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Investigation of urban routes for autonomous transportation using 5G communication and LiDAR data

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INTRODUCTION

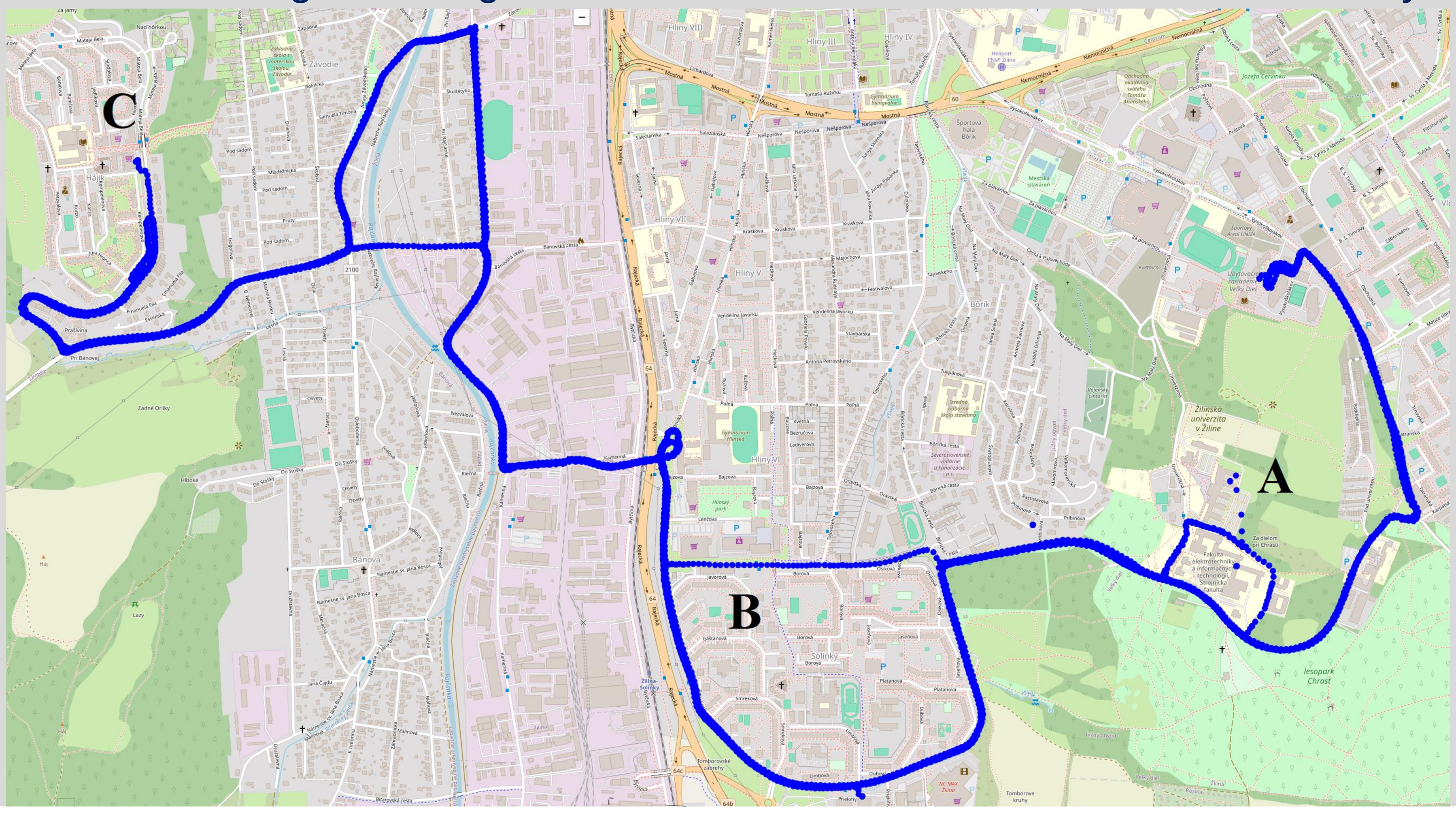
Urban traffic congestion and accidents, primarily caused by human error, highlight the need for Connected, Cooperative, and Automated Mobility (CCAM) solutions. Autonomous vehicles (AVs), leveraging 5G communications and sensor technology, are critical to more efficient transportation systems in cities.

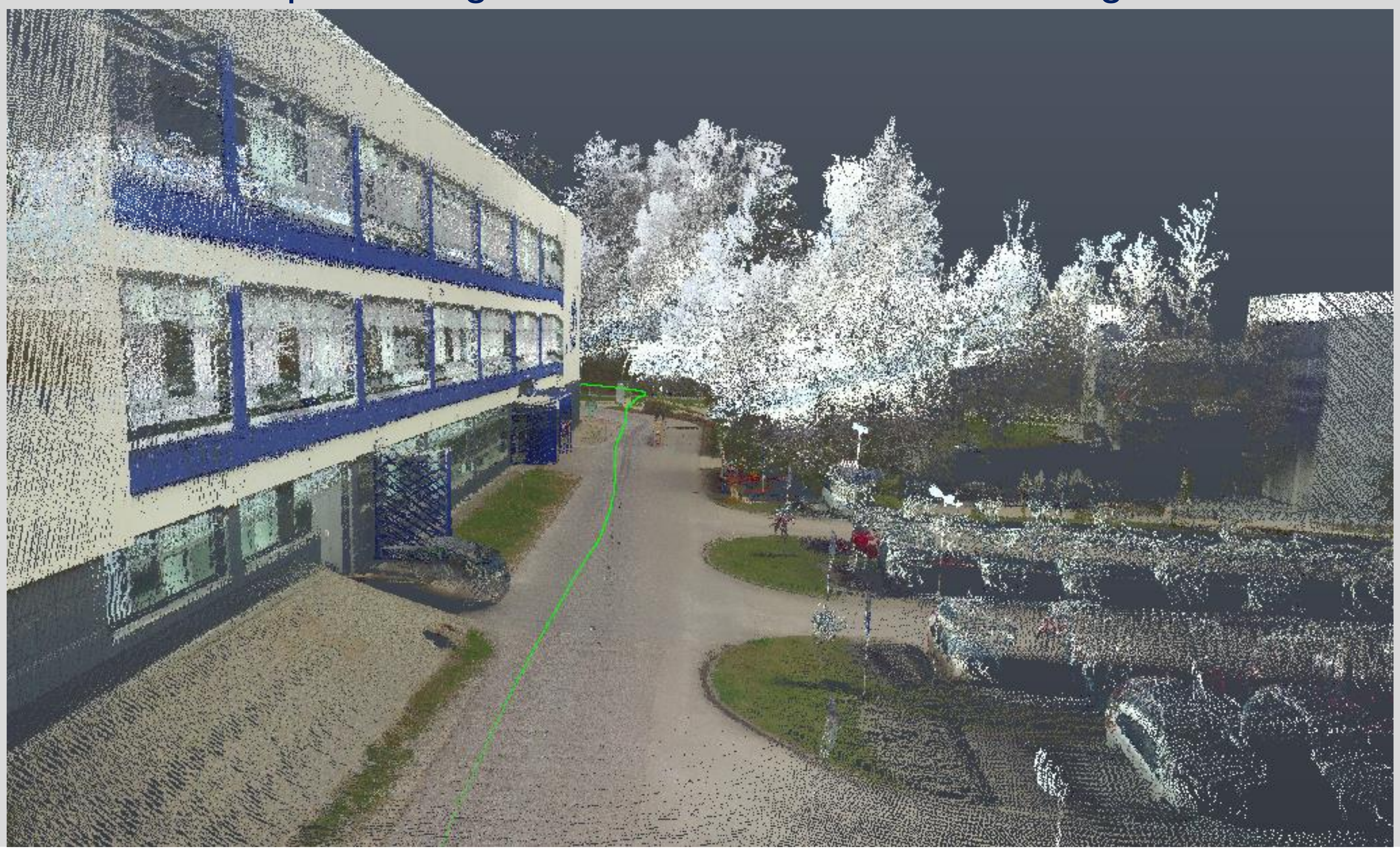
Current AV deployment is hindered by GNSS signal degradation in urban canyons, high latency and LiDAR data reliability issues in adverse weather.
Key stakeholders: City planners, AV manufacturers, telecom providers

This study evaluates urban route readiness for AVs by analyzing network performance and localization accuracy.
Objectives: Evaluate route readiness for AVs using 5G and sensors.
Impact: Improve AV safety, reduce accidents, enable smart city integration.

MATERIALS, METHODS & IMPLEMENTATION

The route spans university campus (A), city parts (B) to Hajik housing estate (C), featuring urban canyons and dynamic traffic. Data included 5G metrics(including uplink/downlink speeds, latency (measured via ping/RTT), GNSS positional logs, and LiDAR scans. Raw LiDAR data underwent noise removal, ground segmentation, and lane classification. MATLAB analyzed service compliance against 3GPP standards, revealing deficiencies.



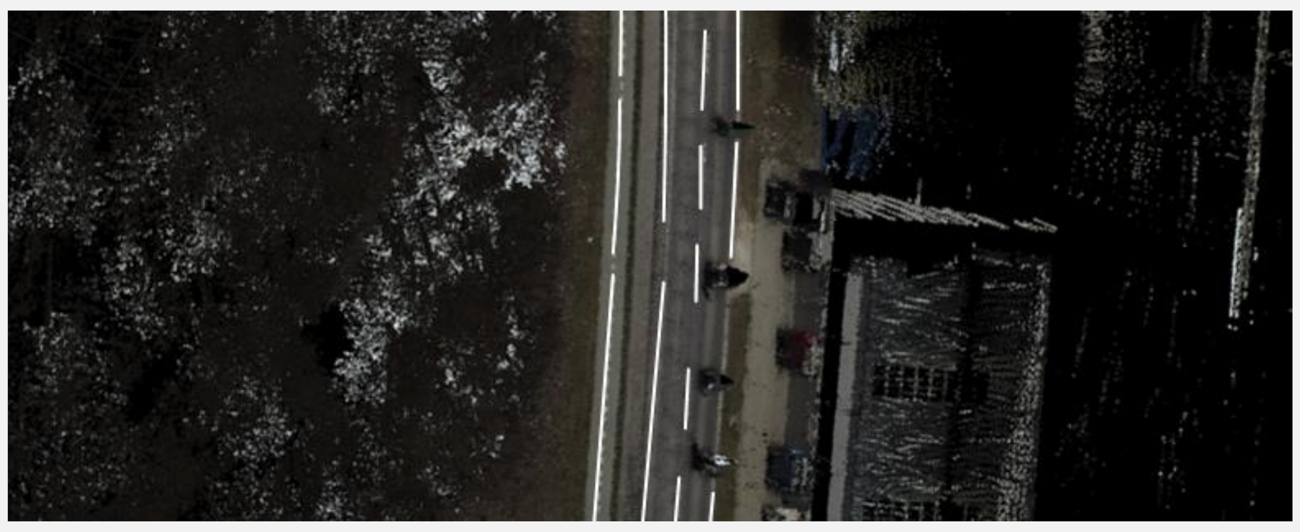


RESULTS

1. Network Performance:
Latency: Median 32.4 ms (exceeds safety thresholds; real ETL likely higher).
Uplink: 19.3 Mbit/s (4 severe deficiencies).
Downlink: 96.3 Mbit/s (sufficient for most services).

Use Case	Uplink[%]	Downlink[%]	Latency[%]
Cooperative collision avoidance between UEs	9.21	1.32	100
Information sharing for automated driving between UEs and RSU	100.00	2.63	1.35
Sensor information sharing (Lower degree of automation)	9.21	1.32	1.35
Sensor information sharing (Higher degree of automation)	100.00	2.63	100
Information exchange between UE and a V2X Application Server	82.89	0.00	100
Advanced Driving, General Requirements	100.00	2.63	100

2. LiDAR Effectiveness:
Achieved lane detection accuracy in GNSS-denied zones.
Challenges: Noise (rain/fog), sparse point clouds beyond sensor range.



CONCLUSION & IMPLEMENTATION PATH

5G Infrastructure Limitations: The study revealed significant gaps in 5G network performance, particularly latency (median 32.4 ms) and uplink speeds (19.3 Mbit/s), which exceed safety thresholds for real-time AV operations.
LiDAR as a Redundancy Solution: LiDAR demonstrated robust lane detection capabilities in GNSS-denied environments (e.g., urban canyons), proving its value as a fail-safe mechanism. However, challenges such as noise in adverse weather (rain/fog) remain, underscoring the need for additional steps. Integrating LiDAR with GNSS and 5G creates a resilient framework for AV navigation. For instance, LiDAR capabilities can compensate for GNSS signal loss, while 5G enables real-time V2X communication to share localized data across vehicles, however that still leaves the situations when no signal is available.
Future Steps include:
Sensor Fusion Optimization: Integrate YOLOv11 for real-time object detection, fine-tuned with automotive datasets to enhance AV perception in situations where communication capabilities are limited or nonexistent.
Computational Efficiency: Reduce latency via TensorRT optimization, batch processing and frame-level compute reuse.
Multi-Sensor Orchestration: Combine LiDAR, cameras, using YOLOv11 for robust obstacle detection in adverse conditions.
Deploy hybrid navigation systems (GNSS + LiDAR + 5G + YOLOv11).
Collaborate with telecom providers for 5G optimization.

ACKNOWLEDGEMENTS

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