1. **What is vehicle computing?**

The concept of Vehicle computing is to assume that CAV’s in the future will have compelling computing capabilities. Nearby less computationally capable devices can then leverage this faster computation power by connecting to the CAV and performing computational tasks. Hence, this technology helps CAV-related services perform computations on the vehicle and provide data back to the end-user.

Some of the functionalities can

1. Analysing real-time data from sensors within vehicles
2. Analysing real-time data from nearby devices
3. performing computations even when a car is parked

Real world example

ex. We can have small drones that can have cameras connected to our vehicles. The drones can share data with our vehicles which can make assessments of the road ahead and make alternate plans in case of lack of cellular connectivity.

1. **Why do we need vehicle computing?**

Identified use cases predominantly used are:

* + - 1. Pushing data to cloud and edge servers

Connected devices to CAV’s can generate TB’s of data every day, which can be privacy sensitive. The data generated is growing exponentially, but the transfer speed to the cloud can still be a bottleneck. If we cannot transfer data to the cloud or edge servers for analysis, then that data can’t help provide a real-time impact in problem-solving. A counterexample here would be compressing before transferring, but even transferring data as it is can again lead to privacy issues and potential threats. Hence due to all these concerns, Vehicle computing seems to be a logical way forward.

* + - 1. Pulling data from IoT devices

There are millions of IoT devices around us, while as per estimates from companies like Cisco, the count for these will surpass 500 billion in the next few years. The amount of data generated by devices like body-worn cameras, bicycles connected to the internet, etc., and their lack of computation power have given rise to Vehicle Computing, where CAV’s compelling computing power will help us process this data in real-time. Our vision for VC can have a massive impact on our lives.

1. Please summarise the technical challenges for Vehicle Computing.

Common Technical challenges are:

* + - 1. Vehicular Communication

We have made tremendous strides in communication where we have capabilities like dedicated short-range communication (DSRC), LTE (long term evolution), WiFi-enabled CAV's which can transfer information obtained from the cloud, vehicles around us, or even sensors at a considerably faster rate, but each one has its shortcomings. While DSCR can be widely deployed, it has small coverage and WiFi, LTE gives better bandwidth but performs poorly in the mobile environment. Considering all this, C-2VX can be used to overcome some of these issues, but due to affordability and lack of availability, we are still a long way in developing a robust mechanism of communication

* + - 1. Open API

Most of the machine learning-based applications used in CAV's are propriety based owned by giants like Ford, GM, etc. We need to have more work on open source platforms like Baidu's Apollo and others so that researchers and developers provide open free APIs in real-world environments.

* + - 1. Computation Hardware

CAV's are now designed to have GPU, FPGA, DSP, and other integrated circuits specific to applications that help improve speed and efficiency. The common problems we face would be maximum speed that hardware can achieve with the limited processing power, managing the limited resources effectively and reducing the cost of the overall sensors and other computation platforms so that they are still pocket-friendly while being efficient at the same time.

1. Energy Consumption

If we want to perform complex computations, we would need enormous sensors in CAV's which directly increases the energy consumption. Therefore, we need to improve the battery energy management and computation system for reliable energy-efficient autonomous driving to overcome this.

1. Computation Offloading

Equipped to perform computations similar to servers', CAV's would be able to provide effective and reliable communication in the future. One of the most effective ways is V2X computation to transfer critical information. Extending their sensing capabilities this way, vehicles and connected devices work in tandem. However, due to latency and reliability constraints, it is not always possible for CAV's and connected devices to work together. Considerable strides in the field are being made to develop optimized task offloading algorithms, but due to a lack of real-world application, some scenarios are still missing.

1. Security & Privacy

Common security issues are:

6.1 Sensing Security

Sensors are one of the critical components which collect data, and hence their security is paramount. We need to make sure sensors are safe from jamming and spoofing attacks so that they can carefully collect their data without any interference.

6.2 Data Security

The devices can collect both historical and real-time data for analysis. Hence we need to prevent data leakages that can occur either during transmission or storage.

6.3 Communication Security

Communication security is categorized under two categories, internal communication security, which comprises (CAN, LIN, and Flex Ray) and external communication are taken care of under VANET with V2X communication. Cryptography is the standard solution for such breaches, but it will limit its use due to the high computational cost.

6.4 Control Security

With everything moving towards electronification everyday tasks like remote car ignition, opening doors, and can control windows from an app or voice-based commands. Unfortunately, security breaches open new attacks like jamming, relaying, etc.

6.5 Privacy

The privacy of drivers and passengers is paramount because CAV's collect a lot of surrounding information comprising user location and address, which can be devastating if fallen into the wrong hands. Hence we need to be put in place specific methods which can help in data desensitization.

Please describe any \*one\* application of vehicle computing. Please expand on what is given in the paper. You may like to do some Internet search to answer this question. [Do not describe more than one.] \*

I want to discuss one of the essential applications for Vehicle Computing in In-Vehicle Meetings. As CAV advances to a point where they barely need human interventions, users can focus on other tasks while commuting instead of wasting it on driving. The use-cases for this are just enormous, and one of them is In-Vehicle meetings. With the advancement in wireless and sensor technologies, we can have secure and interoperable communication between different connected devices. The vision is to be comfortable attending the meetings irrespective of whether it is a car or your home. Also, with Mark Zuckerberg launching Meta and already having stores like H&M and Nike in the metaverse, we can envision similar strides in the communication industry space. Soon players like zoom and skype business can have 3D interactable meeting scenarios where we can imagine ourselves sitting in a meeting room having discussions and sharing ideas while sitting in our car. Metaverse can be one of the following strides in communication space, and its advantages would be phenomenal when considered injunction with in Vehicle computing