Seminar

The Potential of Integrating Cloud and AI in Autonomous Systems

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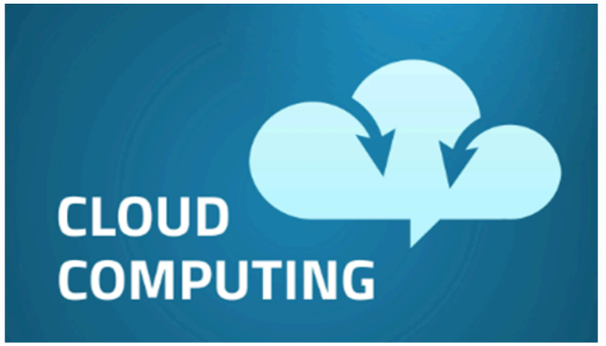
Overview

- Concept Overview
- Introduction
- Why to integrate?
- Framework
- Tools & Techstack
- Working
- Cloud based model training
- Analytical and notifaction services
- Cost Estimations
- Future Scope & Usecases

What is V-2-X ? Cloud ? 🤔

- V2X allows vehicles to communicate with infrastructure, networks, other cars, and people, giving efficiency and safety, for instance, prioritizing traffic flow in emergencies.
- Edge computing is where data is processed, reducing latency and bandwidth use, which is important when in real-time events.
- Cloud computing allows for access to software, processing power, and storage over the web, and users pay only for the resources that users use.
- It is advantageous, it is cost-effective, and highly scalable and flexible. Have architecture Iaas, Paas, Saas. E.g.:Oracle, Azure, and AWS.



Why to Integrate ?

•Cloud computing is changing the architecture of autonomous vehicles.

•Facilitates scalable computing, processing in real time, and collaborative AI.

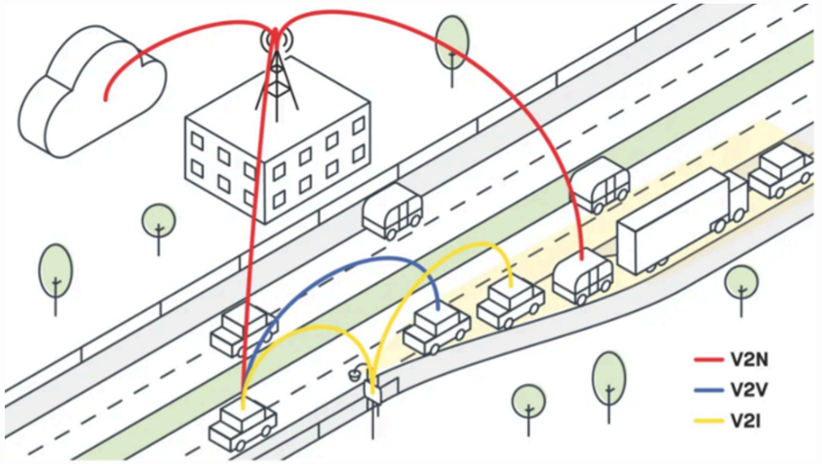
•Provides V2X communications, understands diagnostics, and integrates with infrastructure.

•Offers large-scale data ingestion and analysis for better decisions in safety and mobility.

•There are multiple real-world platforms (e.g., Tesla, VW Group, BMW, etc.) implementing it [7].

•Cloud + AI = Sustainable, scalable, and smarter movement systems.

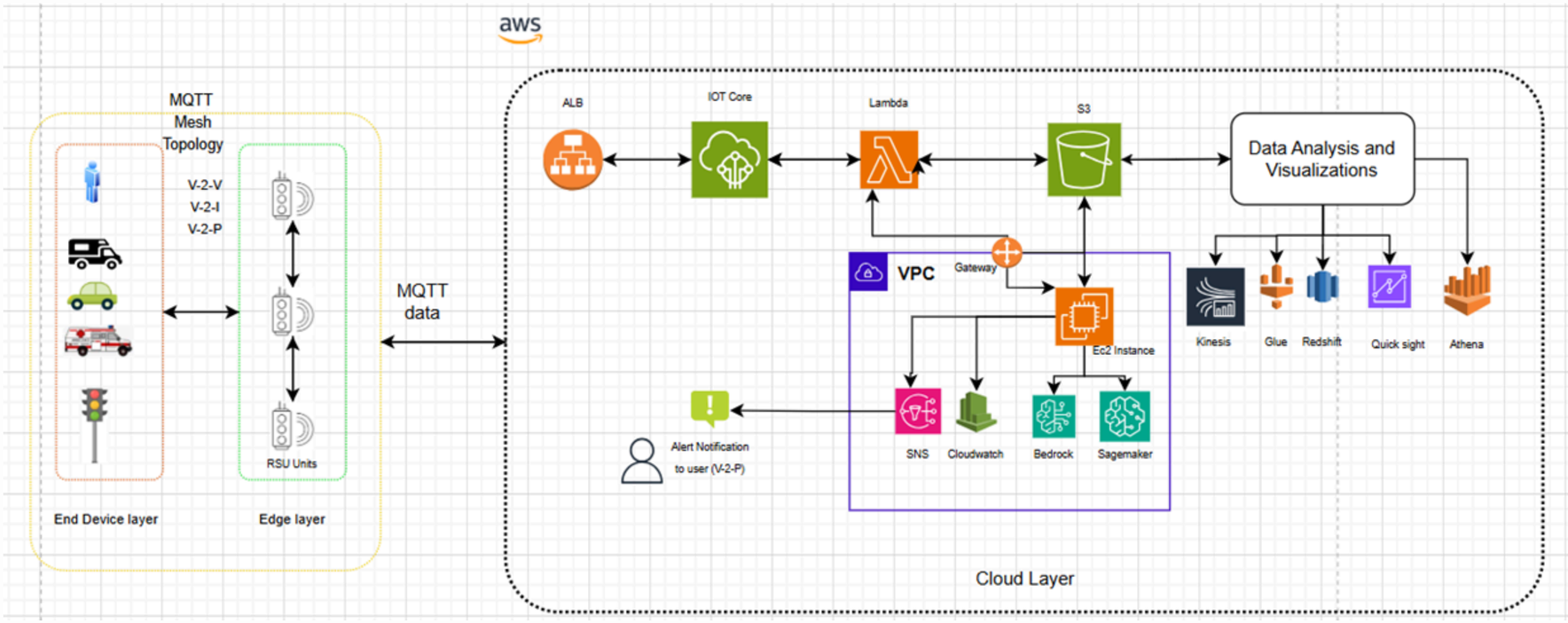
- Fully scalable framework. (Data Storage and Compute)
- Predictive Instinct. (AI &ML Models)
- Real-time Management.
- Over-the-Air info transfer.(fast)
- Cooperative Learning.



https://www.traffictechnologytoday.com/news/connected-vehicles-infrastructure

Architecture Overview

- V2X system integrates **End Devices ↔ Edge ↔ Cloud layer**
- Three layers:
- **End Device**: Cars, mobile devices, RSUs, apps
- **Edge**: RSUs, OBUs with SDN management
- **Cloud**: AWS (IaaS, PaaS, SaaS) for storage, compute, ML.
- Communication over Wi-Fi 6 or 802.11p
- Mesh topology ensures resilience and high throughput [10]



Tools & Techstacks

Categories	Technologies Used
Information Transfer	MQTT, VPC, ALB, IoT Core
Serverless Compute	Lambda, EC2
Storage	S3 (Standard, Glacier, etc.)
Analytics & ETL	Kinesis, Glue, Athena, Redshift, QuickSight
AI/ML	SageMaker, Bedrock
Monitoring & Alerts	CloudWatch, SNS

MQTT And Data

•MQTT

Lightweight protocol for real-time messaging is perfect for the Internet of Things and V2X.

•Clients subscribe to listen to the messages that are sent to subjects from devices via the published messages.

• Often used with smart transport and monitoring systems.

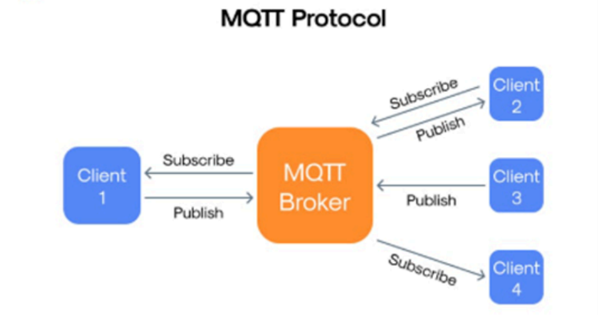
•Why JSON?

• JavaScript Object Notation.

•Light-weight, easy to read, write, and parse for machines.

•Supports arbitrary data.

•Language and platform independent.



C: > Users > Kartik > Downloads > {} json sample > ...

```json
{
  "time": "2025-05-22T14:30:00Z",
  "rsu_connection_id": "RSU-98765",
  "location": "THI, Ingolstadt",
  "vehicle": {
    "type": "SEDAN",
    "model": "BMW",
    "car_number": "IN AA 777"
  },
  "weather": "16°C",
  "alerts": "N/A",
  "warning": "N/A",
  "speed": "35 kmph",
  "connection_id": "MYCAR123",
  "connected_with": [
    "AAA111",
    "BBB22",
    "CCC133"
  ]
}
```

Working

- •Vehicle-RSU Communication: Unmanned vehicles use MQTT over RSUs to send JSON data to the cloud via AWS IoT Core.
- •Efficient Data Handling: Load balancer ensures stable data flow; Lambda filters data and stores it in S3 based on access frequency.
- •Real-Time Analytics: Tools like Kinesis, Redshift, Athena, and Glue enable real-time monitoring, structured analysis, and visualization with QuickSight
- •AI Model Training: SageMaker and EC2 train ML models using S3 data, supporting fast, distributed learning and multiple deployment options.
- •Monitoring & Alerts: CloudWatch tracks system health; SNS sends alerts when thresholds are breached.
- •Instant Decision-Making: Shared, real-time data supports quick, intelligent decisions on traffic, obstacles, and emergencies.
- •Example: A connected vehicle receives real-time cloud alerts about a pedestrian, a breakdown, and slippery roads near an intersection, prompting it to slow down and reroute safely.

Cloud based Ai ML training

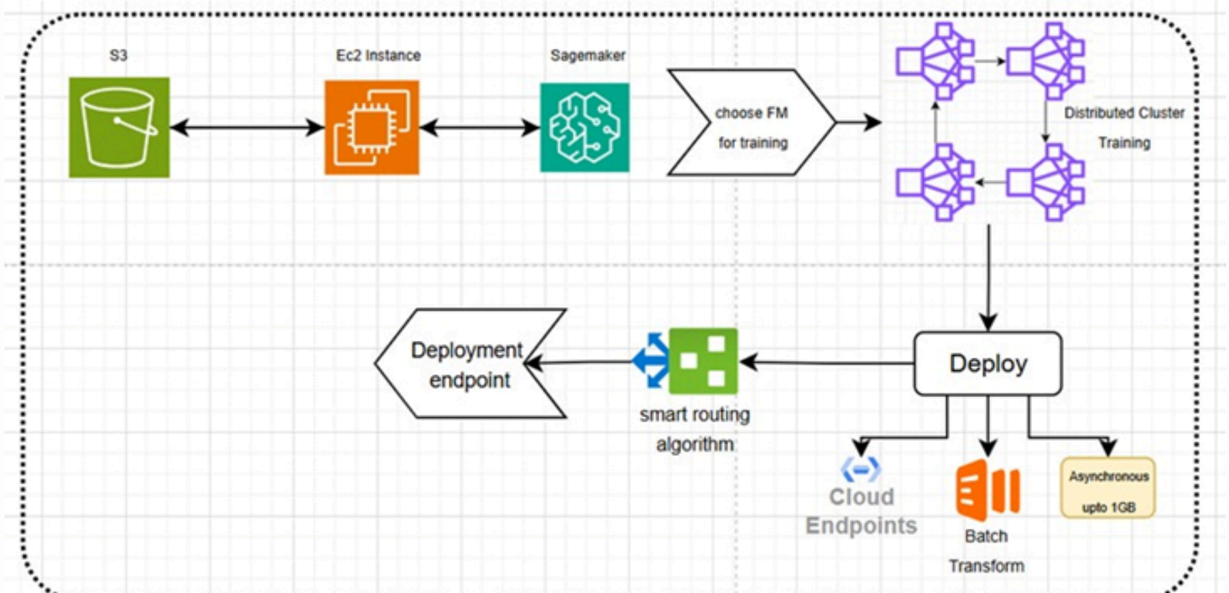
•**Data Source**: Data stored in S3 is used for training AI models via EC2 instances with sufficient computational power.
•Model Types: Models include Neural Networks, Deep Learning Models, LLMs, and Generative AI.

•**Services Used**: Training is done using AWS SageMaker and Bedrock, which provide a fully managed ML environment.

•**Training Setup**: Models are trained in a distributed cluster topology using libraries like TensorFlow, PyTorch, and Scikit-learn.

•**Deployment Options**:
•Direct deployment to cloud endpoints (for edge & device layers),
•Batch transform for offline inference,
•Asynchronous inference for low-latency.

•**Flexibility & Scalability**: Cloud-based training ensures scalable, faster, and efficient AI development workflows.



Cloud Analytics and AI Integration

- **Kinesis**: real-time telemetry ingestion (e.g., traffic events)
- **Redshift**: long-term structured analysis (e.g., speed profiling)
- **Athena**: ad-hoc queries for quick responses.
- **Glue**: ETL (extract, transform, load) for data prep
- **QuickSight**: visual dashboards for decision centers
- **SageMaker** + Bedrock: AI model training & deployment.
- This can help analyse the large data in easy easy-to-visualize dashboard

Notifications and Monitoring

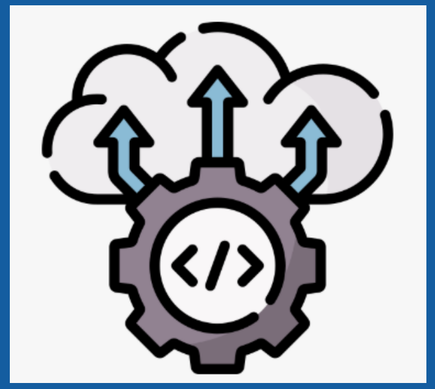
- **CloudWatch**: Tracks system metrics, logs, and health status
- **SNS**: Sends alerts if thresholds are crossed (e.g., critical fault)
- Can set alerts , alarms, warnings

Cost Estimations

• The following are the approximate cost estimations for the above-mentioned framework using the AWS Frankfurt region (eu-central-1). Amount in Euros [9].

Function	Service	Cost Estimation	Others
IoT Connectivity	AWS IoT Core	560	100 million messages/month
Edge & Compute	AWS Lambda	103	10 million lambda requests
Data Storage	AWS S3	74	
Data stream & analysis	Kinesis, Glue, Athena etc	162	10 TB data Ingestion/month
AI/ML Training	AWS SageMaker + Inference	356	300 hrs Training
Notifications & Alerts	AWS SNS	5	10 Million alerts
Monitoring and Alarms	CloudWatch	51	Customized Alerts
Data Transfer	Inbound-Outbound	990	10TB Outbound Data
Geospatial	N/A	-	
	Total	**2168**	

Deployment Cosiderations



- Reliable high-speed Internet WLAN is essential (e.g., Wi-Fi 6) or IEEE 802.11p [8].
- Optimize service configurations for cost + performance balance.
- Compatible RSU setups.
- Must ensure low-latency, secure, fault-tolerant data flows.
- And?..... AWS Account or any other Cloud is fine.

Future Work and Use cases

•With the combination of Cloud, AI, Smart sensor technology, V2X, shared/federated learning mechanism, autonomous systems will achieve greater potential with high accuracy and performance.

• Use cases (Potentials)

1. Digital twinning.

2. Accident analysis.

3 . Risk and fault evaluations.

4. Shared learning. (Solution to the hidden terminal problem)

5. Geofencing and vehicle monitoring.

6. Tracking the CO2 emissions.

7. Adaptive route optimizations.

8. Enhanced data-driven city planning.

9. And many more...

References

1. J. Patil, J. V. Bhiste, D. Pawar and M. V. Pawar, "Framework for Cloud based Messaging System using MQTT," 2020 Advanced Computing and Communication Technologies for High Performance Applications (ACCTHPA), Cochin, India, 2020, pp. 168-174, doi: 10.1109/ACCTHPA49271.2020.9213215.
2. J. Dong et al., "Mixed Cloud Control Testbed: Validating Vehicle-Road-Cloud Integration via Mixed Digital Twin," in IEEE Transactions on Intelligent Vehicles, vol. 8, no. 4, pp. 2723-2736, April 2023, doi: 10.1109/TIV.2023.3243096.
3. W. M. Danquah and D. T. Altilar, "Vehicular Cloud Resource Management, Issues and Challenges: A Survey," in IEEE Access, vol. 8, pp. 180587-180607, 2020, doi: 10.1109/ACCESS.2020.3027637.
4. P. Pierleoni, R. Concetti, A. Belli, and L. Palma, "Amazon, Google and Microsoft Solutions for IoT: Architectures and a Performance Comparison," in IEEE Access, vol. 8, pp. 5455-5470, 2020
5. C. Li, Z. Guo, X. He, F. Hu, and W. Meng, "An AI Model Automatic Training and Deployment Platform Based on Cloud Edge Architecture for DC Energy-Saving," 2023 International Conference on Mobile Internet, Cloud Computing and Information Security (MICCIS), Nanjing, China, 2023.
6. D. Liu, E. Cui, Y. Shen, P. Ding, and Z. Zhang, "Federated Learning Model Training Mechanism with Edge Cloud Collaboration for Services in Smart Cities," 2023 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Beijing, China, 2023.
7. https://aws.amazon.com/automotive/case-studies.
8. https://de.wikipedia.org/wiki/IEEE_802.11p
9. https://docs.aws.amazon.com/#products
10. https://www.emqx.com/en/blog/mqtt-for-internet-of-vehicles

THANK YOU!

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