5G-based Vehicular Infrastructure for Smart Traffic Intersections
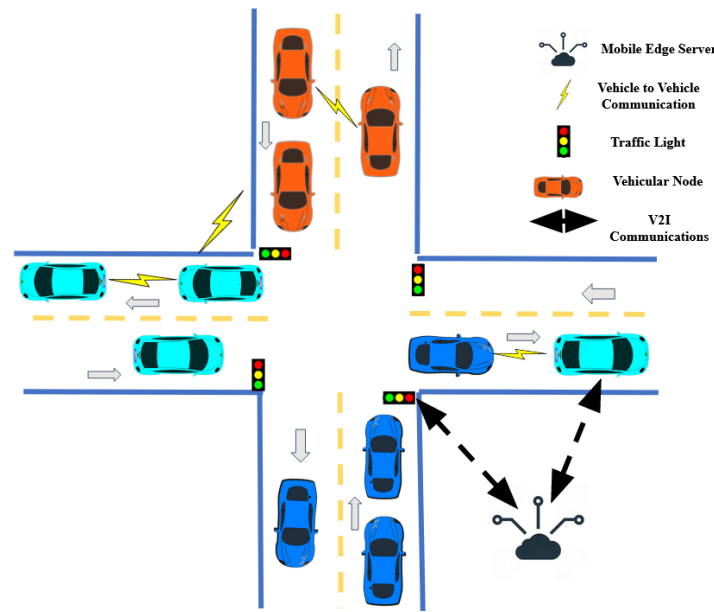
Commonwealth Cyber Initiative

Problem Statement

Develop effective 5G-based communications to facilitate automatic management of the traffic intersection and analyze candidate network architecture options for 5G-based vehicular infrastructure.
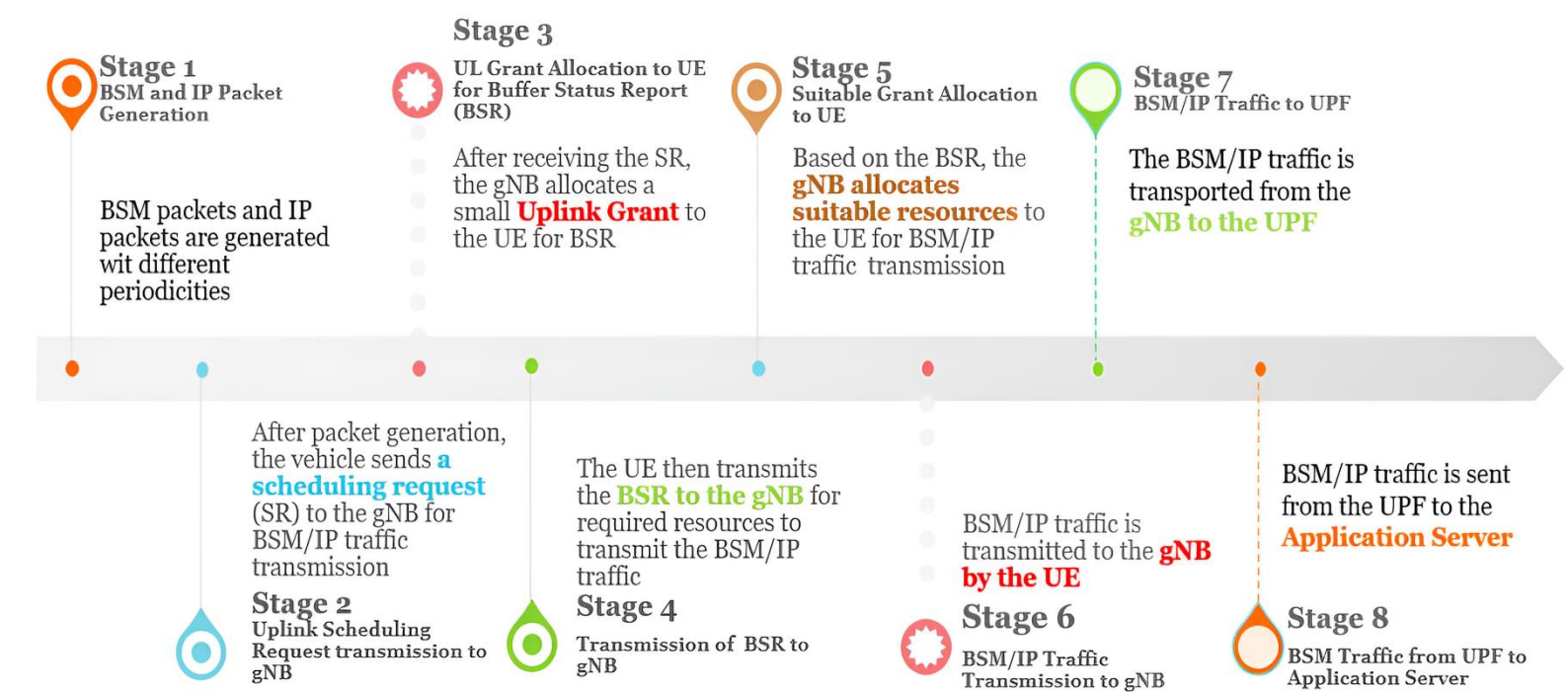
Research Goals and Innovations

Research Goals:
- Develop a 5G based efficient and reliable traffic intersection for regular and autonomous vehicles.
- Identify architectures that support 5G NR V2X communications
- Evaluate the performance of these candidate architectures and determine advantages and disadvantages of these architectures.
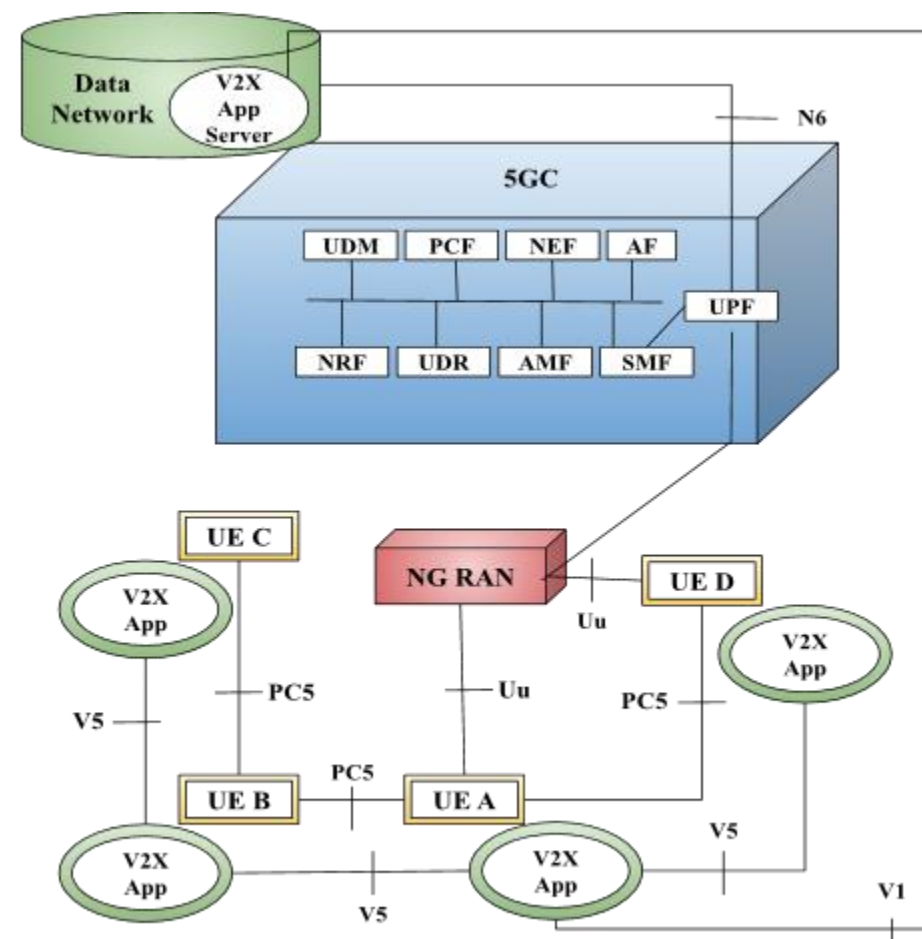
Innovations:
- Hybrid IAB and Integrated Edge Computing and V2X Application Server (VAS) in support of smart traffic intersections
- Distributed V2X Application Server with new inter-VAS interface
- New type of RSU UE with local VAS and gNB-like scheduling
- Extension of Network Slicing to include traffic not traversing the radio and core networks
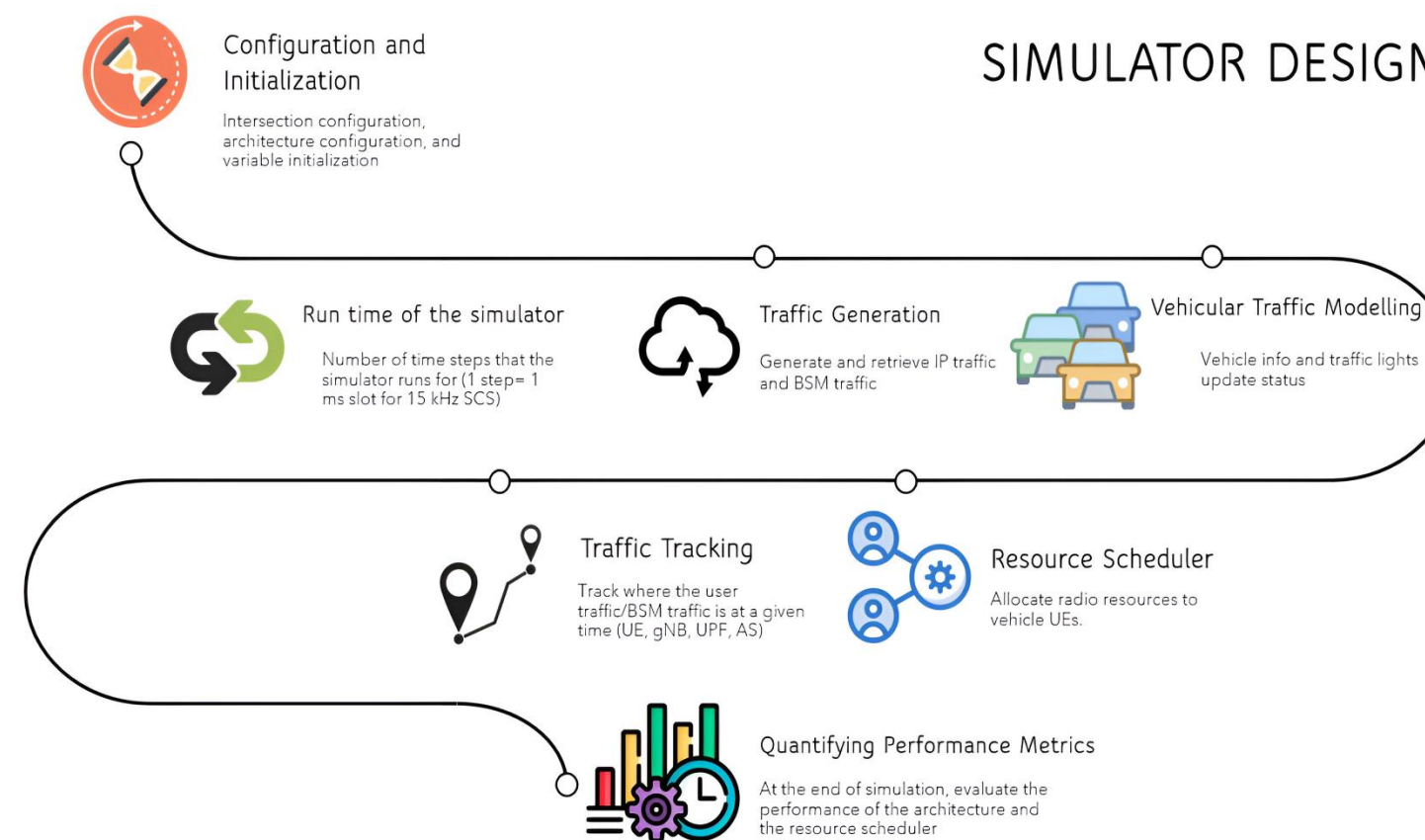
Timeline for Uplink Data Transfer

Stage 1 BSM and IP Packet Generation — BSM packets and IP packets are generated wit different periodicities

Stage 2 Uplink Scheduling Request transmission to gNB — After packet generation, the vehicle sends a scheduling request (SR) to the gNB for BSM/IP traffic transmission

Stage 3 UL Grant Allocation to UE for Buffer Status Report (BSR) — After receiving the SR, the gNB allocates a small **Uplink Grant** to the UE for BSR

Stage 4 Transmission of BSR to gNB — The UE then transmits the **BSR to the gNB** for required resources to transmit the BSM/IP traffic

Stage 5 Suitable Grant Allocation to UE — Based on the BSR, the **gNB allocates suitable resources** to the UE for BSM/IP traffic transmission

Stage 6 BSM/IP Traffic Transmission to gNB — BSM/IP traffic is transmitted to the **gNB by the UE**

Stage 7 BSM/IP Traffic to UPF — The BSM/IP traffic is transported from the **gNB to the UPF**

Stage 8 BSM Traffic from UPF to Application Server — BSM/IP traffic is sent from the UPF to the **Application Server**

Architectural Enhancements

Baseline V2X Architecture

Candidate Architectures:

- **IAB Architecture.** gNB-DU as the RSU and gNB-CU in a local Data Center.
- **Hybrid IAB and Edge Computing Architecture.** gNB-DU as RSU and gNB-CU in a local Data Center/Cloud with UPF and Edge Computing Server (ECS) acting as V2X Application Server (VAS).
- **Local and Centralized VAS.** gNB as RSU with local VAS/ECS. Use of UE-VAS interface for inter-VAS communications.
- **Customized RSU UE.** UE as a Local VAS and/or gNB Resource Scheduler.

Traffic Intersection Simulator

SIMULATOR DESIGN

Configuration and Initialization — Intersection configuration, architecture configuration, and variable initialization

Run time of the simulator — Number of time steps that the simulator runs for (1 step= 1 ms slot for 15 kHz SCS)

Traffic Generation — Generate and retrieve IP traffic and BSM traffic

Vehicular Traffic Modelling — Vehicle info and traffic lights update status

Traffic Tracking — Track where the user traffic/BSM traffic is at a given time (UE, gNB, UPF, AS)

Resource Scheduler — Allocate radio resources to vehicle UEs.

Quantifying Performance Metrics — At the end of simulation, evaluate the performance of the architecture and the resource scheduler
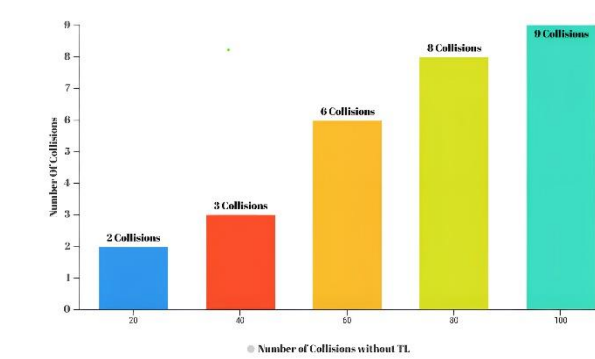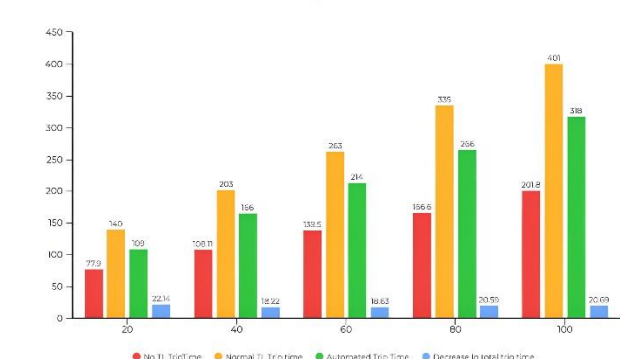
Performance Metrics

Collisions Without Traffic lights

Total Vehicular Trip Time

Metrics for Evaluating Candidate Architectures
1. End-to-End Delay (UE to Application Server)
2. Backhaul Bandwidth Requirements
3. Handover Signaling Load
4. Radio Interface Resource Utilization
5. Normalized Cost

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