mapping.
- Test it in simulations to see if it beats standard 5G methods.
- Find what's next for making it ready for future networks.

Simulation Process :

1. **SUMO Real-Time Simulation**:
   - SUMO, an open-source microscopic simulator, models individual vehicles and supports real-time urban traffic scenarios using OpenStreetMap data (e.g., Kenitra's 4.3 km network).
   - Facilitates dynamic traffic simulation for planning and traffic light optimization.
2. **Vehicle Traffic Flows**:
   - Kenitra simulations modeled 748 vehicles over 750 ms, capturing peak-hour flows (7:30–9:30 AM, 11:30 AM–2:30 PM).
   - Network included 4801 priority junctions, reflecting realistic urban traffic patterns.
3. **Time Delays**:
   - Total departure delay: 41 ms; waiting time: 16,414 ms; average travel time: 350,135 ms for 748 vehicles.
   - High travel times suggest congestion, requiring real-time optimization.
4. **SNR/SINR in Vehicular Networks**:

- Mobi-O-RAN's xApp for V2V link selection achieved full connectivity at high SNR (25 dB) vs. 25% for 3GPP standards, though increased hops raised latency.
- Beam management xApp reduced overhead by 50%, improving SINR and spectral efficiency.

5. **O-RAN Implementation Research:**
   - Research on Open RAN implementation for V2X is ongoing but incomplete, integrating SUMO, OMNeT++, and Veins to simulate and analyze O-RAN in vehicular networks.
   - Further implementation is planned to validate and enhance O-RAN-based solutions for real-world V2X scenarios.

Simulation Results for SUMO Traffic Flow

Open street map of **Edinburgh** in **SUMO**

TABLE II. SIMULATIONS TESTS OF SUMO (Edinburgh)

Node Type	Value
Unregulated junctions	0
Dead-end junctions	0
Priority junctions	520
Right-before-left junctions	151

Network boundaries	Value
Position	620.730000 1063.595000
Original boundary	0.00,0.00,2127.19,1241.46
Applied offset	-486447.84,-6199384.28
Converted boundary	N/A

	Description	Total
0	Number Of Vehicles	450
1	Departure Delay	2583000 (ms)
2	Waiting Time	148444000 (ms)
3	Travel Time	222734000 (ms)
4	Travel Length	470271 (m)

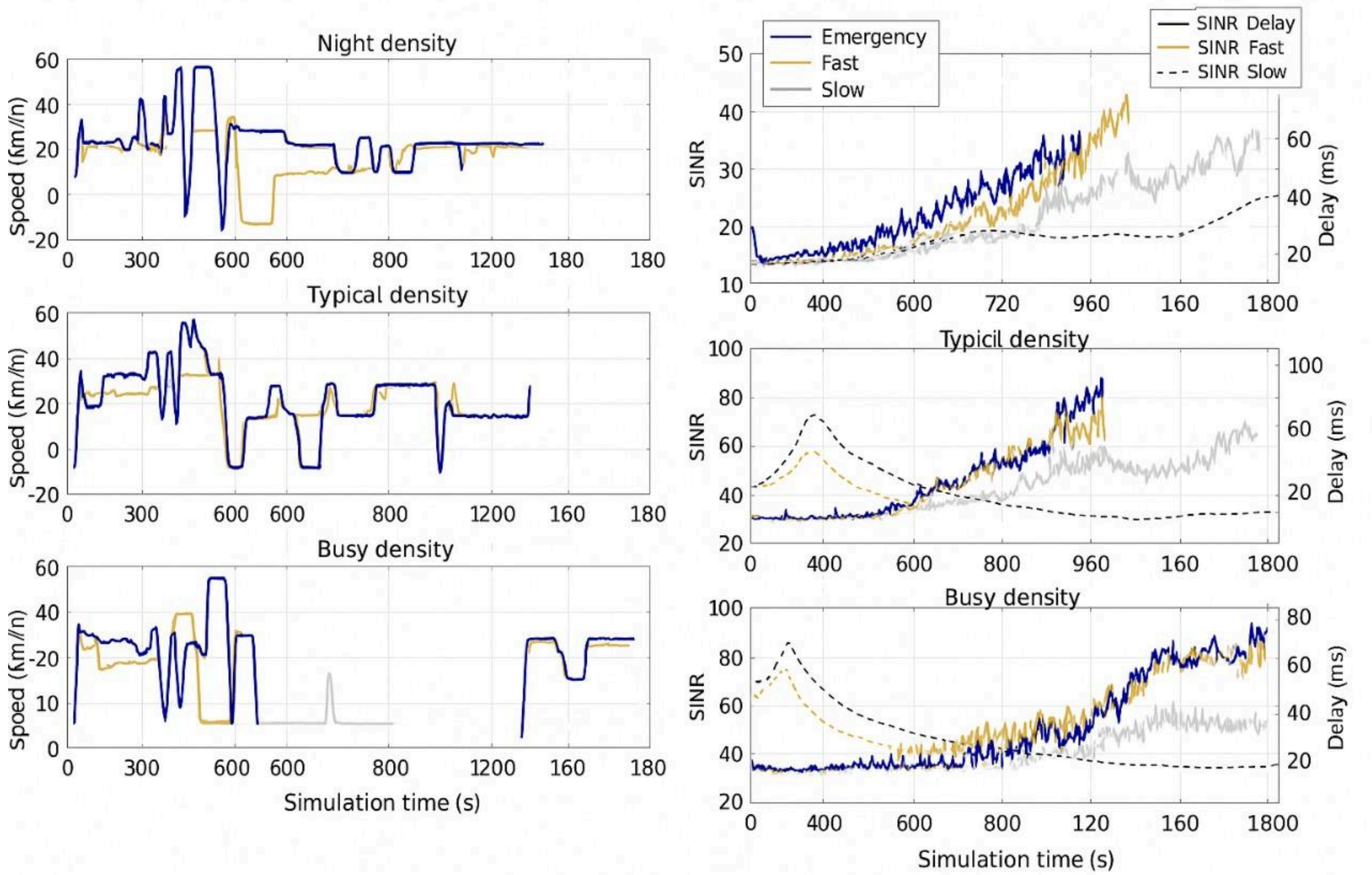
- **Stats**: Depart Delay: 2,583,000 ms; Waiting Time: 148,444,000 ms; Travel Time: 222,734,000 ms; Travel Length: 4,702,271 m.
- **Nodes**: 520 priority junctions, 151 right-before-left junctions, no unregulated/dead-end junctions.
- **Boundaries**: Position (620.73, 1063.59); Original Boundary (0, 0, 2127.19, 1241.46); Applied Offset (-486447.84, -6199384.28).
- **Relevance**: Reflects the paper's high-density (Busy) scenario, showing increased delays and aligning with SUMO-based urban mobility analysis.

Simulation Results of Traffic Densities

TABLE II: Mobility layer configuration.

	Vehicles' configuration	
Class	**acceleration** (m/s^2)	**max speed** (km/h)
Emergency	3.5	80
Fast	3.5	40
Slow	3.5	20
	Vehicular traffic density	
Status	**density** $(veh./km\ road)$	**difference** (%)
Night	25	-37.5
Typical	40	0
Busy	75	87.5

- Defined three scenarios: Night (low density), Typical (moderate density), and Busy (high density).
- Included three vehicle types: Emergency (blue line), Fast (yellow line), and Slow (gray line).
- Recorded speed data (km/h) for each vehicle type across all scenarios.
- Created three line graphs, one per density, with time (0-600s) on the x-axis and speed (0-60 km/h) on the y-axis.
- Added a legend to identify vehicle types and labeled the figure as .Vehicles' speed over time for different densities."
- Aimed to compare how density impacts the speed of different vehicle types.



- Shows more extended simulation periods, potentially capturing more long-term trends and variability.
- Speed plots show negative values, which may indicate reverse movement or errors.
- In both simulated and reference paper plots, delay generally increases over time, especially for 'Emergency' and 'Fast'

vehicles, but the simulated show this trend more clearly due to the longer simulation.

- Delay increases in V2X networks because higher vehicular density leads to more simultaneous transmissions, causing congestion, queuing, and especially more HARQ (Hybrid Automatic Repeat Request) retransmissions when packets are lost or corrupted, each adding extra delay for every retransmission cycle.
- Higher traffic density causes more packet errors and HARQ retransmissions, directly increasing communication delay in V2X networks.

Problems faced during project :

- **Modifying .net.xml to designate the rightmost lane of selected route edges as an emergency lane (restricted to vClass="emergency") was hard**
- **Manual tasks, such as selecting edges in SUMO-GUI, editing .rou.xml files to add Emergency, Fast, and Slow vehicles, and verifying lane usage, were time-intensive.**
- **Synchronizing SUMO, OMNeT++, Veins, Sim 5G, and Inet requires precise configurations, with risks of TraCI connection failure and version mismatches**
- **Large networks and high vehicle counts can cause long simulation times or crashes, demanding optimized setups.**

Further implementation of O-RAN :

- Extend the SMART framework by implementing Open RAN (O-RAN) in vehicular networks for enhanced V2X communication.
- Integrate O-RAN's open architecture using SUMO and OMNeT++ to boost network flexibility and performance.
- Simulate O-RAN in urban scenarios (Angers, France) with Emergency, Fast, and Slow vehicles across Night, Typical, and Busy densities.
- Utilize O-RAN's intelligent controllers (RIC) to optimize resource allocation, minimize delay, and enhance SINR and SNR.
- Solve four big V2X problems: beam alignment, resource sharing, car-to-car links, and real-time mapping.

Conclusion of the project :

- **Researched O-RAN's role in vehicular networks for improved V2X communication.**
- **Implemented SUMO to simulate vehicular mobility with Emergency, Fast, and Slow vehicles.**
- **Analyzed vehicle behavior across Night, Typical, and Busy densities.**
- **Examined time delays, with Busy density showing up to 46 ms delays.**
- **Studied SNR and SINR, noting degradation in denser traffic (SINR near 0 dB in Busy scenarios).**
- **Conducted simulations to validate findings but couldn't implement O-RAN due to issues downloading older software versions.**

- **Plan to complete O-RAN integration in future work to optimize V2X performance.**